COASTAL ADAPTATIONS AT SUBMERGED ARCHAIC SITES, APALACHEE BAY, FLORIDA

by

JESSICA WHEAT COOK HALE

(Under the Direction of ERVAN G. GARRISON)

ABSTRACT

This dissertation explores the application of anthropological archaeology to submerged prehistoric archaeological sites. The study area is the Big Bend, within Apalachee Bay, Florida, along the northeastern edge of the Gulf of Mexico. Prior scholars have thoroughly demonstrated the existence and preservation of these sites, and now the focus of this research turns to documenting and interpreting the human behaviors that created these sites, particularly coastally focused occupations prior to the establishment of modern sea levels. Post-depositional changes in these sites are also a critical aspect for studies in these contexts. The primary methods are well accepted geoarchaeological and geospatial techniques drawn from traditional archaeological studies. The findings are interpreted using a hybrid theoretical framework that incorporates human behavioral archaeology and human behavioral ecology. This extension of anthropological theoretical frameworks into the offshore thus moves the sub-discipline beyond documentation of sites and artifacts, placing human activities back into the now-submerged landscape.

Chapter 2 updates predictive models for sites within this area by testing which environmental variables are correlated with site occurrences across time and space. As expected, variables are not consistent even within the same cultural period, suggesting that different resources were used at different sites. Some correlations could not be explained by environmental variables alone, arguing that these sites were chosen for reasons not directly based solely in ecological conditions. Chapter 3 explores these findings further by examining one site showing prominent use of coastal resources, the Econfina Channel site (8TA129). I use geoarchaeological studies to assess this site for both discrete activity areas and evidence for post-depositional erosion that can affect site integrity. The theoretical model is also used to place the site into a regional context by comparing it to three other known sites nearby within the bay. Certain aspects of all sites suggest that human occupations were again based on detectable cultural choices and not simply ecological conditions. Chapter 4 concerns post depositional corrosion in lithic remains, which examined in detail using additional geoarchaeological techniques; a new set of criteria for the evaluation as artifacts is proposed. Application of these updated criteria allow corroded artifacts to be integrated into the lithic landscape of Apalachee Bay, and the findings that these items were made of non-chert, local carbonate rock, argues that human choices for raw stone materials were more nuanced than previously thought.

INDEX WORDS: Submerged prehistoric sites; Florida archaeology; Geoarchaeology; Behavioral ecology; Behavioral archaeology; Coastal archaeology; Geographic Information Systems (GIS); Spatial analysis; Paleoindian; Archaic; Southeastern United States

COASTAL ADAPTATIONS AT SUBMERGED MIDDLE ARCHAIC SITES, APALACHEE BAY, FLORIDA

by

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DEDICATION

For my family, near and far, however I found you. Especially my father, my grandfather, and my grandmother, who all taught me to never stop learning and to never stop sharing what I've learned.

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Introduction

This dissertation explores the way in which submerged prehistoric archaeological sites in Apalachee Bay, Florida, U.S.A., articulate with past patterns of human behavior, specifically coastally adapted occupations. Prehistoric submerged sites offer insight into human cultural development within landscapes that are now lost to marine transgression. Exploitation of coastal resources historically has often been assumed to be a product of the stabilization of coastlines (approximately 5,000 cal BP in the southeastern United States), and is marked worldwide by the deposition of large shell mounds at the modern coastlines (e.g., Cunliffe 2011, 2001). Recent detection of submerged shell mounds calls this assumption into question, suggesting that coastal lifeways may have much greater antiquity than 5,000 cal BP (Bailey 2014; Erlandson and Fitzpatrick 2006; Reitz 2014; Thompson and Worth 2011). Coastal sites located onshore may, or may not, be good analogs for earlier coastal occupations. Submerged prehistoric coastal sites left behind by people who were living on now-inundated landscapes are the key to addressing this issue, despite the considerable challenges posed by excavating and interpreting submerged sites subjected to considerable erosion.

These issue is of particular interest because scholars have convincingly shown that year-round occupation of the coastal zones was supported by diverse, abundant, terrestrial, estuarine and marine resources bases as early as the late Pleistocene in some areas of the world (Colaninno 2010; Erlandson et al. 2016; Gusick 2012; Jazwa et al.

2015; Reitz 2014; Thomas 2008, 2014; Thompson and Worth 2011). Low mobility, (if not wholly sedentary) occupational patterns also may have played a role in the "spinning up" multiple socially complex behaviors such as monument building, the development of pottery, and increasing political complexity, although this is a topic of considerable debate (Mikell and Saunders 2007; Sassaman 2010; Saunders 2010; Saunders and Russo 2011Thomas 2014; Thompson 2007; Thompson and Turck 2012).Coastal regions within which these developments occurred, in particular, inform discussions on the phenomena that drive increasingly complex human behaviors in foraging groups that either completely lacked agriculture, or only nominally adopted it (Bailey and Milner 2002; Keene 2004; Thomas 2014). Without additional datasets from early coastal sites that are now submerged, however, it is impossible to appreciate fully the development of complex human behaviors within these resource-enriched coastal environments prior to the Late Holocene (Bailey 2014; Erlandson and Fitzpatrick 2006).

The broad, comparatively low gradient and shallow continental shelf of the southeastern United States presents an ideal environment for addressing these questions (Figure 1). Studies of coastal occupations in this region show that the coastal zones were especially preferred as early as 4,500 cal BP, with evidence for earlier settlement now submerged (Thompson and Worth 2011; Turck 2012; Williams 1994, 2000). The southeastern United States has also been identified by multiple scholars as a climate refugium compared to other regions of North America as early as the Pleistocene, with dense settlement patterns compared to other areas of North America (Anderson and Faught 1998; Faught 2008; Russell et al. 2009; Garrison et al. 2012; Littman 2000; Weaver 2002). The archaeological potential of the continental shelves in the Southeast has been demonstrated (e.g., Anuskiewicz 1988; Anuskiewicz and Dunbar 1993; Dunbar 1988; Dunbar et al. 1989; Faught 1988; Faught and Donoghue 1997; Garrison et al. 2016; Harris et al. 2013). The Big Bend of Florida, where the peninsula meets the panhandle, contains the highest number of known submerged sites in North America. It also demonstrates the regional trend towards abundant, early coastal sites showing low residential mobility after the establishment of the modern coastline. For these reasons, this dissertation focuses on the sites of the Big Bend, especially the Econfina Channel site (8TA129), where coastal lifeways appear during the Middle Archaic period by around 6000 cal BP.

To approach this question, ecological reconstructions are well suited to elucidate the diversity in human responses during periods when paleoecology, relative sea level rise, and other edaphic conditions had no analogue to modern environments (e.g., Ford and Halligan 2010, but, c.f. Benjamin 2010). Contextual approaches of this sort are extant for inland sites in this region of Florida (Duggins 2012; Dunbar 2016; Halligan et al. 2016; Thulman 2009). For this dissertation, then, I will combine theoretical perspectives on landscape and human behavioral ecology, with geology, geomorphology, and hydrology, to assess these submerged prehistoric sites in Apalachee Bay in their temporal, spatial, and cultural contexts.

I will also address preservation problems that submerged prehistoric sites can encounter. Sites can be subjected to erosion and scour by high energy events such as tropical storms and hurricanes. Weathering of lithics is also frequently observed in submerged prehistoric sites; this is especially problematic because they are often the most readily recoverable type of artifacts from these pre-ceramic periods, and yet geochemical and mechanical weathering processes specific to transitions from upland, inland locations to brackish tidal marsh, and finally open marine conditions may make identification of lithics as tools more difficult (though by no means impossible) (Faught and Donoghue 1997; Garrison et al. 2016; Lowery and Wagner 2012; Marks 2006). However, in both cases, geochemical and mechanical weathering signatures in artifacts and sites as a whole can also provide valuable proxy data for paleoenvironmental changes during marine transgression events. Documenting and characterizing these taphonomic processes is a critical component to both modeling for new survey areas and in interpreting known submerged sites.

Assemblages, sites, behavioral ecology and historical ecology: multi-scalar contexts

A contextual approach to this problem must integrate artifacts, features, sites, and collections of sites; this dissertation accomplishes this task by using a synthetic approach that combines geoarchaeological methods with behavioral archaeology and behavioral ecology. This synthesis allows us to examine human behaviors such as subsistence practices, site choice, or lithic resource extraction at multiple scales across landscapes undergoing climatic, ecological, geomorphological, and hydrological changes from the terminal Pleistocene through the Middle Holocene. I thus employ geoarchaeological methods to elucidate sites, delineating collections of features and artifacts within different activity areas. I then employ behavioral archaeology and behavioral ecology to understand the collections of human activities within their larger regional ecological, geological, geomorphological, ecological, and cultural landscape through time. This synthetic approach moves beyond mere detection of submerged sites to ask anthropologically focused questions about human behaviors within now-submerged, likely non-analog ecological landscapes.

Archaeological sites are collections of artifacts and features left behind by human actors that are interrogated and interpreted in archaeology as assemblages. These assemblages inform us what sorts of activities, how many activities, and potentially how long these activities took place at a given location (Schiffer 1976, 1972; Skibo and Schiffer 2008). Just as sites are collections of assemblages deposited over time, we can also conceive of a region as containing assemblages of various types of sites with varying spatial and temporal relationships to one another that reflect human activities (e.g., Binford 1980).

Assemblages are not fixed in quality or quantity (Shott 2010), however, and are best understood as the summation of three different filters: the filter of human choices in creation and use of these items, the filter of post-depositional processes that have affected the assemblage after discard, and the filter of the non-objective researcher who approaches any given archaeological deposit with specific research questions. All interpretations of archaeological materials must take the selective forces created by these filters into account before offering any conclusions. To do otherwise is to risk making logically insupportable conclusions (e.g., Dibble et al. 2016).

All of these filters can be framed as part of an overarching ecology that includes geology, geomorphology, hydrology, and floral and faunal ecology – the edaphic stage upon which actors play out their roles (Butzer 1980, 2008). Human behaviors exist as part of it – another component of the faunal ecology, if you will. We are, after all, animals, albeit particularly clever ones inclined to elaborate niche construction. It is our manipulations of the material environment that survive despite the pressure of other forces on our edaphic stage. Reconstructing that edaphic stage is necessary if we hope to grasp the original contexts of those manipulations.

To reconstruct that ecological stage, we must develop an understanding of the overall landscape. There are many types of landscape:

- Geological landscape
- Climatological landscape
- Geomorphological landscape
- Hydrological landscape
- Ecological landscape
- Technological landscape
- Subsistence landscape
- Lithic landscape
- Cultural landscape

These all build on each other to create the cultural and historical landscape in which human groups and individuals make choices and leave behind remains of their behaviors.

I will use human behavioral ecology (HBE) as the theoretical framework to address the nature of the first filter. This middle range theory argues that humans will employ whatever strategies are most likely to lead to reproductive success (Bird and O'Connell 2006; Fretwell and Lucas 1969; MacArthur and Pianka 1966). I will explore how hypothetical distributions of resources, both inland and along the coast, correlate with human choices for site locations and presumably resource exploitation. A review of the regional literature shows that clear evidence already exists for differential distribution of resource patches from the late Pleistocene into the Middle and Late Holocene, and that correlations between archaeological site visibility and these distributions can be detected (Anuskiewicz 1988; Duggins 2012; Dunbar 1988; Dunbar et al. 1989; Dunbar 2006a, 2012, 2016; Faught and Donoghue 1997; Faught 2004a, 2004b; Garrison, Cook Hale, et al. 2012; Pearson et al. 1989; Stright 1986; Thulman 2009). For this study, I will map the inferences I draw from artifacts, assemblages, and sites using behavioral archaeology (Schiffer, *supra*) onto the wider ecological and cultural landscape. I will do this with the goal of documenting variation in human resource use within this now-submerged landscape. This is a critical component of outlining the ways in which human choices on now-submerged coastlines differed from those within upland zones.

My primary method for assessing human behaviors that left behind cultural materials, as well as the post-depositional changes that have occurred since people used any given location, will be geoarchaeological. Quantitative geoarchaeological methods are critical in submerged site detection and interpretation and are the best means by which we can differentiate between the human activities within a site and post-depositional changes. Identification of sites as such will be addressed by using geoarchaeological methods to detect sites and intrasite activity areas using particle size and geochemical analyses (Gagliano et al. 1982; Murphy 1990; Pearson et al. 1982, 1989). When possible additional datasets for pollen, charcoal inclusions, mineralogy, and other indicators for paleo-environments are also incorporated. Petrographic analyses of lithic materials will also be employed, for the same purposes. These methods allow us to differentiate anthropogenic deposits from non-anthropogenic deposits. They also allow us to tease out the effects of post-depositional forces on these sites, such as the potential for erosion and re-deposition within a site during a tropical storm or hurricane.

The third filter that must be addressed is researcher non-objectivity. Studies are designed with specific questions and hypotheses in mind, narrowing the focus of inquiry. This is a necessary component of the scientific method, but to contend with it, I clearly outline study goals and limitations in each chapter. I will attempt to infer potential social behaviors from my findings using both of my theoretical frameworks, such as gender roles and mobility, but my theoretical approaches are explicitly materialist and processual. Future studies may or may not attempt to address issues such as these using non-materialist approaches.

Behavioral ecology, resource use, and its application to the submerged prehistory of the Southeastern United States

Behavioral ecology encompasses several middle range theories used to examine how humans make decisions within their environmental landscape that best support reproductive success. Behavioral ecology in archaeology is ill-suited to examine individual choices, but is a reasonable framework for understanding longer term trends, and it is longer term trends in behaviors that we are more likely to detect at submerged prehistoric sites (Bamforth 2013; Bird and O'Connell 2006).

It borrows from the field of ecology, placing human behaviors that maximize fitness in the evolutionary sense within their environmental contexts (e.g., MacArthur and Pianka 1966). Behavioral ecology does not attempt to determine the mechanism by which a behavior is transmitted, allowing for an integrated biocultural analysis that avoids the environmental determinism of earlier evolutionary-based anthropological theory. Instead, these hypotheses are crafted to operationalize the range of possible, as well as what is optimal, within a given landscape (Bird and O'Connell 2006; Kelly 1995a). As the old adage goes, all models are wrong, but some models are useful (Box 1976). For the purposes of this study, I will compare my findings to subsistence models found in behavioral ecology: optimal foraging theory, diet breadth theory, and central place foraging to create a more useful model.

Optimal foraging (OFT) and diet breadth theory are used for hypothetical diet reconstruction that assesses what prey foragers prefer, and how many prey species they choose from all available taxa. Optimal foraging posits that a predator takes the prey that can offer the most benefit for the least cost. If favored prey decrease, however, the diet will expand to include less preferred items, increasing diet breadth. Energy expenditures are operationalized by search cost and handling cost, and costs/benefits are usually quantified by net caloric gain or loss (Kelly 1995a; MacArthur and Pianka 1966). However, OFT and diet breadth models for coastal occupations often differ considerably from upland occupations (Bird and Bliege Bird 2000; Bird et al. 2002; Bliege Bird et al. 2009; Thomas 2008, 2014).

Central place foraging models "map onto" (Binford 1980:10) spatial and temporal contexts by predicting how far a predator will travel to efficiently forage for prey; beyond a certain distance, moving camp becomes a more efficient strategy. The time taken to deplete resources in a patch controls how often camp is moved. Central place foraging also assesses the handling costs for field processing versus transport back to a base camp; in the case of some prey, field processing is more efficient, creating a vastly different type of archaeological deposit from those created when foragers transport prey back to base camp (Bird and Bliege Bird 2000; Bird et al. 2002; Thomas 2008:211–214) This has obvious implications for archaeological deposits related to subsistence activities.

In North America, these models are used to explore connections between subsistence patterns, tool typologies, intensification in exploitation of various resources, contexts in which non-optimal behaviors were observed during periods of environmental stress or change, demographic changes, and differential gender and age strategies (Blackmar 2001; Bird and Bliege Bird 2000; Bliege Bird et al. 2009; Bird and O'Connell 2006; Bird et al. 2002; Broughton 2002; Byers and Ugan 2005; Cannon and Meltzer 2004, 2008; Elston and Zeanah 2002; Hawkes and O'Connell 1992; MacDonald 1998, 2009, Meltzer 1988, 1999; Newby et al. 2005; Morgan 2008, 2009; White 2013; Winterhalder 1986; Winterhalder et al. 1988, 1999; Winterhalder and Leslie 2002; Wood 1990). Along the Georgia coastline specifically, these models have been employed to assess degrees of mobility, potential for field processing versus camp processing of various subsistence resources, and test hypotheses concerning site type and distribution as early as the Late Archaic (approximately 5,000 cal BP to 3,000 cal BP) and throughout the remainder of prehistory all the way up to contact with the Spanish. Results suggest coastal groups on this coastline were semi- or fully sedentary complex foragers living in ecologically rich environments within larger regional contexts of comparative scarcity, as Kelly predicted (Andrus and Thompson 2012;Kelly 1995; Reitz 1988; Reitz et al. 2008; Reitz 2014; Thomas 2008, 2014; Thompson and Andrus 2011). These extensive and intensive archaeological analyses have shown that these ecological models predict site type, distribution and seasonality reasonably well in this coastal context, with some caveats associated with differential foraging strategies related to gender, age, and possibly cultural choices (Colaninno 2010; Thomas 2014:170–176). This in turn appears to be a function of several very specific edaphic characteristics of coastlines themselves in the southeastern U.S. Given the success of these models in predicting as well as interpreting human occupations along the modern coastline of Georgia, I propose that extrapolation into preceding periods along a nearby coastline, that of the northern Gulf of Mexico, is a reasonable way to proceed. Accordingly, I hypothesize that material remains at different sites should reflect different approaches to foraging depending on whether a site was coastal or upland, allowing me to infer changes in ecology, coastline proximity, and human choices through time within this drowned landscape.

This is not the only theoretical framework used along the coastlines of the Southeast U.S. Other studies approach this archaeological landscape using cultural historical processes to examine coastal lifeways, human social responses to surplus, pauses in marine transgression, or suggested that cultural forces took precedence over environmental factors where complex behaviors beyond baseline nutritional needs are examined (Hadden 2015; Sassaman et al. 2016; Thompson 2007; Thompson and Turck 2012; Thompson and Moore; Thompson and Worth 2011). In some cases, food selection appears to have varied spatially and temporally absent any detectable change in the ecology of the prehistoric food web, suggesting seasonality, or even simple cultural preference, instead of dictates driven by evolutionary forces alone (Hadden 2015). In other cases, habitation sites were relocated multiple times on moving coastlines but using apparently the same geomorphological criteria, such as access to freshwater, higher ground inured to storm surges, and proximity to tidal creeks, each time (McFadden 2016). Clearly some behaviors were dictated by simple baseline needs for survival, and others by cultural preference. In this study, I acknowledge these variations in apparent human motivations by framing hypotheses within ecological contexts, but when results do not indicate a direct connection between baseline needs and archaeological patterns, leaving open the possibility that cultural forces, not pragmatic ones, best explain the findings.

The geoarchaeology of submerged sites: coastal processes

Any study of submerged prehistoric sites must contend with coastal processes. These will influence what types of coastal lifeways may have been followed by prehistoric populations, as well as the forces that act on that coastline before, during, and after submergence., Not all coastlines are created equal, and this study must begin by coming to grips with the nature of the coastline along the shores of Apalachee Bay at the Big Bend.

First, geologic forces acting on a coastline must be understood to understand the underlying ecological context for human behaviors. Coastlines are created by geomorphology plus relative sea level (RSL), and this in turn is created by accommodation space (Nichols 2009). That accommodation space is a function of tectonic forces such as uplift or subsidence, eustatic (global) sea levels, whether rising or falling, and the amount of sediment that has been deposited and is currently being deposited along that shoreline. RSL is typically the only means by which sea level can be characterized in the geologic record, being the equivalent to the coastline position but not to the nature of that coastline. The geomorphological nature of that coastline is instead created by sedimentation type and rate as well as marine energies acting on those sediments. Tides, currents, and storm patterns all work to shape these sediments along the interface between the land and the sea, and human groups living along these interfaces adapt accordingly.

These adaptations will take different forms depending on the types of resources available, however. The coastal type during site creation/deposition may motivate certain behaviors and subsistence patterns, such as a preference for marine or estuarine resources over terrestrial ones, or the extension of foraging rounds using watercraft. Alternatively, coastline transgression may have proceeded so rapidly at certain periods in prehistory that coastally adapted lifeways were difficult if not impossible to sustain. The state of coastal geomorphology during any given period in prehistory must be understood as best as possible to form testable hypotheses about human behaviors during coastal occupations, even during no-analogue ecological periods such as periods of rapid coastline transgression.

Coastal type during submergence will also control taphonomic processes that alter assemblages in certain ways. Sedimentation rates and shelf gradient, and tectonics will control the rate of submergence and the rate of burial, while the presence or absence of features such as tidal marshes versus barrier islands will subject archaeological sites and materials to different types of geochemical and mechanical weathering (Faught and Donoghue 1997; Garrison, Cook Hale, et al. 2012; Garrison, Weaver, et al. 2012; Garrison et al. 2016; Kirwan and Megonigal 2013). Changing coastal geomorphology must also be understood as best as possible to form hypotheses about site preservation.

General geological context

This study is centered the Apalachee Bay area of the northeastern Gulf of Mexico, known as the Big Bend, where the panhandle meets the upper peninsula of Florida. The very low gradient embayment of Apalachee Bay lies at this juncture (Figure 1). There is ample evidence for intermittent occupational discontinuity and cultural hiatus in Southeast United States during prehistory, suggesting that environmental and cultural variables may have both played roles in site choices throughout the region. (Anderson et al. 2011; Faught and Waggoner 2012; Thomas et al. 2010; Thompson and Turck 2009; Turck 2010, 2012, Williams 1994, 2000).

This region is underlain by Tertiary aged carbonate bedrock (Austin et al. 2014; Faught and Donoghue 1997; Hine et al. 1988; Upchurch 2007). Inland and upland, an area of heightened topography is created by the underlying Cody Escarpment, also often called the Cody Scarp. The heightened surface relief is created by a confining clay cap that overlies the Hawthorne formation. The escarpment marks the location of two different Pleistocene-era shorelines; the sea level high stands during both time periods eroded most, if not all, of any terrestrial clay deposits south and west of the escarpment. The geomorphological result of these high stands is a distinct boundary with a noticeable gradient between an inland/upland highland zone (the Northern Highlands of Florida and southern Georgia) and the Gulf Coastal Lowlands, also known as the Woodville Coastal Plain (Hine et al. 1988; Upchurch 2007). The Cody Scarp and the coastal plain zone show significant differences in the expression of karst geomorphology: sinkhole collapse features within the Cody Scarp are larger, hydrological flow trends towards vertical movement into the carbonate bedrock, and there is clear topographic variation; on the coastal plain, collapse features such as sinkholes tend to be smaller, with flatter topography and more horizontal water movement (Upchurch 2007:8–9)

The dominant bedrock on the entire coastal plain is composed of Suwannee Limestone. The coastal lowlands have an extremely low gradient with minimal soil formation over this bedrock in comparison with the Cody Scarp, where soil formation is more prominent. Apalachee Bay is clearly a submerged extension of this coastal lowland landscape (e.g., Faught and Donoghue, 1997). The Suwannee limestone also contains the unconfined portion of the Floridan aquifer. This combination of features leads to a unique karstic landscape dotted with disappearing rivers that will “rise” at one location, flow for some length along the surface, and then disappear again into underground channels created by dissolution of the landscape. The flowing channels are not incised by erosion into the surface sediments, but are instead formed when areas of carbonate bedrock collapse because of dissolution from flowing groundwater. Continuous sections of these karstic river channels are supported by the convergence of the water table and the ground surface as one approaches the coastline. Thus, the regional water table acts as a major control on flow within the fluvial channels; higher water tables foster more surface flow while lowered levels cause the rivers to remain below the surface.

At the present, a water table lowered 3-4 meters below average levels will cause the Aucilla River channels to disappear. At the Page-Ladson site along the Half Mile Rise section of the Aucilla River, a limestone “bench” feature in the west-southwestern edge of the sink site has been designated as the vertical datum for free, above-ground flow in the channel (Dunbar 2006a). When the water table drops below this bench, the channel cannot flow. During more xeric periods in prehistory, the water table clearly dropped below these levels and the rivers were reduced to intermittent sinkhole features dotting the landscape. These constituted the only sources for freshwater during more arid periods, drawing humans as well as their prey.

Another effect of hydrological context is the effect that water table levels have on chert outcrop availability. These are very common throughout the region, are often found near karstic fluvial channels, and were another attractor for human groups during prehistoric periods. During periods of lower water tables, these outcrops were available for human exploitation. During periods of higher water tables, outcrops located within the sinks and formerly dry channels became submerged, making them unavailable. Outcrops located away from newly submerged features remained available, however. This phenomenon acts as a temporal and hydrological control for quarry site occurrences.

Water table levels have cascade effects on food resources as well. More arid periods such as the Bolen drought would have minimized wetland areas in upland zones, as well as drying up fluvial channels (Duggins 2012; Dunbar 2016; Thulman 2009). Upland terrestrial species would have been tethered to remaining watering holes dotting the landscape, while wetland and aquatic species would have experienced minimal abundance and diversity due to loss of habitat. Conversely, wetter periods allowed for expansion of wetland areas, untethered humans and their prey from water sources, and increased diversity and abundance for various taxa, particularly the aquatic and wetland ones (Dunbar 2016:Table 5.1).

The Aucilla is the best-known river, archaeologically speaking, with many very early sites that have been intensively explored (e.g., Dunbar 2006b, 2012; Halligan 2012; Halligan et al. 2016). The Econfina has fewer known sites and does not appear to contain as much evidence for dense, very early occupation. The Aucilla River has its headwaters north of the Cody Scarp, while the Econfina River rises below the toe of the Scarp. Both are sourced to the coastal plain only, unlike larger watersheds such as the Appalachicola and the Ochlocknee Rivers that feed into Apalachee Bay west of the Aucilla drainage. This reduces their sediment loads considerably. It may be the case that the Econfina contains even less sediment load than the Aucilla, as the Aucilla does pass through the Cody Scarp proper, where sediment cover is greater. Furthermore, the Aucilla is dotted with prominent sinkhole features along multiple discontinuous channels whereas the Econfina Channel appears as a continuous fluvial channel from its headwaters to the coast.

Both rivers enter Apalachee Bay along a very low energy coastline with tidal gradients of less than 1 meter. The very low gradient of Apalachee Bay also inhibits wave action. The coastal zone lacks prominent barrier island formation east of Appalachicola Bay and north of Tampa Bay. Instead, salt marsh fringes the coastline along the Big Bend. This is because sedimentation rates are very low; only the Ochlockonee and St. Marks rivers along the western side of Apalachee Bay deposit significant amounts of alluvial sediments, whereas on the eastern coastline of the bay, the Aucilla, Econfina, and Fenholloway rivers deposit virtually none at all. Sediments along the coastline form a thin veneer of sandy sediments and soils with bedrock sometimes shallower than 1 meter below the surface. The coastal forest is today known as the “piney flatwoods” with abundant pine, oak, and cypress. Inland and upland, pine/oak are more common with other species such as beech and magnolia also appearing (Watts et al. 1992:1057).

Soil types are dominated by fine sand and sandy loams in better drained areas, with some sandy clay loams apparent as well. Tidal marsh areas are composed of mucky sediments overtopping mucky loamy sands and sands (http://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx). The tidal ranges are around 1 meter, and wave action even lower, making this a very low energy coastline (Faught and Donoghue 1997:423). Offshore, the surface sediments are composed of a shelly-sandy marine layer. Much of the bay bottom in this region of the bay contains extensive eel grass beds; areas devoid of eel grass often coincide with paleochannels associated with the Aucilla and Econfina rivers. These eel grass beds provide habitat for a diverse suite of marine fauna, including scallops, sea turtles, and blue crabs (Mattson et al. 2007). Rock outcrops composed of dolomitized limestone and chert are common as well.

The archaeological landscape

The Paleoindian period (14,550 cal BP to 11,500 cal BP)

The terminal Pleistocene of the southeastern United States is characterized as a climate refugium. After the end of the last glacial maximum, both human and non-human occupants of the continent, and most assuredly the American Southeast, were responding to climatologically driven changes in ecology and landforms. Coasts were transient, even on a human time scale. Megafauna and ecotones were disappearing, with or without human help. Grasslands were shrinking along with formerly broad coastal plains; forests were changing from evergreen to temperate species. It was a world of strange creatures such as ground sloth, mammoths and attendant no-analog ecologies – a world with “many animals and not many humans” (Anderson 2001; Anderson and Faught 1998; Balsillie and Donoghue 2011; Clottes 1993; Dunbar 2016; Russell et al. 2009).

Climatologically-speaking, conditions within the coastal plains of Georgia and Florida's panhandle region were comparatively mild, with a climate only slightly cooler than today, but considerably more arid than today, consisting of a more open parkland, savannah-type environment (Dunbar 2016:183, Table 5.1; Garrison, Weaver, et al. 2012; Garrison et al. 2016; LaMoreaux et al. 2009; Leigh et al. 2004; Leigh 2008; Otvos 2005; Otvos and Price 2001; Russell et al. 2009; Watts et al. 1992; Weaver 2002). Not surprisingly, given these mild conditions, the Southeast United States study area contains some of the oldest archaeological sites in North America. Paleoindian occupations are extremely dense along the Big Bend study area, as well as northeast of the study area along the Savannah River valley and westward into the Cumberland Plateau in Tennessee (Anderson 1991, 1995; Anderson and Faught 1998; Anderson and Gillam 2000; Anderson et al. 2011; Dunbar 2012; Faught 2008; Halligan et al. 2016; Haynes 2002; Waters et al. 2009; Webb et al. 1984). Paleoindian groups were primarily associated with the distinctive Clovis and post-Clovis fluted point forms, although the debate over whether they practiced specialized foraging strategies using these distinctive tools is not settled (Byers and Ugan 2005; Cannon and Meltzer 2004, 2008; Haynes 2002; Hill 2008; Webb et al. 1984). A high degree of population mobility within the landscape is hypothesized although smaller ranges have also been proposed (Blackmar 2001; Buchanan et al. 2016), and regional variability in tool types has been detected in the Southeast U.S. both within and nearby to the study area (Smallwood 2010; Thulman 2012). Sites along the Big Bend tend to be clustered around sinkholes along the river channels that were the primary source of freshwater due in more arid climate of the late Pleistocene. Nearby high quality chert outcrops were clearly utilized as quarries for tool manufacture. Specifically coastal ways of life have not been shown for the late Pleistocene in the southeastern United States or along the Big Bend itself, although they have been argued for the west coast of North America (e.g., Erlandson et al. 2011). What form a coastal Paleoindian culture in the Southeast U.S. might take is currently opaque, to say the least.

The Early Archaic period (11,500 cal BP to 8700 cal BP)

The Early Archaic begins at the close of the Younger Dryas, a "pause" in the warming trend at the end of the Pleistocene. Conditions in the Southeast were warming and the more arid episodes of the terminal Pleistocene were replaced by a wetter climate, although it was still punctuated at times by droughts (Dunbar 2006a, 2012, 2016; Otvos 2005; Watts et al. 1992). The last of the megafauna disappeared at this point, changing the floral and faunal assemblages considerably (Anderson et al. 2008, 2011, Dunbar 2006a, 2016). Scholars believe that these change in flora, fauna, and human cultural practices led to smaller ranges for human groups living throughout the Southeast, possibly distributed along watersheds, carolina bays, beaver ponds, and other hydrographic features (Anderson and Hanson 1988; Anderson 1991; Brooks et al. 2010; Daniel 2001; Sassaman 2010). There is some evidence in Florida that Early Archaic groups may have been more tightly tethered to water sources than Paleoindian groups during intermittent drought periods such as the Bolen drought (Duggins 2012; Thulman 2009). Projectile point types generally decreased in size with an increase in features such as basal side notching such as those seen in Bolen and Kirk type points. Numerous submerged sites have been detected and excavated within sinkhole features, but these locations were still well inland and upland from the coastline (Clausen et al. 1979;

Dunbar 2006a; Halligan et al. 2016; Royal and Clark 1960). Shellfishing and use of aquatic resources along inland waterways within the Southeast do become archaeologically visible by this point (Randall et al. 2014), and coastal occupations may be suggested by shallow submerged sites along the Atlantic and Gulf of Mexico coastlines. Most of these offshore submerged sites have been detected in the Big Bend area but possible Early Archaic tools have been recovered from the Atlantic coastline as well (Anuskiewicz 1988; Cockrell and Murphy 1978; Dunbar 1988; Faught 2004b; Garrison et al. 2016; Murphy 1990). Coastal ways of life in these drowned sites in the Southeast have not been conclusively shown thus far for the Early Archaic, however, and inland submerged sires within sinkholes offer no real insight into what forms coastal lifeways might have taken.

The Middle Archaic period (8700 cal BP to 5600 cal BP)

The Middle Archaic coincides with the Holocene Altithermal, or Hypsithermal, the period during which the greatest amount of insolation reached 60 N since the last glacial maximum ended and insolation began to increase. This thermal maximum included the greatest degree of seasonality during the last 22,000 years, and on the coastal plains of the southeast in Georgia and the Florida panhandle, the climate may have averaged several degrees warmer than today (Jones et al. 2005). There is some debate over the timing and nature of potential arid episodes and it may be the case that the position of the Bermuda High created seasonal flooding events in the coastal plains of central and southern Georgia while the panhandle was more arid (Brooks et al. 2010; Ivester et al. 2001; LaMoreaux et al. 2009; Leigh 2008; Goman and Leigh 2006; Otvos and Price 2001; Otvos 2004, 2005). In the study area around the Big Bend, open woodlands appear to have been replaced by a more closed, warm humid forest, and formerly dry karst fluvial channels flowed consistently from this point forward (Faught and Donoghue 1997; Thulman 2009; Watts et al. 1992).

Middle Archaic groups in the Southeast appear to have experienced even more range circumscription than during previous periods (e.g., Sassaman, 2010; Sassaman et al. 1988). Generally, tool types continued to diversify, and were replaced by stemmed point types such as Putnam and Newnan points in the Big Bend area. Some scholars argue for possible abandonment of areas of Florida and the lower coastal plain of Georgia, and resettlement elsewhere, based on gaps in radiocarbon dating chronologies, changes in burial practices and tool types, and obvious shifts in site distributions (Faught and Waggoner 2012; Thompson and Turck 2009; Turck 2012; Williams 1994, 2000). Intensive use of coastal resources such as shellfish become visible during this period along the Gulf Coast (Mikell and Saunders 2007; Randall 2013; Saunders 2010; Turck 2012). In other areas of the southeastern United States, monumental architecture appears by the end of this period in places such as Poverty Point and has been argued for along the Gulf Coast of Florida (Randall et al. 2014; Russo 1994; Saunders and Russo 2011). While residential mobility may have decreased, there is still good evidence for the movement of goods and individuals across long distances (Sassaman 2010; Tomczak and Powell 2003; Quinn et al. 2008).

The archaeological context of the offshore landscape of the Big Bend

Within the Big Bend, prehistoric sites date from the Paleoindian through historic periods. Many of the earliest sites are associated with sinkholes, chert outcrops within the carbonate bedrock, and discontinuous river channels (Anuskiewicz and Dunbar 1993;

Anuskiewicz 1988; Dunbar 1988; Faught and Donoghue 1997:421; Faught 2004a, 2004b; Halligan et al. 2016). During the late Pleistocene and early Holocene, from around 22,000 cal BP until around 8,500 cal BP, when relative sea levels were well below modern positions, rivers fed by the Floridan Aquifer dropped as well, leaving a series of sinkholes in the channels (Dunbar 2006a; Faught and Donoghue 1997). Humans and animals were tethered to the sinkholes as water became scarce (Duggins 2012; Thulman 2009). Foragers could easily target prey at these sinkholes, while chert outcrops dotting the landscape also conveniently provided raw material for stone tools (Dunbar et al. 1989; Dunbar 2006a, 2016)

Contextual models for framing interpretations of inland, submerged river sites have been synthesized by Dunbar (2016:182–183, Table 5.1). This synthesis explores the interplay between climate regime, hydrology, access to different types of prey species (upland terrestrial, wetland, and aquatic), and access to raw lithic materials and was summarized in the geological and archaeological discussions above. Like the site prediction models for inland sites that have been extrapolated to offshore zones with great success, this model can be carried into the offshore zone in Apalachee Bay, too (Anuskiewicz and Dunbar 1993:2–3; Faught and Donoghue 1997:422–423).

More than a dozen sites or smaller artifact scatters were identified during initial offshore surveys, and several of them were more closely investigated. For this study, the focus rests on primarily the Econfina Channel site, with additional analyses of J&J Hunt (8JE00740), Ontolo (8JE01577), Ray Hole Springs, and Fitch (8JE00739). These sites, J&J Hunt, Fitch, and Ontolo, contained the following components in common: remains of lithic manufacture, faunal remains, including some aquatic taxa, and organic materials such as wood. Their dissimilarities appear to mainly be temporal. Fitch, J&J Hunt, and Ontolo all appear to have been occupied as early as the Paleoindian period, while Econfina Channel shows no evidence for use before the Middle Archaic. Curiously, Ontolo also shows evidence for occupation into the earlier portions of the Late Archaic, given the appearance at this site of Savannah type points (Faught, 2016, personal communication). This raises the question of how much continuity there may be between onshore analog sites, and these offshore sites.

The PaleoAucilla sites appear to show more continuity with inland sites such as Page Ladson (8JE00591A) and Sloth Hole (8JE00121). These sites contain Clovis and even pre-Clovis components, suggesting very early and continual occupation of the PaleoAucilla watershed (Dunbar 2006b, 2016; Halligan et al. 2016). The PaleoAucilla sites also appear to contain multiple cultural components ranging from the Paleoindian period forward into the Middle Archaic and even Late Archaic. Within the onshore sites, the best preservation is found within stratified alluvial and colluvial sediments within sinkhole features at each site (Dunbar 2006a; Halligan 2012; Halligan et al. 2016). Offshore, J&J Hunt is the most similar example; like the Aucilla sites, it contains “rise” and “sink” features at the start and end of what was most likely a discontinuous fluvial channel prior to the approach of the coastline. J&J Hunt and Fitch also yielded stratigraphic evidence for freshwater sediment deposits such as those found within the onshore sites, although these are younger than the deposits at sites along the Aucilla (Faught and Donoghue 1997:435–437).

Unlike the PaleoAucilla watershed sites, the Econfina Channel only shows evidence for one cultural component, the Middle Archaic, and has minimal stratigraphy.

The site consists of a large midden feature next to, or perhaps within, a larger chert quarry zone. The midden consists primarily of crassostrea. The quarry zone is dotted with prominent outcrops and ample debitage, much of it consistent with primary reduction sequences. These features lie south-southeast of the paleochannel itself. A freshwater seep/spring has been detected by surveys in the 1980s and 1990s, and during recent excavations as well. This feature lies perhaps within the paleochannel itself, or along the edge. Radiocarbon dates from the initial surveys suggest occupation around 6000 cal BP (Faught 1988; Faught and Donoghue 1997), making it contemporary to similar components at J&J Hunt particularly, but without archaeologically visible antecedents. This location offered its inhabitants access to multiple high priority resources: tool making materials, estuarine resources, and fresh water. The coastline was most likely nearby during the time the site was occupied. This is consistent with coastal sites from the Middle and Late Archaic along the panhandle, suggesting continuity with onshore trends in sites where human activity appears to have prioritized use of coastal resources (Hadden 2015; McFadden 2016; Mikell and Saunders 2007; Saunders et al. 2009; Saunders and Russo 2011).

Research design

This study focuses on submerged offshore sites within Apalachee Bay but will also refer to several other submerged sites within Florida as a whole (Figure 1.1): First I will discuss the current need for better potential settlement models for submerged archaeological sites. Current models either rely wholly on tracing geomorphological features necessary for human subsistence into the offshore without incorporating potential cultural dynamics, or they rely wholly on local cultural and geomorphological trends that are not applicable outside any given specific study area. Further, few, if any, models account for changes in paleoclimate and paleoecology, despite the clear evidence for dramatic changes within the last 22,000 calendar years of human prehistory. In this chapter I synthesize changes in climate, relative sea level, hydrology, coastline position, and access to various resources for subsistence and technology, to test for which variables are most predictive for sites within upland and coastal regions, and for two cultural periods: The Early and Middle Archaic. While HBE models are a starting point for hypothesis formation and testing, I will also quantify the degree to which site location choices may reflect cultural, instead of ecological, variables.

In Chapter 3, one site, the Econfina Channel site, will be examined using both previous and recent excavations. This site contains only one known cultural component and might suggest what sites used by people exploiting coastal resources prior to the Late Holocene looked like. This chapter describes recent excavations at the Econfina Channel site in detail. It also examines in detail evidence for archaeological and edaphic features suggesting the way the site was used as well as the different degrees of preservation within different areas of the site. Site use through time will be examined through the dual lenses of HBE and behavioral archaeology, while quantitative assessments of site formation processes during occupation, submergence, and post-submergence will employ geoarchaeological methods designed for submerged sites.

All sites discussed within the study
Top right: southeastern United States. Below: insets of study area
Shorelines estimated using Balsillie and Donoghue (2011)

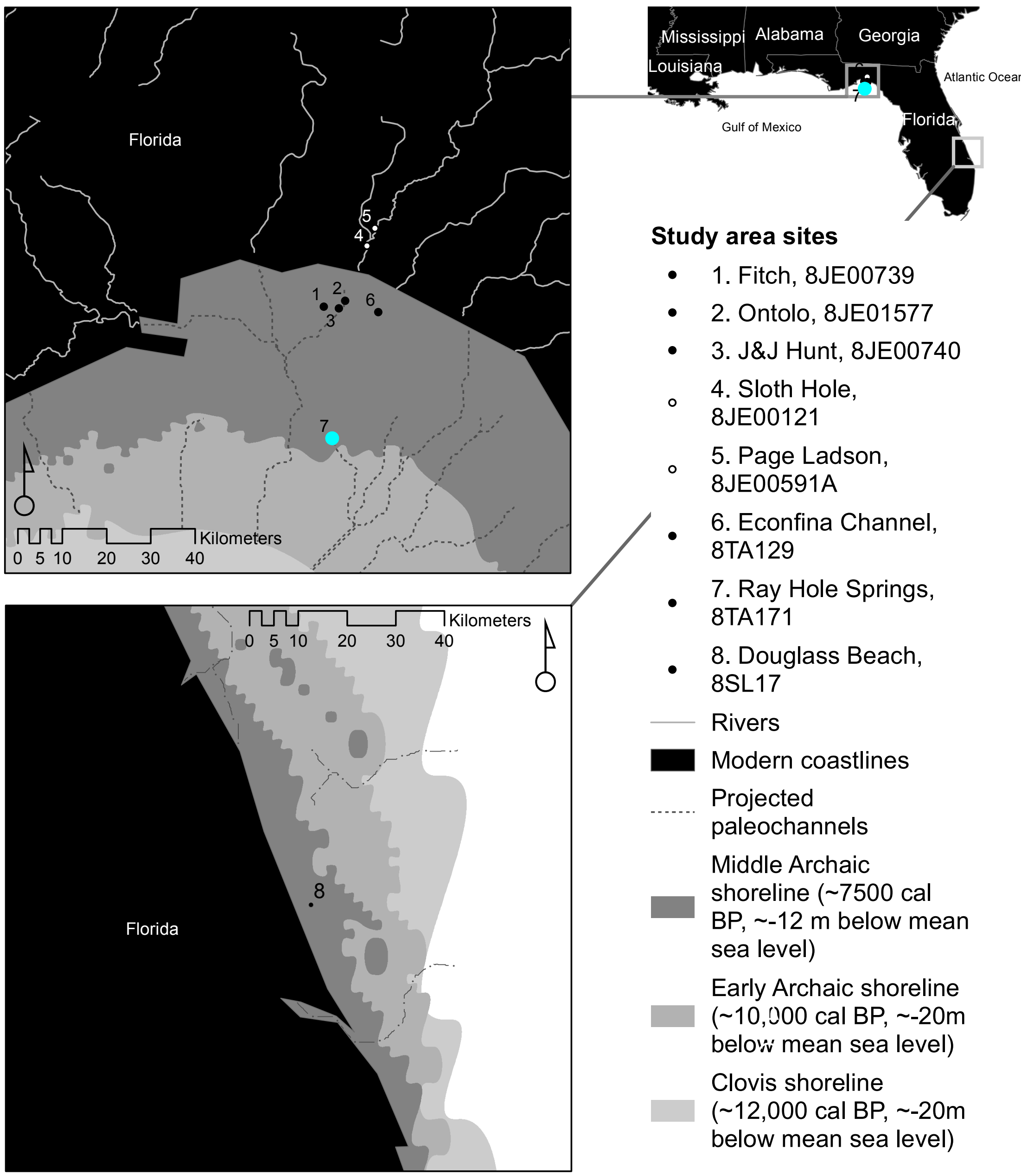

Figure 1.1: All sites discussed within the study

In Chapter 4, I will address a different type of weathering and corrosion: that which affects lithic and bone materials during submergence. Other studies have documented it, but until now, artifacts from multiple sites have not been examined and compared for petrological and mineralogical differences and/or similarities. I will demonstrate a means by which weathering can be documented as well as a means by which weathered lithic items can be assessed for sufficient evidence of human modification such that they can be categorized as artifacts and not geofacts. This is necessary when dealing with assemblages from submerged sites, because if we reject weathered lithics out of hand, we may come to lack sufficient data to assess the lithic landscape within which a site lies. Lithic landscapes offer us multiple proxy inferences for all manner of human behaviors, including mobility, raw material choices that may imply cultural meaning over pragmatic evaluations, and long distance movement of materials and people. This chapter will address the problems of weathering in lithics as well as expand our methods for interpreting the lithic landscapes of submerged prehistoric sites. As before, I will begin with geoarchaeological methods and interpret my findings using HBE and behavioral archaeology.

Then, the contexts will be widened to examine extant literature and archaeological inventories for three additional sites in Apalachee Bay. The final chapter, Chapter 5, will synthesize known sites in this area within their temporal, spatial, and cultural contexts. This chapter addresses the way human use of the landscape over time can be integrated with ecological, geomorphological, and hydrological changes. This chapter will also address differences in site preservation in Apalachee Bay, and expand on what sorts of geological and geomorphological forces interact to create these differential types of preservation. This final chapter will summarize my conclusions drawn from the geoarchaeological findings and interpret them within the wider regional contexts, again using behavioral archaeology and HBE to discuss the changes in human-landscape interactions as the climate changed, ecologies shifted, and the coastline approached.

In conclusion, this study should be able to offer several contributions to debates surrounding submerged prehistoric sites both within this region, and globally. This study will move beyond questions about how to locate and excavate such sites, by focusing on questions concerning specific human behaviors at specific types of sites: coastal lifeways during periods when the coastline was transgressing inland. It will move beyond documentation of these sites and demonstrate the efficacy of geoarchaeological techniques in defining sites themselves, as well as activity areas within sites. Third, it will further quantify current studies on geochemical and mechanical weathering of lithic artifacts and offer suggestions on how to obtain useful data from these items despite their degradation. Fourth, it will incorporate anthropological theory at the forefront of interpretation of my findings, instead of merely documenting artifacts, features, and sites. This is an important step forward in understanding the offshore prehistoric landscape, and elucidate our understanding of the submerged prehistoric landscapes of the Big Bend, and will also offer potential directions for work in submerged prehistoric landscapes in a global context.

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CHAPTER 2 : CLIMATE CHANGE, CULTURAL ADAPTATIONS, AND THE PEOPLING OF APALACHEE BAY, FLORIDA, U.S.A., FROM THE EARLY TO MIDDLE HOLOCENE.[1]

[1] Jessica W. Cook Hale and Ervan G. Garrison. To be submitted to the Journal of Anthropology Archaeology

Introduction

The first step in research design for submerged sites is the same one that terrestrial sites require: where are they? Surveys for submerged prehistoric sites are typically expensive, time consuming, and thus usually employ predictive models to maximize efficiency to answer this question (Faught and Donoghue 1997; Faught 2004a; Fitch et al. 2005; Gaffney et al. 2007; Gagliano et al. 1982; Stright 1986a, 1986b). Even then, the discovery of submerged prehistoric sites has been difficult at best, and almost impossible when these sites are not exposed at the sea floor. "Heroic measures" utilizing marine geophysical methods in concert with sediment coring have produced few positive results (Pearson et al. 1986; 2008; Evans, 2012). Incorporation of extant archaeological data is routine, as are syntheses of geological, geomorphological, and bathymetric features, relative sea levels curves, and taphonomic processes (Dunbar 2006; Evans and Keith 2011; Faught and Donoghue 1997; Faught 2004a, 2004b; Stright 1995). The way early human groups interacted with their environment also is a critical component of this modeling process, but it is dangerous to assume straightforward cultural continuity into time periods without modern analog, or to treat environmental variables as static (Butzer 1980, 2008; Ford and Halligan 2010). To avoid these weaknesses, predictive models must move beyond static approaches to dynamic methods that can account for local trends while employing a robust method both temporally and spatially scalable.

Our underlying theoretical view is that our models must operate at the intersection of cultural choices and ecological contexts instead of relying solely on physiographic variables. We argue here that favorable locations for drowned sites can be modeled by using spatial statistical analysis within a geographic information system (GIS) that establishes a robust quantitative relationship between site occurrences and the environmental contexts in which those sites were chosen even as they change through time. Our hypothesis is that humans chose sites at least partially for their proximity to valued resources within the local and regional environment. Therefore, we will test site locations first for quantifiable links between environmental factors and the site locations. This allows us to ask which environmental variables, if any, are in fact valid predictors for site choice during different cultural periods such as the Archaic Period of the American Southeast.

We also assume that our model includes knowledge gaps; cultural choices surely played a role in site locations, just as is the case with onshore sites, and our knowledge of the paleoenvironments offshore in question is in no way complete. These knowledge gaps will be evident, statistically speaking. The variance in a model unexplained by the relationship between the dependent variable – in this case, site locations – and the independent variable – environmental factors – implies a missing variable. This missing variable may imply cultural choices that do not have direct links to environmental conditions, or may be an undetected environmental variable(s). It is critical that a model quantify the degree to which site locations are not predicted by our chosen environmental variables, and thus the degree to which predictive models are lacking. We can then more confidently assign unexplained variance to either undetected environmental and cultural factors. Only then can we discuss how these findings inform predictive models for submerged sites along paleoshorelines.

We are particularly interested in coastal settlement of the southeastern United States during periods prior to the stabilization of Late Holocene sea levels at or near 4000 cal BP (Balsillie and Donoghue 2011; Engelhart and Horton 2012). Some of these earlier coastal settlements may be without modern ecological or archaeological analogs; others may be very similar. As a starting point for our study, we rely a rigorous body of literature concerning coastal occupations that tested hypotheses drawn from human behavioral ecology. Scholars have convincingly shown that year-round occupation of the coastal zones could be supported by highly diverse, abundant terrestrial, estuarine and marine resources bases as early as the late Pleistocene and Early Holocene in some areas of the world (Colaninno 2010; Erlandson et al. 2016; Fladmark 1979; Gusick 2012; Jazwa et al. 2015; Reitz 2014; Thomas 2008, 2014; Thompson and Worth 2011). Low residential mobility also may have played a role in the "spinning up" of multiple socially complex behaviors such as the inception of monument building, technological innovations such as the development of pottery, and increasing political complexity, although this is a topic of considerable debate (Mikell and Saunders 2007; Sassaman 2010; Saunders 2010; Saunders and Russo 2011Thomas 2014; Thompson 2007; Thompson and Turck 2012). Coastal regions in particular inform discussions on the phenomena that drive increasingly complex human behaviors in foraging groups that either completely lacked agriculture, or only nominally adopted it (Bailey and Milner 2002; Keene 2004; Thomas 2014).

One way of testing relationships between human activities and environmental variables is by using models drawn from these studies of coastally adapted human behaviors. Studies by Thomas on St. Catherines Island, along the Georgia coastline, have assessed site formation processes and distributions by testing hypotheses for optimal foraging, field processing models, and diet breadth, among other approaches (Thomas

2008, 2014). Many of the initial hypotheses were partially supported, but in other cases, the relationships between environmental conditions and human activities such as foraging and settlement patterns were not straightforward. For example, Reitz has established that prehistoric coastal communities relied on a tightly telescoped distribution of abundant, diverse terrestrial, estuarine, and marine resources, allowing for low settlement mobility and a high degree of ecological resilience during periods of environmental stress in prehistory (Reitz 1988, 2014). On the other hand, along the northern Gulf Coast, Hadden traced similar resilience prior to contact, but also finds potential cultural associations with differential resource use (Hadden 2015). Outside the southeastern United States, ideal free distribution (IFD), which argues that human groups will settle the areas within the landscape most likely to support long-term reproductive success, has been successfully employed to account for site distributions on the Channel Islands (Fretwell and Lucas 1969; Winterhalder et al. 2010); the Channel Islands study is particularly pertinent because it quantified both environmental and cultural variables (Winterhalder, et al. 2010:474, 478-9).

Clearly, coastal zones have the potential to offer highly diverse, abundant, resilient resources, and this is particularly the case in the southeastern United States. However, not all the human choices detected in the archaeological record showed linear relationships with solely environmental variables; for example, shellfish composed a much greater component of the diet on the Georgia Coast than predicted by hypothetical diet breadth models, while hypothetically high value prey such as alligator were underrepresented (Colaninno 2010; Thomas 2014:172). These departures from ecologically based models strongly suggest that modeling for now-submerged, formerly coastal sites must account for cultural variables that may exert influence on site choice. Without additional datasets from early examples of coastal sites that are now submerged, however, it is impossible to fully appreciate the development of human behaviors within coastal environments prior to the Late Holocene (Bailey 2014; Erlandson and Fitzpatrick 2006).

This approach is better positioned to account for regional trends through time and across the changing landscape. Methods such as ideal free distribution analysis rely on a higher level of resolution in radiometric dates for occupations than currently exists for most areas where submerged sites have been detected; this is certainly true for our study area, making an in-depth, quantitative analysis such as IFD impossible. What is possible, however, is to test long term trends in site choice trends in the aggregate against environmental variables, and to potentially detect where cultural choices departed from correlations to ecological boundary conditions. This approach can be applied to any coastline and at different spatial and temporal scales. For our application, first we will discuss the study area, its physiographic characteristics, and the archaeological landscape. We will then introduce a specific paleoecological model following Dunbar that draws upon ecological interpretations of human choices within the prehistoric landscapes of this study area (Dunbar 2016:Table 5.1). We will then test these variables to determine if they accurately predict site occurrence in a quantifiable manner. We will finally assess whether our method works to bridge the gaps between very general predictive models that lack sufficient specificity to be useful, and very local ones that translate poorly to other regions of the world.

The study area

The continental shelf of the southeastern United States presents an ideal environment for addressing these questions (Figure 1). The southeastern United States has been identified by multiple scholars as a climate refugium compared to other regions of North America as early as the Pleistocene with dense settlement patterns compared to other areas of North America (Anderson and Faught 1998; Faught 2008; Russell et al. 2009; Garrison et al. 2012; Littman 2000; Weaver 2002). The results of archaeological survey in the Gulf of Mexico in an area known as the Big Bend have been highly productive due to a concerted effort at survey and excavation since the 1980s and generally good conditions for preservation of submerged sites (Anuskiewicz 1988; Anuskiewicz and Dunbar 1993; Dunbar 1988; Dunbar et al. 1989; Faught 1988; Faught and Donoghue 1997). Studies of coastal occupations in this region show that the coastal zones were especially preferred as early as 5000 cal BP, but evidence for earlier settlement is now submerged (Thompson and Worth 2011; Turck 2012; Williams 1994, 2000). These also demonstrate the regional trend towards abundant, early coastal sites showing low residential mobility after the establishment of the modern coastline, much like the rest of the coastal southeastern United States (Andrus and Thompson 2012; Hadden 2015; Thompson and Andrus 2011). Recent studies have demonstrated that coastal groups living along the Big Bend chose new site locations based on the preferred combinations of landscape features when Late Holocene coastline fluctuations eroded the coastline; the coastal occupants repeatedly chose protected, more upland zones in proximity to tidal creeks, freshwater resources, and estuarine environments with easy access to marine waters. This pattern suggests an overt link between local changes in relative sea level, local coastal ecology, and active human choices over time (McFadden 2016). However, studies of coastal sites have yet to be synthesized with studies of submerged sites lying directly offshore. These factors make the coastal Southeast U.S. an ideal location for testing a predictive model that incorporates changes in paleoecology, relative sea level, and culturally driven resource choices from the Early Archaic until the end of the Middle Archaic.

This study is centered the Apalachee Bay area of the northeastern Gulf of Mexico, known as the Big Bend, where the panhandle meets the upper peninsula of Florida (Figure 2.1), and focuses on the Early and Middle Archaic periods (11,500 cal BP - 8500 cal BP and 8500 cal BP – 5000 cal BP). There is ample evidence for intermittent occupational discontinuity and cultural hiatus in southeastern United States during prehistory, again suggesting that environmental and cultural variables both played roles in site choices throughout the region. (Anderson et al. 2011; Faught and Waggoner 2012; Thomas et al. 2010; Thompson and Turck 2009; Turck 2010, 2012, Williams 1994, 2000). Therefore, we assumed for this study that variations in site distributions in the Big Bend are part of larger regional processes and used parameters from the wider regional context when choosing our variables. A review of the study area's physiographic and archaeological characteristics is in order.

The physiographic characteristics

The study area encompasses Leon, Jefferson, Taylor, and Wakulla counties in Florida, an area of approximately 8565 square km. This area consists entirely of coastal plain that is underlain by primarily karstic sedimentary bedrock of Cenozoic age. During the late Pleistocene and initial part of the early Holocene the coastal plain appears to have been more arid, with a parkland - prairie environment. Lowered water tables created a landscape dotted with sinkhole features instead of flowing river channels (Dunbar 2006, 2012; Faught and Donoghue 1997). Warmer humid conditions developed during the early Holocene, although arid episodes have been proposed during the early to middle Holocene, albeit with considerable debate over timing and extent; what is clear is that once water tables rose, the discontinuous karst water features became continuous flowing channels again, and springs began to flow (Goman and Leigh 2006; Dunbar 2006, 2016; Faught and Carter 1998; Halligan 2012; Otvos 2004, 2005; Russell et al. 2009; Thulman 2009). Forest cover expanded during the two cultural periods used in this study, transitioning to warm temperate forest by the middle Holocene. This transition was not a steady state process, however, and southeastern grassland prairie patches appear to have persisted even as the forest cover increased (Russell et al. 2009:186–188; Watts et al. 1992)

The modern coastal zone lacks prominent barrier island formation east of Appalachicola Bay and north of Tampa Bay. Instead, salt marsh fringes the coastline along the Big Bend. This is because sedimentation rates are very low; only the Ochlockonee and St. Marks rivers along the western side of Apalachee Bay deposit significant amounts of alluvial sediments, whereas on the eastern coastline of the bay, the Aucilla, Econfina, and Fenholloway rivers deposit virtually none at all. The tidal ranges are around 1 meter, and wave action even lower, making this a very low energy coastline (Faught and Donoghue 1997:423). The coastal forest is today known as the “piney flatwoods” with abundant pine, oak, and cypress. Inland and upland, pine/oak are more common with other species such as beech and magnolia also appearing (Watts et al. 1992:1057).

The archaeological landscape

The Early Archaic period (11,500 cal BP to 8500 cal BP)

By the Early Archaic scholars believe that the change in flora, fauna, and human cultural practices led to smaller ranges for human groups than during the Paleoindian period; distribution patterns may have been oriented along watersheds, carolina bays, beaver ponds, and other hydrographic features (Anderson and Hanson 1988; Anderson 1991; Brooks et al. 2010; Daniel 2001; Sassaman 2010). There is some evidence in Florida that Early Archaic groups may have been more tightly tethered to water sources than Paleoindian groups (Duggins 2012; Thulman 2009). Projectile point types generally decreased in size from earlier Paleoindian forms with an increase in features such as basal side notching. First Bolen, and then Kirk, type points are the most representative diagnostic tool types for this period. Scholars have confirmed several submerged sites offshore in both the Gulf of Mexico and off the Atlantic Coast from this period. Most have been detected in the Big Bend area, but possible Early Archaic tools have been recovered from the Atlantic coastlines of Georgia and Florida (Anuskiewicz 1988; Cockrell and Murphy 1978; Dunbar 1988; Faught 2004b; Garrison et al. 2016; Murphy 1990). Coastal ways of life in these drowned sites in the Southeast have not been conclusively shown thus far for the Early Archaic but cannot be ruled out, either.

The Middle Archaic period (8500 cal BP to 5000 cal BP)

Middle Archaic groups appear to have experienced even more range circumscription in the Southeast as a whole (e.g., Sassaman, 2010; Sassaman et al. 1988).

Some scholars argue for possible abandonment of areas of Florida and the lower coastal plain of Georgia, and resettlement elsewhere, based almost entirely on gaps in radiocarbon dating chronologies, changes in burial practices and tool types, and obvious shifts in site distributions (Faught and Waggoner 2012; Thompson and Turck 2009; Turck 2012; Williams 1994, 2000). Intensive use of coastal resources such as shellfish become visible during this period along the Gulf Coast (Mikell and Saunders 2007; Randall 2013; Saunders 2010; Turck 2012). In other areas of the southeastern United States, monumental architecture appears in places such as Poverty Point and has been argued for along the Gulf Coast of Florida (Randall et al. 2014; Russo 1994; Saunders and Russo 2011). While residential mobility may have decreased, there is still good evidence for the movement of goods and individuals across long distances (Sassaman 2010; Tomczak and Powell 2003; Quinn et al. 2008). Extrapolating known coastal human behavioral patterns into the drowned continental shelf is a reasonable way to approach modeling for submerged coastal sites for this period

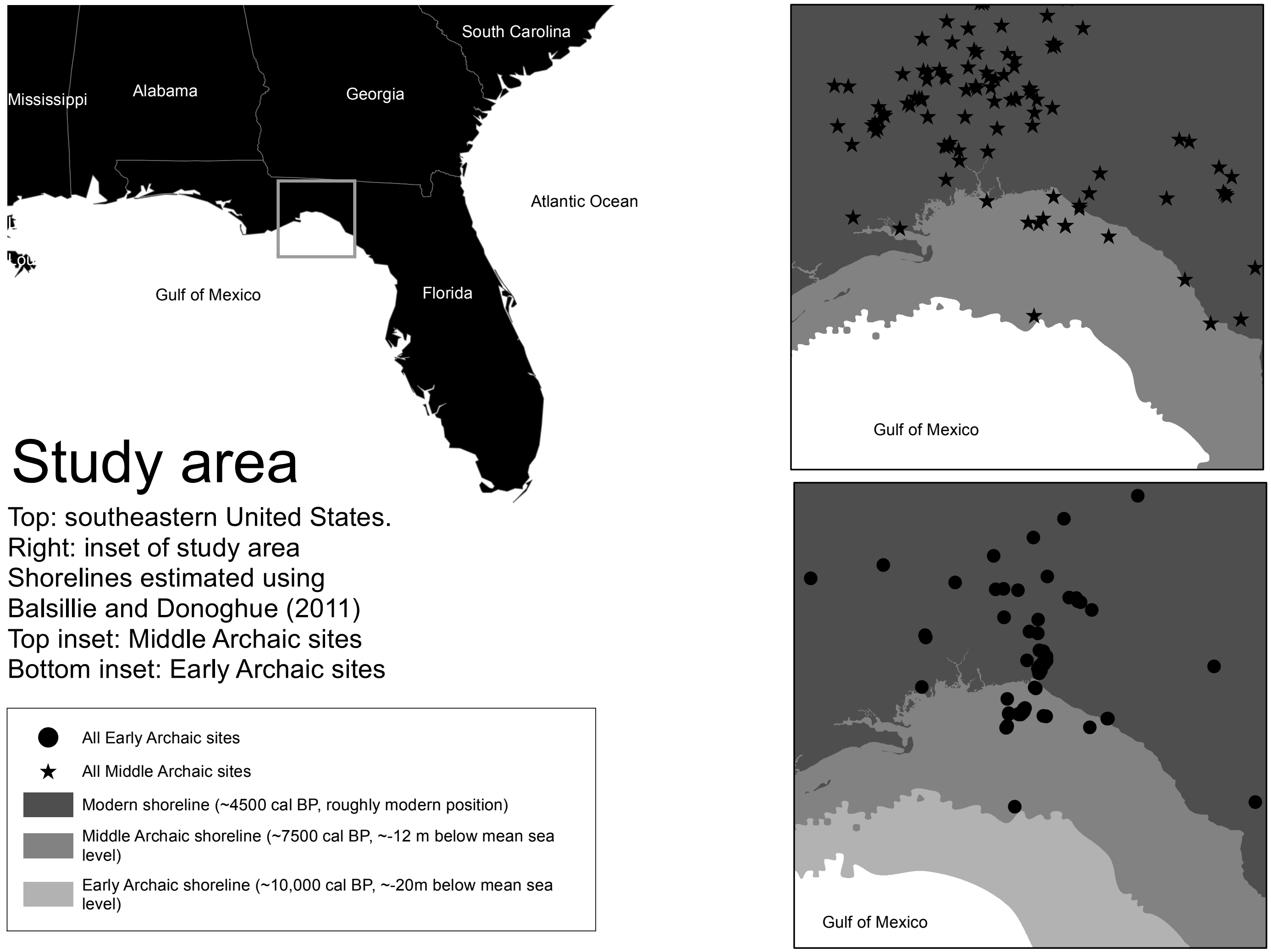


Figure 2.1: Study area in the Big Bend of Florida, U.S.

Study hypotheses

Because we used statistical measures that rely on rejection of null hypotheses to argue for any given interpretation, we first framed our foundational hypothesis that sites appear across the landscape in meaningful patterns as a null; that is, we started with a null hypothesis that sites do not appear across the landscape in statistically meaningful patterns. This hypothesis must be falsified before testing for site patterning across the landscape and potential correlative or causative variables. We do not ignore the body of work that already documents demonstrated connections of site placement to assorted environmental characteristics. Instead, we frame our hypotheses this way to avoid as best as possible underlying extant assumptions about human choices within this landscape, keeping in mind Ford and Halligan's (2010) caution that it is unwise to merely extrapolate backwards in time using archaeological patterns left behind during different ecological conditions form those of the Late Holocene. This approach is consciously "black-boxed" to avoid incorporating false assumptions derived from later archaeological trends.

If our initial null hypothesis can be falsified, we framed the following additional hypotheses:

> H1: Human choices for site locations in the Big Bend through time follow quantifiable patterns at least partially controlled by access to resources sufficient to support group survival. This hypothesis rests on three assumptions: First, that demographic density never exceeded the carrying capacity of the most favored locations; Second, that most sites were thus located where environmental

conditions best supported group survival; Third, that some unknown number of site locations do not represent settlement in less favored locations.

H2: Environmental conditions, human cultural values, and site locations are functionally related through time and that these relationships can be quantified using spatial statistical measures;

H3: Site patterns can be extrapolated onto the continental shelf to create models for site distributions at different temporal periods, and in different geomorphological contexts, i.e., upland occupations instead of coastal ones.

Methods

We employed GIS analysis for this study using ESRI Arcmap 10.3 using the following parameters: individual site locations obtained from the Georgia and Florida master site file databases; a basemap constructed using elevation and bathymetric data obtained from the National Oceanographic and Atmospheric Administration's (NOAA) National Geophysical Data Center (NGDC) using the "Design-A-Grid" tool and the coastal relief model (http://maps.ngdc.noaa.gov/viewers/wcs-client/); paleoclimate models created using Bryson and DeWall's site specific projection software; extant literature for paleoclimate for the panhandle of Florida; fluvial features from the National Hydrological Dataset from the United States Geological Survey; projections for potential paleochannels and sinkholes offshore following Duggins' (2012) GIS-based hydrological analysis of bathymetric data; geologic maps showing potential chert bearing formations in Georgia and Florida; and locations of springs downloaded from the Florida Department of Environmental Protection's GIS database. While our area of interest was primarily Apalachee Bay along the Big Bend, we used environmental data across the entire Panhandle of Florida and southern Georgia to reconstruct the paleo-landscape. Using data only local to the study area itself could obscure, or worse, exaggerate spatial trends.

Site distributions and variable choice

We base our model in part on a detailed examination of resource availability in the Big Bend developed by Dunbar (2016:183, Table 5.1). This model assesses the interplay between climate, hydrology, raw material availability for stone tool manufacture, and floral and faunal distributions. To summarize, during the late Pleistocene, regional water tables and relative sea level were lower, freshwater resources were reduced to sinkhole features dotting the landscape, and faunal taxa were, in many cases, tethered to these locations; further, aquatic and wetland faunal taxa would have been particularly restricted in range and number. Raw materials for tool manufacture were highly abundant, given the exposure of outcrops within and without non-flowing karst collapse fluvial channels. As the climate became warmer and more humid, fluvial features reappeared within the karst collapse channels, wetland and aquatic taxa ranges and numbers expanded, and terrestrial fauna were less tethered to water features. At the same time, some tool stone outcrops would have become submerged in formerly dry channels, although abundant resources remained outside of these locations.

This model can be applied spatially as well as temporally. Although the model does not explicitly account for the specific distributions of marine, estuarine, and nearby terrestrial resource patches along the transgressing coastline for each temporal period assessed, the coastal oasis effect should have created flowing river channels and less water-stressed zones along the coastline, probably along a 7-10 km wide zone bordering the shoreline itself where the less dense fresh water from the aquifer overrides the salt water at the shoreline (Faure et al. 2002; David Thulman, personal communication, 2016). Therefore, the distributions of water resources, raw lithic materials, and biota along the coastline even during arid periods may have more closely resembled those hypothesized for later, humid periods.

If this assessment of resource distribution is accurate, then it follows that site distribution where/when water resources were restricted should be clustered around water sources while site distributions within coastal zones should be more evenly distributed throughout the landscape. Thus, the first step in our study was to test site distributions for clustering versus non-clustering by period, simply to see if this pattern was evident.

However, water is not the only resource needed to support human activities. Food resources and raw materials for technological needs factor into human choices as well. The next step was to assemble multiple environmental variables related to temperature and precipitation rates, net primary productivity (NPP) of biomass, water resources, and geologic resources such as raw materials for stone tool manufacture, and to test the site distributions against these, seeking out which additional variables best explained site occurrence. Some of these are already explicitly included in Dunbar's matrix, such as raw materials for lithic tool manufacture, while others are implied, such as precipitation rates and NPP. One variable we did not test was distance between watersheds; within the modern terrestrial landscape, watersheds enter Apalachee Bay at almost a parallel configuration. This orientation changes once paleochannels are traced on the shelf itself, and so distributions of sites based on distances between watersheds is unlikely to be a stable variable.

We tested Middle Archaic sites against Early Archaic sites instead of testing coastal zones against upland zones. We did this for two reasons: first, because the coastal zone for the Early Archaic is not archaeologically visible; and second, because even upland sites might be less clustered by the Middle Archaic due to the warmer, more humid climate. We also acknowledge that certain coastal resources may not be evenly distributed spatially, and that this may cause coastal sites to cluster despite the more abundant water resources. Finally, our theoretical foundation assumes that cultural values or undetected environmental variables may play significant roles in site choice and that this will be evident in our quantitative results in the form of residual values. We therefore chose statistical measures that assess known variables as well as methods that can detect the missing variables. One measure of a missing variable, for example, can be the presence of spatial autocorrelation in regression analyses; another may be the value of residuals in correlation analyses. These quantitative results may or may not identify the specific nature of a missing variable but do point clearly to how much environmental variables account, statistically, for the occurrence of a site at a given location.

Environmental modeling

Cultural choices play an enormous role in human selection of subsistence resources, but ecological boundary conditions control the range of those choices (e.g, Binford 1980, 2001; Bird and O'Connell 2006). We calculated subsistence variables in the landscape by measuring distance to a water source, whether it was a known fluvial channel, a calculated paleochannel, or a known flowing spring, using hydrographic datasets, and by estimating bulk biomass using net primary productivity (NPP), as a proxy variable for potential food resources. NPP is a general estimate of the amount of potential biomass a given location can produce within its climate parameters (Roy et al. 2001; Del Grosso et al. 2008). While it does not capture the specifics of which floral and faunal taxa were preferred by human groups, it does suggest which areas within our study area could offer the greatest overall potential for subsistence. It has also been successfully tested as an explanatory variable for prehistoric population movements in other studies, suggesting its utility here (Codding and Jones 2013). Obviously, biomass changed through time as climate conditions changed, so we calculated NPP using variations in precipitation and temperature across the landscape for both cultural periods.

We projected paleoclimate using Bryson and DeWall's site specific model (Bryson 2005; Bryson and DeWall 2007). This model generates projected temperature and precipitation ranges on a centennial scale (individual model results, including r^2 values for each regression are available in the supplementary materials). The basic concept that underlies this model argues that the locations of circulation centers such as North Atlantic High or the jet streams are controlled by the global heat budget. Global heat budget is in turn affected by orbital forcing, albedo that reflects heat incoming radiation back into space, and intermittent impacts on the atmosphere such as volcanic eruptions. These effects on circulation centers thus create the boundary conditions for climate.

The model calculates the effects of these boundary conditions on specific locations. Different regions experience different impacts from circulation centers depending on their proximity. Therefore, the circulation centers are grouped by region. When calculating climate conditions for a specific location, the model incorporates appropriate regional circulation centers, termed modules. This study employed the North

American model, including the latitudes of the subtropical high at 0 W longitude, the subtropical high at 135 W longitude, the intertropical convergence at 90 W longitude, and the jet stream at 120 W longitude. Modern climate conditions (using climate normal data from 1960-1990) were regressed using the appropriate regional circulation centers non-linearly using a least squares best fit approach. The use of local climate normal data instead of regional trends incorporates local effects such as topography and proximity to physiographic features such as lakes that can affect climate trends at a local level (Bryson and DeWall, 2007:4-10).

We used 20 weather stations for this study from Georgia as well as Florida to prevent edge effects from skewing the model. The projected values were then fed into the Miami model for net primary productivity (NPP), which estimates the number of grams of carbon (dry matter) produced per square meter under those conditions (equation 1). The maximum amount of carbon production has an upper limit of 3000 grams of carbon/m^2 per year. We used two archaeological periods: The Early Archaic period (11,500 cal BP to 8500 cal BP), and the Middle Archaic period (8500 cal BP to 5000 cal BP). We derived values for total NPP using the precipitation and temperature values generated for each weather station. We used the Miami model despite its potential to overestimate NPP for grassland areas (Del Grosso et al. 2008) because current findings suggest that forest cover became more extensive within the study area after the end of the Pleistocene.

Equation 1: Miami model, equation for calculation of net primary productivity values (Lieth 1972)

$$\boldsymbol{NPP} = \mathbf{min}\ \ \boldsymbol{NPP_P}, \boldsymbol{NPP_T}$$

$$NPP_T = 3000 * (1 + \exp{(1.315 - 0.119 * T)})^{-1}$$

$$NPP_P = 3000(1 - \exp(-0.000664 * P))$$

We time-averaged the projected estimates for temperature and precipitation by cultural period. We then tested estimated paleoclimate projections of each cultural period for accuracy and precision using two methods: comparison with extant literature on paleoclimate in the study area, and statistical analyses for outliers that could skew the mean precipitation and temperature measures. The statistical analyses revealed outliers in precipitation estimates for the Early Archaic period, and so the standard deviations for these estimates were added as an additional variable and used as a proxy for variations in mean annual precipitation, for both periods.

We then created raster images from the 20 weather station data points using universal kriging with linear drift. We chose this method of raster interpolation because prior studies have demonstrated that a global kriging method is the most effective means of interpolating climate data across larger regions, and universal kriging in ArcMap10.3 assumes a general underlying spatial trend, even if the exact parameters are unknown (Hofstra et al. 2008). We also interpolated rasters using standard deviations for precipitation variation for each cultural period.

The final step in landscape modeling required that we account for fluctuations in the regional water table. During periods when the water table drops more than 2-3 meters, karst controlled rivers in the Big Bend, such as the Aucilla, cease to flow. During the

Early Archaic and the Paleoindian periods, the water table was far too low to support regular river flow, leaving only chains of sinkholes along the former fluvial channels (e.g., Dunbar, 2004; Faught and Donoghue 1997). Therefore, we added sinkhole features using the hydrological toolbox in ArcMap. First, we filled the low spots in the bathymetric raster, then subtracted the "filled" raster from the original one, leaving the low spots as potential sinkhole features. We selected possible sinkhole features near paleochannels to represent the low spots that were most likely to be connected to river channels and converted the results to a vector shapefile. One area of the original bathymetric raster for Apalachee Bay was too low in gradient to detect reliable paleochannels or sink features, leaving a gap in the data. We addressed this by selecting features from Coast Guard navigational charts for the bay showing bathymetric features, including clear examples of karst collapse features. We added these karst features to the those derived from the bathymetric raster and used the resulting shapefile to approximates potential sinkholes.

Hybrid variables

The suitability of a habitat is not just a function of basic environmental characteristics. Subsistence and technology that support long-term group fitness can be satisfied in any number of ways within a given environment. Winterhalder, et al. (2010:474, 478-9) include length of sandy beaches suitable for hauling out canoes in the Channel Islands model, for example. Therefore, we started with the assumption that some variables underlying choices for site locations were based in environmental features such as those tabulated by Dunbar, but that others were also embedded with cultural values. Therefore, we treat certain landscape features as hybrid variables reflecting cultural preferences and not just baseline subsistence needs. While they are primarily landscape features with specific ecological or geological characteristics and limited extent, we assumed that proximity of sites should be a matter of human choices governed by cultural values in addition to baseline subsistence needs.

For the southeastern United States during the Early and Middle Archaic (11,500 cal BP to 5000 cal BP), the primary evidence we have for technological innovation is in lithic and bone tool forms. Ceramic technology did not appear until after 5000 cal BP and was not considered here. Bone and horn were products of predation and can be subsumed into subsistence activities. While textiles and other organic technologies were used (see Adovasio et al. 2001), evidence for them is unfortunately not sufficient for inclusion here. This left lithics. The lithic landscape has historically been a useful source of proxy data for a wide range of studies concerned with topics such as mobility, population circumscription, subsistence activities, transmission of technological traditions, and cultural characteristics (e.g, Anderson and Hanson 1988; Andrefsky 1994, 2009; Austin et al. 2014; Buchanan et al. 2016; MacDonald 1998, 2009; Sassaman 2010). Chert appears to have been the preferred raw material during the Early Archaic period but a greater variety of lithic materials was used after that point. (Daniel 2001; Sassaman et al. 1988). Accordingly, potential source locations for chert within or near the Big Bend were mapped using geological maps of Georgia and Florida available in the public domain from USGS (http://mrdata.usgs.gov/geology/state/).

The choice to exploit coastal resources versus upland resources is also partially governed by cultural norms. Intensive use of coastal resources is archaeologically visible in the southeastern United States by the end of the Middle Archaic even while the interior, such as along St. Johns River, was intensively occupied (Mikell and Saunders 2007; Randall 2013; Randall et al. 2014; Sassaman 2010; Saunders and Russo 2011). There is no reason to believe that coastal sites did not exist earlier but currently, the few examples of this are poorly understood (e.g., Cockrell and Murphy 1978; Murphy 1990). Average site distance from the coastline is one way to assess preferences for coastal resources versus solely terrestrial ones; higher densities of sites skewed towards the coastline may suggest a preference for proximity to the coast itself, whereas different patterns of distributions – higher densities further away from the coast, or even distributions of sites across upland zones – may suggest preferences for upland occupations.

To measure this, we recreated paleocoastline positions using the elevation/bathymetric basemap following Balsillie and Donoghue's (2011) relative sea level (RSL) curve for the Gulf of Mexico, using 3 arc second bathymetric and topographic data downloaded for the region from NOAA's NGDC website. These 3 arc second data have a resolution of about 90 meters square for each pixel at the study area's latitude range. We then extracted single polyline files for the Early Archaic coastline at around 10,000 cal BP at ~-20 meters bmsl, and the Middle Archaic coastline at around 7,500 cal BP at ~ -12 meters bmsl.

The final landscape model thus synthesized shoreline positions, NPP projections, variation in mean annual precipitation rates, fluvial/sinkhole features, and the location of geologic formations with the potential to contain high quality chert for tool manufacture. Finally, we added point location data for submerged archaeological sites in the Big Bend provided by the Florida Master site file

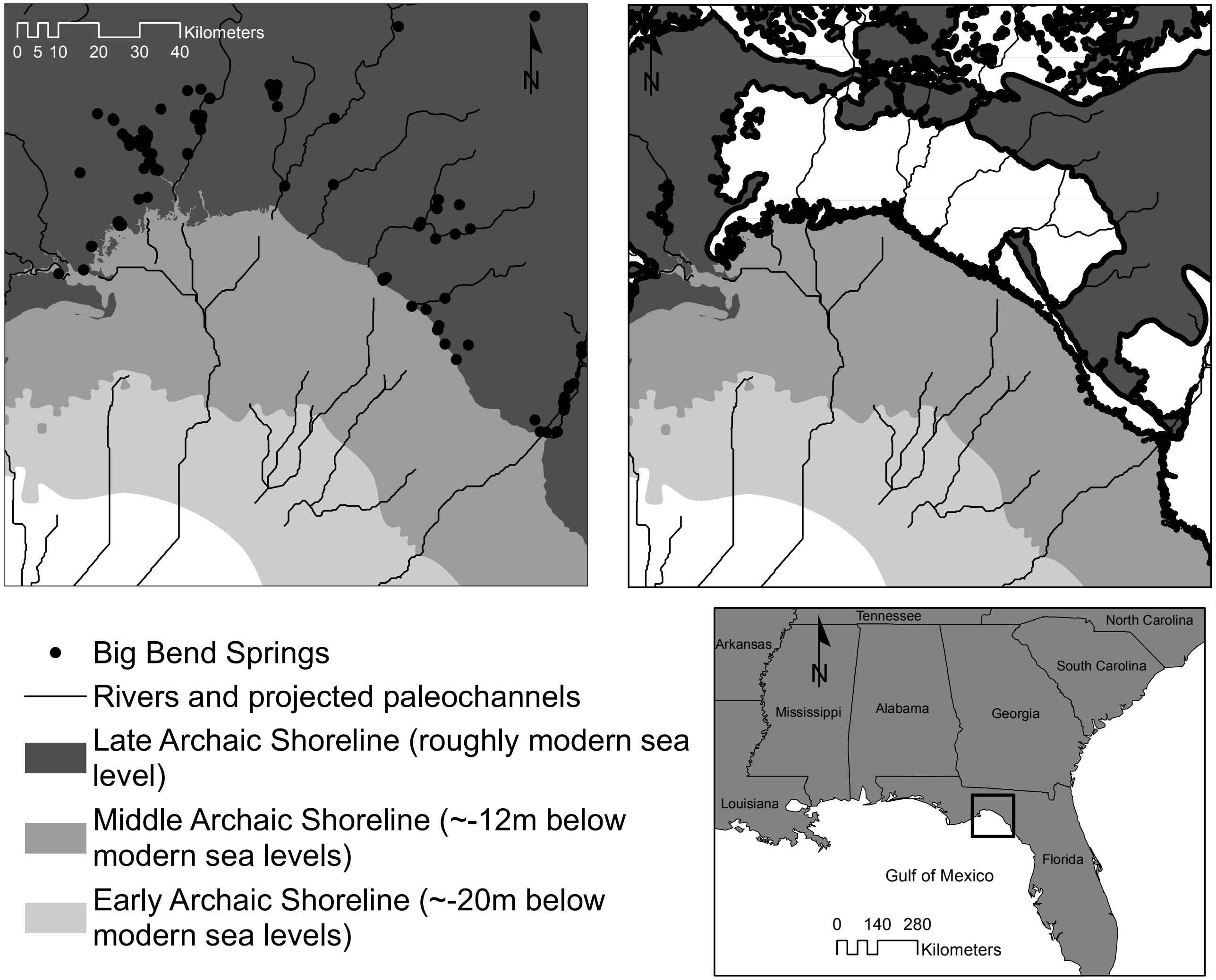


Figure 2.2: Springs sites within the Big Bend region

Limitations of the model

This analysis, like all, has limitations. The most prominent ones are site visibility within the archaeological record, and our use of modeled climate projections. These limitations require mitigation insofar as it is possible.

Site size and preservation is at least partly a function of intensity and regularity of occupation. Most prehistoric sites of these periods are small (<30 m diameter). They are also spread across a relatively large landscape, so overall site density is expected to be low as well. We assumed, then, that the presence of any site implies that subsistence or technological needs could have been satisfied at that location for enough time to create an archaeological deposit. We cannot make claims regarding seasonality or mobility within our spatial analyses or our predictive models. We also cannot make claims concerning exact site type for the same reasons. Furthermore, known site distributions are unlikely to be fully representative of the archaeological record. Site visibility is at least partially a function of the amount of research that has been conducted in an area. Further, the assignment of sites to a given cultural period relies on the accuracy and precision of the archaeological work itself, and may contain errors.

Site distribution uncertainty was dealt with in the following way: first, we chose all Early Archaic and Middle Archaic sites logged in Leon, Jefferson, Taylor, and Wakulla counties. This area has been subject to comparatively intensive archaeological investigation due to the density of development (Leon county, home county to Tallahassee, the state capitol), and long term research interest in very early sites since the digs at Wakulla Springs in the 1930s, and moving forward into the intensive research program in the Aucilla watershed during the 1970s – 2000s (Wakulla, Jefferson, and Taylor counties). We assume that intensive research has minimized the improper classification of sites, that the scale of modern development has exposed a sufficiently large number of sites that they are reasonably representative of human choices during the Early and Middle Archaic periods, and that any remaining improperly classified sites or gaps in site distribution data constitute an acceptable level of noise in the signal. In other words, we have presumed these data have detected enough sites from these periods to allow summary statistics to be calculated with a reasonable degree of confidence. Future surveys may reveal different patterns of sites across the landscape, however, and we acknowledge that the potential for site patterning to change may have significant effects on the validity of this model.

In addition to potential biases in the site data, paleoclimate models rely upon built-in assumptions and are only approximations of past climate conditions. These are described in detail in Bryson and DeWall (2007:12-14), but generally, this model assumes that the boundary conditions created by climate forcing mechanisms have been accurately described and quantified. To further address the limitations of the climate model, we compared the results with extant paleoclimate studies based on proxy data such as sediment cores, fluvial geomorphology, and pollen analysis. We used these studies to assess the model for consistency with the current research findings of paleoclimate in the study. We also tested modeled temperature and precipitation values using descriptive statistics to determine if outliers biased our mean values for NPP. The results from these assessments will be discussed below.

Testing the model for explanatory variables

To prepare our data, we added all the site point locations to the map and separated them into two different shapefiles based on cultural period. For the Early Archaic sites, we had a total count of 98, and for the Middle Archaic sites, we had a total count of 97. We then added temporally appropriate environmental attributes to each point location by calculating each site's distance from a fluvial feature, spring, karst feature, coastline position, and chert using the "Near" tool in the Analysis toolbox. We added site elevation, NPP and precipitation variability using the "Surface Information" tool in the 3D Analysis toolbox.

First, we tested site distributions for clustering within the landscape using three methods. For our first pass, we used Nearest Neighbor Cluster Analysis tool to detect statistically significant clustering. We did this to falsify a hypothesis that they are randomly distributed, which is necessary before one tests for explanatory variables associated with site choice. Nearest Neighbor analysis is an inferential statistical method that tests the null hypothesis that there is no detectable clustering of features such as archaeological sites on a landscape. It also assumes that there are no natural barriers to feature distribution in the landscape, and that the spatial extent of the study area is sufficient to detect clustered distributions. While we can detect no examples in our dataset, should future studies reveal any such barriers, a finding that there is site clustering would require that these be incorporated. Should the spatial extent appear to be incorrect, Ripley's K function analysis that maps clustering patterns at different distances can assist in determining an appropriate spatial extent. Nearest Neighbor analysis also does not analyze these clusters for correlating environmental variables, however, so to test environmental variables for correlations to potential site clusters, we ran the Getis-Ord G tool in the Spatial Statistics toolbox found in ESRI ArcMap 10.3.

This tool looks for non-random clusters of high or low values within a variable. The null hypothesis that one tests with this tool is that values are randomly dispersed; when the p-value is significant and the z-score is high, the clusters contain higher values than one would expect. When the p-value is significant and the z-score is low, the cluster contains lower values than one would expect. There are two forms of this analysis, which is essentially simply hot spot/cold spot analysis. One, The Getis-Ord General G tool, returns an analysis of overall distribution. If sites overall tend to show proximity to springs, for example, this tool will show that clustering around spring locations is statistically significant (p value <= 0.05, negative z score). This test should detect general trends in site patterning; for example, if all sites tend to be located near areas with higher biomass, The Getis-Ord General G tool should indicate this. The other, The Getis-Ord Gi tool, returns an analysis of each individual point's value within the overall distribution and is useful for detecting local trends that may not be revealed by the Getis-Ord General G tool and is more informative than a simple finding of clustering by Nearest –Neighbor analysis, or Getis-Ord General G analysis. If some sites cluster close to the coastline, for example, but others are distinctly within upland zones, this tool is well suited to detect this bivariate distribution. The sites located more closely to the coast than one would expect will show p values <= 0.05, and negative z scores; sites clustering away from the coast will also show p values <= 0.05 but z scores will be positive. Should clustering patterns follow variables we have not included within our analysis, however, Getis-Ord analyses will not reveal them.

This requires regression modeling. These methods can demonstrate a statistically robust relationship between variables and site occurrence, either. Additionally, when regression modeling fails to solve, it can reveal the presence of undetected variables in addition to non-linear causative variables. Like the other analyses, it will not directly indicate the nature of undetected variables, but can better suggest what these may be based on pattern of residuals revealed in the regression models themselves. For example, statistical measures such as variance inflation may reveal that some variables are redundant, suggesting an underlying more general phenomenon. Errors such as non-stationarity or heteroscedasticity can suggest that that variables have different causative properties at different spatial locations within the study area, allowing one to change the spatial extent if necessary. Thus, even when these regression models do not solve, they can still reveal valuable information. When they do solve, they can demonstrate a quantitatively robust relationship between explanatory variables and site occurrences.

We used two different types of linear regressions: Exploratory Regression and Ordinary Least Squares (OLS) regression. These methods require that GIS point shapefiles be incorporated into polygon shapefiles to measure occurrences of the dependent variable – the sites themselves - within a given area. First, we prepared our data by creating two different polygon shapefiles, one for each cultural period, using the "Create Fishnet" tool within the "Feature Class" sub-toolbox within the "Data Management" toolbox in ArcMap. Each polygon cell was 1000 m by 1000 m. We then added the total number of sites from each cultural period to each cell along with the environmental variables using the Join tool in ArcMap 10.3. Where a polygon cell contained multiple points, mean and standard deviations for the environmental attributes were calculated. We then tested the variables to see which were most explanatory for the number of sites per polygon cell by using the Exploratory Regression Tool in the Spatial Statistics Toolbox in ArcMap 10.3.

First, we tested each full fishnet dataset, including cells that did not contain any sites at all. However, when both types of analysis were run on the full dataset, both methods failed to process due to the strongly right-leaning skew created by cells with no sites at all. We also removed one cell from the Early Archaic fishnet shapefile that contained a radical outlier for site count, as outliers this serious can badly distort otherwise well-specified model. Next, we ran regression models only on cells that contained sites and these models performed better. We ran these models in an iterative fashion: first we ran exploratory regressions using correlative variables identified by the Getis-Ord General G analyses. Next, we selected variables from the exploratory regressions that showed statistically significant p values, and ran OLS analysis to test for significance and goodness of fit.

Results

Quality control for paleoclimate models and site distributions

We compared the results of the paleoclimate model to several paleoclimate studies for northern Florida and the Big Bend. For the terminal Pleistocene/Early Holocene, both pollen records from Camel Lake near Tallahassee, Florida, and sedimentological studies from the Page-Ladson site on the Aucilla River suggest a climate that cycled between arid and humid spells. An unusual mesic spruce-hickory forest appeared in the Big Bend and Panhandle during the very end of the Pleistocene, for example, probably caused by meltwater from the Laurentide ice sheet discharging into the Gulf of Mexico, creating a regional micro-climate (Dunbar, 2012:183; Watts, et al., 1992:1064-1065). A precipitation decrease in the early Holocene can be seen in our projections that correlates well to a severe drought period (Watts et al. 1992:1063; Otvos 2004, 2005). These results suggest that there is reasonable agreement between extant paleoclimate proxy data and the climate estimates generated in this study.

Sediment cores taken from both Camel Lake and Page Ladson (8JE00591A) on the Aucilla River do not show evidence for consistent flow before the Early Holocene. The Aucilla river sediment profiles show evidence that the river went dry completely during the Younger Dryas, between about 12,500 cal BP and 11,500 cal BP, with regular flow resuming at the beginning of the Holocene (Dunbar, 2012: 189; Halligan, et al. 2016:3). The interplay between groundwater and relative sea level/shoreline position is a major driver for river discharge rates in this region (Faught and Donoghue, 1997:424; Fauré, et al., 2002, Thulman 2009), and lower relative sea levels may have prevented regular flow until around 10,000 cal cal BP, when relative sea levels raised the water table ((Anuskiewicz 1988; Anuskiewicz and Dunbar 1993; Balsillie and Donoghue 2011; Dunbar et al. 1989). Lakes and rivers that were dry, or only intermittently filled, flowed or filled after this point (Watts, et al.,1992:1065).

In addition to comparing our modeled estimates to extant proxy data, we also used standard deviations for the mean values for each cultural period to identify outliers in the model. The standard deviations for temperature were small, indicating that mean temperature estimates did not obscure significant excursions. So were standard deviations for mean annual precipitation for the Middle Archaic period. However, we found large standard deviations in mean annual precipitation for the Early Archaic in Florida. During the late Pleistocene and beginning of the Holocene, this may have been driven by climate oscillations associated with the end of the Pleistocene, the Younger Dryas, and the onset of Holocene conditions (Dunbar 2012:184, 189–190). Because the Miami model for NPP estimation uses the minimum limit for T or P to calculate the final NPP values, NPP values derived from these estimates failed to detect critical trends in regional precipitation variation. Therefore, while we retained NPP measures for spatial statistical analysis, we considered the standard deviations in mean precipitation rates more robust. We designated this variable as “precipitation variation”.

Nearest neighbor analysis

Both Early and Middle Archaic sites showed statistically significant clustering across the study area (Table 2.1). Early Archaic sites had an expected mean distance of 5.9 km from one another but averaged only 3.4 km from another; this finding had a nearest neighbor ratio of 0.57, a p value of 0.00 and a z-score of -8.01. Middle Archaic sites had an expected mean distance of 4.8 km from one another but averaged only 3.1 km from another; this finding had a nearest neighbor ratio of 0.64, p value of 0.00, with a higher z score of -9.02. Extent of study area was the same for both analyses.

Getis-Ord General G analysis:

Both Early and Middle Archaic sites showed statistically significant “hot spots” and “cold spots” for certain variables, but these varied by period (Table 2.2). Early Archaic sites showed higher values for distance to chert, distance to springs, and NPP, and lower values for distance to the coastline, while Middle Archaic sites showed higher values for NPP and lower values for distance to the coastline.

Table 2.1: Average nearest neighbor analysis

	Average Nearest Neighbor analysis					Accept or reject null hypothesis?
Period	Observed Mean Distance:	Expected Mean Distance:	Nearest Neighbor ratio	Z-Score	P-Value	
Early Archaic (98 sites)	3408.57 Meters	5907.43 Meters	0.57	-8.01	0.00	Reject, sites cluster
Middle Archaic (97 sites)	3082.50 Meters	4790.11 Meters	0.64	-9.02	0.00	Reject, sites cluster

Table 2.2: Getis-Ord General G statistics

Getis-Ord General G statistic							
Early Archaic Period	To water	To chert	To springs	To the coast	To karst features	NPP	Variation in annual precipitation
Observed General G:	0.000209	0.007182	0.002454	0.000864	0.000672	0.001155	0.000672
Expected General G:	0.001147	0.001147	0.001147	0.001147	0.001147	0.001147	0.001147
Variance:	0.000003	0.000002	0	0	0	0	0
z-score:	-0.51	3.85	2.03	-2.72	-1.27	1.86	-1.27
p-value:	0.61	0.00	0.04	0.00	0.20	0.06	0.20
Clustered?	Random	Hot spot, higher values than expected	Warmer spot, higher values than expected	Cold spot, lower values than expected	Random	Warm spot, higher values than expected	Random
Middle Archaic Period	To water	To chert	To springs	To the coast	To karst features	NPP	Variation in annual precipitation
Observed General G:	0.00005	0.000088	0.000217	0.000083	0.000154	0.000193	0.000178
Expected General G:	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018	0.00018
Variance:	0	0	0	0	0	0	0
z-score:	-0.39	-0.16	0.35	-2.19	-0.19	2.04	-0.10
p-value:	0.69	0.87	0.72	0.02	0.84	0.04	0.91
Clustered?	Random	Random	Random	Cold spot, lower values than expected	Random	Warmer spot, higher values than expected	Random

Getis-Ord Gi results

We ran this analysis on every variable after Nearest-Neighbor and Getis-Ord General G analyses, and created histograms to show distributions using the raw scores as for each site. Few of the variables showed normal distributions (Figures 2.3 and 2.4).

Early Archaic sites showed the following groupings (Table 2.3): The proximity to springs was slightly bimodal, with most sites located close to known springs, but others not so closely. Proximity to chert was skewed right, with many sites located within or only a short distance away from the zone where chert outcrops are common. There was a moderately strong right skew towards water sources in the form of fluvial features and a very strong right skew to karst features and springs. These are expected findings based on the extensive prior work exploring the tightly coupled dynamic between water table levels, rainfall rates, and water availability within karst features during this period. Additionally, sites showed tendencies to be located where precipitation variation values were moderate, but with a left skew towards higher NPP values. Coastal proximity values were skewed right, towards the coast, but the strongest trend was in proximity to the Aucilla river itself; no other feature we tested showed as strong a correlation to site location.

Table 2.3: Clustering near variables, Early Archaic period sites (sample size 98)

CLUSTERING NEAR VARIABLES							
NPP	Precip_var	To_springs	To_water	To_karst	To_chert	To_coast	To_Aucilla
64	6	91	29	84	40	71	89
FAVORING HIGHER NPP	Favoring higher precipitation variability	Closer to springs	Closer to water	Closer to karst	Closer to chert	Closer to the coast	Closer to the Aucilla
CONFIDENCE INTERVAL: 95%							

Middle Archaic sites showed the following groupings (Table 2.4): for proximity to springs, the distributions were nearly normal a slightly right skew showing that more sites located near, or within the mean distance, to springs. This was also the case with karst features. For fluvial features (“to water”), site distributions showed that the smallest groups were furthest away from water, and the skew towards these features was stronger than that for karst features or springs. Distribution of sites around chert bearing zones was U-shaped, with some sites located near these zones, some located at middle distances, and another group, the smallest of the three, that was furthest away. Distribution of sites with respect to precipitation variation was nearly bimodal, as was proximity to coastline, and distributions of sites according to local NPP values.

Table 2.4: Clustering near variables, Middle Archaic period sites (sample size 97)

CLUSTERING NEAR VARIABLES							
NPP	Precip_var	To_springs	To_water	To_karst	To_chert	To_coast	To_Aucilla
41	17	16	24	31	30	31	34
FAVORING HIGHER NPP	Favoring higher precipitation variability	Closer to springs	Closer to water	Closer to karst	Closer to chert	Closer to the coast	Closer to the Aucilla
CONFIDENCE INTERVAL: 95%							

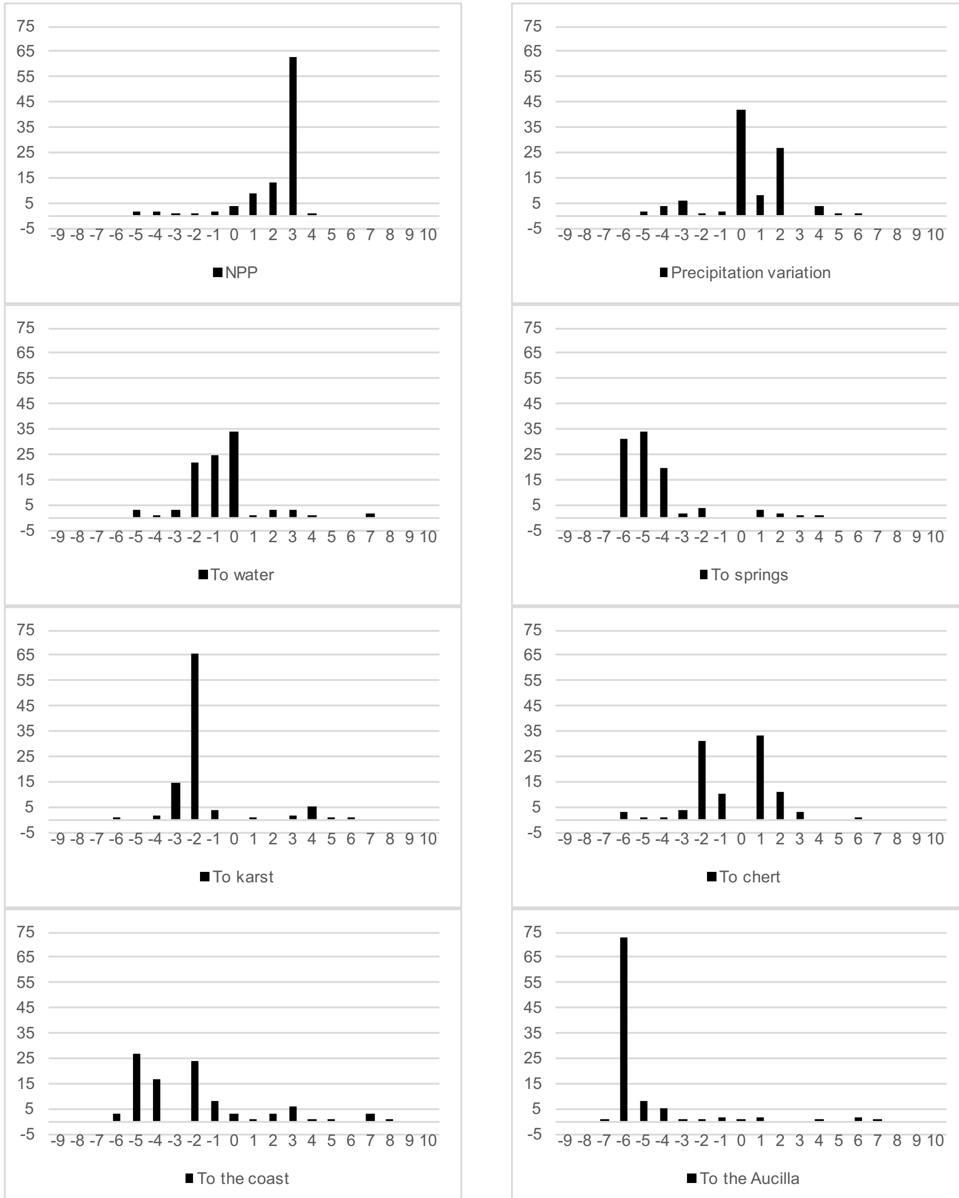


Figure 2.3: Getis-Ord Gi results for Early Archaic sites and variable distributions. Vertical axis represents counts, horizontal axis represents Gi z score.

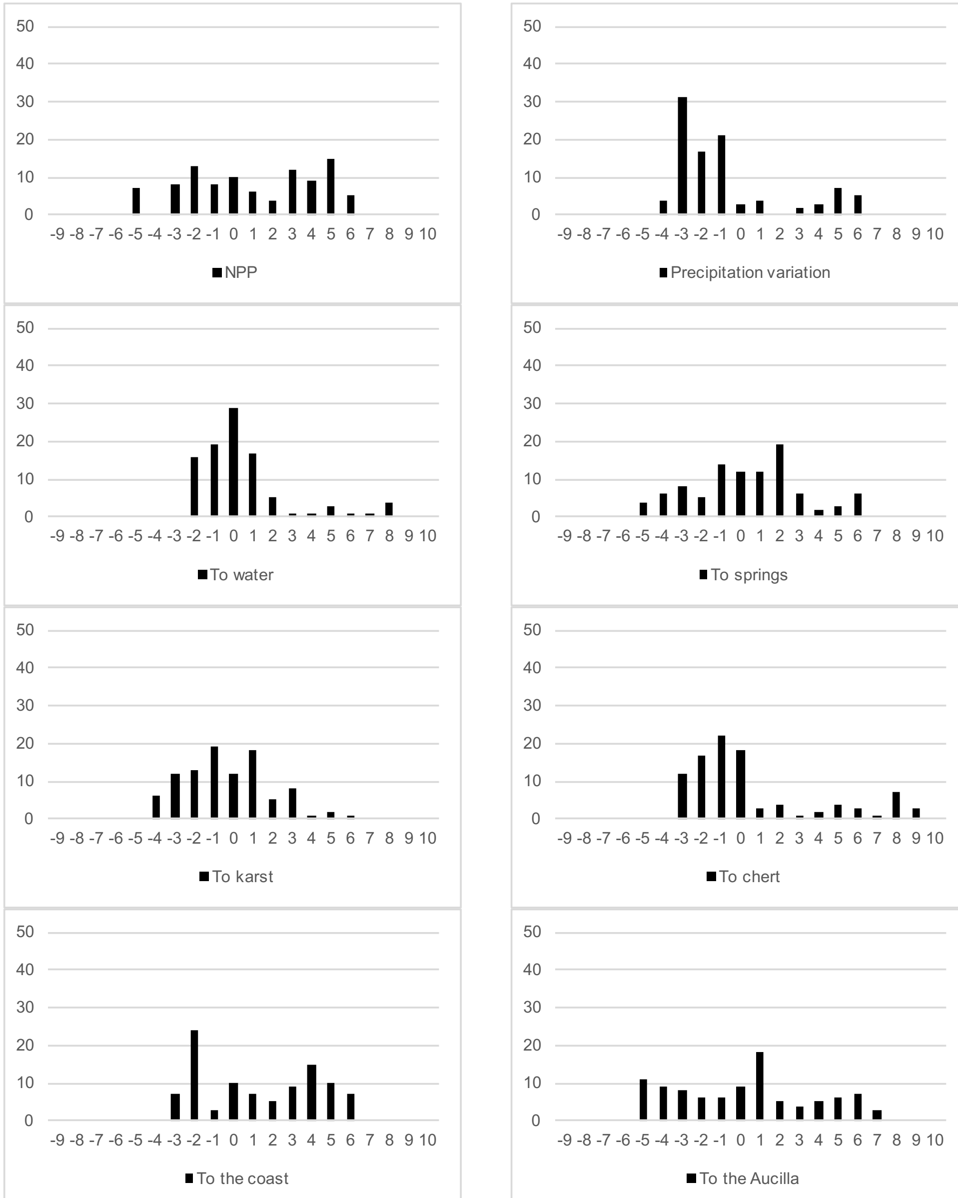


Figure 2.4: Getis-Ord Gi results for Middle Archaic sites and variable distributions. Vertical axis represents counts, horizontal axis represents Gi z score.

Regression modeling:

Given the findings for individual variables using Getis-Ord G statistics that suggest that different sites cluster around different variables, it is unsurprising that regression modeling using both OLS and Exploratory Regression did not return statistically significant passing models for any combination of variables for either period. Passing models were assessed using default parameters for minimum adjusted r-square values, maximum coefficient p –value, maximum variance inflation rate value, and minimum Jarque-Bera p value (see table 3, below, for passing values). When only average values for each variable per cell were assessed, r square values rarely reached even 0.25. When we added standard deviations for each variable per cell, r square values improved significantly, overtopping 0.5 easily in most cases. In most cases, however, either variance inflation, non-normal distributions, or spatial autocorrelation disqualified models even when they returned passing r-square values over 0.5. This only improved marginally when we attempted to transform our dependent variable (number of sites per 1000 m square cell). We used log transformation and inverse transformation; Log transformations retained the right skew in the original count data, while inverse transformation simply reversed the skew to a left orientation. None of these transformations were successful in resolving the problem of non-normal distributions.

Early Archaic sites

Out of the two cultural periods tested, the Early Archaic period was more poorly fitted to the exploratory regression model (Table 2.5). None passed all goodness of fit tests. However, the following exploratory regression was the least poor fit, based on passing values for spatial autocorrelation, variance inflation rate, and Akaike's information criterion. Jarque Bera statistics, and Koenker statistic p values indicate non-normal variable distributions and spatial non-stationarity, indicating that the explanatory powers for variables change across the study area. Thus, this one model appears to indicate some correlative value, but is not fully explanatory for site occurrence in any 1km square area of the study zone. More than 66% of the variance in site count per polygon cell cannot be accounted for by any collection of variables. In sum, we can say that site density per polygon cell correlates to the standard deviations in distance to the coastline during this period variables for each polygon cell, but not all sites do, and that these relationships change across the study area. The table below is summarized from the full report, available in appendices.

Table 2.5: Exploratory regression results, Early Archaic period sites

Choose 1 of 12 Summary Highest Adjusted R-Squared Results AdjR2 AICc JB K(BP) VIF SA Model 0.32 199.93 0.00 0.00 1.00 0.44 +Standard deviation in distances to the coast**; site counts per polygon cell have a very weakly positive correlation with higher standard deviations in distance from the coastline
Passing Models Exploratory Regression Global Summary (COUNT_) Percentage of Search Criteria Passed Search Criterion Cutoff Trials # Passed % Passed Min Adjusted R-Squared > 0.50 1023 768 75.07 Max Coefficient p-value < 0.05 1023 2 0.20 Max VIF Value < 7.50 1023 1023 100.00 Min Jarque-Bera p-value > 0.10 1023 0 0.00 Min Spatial Autocorrelation p-value > 0.10 31 16 51.61

Middle Archaic sites

None of these exploratory regressions passed all goodness of fit tests for this period, either, although their performance was somewhat improved from the Early Archaic models (Table 2.6). The following exploratory regressions were the least poor fits, again based on passing models values. Jarque Bera statistics, and Koenker statistic p values still indicate non-normal variable distributions and spatial non-stationarity. Like the Early Archaic models, these appear to indicate that there is some correlative value for certain variables, but that they are not fully explanatory for site occurrence in any 1000 m square area, either. As with the Early Archaic models, we can say that some sites correlate to some variables, but not all sites do, and that these relationships change across the study area. The table below is summarized from the full report, available in appendices.

Table 2.6:Exploratory regression results, Middle Archaic period sites

Choose 1 of 10 Summary
Highest Adjusted R-Squared Results AdjR2 AICc JB K(BP) VIF SA Model 0.76 -105.77 0.00 0.00 1.00 0.93 +Standard deviation of the distance to the Aucilla; higher values are positively correlated with more sites per 1 square km area.
Choose 2 of 10 Summary Highest Adjusted R-Squared Results AdjR2 AICc JB K(BP) VIF SA Model 0.95 -251.83 0.00 0.00 1.01 0.42 -Average distance to springs + Standard deviation of the distance to the Aucilla; lower distance to springs, and higher values for standard deviation in mean distance to the Aucilla per 1 square km area.
Choose 3 of 10 Summary Highest Adjusted R-Squared Results AdjR2 AICc JB K(BP) VIF SA Model 0.95 -253.12 0.00 0.00 4.19 0.68 -Average distance to chert bearing bedrock zones +Standard deviation to karst features, + Standard deviation of the distance to the Aucilla; lower average distance to chert bearing zones, higher standard deviations in distance to karst features, higher standard deviations in distance to the Aucilla.
Passing Models Exploratory Regression Global Summary (COUNT_) Percentage of Search Criteria Passed Search Criterion Cutoff Trials # Passed % Passed Min Adjusted R-Squared > 0.50 1023 768 75.07 Max Coefficient p-value < 0.05 1023 2 0.20 Max VIF Value < 7.50 1023 1023 100.00 Min Jarque-Bera p-value > 0.10 1023 0 0.00 Min Spatial Autocorrelation p-value > 0.10 31 16 51.61

Finally, we compared individual Gi scores for coastal proximity and proximity to the Aucilla during the Early Archaic and Middle Archaic periods using principal components analysis (PCA) and linear discriminant analysis (LDA). We chose these two variables during this period alone for three reasons: first, because distance to the Aucilla and distance to the coastline were returned as a significant, if not explanatory, variable for both periods; and second, because both zones represent potentially significant cultural choices that were both capable of providing access to fresh water and diverse biomass. We classified all sites with z scores less than -1.96 as coastal, all sites with z scores over 1.96 as upland, and all sites with z scores between -1.96 and 1.96 as NA (none of the above). Clear groupings emerge (Table 2.7, Figure 2.5). For the Early Archaic, Aucilla sites that are close to the coast, or that show no significant score for coastal proximity, appear conflated. Upland sites along the Aucilla appear to constitute a distinct group, and upland sites without significant scores for proximity to the coastline appear to be another group.

PCA and LDA results for the Middle Archaic period are more complex (Table 2.8, Figure 2.6). Attempts to classify sites using both proximity to coastline and proximity to the Aucilla failed to detect clear groups of any sort. Likewise, PCA and LDA using proximity of the sites to the Aucilla also failed to detect specific groupings. However, PCA and LDA classifying sites by proximity to the coastline showed clear distinctions between coastal sites and upland ones, with some overlap created by an "N/A" group. Loadings are complex, with NPP, distance to chert, and distance to the Aucilla the strongest positive coefficients, and distance to the coastline the most negative coefficient on axis 1. Results appear to suggest that a coastal zone of sites with distinct characteristics exists, but that their relationship to the Aucilla is less strong than during the Early Archaic period.

These results appear to suggest that coastal zones existed during both periods. However, during the Early Archaic, there appears to be a strong association of coastal sites with the Aucilla, while this is not the case during the Middle Archaic. The role of biomass and precipitation variation is detectable for both periods but is difficult to interpret in detail because we lack resolution for habitat ranges for specific taxa. We can say that both periods saw a preference for higher NPP zones. However, overall variation in NPP is small for both periods, and future syntheses of zooarchaeological and botanical remains can offer badly needed insight here.

Table 2.7: Principal components analysis and linear discriminant analysis, Early Archaic period, all groups

Early Archaic period principal components analysis (PCA)						
PC	Eigenvalue	% variance				
1.00	23.16	58.31				
2.00	8.99	22.64				
3.00	3.53	8.89				
4.00	2.10	5.29				
5.00	1.07	2.70				
6.00	0.44	1.10				
7.00	0.38	0.96				
8.00	0.04	0.11				
Early Archaic period linear discriminant analysis (LDA)						
	Axis 1	Axis 2	Axis 3	Axis 4		
NPP	-0.03	-0.49	-0.27	-0.32		
Precip_var	-0.09	-0.27	0.67	0.65		
To_springs	0.15	-0.32	0.45	-0.40		
To_water	0.21	0.00	-0.01	-0.37		
To_karst	0.26	-0.18	-0.44	0.08		
To_chert	-0.14	-0.63	0.44	0.33		
To_20mcoas	0.38	0.77	-0.64	-0.27		
To_Aucilla	0.34	-0.49	0.36	-0.51		
LDA confusion matrix						
	Aucilla; Coastal	Aucilla; NA	NA; NA	Aucilla; Upland	NA; Upland	Total
Aucilla; Coastal	68.00	3.00	0.00	0.00	0.00	71.00
Aucilla; NA	0.00	13.00	0.00	0.00	0.00	13.00
NA; NA	0.00	0.00	0.00	0.00	2.00	2.00
Aucilla; Upland	0.00	0.00	0.00	5.00	0.00	5.00
NA; Upland	0.00	0.00	2.00	0.00	5.00	7.00
Total	68.00	16.00	2.00	5.00	7.00	98.00
% classified correctly: 92.86						

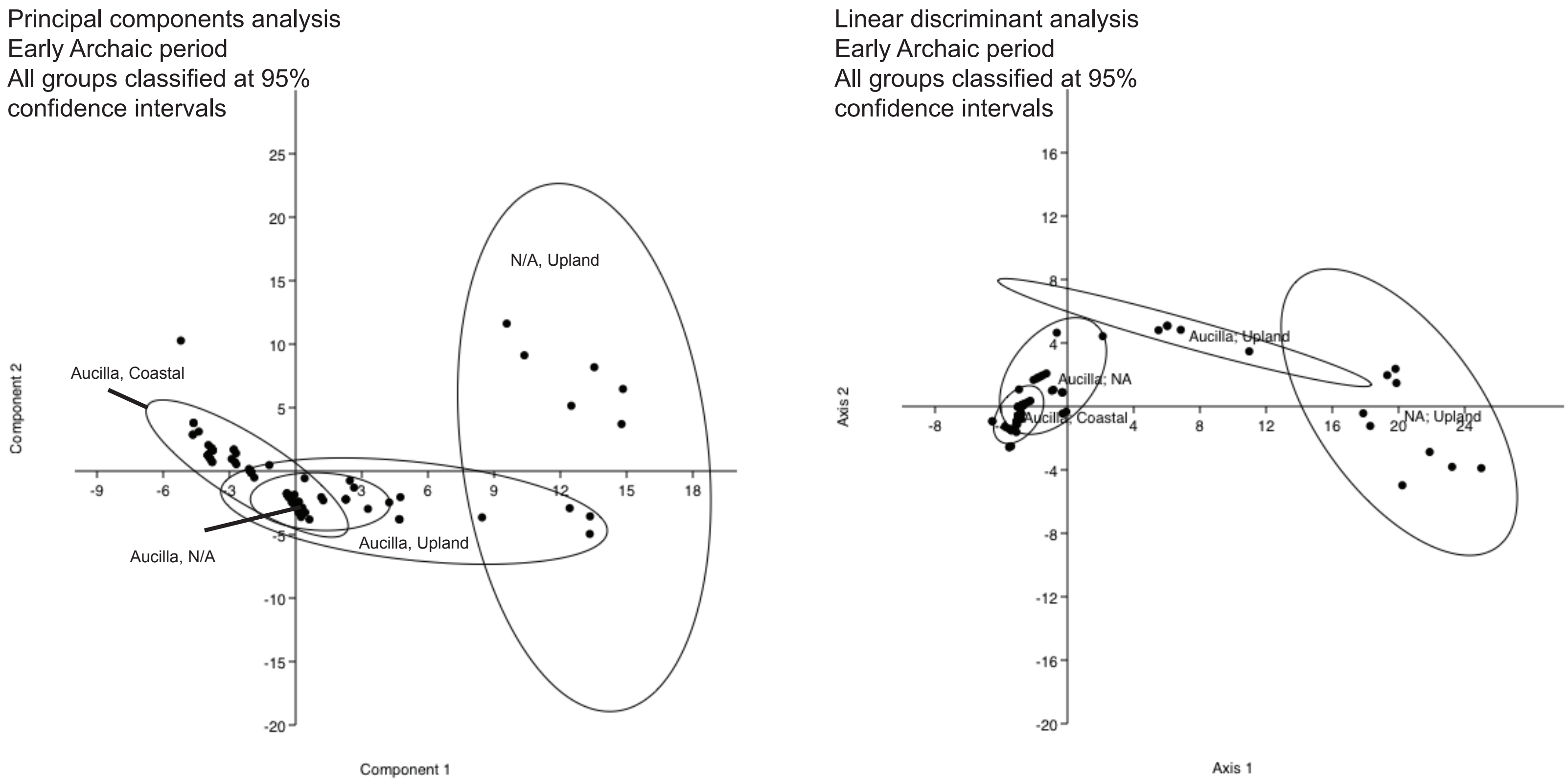
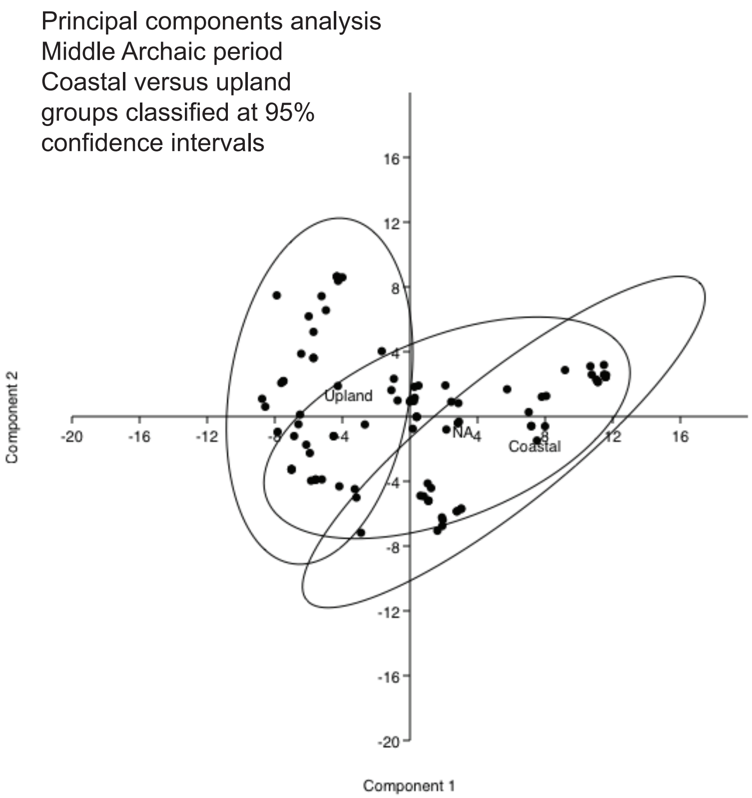


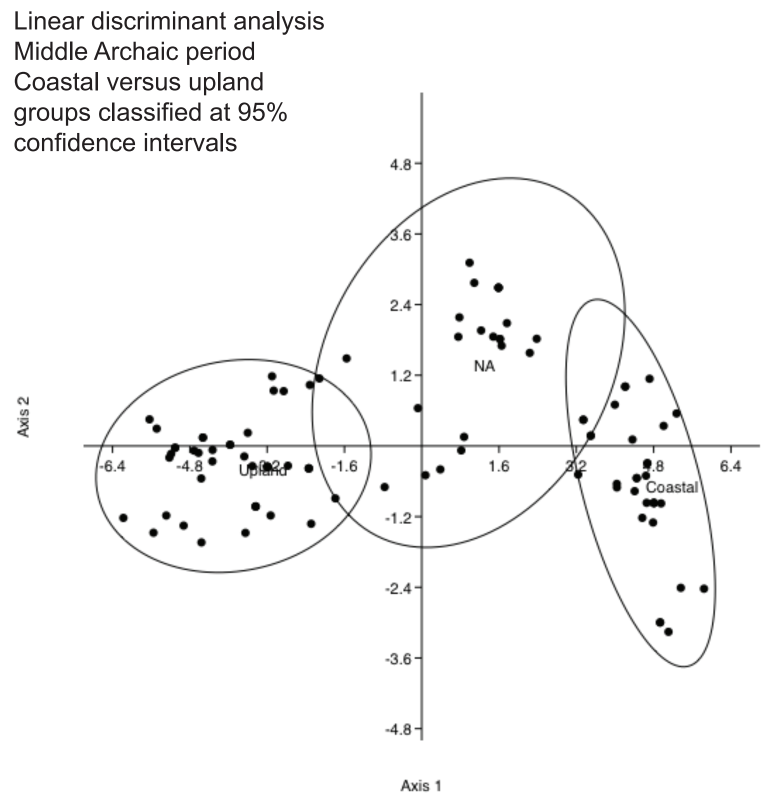
Figure 2.5: Principal components and linear discriminant analysis, Early Archaic period sites

Table 2.8: Principal components and linear discriminant analysis, Middle Archaic period sites, coastal versus upland locations

Middle Archaic period principal components analysis (PCA)				
PC	Eigenvalue	% variance		
1.00	35.96	51.58		
2.00	15.66	22.46		
3.00	11.08	15.88		
4.00	3.35	4.81		
5.00	2.49	3.57		
6.00	0.77	1.10		
7.00	0.30	0.44		
8.00	0.12	0.17		
Middle Archaic period linear discriminant analysis (LDA)				
	Axis 1	Axis 2		
NPP	0.54	0.11		
Precip_var	0.36	0.34		
To_water	-0.37	-0.57		
To_Springs	-0.22	-0.36		
To_karst	0.45	-0.51		
ToChert	0.56	0.60		
To_coast	-0.77	-0.06		
To_Aucilla	0.51	0.47		
LDA confusion matrix				
	Upland	NA	Coastal	Total
Upland	42	0	0	42
NA	2	21	1	24
Coastal	0	0	31	31
Total	44	21	32	97
% classified correctly: 96.91				

Table 2.9: PCA and LDA analysis, Middle Archaic coastal versus upland sites





Discussion

The paleoclimate model:

Overall, the paleoclimate model created using the Bryson and DeWall method correlated reasonably well with extant paleoclimate studies. The most significant finding was the wide fluctuation in mean annual precipitation rates during the Early Holocene/Early Archaic. Closer examination using the projected precipitation rates suggested that the variability is highest during the summer months; One example of this can be seen in estimated rainfall rates for the area around the St. Marks Lighthouse; only October rates show relative stability during both the Early and Middle Holocene. January, April, and July rates vary considerably, especially between 11,500 -9400 cal BP and 6600-5600 cal BP. The only relatively stable periods appear between 9500 – 6800 cal BP, and even then, July precipitation was unstable. (Figures 2.6, 2.7).

These fluctuations should have had a noticeable effect on the rate and timing of the return of forest cover to the landscape. Grassland/parkland environments were present during the Pleistocene but forest cover is thought to have spread into the area as early as the mesic forest at Camel Lake between~14,000 cal BP and ~12,000 cal BP (Garrison, et al., 2008; Garrison, et al., 2012; LaMoreaux, et al., 2011; Leigh, 2008; Littman, 2000; Otvos, 2004, 2005; Russell et al., 2009; Watts, et al. 1992; Weaver, 2002). It seems that this succession to forest cover was not an even process, however. Russell, et al. note that a mix of trees and forest cover was intermingled with abundant grasses in Coffee County, Georgia, during the Middle Holocene, and that even as late as first European contacts, areas of grassland/prairie were documented by Spanish explorers in the Carolinas, notably managed by intentional burns by Native Americans (Russell, et al., 2009:187-

188, 192). Forest cover, where it persisted, should have created a buffer that ameliorated the worst effects of drought, but it is reasonable to infer that the transition to a more closed canopy, warm temperate forest, was not a linear process.

Areas of high biodiversity such as wetlands would have been particularly vulnerable to drought (Thulman, 2009:251). NPP rates in grassland/prairie zones would also have been affected due to the greater impacts of precipitation rates on NPP in these locations (DelGrosso, et al., 2008:2124). Because of these intermittent droughts, both grassland zones and forest cover should have experienced fluctuations in NPP that should have in turn created a state of comparatively rapid ecological turnover. This in turn could have temporarily increased biodiversity (Bird and Tayor 2013; Odum 1960; Roy et al. 2001:170-172). The landscape thus appears to have been composed of dynamic, shifting patchwork communities during the Early Holocene. The role of human interference by intentional burning cannot be inferred from this study, but should be considered as well.

This variability in precipitation also does not correlate well to the divisions assigned to the general cultural periods. It may be the case that the climate model is erroneous, although its overall correlation to extant proxy data such as Watts, et al.'s pollen study from Camel Lake (Watts et al. 1992), and the climate proxies recovered at Page Ladson (Dunbar 2016; Halligan et al. 2016), argue that it is a reasonable approximation. Cultural period is generally assigned based on changes in material culture, which in turn are thought to represent some blend of cultural values and pragmatic engineering (e.g., Binford 1962; Binford and Binford 1966; Binford 1980; Bordes and de Sonneville-Bordes 1970). The lack of correlation of typological change with precipitation change effectively decouples ecological transitions from tool typologies (O'Brien 2015, 2016; but c.f. Faught and Carter 1998; Faught and Waggoner 2012). Only a closer examination of tool assemblages, and tools themselves, from individual sites can potentially tease out associations of tools with tasks, cultural groups, or environments (e.g., Thulman 2012; Andrefsky 1994, 2009).

This in turn suggests that changes in paleoecology were not driving changes in tool typologies. There are many different reasons that this might be the case: 1) It could indicate that cultural aesthetics drove tool typologies much more so than pragmatic applications; 2) This could also indicate an inherent conservatism in tool typology; 3) Finally, it could suggest that diagnostic tools were being used to manipulate resources found in multiple habitats. None of these hypotheses are mutually exclusive of the others, and this underscores our argument that both cultural and environmental variables must be integrated into predictive models and interpretive frameworks when assessing submerged prehistoric sites from varying time periods and relative sea level contexts.

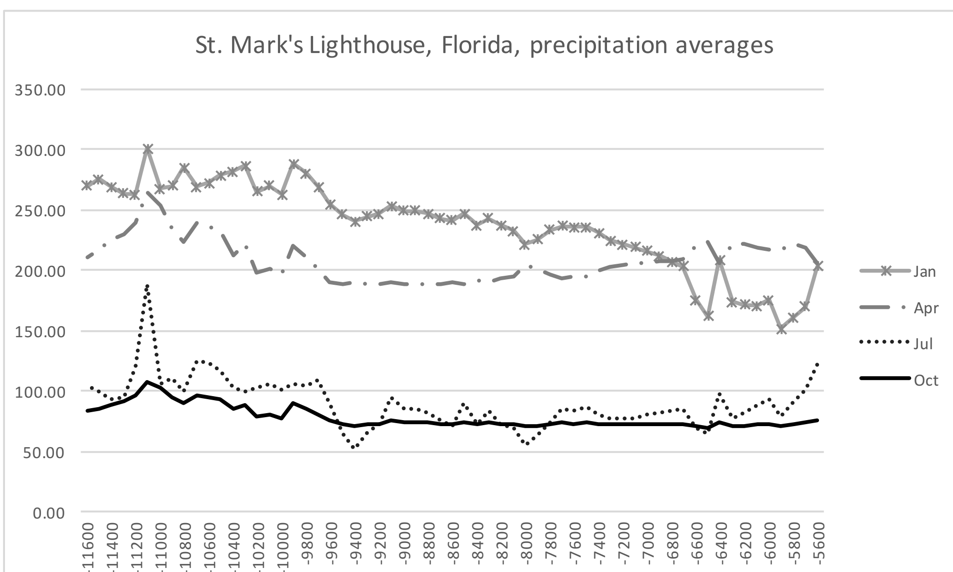


Figure 2.6: Variation in precipitation rates, St. Marks Lighthouse. Y axis is precipitation in mm/month, x axis is years cal BP.

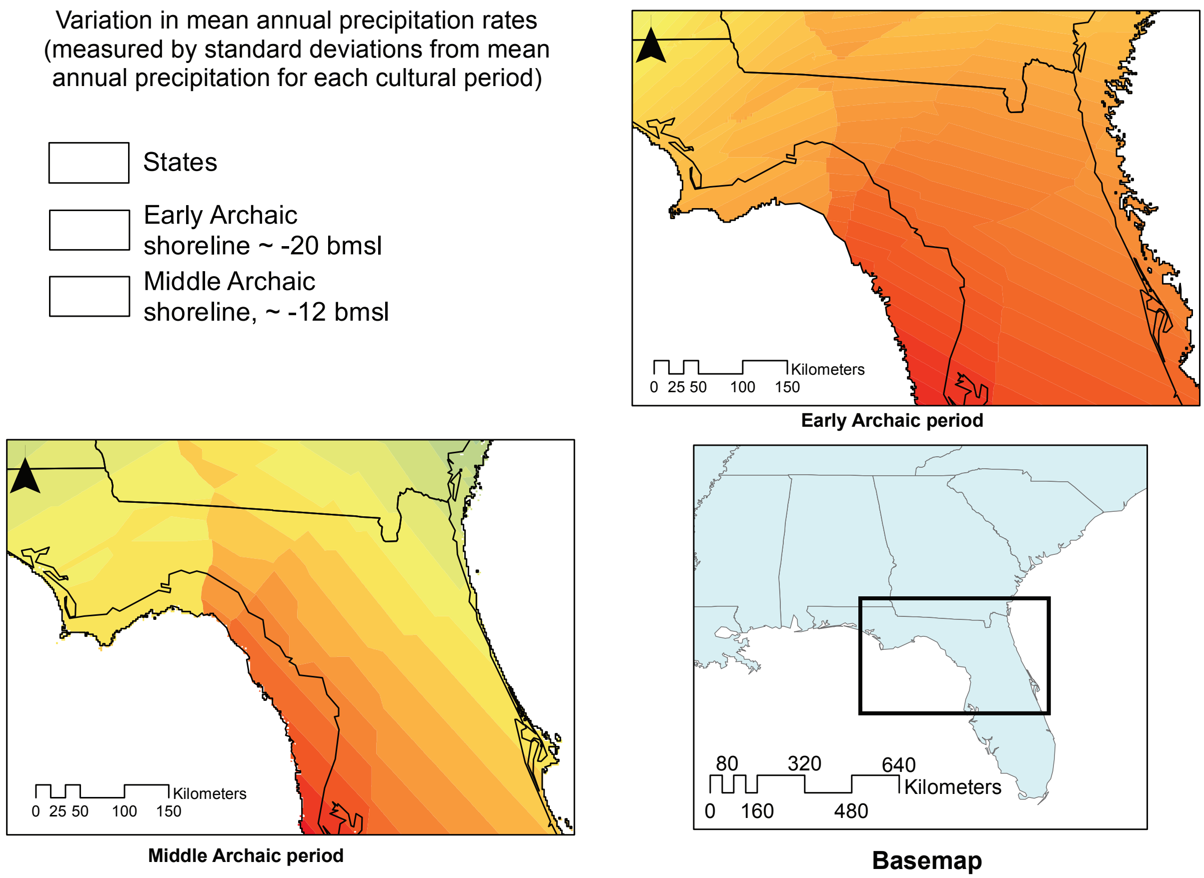


Figure 2.7: Variation in mean annual precipitation rates for each cultural period.

Spatial analysis results

Our results suggest that strictly environmental variables only partially correlate with site distributions, as we expected. We also found that each spatial analysis method differed in degree of effectiveness. We will discuss our results by assessing each method first, and then will offer additional overall interpretations.

Nearest neighbor analysis indicates that sites during both periods clustered in statistically significant ways. This falsifies the null hypothesis that site clustering either does not exist, or cannot be detected. However, Middle Archaic sites returned a more negative z score value than Early Archaic sites, indicating that they were more clustered than Early Archaic sites, but the nearest neighbor ratio is larger, suggesting a distribution closer to a random one. These contradictory results initially appear to partially argue against Dunbar's hypothesis that water resources no longer tethered human groups to restricted zones. However, if access to water was less restricted by the Middle Archaic period, this left human groups free to choose locations based on other variables, accounting for the nearest neighbor ratio. It is also consistent with lower mobility, which multiple scholars argue for in the Southeast by the Middle Archaic (e.g., Anderson 1991, 2001; Daniel 2001; Sassaman et al. 1988; Sassaman 2010; Quinn et al. 2008; Tomczak and Powell 2003; Tuross et al. 1994).

General Getis-Ord G analyses appear demonstrate that sites from different cultural period correlate to different environmental variables. This supported our hypothesis that cultural groups prioritized different environmental variables during different periods. Early Archaic sites correlate well in this analysis to proximity to chert resources, springs, higher NPP values, and springs, but did not favor the coast. The apparent clustering of sites near multiple resources appears to account for the lower z score values returned by nearest neighbor analysis, and the lack of coastal orientation was expected, given that these sites were upland when they were occupied. Middle Archaic sites only correlate well to proximity to higher NPP values but surprisingly also did not seem favor the coast in this analysis. The most reasonable explanation for this phenomenon is that the approach of the coastline to its modern position by the Middle Archaic brought the coastal oasis into formerly inland areas, allowing water resources to disperse, and untethering human groups from karst features such as sinkholes, springs, and presumably the coastal zone where water was more accessible. This could also suggest that spatial separation existed between coastal and upland communities for both cultural periods, because use of coastal resources has been more than adequately demonstrated by the Middle Archaic (Mikell and Saunders 2007; Saunders et al. 2009; Saunders and Russo 2011; Russo 1994). It could also be an artifact of using paleoshoreline constructions based on the current understanding of relative sea level curves, but this seems less likely given the Getis-Ord Gi tests on individual sites.

These individual Getis-Ord Gi tests for each variable per cultural period indicated that some sites did cluster around certain variables that had failed to return significant z-scores in the General Getis-Ord G tests (Table 2.8). Unsurprisingly, variable significance and distributions changed by cultural period, as we hypothesized. Moreover, they showed that Early Archaic sites were indeed tethered to springs, water sources, and karst collapse features, supporting the argument that water resources were only available where the surface geology allowed access to the aquifer (Duggins 2012; Dunbar 2016; Thulman 2009). Importantly, not all Early Archaic sites were in proximity to water resources, however. Statistically significant hot spots of sites located away from karst features, springs, and potential fluvial channels were all present in the dataset, suggesting the possibility that multiple site types are represented here.

By the Middle Archaic, however, the distributions of sites in proximity to all features was much more expansive, supporting contentions that water resources were more dispersed. This is also suggested by our results for coastal proximity. Our results demonstrate that one group of Middle Archaic sites shows statistically significant proximity to the coastline. Other sites show significant z scores for upland zones, or no statistical grouping at all, however, which accounts for the failure of the first Getis-Ord G analysis to detect a preference for coastal occupation zones. In contrast, z-scores for Early Archaic sites' proximity to the coastline was clearly stronger than the Middle Archaic. If we follow these individual results, it appears that upland Early Archaic sites were also skewed towards the coastal oasis. As we noted above, the coastal oasis effect should have made water resources more available closer to the coastline, and these results appear to quantify this phenomenon.

Further, the Early Archaic sites closest to the coastline in the study area all cluster around the Aucilla River watershed, whereas Middle Archaic sites, both coastally oriented and not, are distributed throughout the Big Bend. Additional Getis-Ord Gi examination of this observation indicate that the Aucilla watershed as clearly a locus of settlement during the Early Archaic, but that other watersheds experienced increased attention during the Middle Archaic. Taken together, these findings again support Dunbar's argument that the greater availability of water resources allowed for site dispersal by the Middle Archaic, but there are additional interpretations that should be considered, as well. These include the possibility that the Aucilla River watershed was a socially recognized territory during the Early Archaic, with human groups less interested in nearby watersheds regardless of their resource potentials. This would constitute a culturally driven, not strictly environmentally driven, set of choices. As we noted above, our results for both periods may also be detecting different types of sites and/or that there are statistically significant missing variables from our model. It may also be the case that distinct social groups occupied clear territories, including coastal zones, during both periods, but that hypothetical Early Archaic period coastal sites are less archaeologically visible. More may lie offshore, however, and the characteristics of the archaeologically visible sites, both upland and coastal suggest what forms they may take, as we will discuss below.

An additional difference between cultural periods also appears to be present within our results. The nature of clustering for Early Archaic sites, with stronger preferences for access to springs, karst collapse feature, chert, and proximity to the Aucilla and the paleoshoreline, suggest a specific territory within which different sites may have served individual task different purposes. In contrast, more Middle Archaic sites rendered z scores for clustering around individual variables that were "middle of the road", so to speak, as if these sites were chosen to place them "close enough" to a variety of resources. However, as we discussed above, nearest neighbor results for the Middle Archaic show more negative z scores than the Early Archaic, but less clustered nearest neighbor ratios. While we can only offer tentative interpretation for these seemingly contradictory findings, it may be the case that these analyses are picking up a change in mobility patterning in the Big Bend from the Early Archaic to the Middle Archaic. Nearest neighbor analyses showing less negative z scores for the Early Archaic may be indicating that Early Archaic groups had longer range mobility, while the more negative z scores for Middle Archaic sites may indicate reduced mobility. Getis-Ord Gi analyses by variable also seem to indicate that despite the potential higher degree of mobility, Early Archaic groups picked their sites based at least in part on proximity to key variables, while Middle Archaic groups located themselves, at least in part, "close enough" to desired environmental variables. This change is likely predicated at least partially on the change in water availability, and may or may not be connected to coastline proximity. Because we did not include site size, only point locations, we cannot comment on how this factor may have influenced these results. Site size and number of different features is often used to infer mobility (Kelly 1992; Kelly et al. 2005). Future studies may include these data to see if size correlates to differences in predictive variables and thus may suggest changes in mobility.

Exploratory Regressions

As shown in the Results section, these tests performed poorly due to non-stationarity and missing variables. However, the residuals from the r square values do suggest what some of these factors might be. For the Early Archaic, 68% of the residual correlation in the adjusted r square is not accounted for by the model. The very strong correlation of sites seen in the Getis-Ord Gi results for proximity to the Aucilla River, higher NPP values, proximity to springs, karst features, potential chert bearing areas, the coastline, and the Aucilla suggest that Early Archaic groups preferred this watershed and its attendant environmental resources, but the inability to the regression models to solve also suggest that other explanatory variables are also a factor. This is unlikely to reflect a decision based on water access alone; other watersheds such as the St. Marks could have been occupied during the Early Archaic but either weren't, or the archaeological visibility for early sites outside the Aucilla Watershed needs to be improved. The only way to test these hypotheses is additional research on very early sites along neighboring watersheds such as the St. Mark's and Econfina Rivers, especially near deeper sinkhole features (James Dunbar, personal communication, 2017). If archaeological visibility is not the cause for this patterning, then this is further support for our argument that this analysis has detected territorial behavior. Additional missing cultural variables such as preferences for certain taxa of flora or fauna, and/or well as higher mobility organized around different site types such as quarry sites, likely also play a role in these ambiguous regression results. Testing for these variables in a meaningful manner will require further paleo-environmental reconstruction.

Middle Archaic r square values were much higher with the distance to Aucilla remaining a component of the least poorly fit model, but the Getis-Ord Gi results appear to indicate dispersion of sites both away from and around this watershed. Proximity to springs and chert bearing zones also appear in these models, but not in the Getis-Ord Gi tests. Further, dispersion at different distances from the coastline is a factor revealed by Getis-Ord Gi tests, as well as preferences for higher NPP values, and low variability in precipitation rates, but the regression models did not indicate that these were significant over the entire study area. If the Aucilla River was a distinct social territory during the Early Archaic, and the other watersheds were ignored even if water access was possible, then the dispersion of sites away from the Aucilla during the Middle Archaic period may represent socio-cultural decisions, population growth, or some other transition in site location decision making that is difficult to quantify. Again, this suggests that either social territories played a role in site choice, or that missing environmental variables were in play.

One major factor in the failure of regression models to resolve was the present of non-stationarity in the influence of variables on site locations. Non-stationarity indicates that a given variable or set of variables does not have the same influence on dependent variables across a landscape. The Getis-Ord Gi results corroborate that this is the case: not only are environmental choices different both within and across each cultural period, different groups of sites appear within our larger subsets for each cultural period (Table

2.8). This may be a problem of chronological control, given the extent of the time spans under study (millennia, not centuries). At present, there are too few known sites with absolute dating controls for these periods, however, making statistical analyses at higher temporal resolution impossible. One possible way forward would be analysis of sites using the presence of specific tool types (such as Bolen versus Kirk for the Early Archaic period), but this assumes that chronological control on these types is accurate and precise. This is not always a given, as interpretations of tool type chronologies are routinely refined or changed as new data are collected. This problem highlights an issue that permeates archaeology as a discipline, and not just modeling for settlement patterns: We routinely examine cultural periods spanning hundreds and thousands of years, and a great many details are inevitably lost in the aggregate. This problem is likely to remain for the foreseeable future and will represent a significant challenge to detailed modeling for settlement patterns both onshore and off.

To summarize, then, we cannot understate the role that cultural choices played in site locations, or the need for higher resolution temporal data on both sites and environmental conditions. Human groups clearly made different decisions using different priorities over time and space during these cultural periods. This should not come as a surprise. It does, however, complicate assembling a site prediction model based on cultural period alone. As we noted in our introduction, we assume that cultural choices played a role in site choice, and the non-normal distributions in the Getis-Ord Gi results and the residuals in the r square values from the failed exploratory regressions support this interpretation. We point particularly to the locus of Early Archaic activity around the Aucilla River, arguing that it should not be interpreted to mean that it offered the only area in which prioritized resources could be acquired. Instead, we should consider that the extreme time-depth of occupation there, dating back to the early Paleoindian/pre-Clovis period, suggests the possibility that this was an ancestral territory with cultural as well as environmental value – and that Middle Archaic territories and site types were organized around very different environmental and cultural priorities. Once again, this plays up the need to consider human choice within the landscape that are only indirectly related to biological constraints (e.g., Bird and Bleige Bird 1997; Bird and Bliege Bird 2000; Bird and O'Connell 2006; MacDonald 2009).

Table 2.10: Getis-Ord Gi z scores, Early and Middle Archaic sites

Early Archaic	NPP	Precipitation variation	To springs	To water	To karst	To chert	To coast	To the Aucilla
Count				GiZScore				
Low z score (<=-2	6.00	13.00	91.00	29.00	84.00	40.00	71.00	89.00
High z score (>=2)	63.00	6.00	2.00	6.00	9.00	4.00	12.00	4.00
Percentage								
Low z score (<=-2	6%	13%	93%	30%	86%	41%	72%	91%
High z score (>=2)	64%	6%	2%	6%	9%	4%	12%	4%
Middle Archaic	**NPP**	**Precipitation variation**	**To springs**	**To water**	**To karst**	**To chert**	**To coast**	**To the Aucilla**
Count				GiZScore				
Low z score (<=-2	28.00	52.00	23.00	16.00	31.00	29.00	31.00	34.00
High z score (>=2)	41.00	17.00	17.00	11.00	12.00	21.00	41.00	25.00
Percentage								
Low z score (<=-2	29%	54%	24%	16%	32%	30%	32%	35%
High z score (>=2)	42%	18%	18%	11%	12%	22%	42%	26%
	Higher values indicate higher NPP, meaning greater bulk biomass production per year.	Higher values indicate greater variations in mean annual rainfall amounts	Higher values indicate greater distance from springs	Higher values indicate greater distance from fluvial channels	Higher values indicate greater distance from karst collapse features	Higher values indicate greater distance from bedrock known to bear chert outcrops	Higher values indicate greater distance from the coast, ~ -20m isobaths at 10,000 cal BP	Higher values indicate greater distance from the Aucilla River

Onto the offshore: how these results inform predictive modeling for the continental shelf

We have shown that developing a method that renders a model based on quantitative, statistically robust examination of known environmental variables will be exceedingly difficult using general trends. Instead, our results suggest to us that we do better to model using individual variables or collections of variables from each period, assuming the likelihood that different site types and cultural groups existed.

So how do these findings modify current approaches to modeling for offshore sites? This model validates prior arguments that water access via springs, karst collapse features, and fluvial channels played a role in site distribution during the Early Archaic, and shows that access to raw materials for lithic manufacturing played a role as well. Our study validates, more quantitatively, that the longstanding focus by Faught and others on the antiquity of occupation along the paleochannel of the Aucilla River itself, is the most fruitful approach for detecting upland, Early Archaic (and possibly earlier) submerged sites. These sites are more likely to be found along the paleochannel of the Aucilla river offshore where it intersects with deep karst collapse features. As data points for offshore springs within this watershed become increasingly available, these should also be tested.

One point that we emphasize is that the Getis-Ord Gi analyses of Early Archaic site proximity to the Aucilla watershed is quantitatively robust, suggesting that this watershed will be particularly densely occupied in the offshore zone. This observation does not rule out the possibility that other large watersheds such as the St. Marks River were also densely occupied. Future research should target nearby watersheds, testing deeper karst collapse features and springs wherever they appear along these paleochannel zones. This Aucilla-focused model does not, however, offer equally good potential for locating other types of sites, such as hypothetical coastal Early Archaic occupations, or Middle Archaic sites of either an upland or coastal nature.

Our findings instead show that, as we and previous scholars such as Dunbar predicted, correlative variables changed during the Middle Archaic as water tables rose and the shoreline approached the modern position. The strong correlations of sites to springs and karst features weakened, with only attraction to chert bearing zones remaining somewhat strong. Areas of higher NPP were also preferred. While cultural choices may have played a role in the dense occupation along the Aucilla River during the Early Archaic, this feature was not nearly as strong an attractor by the Middle Archaic. The analyses appear to pick up differences in mobility as well. Middle Archaic sites tend to be closer to one another, with moderately close access to various resources, suggesting lower mobility and possibly population growth, while Early Archaic sites are further apart but more closely tied to water resources only. Given the wider dispersion of Middle Archaic sites across the Big Bend and the weaker relationships between variables, it seems more productive to seek for specific types of sites within this landscape instead of overall settlement patterns. Therefore, we focused on developing models for coastal sites from both periods, and for upland Early Archaic sites.

For Early Archaic upland sites, we isolated potential karst features lying within 5 km of the paleochannel of the Aucilla River on the continental shelf (Figure 2.9). A few offshore springs are known, but the sample size is insufficient presently to include these; however, any future discoveries of these features should include archaeological assessment. Figure 2.9 shows the karst features indicated by our analysis that are located within 5 km of the paleochannel of the Aucilla.

If we assume that Middle Archaic coastal site patterns provide us with an analog for all coastal zones, then Early Archaic trends should resemble Middle Archaic trends. PCA and LDA analyses indicate that Middle Archaic sites group into two different zones: those located in upland zones, and those located closer to the coast at varying distances from the Aucilla. For Middle Archaic sites, one of the strongest predictors was distance to water a fluvial feature or projected paleochannel, and distance to chert outcrops. Currently, we have very little data for offshore zones for chert distributions. This leaves fluvial features as the most reasonable predictive variable.

For coastal sites, in both periods, fluvial channels and the areas around them should be targeted. The average distance of known offshore sites to a paleochannel feature is ~150 m, with a standard deviation of ~150 m. Paleochannel projections in our study are based on 3 arc second data, which at this latitude amounts to ~90 m per pixel. If we assume that our paleochannel projections have an error of 1 pixel on either side, then our margin of error for paleochannel location is ~200 meters across. Adding the mean and standard deviation to this suggests that a buffer of 500 m per side is appropriate for delineating the area around these projected paleochannels that are most likely to contain sites. Coastal sites for both periods are hypothesized to follow this pattern (Figure 2.9 and Figure 2.10). The coastal oasis zone as it probably existed around 10,000 cal BP, within 10 km of the -20 m isobaths, is highlighted to show the strip of continental shelf where the highest probability for fluvial channels to predict sites would lie at this period. This zone shifted with sea level rise, however, and the range of coastal oasis would have shifted accordingly. Interestingly, Ray Hole Springs, the Early Archaic site furthest offshore, appears right at the margin of one of the high probability areas. At the time it was most likely used, it would have lain within the coastal oasis.

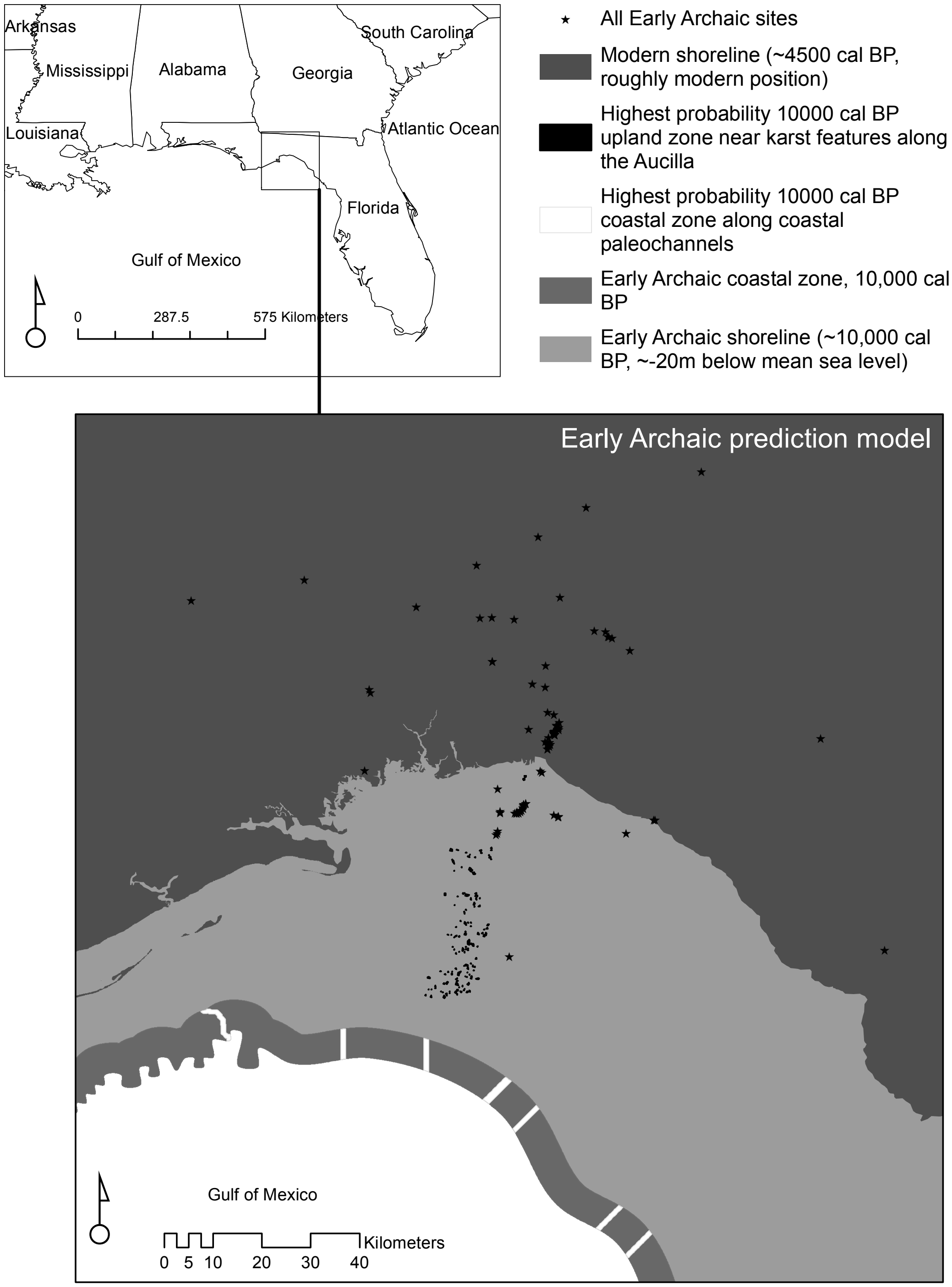

Arkansas
Mississippi
Alabama
Georgia
South Carolina
Louisiana
Atlantic Ocean
Florida
Gulf of Mexico
0
287.5
575 Kilometers
All Early Archaic sites
Modern shoreline (~4500 cal BP, roughly modern position)
Highest probability 10000 cal BP upland zone near karst features along the Aucilla
Highest probability 10000 cal BP coastal zone along coastal paleochannels
Early Archaic coastal zone, 10,000 cal BP
Early Archaic shoreline (~10,000 cal BP, ~-20m below mean sea level)
Early Archaic prediction model
Gulf of Mexico
Kilometers
0 5 10 20 30 40

Figure 2.8: Prediction modeling for upland versus coastal occupation during the Early Archaic

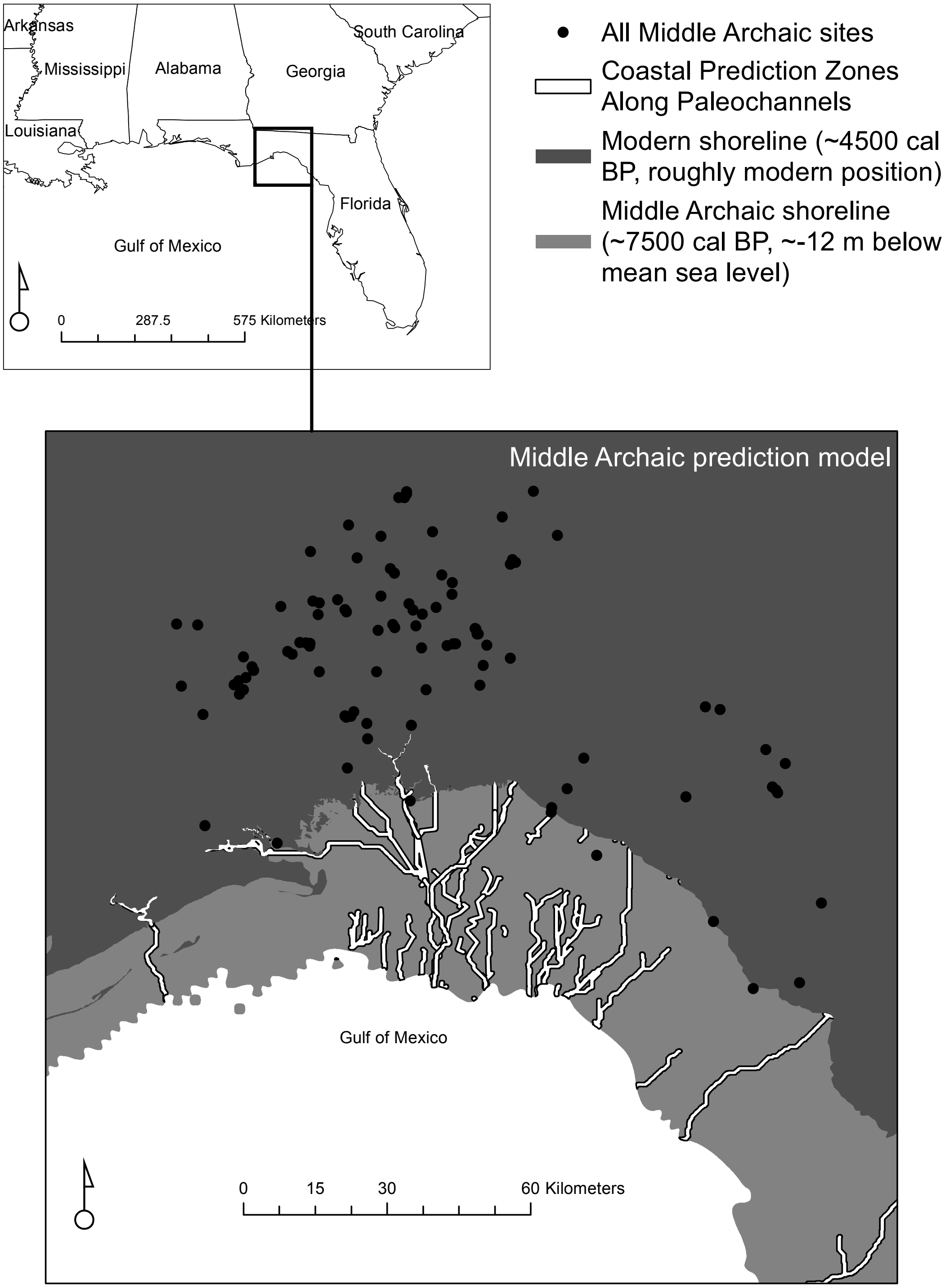


Figure 2.9: Predictive modeling for Middle Archaic sites located within the coastal zone

Conclusions

Our theoretical foundation rests on behavioral ecology studies that indicate that human groups choose habitats that support overall, long term fitness. However, they do so by actively articulating with their wider landscape in ways that do not simply follow environmental dictates, and our findings demonstrate this. Because cultural constructs and paleoecology change across time as well as space, fitting a straightforward model to human activities is not possible. High probability models for settlement patterns on the continental shelf that are predicated on static variables such as landforms, or onshore settlement patterns that represent upland occupations alone are likely to fail in detecting a wider range of human activities.

Our approach here seeks to overcome this flaw by testing for trends across time, space, changing ecological conditions, and shifting cultural choices. Our first objective was to tease out which environmental variables played a meaningful role in explaining site locations. If human choices were governed by access to environmental conditions most likely to support reproductive success, as predicted by behavioral ecology models, then sites should at the very least correlate, or even be explained wholly by, proximity to areas with higher biomass, more water, and access to tool stone resources that supported subsistence activities. While these do play a measurable role in explaining site distributions, they are not normally distributed across time or space. This likely indicates multiple site types and changing mobility patterns in our dataset. Nor does proximity to water resources or zones with higher net primary productivity explain site occurrences during the Early Archaic – instead, proximity to one watershed alone is a better predictor, despite the presence of other nearby watersheds such as the St. Marks that were equally capable of supplying adequate water. While this could be a result of archaeological visibility, it is also possible that this represents social choices beyond those made to satisfy base level subsistence needs.

Other statistically significant predictors such as the change in human preferences for living within the Aucilla watershed versus living along the coastline, do not appear to be solely governed by access to local resources. Therefore, we argue that predictive models for offshore occupations must incorporate both environmental and cultural factors. This is essentially a spatial visualization and in depth analysis of the landscape akin to the Danish Method discussed by Benjamin (2010); it is different in that it seeks to detect changes in landscape use using quantitative approaches, including spatial statistics that can measure the effects of both cultural and environmental predictors on site appearance.

It is also potentially scalable anywhere in the world. While our study assessed variables drawn from local prediction models along with paleoclimate data, these spatial statistical methods can be applied anywhere. Additionally, our underlying foundational theory relies on scholarly explorations of links between human behavioral ecology and histories of practice within the archaeological landscape, and these also can be applied globally. This approach allows us to bridge the gap between local/regional trends and generalist approaches that can miss these nuances. This approach builds a more useful model; one that is perhaps less wrong.

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CHAPTER 3 : WHAT'S PAST IS PROLOGUE: EXCAVATIONS AT THE ECONFINA CHANNEL SITE, APALACHEE BAY, FLORIDA, U.S.A.[2]

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Introduction: Submerged sites on the inner continental shelf

While the challenges associated with identification and excavation of submerged prehistoric sites are considerable, they have the potential to offer us badly needed insight into human behaviors during periods when now submerged landscapes were dry (Anderson and Faught 1998; Bailey and Flemming 2008; Bailey and Milner 2002; Dixon 2013; Erlandson and Fitzpatrick 2006; Faught 2004a, 2004b; Faught and Donoghue 1997; Garrison et al. 2012, 2016) One such behavior is the use of coastal and marine resources in prehistory. Coastal archaeologists have long noted the appearance of dramatic shellfish midden deposits dating from the end of major sea level rise around 5,000 BP, and sometimes earlier (Cunliffe 2001, 2011; Habu 2004; Jöns and Harff 2014; Thompson and Worth 2011) These shell mounds are probably not evidence for a sudden population increase, or a radical shift in food strategies, but instead simply mark a coastline position, leaving evidence for coastal subsistence patterns submerged offshore (Bailey 2014:293; Jöns and Harff 2014:180).

Scholars who explore the nature of these coastal occupations are increasingly calling for investigation into this type of submerged site (Erlandson and Fitzpatrick 2006; Grøn 2006, 2007, Reitz 1988, 2014; Turck 2010; Thompson and Turck 2009; Thompson and Worth 2011). This is partially based in the observation that multiple coastal groups developed complex foraging economies with minimal mobility, but the earliest evidence for this development in human behaviors probably lies submerged offshore. The Southeast United States is one such area where coastlines saw the establishment of complex foraging by 4,500 cal BP and possibly earlier (Andrus and Thompson 2012; Russo 1994; Thomas 2014; Thompson and Andrus 2011).

If we seek evidence for the development of coastal adaptations on the continental shelf, we should first examine the most accessible sites of this type. In the Southeast United States, these are between 5,000 and 8,600 years old (the Middle Archaic in the Southeast), in waters usually no deeper than 15 meters (less than 45 feet). Apalachee Bay, Florida, is one such location within this region that has already demonstrated the presence of sites of this type. Multiple studies have demonstrated occupation in this landscape as early as 14,500 cal BP and numerous offshore sites from the Paleoindian to the Middle Archaic periods were documented during the 1980s, 1990s, and early 2000s (Dunbar 1988; Dunbar et al. 1989; Dunbar 2006, 2012; Faught 1988; Faught and Donoghue 1997; Faught 2004a, 2004b; Halligan et al. 2016).

Local prediction models for submerged offshore sites initially employed onshore trends that correlated archaeological remains to sinkhole features and high quality chert outcrops (Faught and Donoghue 1997; Faught 1988). These sinkhole features were the only places where freshwater was available for humans and fauna during periods when lowered sea levels lowered the water table, while the chert outcrops met the need for high quality raw materials for tool manufacture. The Econfina Channel site was one of the first sites within Apalachee Bay to be located using this model. It was first documented in 1986 during the initial surveys testing for submerged sites in Apalachee Bay (Faught 1988).

However, it did not entirely conform to the initial predictive model, which assumed upland, not coastal occupations. It possessed prominent chert outcrops and a small spring, but no obvious sinkhole feature. Furthermore, while archaeological sites in the Aucilla and PaleoAucilla River watershed generally show continuity from

Paleoindian period into the Middle Archaic, the Econfina paleochannel has fewer sites, and only one documented cultural component: Middle Archaic (Faught 2004a, 2004b; Faught and Donoghue 1997). It does, however, show abundant use of coastal resources without strong evidence for terrestrial fauna, suggesting a coastally adapted occupation of some type by this period. The goal of our study here is to outline our recent work at Econfina Channel in search of additional details on coastal occupations during this period. First, we will outline the physiographic and archaeological setting, and then discuss our methods and theoretical approach to this study. Next, we will present our findings and discuss their implications for our understanding of this site and others like it.

Coastal sites in Florida

Florida is home to some of the oldest sites in North America and the Big Bend itself has a high density of prehistoric archaeological sites from the Pre-Clovis period forward (Anuskiewicz and Dunbar, 1993; Anuskiewicz, 1988; Dunbar, 1988; Faught and Donoghue, 1997; Faught and Donoghue, 1997, p. 421; Faught, 2004a, 2004b; Halligan et al., 2016). There is minimal evidence for coastal occupation in Florida on either coastline prior to the Middle Archaic, however. Along the Atlantic shoreline where paleoshorelines lie much closer to the modern shoreline due to the narrower continental shelf, sites such as Vero and Douglass Beach may represent visits to this coastline by Paleoindian and Archaic groups from further afield. This coastline is particularly lithics poor, and the appearance of exotic lithics in these locations indicates movement of people or goods across significant distances (Cockrell and Murphy 1978; Cook Hale, in prep; Hemmings et al. 2015; Murphy 1990). Currently, these sites are poorly understood when compared to those of the Gulf Coast and the St. John’s River valley (Russo 1988). Frustratingly, on the Gulf of Mexico shoreline, the continental shelf is much wider and flatter, and occupations older than the late Middle Archaic are submerged much further away from the modern shore; Ray Hole Springs, a site that dates to the terminal Early Archaic or early Middle Archaic, is over 30 km from the modern coastline in 12 m of water (Anuskiewicz 1988; Anuskiewicz and Dunbar 1993; Dunbar et al. 1989).

By the end of the Middle Archaic period, shell mound sites appear along the coastline of the Gulf and within the St. John's River valley. Many early examples do not appear to contain burials or show other evidence for ritual activities, while others do. The ones lacking ritual components instead appear to represent pure extraction sites where riverine, estuarine and marine resources were processed for consumption, (Mikell and Saunders 2007; Randall 2013; Randall et al. 2014; Russo 1988; Saunders et al. 2009; Saunders 2010; Saunders and Russo 2011). By the Late Archaic, however, more of these sites took on ritual aspects, and it is an open question as to whether earlier sites with similar uses lie offshore (Russo 1994). Additional examples of ritually oriented activities can be seen in mortuary pond sites. Onshore sites such as Windover, Little Salt Springs, and Warm Mineral Springs are the best known (Adovasio et al. 2001; Clausen et al. 1979; Doran 2002; Royal and Clark 1960; Tomczak and Powell 2003; Tuross et al. 1994), but offshore examples exist. A wooden stake like those found at Windover that dated to the Middle Archaic is known from Douglass Beach, suggesting the possibility of this site type offshore during this period (Murphy 1990). In late 2015, a submerged pond burial site was detected off Venice Beach, Florida, on the west coast south of Tampa, indicating that this site type predates the arrival of the modern shoreline, around, 5000 cal BP (Ryan Duggins, 2015, personal communication).

Generally, as sea levels and water tables rose, some sites became unavailable for use while others became more attractive. This is true at both inland sinkhole sites as well as offshore. For example, many of the human remains recovered at Warm Mineral Springs date to the Early Archaic, while at Little Salt Spring, younger Middle Archaic burials are documented within a slough draining into the sinkhole as well as the sink itself (Royal and Clark 1960:286; Wentz and Gifford 2007:330). Shell mounds, pond mortuary sites, and non-ritually oriented sites of all types are more archaeologically visible by the Middle Archaic when relative sea levels approached the modern coastline, but they cannot be ruled out for earlier periods along older coastlines. In sum, site usage and placement may be as tied to geomorphology as it is to cultural values. Our question then, is where does the Econfina Channel site fit into this picture?

Theoretical framework

The goal for this study is to answer two questions: first, what activities are evident within these sites; and second, how do these inform us about human behaviors and their coastal adaptations prior to the establishment of the modern shoreline? Our first question must be addressed first by contending with site formation processes specific to submerged contexts. The second question can be answered by comparing our findings to trends for coastal sites, within Florida and elsewhere. To answer these questions, we use a synthetic methodology that combines geoarchaeology, behavioral archaeology, and behavioral ecology. Geoarchaeology provides the framework to discern natural processes from anthropogenic ones and to place the material remains within cultural deposits into their environmental contexts (Gagliano et al. 1982; Garrison et al. 2016; Murphy 1990; Pearson et al. 1989; Stright 1995). Historical and behavioral ecology have been used in this region, and beyond, in prior studies that address questions of site location choices, subsistence practices, mobility, and the development of social complexity in coastal regions (e.g., Bird and Bleige Bird 1997; Bird and Bliege Bird 2000; Bird et al. 2002; Colaninno 2010; Hadden 2015; McFadden 2016; Reitz 1988, 2014, Thomas 2008, 2014).

Physiographic and archaeological background

Apalachee Bay possesses a low energy coastline with minimal wave, current, and tidal action. This region is also defined by its karst terrain. Carbonate bedrock lies beneath the modern veneer of sediments, acting as both the primary aquifer and the most obvious control on fluvial processes, particularly the Aucilla and Econfina rivers. The aquifer is unconfined by overlying formations in this region, leading to the upwelling of springs throughout the region. Sediment loads within the rivers in this region are often minimal, and fluvial channels are often defined not by incision, but by collapse features and discontinuous channels that only flow continuously once they are within a few miles of the coastline itself; thus, sediment load from the fluvial systems entering the bay is minimal at best (Brooks et al. 2003; Goodbred et al. 1998; Hine et al. 1988).

Karst collapse features are created when weakly acidic ground waters create dissolution features within the carbonate bedrock, usually along previously existing fracture planes and joints. The net result is a geomorphology unique to this region, wherein rivers drop down into subterranean channels and reappear some distance away. During periods of drought or lowered relative sea levels, the lowered water tables cause the fluvial channels to disappear into the bedrock channels completely (Dunbar et al. 1989; Faught 1988, 2004b; Faught and Donoghue 1997; Thulman 2009). Another net result of this regional geology is the widespread appearance of springs fed by the

Floridan Aquifer, which is contained within this karst bedrock. Rises, sinks, emergent springs (some of which appear to still be flowing offshore), and prominent chert outcroppings within the carbonate bedrock are common throughout the region.(Dunbar 2016:46-51; Faught and Donoghue 1997:423–425; Hine et al. 1988:568–570).

Topographically the regional study area contains two zones: The Woodville coastal plain, and the Cody Scarp. The Cody Scarp consists of more resistant sand, clay, and carbonates of the Miocene Hawthorne group representing at least two Pleistocene high stands, while the nearby Woodville coastal plain is underlain by less resistant Eocene and Oligocene limestone deposits (Upchurch 2007:4). Sinkholes and disappearing rivers are common to both zones, but there is difference in the matter of scale. Along the Cody Scarp, sinks and lakes are larger, flow is dominated by vertical movement down into the carbonate bedrock, and the landscape possesses considerable topographic relief, while on the Woodville coastal plain, sinks are smaller, the topography much flatter, and the movement of waters is horizontal (Upchurch 2007:8–9).

Both the Aucilla and Econfina rivers are sourced to the regional coastal plain only, unlike the Appalachicola River that feeds into the western side of Apalachee Bay. Their available sediment loads are thus much less. The Aucilla River headwaters lie north of the Cody Scarp, while the Econfina River rises below the toe of the Scarp and may contain even less sediment load than the Aucilla, as the Aucilla passes through the Scarp proper where sediment cover is greater. Few sinkhole features are associated with the Econfina, suggesting less direct connection communication with the aquifer. Abundant chert outcrops dot the Econfina channel, making navigation challenging. As one approaches the coastline, the subtropical coastal woods, known as "piney flatwoods", are replaced by tidal marshes with interspersed hammocks that still retain some tree cover.

The very low gradient of Apalachee Bay inhibits wave action and the coastline contains no barrier island formations. Instead, tidal marsh fringes the shoreline. The coastline is composed of a thin veneer of sandy sediments and soils, with bedrock sometimes shallower than 1 meter below the surface. Soil types are dominated by fine sand and sandy loams in better drained areas, primarily spodsols, with some sandy clay loams apparent as well. Tidal marsh areas are composed of mucky mollisols overtopping mucky loamy sands and sands (http://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx).

Depth from the mouth of the Econfina into Apalachee Bay proper is only 1-2 meters deep outside of paleochannel areas. Areas of the bay are dotted with eel grass beds that tend to obscure any archaeological materials within them. Eel grass beds provide habitat for a diverse suite of marine fauna, including scallops, sea turtles, and blue crabs (Mattson et al. 2007). These beds are absent from paleochannels, including the Econfina paleochannel. Depths increase detectably once within these paleochannels, further distinguishing them from the rest of the bay bottom (Faught 1988). The paleochannel of the Aucilla has been traced offshore using marine geophysical methods, but this type of survey has not been conducted for the Econfina (Faught 2004a, 2004b, 1988; Faught and Donoghue 1997). Recently, bathymetric LiDAR datasets have been gathered for both paleochannels but are still being classified and interpreted.

During the late Pleistocene and Early Holocene, rivers fed by the Floridan Aquifer dropped in tandem with lowered relative sea levels, leaving a series of sinkholes/cenotes dotting the landscape instead of flowing channels (Dunbar 2006; Faught and Donoghue 1997). This likely attracted fauna in search of food and water and human groups following them as prey to these locations (Duggins 2012; Thulman 2009). Abundant chert outcrops also conveniently provided access to stone tool source materials across the landscape (Dunbar et al. 1989; Dunbar 2006, 2016; Halligan et al. 2016).

The local prediction model for submerged sites extrapolated inland locations into the offshore zone with great success. (Anuszkiewicz and Dunbar, 1993:2-3; Faught and Donoghue, 1997:422-423). More than two dozen total sites or activity areas were identified during initial offshore surveys, many of the along the PaleoAucilla. The Econfina Channel site itself is approximately 5 km offshore in water depths that range from 2-5 meters in depth, depending on intrasite location and tidal gradient. [3]When the site was first documented, a shell midden (trash) deposit and abundant lithic debitage deposits were observed, suggesting human exploitation of marine foods and quarrying at the multiple chert outcrops, but no sinkhole features were detected (Dunbar et al. 1989; Faught 1988; Faught and Donoghue 1997; Faught 2004b, 2004a).

The site is located on the south-southeastern side of the paleochannel. The most visible feature is the large shell deposit, located north of dense eel grass beds along a roughly east to west orientation. Reports during the 1980s surveys speculated that the deposit constitutes a shell midden that may extend into the eel grass (Faught 1988). Eel grass extends south and east of the site, and the bottom shallows up to water depths of 1.4-1.8 m moving east and south of the midden. Chert and dolomite boulders outcrop

[3] Tidal range in Apalachee Bay is approximately 0.7 m (2 feet), on a 12-hour cycle, and depth ranges vary based on the cycle. The net effect is that a feature can be found at 2.7 m (9 feet) in depth at one point in the day, or closer to (1.8 m) 6 feet when the slack tide is at its lowest point.

north, east, and west of the midden surrounded by extensive lithic debitage. A freshwater seep/spring was detected within an area of dense rocky outcrops west of the midden, near the paleochannel. The paleochannel bends from a west-southwest orientation along the quarry zone, to a truly southwest orientation just to the west of it. Current is detectably stronger within the paleochannel, especially during "king tides" caused by full moons.

Methods and materials

While there are clearly anthropogenic features present at the site, their full extent is unclear. Excavation and subsequent sediment analyses offer the best potential for recovering microscopic charcoal, macro/micro-debitage, and sediment size distribution data that can potentially delineate activity areas and/or different depositional zones. Alternatively, if marine transgression has "smeared flat" the different sediments, this too will be apparent. Therefore, the first objective was to recover and test geoarchaeological datasets from the Econfina Channel site using sediment analysis techniques modified from Gagliano, et al. (1982).

Bulk sediment sampling has a long history in geoarchaeology and archaeology. Archaeologists examine pedogenic materials for inclusion such as artifacts, and faunal and botanical remains, and note basic parameters such as Munsell color and texture (sand, silt, loam). Geoarchaeologists include additional data to characterize the geological, mineralogical, and geochemical nature of these materials. With the rise of modern geoarchaeology in the late-20th century, sedimentological studies have taken on a central role in more and more sites (e.g., Wendorf 1955; Butzer 1971; Hassan 1979)

Gagliano, at al., (1982) were among the first to suggest that sediments in submerged archaeological sites could be characterized by the presence or absence of anthropogenic inclusions and geochemistry (Gagliano et al. 1982; Pearson et al. 1989, 1982, Stright 1986a, 1986b). These techniques have been successfully employed at other submerged sites where only the most obvious features remain, such as the Douglass Beach site (8SL17) (Cockrell and Murphy 1978; Murphy 1990). These methods first falsify the hypothesis that sediments from submerged contexts do not retain signatures diagnostic for human activities, such as burned bone, debitage, and geochemical traces for human activities such as elevated phosphates. Once the anthropogenic nature of sediments has been demonstrated, inclusions and geochemistry can be used to delineate activity areas and geomorphological context. For example, charcoal concentrations could indicate hearth areas, concentrations of micro-debitage could indicate lithic workshop areas, and burned bone or copious shell hash could indicate food processing (Murphy 1990).

For this study, we are testing the following hypotheses: First, that the extent of the site is larger than initially thought; second, that individual activity areas can be delineated. The converse of the first hypothesis is that the site extent cannot be determined; the converse of the second hypothesis is that marine transgression has-been highly destructive to anthropogenic signatures across the site, and that only different depositional environments can be detected. The first objective to test these hypotheses was to relocate and excavate features reported during initial excavations and to map them. The second objective was to collect bulk sediment samples and to analyze them following the methods outlined by Gagliano, et al., and modified by others such as Murphy (Gagliano et al. 1982; Murphy 1990; Pearson et al. 1982, 1989).

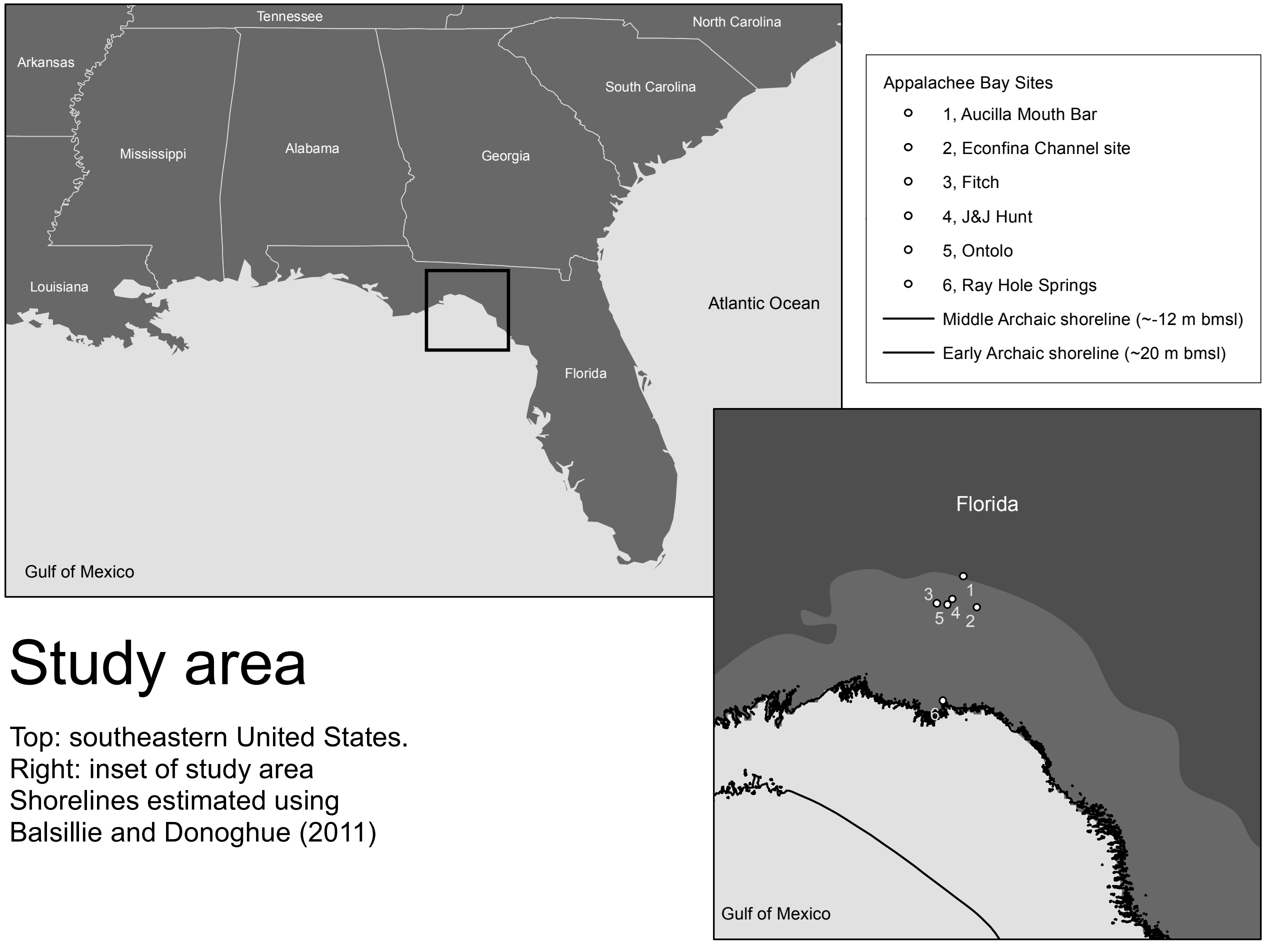


Figure 3.1: Study area:
Econfina Channel sites and the best-known sites along the Paleo-Aucilla

Methods

We used a combination of mapping, bulk sediment sampling, excavation units, lithic analysis, radiocarbon dating of excavated materials, and particle size analysis (PSA) in our study.

We placed six excavation units within different zones of the site: the paleochannel, the quarry area outside the midden, the eel grass zone, and the midden itself, and examined their stratigraphic profiles. Submerged excavation units in sandy marine sediments can be more difficult to document than units placed in cohesive terrestrial sediments because they tend to collapse and erode. Thus, we used photography to document plan views and profiles in addition to drawings.

Second, we collected two separate sets of bulk sediment samples across the entire site. Sampling was carried out in late October of 2015 and, again, in October 2016, after the passage of Hurricane Hermine. The 2016 bulk samples are especially important because they nearly doubled the total sample size and provided interesting data for the effect of a tropical hurricane (Cook Hale, Hale, Marrioneaux, Newton, and Garrison, in prep). The 2015 dataset contained 26 samples and the 2016 dataset contained 20 samples and each sample was around 1 kg. total. In 2015, we collected samples every 3 meters for the north - south transect, every 3 meters for the transect running from the midden to 30 meters east into the eel grass zone, and every 5 meters on a 15 meter transect running west from the midden into the quarry zone. In 2016, we collected samples every 3 meters along transects running north from the midden, south into the eel grass zone, west towards the paleochannel, and east towards eel grass beds (see figure 3.2). Each transect was 15 meters long. We reserved bulk sediments for particle size analysis, charcoal analysis, and micro/macro-inclusion analysis.

Results

2015 excavations

In 2015, we placed three excavation units: U1 measured 2 m north and 1 m west of the datum drop point on the midden, U2 measuring 1m by 1m within the quarry zone, 55 meters north of U1 bearing 15 degrees N; and U3, measuring 0.5m by 0.5m, 12 meters due south of U1, within the eel grass beds.

At U1, hand excavations, screening with a 2.54 cm (1") opening plastic tray allowed recovery of the following taxa in the midden: *crassostrea virginica* (oyster), *pectin* (scallop), *Melongena corona* (crown conch), and *Ampullariidae* (apple snail), a freshwater species. We did not perform formal zooarchaeological analysis on these taxa, opting instead to record their presence alone. A formal zooarchaeological study should be a critical aspect of future studies at this site.

Stratigraphy was consistent with the stratigraphy reported by Faught, et al., with a top layer of a marine shell hash underlain by black, finer grained sediments in which copious shell was embedded. A buried outcrop was detected in the southwestern corner of the unit about 4 cm below surface and small outcrops were observed north and west of the unit. Shell was screened and bagged.

U2 provided abundant lithic debitage, most likely from primary reduction activities within the quarry zone. Stratigraphy in this unit was also consistent with that reported by Faught, et al., but lacked the prominent midden debris seen at U1 (Figure 3.2). It consisted of marine shell hash underlain by dolomite boulders and cobbles at a depth of around 50 cm. We recovered debitage, worked flakes, and limestone outcrop rock samples. All the debitage was found within the marine shell hash.

U3 was taken down to ~40 cm in the eel grass (Figure 3.2). We observed fine to very fine sand sediments with midden visible to ~30-35 cm below the surface. Below the large shell hash, we observed another level with finer shell hash, and finally a bed of articulated crassostrea deposits that are most likely natural, not anthropogenic. We recovered one chert flake and some broken scallop. The chert flake reinforced the identification of the shell deposits from the surface to ~30 cm below the surface as anthropogenic midden deposits, and not natural accumulations of shell.

U4 was placed in the paleochannel areas next to an iron rebar datum hammered into the dolomite boulders. The depth of the unit reached 60 cm and we recovered copious large debitage with prominent cortex. However, the rock samples recovered here showed minimal to no evidence for human modification. Rock outcrops were minimal in this area, with lower relief than those observed near the U1 and U2. Stratigraphy was minimal here as well, with a marine shell hash layer overlying dolomite boulders and cobbles. The marine sediments were thicker here than at U1 and U2.

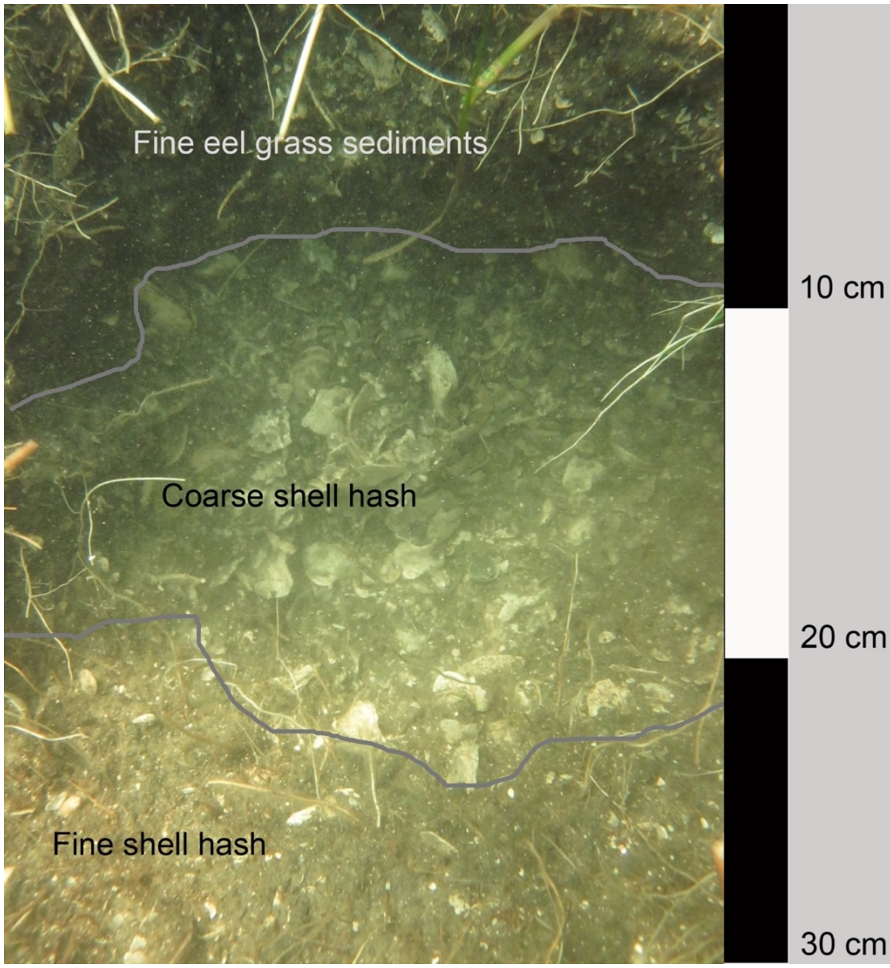


Figure 3.2: Stratigraphic profile, Econfina Channel site, eel grass zone

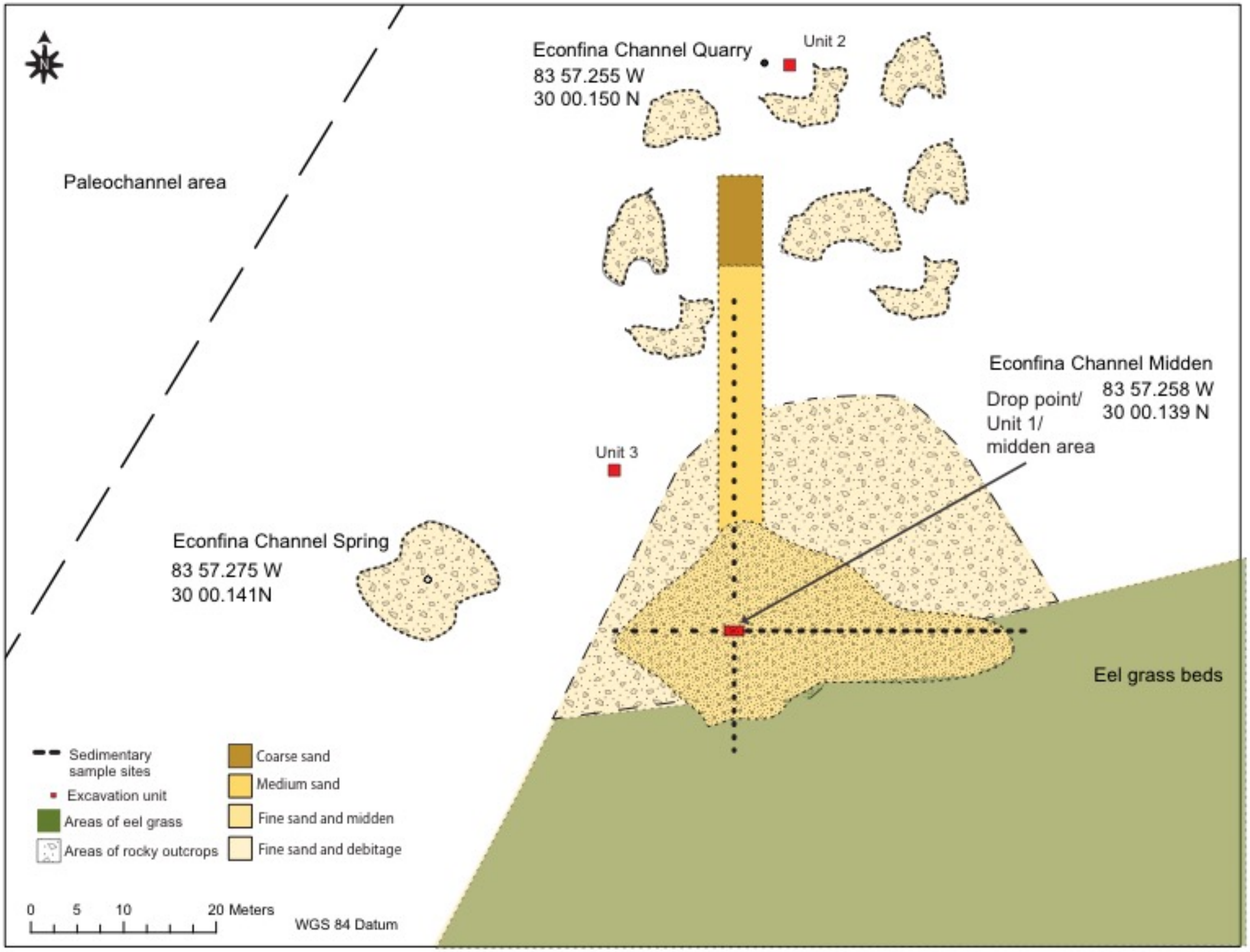


Figure 3.3: Site map

2016 excavations

We tested the freshwater weep/spring area using hand fanning only, primarily along the eastern side. This area is located to the west of the paleochannel and midden areas. We recovered several flakes that were clearly human-modified. We also collected one possible unifacial lunate scraper tool. The convex edge of the item showed a clear striking platform, although flake scars are now obscured by marine corrosion. It is considered equivocal. We also recovered one large core that appeared to be only partially exhausted.

We placed two 0.5m by 0.5m units during 2016 surveys along the edge of the eel grass beds approximately 50 m east of the main midden, designated U5 and U6. This area contained shell scatter at the surface, but not as prominently as the midden itself. These units revealed the same stratigraphic profile as U2 from 2015, with larger shell hash at the surface, a level below with smaller shell hash, and a bottom level of articulate crassostrea shells. Sediments were primarily composed of fine sand and silt.

Mapping

We focused first on mapping the extent of the midden. We measured the extent of it twice, in August 2015 and August 2016. Our initial measurements indicated that it was 9 meters across along a north to south axis outside the eel grass zone. In August 2016, we measured the midden dimensions again. Using only shell deposits and not sediments as a guide, the midden feature's most visible components measured approximately 10 meters across on a north to south axis outside the eel grass zone, but closer to 25 meters east to west.

The distance between U1 and U2 was measured using a tape and a compass; U2 was 55.45 m north of U1, off due north bearing 15 °. We measured the distance from U1 to the seep/springs area using the same method. The springs were first identified by the presence of ample fish, rock outcrops, and water temperature changes (freshwater flowing from these springs was cooler), and a buoy was placed at this location. We then used a tape to measure from the U1 to the springs buoy. The distance from the midden to the spring was 51.45 m bearing W at 280°.

We measured depth variation between features to assess their three-dimensional spatial relationship to one another. Depth variation occurs over submerged sites due to the tides. In areas with low tidal gradient and at depths greater than 10 meters or so, this may be barely perceptible, but in shallow water less than 5 meters, the effect can be considerable during the tidal cycle. Tidal gradients vary during the lunar cycle, as well.

The freshwater seep/spring depth relative was confirmed to be approximately 0.5-1 meters deeper than the midden. Unit 2 compared to the midden was 1-1.25 meters deeper, depending on proximity to the paleochannel area. The midden was approximately 0.75 meters deeper at the drop point than at the furthest point east from the midden. During dead low tide, the point 30 m east of the drop point on the midden was only 1.25-1.5 meters deep. We concluded that the quarry zone and freshwater seep/spring were clearly downslope from the midden, which is itself downslope from the eel grass zone away from the paleochannel area. This is consistent with Faught, et al.'s observations during their initial surveys (Faught 1988).(Figure 3.3, above).

Lithics analysis

No diagnostic bifaces were recovered during these excavations, and only five securely identifiable tools were found. One scraper recovered from unit 2 (2015), one scraper from the sediment bulk sampling at station N9 (2015), one blade tool and another scraper tool were recovered from the surface at the datum point on the midden (2016), and another scraper was recovered from the surface at the seep/spring. The lack of diagnostic tools is similar to earlier findings at Econfina Channel site, although they recovered several bifaces consistent with Middle Archaic stemmed point traditions (Faught and Donoghue 1997).

We weighed and measured individual items that clearly showed signs of human modification to compare debitage assemblages from each unit to one another. We then used ANOVA tests to determine if the means lengths and weights for lithics, regardless of whether they were debitage or tools, from each unit were significantly different (Table 3.1). ANOVA tests are appropriate when there is more than one independent variable and one dependent variable. We chose this test instead of chi-square or t-tests because lithic reduction sequences contain more than two stages that can in turn produce debitage and tools. Table 3.2 shows that, for all units, mean weights varied significantly, but that mean weights for the quarry, seep/spring, and paleochannel zones were not significantly different, and that mean weights for debitage found in the midden and in the bulk sediment samples were also not significantly different. Table 3.3 shows that mean lengths varied significantly between all units, but that mean length was the same for debitage from the bulk sediments and midden units, while it differed again between units from the quarry, seep/spring, and paleochannel

Table 3.1: Lithic measures, all items and all units

Length	Unit 2 2015	Unit 3 2015	Unit 2 Quarry zone 2016	Freshwater seep/spring	Bulk sediments	Unit 1 midden datum 2016
	98.90	81.50	79.30	146.60	9.40	13.00
	114.50	86.00	94.30	82.70	16.70	19.60
	106.80	95.60	69.30	114.60	13.10	33.20
	81.90	92.90	45.50		12.20	24.70
	69.90	98.20	36.80		2.22	
	77.90	81.40			20.60	
	73.50	88.10			8.60	
	54.50	67.10			2.19	
	50.20	42.50			11.80	
	64.00	52.40			2.33	
	61.90	40.00			0.63	
	53.60	61.50			1.66	
	41.00	42.10			3.37	
	27.00	53.50			33.40	
	26.80	41.30			0.66	
	84.50	40.10			1.18	
	37.60	48.90			7.10	
	61.90	43.40			1.53	
	61.60	45.80			15.20	
	24.40	35.10			24.60	
	58.10	34.90			2.66	
	40.70					
Mean	62.33	60.59	65.04	114.63	9.10	22.63
STD	25.00	22.32	23.75	31.95	9.02	8.52
Skew	0.41	0.52	-0.06	0.00	1.23	0.29

Weight	Unit 2 2015	Unit 3 2015	Unit 2 Quarry zone 2016	Freshwater seep/spring	Bulk sediments	Unit 1 midden datum 2016
	193.00	148.00	164.00	70.00	0.25	1.00
	183.00	80.00	111.00	106.00	1.3	1.00
	156.00	206.00	67.00	221.00	0.9	24.00
	142.00	177.00	13.00		0.81	4.00
	81.00	114.00	26.00		1	
	77.00	76.00			1.4	
	72.00	61.00			0.21	
	60.00	75.00			3.26	
	57.00	30.00			1.54	
	45.00	16.00			1.1	
	36.00	5.00			0.2	
	31.00	31.00			1.23	
	16.00	31.00			4.5	
	4.00	11.00			3.98	
	2.00	12.00			0.3	
	189.00	11.00			0.9	
	11.00	13.00			0.35	
	26.00	25.00			0.6	
	37.00	15.00			2.21	
	3.00	5.00			4.11	
	21.00	10.00			4.70	
	13.00					
Mean	66.14	54.86	76.20	132.33	1.66	7.50
STD	64.22	59.84	62.29	78.87	1.51	11.09
Skew	1.03	1.41	0.58	1.33	1.06	1.91

Thus, it appears that all stages of lithic reduction sequences are represented in the lithic assemblage from Econfina Channel. Spatial patterning of different reduction stages is apparent, as well. One blade core was identified from the freshwater seep/spring area, and was re-fitted to a blade tool recovered from the midden over 30 meters away. Multiple examples of cobble testing, primary reduction debitage, and scraper/flake/blade tools were seen at the quarry zone, at the freshwater seep/spring, and close to the paleochannel itself, while smaller flakes were recovered from the midden and eel grass area. The occupants at this location clearly made, used, and discarded tools within specific zones around the site.

We also analyzed known tools for potential uses and use wear following criteria from Tringham, et al. . (Tringham et al. 1974)(Table 3.4, Figure 3.4). Several showed over-steepened working edges consistent with working durable materials such as bone, antler, or shell. Others showed evidence for detachment and other breakage. Smaller lithic remains were also recovered from bulk sediment samples. They are large enough to assess for use wear, however, which we performed using a dissecting microscope. Again, we saw evidence consistent with working durable materials, as well as evidence for wood-working and working softer materials such as hides or textiles. Outside assessment of the known tools supported the argument that all types of materials were worked by this assemblage (Scott Jones, Russell Cutts, personal communication, 2016).

All debitage and tools showed signs of staining or corrosion (Figure 3.5). Some of this may be tannic acid staining that typically occurs in freshwater contexts, and some may result from the production of pyrite and other sulfides within pore space. Due to submergence in organic rich, anoxic tidal salt marshes (Cook hale, in prep; Garrison et al. 2016; Lowery and Wagner 2012); Lithics showing this kind of sulfidization process undergo the reverse of the initial chemical reaction, reversing the sulfidization by sulfuricization, when exposed to aerobic conditions, producing a new suite of minerals within the fabric of the lithic item, including iron oxides, as well as sulfuric acid which degrades the surface fabric itself. Since recovery from the site, a powdery, chalky white coating has developed on some of the chert debitage. This suggests that at least some of the samples are stained due to sulfidization, and that the reverse reaction driven by re-exposure to aerobic conditions, sulfuricization, is occurring.

Table 3.2: ANOVA results comparing lithic weights for all samples

Anova: Single Factor, all units/locations						
Groups			Count	Sum	Average	Variance
Unit 2 2015			22.00	1455.00	66.14	4123.65
Unit 3 2015			21.00	1152.00	54.86	3581.23
Unit 1 2016			4.00	30.00	7.50	123.00
Unit 2 2016			5.00	381.00	76.20	3879.70
Seep			3.00	397.00	132.33	6220.33
Bulk sediments			11.00	17.06	1.55	1.89
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	62773.59	5.00	12554.72	4.04	0.00	2.37
Within Groups	186568.50	60.00	3109.48			
Total	249342.09	65.00	Means are significantly different			

Anova: Single Factor, Quarry, Seep/Spring, and Paleochannel zones SUMMARY						
Groups			Count	Sum	Average	Variance
Unit 2 2015			25.00	1586.38	63.46	3777.48
Unit 3 2015			24.00	1268.11	52.84	3235.13
Unit 2 Quarry zone 2016			8.00	520.07	65.01	2918.30
Seep			6.00	609.54	101.59	5357.72
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	11447.17	3.00	3815.72	1.06	0.37	2.76
Within Groups	212284.34	59.00	3598.04			
Total	223731.51	62.00	Means are not significantly different			

Anova: Single Factor, bulk sediments and midden zone SUMMARY						
Groups			Count	Sum	Average	Variance
Bulk sediments			11.00	17.06	1.55	1.89
Unit 1 2016			4.00	30.00	7.50	123.00
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	103.82	1.00	103.82	3.48	0.08	4.67
Within Groups	387.87	13.00	29.84			
Total	491.69	14.00	Means are not significantly different			

Table 3.3: ANOVA analysis comparing lengths for all lithics

Anova: Single Factor

Groups			Count	Sum	Average	Variance
Unit 2 2015			22.00	1371.20	62.33	625.03
Unit 3 2015			21.00	1272.30	60.59	498.15
Unit 1 2016			4.00	90.50	22.63	72.64
Unit 2 2016			5.00	325.20	65.04	564.24
Seep			3.00	343.90	114.63	1020.80
Bulk sediments			11.00	172.70	15.70	61.60
Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Between Groups	34146.21	5.00	6829.24	14.52	0.00	2.37
Within Groups	28221.18	60.00	470.35			
Total	62367.39	65.00	Means are significantly different			

Anova: Single Factor
SUMMARY

Groups			Count	Sum	Average	Variance
Unit 2 2015			23	1433.52	62.32	596.61
Unit 3 2015			22	1332.88	60.58	474.431
Unit 2 Quarry zone 2016			6	390.24	65.04	451.39
Freshwater seep/spring			4	458.53	114.63	680.53
Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Between Groups	10417.50	3	3472.50	6.46	0.00	2.783
Within Groups	27387.20	51	537.01			
Total	37804.71	54	Means are significantly different			

Anova: Single Factor
SUMMARY

Groups			Count	Sum	Average	Variance
Bulk sediments			11	172.7	15.7	61.61
Unit 1 midden datum 2016			4	90.5	22.62	72.64
Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Between Groups	140.67	1	140.66	2.19	0.16	4.67
Within Groups	833.97	13	64.15			
Total	974.63	14	Means are not significantly different			

Table 3.4: Use wear patterns seen on debitage from bulk sediment samples

Activity	Locations
Reduction/ finishing	E3, E12, E15
Primary reduction	E15, W9, N6
Retouch	E12, W3
Wood working	E3
Durable material working (bone, antler)	E9, E12
Soft materials such as hide or textiles	N6

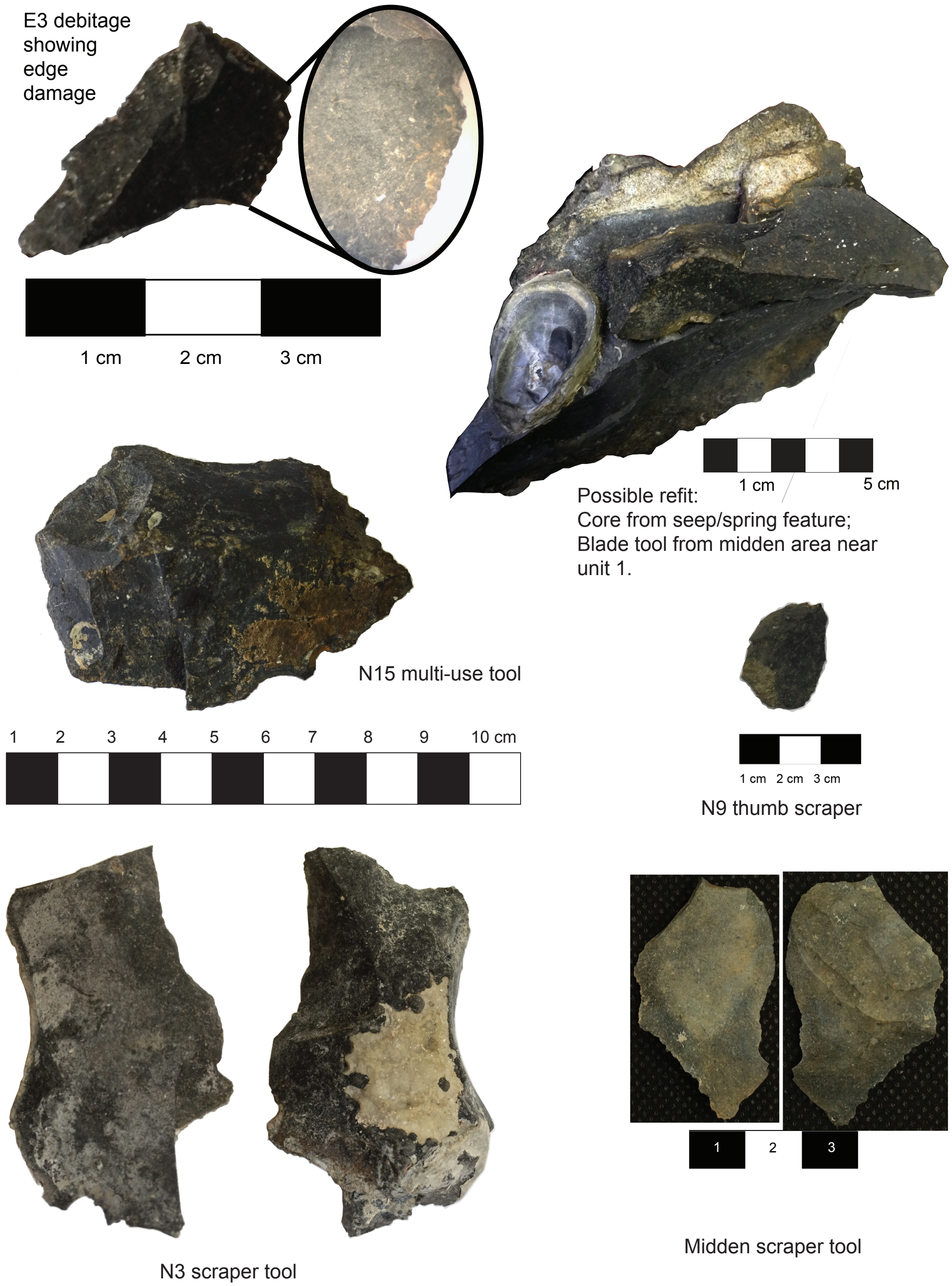


Figure 3.4: Tools recovered during excavation and bulk sampling

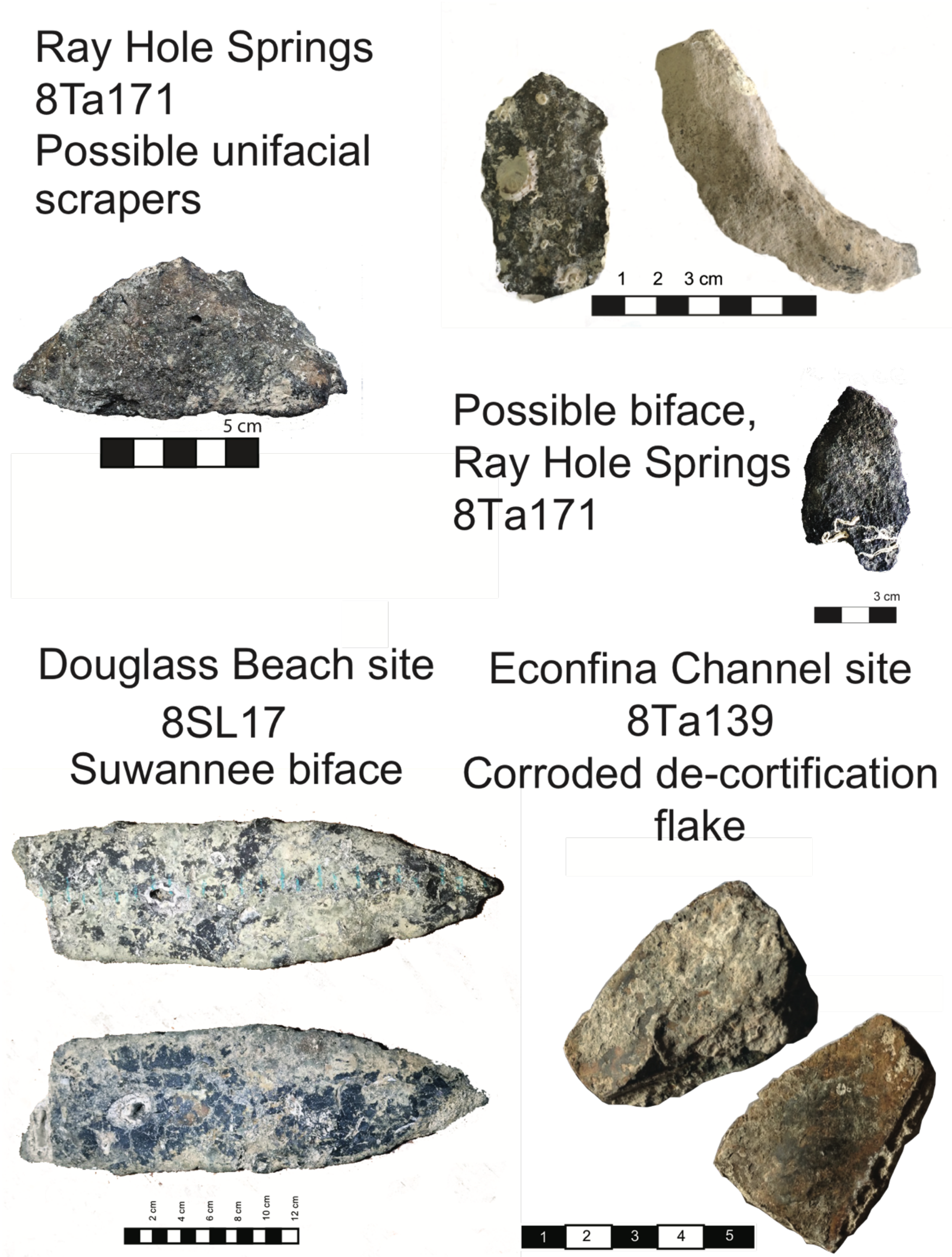


Figure 3.5: Corrosion sequence showing examples from multiple sites

Bulk sediment sampling

Crassostrea shell deposits were observed in samples taken in the eel grass beds, supporting suggestions made by the investigators during 1986-1988 surveys that large portions of a midden area are obscured by this growth. This also increased the estimated size for the potential midden by nearly 10 meters, totaling approximately 25-30 meters, potentially, from north to south. This is a notable finding given the age and submerged context of this site.

Gradistat analysis assigned 5 different Folk classifications to the bulk sediments from the site: 1) a fine gravelly fine sand; 2) sandy fine gravel; 3) sandy very fine gravel; 4) very fine gravelly coarse sand; 5) slightly very fine gravelly fine sand. The slightly very fine gravelly fine sand correlated to the eel grass beds to the south of the midden, and the sandy fine gravel correlated to the midden itself. The sediments beyond the midden were composed of the sandy very fine gravel and the very fine gravelly coarse sand. The very fine gravelly coarse sand also appears to correlate best to the paleochannel.

Correlation analysis showed that the 4-mm fraction corresponds only to the shell gravel observed in the midden (Table 3.5). East of the midden, a finer fraction interrupts what appear to be two lobes of midden sediments (Figure 3.6). The midden sediments also extended into the eel grass beds, which began 6 meters south of and 18 meters east of the drop point. The 62.5-micron size fractions correlate best to these. Interpolations of these size fractions shows distinct zonation between the midden zone and the eel grass zone.

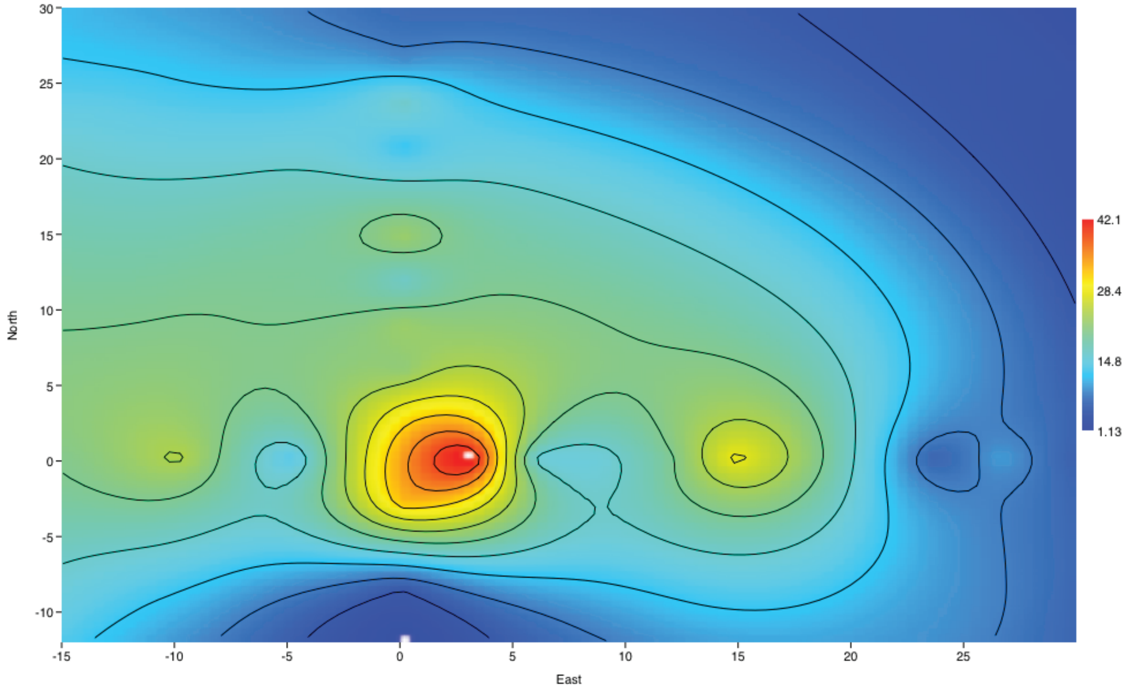
We performed correlation analysis to test for positive or negative associations in the sediment inclusions. Charcoal positively correlates to "other minerals" and "heavy minerals". Negative correlations were demonstrated for quartz to "other minerals", charcoal, feldspar, and heavy minerals. No correlations were detected for quartz to shell, shell to anything else, and charcoal to feldspar or heavy minerals (Figure 3.7). We infer two things from these results: one, that charcoal has been distributed throughout sediments more consistent with fluvial or continental shelf contexts, and not with the sediments most consistent with human activities such as the midden itself; and two, that the shell deposit is less likely to be associated with natural processes, and more likely to be anthropogenic.

Correlation analysis confirmed a positive correlation between the 2000 micron and 1000-micron size fractions (very fine gravel and very coarse sand). We detected a negative correlation between carbonate percentage and all sizes smaller than 125 microns (125 microns, 62.5 microns, catch pan component) (Table 3.5, Figure 3.7).

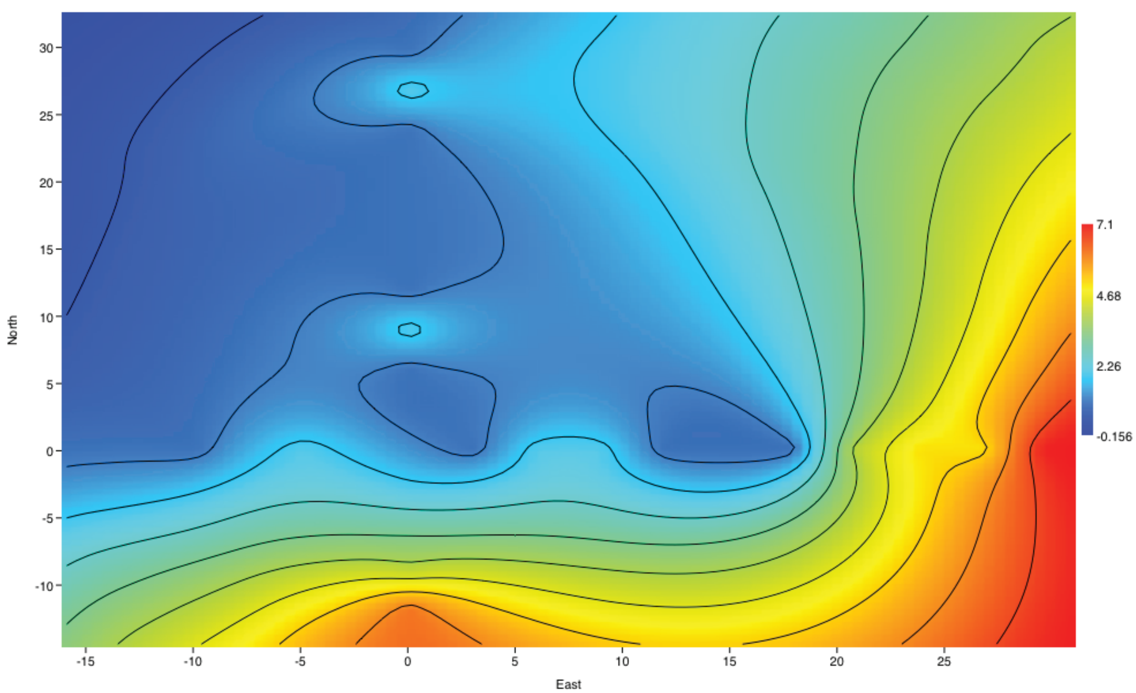
Samples from the 500-micron sample size were selected, weighed, and then dissolved in HCl to remove the carbonate fraction. Carbonate percentage in a sediment sample does not appear to be a reliable means by which to assess the degree to which a sediment is composed of midden, although percentage of carbonate showed trends across the site (Figure 3.8).

We used multivariate analysis to explore if sediment types could be differentiated from one another. Principle components analysis (PCA) suggests that multiple groups of sediment types exist, although there is significant overlap between the midden and the quarry sediments. Linear discriminant analysis plot bears this out, suggesting at least 3 different sediment groups: eel grass zone, quarry zone/midden zone, and, at 30 North, a visible outlier interpreted as the start of the paleochannel zone (Figure 3.9). LDA also assigned classifications to sediment types with reasonable accuracy (Table 3.6). We interpret the overlap between the midden and the quarry zones as evidence for post-depositional erosion and deflation of these sediments during transgression. During this process, they were presumably exposed to a highly erosive surf zone and even today, tidal surge is stronger within the channel zone than it is within eel grass zones. Nevertheless, interpolations using sediment classifications correlate well with the zones mapped during visual survey (Figure 3.10).

The 2016 samples were reserved for assessment of the effects of Hurricane Hermine on the site (Cook Hale, Hale, Marrioneaux, Newton and Garrison, in prep).



(a). 4000 micron (4 mm) particle size fraction, krigged

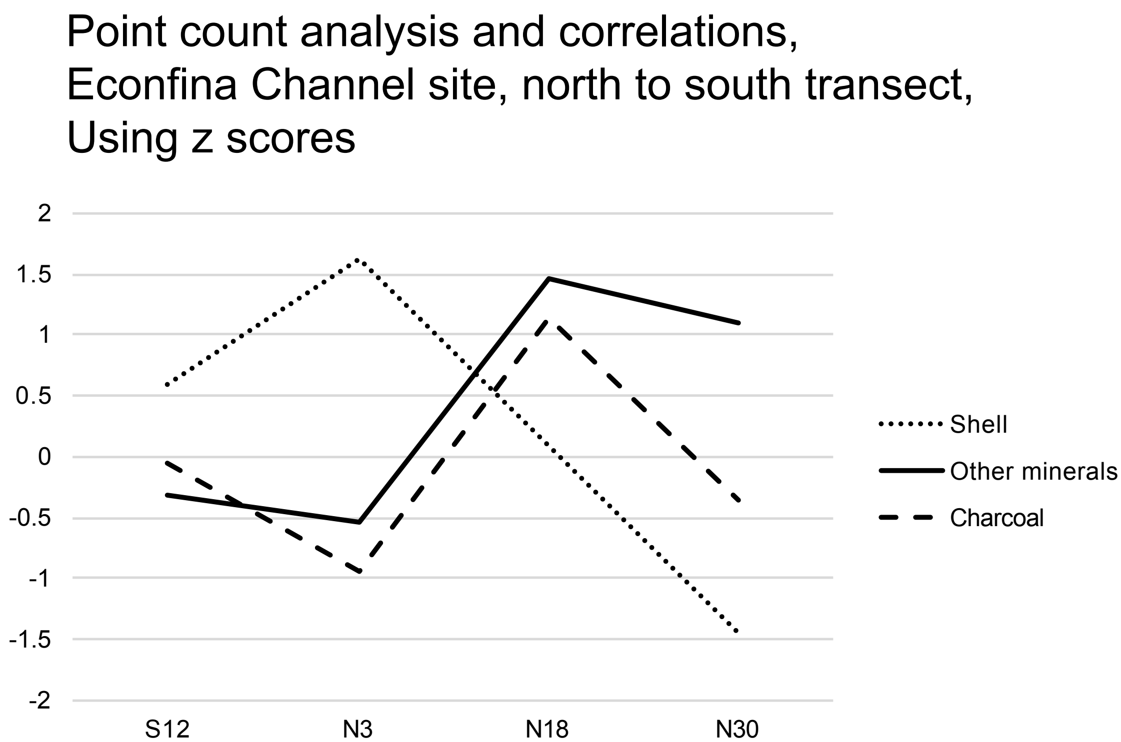


(b). 62.5 micron (0.0625 mm) particle size fraction, krigged

Figure 3.6: 4000 micron and 62.5 micron size fractions, krigged

Table 3.5: Correlation analysis particle size fractions and carbonate components

	$CaCO_3$	4000 microns	2000 microns	1000 microns	500 microns	250 microns	125 microns	62.5 microns	CATCH PAN
$CaCO_3$	1.00								
4000 m	0.34	1.00							
2000 m	0.68	0.44	1.00						
1000 m	0.58	0.27	0.89	1.00					
500 m	0.20	0.02	0.59	0.78	1.00				
250 m	-0.50	0.13	-0.25	-0.14	-0.22	1.00			
125 m	-0.53	0.06	-0.55	-0.50	-0.43	0.79	1.00		
62.5 m	-0.66	-0.29	-0.66	-0.68	-0.53	0.56	0.81	1.00	
CATCH PAN	-0.59	-0.22	-0.55	-0.59	-0.51	0.45	0.64	0.83	1.00



	Quartz	Shell	Other Minerals	Charcoal	Feldspar	Heavy Minerals
Quartz	1.00					
Shell	-0.03	1.00				
Other Minerals	-0.92	-0.19	1.00			
Charcoal	-0.56	0.06	0.56	1.00		
Feldspar	-0.72	-0.20	0.76	0.38	1.00	
Heavy Minerals	-0.87	-0.07	0.75	0.50	0.90	1.00

Figure 3.7: Correlation analysis for all inclusions

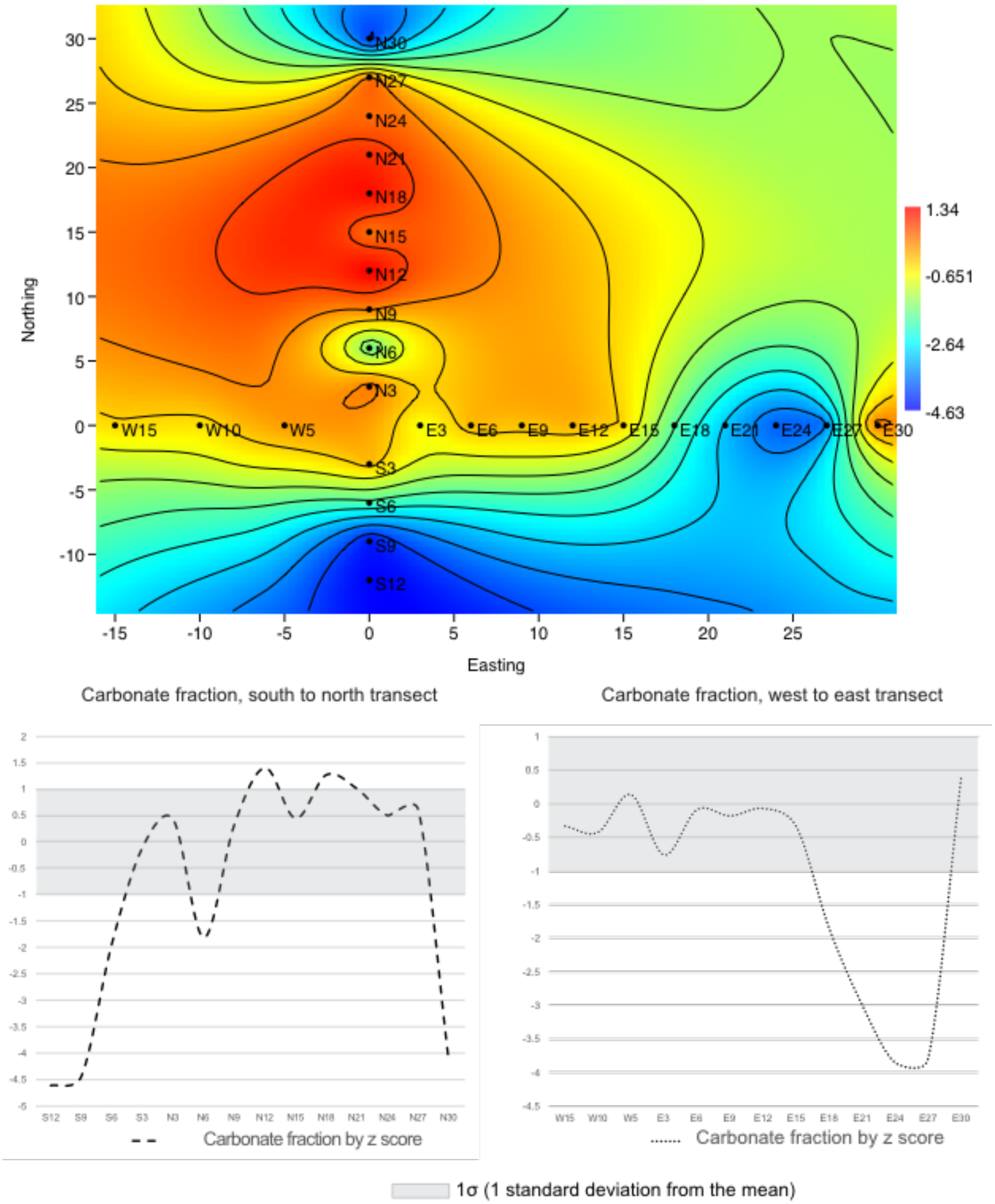


Figure 3.8: Carbonate fraction, krigged, above, and by z scores along the north to south and east to west transects.

Principal components analysis (PCA 1 and PCA2) 2015 sediment data

Linear discriminant analysis 2015 sediment data

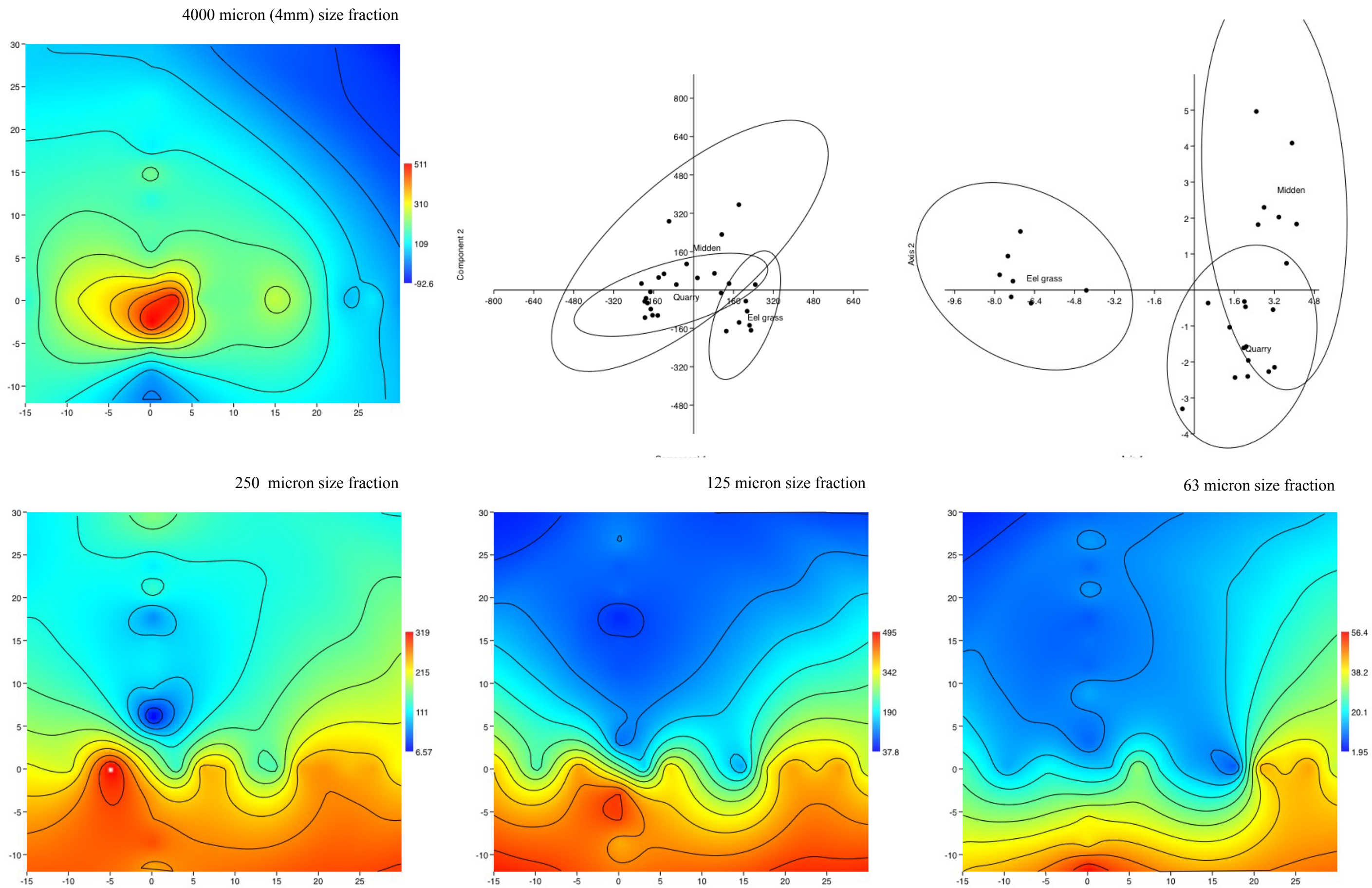


Figure 3.9: Principal components and linear discriminant analysis with krigged plots showing size fractions

Table 3.6: Sediment classes according to LDA, 2015 samples

Point	Given group	Classification	Jackknifed
S12	Eel grass	Eel grass	Eel grass
S9	Eel grass	Eel grass	Eel grass
S6	Eel grass	Eel grass	Eel grass
S3	Midden	Midden	Midden
N3	Midden	Midden	Quarry
N6	Quarry	Quarry	Channel
N9	Quarry	Quarry	Quarry
N12	Quarry	Quarry	Quarry
N15	Quarry	Quarry	Quarry
N18	Quarry	Quarry	Quarry
N21	Quarry	Quarry	Quarry
N24	Quarry	Quarry	Quarry
N27	Quarry	Quarry	Quarry
N30	Channel	Channel	Quarry
W15	Quarry	Quarry	Quarry
W10	Quarry	Midden	Midden
W5	Midden	Midden	Quarry
E3	Midden	Midden	Midden
E6	Quarry	Quarry	Quarry
E9	Quarry	Quarry	Quarry
E12	Midden	Quarry	Quarry
E15	Midden	Midden	Midden
E18	Quarry	Quarry	Midden
E21	Eel grass	Eel grass	Eel grass
E24	Eel grass	Eel grass	Eel grass
E27	Eel grass	Eel grass	Eel grass
E30	Eel grass	Eel grass	Eel grass

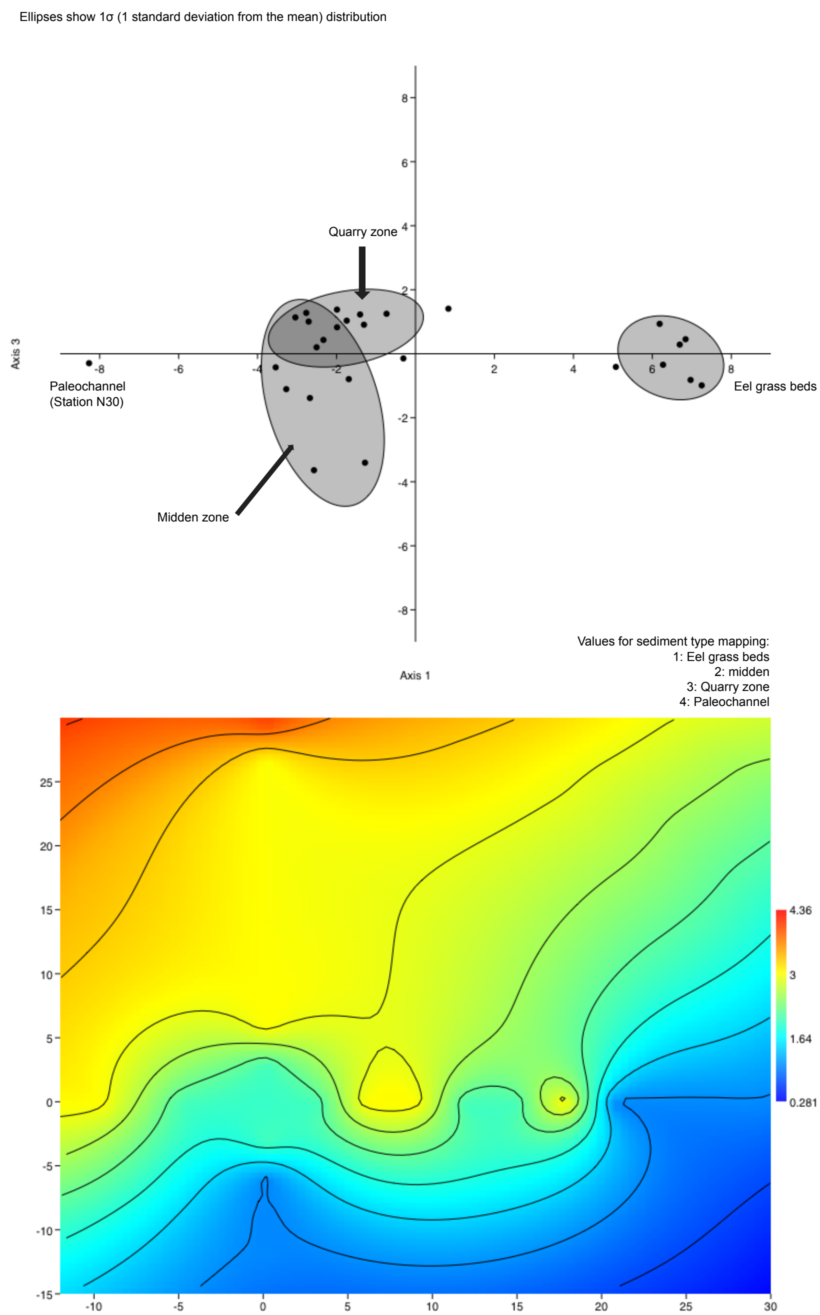


Figure 3.10: Linear discriminant analysis of bulk sediments and carbonate components. Ellipses show 1 σ distributions (1 standard deviation from the mean)

Stratigraphy

Figure 3.2, above, shows the stratigraphic profile exposed in U4 within the eel grass beds. The top layer is most consistent with the shell midden deposits, although it retains more of the fine particle fraction than the deposits observed outside of the eel grass beds. Below the fine eel grass sediments lies a deposit of coarser shell hash, underlain finally by a finer shell hash. All layers appear to be primarily composed of *crassostrea.* A layer of articulated *crassostrea* valves interpreted as a natural deposit lies at the bottom of the profile, not visible in this view.

The presence of natural *crassostrea* below anthropogenic deposits is more suggestive of a river channel avulsion than a relative sea level oversteps at the site prior to occupation. The Balsillie and Donoghue curve (2011:63) suggests the possibility for a relative higher stand at ~6000 cal BP, somewhere near the modern position but only as a moving average calculated from multiple data points. Two studies show RSL as much as -8 to -6 m bmsl, while four others argue for shoreline position as much as 2 meters higher than the modern position (Balsillie and Donoghue 2011:60). Our findings suggest that additional data points will be helpful in verifying this.

Radiocarbon dates

We obtained two radiocarbon dates from shell excavated from the upper and lower stratigraphic portions of the midden taken from U5. These dates have significant limitations to them. *Crassostrea* shell is a problematic material for dating due to the varying degrees of environmental influences on the 14C content. These can include the presence of old carbon dissolved from local/regional carbonate bedrock, and water salinity in estuarine environments – both of which are significant concerns at this site. Calibration can take these reservoir effects into account, but only when used at a highly local level (Hadden and Cherkinsky 2016). These are both serious limitations to dating shell material within a site such as this. However, we recovered no non-shell organic materials suitable for radiometric dating.

Dates were obtained using standard practices at the University of Georgia's Center for Applied Isotope Studies (CAIS) using their AIS 0.5 MeV accelerator mass spectrometer. The sample $^{13}C/^{12}C$ ratios were measured separately using and expressed as δ13C with respect to PDB. The date has been corrected for isotope fractionation. We then calibrated the dates using Oxcal 4.2 and a marine reservoir correction average using Calib (http://calib.org/marine/) (Reimer et al. 2009, 2013; Bronk Ramsey 2009). The marine reservoir correction we used was calculated using an average of 136 +/- 100 years, taken from two studies from the Apalachee Bay area (Hadden and Cherkinsky 2015, 2016). Table 3.7 summarizes our results.

The mean date for the lower level was 4,510 cal BP, +/- 461, and the date for the upper level was 2,621 cal BP, +/- 423 (Figure 3.11). This suggests that midden deposition lasted from the end of the Middle Archaic period into the Late Archaic period, and possibly even into the early Woodland period. Faught and Donoghue reported broken bifaces from Econfina Channel site that are probably Marion or Putnam type (Faught and Donoghue 1997:444). Bullen classified Marion and Putnam as lasting from the Middle Archaic into the Late Archaic, but Farr has argued that Marion should be considered part of the Florida Archaic Stemmed point tradition spanning the entire Middle Archaic and into the Late Archaic (~8,500 cal BP to 4,000 cal BP), while Putnam should be classified by some as a separate type with a shorter use period of ~7,250 cal BP - ~6,250 cal BP (Farr 2006:107, 111). Our late dates do not clarify that situation and it is possible that the unusually young early Woodland date is in error.

Table 3.7: 14C dates, Econfina Channel site

14C dates, Econfina Channel site	**Unmodelled (BP)**					
	From	**To**	**%**	**σ**	**μ**	**Median**
Econfina Midden level 2 R_Date(4490,25)	5465 BP	3546	95.3	4510	461	4512 BP
Econfina Midden level 1 R_Date(3010,25)	3450 BP	1784	95.4	2621	423	2617 BP

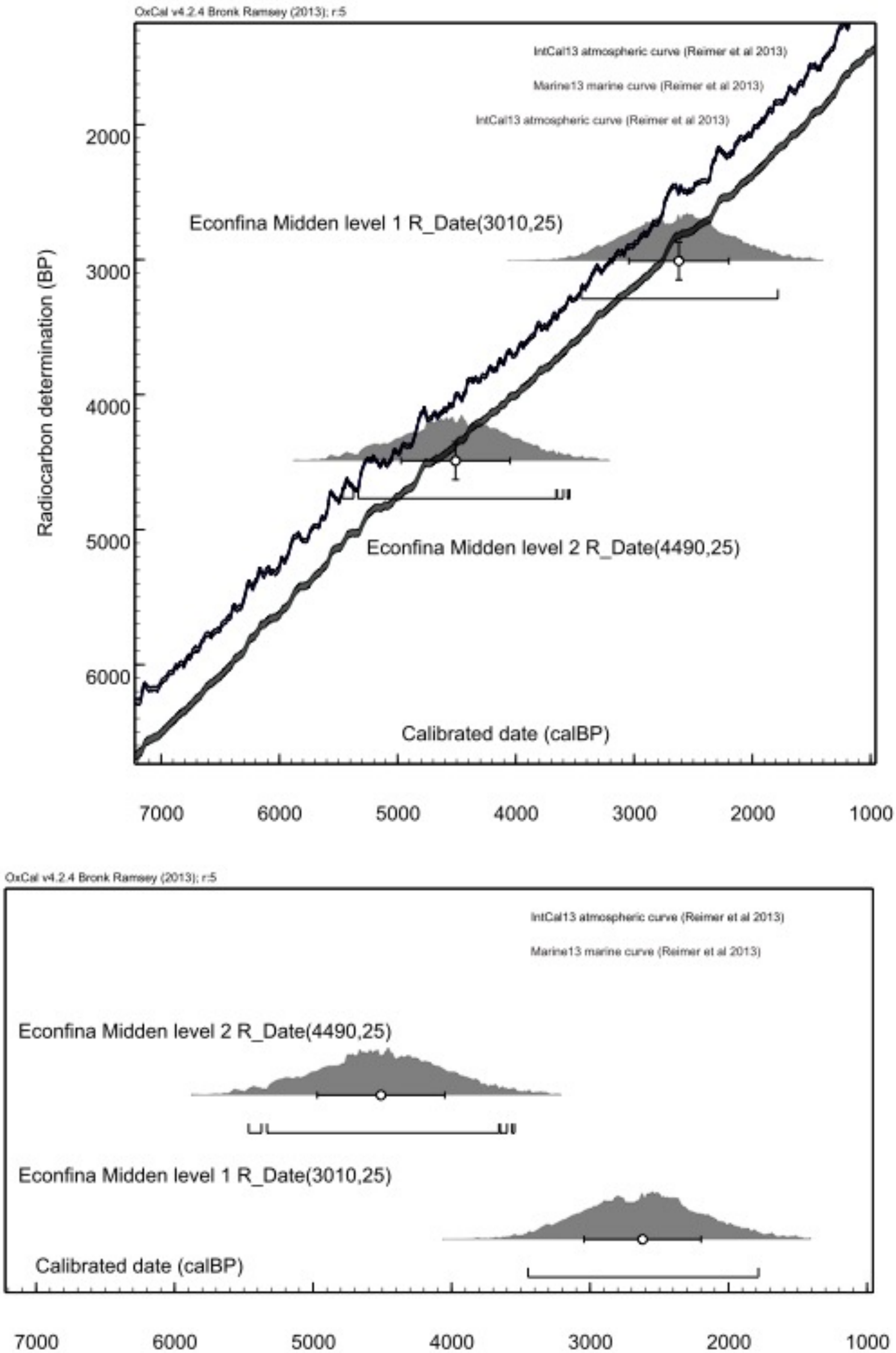


Figure 3.11: Calibrated 14C dates from the Econfina Channel site midden

Discussion

Econfina Channel site contains multiple features: a possible midden, a quarry with every stage of lithic reduction and manufacture, and a freshwater spring. It is also mixed in terms of preservation of these features. First, we will discuss what activities we can infer from the evidence recovered from these features, and then we will discuss the shortcomings of preservation.

Identification of the shell deposit as anthropogenic relies on multiple lines of evidence. First, the shell deposit is composed of *crassostrea* (oyster), with some examples of *pectin* (scallop), *Melongena corona* (crown conch), and *Ampullariidae* (apple snail) (Figure 3.12). All taxa except for the apple snail can be found in estuarine and open marine contexts, and do not argue for human intervention to create this deposit, but the apple snail is a freshwater species that would have been deposited before the paleochannel next to the shell deposit became brackish or saline. Modern salinity in Apalachee Bay averages around 25 ppt. (Bianchi et al. 1999:39), which is at the upper end of the range of salinities tolerated by *crassostrea virginica* (NOAA Fisheries Eastern Oyster Review 2007). It is more likely that a natural oyster deposit would form when salinities were brackish or closer to modern marine conditions. A natural estuarine oyster deposit could have only formed above a freshwater deposit containing apple snail; The intermingling of these two taxa from very different salinity environments plus the occurrence of human modified lithics among them argue that human subsistence activities carried out when the fluvial channel was a freshwater environment is the more likely explanation for the appearance of this shell deposit (Garrison et al. 2013:73).

Furthermore, all the oyster valves are disarticulated, and they show no signs of intergrowth such as is commonly seen in natural oyster reefs.

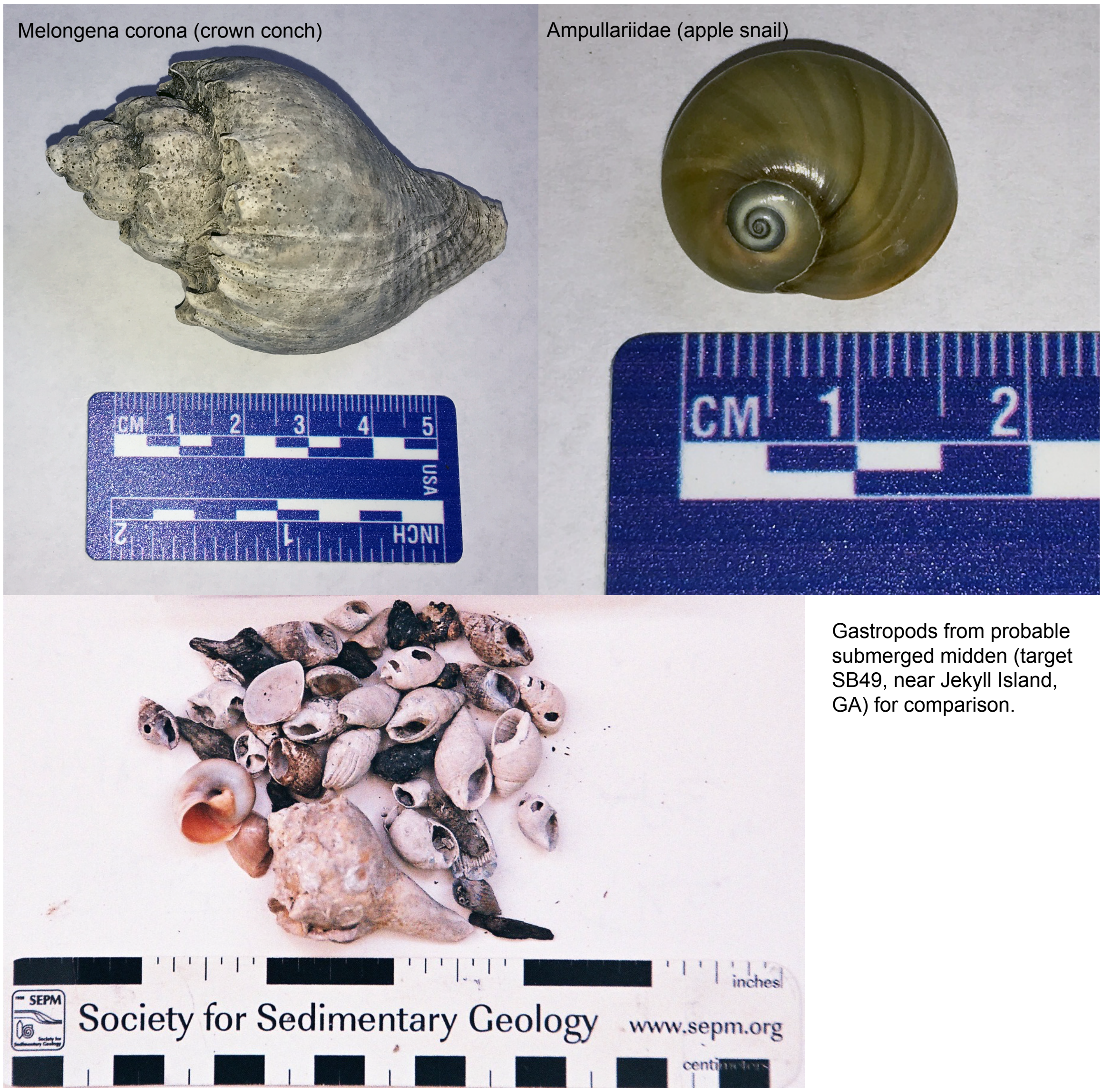


Figure 3.12: Gastropods from midden deposits, Econfina Channel site and SB49, Jekyll Creek, GA.

From this we infer that we have evidence for one type of subsistence activity: shellfishing. Clearly, estuarine resources were exploited at Econfina Channel consistent with other Archaic shell middens along the northern Gulf Coast (Hadden 2015; Saunders and Russo 2011). We recovered the same suite of invertebrate taxa as Faught, et al., did during initial investigations (Faught 1988; Faught and Donoghue 1997). Significantly, the possible midden zone is much larger than initially thought, and appears to have two lobes based on sediment size analysis, suggesting either multiple contemporary shellfish processing areas, or two different shellfish processing episodes and/or possibly occupations. Additional 14C dates would help to clarify this question.

δ13C/14C ratios become less negative in the younger levels, indicating that water salinity was lower for the lower stratigraphic layer but increased in the younger layer (Andrus and Crowe 2000:39). The most reasonable explanation for this shift is that the *crassostrea* in the lower levels were collected further inland, in somewhat fresher water than the younger ones. This is consistent with what should have occurred as the sea levels shifted landward as the coastline approached its modern position instead of proxy evidence for multiple collection locations. The appearance of *pectin* in the midden indicates that this taxon from an offshore, fully marine environment may have been consumed here as well, though this is equivocal; if this was the case, these items imply the use of watercraft despite the lack of direct evidence for them at this location.

Debitage showing use wear for multiple activities was found throughout the midden, as well. These activities include processing durable materials such as bone or antler, possibly shell, moderately durable materials such as wood, and soft materials such as meat or hides. Neither our study nor earlier excavations by Faught, et al., detected bone from terrestrial taxa. This could be a preservation issue, but it is unclear to what degree this may explain the lack of terrestrial bone at Econfina Channel given the recovery of bone from other nearby submerged sites such as J&J Hunt. The debitage could be a secondary deposit but the distribution of the 4-mm particle size fraction does not support this, either. Instead, the most parsimonious explanations are that either terrestrial faunal bone was systematically deposited elsewhere in the site, or that the use wear from working durable materials was created by manufacturing shell tools.

Mobility patterns cannot be directly inferred from our data, but several of our findings are suggestive. The high ratio of informal to formal tools is typically considered suggestive of lower mobility but the relationship between tool type and mobility is not linear and can be complicated by other variables such as raw material availability or the nature of environmental risk in the local environment (Andrefsky 1994; Kelly 1992; Odell 1998). The dominance by shellfish of the midden as opposed to higher ranked prey is also suggestive of lower mobility. Lower ranked resources such as shellfish are less likely than higher ranked resources to undergo field processing, and this is especially the case when children or other physiologically limited members of a group are foraging (Bird and Bliege Bird 2000:471–472). The lack of evidence for terrestrial fauna could indicate that these prey were field processed elsewhere and brought to the site (Bird and Bleige Bird 1997; Bliege Bird et al. 2009:467). It could also indicate that terrestrial fauna were simply not consumed at this location. Shellfishing at this scale is typical for lower mobility coastal populations during later periods along the Atlantic seaboard (Reitz 1988, 2014, Thomas 2008, 2014), although fully sedentary occupations are not currently demonstrated along the northern Gulf Coast or within Florida as a whole (Hadden 2015; Mikell and Saunders 2007; Saunders et al. 2009; Saunders 2010; Quinn et al. 2008). Finally, the number and diversity of site features can also be used as a proxy for mobility; this site contains two different quarry areas in addition to the evidence for tool retouch and finishing at the midden itself, and if there is remaining evidence for structures, it is not within the excavated areas, indicating that either the evidence was destroyed during/after submergence, or that it lies elsewhere in the site (Kelly 1992; Kelly et al. 2005). Therefore, we cannot negate a hypothesis that this site was occupied by low mobility coastal foragers, even if we cannot definitively demonstrate it.

The large marine reservoir correction required for radiocarbon dates on shell in this region makes it difficult to pinpoint when midden deposition began more precisely than the calibrated age of 4,510 +/- 461 cal BP, which is Late Archaic, not Middle Archaic. Despite this shortcoming, we can say that midden deposition was occurring during the same period that Florida Stemmed Archaic points were being produced. The younger date on the top level of the midden, recovered from an apparently anthropogenic context, returned a mean 14C date of 2,621 +/- 423 cal BP, which is at least 1,400 years, well into the Woodland period after the shoreline was thought to have reached its roughly modern position in Florida. This raises questions about the relative sea level curve in this area because the midden deposit averages 2-3 meters below the modern position. The earliest portion of this age range, at around 3,000 cal BP, is more consistent with the Younger Dataset A compiled by Balsillie and Donoghue that consists of seaward indicators for relative sea level, and not landward geomorphological features left behind by high stands; this dataset indicates a relative sea level of around -2 meters, (Balsillie and Donoghue 2011:65). More data are needed to clarify this issue.

The site has undergone significant post-depositional erosion, however, and to different degrees depending on location within the site. Sediment analyses suggest that fine sands in the quarry/midden zones experienced greater erosion and deflation since submergence than the same fractions in the eel grass zones. Particle size analysis also cannot completely distinguish between midden versus quarry. Particle size analyses using PCA and LDA show significant overlap between midden and quarry sediments, even while the eel grass zone clearly separates from the two. Charcoal appears in midden, quarry, and channel samples, suggesting either non-anthropogenic fire, or charcoal from anthropogenic fire that has been reworked by fluvial and marine processes. Either post-depositional fluvial and marine processes have conflated the midden and quarry zone sediments, or these areas graded into one another during initial deposition.

Shell alone does not correlate with any other sediment component, and is most abundant in locations within the midden itself. Along with this line of evidence, we can currently discriminate between midden and quarry sediments based on the presence of larger primary reduction debitage. The site contains evidence for the entire reduction sequence of lithic manufacturing, but the largest primary reduction debitage is found within the quarry zone and the seep/spring feature; smaller debitage was found within the midden itself. The possible refit of a blade core from the seep spring area to a blade tool found at the datum location on the midden adds a spatial dimension to these findings, and supports an argument that the midden and quarry were used contemporaneously.

While there was no serious argument against the anthropogenic nature of these features, following Gagliano, et al. we have falsified a hypothesis that any of them are natural. Along with the failure of shell to correlate with any other sediment component, our findings parallel Murphy's at the Douglass Beach site (8SL17) (Murphy 1990), that individual components within the sediments are better suited to delineating intrasite areas, while the totality of all components appears to best distinguish the site from the surrounding areas. In this case, shell, macro-debitage, smaller debitage, and charcoal are the individual components separating the intrasite zones, while taken together they support the argument that these sediments experienced anthropogenic alternation.

The particle size analysis also leaves open the possibility that the eel grass zones may contain better preserved features. This confirms earlier assertions by Faught, et al., that the best opportunities for preservation at submerged sites in Apalachee Bay lie within areas protected them from tidal and wave action during relative sea level rise. In addition to sink features such as those observed along the PaleoAucilla, lower energy zones such as the eel grass zone may also satisfy this requirement. At Econfina Channel, future work should include sediment sampling in the eel grass beds away from the channel and at the freshwater seep/spring feature to test for statistically meaningful differences between deposits along with potentially undetected features.

Conclusions

Econfina Channel site does not contain the high degree of preservation often seen in onshore submerged sites such as Page Ladson (8JE00591A), or Warm Mineral Springs. Nevertheless, evidence for multiple activity areas can still be discerned using geoarchaeological methods designed to tease out evidence for human activities. Further, these findings expand upon the predictive model that has been used to search for submerged sites in Apalachee Bay since the 1980s, because they demonstrate a site type quite different from Page Ladson inland, or J&J Hunt offshore. Despite the shortcomings of preservation at Econfina Channel, we have good evidence that it is more akin to sites such as Mitchell River, west of Apalachee Bay, which was first used during the Middle Archaic, and occupied into the Late Archaic (Mikell and Saunders 2007:172–174). These findings argue for extending Late and Middle Archaic patterns for coastal resource use into the offshore zone, in addition to the predictive models currently in place for older periods. These finding also further the argument that testing for intensively occupied older coastal sites should continue.

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CHAPTER 4 : POST DEPOSITIONAL CORROSION IN LITHIC ITEMS RECOVERED FROM SUBMERGED MARINE CONTEXTS[4]

[4] Jessica Cook Hale. Submitted to First Floridians, University of Florida Press

Introduction

In this chapter, my primary goal is to identify criteria that could be used to differentiate corroded artifacts from marine prehistoric archaeological sites from geofacts. Items identified as artifacts can add to our understanding of the local lithic landscapes from which they came. To do this, I conducted an experiment comparing the usefulness of four instrumental analytical techniques to identify the elemental and mineralogical constituents of items recovered from two submerged marine sites on the coast of Florida that exhibit chemical or mechanical corrosion and are excellent examples of this problem. Human modification of these samples must be demonstrated due to the significant impacts of this corrosion; otherwise their interpretive value is limited to geological inferences only.

Submerged prehistoric archaeological sites have good potential for preservation of organic materials, but perversely, lithic materials, the most durable remains in terrestrial sites, often undergo severe degradation in marine contexts. Marine inundated sites experience a different suite of post-depositional processes than terrestrial sites that can be extremely destructive via both mechanical and chemical weathering (Faught and Donoghue 1997; Faught 2004a, 2004b; Gagliano et al. 1982; Lowery and Wagner 2012; Marks 2006; Nichols 2009:204, 208–209; Pearson et al. 1982, 1989). Many lithic assemblages from these contexts are heavily corroded, obscuring typical characteristics for human modification, making their identification as artifacts problematic.

However, corroded lithics can still yield useful data, if human modification can be demonstrated. These data can contribute to our understanding of the lithic landscape, which describes human use of the stone resources within a region. The lithic landscape includes the abundance, quality, and size of raw materials; the technological needs of human groups; mobility and subsistence strategies; and any culturally driven choices, such as preference for one type of source rock over another when both are equally reasonable choices from a purely technical point of view (Andrefsky 1994, 2009; Binford and Binford 1966; Binford 1980; Bordes and de Sonneville-Bordes 1970; Burroni et al. 2002; Purdy and Brooks 1971; Clark and Purdy 1979; MacDonald 2009; Purdy and Clark 1987). These factors contribute to how and why prehistoric people used geologic resources.

Various types of human activities within the lithic landscape can be suggested by data derived from lithic artifacts. Use of exotic source versus local source materials may suggest movement of materials or people; tool types can offer information about temporal and spatial distributions for cultural groups or activities; and the corrosion itself can allow us to infer environmental conditions after deposition. On terrestrial sites these analyses are comparatively straightforward, but corroded lithic assemblages from submerged marine sites require techniques for overcoming this hurdle.

First I will provide background on the sites and their regional lithic landscapes, and then I will describe the samples. I will then review the analytical techniques, describing how they operate and how this contributes to understanding both surface corrosion and sample composition. I will then discuss the results, evaluate the relative usefulness of each technique, and examine the findings for both sample composition and surface corrosion. In the end, I will propose criteria for determining whether corroded stone from a site should be considered an artifact or geofact. Finally, I offer interpretations for how these particular items fit within their respective lithic landscapes.

The lithic landscapes, sites, and samples tested

The lithic landscapes of interest in this study are the Big Bend region, where the peninsula meets the panhandle of Florida, and the Atlantic coastline of the central Florida peninsula. Both areas are underlain by carbonate bedrock, but differ in their surface sediments, hydrology, and geomorphology. Carbonates in the Big Bend are primarily composed, from east to west, of Eocene Ocala Limestone, Oligocene Suwannee Limestone, and Miocene St. Marks Limestone, with a thin veneer of Quaternary sediments. Along the central peninsula, the Ocala and Suwannee limestones extends southward along the west coast, but younger formations dominate towards the Atlantic coastline. The Pliocene Cypresshead formation appears along the central peninsula, and by the time one reaches the Atlantic coastline, sediments are, at the oldest, Pleistocene. The eastern coastline is thus far more siliciclastic than the Big Bend.

Along the Big Bend, the carbonate bedrock acts as both the primary aquifer and the control on fluvial processes. Bedrock weathering takes place when weakly acidic rainwater reacts with carbonate bedrock along bedding planes and fracture surfaces creating dissolution features (Hine et al. 1988; Upchurch 2007). Sediment loads within the rivers are minimal, and fluvial channels follow discontinuous collapse features within the bedrock. The net result is that local rivers such as the Aucilla "rise" and "sink" along intermittent channels, and springs fed by the Floridan Aquifer are widespread. Finally, chert suitable for tool manufacture outcrops frequently throughout the region (Dunbar 2016:46-51; Faught and Donoghue 1997:423–425; Hine et al. 1988:568–570). This trend extends southward along western shoreline of the Gulf of Mexico south towards Tampa (Brooks et al. 2003:326; Hine et al. 1988; Locker et al. 2003).

Fluvial geomorphology and sedimentation differ along the Atlantic shoreline. Siliciclastic surface sediments are thicker and karst features diminish in surface expression, although some can be detected offshore (Finkl and Andrews 2008). Fluvial geomorphology is not controlled by karst collapse features. Instead, the flow of river systems tends to the north-south orientation of the Pliocene-Holocene siliciclastic beach terrace formations along the Atlantic coastal ridge. The St. John's River, whose headwaters are found in this area, is the most obvious example of this. Because of thicker siliciclastic sediments, chert outcroppings like those in the Big Bend are non-existent along the eastern coastline. Local, high quality cryptocrystalline quartz tool stone is lacking, although projectile points of calcareous sandstone have been documented from submerged sites off the Georgia Coast to the north of this area, suggesting that other rock types could have been used instead (Garrison, Cook Hale, et al. 2012; Garrison, Weaver, et al. 2012; Garrison et al. 2016; Harris et al. 2013).

The archaeological landscape of the Big Bend

The coastal plain of the Big Bend extended as much as 250 km offshore from its modern extent around 22,000 cal BP, over 100 meters below modern sea level (bmsl) at the height of the last glacial maximum. Once modern sea level was established around 5,000 cal BP, Florida lost around 40% of its former landmass, much of it along its western coastline. Relative sea level curves suggest that the shoreline rose from around -40 meters bmsl at 12,500 cal BP to around -20 meters bmsl by 10,000 cal BP (Balsillie and Donoghue 2011). The shoreline reached the area of Ray Hole Springs, around -12 m bmsl, 32 km from the modern shoreline, by 7,500 cal BP (Anuskiewicz 1988; Anuskiewicz and Dunbar 1993; Balsillie and Donoghue 2011; Dunbar et al. 1989; Faught

1988, 2004a). Sites such as Ray Hole Springs were transformed from upland locations where karst features controlled access to water, to a warm coastal mixed forest where fluvial features would have flowed more regularly, to tidal marsh, and then finally completely submerged (Anuskiewicz 1988; Anuskiewicz and Dunbar 1993; Dunbar et al. 1989; Faught and Donoghue 1997; Halligan et al. 2016; Watts et al. 1992).

Onshore prehistoric sites in this area date from the Paleoindian through historic periods. Early sites tend to be associated with sinkholes, chert outcrops within the carbonate bedrock, and discontinuous river channels (Anuskiewicz and Dunbar 1993; Anuskiewicz 1988; Dunbar 1988; Faught and Donoghue 1997:421; Faught 2004a, 2004b; Halligan et al. 2016). When relative sea levels were low, rivers fed by the Floridan Aquifer dropped as well, leaving a series of sinkholes in the channels (Dunbar 2006a; Faught and Donoghue 1997). Humans and animals were tethered to the sinkholes when water was scarce (Duggins 2012; Thulman 2009). Foragers could easily target prey at these sinkholes, while chert outcrops dotting the landscape conveniently provided raw material for stone tools (Dunbar 2016).

The archaeological landscape of the Altantic coastline

Along the Atlantic coastline, the continental shelf is narrower and offshore sites are closer to the modern shoreline. Shoreline proximity during periods of lowered sea level may have minimized hydrological effects along this coastline, allowing rivers to flow instead of drying them (Thulman 2006:74). Pollen data suggest that central and southern Florida were drier than the panhandle during the terminal Pleistocene (Thulman 2006:78, table 3.1). Warmer, wetter forest returned by the Middle Holocene as lakes and rivers throughout the state filled (Watts et al. 1992:1063). Models for human occupation along the Atlantic shelf are less well developed than for the Big Bend, unfortunately. Aside from freshwater, few other predictive landscape features can be identified for this coastline.

There are fewer Paleoindian sites known along the Atlantic shoreline of Florida. It is not clear if this was because human groups preferred different locales, or because these sites are now submerged (Anderson and Faught 1998; Anderson et al. 2011; Faught 2008; Thulman 2006). The early site of Vero Beach may provide one possible onshore analog to offshore Paleoindian sites along this coastline. It is located on a marine terrace approximately 120,000 years old. Human remains were recovered by Sellards at Vero in the 1920s, although their antiquity was hotly debated. Pleistocene faunal remains have been recovered since excavations have been renewed since 2014. While the full extent and nature of the site is still unclear, these excavations should provide clarification (Hemmings et al. 2015).

Occupation increased during the Archaic period, primarily along the St. John's river valley, and is characterized by shell middens and mounds (Randall 2013; Randall et al. 2014; Saunders and Wrenn 2014). Mortuary pond sites such as Windover, near Jupiter Beach, and shell mound cemeteries such as Tick Island, along the St. John's river, have yielded paleobotanical and bioarchaeological data. Population mobility appears to have been low, but long range contact with groups outside of Florida did exist; two individuals at Harris Creek, along the St. John's River, were not born locally (Quinn et al. 2008; Tomczak and Powell 2003; Tuross et al. 1994). In summary, possible site types for the Atlantic coastline could include sites located along now-submerged marine terraces, mortuary pond sites in low lying areas, and shell midden sites along fluvial channels.

The sites

Ray Hole Springs (8Ta171)

Ray Hole Springs was a sinkhole like sinkhole sites onshore. It is located in 12 m of water approximately 32 km offshore and was discharging fresh water as late as the mid-1980s. It encompasses a roughly oval area ~7.6 meters in diameter at its widest point, with a surface veneer of marine sediment and a limestone outcrop along the southeastern curve of the sink. An excavated level 1 m below the surface contained oak fragments dated to 8,220+/-80 BP and possible artifacts or debitage. An overlying natural shell deposit dated to 7,740 +/- 60 BP, which is inferred as the date of submergence and the end of human occupation (Anuskiewicz 1988; Anuskiewicz and Dunbar 1993; Dunbar et al. 1989). The cultural groups occupying Ray Hole Springs may have used lithic, bone, and perhaps ivory tools, but not ceramics (Bradley et al. 2010; Byrd 2011; Dunbar 2006b; Halligan et al. 2016).

The nature of the site remains opaque. It was mapped in 1986, but bad weather and technical difficulties during the 1992 field season halted subsequent work (Anuszkiewicz and Dunbar, 1993). Surveys of the area in 2008-2009 detected three sinkholes, not one, leaving it unclear which sink was excavated (C. Andrew Hemmings, 2015, personal communication). Although one chert flake was identified as human modified, most of the stone items recovered from Ray Hole Springs were characterized as “pseudo” artifacts, because they were so corroded.

Douglass Beach(8SL17)

The Douglass Beach site (8SL17) is located in St. Lucie County, off the Atlantic Coast. It is best known as the location of a vessel from the 1715 Plate Fleet, but prehistoric components were documented during initial, poorly controlled salvor excavations in the early 1960s and 1970s. The underlying geological formation is the Anastasia formation, which consists of coarse coquina rock to shelly sand, and abundant broken shell. Peat and clay were observed during excavation as well, suggesting the formation of wetlands during marine transgression (Murphy 1990:13).

The prehistoric components at Douglass Beach lie in 3-5 m of water, within 200 meters or so of the shore. Excavators recovered Pleistocene and Holocene faunal remains, human remains, and artifacts, including the sample examined here, all beneath marine sediment. Unlike Ray Hole Springs, excavations recovered a comprehensive, well preserved faunal collection containing fragmentary pieces possibly created by either human or scavenger activity. The assemblage is composed of upland, estuarine, and marine taxa, consistent with diets in the Middle to Late Archaic (Murphy 1990:32). The artifact assemblage was less equivocal than that recovered at Ray Hole Springs. Two diagnostic bifaces were identified in addition to the sample studied here: one Newnan, a Middle Archaic type dating to around 5500-6000 cal BP, and a Bolen, dating to around 9500 cal BP. The sample examined here is easily identifiable as a Paleoindian Suwannee biface.

The samples

From the Ray Hole Springs assemblage, I chose 17 items identified as pseudo artifacts for further testing. All showed signs of corrosion and were either mottled gray to black, or chalky white. Only one, a flake, had flake scars diagnostic for human modification. One appeared morphologically similar to known projectile point types. Two appeared similar to scraper tools. One appeared to be a flake tool. The remainder were even more equivocal.

I selected only the Suwannee biface from Douglass Beach. This biface is diagnostic for the Paleoindian period, but lacks both vertical and horizontal provenience (Cockrell and Murphy 1978; Murphy 1990). Like the Ray Hole Springs assemblage, it lacks flake scars and is corroded. The surface of the biface is black to gray, while the interior, visible at a break at the base, is chalky white.

The Ray Hole Springs assemblage is being compared to the Douglass Beach biface because the latter is clearly a human modified artifact, but shows similar corrosion and lack of flake scars. I added this artifact to test the hypotheses that corrosion patterns are similar in both sites, that these corrosion patterns indicate similar post-depositional geochemical environments, and that flake scars are not the only line of evidence for human modification. The Douglass Beach biface serves as a potential example of what artifacts from Ray Hole Springs may have looked like before corrosion became severe, and could indicate that lithic corrosion patterns exist along a continuum. Finally, the Douglass Beach biface was found in a landscape depauperate in local tool stone, and its composition should shed light on the human activities that deposited it within a landscape not known for local lithic resources.

Methods and materials

My primary goals were: first, to offer hand sample descriptions for each sample, including possible artifact type; and second, to characterize the composition of the corroded exterior and uncorroded interior of each sample using instrumental analysis. Hand sample analysis was performed to assess how similar each sample was to known artifact types. General composition data for each sample can allow me to infer source material, suggesting its potential source in the lithic landscape. Data on corrosion allows me to infer post-depositional environmental conditions. The corrosion boundary widths were not examined in detail; these cannot suggest duration of exposure to corrosive conditions, as the geochemical systems involved are too complex to constrain (Burroni et al. 2002; but c.f. Purdy and Clark 1987).

A secondary goal of this study is to identify which methods were most successful in rendering useful data. The best methods are easy to use, give detailed results, and do not require destruction of artifacts. All of the instrumental methods operate using the physics of interaction between some form of electromagnetic radiation and the sample itself; when these interactions occur, different elements within the sample react differently. Different reactions are visualized as spectral peaks at different frequencies. The height of a peak reflects its strength, and the best methods produce more peaks, giving more detail.

For hand sample analysis, I relied on artifact types already documented in the southeastern United States. For the non-biface items, I referenced Purdy (1981). For the bifaces, I referenced the Florida Museum of Natural History's online database of Bullen Collections (https://www.flmnh.ufl.edu/flarch/collections/bullen/explore/period/).

I used four instrumental methods to characterize the rock type and geochemical corrosion: Electron Microprobe Analysis (EMPA), scanning electron microscopy (SEM), x-ray diffraction (XRD), and x-ray fluorescence (XRF). EMPA and XRD require destructive methods. Therefore, I used thin sections of the materials. All but one sample from Ray Hole Springs were thin sectioned; this sample was already tentatively identified as a potential biface in Florida Bureau of Archaeological Research inventories and unsuitable for destructive analysis. XRF and SEM do not require destructive preparation methods, and the Suwannee biface from Douglass Beach was tested intact using these methods. XRD, SEM, and EMPA analyses were carried out at the University of Georgia (UGA). XRF and SEM analyses of the Douglass Beach biface was carried out at the UGA Georgia Electron Microscopy Center, and the UGA Center for Applied Isotope studies

Both SEM and XRF were chosen to test their effectiveness in comparison to destructive techniques such as EMPA and XRD. The primary goal in choosing these additional machines was to determine if these non-destructive techniques can offer the same high resolution of elemental and mineralogical detail as the destructive techniques. These comparisons contribute to a final assessment of which techniques are most effective for samples that can, and cannot, be analyzed using destructive methods.

XRD analysis

XRD scans a sample with x-rays to measure crystal structures in the sample. Because each mineral has its own particular crystalline structure, different minerals create different reflection and refraction patterns. The instrument measures x-ray patterns (diffractograms) at different angles and according to their respective strengths. Once the machine compiles a pattern of diffractograms, software is used to match the measurements to specific minerals. XRD is very useful for measuring mineral composition within an unknown material, such as a corrosion layer.

XRD analysis was performed using standard settings. These technical aspects included using a Bruker D8-Advance instrument owned by the UGA Department of Geology and a wide range of crystallographic software. Possible mineral matches for each peak were identified with a general search option in the software. Spectra were compared to known value and verified or disqualified as a match, using Powder Diffraction Database Search software by Scintag, Inc.

XRD analyses can be performed on thin section samples or random powder mounts. Here, XRD analysis was conducted on thin section samples. Each destroys sample integrity and can only be used with samples suitable for destructive analysis. Random powder mounts are more sensitive to analysis, because they maximize the chances that an x-ray will encounter any given crystal face within the sample by randomizing the orientation of all of the crystalline shapes within the powder. Thin section samples do not create this randomizing effect.

Electron microprobe analysis (EMPA)

EMPA is useful for generating elemental composition data on individual locations within a sample, from which one can infer mineralogy. It differs from XRD analysis, which generates an overall mineralogical composition profile. Electron microprobes fire an electron beam at a sample in a vacuum chamber, causing electrons to reflect back to a detector. The degree of reflection depends on the atomic density of the sample. Some electrons from the sample are displaced, and others are reflected by the beam. The reflected electrons display sample composition (backscatter electron image, or BEI), while the displaced electrons create a picture of the sample's surface relief (secondary electron image, or SEI); both can be compiled into an image for visual analysis of the sample. X-ray energy is also created when the beam hits the sample. Because every element generates its own signature x-ray, the sample's elemental composition can be determined.

Beam strength is measured in thousands of electronvolts (KeV). Lower beam strengths tend to detect fewer elements, but are less likely to cause the sample to take on its own electrical charge. These charging effects can distort the data by blurring the image, so an analysis must balance the need for higher resolution detail with the potential for charging effects to occur. One way to reduce charging effects is to coat the surface of the sample with a thin layer of carbon, and I did this for all of the samples tested using EMPA. I then scanned each sample for basic elemental composition to confirm rock type, and targeted individual areas of the corrosion surface for more detailed mineralogical and elemental analysis.

EMPA allows for both energy dispersive spectrometry (EDS) and wavelength dispersive spectrometry (WDS). EDS counts and compares the number of different x-rays generated when the beam hits the sample. WDS measures the strength of each x-ray spectrum generated by each individual element within a point location on the sample. EDS is useful for overall mineral identification, whereas WDS is preferred when different mineral phases need to be compared. WDS is more sensitive than EDS, but takes longer. Because I focused on mineral identification, I relied primarily on EDS.

As with XRD analysis, I used standard machine settings. Samples were analyzed with the UGA Department of Geology JEOL 8600 electron microprobe using a 15 KeV accelerating voltage and a 15 nA beam current. Minerals grains were qualitatively identified using a Bruker EDS detector controlled by a Bruker Quantax energy dispersive analysis system. Backscattered electron images (BEI), secondary electron images (SEI), and x-ray maps were acquired using imaging software of the Quantax analysis system.

Scanning electron microscopy (SEM)

Scanning electron microscopy uses the same principles as EMPA, but does not perform the same level of detailed, point-specific analyses as EMPA. SEM quickly assesses samples for different elements to infer mineral composition. Beam strength can be varied to minimize charging effects. In this study, I used a beam strength of 10 KeV.

I examined the Ray Hole Springs samples and the Douglass Beach biface using a Zeiss 1450EP SEM. The Zeiss 1450EP has a variable pressure sample chamber that allows imaging for entire samples as well as thin sections. It is equipped with an Oxford INCA EDS system. I analyzed the thin sections from the Ray Hole Springs assemblage but mounted the entire Douglas Beach biface on the stage, avoiding the need to thin section it. I scanned each sample at low (100x) magnification to assess overall composition. I scanned mineral inclusions detected at low magnification at medium (1000x to 1250x) and high (4000x to 5000x) magnification to analyze their individual compositions. I then compiled x-ray map images of the distribution of different elements at all magnification levels.

Portable x-ray fluorescence (XRF)

An x-ray fluorescence analysis was performed on the Douglass Beach biface by Jeff Speakman at CAIS. XRF uses x-rays to eject electrons from their atomic orbits in a sample. The space left by the ejected electron is filled by another electron from a different orbital shell around the atom, which then emits a signature x-ray. XRF can operate at higher accelerating voltages than EMPA or SEM, allowing for collection of greater elemental detail without charging effects. For this analysis, a beam strength of 40 KeV was used. Various filters can be used to reduce noise in the signal from very weak peaks. The presence or absence of elements indicates possible mineral inclusions, but XRF does not identify individual minerals like XRD or EMPA. Like SEM, XRF does not require sample destruction.

Results

Ray Hole Springs

Table 4.1 summarizes the results from Ray Hole Springs. Hand sample analysis was inconclusive for all but five samples. These showed the most similarity to artifact types documented in the southeastern U.S. and are the only samples discussed here.

Sample 92-517-41-8D was triangular to lunate shaped, mottled gray to black. Sample 92-517-41-6A was roughly rectangular and mottled gray to black. It is one of the thinnest samples, less than 1 cm thick along its thickest profile. Sample 91-517-41-6B was chalky white, and also lacked clear flakes scars; however, it retains a lunate shape. One end attenuates to a near-point while the other appears reminiscent of a potential striking platform. Additionally, the planes of the sample follow a medial crest that parallels the shape, terminating at the blunt end. Sample 93-586-1-1 was a small flake with clear flakes scars Finally, sample 92-517-41-2 was mottle gray to black and clearly possessed a stemmed base and at least half of a blade, consistent with stemmed point types such as Newnan or Putnam. It was assessed in hand sample only, and not tested using EMPA, SEM, or XRD. This left four samples for assessment by the instrumental methods: Samples 93-586-1-1, 92-517-41-6A, 92-517-41-6B, and 92-517-41-8D. Table 8.1 describes the hypothetical artifact types as well as instrumental analysis findings.

XRD revealed the mineral dolomite in samples 92-517-41-6A, 92-517-41-6B, and 92-517-41-8D, and quartz in sample 93-586-1-1. This is a carbonate mineral similar to calcite, with magnesium substituting for calcium in the mineral structure, though it is more likely that this material is a dolomitized siliceous material. The presence of only quartz in 93-586-1-1 indicates that it is composed of chert. XRD identified no other minerals. Figure 4.1 shows EMPA and XRD results from sample 92-517-41-6A, the possible flake tool.

EMPA confirmed general compositions shown by XRD. EMPA revealed that pyrite (FeS_2), a sulfide mineral composed of iron and sulfur, was common throughout the edges of all the samples. Manganoan calcite, composed of manganese, calcium, carbon, and oxygen, was detected as well. EMPA also detected clay minerals in pore spaces, and revealed another boundary zone where the magnesium in the dolomitized material had been replaced by calcium, a process called de-dolomitization. These results are also found in similar degrees in samples 92-517-41-6B and sample 92-517-41-8D. All of these minerals appear in the surficial boundary zone. This suggests that some additional geochemical process deposited these minerals after each item was formed into its final shape.

SEM rendered results similar to EMPA. No additional minerals were detected in either the interior or the exterior of each sample. However, SEM did not render images of the same high resolution as the combined BEI/SEI images rendered by EMPA.

Table 4.1: Results of analyses of Ray Hole Springs assemblage

Sample/Slide#	Methods used	Sample description	Rock type	Mineralogy
92-517-41-2	Hand sample analysis only	Possible stemmed base archaic projectile point	N/A	N/A
2-517-41-6A	Hand sample analysis, EMPA, SEM, XRD	Possible flake tool	Dolomitized material	Dolomite, pyrite, clay
92-517-41-6B	Hand sample analysis, EMPA, SEM, XRD	Lunate unifacial scraper?	Dolomitized material	Dolomite, calcite
92-517-41-8D	Hand sample analysis, EMPA, SEM, XRD	Unifacial scraper or flake tool	Dolomitized material	Dolomite, pyrite, clay
93-586-1-1	Hand sample analysis, EMPA, SEM, XRD	Flake. Debitage	Chert	Chert (cryptocrystalline quartz)

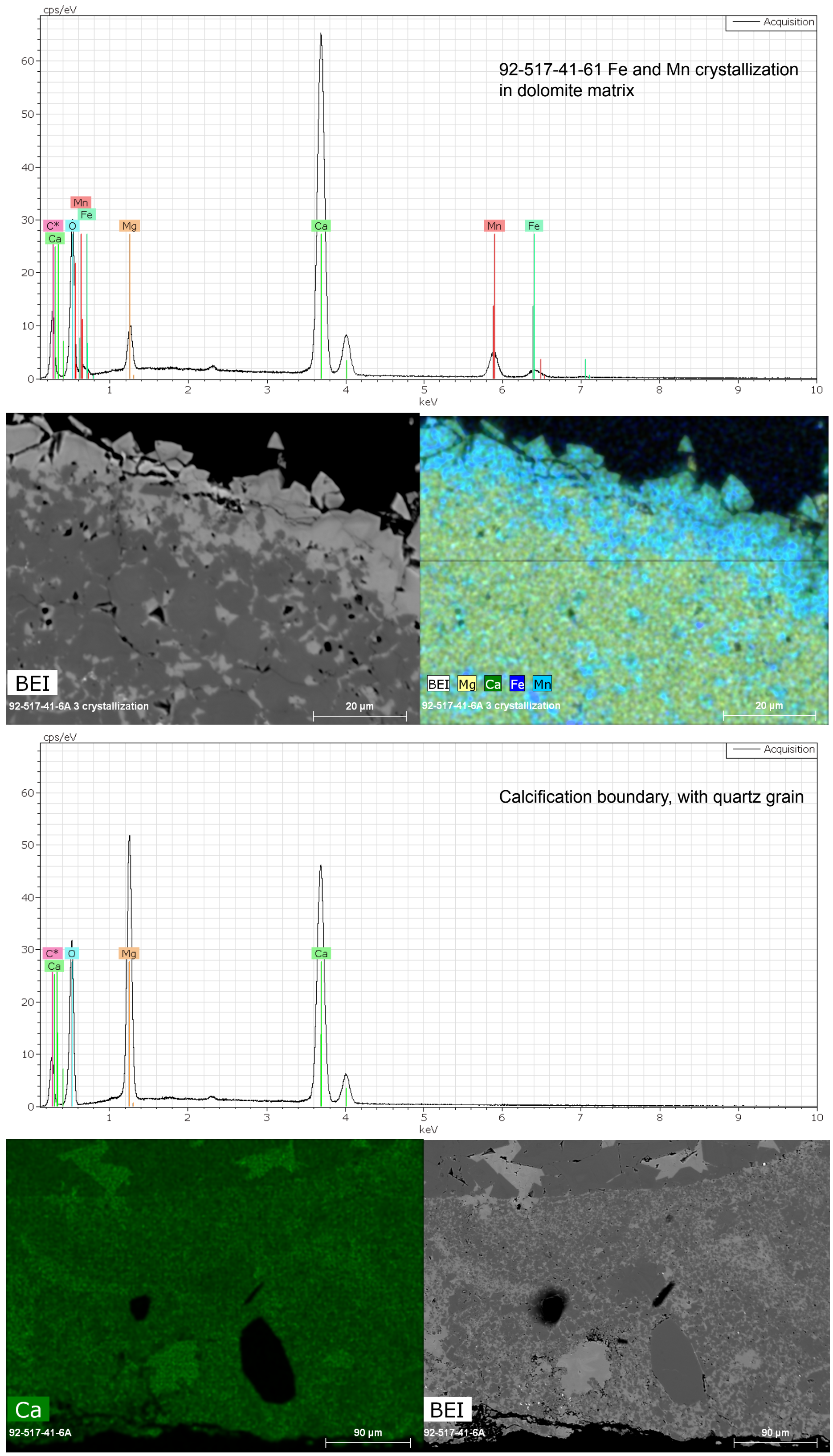

Figure 4.1: Corrosion boundary mineralization in sample 92-517-41-6A. Bright grains are pyrite.

Douglas Beach point

SEM analysis of the Douglass Beach biface showed that the item was composed of quartz with a prominent iron signature (Figure 4.2). Trace amounts of magnesium, aluminum oxide, calcium carbonate, and sulfur, were also detected. The iron and sulfur signatures might indicate trace pyrite within the sample, although no clear examples of pyrite crystal structures were visible. Likewise, attempts to resolve the details of the corrosion boundary at the broken base of the biface were unsuccessful.

XRF analysis detected more elements, including iron, copper, zinc, lead, strontium, and zirconium. Iron was the strongest signature aside from the quartz, measuring at just over 3%. None of these results suggest anything about the potential mineralogy indicated by these elements. However, XRF provided more detailed resolution about overall composition than SEM.

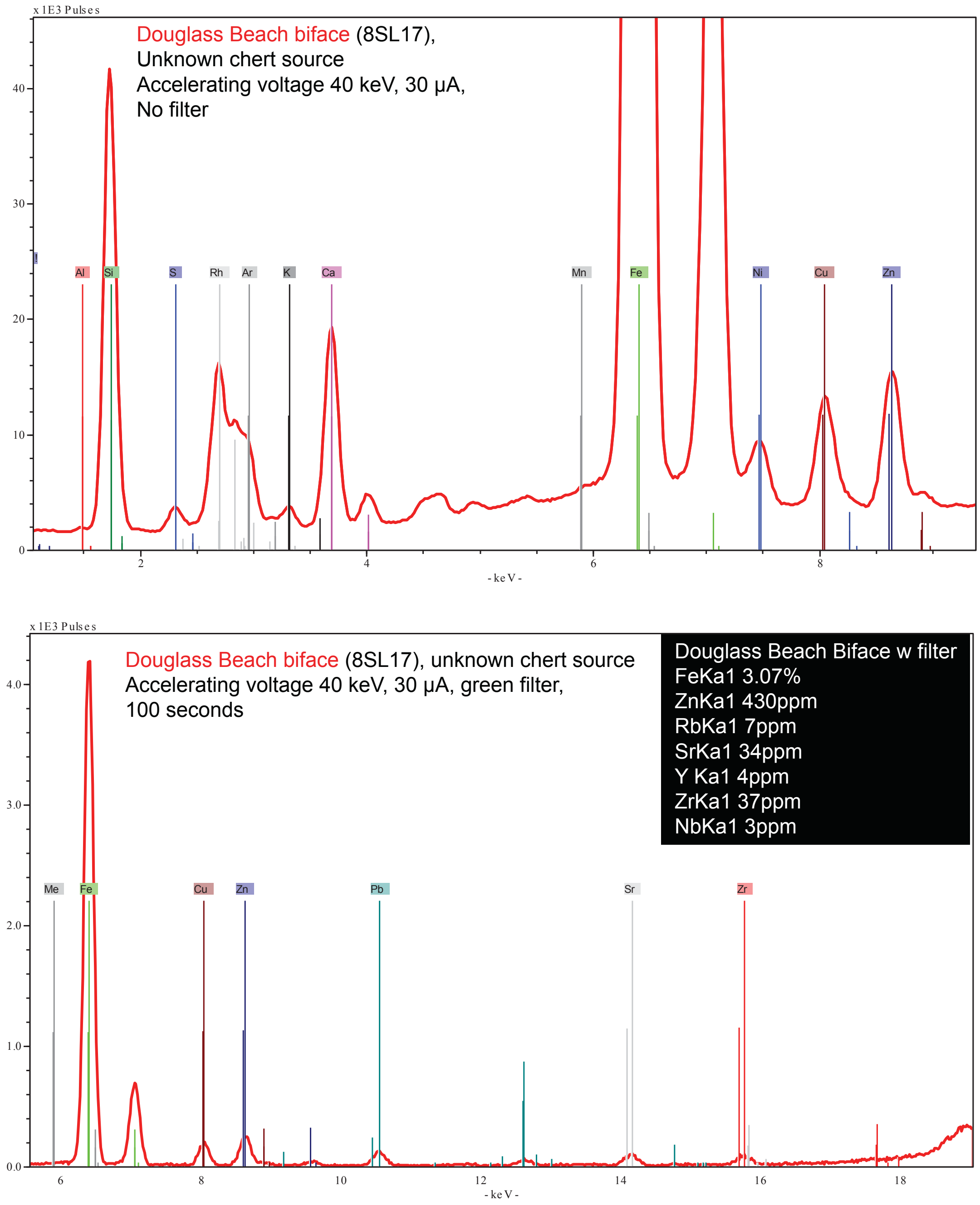

Figure 4.2: XRF spectra, filtered and unfiltered, Douglass Beach biface

Discussion

The results are useful for understanding post-depositional site formation processes, assessing these items as artifacts or not, and inferring prehistoric uses of each lithic landscape. I will first assess the relative effectiveness and limitations of each technique and recommend their best uses. I will then explore sample and corrosion compositions, and discuss how these results inform assessment of these items as potential artifacts. Finally, I will expand the discussion to how these findings can add detail to the lithic landscapes within which these samples were recovered.

Effectiveness of the analyses

Of all of the geochemical analysis methods, EMPA was most successful, because it rendered the highest level of mineralogical detail in the Ray Hole Springs samples. SEM also rendered a mineralogical detail but not to the same degree as EMPA. It was particularly impeded by the whole sample analysis of the Douglass Beach biface. The chert composition for the sample was clear. However, using the whole sample lowered the resolution of mineralogical detail, and the composition of the corrosion boundary could not be detected. The Zeiss SEM uses lower accelerating voltages (10 KeV in this study), making detection of lighter elements and mineral inclusions within the sample matrices more difficult.

XRF used an accelerating voltage of 40 KeV, increasing resolution for trace components, but like SEM, without resolving individual mineral inclusions. XRD was useful for confirming the general composition of the Ray Hole Springs samples but did not supply data on mineral inclusions. The lack of detail resulted from the use of thin section mounts rather than random powder mounts. Future analyses could test the use of random powder mounts for XRD analysis. This would allow XRD to detect mineral inclusions in addition to detecting overall sample composition.

XRD and SEM will require destructive techniques to approach the effectiveness of EMPA analysis. XRD has potential for resolving finer mineralogical details if random powder mounts are used. SEM analysis is most effective when using thin sections, which are also destructive. XRF appears to be least suitable for analyzing corrosion, but is a reasonable method for non-destructive analysis of overall sample composition. These limitations constitute a challenge for non-destructive analysis of corrosion surfaces in lithic items.

Composition

EMPA, SEM, and XRD showed that the three of the four samples possible artifacts tested from Ray Hole Springs were dolomite or dolomitized siliceous material (referred to as dolomitized hereafter), and one was chert. The probable biface was not tested by instrumental analysis but is identical in all aspects of its appearance to the confirmed dolomitized items. This suggests it, too, is most likely dolomitized, or chert. This suggests the possibility that these items are derived from local materials. Ray Hole Springs is located within the Wacissa chert quarry cluster, which has been heavily used since the Paleoindian period and the chert flake in this assemblage is consistent with this chert type (Austin et al. 2014; Burke, personal communication, 2015; Endonino 2007). The site itself has dolomitized outcrops. Debitage recovered from analogous inland sites is usually, but not always, local material. Given the regional tendency to use local materials, the dolomitized samples were probably derived from local materials, although this cannot be proven.

This is of interest because chert was the favored material for chipped stone tools regionally, although non-chert lithics are also known to have been used throughout prehistoric both within and outside of Florida, including dolomitized siliceous materials rated good to very good quality once knapped (Austin et al. 2014; Endonino 2007; Nami 2015; Upchurch et al. 1982:132, Table 1). The high priority prehistoric people placed on this material is evident when comparing the composition of the Douglass Beach biface to these. Previous studies have argued that the source material for the Douglass Beach biface is chert from the Hillsborough River quarry cluster in the Tampa Bay area (Austin et al. 2014) and it is clearly not local to the area in which it was found, where no chert is available. Moreover, no chert outcrops have been found in this area of the Atlantic Coast or offshore. This biface was clearly crafted from materials brought from elsewhere, instead of local materials, as may have been the case for the Ray Hole Springs samples.

Corrosion as proxies for depositional environments and marine transgression

Post-depositional processes can be inferred from chemical corrosion. Chemical corrosion changes the structure or color of the item, either by changing the minerals themselves or removing or adding minerals in the item. Specific types of geochemical corrosion require specific environmental conditions, such as higher pH levels, or the presence of abundant organic materials within sediments surrounding an artifact. Coloration of an item and mineralogical composition are the primary indicators for what types of geochemical corrosion may have affected an artifact or geofacts.

Three of the Ray Hole Springs samples were dark grey to black, and two samples had chalky white exteriors. These surface colorations are common in lithic items recovered from submerged marine contexts and have been widely observed in artifacts recovered in Apalachee Bay (Anuskiewicz and Dunbar 1993:7–8; Faught and Donoghue 1997:449–450). Assemblages from the Chesapeake Bay area and from off the Georgia Coast also display black color (Garrison et al. 2016; Lowery and Wagner 2012).

The dark gray to black corrosion typically occurs when lithics are deposited in an anoxic environment with abundant sulfates and organic materials and is known as sulfidization. Sulfide minerals form when elements in artifacts and surrounding sediments, such as iron or manganese, are converted from oxide to sulfide form. Pyrite microcrystals only a few microns wide are most common, giving the artifacts their black surface color. The most likely depositional environment within which this can occur is a tidal marsh (Lowery and Wagner 2012:693).

The white chalky corrosion forms when artifacts already corroded by sulfides are re-exposed to aerobic conditions, and the sulfide minerals began to oxidize. This reaction creates iron oxide minerals such as goethite when fully oxidized, or rozenite when partially oxidized. Rozenite in particular imparts a chalky corrosion (Lowery and Wagner, 2012:693-694). An additional byproduct of this second reaction is sulfuric acid production. Presumably it is this byproduct that is most destructive to a lithic item. Recognition of a sample as an artifact can be very difficult once this type of corrosion occurs (Garrison, et al., 2016; Lowery and Wagner, 2012).

These corrosion processes are most likely to happen to lithic artifacts deposited in a terrestrial environment that becomes a tidal marsh during marine transgression, or in lithic artifacts deposited into an area that is already a coastal tidal marsh. Either case implies that the artifact was in use in a terrestrial or coastal context, not offshore. An alternate hypothesis is that lithics were dropped from a boat, landed in a relic now-submerged marsh mud, buried, sulfidized, and then oxidized. However, during marine transgression, erosion tends to remove most, if not all, of the terrestrial soils and sediments, including the organic materials necessary to drive these geochemical changes (Hine et al. 1988:577–578; Nichols 2009:359–360). Tidal marshes are especially vulnerable to destruction during marine transgression (Kirwan and Megonigal 2013:54). This argues against items such as these having been simply dropped from a boat, because these sediments are highly unlikely to still exist on the surface of the continental shelf once marine conditions have been established.[5]

The de-dolomitization, in the corrosion patterns are also suggestive. Exposure to meteoric freshwater such as a spring is the most likely source for this de-dolomitization (Nader et al. 2008:1484; Rameil 2008:82–83). A flowing sinkhole such as Ray Hole Springs provides that environment, so de-dolomitization alone only means that these items were exposed to freshwater flow at some time, even after submergence. When considered along with corrosion created by tidal marsh conditions, however, it suggests that these geochemical changes are more likely to have occurred within water changing from fresh to fully saline. Deposition in a terrestrial environment that was converted to tidal marsh and then to an open marine environment is the best means by expose lithics to these conditions.

XRF and SEM were less useful for assessing depositional environments for the Douglass Beach biface. Pyrite was indicated by elemental signatures seen in the SEM

[5] In fact, I would go further, and argue that any association of artifacts with maritime activities should be only be argued for in association with direct archaeological evidence for watercraft at a submerged site, and not as a means to falsify an argument that the deposit was originally terrestrial.

results but was not directly visible. A weak sulfur peak was generated during XRF analysis but was eliminated when a filter reducing the weakest signals was applied. This suggests that the Douglass Beach biface may have experienced exposure to post-deposition brackish tidal marsh conditions, but that any sulfide minerals that formed were less abundant than those in the Ray Hole Springs assemblage. They may also have been eroded away by mechanical weathering. This also demonstrates that SEM and XRF were not as useful for identifying specific minerals in whole samples.

These findings also suggest that post-depositional changes may involve both chemical corrosion and mechanical weathering, making teasing out the evidence for the chemical weathering difficult. Nevertheless, the non-local chert source material, which is not found in this area, and the combination of possible sulfidization with mechanical weathering argue that this item was more likely deposited at the site when it was still terrestrial.

Artifacts or not?

The primary goal of this study is to falsify a hypothesis that corroded lithics are natural rock, not artifacts. This can be shown by either demonstrating that the lithic items were made of non-local materials, or that alternate evidence for human modification of local material exists. We know from the Douglass Beach biface that artifacts can be identified when traditional indicators are missing, because it clearly lacks flake scars. If we reject all items lacking flake scars and other indicators, then we must reject the Douglass Beach biface. This raises the question of how much corrosion must be present to render an artifact unidentifiable as such. The Ray Hole Springs assemblage is an excellent example of moderate to severe corrosion. What criteria can be used for identification of corroded artifacts are this equivocal?

Prior studies on lithics from submerged sites have demonstrated that corroded lithics were anthropogenic by showing that they were made of non-local materials requiring human modification and transport. Other have detailed corrosion to demonstrate that items in question were deposited in terrestrial contexts that were only later submerged (Garrison et al. 2016; Lowery and Wagner 2012; Marks 2006:45–51). For this study, we use both approaches along with additional considerations of local weathering patterns and known regional artifact types to create a holistic method for assessing corroded lithics.

These multiple lines of evidence allow us to evaluate human activities that created relationships between locations, raw materials, finished products, and anything associated with their use and discard; Schiffer terms these processes “transformations” reflecting both behaviors and taphonomy (Schiffer 1976). Source material can suggest movement of people or materials, or raw material preferences. Corrosion patterns help reconstruct post-depositional processes at sites. Hand sample analysis places these items into known cultural patterns. An understanding of regional bedrock suggests what non-artifacts should look like. All of these lines of evidence can suggest whether or not these samples can, in fact, be treated as artifacts and not geofacts.

In essence, we must disentangle features of natural processes (primarily corrosion and weathering) from features of human agency. The first criterion is that the item has the unmistakable shape of an artifact. Sometimes the criterion is easy to meet, like the Douglass Beach biface. Fragments such as a broken base, blade, or working edges are more ambiguous. For ambiguous items, we must determine first whether local weathering processes, such as freeze-thaw cycles or colluvial episodes, could fragment local bedrock into similar forms. Second, we should look for general aspects of the items that would indicate human agency, such as object symmetry, cross-sections typical of artifacts, possible obscured flake scars, or striking platforms, while keeping in mind these aspects may be obscured through corrosion. Third, we must identify positive evidence that an item is consistent with known forms that humans used to create tools. For example, if an item is spherical, then it is less likely to be a flake than one that is flat with a slight curve.

This analysis is one of accumulating evidence. Bifaces possess a base that can take a number of known forms (concave, bifurcate, stemmed), the blade, and a distinctive cross section. Likewise, unifacial tools have distinct working edges. Any one of these basic features could hypothetically result from natural processes, but that becomes less likely if an item contains two or three. If the basic features can be described in even greater detail such as type of shoulder or base, then the probability that the item is naturally formed is reduced even further. The more formal the finish of the tool, the better the potential. Finally, the presence of multiple items sharing multiple similar morphological aspects in a natural assemblage is also unlikely, and recovery of an equivocal item at a known site also increases the odds it may be human modified. A holistic assessment takes both individual items and the entire assemblage into account before arguing that lithics are anthropogenic, not natural.

If typical diagnostic features such as flake scarring are not present, I propose the following criteria for evaluating whether a corroded lithic item recovered from a submerged site is an artifact:

1. Recovery from an environment where mechanical weathering is unlikely to fragment local outcrops in sizes and shapes similar to artifacts;
2. Corrosion layers observed in this study;
3. Recovery from an undisturbed context within clearly terrestrial sediments;
4. The presence of two or more general features consistent with an artifact (discernible edge, basal shape, or cross section);
5. Correlation with an artifact type or form consistent with the estimated or potential age of the site.
6. Recovery of the item from a location that is already accepted as an archaeological site.
7. Rock type not local to the local lithic landscape.

To apply these criteria to the Ray Hole Springs assemblage, we start by with the geological context first. The karst terrain of the Big Bend is more susceptible to chemical weathering than mechanical (Faught and Donoghue 1997; Hine et al. 1988; Marks 2006:79–90; Upchurch 2007). This is not consistent with the shapes in the Ray Hole Springs assemblage, and satisfies criterion 1. The items shown in Figure 4.3 from the Ray Hole Springs assemblage also show features consistent with components of tools. Unifacial-type items are symmetrical and possess clear edges. One hypothetical biface possesses a well enough preserved stemmed base and blade edge to be positively compared with terminal Early Archaic to Middle Archaic stemmed point types. This suggests deposition between 11,400 and 8,600 cal BP, in good agreement with radiocarbon dates for the site. One flake is accepted as anthropogenic, indicating that human activities are this location did occur. These observations along with the geochemical corrosion of the assemblage satisfy criteria 2-6. Thus, I argue that these samples should be treated as artifacts, not geological samples. These are shown in Figure 4.3 with the Douglass Beach biface.

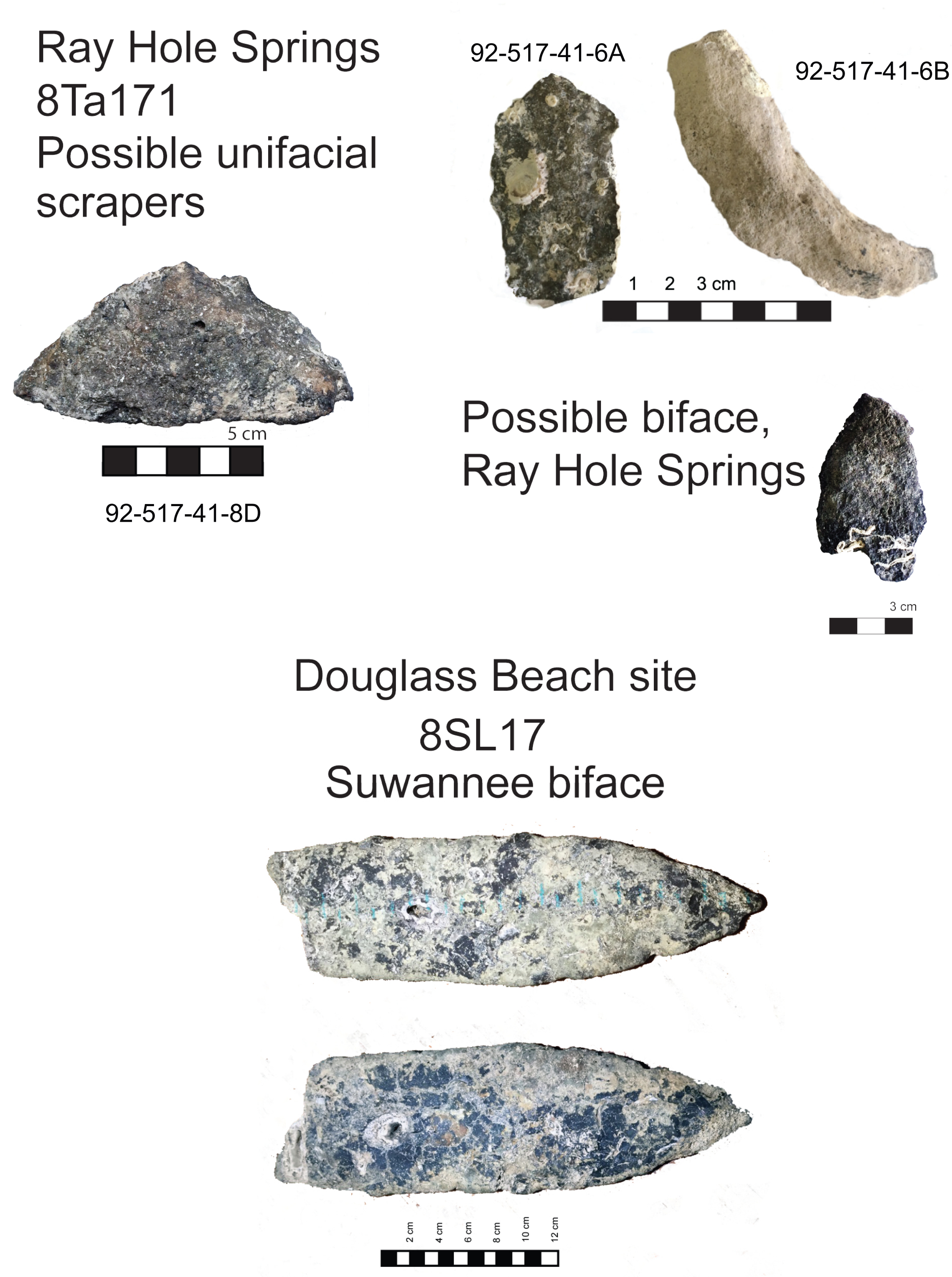

Figure 4.3: Hand sample images of all artifacts that meet criteria for consideration

The samples and the regional lithic landscape

The final goal of this study is to place the samples into their respective lithic landscapes. The Douglass Beach biface was made of non-local material, probably from a chert quarry near Tampa. This means either people, raw material, or both moved over 200 km from the Tampa area to Douglass Beach. In contrast, the Ray Hole Springs assemblage contained local chert and dolomitized artifacts, indicating its occupants lived in a more constrained landscape. The use of dolomitized material as a tool stone when chert is available is uncommon for assemblages from this area and unexpected (Austin et al. 2014:6–8; Dunbar, personal communication, 2015; Endonino 2007:88; Hemmings, personal communication, 2015). The use of non-chert material for tool manufacture has been interpreted for as evidence of lack of access to higher quality chert resources (e.g., Austin et al. 2014:6; Sassaman et al. 1988), but that is not the case here. The presence of dolomitized tools requires a rethinking of this particular lithic landscape.

It is fair to say that the use of non-local versus local tool stone resources within this lithic landscape is not straightforward. Perhaps proximity to chert alone is not a controlling variable. Perhaps dolomitized material was a good enough raw material for some tools. The answers are not obvious, and some may never be archaeologically visible, but the data raise interesting questions of human choices and behaviors that require our attention.

Conclusions

Corroded and weathered stone items are often ignored by archaeologists or assumed to be geological samples. I show in this chapter how elemental and mineralogical analyses can reveal previously hidden and valuable information. The presence of certain types of corrosion such as those documented here argue that the lithics containing them were deposited in a terrestrial context, not merely dropped from a boat. Instrumental analysis such as the techniques used here also indicate rock type, which can indicate if a lithic is made of a material local to the find location or not; in cases where a lithic item is made from an exotic material these analyses can demonstrate human intervention in conveying the item to the find location. In both cases, the instrumental analyses collect data that would otherwise be missed by simple visual analysis. Thus, even corroded lithics from submerged prehistoric sites are potentially useful for articulating human occupations in lithic landscapes, and they can retain the geochemical signatures left behind as the surrounding sediments transition from upland, to tidal marsh, and finally to open marine waters. Mechanical weathering can also degrade diagnostic flake scars, and even remove a sulfide overprint created by deposition within tidal marsh. For these items to be productively interpreted as artifacts studies must overcome the degradation caused by these weathering patterns and corrosion. Instead, a more holistic analysis can be made based on the presence and types of weathering patterns, a match to a known artifact type or form, and/or non-local rock type. Only once these criteria have been satisfied is it possible to place these items within the lithic landscape.

Ray Hole Springs' lithic assemblage was severely corroded. However, a date of 7,500 cal BP for submergence along with application of the holistic analysis described above suggests that at least some of these items were intentionally manufactured by Early to Middle Archaic period groups who elected to use possibly local dolomitized outcrops, despite easy access to high grade chert nearby. In this case, the lithics may indicate a nonstraightforward relationship between local resource availability versus specific rock type. The Douglass Beach biface is more in line with our understanding of Paleoindian rock type preferences, as well as supporting arguments for high levels of mobility.

These findings encourage further inquiry into mobility and resource exploitation along the drowned continental shelves of both the Atlantic and Gulf coasts of Florida from the Paleoindian period through the Middle Archaic. Whereas it is impossible to directly infer mobility patterns at Ray Hole Springs solely based on the source materials, it is critical to consider how human choices might have differed from the practices of inland groups during periods of lowered sea levels and rapidly changing ecologies. Simply extending trends from terrestrial sites is insufficient for contextualizing human behaviors into drowned landscapes, even as lithics analysis must move beyond current models to contend with different taphonomic processes within these submerged landscapes.

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CHAPTER 5 : WHAT’S PAST IS PROLOGUE

Introduction

Since 2014, I have engaged in a focused study of one prehistoric site within Apalachee Bay, Florida, with the overarching goal of pushing beyond asking where submerged offshore prehistoric sites lie, to asking anthropologically focused questions. I am specifically concerned with the nature of coastal occupations during periods prior to the establishment of the modern coastline. (Erlandson and Fitzpatrick 2006; Grøn 2006, 2007, Reitz 1988, 2014; Turck 2010; Thompson and Turck 2009; Thompson and Worth 2011). Understanding these occupations is a critical component to understanding the human foraging and mobility patterns in deep time, and coastal occupations are particularly poorly understood within submerged landscapes. Multiple coastal groups clearly developed complex foraging economies with minimal mobility around the period when modern sea levels were first established, but the earliest evidence for this development in human behaviors probably lies submerged offshore (Anderson and Faught 1998; Bailey and Flemming 2008; Bailey and Milner 2002; Bailey 2014; Cunliffe 2001, 2011; Dixon 2013; Erlandson and Fitzpatrick 2006; Faught 2004a, 2004b; Faught and Donoghue 1997; Garrison et al. 2012, 2016; Habu 2004; Thompson and Worth 2011).

The Southeast United States is one such area where coastlines saw the establishment of complex foraging by 5,000 cal BP. Much of the research into complex coastal foragers has focused on the Atlantic coastline of Georgia, but evidence for specifically coastal occupation patterns extending back in time to preceding periods is scant (Andrus and Thompson 2012; Reitz 1988, 2014; Russo 1994; Thomas 2008, 2014; Thompson and Andrus 2011; Turck 2010, 2012, Williams 1994, 2000). However, there is evidence for precursor coastal occupations prior to 5,000 cal BP along the northern Gulf of Mexico, suggesting the possibility for even earlier coastal traditions given the antiquity of human occupation in this region (Dunbar 1988; Dunbar et al. 1989; Dunbar 2006a, 2012; Faught 1988; Faught and Donoghue 1997; Faught 2004a, 2004b; Halligan et al. 2016; Mikell and Saunders 2007; Saunders et al. 2009; Saunders 2010; Saunders and Russo 2011). A large body of work has already been focused on the earliest occupations of the northern Gulf, specifically within the Big Bend region of Apalachee Bay, and has been highly successful. However, it has also primarily been focused on upland, not coastal occupation patterns. This is true for offshore sites as well as the submerged inland sites such as Page Ladson. The nature of coastal sites from periods earlier than the late Middle Archaic currently remain opaque. My study has been designed to address this gap.

First I will review general regional site types to provide context. These site types offer some general insight into human activities during the periods prior to the establishment of roughly modern relative sea levels, around 5,000 cal BP. These types suggest potential site types in now-submerged regional landscapes. Then I will review a body of literature useful for interpreting these site types within changing paleoenvironmental, geomorphological, and cultural contexts. I will then go on to discuss how both regional site types and general contexts provide insight into changes in site use through time within the submerged landscapes of Apalachee Bay.

Potential Site types

Florida is home to some of the oldest sites in North America, and the Big Bend itself has a high density of prehistoric archaeological sites from the Pre-Clovis period forward (Anuskiewicz and Dunbar, 1993; Anuskiewicz, 1988; Dunbar, 1988; Faught and Donoghue, 1997; Faught and Donoghue, 1997, p. 421; Faught, 2004a, 2004b; Halligan et al., 2016). Generally, site types for all periods under study can be characterized as occupation areas, resource extraction locations (e.g., *sensu* Binford 1980), and ritually oriented sites. The Pleistocene-Holocene transition during which these cultural periods flourished was a time of significant change in human and general ecology in Florida, however, resulting in different site patterning, and possible population relocations (Anderson 2001:156–160; Dunbar 2016; Ellis et al. 1998; Faught and Carter 1998; Faught and Waggoner 2012). The archaeological record reflects these changes through time.

Sinkhole sites such as Page Ladson (8JE00591A) are some of the oldest types of occupation sites in Florida and are particularly concentrated in the Big Bend. These were used by Paleoindian groups during the Pleistocene and remained in use during the often-unstable Early Holocene climate. They appear to represent good examples of occupation surfaces during periods when lowered water tables reduced access to water (Dunbar 2016; Halligan et al. 2016).

The most obvious resource extraction sites were chert quarrying locations. These can be found virtually wherever outcrops are found, including within Apalachee Bay, where they were specifically targeted for archaeological survey (Dunbar 1988; Dunbar et al. 1989). Outcrops are not uniformly distributed across the landscape, however, because they are controlled by bedrock geology (Endonino 2007:77–78; Upchurch et al. 1982). Their occurrence in Apalachee Bay indicates that relative sea level also controlled access to these locations, as is the case elsewhere in Florida (Upchurch et al. 1982; Austin et al. 2014).

Ritually oriented sites are less visible for the Paleoindian period, but pond mortuary sites such as Warm Mineral Springs were in use by the Early to Middle Archaic (Anderson 2001:160; Royal and Clark 1960:295). By the end of the Middle Archaic, more sites of this type such as Bay West, Republic Groves, Tick Island, and Windover become archaeologically visible (Wentz and Gifford 2007:332). A wooden stake dating to the Middle Archaic is known from Douglass Beach, suggesting the possibility of this site type here during this period (Murphy 1990), and in late 2015, a submerged pond burial site was detected off Venice Beach, Florida, on the west coast south of Tampa, indicating that this site type predates the arrival of the modern shoreline, around 5000 cal BP (Ryan Duggins, 2015, personal communication).

Along the Atlantic shoreline, sites such as Vero and Douglass Beach are less understood, but may represent visits to this coastline by Paleoindian and Archaic groups from further afield. This coastline is particularly lithics poor, and the appearance of exotic lithics in these locations indicates movement of people or goods across significant distances. Human burials also cannot be ruled out for the Paleoindian and Early Archaic periods, suggesting possible ritual sites along this coastline (Cockrell and Murphy 1978; Cook Hale, in prep; Hemmings et al. 2015; Murphy 1990).

By the end of the Middle Archaic period, shell mound sites appear along the coastline and the St. John’s River valley along with evidence suggestive of increasing sedentism (Russo et al. 1992; Tomczak and Powell 2003; Tuross et al. 1994). The earliest examples do not appear to contain burials or show other evidence for ritual activities, and instead appear to represent pure extraction sites where riverine, estuarine, and marine resources were processed for consumption (Mikell and Saunders 2007; Randall 2013; Randall et al. 2014; Russo 1988; Russo et al. 1992; Saunders et al. 2009; Saunders 2010; Saunders and Russo 2011). By the Late Archaic, however, these sites took on ritual aspects, and it is an open question as to whether earlier sites with similar uses lie offshore (Russo 1994).

The changes over time for these varied sites suggest a continuous, but variable, human relationship to the Pleistocene and Holocene landscapes (c.f. Faught and Waggoner, 2012, however). Generally, as sea levels and water tables rose, some sites became unavailable for use while others became more attractive. Many of the human remains recovered at Warm Mineral Springs date to the Early Archaic, while at Little Salt Spring, younger Middle Archaic burials are documented within a slough draining into the sinkhole as well as the sink itself (Royal and Clark 1960:286; Wentz and Gifford 2007:330). Paleoindian and Early Archaic sinkhole sites along the Aucilla River were likewise abandoned as sea level rose (Dunbar 2016; Halligan 2012:272). Shell mounds and pond mortuary sites may have become more archaeologically visible by the Middle Archaic when relative sea levels approached the modern coastline, they should not be ruled out for earlier periods along older coastlines (Russo 1988, 1994). In sum, site usage and placement may be tied to geomorphology as well as to cultural values. It is this interplay that this study explores within the submerged landscape of Apalachee Bay.

Theoretical framework

The goal for this study is to answer two questions: first, what activities are evident within these sites; and second, how do these compare to extant studies of human landscape interaction regionally? I use a synthetic methodology that combines geoarchaeology, behavioral ecology and behavioral archaeology. Geoarchaeology provides the framework to discern natural processes from anthropogenic ones and to place the material remains within cultural deposits into their environmental contexts. Behavioral ecology suggests how human groups might have articulated with their surrounding landscape and its assorted resources, and behavioral archaeology contextualizes the activities inferred from archaeological deposits within their cultural contexts. Thus, I base my assessments of human/environmental interaction upon the range of what was possible in the larger environmental context. Models such as Binford's differentiate between site types based on the number and types of inferred activities visible in the archaeological record, while later work has refined the means by which we might infer mobility, technological organization and subsistence choices (e.g., Andrefsky 1994, 2009, Binford 1980, 2001; Bird and Bleige Bird 1997; Bird et al. 2002; Kelly 1992, 1995; Bird and O'Connell 2006; MacDonald 2009; Reitz 1982, 2004, 2014, Thomas 2008, 2014).

To infer the suite of activities evident at sites, I propose to synthesize features and artifacts found at these sites using the concept of the assemblage at multiple spatial and temporal scales (Binford 1980; Schiffer 1976, 1972, 1996:644-645-648). Collections of features and artifacts constitute the archaeological assemblage (Shott 2010). Recent discourse has argued that this concept is most useful when understood as existing along gradients, not as rigid categories with discrete distributions in time and space. Ecological measures best capture this non-essentialist approach to assemblage analysis (Shott 2010:889). This approach understands that the accumulation of material cultural items in the archaeological record is a better proxy for time depth of occupation and number of activities at a site and will better help us to assess changes in human activities as environmental and cultural contexts change. These contextual changes also exist along a continuum, not as discrete episodes, and we should expect human activities to mirror this.

I will first assess the archaeological landscape of Apalachee Bay using number and type of activities represented by their assemblages within the context of the local ecology, spatially and temporally, interweaving these interpretative methods. For example, what types of lithic activities occurred, and what other activities are found nearby? Where was the shoreline during the period for which we have absolute or relative dates for each activity/site? Was the climate humid or arid, and what effect did this have on water resources? The link between landscape use and human use of resources within it has been explored before for the onshore sites in the Big Bend (Dunbar 2016:183, Table 5.1). This synthesis examines the interplay between general climatic conditions, physiographic features within the karst landscape, water availability, lithic resource availability, and faunal types within upland, wetland, and aquatic contexts. Using this matrix, it is possible to form and test hypotheses about what sort of human activities and resource usage patterns may be evident at a given site, depending on archaeological visibility and sampling methods. This analysis can, and should be, extrapolated into the offshore zone using a careful examination of site components and assemblages.

Methods and materials

For this study, I synthesize findings from recent preliminary work to place coastal occupations within Apalachee Bay within their surrounding landscape contexts. My overall goal is to explore the questions raised by differences between the Econfina Channel site (8TA129) and four other Apalachee Bay sites: J&J Hunt (8JE00740), Ontolo (8JE01577), and Fitch (8JE00739). How do these differences shed light on changing landscape use from the Paleoindian period into the Middle Archaic? Where does coastal resource exploitation fit into this picture?

Local prediction models for submerged offshore sites in the Big Bend extrapolated onshore site patterns that correlated archaeological remains to sinkhole features and high quality chert outcrops (Faught and Donoghue 1997; Faught 1988). The Econfina Channel site (8TA129) was one of the first sites within Apalachee Bay to be located using this model, but did not entirely conform to the model, which assumed upland, not coastal occupations; it lacked an obvious sinkhole feature. Furthermore, while archaeological sites in the Aucilla watershed generally show continuity from Paleoindian period into the Middle Archaic, the Econfina Channel site contains later cultural components: The Middle Archaic and Late Archaic (Faught 2004a, 2004b; Faught and Donoghue 1997). It does, however, show abundant use of coastal resources, suggesting a coastally adapted occupation of some type, possibly confined to the Middle Archaic period only.

Clearly, the predictive model for sites required adjustment given these differences. Models predicated only on geomorphological features fail to capture cultural choices not directly tied to environmental conditions, while models that simply extend cultural patterns into the offshore zone fail to capture the effects of environmental change on human-landscape interactions. An approach that can assess both environmental and cultural change through time and space is required.

In a preliminary study, then, I updated the predictive model to incorporate ecological and cultural change through time by using spatial statistical methods. To do this I used Geographic Information Systems (GIS) to examine patterns for site selection for both upland and coastal sites from both periods. In doing so, I confirmed that predictive variables for site occurrence are not suitable for linear regression models that statistically establish causality. There are multiple possible explanations for this: sites were used for different purposes; the landscape changed through time; cultural values shifted; and thus, site locations shifted accordingly. Instead, the best predictor for Early Archaic sites was not simply proximity to springs, or chert; It was one specific watershed, the Aucilla River. There is no strictly environmental reason why this watershed should have been preferred, suggesting that cultural associations within the overall landscape played a role. This effect weakened in the Middle Archaic, and quantifiable distinctions can then be made between upland sites oriented around watersheds, and sites oriented along the coastline itself. This may suggest establishment of seasonal mobility patterns between the coast and the uplands or an entirely different set of subsistence practices and cultural organizations: one that was focused on the coast, and the other that was focused on the upland areas.

My larger point is that predictive models for different occupation types during different time periods must incorporate both environmental and cultural variables, and those variables must be tested using rigorous quantitative methods to demonstrate their validity. The updated predictive model suggested that there is substantial use of coastal sites during the Middle Archaic, thought this may be visible because the coastline was closer to the modern position by this point. Further, these coastal occupation patterns did not replicate upland patterns. It also suggested that coastal occupations were possible during earlier periods and are also unlikely to replicate trends from upland zones. The next step was to test one specific site for evidence of this. I chose the Econfina Channel site because it showed no signs of occupation before the Middle Archaic, and because it had evidence for use of coastal resources. By examining a site more representative of Middle Archaic and later development, I intended to delineate similarities and differences in human activities between Econfina Channel and nearby sites with older components such as J&J Hunt, Ontolo, and Fitch.

Step two: excavation at a known site with evidence for coastal resource use

Econfina Channel site contains multiple features: midden, a quarry, and a freshwater spring. Evidence for all stages of lithic reduction were found within various areas of the site; primary reduction remains were found in the quarry area, while finishing flakes and breakage debitage were recovered from the midden area. Work there focused on mapping the site, excavating obvious activity areas, and bulk sediment sample to determine the extent and nature of additional human activities and post depositional changes. I describe these results in Chapter 3. To recap, the study recovered evidence for primary and some secondary lithic reduction around the seep/spring feature, ~50 WNW of the midden, and within the quarry zone surrounding the midden itself. Within the midden excavations recovered smaller flakes more characteristic for finishing sequences, retouch, and breakage during use. Excavations also recovered five tools, mostly unifacial scrapers, but no diagnostic bifaces.

Overall, the findings demonstrate a site type quite different from Page Ladson inland, or J&J Hunt offshore. Instead of a sinkhole or chert quarry site, we have a consistent set of the components common in Middle and Late Archaic coastal sites onshore: fresh water, either in the form of a spring or a fluvial channel and coastal/estuarine food remains. These features are more akin to sites such as Mitchell River, west of Apalachee Bay, which was first used during the Middle Archaic (Mikell and Saunders 2007:172–174). The chert quarry component at Econfina Channel may or may not have been exploited prior to the Middle Archaic, but the coastal resources used there were clearly deposited there during this period, and possibly later. These findings supported the updated predictive model and argue for extending Late and Middle Archaic patterns for coastal resource use into the offshore zone.

Step three: post-depositional processes

Finally, it is necessary to assess post-depositional processes typical for sites in this region. One must account for sedimentological and geochemical changes in both the sediment matrix and the material remains contained therein. To do this, I relied on two different geoarchaeological methods. First, I used bulk sediment analyses to determine how which depositional environments and/or activity areas may exist at the Econfina Channel site. Second, I conducted scanning electron microscopy (SEM), x-ray diffraction (XRD), and electron microprobe analysis (EMPA) on corrosion surfaces in lithics from several submerged sites from Apalachee Bay and the Atlantic coastline of Florida.

Together, these studies have quantified how these sites, and the artifacts contained within, can be affected by submergence.

For the sediment study, I treated these sediments as hybrid sedimentary deposit affected by natural and anthropogenic forces. Signatures for anthropogenic activities include materials that can only be deposited by humans; these include burned bone, shell, charcoal, lithic debris, and in some cases (though not in our study), ceramics (Gagliano et al. 1982; Murphy 1990). Signatures for non-anthropogenic processes include evidence for changes such as deflation of finer particle sizes or erosion and re-deposition of lag deposits. Analyses therefore sought to not only detect human activity areas, but also to draw distinctions between natural depositional areas within the site.

I successfully distinguished both depositional zones and activity areas using particle size analysis and the distribution of inclusions. The findings indicated three different depositional zones: the eel grass area south of the midden, the midden/quarry, and the paleochannel. The eel grass zone remains distinct, and has apparently undergone less post-depositional erosion than quarry/midden zones. However, I could not completely distinguish between midden versus quarry sediments. Either post-depositional fluvial and marine processes have conflated the midden and quarry zone sediments, or these areas graded into one another during initial deposition.

Activity areas can still be detected, however. Shell alone does not correlate with any other sediment component, and is most abundant in locations around the midden zone itself. The shell is all disarticulated within the midden zone, as well, and the presence of lithics along with invertebrate taxa from marine, estuarine, and freshwater taxa within the midden zones argues that this is an anthropogenic deposit, not a natural one. Primary reduction debitage is only found within the quarry zone and the seep/spring feature, and not in the midden. The possible refit of a blade core from the seep/spring area to a blade tool found on the midden adds a spatial dimension to these findings, and supports an argument that the midden and quarry were used contemporaneously.

These findings parallel Murphy's at the Douglass Beach site (8SL17) (Murphy 1990), that individual components within the sediments are better suited to delineating intrasite areas, while the totality of components distinguishes the site from non-anthropogenic sediments. In this case, shell, macro-debitage, and smaller debitage are the individual components separating the intrasite zones, while taken together they support the argument that these sediments are anthropogenic.

I also studied the effects of submergence on lithic items from several different sites off the coastlines of Florida. Multiple lithic items were recovered from Ray Hole Springs, a site that was submerged around 7,500 cal BP, but could not be securely identified as artifacts because corrosion had removed key diagnostic characteristics for human modifications, such as flake scars. Some still retained the general shapes of tool types known from Florida, however. For comparison, I included a Paleoindian projectile point that showed signs of the same corrosion, but less severely.

I analyzed all items for a form of corrosion previously documented in lithics from other submerged sites along the Eastern seaboard of the U.S. This form of corrosion, dubbed sulfidization, is diagnostic for lithics deposited in locations that transitioned from terrestrial to marsh (Garrison et al. 2016; Lowery and Wagner 2012). I then advanced an argument that corroded items such as these can still be assessed as tools provided they meet the following criteria for human modification: they must show geochemical evidence for this form of corrosion; they must be consistent with a type; and they must show more than one morphological characteristic for this type. It is also helpful if the tool is made from a non-local material, but not required.

In the case of the Ray Hole Springs assemblage, several items met the first three criteria, but turned out to be made of a non-typical material, possibly local; they were crafted from high grade dolomitized material, not chert. This finding raises questions about how prehistoric human groups in this landscape chose their raw lithic materials, because high grade chert is plentiful in this region. I suggest that this may indicate a preference for local, "good enough" raw material, over a specific type. Without coming to grips with the effects of post-depositional corrosion, we would lack this insight into the lithic landscape of Apalachee Bay.

Both geoarchaeological studies now provide a foundation for assessment of the sites of Apalachee Bay within their wider contexts. Understanding how to differentiate between artifacts, features, and assemblages within these sites, and post depositional processes that have disturbed these anthropogenic signatures, provides an appropriately conservative baseline for both aspects of these sites. Accounting for post-depositional processes in lithics, modifying our criteria for lithic analysis accordingly, and using these updated criteria to understand the local lithic landscape, allows us to understand this specific facet of human niche construction in this region.

Step four: synthesis of our study results with earlier studies

I will bring these threads together by presenting a synthesis of the results from Econfina Channel, existing Florida Bureau of Archaeological Research inventories, and extant published and unpublished literature. This synthesis examines these four sites using lithic analyses, faunal remains, activity areas, stratigraphy, radiometric dates, and proximity to the shoreline as the coastline encroached towards its modern position. I do this with the knowledge that the available data are tentative, incomplete, and as representative of archaeological sampling and differential preservation as they are of human activities in prehistory. Despite these limitations, I assert that this is necessary to move debate about human behaviors in now-drowned landscapes beyond the exploratory stage and to ask anthropological questions about human adaptations to non-analog ecological periods such as the Early and Middle Holocene.

The limitations I acknowledge make it impossible to account completely for differential recovery of artifacts, ecofacts, geofacts, and stratigraphic data. Accordingly, the only quantitative measures will be lithic analyses, because recovery techniques, as well as site formation processes, for lithics across all sites has been much the same. I will then more broadly characterize faunal remains and any recognizable activity areas at each site. This in turn will allow me to integrate these sites into the wider regional contexts of Florida and the Southeast (Figure 5.1)

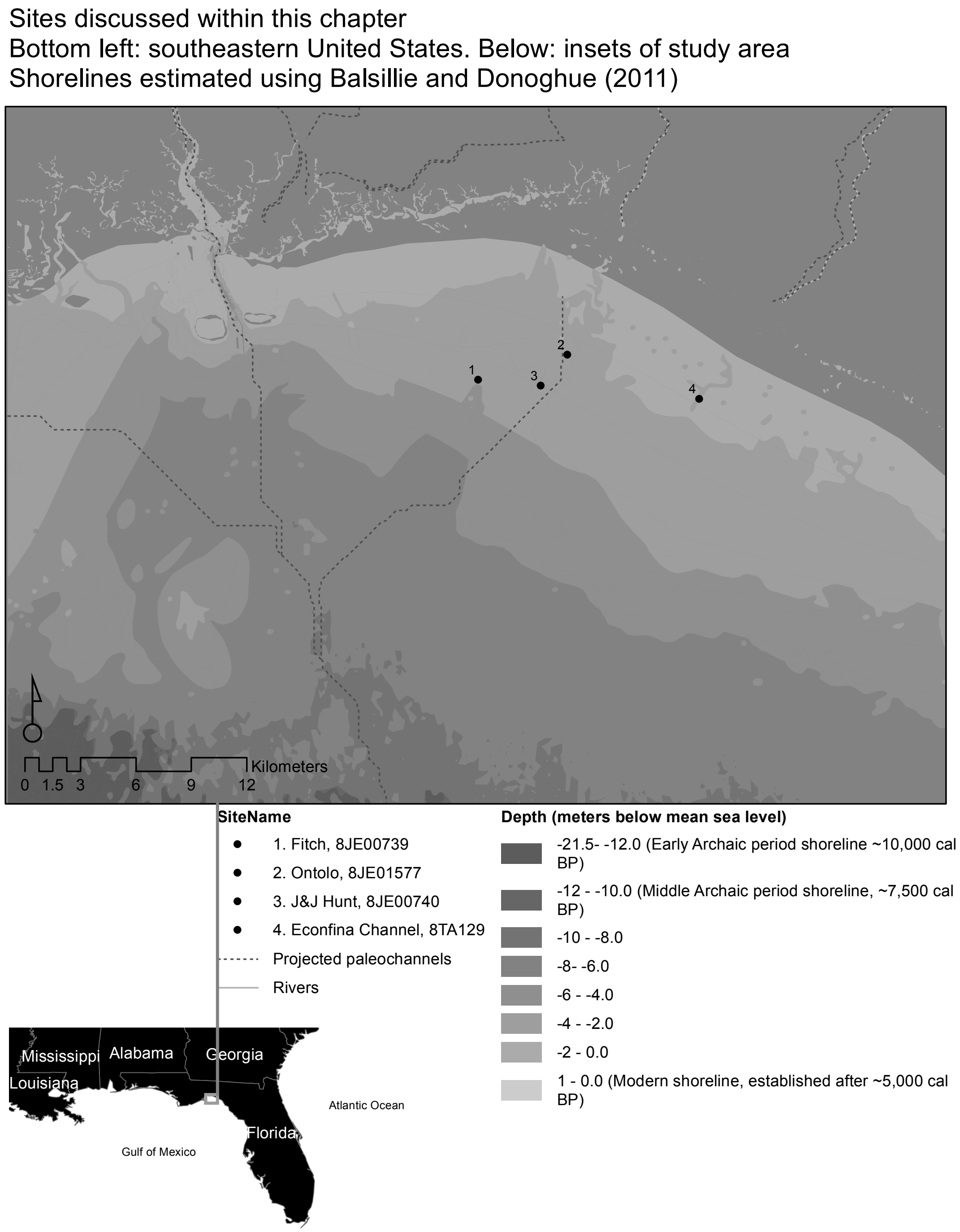

Figure 5.1:Study area showing Econfina Channel sites and the best-known sites along the Paleo-Aucilla

Comparisons to other sites in Apalachee Bay

As I stated at the outset this site must be understood within the greater archaeological context, including the different site types enumerated in our introduction to this study. Econfina Channel (8TA129) shows similarities and differences to sites in Apalachee Bay itself, and to other site types known in Florida. Locally speaking, it contained the following components in common with nearby sites: remains of lithic manufacture, faunal remains, including aquatic taxa, and organic materials such as wood. However, Fitch, J&J Hunt, and Ontolo all appear to have been occupied as early as the Paleoindian period, while Econfina Channel shows no evidence for use until the later part of the Middle Archaic, and the scale and number of features differs across each site. Therefore, comparisons between nearby sites are best understood within the ecological trajectory of the region, including the changes in site types.

First, how much continuity can be inferred for Econfina Channel with onshore sites and occupation patterns? The PaleoAucilla sites appear to show more continuity with inland sites such as Page Ladson that contain Clovis to Middle Archaic components, suggesting very early and continual occupation of the PaleoAucilla watershed. (Dunbar 2006b, 2016; Halligan et al. 2016). Activities at the PaleoAucilla sites prior to the coastline's arrival nearby suggest a focus oriented around the paleochannel/sinks and associated lithic outcrops. A karst collapse feature was detected at J&J Hunt along the paleochannel, and two different paleochannels were detected at Ontolo on the western and eastern sides of the site (Faught 2004b, 2004a; Marks 2006:189). Fitch may have been located along a paleochannel of the Pinhook River, but no published data confirm this. Onshore, the best preservation is found within stratified freshwater sediments within sinkhole features. J&J Hunt yielded stratigraphic evidence for freshwater sediment deposits similar to those found at onshore sites such as Page Ladson, although they are younger than the deposits within the onshore sites (Dunbar 2006a; Faught and Donoghue 1997:435–437; Halligan 2012; Halligan et al. 2016).

Econfina Channel, on the other hand, is more akin to Middle and early Late Archaic sites along the coast. These sites have prominent midden features and appear to have been chosen for their proximity to coastal resources. (Mikell and Saunders 2007; Saunders 2010; Saunders et al. 2009; McFadden 2016). It appears that the PaleoAucilla sites are more representative of upland, inland occupations prior to the approach of the coastline, with an overprint of coastal resource use when relative sea level was near the modern location. The approach of the coastline after 7,000 cal BP brought with it reliable, flowing fluvial channels, and along with it, the appearance of middens containing aquatic taxa from estuarine and possibly open marine taxa at J&J Hunt and Ontolo.

If one treats these sites as assemblages of features, one can test them for similarities and differences by comparing data for stratigraphy, geomorphology and general preservation, faunal remains, lithic remains, and inferences on activity areas. Much of the published data is best suited for qualitative, not quantitative comparisons, due to differences in archaeological questions asked and methods used during studies at each site. Despite these gaps, some helpful distinctions can be drawn between these sites, and from these distinctions, it is possible to test how hypotheses drawn from our predictive model stand up to the extant archaeological data.

Results

RSL and site cultural association

Relative sea level curves are often used to constrain cultural periods within submerged sites because they can provide a *terminus ante quem* for these sites based on date of final submergence. The relative sea level curve calculated by Balsillie and Donoghue (2011) for the Middle Holocene are not especially helpful in this study, however. Part of this problem lies with the fact that their younger datasets, A and B, are modeled from multiple data points. Dataset A was modeled from seaward indicators while Dataset B was modeled from landward indicators (Balsillie and Donoghue 2011:59–65). Marine transgression at Econfina occurred after the period during which the midden was in use, but our younger radiocarbon date suggests that this may have been as late as ~2,600 cal BP. This lack of clarity on the final stages of relative sea level rise after 6,400 cal BP make it difficult to estimate precisely when the youngest submerged sites were abandoned. All one can infer from relative sea level is that cultural associations for all the known sites in Apalachee Bay could correlate to anything from the Paleoindian period to the Late Archaic period. Clearly, more data points on relative sea level within Apalachee Bay are needed. To tease out further detail I turn to the details of lithics, faunal assemblages, and activity areas at each site, as they are currently understood.

Lithics

Lithic assemblages are created along a continuum of behaviors, some of which are purely symbolic and others that are quite pragmatic (Andrefsky 1994, 2009; MacDonald 2009). I will not attempt to distinguish where cultural symbolism leaves off and pragmatic choices begin in this analysis, however. Instead, my focus is on which stage of lithic manufacturing occurred at each site based on the composition of the lithic assemblages.

To compare lithic assemblages at these sites, I measured the ratio of tools to debitage and cores using BAR inventories. After converting the BAR inventories for each site into Excel spreadsheets, I used a COUNTIF formula to count instances of biface/blade tools, cores, flakes, debitage, and unifacial tools. I then summed all tools together, and all waste materials from manufacture, and calculated relative frequencies. I then classified lithic manufacturing activities as either quarrying/primary reduction, or as secondary/retouch based on the ratio of tools to all debitage, operating on the assumption that more tools should be found in assemblages where the focus of lithic manufacturing was on secondary reduction or retouch. Conversely, I assumed that primary reduction/quarrying was the focus where fewer tools, and more debitage and cores were found. Additionally, I calculated the ratio of primary/secondary reduction debitage to shatter to determine the degree to which various stages of lithic reduction processes account for the final debitage assemblage (Table 5.1). It appears that Fitch and Econfina Channel contain the most evidence for primary quarrying activities and secondary reduction, while J&J Hunt and Ontolo both appear to contain more tools than debitage. However, when one considers the ratio of various types of debitage, it becomes clear that Econfina Channel, unlike Fitch, contains far more evidence for finishing, retouch, and tool breakage. Econfina Channel is most like Ontolo where debitage ratios are concerned, while Fitch has virtually no evidence for finishing and retouch, and J&J Hunt contains the most.

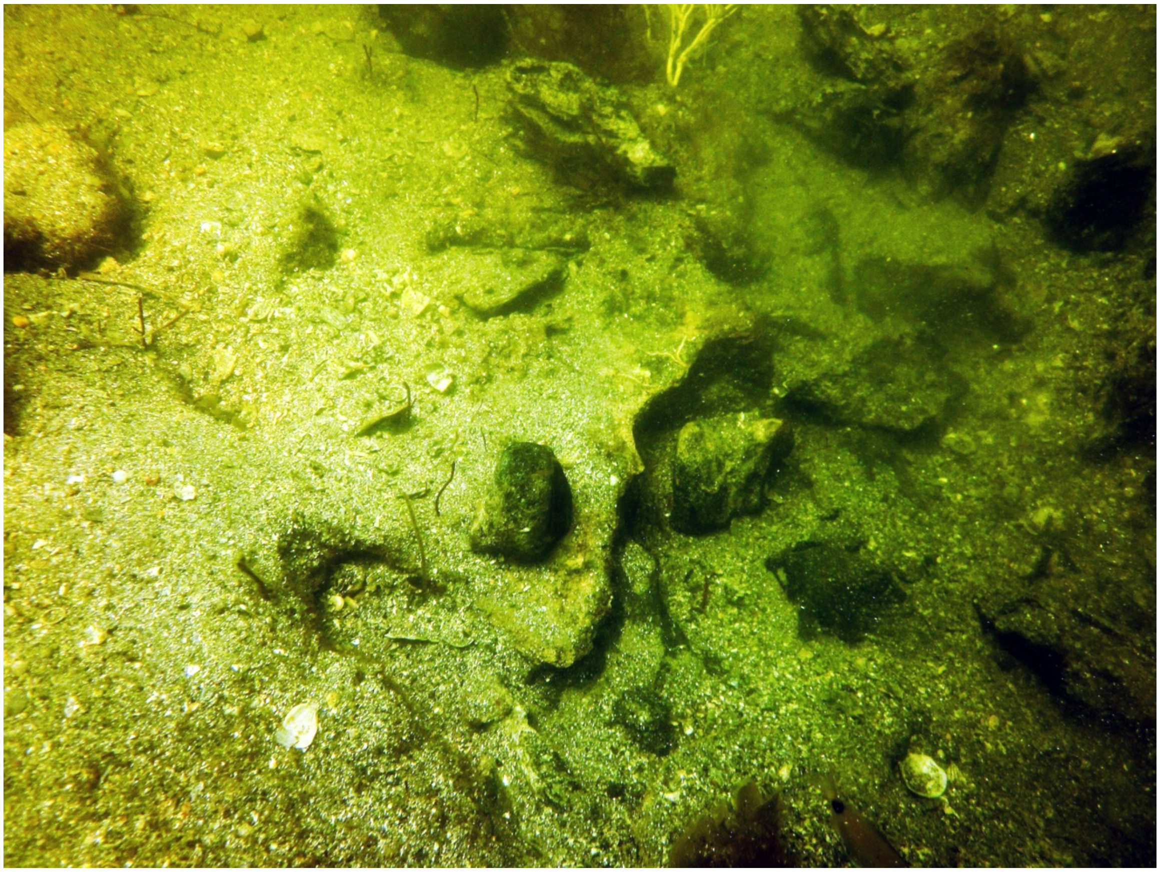

Figure 5.2:Econfina Channel site quarry outcrops clearly showing detached blocks and detachment scars on the outcrop itself. Photograph by Cook Hale, 2015.

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Table 5.1: Comparisons of lithic assemblages, all sites

Site	Lithics							Debitage frequencies only		
Econfina Channel	Biface/blade	Flake/scraper/unifacial tools	Other Unifacial tools	Core	Primary/secondary debitage	Shatter/ finishing debitage	All tools	All debitage	Larger debitage	Finish/retouch
Count	7	8	0	14	100	117	15	231	100	117
Relative frequency	0.03	0.03	0.00	0.06	0.41	0.48	0.06	0.94	0.43	0.51
Lithic activities			Primary reduction, secondary reduction, finishing, retouch							
Fitch	Biface/blade	Flake/scraper/unifacial tools	Other Unifacial tools	Core	Primary/ secondary debitage	Shatter/ finishing debitage	All tools	All debitage	Larger debitage	Finish/retouch
Count	3	7	0	6	51	2	10	59	51	2
Relative frequency	0.04	0.10	0.00	0.09	0.74	0.03	0.14	0.86	0.86	0.03
Lithic activities			Primary reduction							
J&J Hunt	Biface/blade	Flake/scraper/unifacial tools	Other Unifacial tools	Core	Primary/ secondary debitage	Shatter/ finishing debitage	All tools	All debitage	Larger debitage	Finish/retouch
Count	42	957	0	32	82	240	999	354	82	240
Relative frequency	0.03	0.71	0.00	0.02	0.06	0.18	0.74	0.26	0.23	0.68
Lithic activities			Secondary reduction, finishing, retouch							
Ontolo	Biface/blade	Flake/scraper/unifacial tools	Other Unifacial tools	Core	Primary/ secondary debitage	Shatter/ finishing debitage	All tools	All debitage	Larger debitage	Finish/retouch
Count	65	1188	0	14	84	82	1253	180	84	82
Relative frequency	0.05	0.83	0.00	0.01	0.06	0.06	0.87	0.13	0.47	0.46
Lithic activities			Secondary reduction, finishing, retouch							

Faunal remains

Quantitative analyses are impossible because standard zooarchaeological collection and analysis techniques were not employed at any of the sites. However, the faunal assemblage can at least be characterized in general terms. Table 5.2 summarizes these characteristics.

Table 5.2: Faunal remains by site

Site	Taxa represented	Anthropogenic?
J&J Hunt	*Alligator mississippiensis*, *aves, Odocoileus virginianus*, fish, shark, *testudes, Ampullariidae* (apple snail), *chama, crassostrea, pectin,* and *Busycon* remains. Source: Faught and Donoghue 1997:441	Some specimens are modified, but not all. *Crassostrea* deposits are tentatively identified as potential middens. Other faunal remains are more equivocal.
Fitch	*Pectin, chama, crassostrea,* and various UID gastropods were observed at the site. Source: BAR inventories	Unclear
Ontolo	*Mercenaria* and *crassostrea*; UID bone and shark's teeth. Source: BAR inventories, Marks 2006:113	Unclear
Econfina Channel	*Crassostrea virginica, pectin, dugong, Ampullariidae, Melongena corona*, UID fish vertebrae. Source: BAR inventories, Faught and Donoghue 1997:438; Cook Hale and Hale, in prep.	*Crassostrea* midden is anthropogenic. Midden contained UID fish vertebra

Activity areas

Econfina Channel

Bulk analysis of sediments from the Econfina Channel site indicate multiple depositional zones: the paleochannel area, the eel grass zone, and the quarry/midden area. Linear discriminant analysis (LDA) detected some conflation between the midden and the quarry zone, likely the result of post-depositional disturbance. These depositional zones are not to be confused with *activity areas.* Instead, I turned to midden composition and lithic distributions to infer activity areas. Lithic artifacts representing primary reduction sequences were common in the quarry zone and the seep/spring area. Excavations recovered more tools and smaller debitage consistent with finishing, retouch, and breakage closer to, and within the midden itself. Debitage showing use wear for multiple activities such as processing durable materials (probably shell), moderately durable materials such as wood, and soft materials such as meat or hides was recovered from within the midden.

The middle area itself was defined by obvious shell deposits and by the 4-mm sediment fraction, and showed evidence for shellfishing consistent with other Middle Archaic shell middens along the northern Gulf Coast (Hadden 2015; Saunders and Russo 2011). These deposits were intermingled with the finishing/retouch/breakage debitage. This suggests that the midden area was a processing zone for food materials and possibly other technological activities such as woodworking. Given these findings, I suggest that the midden and quarry zones probably represented different activity areas during the site's occupation despite their conflation either during or after their use.

J&J Hunt

Faught, et al., do not argue for specific activity areas, but do note different loci for artifact types and faunal remains, although contemporaneity cannot be assumed. Several shell deposits consistent with middens are noted, as well as bone deposits (Faught 2004a:282). Actual lithic tools, as opposed to debitage, were most common along the southern side of the site, but no evidence for on-site rock outcrops suitable for quarrying were detected even though cores and hammerstones indicated tool production (Faught 2004a:283). Lithics lacked weathering patterns consistent with rolling and tumbling within and/or on top of the marine sediments, suggesting minimal displacement through time. The degree of re-deposition of shell deposits is not examined in detail, but taken together with the lack of mechanical weathering in lithics, studies of shell preservation in natural deposits, and additional studies on displacement of artifacts in submerged sites in this region, it seems reasonable to interpret these loci as remnants of specific activity areas (Marks 2006:79–91) This suggests that shell and bone deposits may constitute activities areas related to subsistence, while the lithic deposits may suggest finishing or retouch for tools in these locations.

Fitch

Fitch was not analyzed for intrasite activity areas. Surveys and excavations focused on rock outcroppings and associated lithic remains. The only activity that can currently be identified at the site is primary reduction of lithic tools. Fitch appears to have been more disturbed by submergence during marine transgression as well, suggesting that identification of intrasite variations will be difficult, if it is possible at all (Faught and Donoghue 1997:442–443). No faunal remains were recorded in the BAR inventories and it does not appear that remains from possible subsistence activities were sought.

Ontolo

Ontolo appears to contain multiple activity areas; currently those associated with lithic manufacturing and maintenance activities are the best understood. Marks' quantitative lithic analyses suggest multiple activity areas within the site, even after accounting for potential artifact displacement due to marine processes (Marks 2006:104:113). Further, intrasite analyses suggest areas of discard just to the west of the datum, implying a midden area. There was no evidence for a quarry zone on the site and based on his analyses he identified Ontolo as an occupation site with activity areas focused on lithic manufacture and/or maintenance. Unfortunately, minimal information concerning faunal remains is available beyond the BAR inventories, making it impossible to identify other activities beyond those pertaining to lithics. Like J&J Hunt, it seems reasonable to infer subsistence activities and end stage lithic manufacturing. As noted above, lithic debitage ratios suggest the most similarity to Econfina Channel.

Geomorphology, sediments and stratigraphy

Stratigraphy is generally minimal across these sites, except for J&J Hunt. The only intact recognizable strata at the Econfina Channel site are found in the eel grass zone, where excavations exposed a stratigraphic profile in the midden deposits (Figure 5.3). No freshwater sediment deposits were detected, only a few small areas of tidal marsh muds, anthropogenic shell deposits, and a mixed fluvial/marine sediment of shell hash and sand. This profile shows a coarse shell hash layer overlying a contact with a finer shell hash layer; the profile is approximately 40 cm deep.

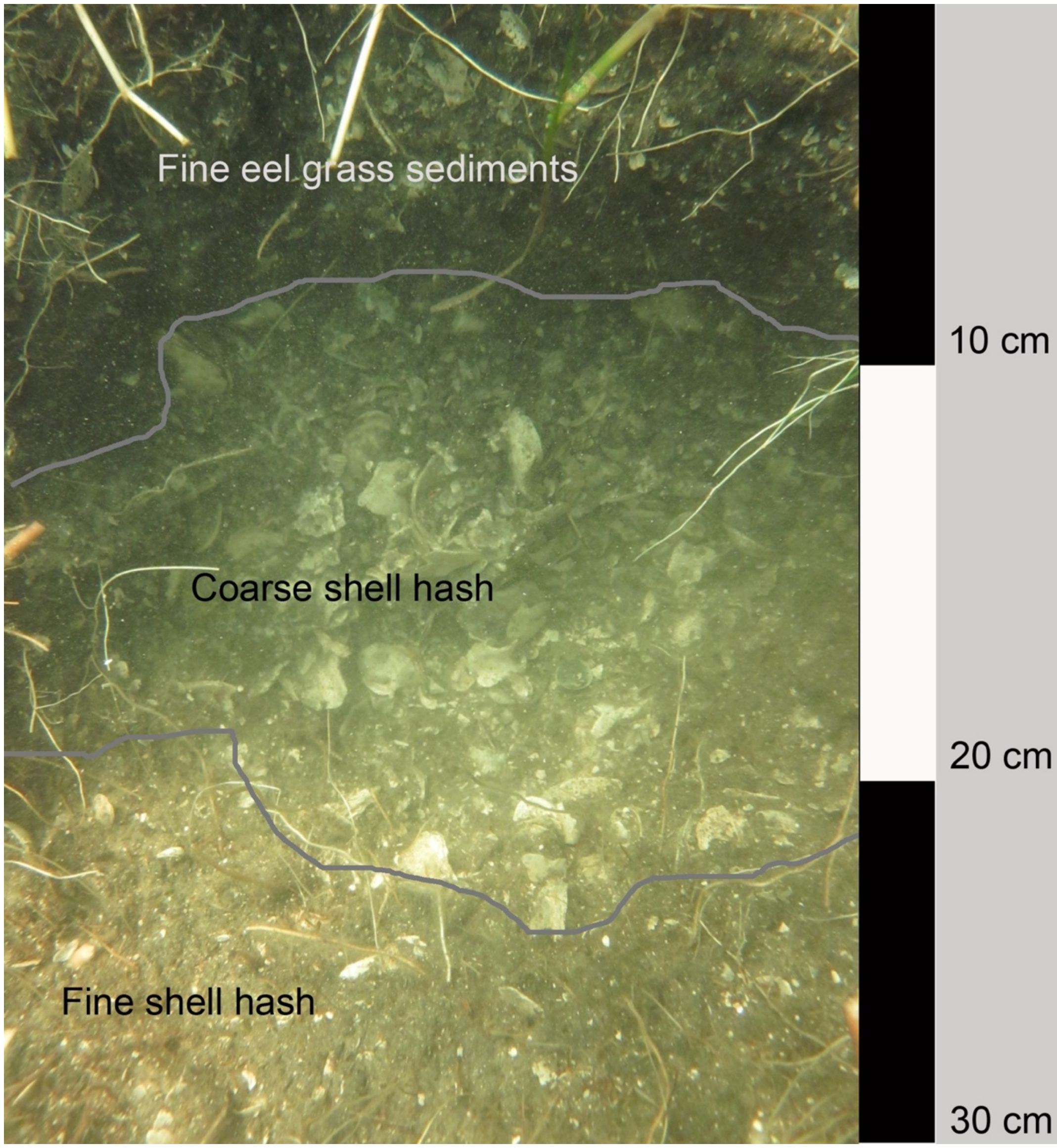

Figure 5.3: Stratigraphic profile, Econfina Channel site, eel grass zone

Fitch and Ontolo both contained marine shell hash but no other stratigraphic levels were described in any detail. J&J Hunt retains a more complex stratigraphy than Econfina Channel (Faught 2004:439-440, figures 10 and 11). A Pleistocene freshwater marl deposit is apparent underneath an organic rich stratigraphic that is in turn overlain by a marine shell hash/sand sediment. Dolomite boulders and cobbles were observed at all sites. At Econfina Channel, these are located directly underneath the sandy/shell hash marine surface level, between 30 and 50 cm below the surface. At J&J Hunt these were observed underneath the freshwater marl level. These were also noted at Ontolo and Fitch but further details were omitted. The more complex nature of the deposits at J&J Hunt is likely due to the presence of the sink feature there, within which most of these levels are contained.

The Econfina Channel site is next to a fluvial channel with lithic outcrops, freshwater spring, and a midden feature showing clear use of estuarine resources. J&J Hunt consists of sink feature, fluvial channel, and multiple activity areas dating to multiple cultural periods. The geomorphology is akin to the section of the Aucilla River known as Half Mile Rise, where the channel emerges from a "rise" feature that allows it to flow sub aerially, then drops back down into a subterranean channel approximately ½ mile downstream (hence the name, "Half Mile Rise"). At Fitch, archaeological materials were found in association with rock outcrops and on top of marine sediments. The site was described as a lithic scatter within an open area of marine sandy shell hash, surrounded by eel grass. No obvious paleochannel feature was noted during investigations by Faught, et al., although the Pinhook paleochannel is mentioned as possibly being nearby.

Sediments and stratigraphy were poorly described for Ontolo. Like Fitch, marine shell hash at the surface is described, with eel grass beds surrounding the site. Unlike Fitch, Ontolo is close to two paleochannel features detected using sub bottom profile methods (Marks 2006), and these channels are most likely associated with the PaleoAucilla. At present, the only clear sink feature associated with a site is at J&J Hunt. Ontolo, Econfina Channel, and possibly Fitch are associated with paleochannels instead.

Radiometric Dating

Radiometric dates indicate that relative sea level rise had an impact on site use and landscape use patterns. J&J Hunt yielded multiple radiometric dates, ranging from ~7,000 cal BP, to 6,100 cal BP, and artifacts diagnostic for all periods from the Paleoindian period to the Middle Archaic were also recovered, suggesting long term use until the site was submerged in the Middle Archaic sometime after 6,000 cal BP (Faught and Donoghue 1997:438, Table 1). No radiometric dates are reported from Ontolo, but artifacts diagnostic for the Paleoindian periods through the Middle and possibly Late Archaic are documented (Michael Faught, personal communication, 2016). The site lies in 4-5 m. of water, however, suggesting a *terminus ante quem* similar to that at J&J Hunt. Fitch also has no radiometric dates associated with it but debitage consistent with Paleoindian and possibly Early Archaic techniques place it within those periods, suggesting that it was submerged by ~8,000 cal BP, placing its quarry components out of reach for Middle Archaic groups (Faught and Donoghue 1997:442).

Econfina Channel consistently dates to the Middle and Late Archaic, however. No artifacts diagnostic for earlier periods have ever been recovered, and the available radiometric dates are all consistently younger than 5,500 cal BP. Faught and Donoghue obtained a date of 5,140 +/- 100 from a wood fragment recovered from a marine sand deposit near the paleochannel, and our dates are even younger: 4,510, +/- 461, and 2,621, +/- 423, for two *crassostrea* shell fragments. The large marine reservoir correction required for radiocarbon dates on shell must be taken with great caution. What we can say is that midden deposition began probably sometime during the Middle Archaic, consistent with the recovery of Florida Stemmed Archaic points by Faught, et al. The younger date on the top level of the midden, recovered from an anthropogenic context, returned a mean 14C date of 2,621 +/- 423 cal BP, at least 1,400 years after the shoreline was thought to have stabilized at approximately the modern position. This raises questions about the relative sea level curve in this area because the midden deposit averages 2-3 meters below current sea level. (Balsillie and Donoghue 2011:65). More data are needed to clarify this issue.

By all appearances, Econfina Channel is the youngest site. Fitch was probably abandoned first, then J&J Hunt. It is unclear when Ontolo and Econfina Channel were finally submerged; they may have been in use as recently as the Late Archaic. Interestingly, Ontolo and J&J Hunt both show continuity from the Paleoindian period until final submergence, but there is no evidence for occupation at Econfina Channel while any of the PaleoAucilla sites were in use.

Discussion: sites and assemblages

I began with the question of how these sites can inform us about the changes in human landscape interactions in a rapidly changing paleoecological setting. By treating assemblages and features at each site as continuums along which human behaviors can be preserved, I will offer some interpretations into the intensity and nature of site use over time.

Lithic assemblages tell us something about how technological needs were satisfied at each of these sites. Econfina Channel site contains evidence for all stages in lithic quarrying and reduction. J&J Hunt appears to contain evidence for secondary reduction and retouch and the same is true for Ontolo, with actual activity areas associated with lithics appearing evident based on Marks' analyses (Marks 2006). At both of these Aucilla sites, lithics were diagnostic for late Paleoindian period occupations and younger, and probably were brought to each site from other quarry locations. (Faught, 2004a:282-283).This is unlike Econfina Channel, where raw lithic materials were easily accessible onsite. Interestingly, Ontolo's ratio of primary/secondary reduction debitage to smaller debitage most likely left behind by the final stages of lithic manufacturing is most like Econfina Channel site, raising the question of whether an as-yet undetected quarry zone lies nearby. Fitch does offer raw materials, and contains evidence for quarrying and primary reduction techniques, but there is no evidence for secondary reduction of the lithic materials (Faught and Donoghue 1997:422). Thus, I infer Fitch may better represent a raw lithic resource extraction location only because it lacks evidence for any other activities (Binford 1980:9–10, 18). In the case of the other sites, the greater range of lithic activities suggests something about the overall human use of each site, with evidence for finishing of tools as well as their use in other activities. Locations where end-stage reduction traces are more visible appear to also contain more direct evidence for other activities.

Clearly, then, lithics must be considered along with other activities and resources at these sites. Fitch contains no definitive evidence for activities beyond lithic raw material extraction, but Econfina Channel site, J&J Hunt, and Ontolo all contain some evidence for subsistence activities. The data for these subsistence practices are less detailed but offers some useful observations. J&J Hunt and Ontolo appear to contain evidence for multiple food sources, both terrestrial and coastal, although there is no evidence for contemporaneity between the terrestrial bone deposits and the shellfishing deposits. Econfina Channel contains coastal resources alone. Further, these coastal resources at Econfina Channel all date to the Middle Archaic or later. This observation suggests that human coastal resource is most visible during later periods when the coastline was closer. However, all sites badly need detailed zooarchaeological study combined with secure radiometric dating to test hypotheses that address topics such as seasonal use, exploitation of different aquatic zones, cultural preferences across space and time, and the way in which different degrees of coastline stability may have impacted the availability of specific taxa and/or their native aquatic habitats.

I argue based on our data that the presence of multiple activities implies more intensive use of a site, and that by this standard, J&J Hunt and Ontolo represent possible base camps used as early as the Paleoindian period where the occupants used terrestrial and then later coastal resources. Econfina Channel represents a more coastally oriented Middle to Late Archaic base camp lacking clear terrestrial subsistence resources. J&J Hunt, Ontolo, and Econfina may have been used contemporaneously by the Middle Archaic, but human activities at J&J Hunt and Ontolo were clearly in use well before Econfina Channel was occupied.

This argues that occupation patterns across the landscape clearly changed by the Middle Archaic, when the coastline was encroaching. The primary evidence for habitation, including both base camps and logistical resource extraction points, is oriented along the PaleoAucilla during the Paleoindian and Early Archaic periods. J&J Hunt resembles early inland sites such as Page Ladson in geomorphological context; both are located next to, and within, sinkhole features. Fitch was probably a chert extraction site that could no longer be reached after submergence, likely by the Early Archaic. However, J&J Hunt and Ontolo retained inhabitants into the Middle Archaic, while

Econfina Channel appears to be newly inhabited by the end of this period. Water was more abundant on the landscape by this point, making smaller watersheds such as the Econfina more reasonable choices for occupation than during earlier periods. Still Ontolo lacks a known sinkhole feature, and yet still shows evidence for early occupation near a fluvial channel that may or may not have flowed during the Paleoindian and Early Archaic periods. This suggests the possibility that the Aucilla watershed was a preferred landscape in the Paleoindian and Early Archaic periods, not only because it offered access to water, but was also a valued cultural landscape. In contrast, the Middle Archaic and Late Archaic peoples occupied new biozones such as the newly flowing Econfina River watershed.

Contexts through time, across space, and within cultures

I opened this chapter by arguing that understanding human occupations of submerged landscapes requires that we ask anthropological questions in addition to simply identifying the sites themselves. I have also argued that the spatial locations of these sites exercise control over potential access to various resources, which in turn should have affected the range of human activities at these locations. Site location within ecological context should thus allow us to infer possible site types allowing for change through time. Using this framework, we should be able to craft hypotheses about how humans used these submerged landscapes. The comparisons between these four sites that I have made thus far can be compared to what we should expect from human activities in this changing landscape.

During the terminal Pleistocene and Early Holocene, water resources were localized around sinkhole features in the upland zone (and the role of beaver ponds cannot be ruled out during less arid periods). This restricted the distribution of terrestrial species tethered to water, wetland species, and non-marine aquatic species to these locations. Non-migratory terrestrial animals would have been most abundant in these locations, as well as certain kinds of plants. Along the coastline, the coastal oasis effect pushed freshwater discharge towards the surface along the coastline, causing rivers to flow continuously and creating a coastal oasis zone that could have included warm temperate coastal plain forests (Faure et al. 2002; Thulman 2009). Terrestrial species, wetland species, and aquatic species could expand their ranges, distributing potential prey across the coastal landscape (Dunbar 2016:183, table 5.1). The potential for prey encounters should have changed accordingly; the highest potential in the upland zones for prey encounters as well as water resources, would have been at sinkhole features. At the coastline, the potential for prey encounters would have become more distributed across the landscape and could have included marine aquatic taxa. The coastal zone would probably have contained the highest number and diversity of prey, as well. Critically, the change in paleoclimate and relative sea level should have pushed the coastal zone inland during each period, although at different rates, even while increased humidity by the Middle Archaic filled rivers, lakes, and pond in both upland and coastal zones. While this is likely an oversimplification of a diverse ecological landscape, these two zones should have offered different foraging potentials for their inhabitants, leading to different uses of the landscape. Upland sites should be clustered around sinkhole features or lithic raw material sources, while coastal sites should be more dispersed, with a greater number and diversity in taxa represented in food remains.

When assessing the data at these four sites, some of these predictions are borne out. Fitch is clearly an extraction site, and J&J Hunt is clearly a sinkhole site, at least during periods when it was still upland. But Ontolo is not a sinkhole site, yet was occupied around the same time as the other two, suggesting that a sinkhole feature may not always be present at these early sites, and/or that the Aucilla watershed was preferred for reasons beyond simple access to water and prey. When Fitch was submerged and the coastline approached J&J Hunt and Ontolo, human groups still used these locations, adding coastal resources to their diets and possibly still using terrestrial game. This is reasonably consistent with our hypothesis that coastal sites should show greater diversity in prey taxa. However, once these sites were submerged, Econfina Channel was occupied by people that were shellfishing and manufacturing lithics, but apparently not using terrestrial fauna. This is not consistent with Dunbar's projections for coastal sites. It is consistent, however, with observations that coastal sites in the southeastern U.S. often show a greater dependence on low risk, low yield taxa such as *crassostrea* than diet breadth models predict; close study of these departures from projected diet breadth models along the Georgia coastline point to the potential for social behaviors such as costly signaling and gendered foraging roles to play a role in subsistence choices (Thomas 2008:1056-1060-1107). While behavioral ecology models can account for these differences, it is important to note that these are social behaviors, only indirectly tied to landscape features. Just as the location of Ontolo does not follow the predictive model for Paleoindian and Early Archaic site choices, the subsistence remains at Econfina Channel do not include the diverse faunal assemblage in the midden that we might expect.

Cultural choices played a role in human activities at both sites. This further suggests that variations in known site types exist on the continental shelf.

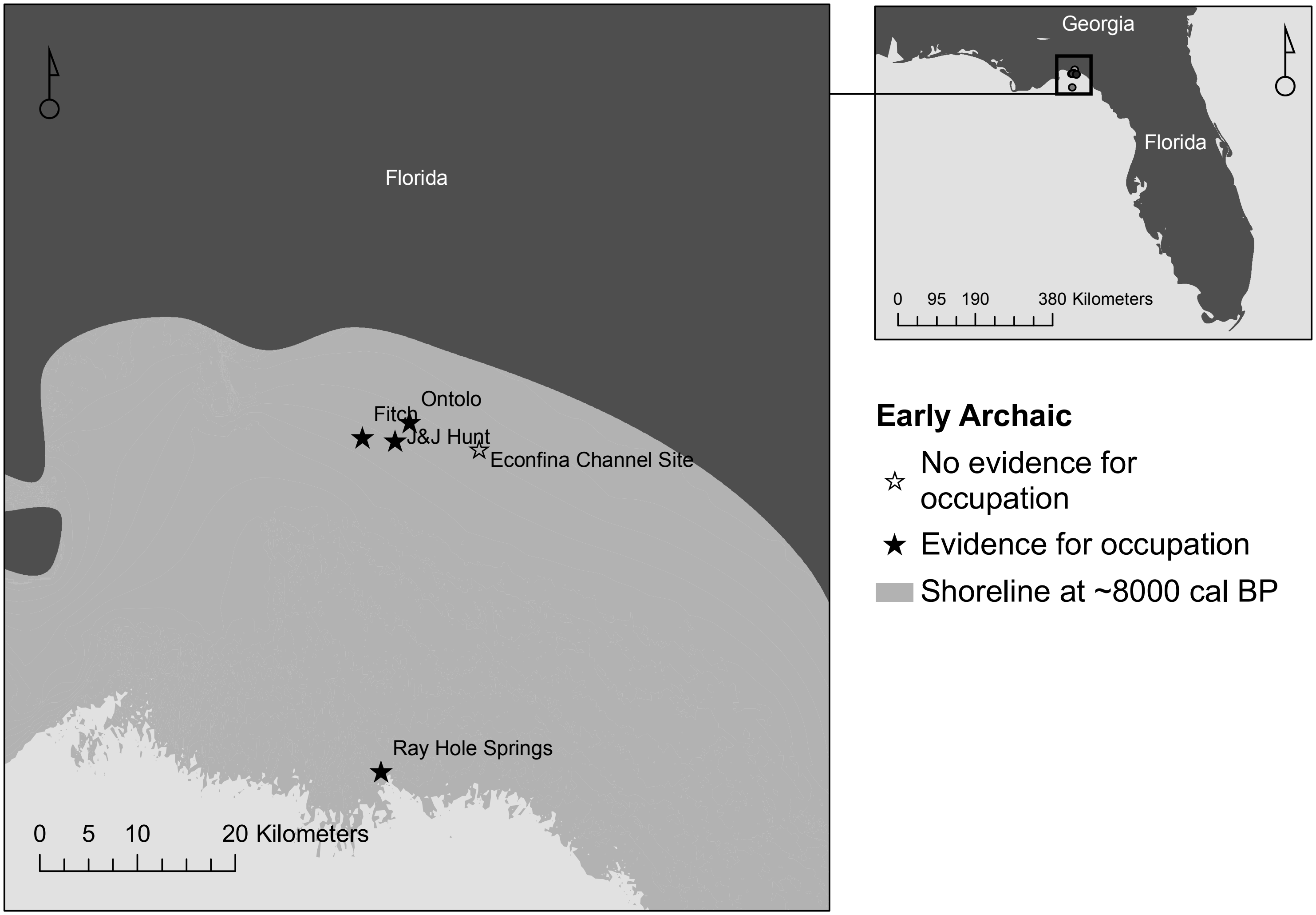

Figure 5.4: Occupations during the Early Archaic

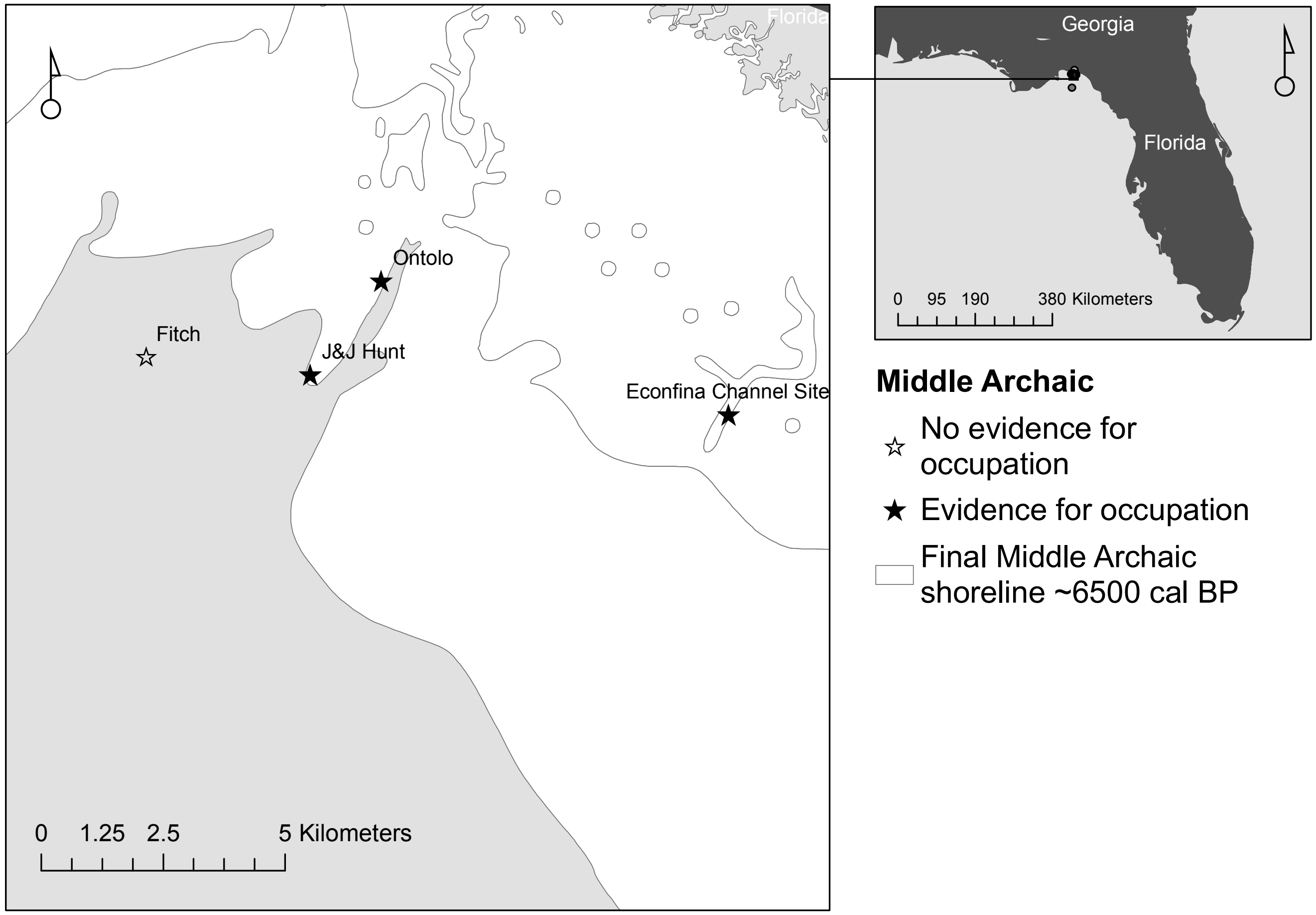

Figure 5.5: Occupation during the Middle Archaic period

Table 5.3: Site type, local ecology, and occupation history

Site	Period	Climate	Potential for prey encounters			Activity areas	Occupied?	Probable site function
			Upland taxa	Wetland taxa	Aquatic taxa			
Econfina Channel	Early Archaic	Transitional	Moderate	Low	Low	None known	No	None known
Fitch	Early Archaic	Transitional	Moderate	Moderate	Low to moderate	Quarry	Yes	Quarry
J&J Hunt	Early Archaic	Transitional	Moderate	Moderate	Low to moderate	Middens? Lithic manufacturing areas, fluvial features	Yes	Habitation
Ontolo	Early Archaic	Transitional	Moderate	Moderate	Low to moderate	Middens? Lithic manufacturing areas, fluvial features	Yes	Habitation

Site	Period	Climate	Potential for prey encounters			Activity areas	Occupied?	Probable site function
			Upland taxa	Wetland taxa	Aquatic taxa			
Econfina Channel	Middle Archaic	Wet	Abundant, dispersed	High	High	Midden, quarry, freshwater spring	Yes	Habitation
Fitch	Middle Archaic	Wet	None	None	High	None	No, submerged	None at this time
J&J Hunt	Middle Archaic	Wet	Abundant, ranges most extensive	High	High	Middens? Lithic manufacturing areas, fluvial features	Yes	Habitation
Ontolo	Middle Archaic	Wet	Abundant, ranges most extensive	High	High	Middens? Lithic manufacturing areas, fluvial features	Yes	Habitation

Conclusions: Final comparisons and comments on the predictive model

All four sites are different although some have components in common: chert quarrying at Econfina Channel and Fitch; Coastal subsistence resource use at J&J Hunt, Ontolo, and Econfina Channel; proximity to water resources at every site but Fitch (even Fitch may be close to the Pinhook paleochannel). J&J Hunt conforms well to the predictive model for sink/cenote sites during the Paleoindian and Early Archaic periods, and is the only one that is remotely consistent with other sink/cenote sites such as Page-Ladson and Sloth Hole. Fitch also conforms to the prediction model for chert quarry sites in this region. However, Econfina Channel and Ontolo depart from these models. Ontolo shows evidence for very early occupation along the PaleoAucilla watershed that was probably contemporary with J&J Hunt and Fitch, but it lacks a sinkhole feature or an obvious quarry despite evidence for all stages of lithic manufacturing and various subsistence activities. Econfina Channel is most like Ontolo, being located along a paleochannel, but contains a clear chert quarry component while lacking the diverse assemblage of faunal remains that could have been used along the coastline. Clear adherence to general site types such as those outlined at the outset of this chapter, or subsistence remains predicted by simpler types or diet breadth models, breaks down when compared against these data.

Clearly the predictive model was successful in practice because no potential sites were ignored for lacking a component. However, cultural choices appear evident in each of these sites as well as their ecological contexts. This is an important point because it highlights two key observation: human relationships to their ecological contexts do change through time, and human relationships to the surrounding ecology can be complex. It is for this reason Ford and Halligan caution that static onshore models must not be extrapolated onto the continental shelf, especially for periods during which the climate lacks modern analogs ((Ford and Halligan 2010).

The differences between these sites further highlight the need to foreground the nuanced way people integrate with their landscapes when studying submerged sites. If we assume that J&J Hunt, Fitch, and Ontolo were upland sites all used contemporaneously from the Paleoindian period until submergence, and that the known components are reasonably representative of human activities at these sites, then the variations in their components indicate both flexibility in human prioritization of resources and intangible cultural priorities. The emergence of the Econfina Channel site during the Middle Archaic supports this argument as well, but within a wholly different, coastally oriented context. We must account for the role of cultural choices in submerged sites by asking anthropological, not simply ecological, questions about human activities within submerged sites and their onshore counterparts.

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CHAPTER 6 : CONCLUSIONS

Introduction

Current scholarship has conclusively demonstrated that submerged archaeological sites on the continental shelf not only exist, but can be detected, excavated, and interpreted. The subfield of submerged prehistoric archaeology is now ready to move to a more complex level of development, such as sites examining anthropological questions about the nature and timing of human cultural change through time and space. The nature of prehistoric, formerly coastal occupations that are now part of submerged landscapes is one such question, and this is the topic explored by this study. Not only are the natures of these occupations currently opaque, they also likely offer insight into important developments in human behaviors.

That said, challenges remain. The archaeology of submerged prehistory as demonstrated in the preceding chapters is challenged by taphonomic and diagenetic processes not commonly encountered in terrestrial settings. These processes alter the geoarchaeological setting of these sites and their contents – features and artifacts. With the rare exception, prehistoric settlements were relatively small, transitory – semi sedentary, and were produced by relatively few people. The subsequent alteration or transformation of these deposits – termed N-transforms by Schiffer – must be expected and accounted for by this or any study.

N- transforms in submerged sites address difficulties unlike those encountered in terrestrial landscapes, however. These processes operated at all scales, from geomorphological changes such as erosion and deflation of dry land sediments to geochemical corrosion that changes lithic and bone artifacts at a mineralogical level.

Delineating human activities from non-human processes must be performed or valuable data will be lost. To accomplish this, this study, therefore, also explored the specific nature of post-depositional processes that occur when terrestrial landscapes occur.

The first component of this study refined settlement models for submerged sites. Settlement modeling has been a vital first step towards detection of submerged sites, but typically has focused in the past on either searching for gross geomorphological features on the continental shelf such as paleochannels, or has relied on highly regionalized understandings of site occurrences. Models also often fail to account for long term ecological changes tied to changes in climate and sea level. Additionally, human responses in any given region are bound to be a combination of pragmatic and cultural values. A general method is needed that can be applied at any scale and within any region, but must be sensitive enough to detect human behaviors not strictly tied to pragmatic needs alone. To bridge the gap, I developed a method for spatial analysis that first used spatial statistical methods to establish which geomorphological features were most predictive for individual cultural periods. It was also designed to detect specific cultural indicators. I applied this method within the study region of Apalachee Bay for two cultural periods: The Early and Middle Archaic, using relative sea levels, paleochannel projections, ecological measures for net primary productivity within the biome, access to various types of water features, measure of rainfall predictability, and preferences for either coastal zones or specific watersheds. My results indicated that site prediction is, in fact, not at all straightforward. First, foragers do not use every site for simple occupation purposes; some sites were used for quarrying, while others may represent locations allowing access to other materials such as specific subsistence resources. This made linear regressions break down during spatial statistical analysis. Second, during the Early Archaic, sites clustered in a statistically meaningful way around one watershed alone, the Aucilla River, with little attention paid to other potential watersheds and in a manner that did not suggest the Aucilla was ecologically distinct. Further, principal components analysis and linear discriminant analysis for Middle Archaic sites showed a clear preference for either the coastal zone, or inland watersheds, suggesting that distributions of sites for coastal zones lie parallel to the shoreline, which the inland sites are oriented along individual watersheds perpendicular to the shoreline. While the Aucilla was still a significant predictor for inland sites, other watersheds showed signs of increased settlement. This suggests that during earlier periods, inland sites were defined not merely by access to more productive ecological zones, but also by social territories or ancestral landscapes of some sort. By the Middle Archaic period, a coastal occupation zone can be detected, but without concurrent indicators that this coastal zone was more ecologically productive than the inland watersheds. The study was also able to quantify the predictive values of all variables, both environmental and cultural. This supports my hypothesis that this method can be applicable in other locations, and indeed should be, to refine both environmental and cultural predictive variables.

To elucidate further the nature of coastal occupations during the Middle Archaic, Chapter 3 focused on higher resolution survey and testing at one submerged Middle Archaic coastal site in Apalachee Bay, The Econfina Channel site. At this point, examination of post-depositional processes tied to submergence was critical. Using a method adapted from earlier sedimentological studies of submerged sites that treats archaeological deposits as a specific type of anthropogenic sediment, I sought to tease out differences between signatures left by human activities and those created by non-anthropogenic processes such as marine transgression. I primarily employed site mapping and bulk sediment sampling, with limited excavation and lithic analysis, to delineate individual activity areas within the site as well as sedimentary depositional zones. Sediment bulk sampling analyses highlighted the fact that the most prominent features within the site, a large midden composed mostly of *crassostrea* (oyster) shell and a chert quarrying zone around it, have become conflated due to marine transgression processes. However, within the midden and quarry zones, different sizes and types of lithic remains could be detected, and preliminary use wear and morphological assessments of these lithics indicate that multiple activities were carried out with these stone tool items. These ranged from manipulation of durable materials (probably shell, given the utter lack of bone, antler, or horn remains at the site) to working softer goods such as wood or even fiber. Evidence for every stage of lithic reduction was also recovered, from cobble testing and primary reduction all the way to finishing, retouch, and breakage of stone tool items. Minimal evidence for formal tools has been recovered from this site, and a seemingly exclusive focus on shellfishing only. When compared against ethnoarchaeological evidence for coastal subsistence and occupational strategies, this suggests a low mobility population whose diet breadth, at least based on these remains, did not include higher ranked terrestrial game. This is consistent with findings at other, still terrestrial and somewhat younger, coastal sites along the coastline of the Southeast United States. In turn, these findings argue for extending coastal occupation patterns from later periods into the offshore, older locations, and further suggests that low mobility coastal occupations may have greater antiquity in this region than were heretofore thought to exist.

As a follow on to lithic analyses in Chapter 3, and other previous studies by other scholars, Chapter 4 examines geochemical corrosion in durable materials such as stone and bone in greater detail. This chapter builds on earlier work by other scholars such as Purdy and Lowery that has identified specific geochemical processes that occur in lithics when they are deposited in upland terrestrial zones that are submerged by first tidal marsh and then finally open marine conditions. These geochemical changes manifest as the formation of sulfide minerals within the pore spaces of a lithic item. These minerals can only form in anoxic, organic rich environments such as tidal marsh sediments. Once aerobic conditions are restored, these chemical reactions run in reverse, forming oxides and another particularly problematic reaction by-product: sulfuric acid that corrodes the surface of the lithic item, sometimes past the point at which it can be recognized as artifacts modified by human hands. Chapter 4 documents this process in an artifact from the submerged site at Douglass Beach, Florida. This process did not destroy the item in question to the point at which a projectile point type – the (hypothetically) Late Paleoindian Suwannee type - could be assigned, but did remove morphological characteristics such as flake scars usually required by analysts for classification as an artifact. I used this finding as reasonable grounds to reject the notion that lithic items must retain flake scarring to be considered anthropogenic, and instead proposed multiple other criteria for classifying a corroded lithic (or bone) item as an artifact once evidence for this particular form of geochemical corrosion can be demonstrated. I then examined a corroded assemblage from an Early-Middle Archaic submerged site in Apalachee Bay using the same methods as the Douglass Beach point, and, using my new criteria, argue that this assemblage should be treated as artifacts. The additional finding that this assemblage was composed of very high grade, cryptocrystalline dolomitized material (a carbonate rock, unlike chert, which is a silicate) instead of local or exotic chert, complicates the lithic landscape. Unlike the Douglass Beach point, which was probably made from Tampa Bay Bottom chert obtained over 150 km from the artifact's final resting place, this assemblage was made of presumably local material that occurs in the same locations as high grade chert. During this period, it was thought that chert would have been used to the exclusion of other rock types, and would have been deliberately sought out if not locally available. This finding raises questions about how prehistoric people evaluated geologic resources such as raw stone materials, and suggests that local access to "good enough" rock was sufficient instead of a specific rock type recognized by modern geologists and archaeologists. Again, cultural views are evident in the way that prehistoric groups used their landscape on this drowned continental shelf.

Finally, in Chapter 5, I synthesize findings from the work at Econfina Channel, and earlier work by others at several nearby sites within Apalachee Bay. This chapter's purpose is to examine how well each of these sites conform to known site types for the region, predicted landscape use based on changing ecology proposed by earlier scholars such as Dunbar, ethnoarchaeological observations for human behaviors such as site type and mobility patterns, and the earlier findings from the predictive model study in Chapter 2. A priori site types and predictions are a necessary straw man in the argument over site use interpretations that allows us to refine our understanding of human behaviors. However, by instead treating artifacts and features at each site as non-essentialist assemblages that exist along continuums that reflect both the wide range of human behaviors and post-depositional processes, similarities and differences between each site can be better defined and interpreted. These comparisons have shown that each site was used somewhat differently, and does not necessarily wholly correspond to the known site types and ecological prediction models to different degrees. Cultural decisions to prefer the Aucilla River during earlier periods, or cultural decisions to focus on estuarine and marine resources over terrestrial ones, can be detected in the findings. However, these cultural decisions were made within an overarching environmental context, and it is this nuance that is often lost in essentialist definitions of “site type”, whether those types are based solely on ecological contexts or entirely divorced from them.

In summary, then, this study has highlighted and added to conversations around several important issues in submerged prehistoric archaeology. The first is the need to ask anthropological questions of these sites, instead of merely documented and describing them. The second is the need to focus on discussions around when, how, and in what manner coastal occupations differed from inland ones. Clearly, environmental contexts matter, but so do cultural ones, and within every single chapter, instances of cultural choice layered on top of environmental possibility can been clearly seen. This is true not merely in spite of, but often in tandem with, the effects of post-depositional processes, and Chapter 4 in particular demonstrates this. Studies using this hybrid approach during examinations of submerged landscapes have much to offer when adding to the corpus of our understanding of human behaviors in non-analog ecological conditions and periods.

APPENDIX A Climate normals data

Evaporation and/or climate data source:	
Source for climate data:	NCDC 1961-1990 normals, Southeast Regional Climate Center
Source for evaporation data:	http://www.nws.noaa.gov/oh/hdsc/PMP_related_studies/TR34.pdf

St. Mark's 5 SSE FL **87867**								**Date Created:**	4/6/07	
								Last Modified:		
								Modified By:	Jessica Cook Hale	
	Precip mm	**Tmax C**	**Tmin C**	**Tmean C**	**Evap mm**	**Snow mm**	**Rain Days**	**Days < 0°C**	**Days > 40°C**	
Jan	128.02	16.33	5.06	10.69	0.70	0.00	8.00	5.60	0.00	
Feb	110.74	17.78	6.33	12.06	1.18	0.50	7.00	4.20	0.00	
Mar	120.40	21.67	10.00	15.83	1.64	0.00	8.00	1.40	0.00	
Apr	95.76	25.94	14.06	20.00	2.46	0.00	5.00	0.00	0.00	
May	89.92	29.33	17.72	23.53	2.45	0.00	6.00	0.00	0.00	
Jun	130.30	32.11	20.83	26.47	3.56	0.00	9.00	0.00	0.00	
Jul	190.50	32.67	22.17	27.42	3.56	0.00	13.00	0.00	0.00	
Aug	167.64	32.56	22.11	27.33	3.59	0.00	12.00	0.00	0.00	
Sep	132.33	31.28	20.22	25.75	2.26	0.00	9.00	0.00	0.00	
Oct	78.23	27.39	14.67	21.03	1.95	0.00	5.00	0.10	0.00	
Nov	69.60	20.83	8.56	14.69	1.49	0.00	6.00	2.00	0.00	
Dec	111.51	18.00	6.44	12.22	0.96	0.00	7.00	5.80	0.00	
Annual	**1424.94**	**25.61**	**14.11**	**19.86**	**25.80**	**0.00**	**96.00**	**19.00**	**0.00**	

Belle Glade Experiment Station								Date Created:	4/6/07	Version 2007
FL								Last Modified:	3/12/16	
							80611	Modified By:	Jessica Cook Hale	
	Precip mm	**Tmax C**	**Tmin C**	**Tmean C**	**Evap mm**	**Snow mm**	**Rain Days**	**Days < 0°C**	**Days > 40°C**	
Jan	51.56	23.50	10.61	17.06	85.43	0.00	7.00	0.90	0.00	
Feb	50.80	24.22	11.06	17.67	101.75	0.00	6.00	0.30	0.10	
Mar	71.37	26.50	13.50	20.00	145.35	0.00	7.00	0.20	0.60	
Apr	58.67	28.50	15.00	21.78	164.48	0.00	6.00	0.70	2.40	
May	135.64	30.33	18.00	24.22	180.29	0.00	9.00	0.00	7.70	
Jun	196.09	31.67	20.83	26.28	160.40	0.00	16.00	0.00	15.40	
Jul	194.56	32.56	21.61	27.11	161.42	0.00	17.00	0.00	22.50	
Aug	184.15	32.61	21.67	27.17	156.83	0.00	17.00	0.00	24.00	
Sep	182.37	31.78	21.28	26.56	135.15	0.00	17.00	0.00	15.70	
Oct	90.42	29.61	18.44	24.06	120.62	0.00	11.00	0.00	3.80	
Nov	52.58	26.67	14.89	20.83	93.33	0.00	7.00	0.00	0.10	
Dec	42.93	24.22	11.83	18.06	80.07	0.00	6.00	0.60	0.00	
Annual	**1311.15**	28.50	16.56	22.56	**1585.08**	**0.00**	**125.00**	**2.70**	**92.30**	

Lake City 2 E FL 84731								Date Created:	4/6/07	Version 2007
								Last Modified:		
								Modified By:	Jessica Cook Hale	
	Precip mm	**Tmax C**	**Tmin C**	**Tmean C**	**Evap mm**	**Snow mm**	**Rain Days**	**Days < 0°C**	**Days > 40°C**	
Jan	105.66	17.72	4.89	11.33	75.95	0.00	9.00	5.80	0.00	
Feb	107.70	19.33	6.06	12.72	95.50	0.00	8.00	3.50	0.00	
Mar	118.11	23.28	9.61	16.50	144.78	0.00	8.00	1.10	0.40	
Apr	77.47	26.83	12.56	19.72	179.32	0.00	6.00	0.00	1.50	
May	112.52	29.89	16.22	23.06	195.58	0.00	8.00	0.00	10.20	
Jun	171.70	32.11	19.89	26.00	191.77	0.00	13.00	0.00	18.70	
Jul	178.05	32.83	21.33	27.11	190.25	0.00	16.00	0.00	21.70	
Aug	199.64	32.67	21.22	27.00	167.39	0.00	15.00	0.00	21.90	
Sep	129.03	31.00	19.72	25.39	150.37	0.00	11.00	0.00	13.20	
Oct	52.83	27.17	14.39	20.78	125.48	0.00	6.00	0.00	1.90	
Nov	62.99	23.06	10.00	16.56	90.42	0.00	6.00	1.40	0.00	
Dec	93.73	19.22	6.28	12.78	75.69	0.00	8.00	4.60	0.00	
Annual	**1409.45**	**26.28**	**13.50**	**19.89**	**1682.49**	**0.00**	**114.00**	**16.40**	**89.50**	

Titusville FL 88942								Date Created: Last Modified: Modified By:	3/16/15 3/16/15 Jessica Cook Hale	Version 2007
	Precip mm	**Tmax C**	**Tmin C**	**Tmean C**	**Evap mm**	**Snow mm**	**Rain Days**	**Days < 0°C**	**Days > 40°C**	
Jan	61.47	21.06	8.50	14.78	74.93	0.00	7.00	1.50	0.00	
Feb	81.28	21.83	9.00	15.44	94.23	0.00	7.00	0.80	0.00	
Mar	78.99	24.83	12.00	18.39	143.51	0.00	7.00	0.20	0.70	
Apr	51.56	27.94	14.83	21.39	181.36	0.00	6.00	0.00	2.30	
May	95.50	30.39	18.00	24.22	202.44	0.00	8.00	0.00	8.40	
Jun	172.97	32.11	20.89	26.50	192.79	0.00	13.00	0.00	16.10	
Jul	204.47	33.00	21.67	27.39	181.36	0.00	14.00	0.00	22.70	
Aug	193.80	32.89	21.94	27.44	170.43	0.00	13.00	0.00	22.60	
Sep	182.88	31.39	21.50	26.44	145.80	0.00	13.00	0.00	12.70	
Oct	104.90	28.33	18.06	23.22	126.24	0.00	11.00	0.00	3.00	
Nov	84.84	25.06	13.50	19.28	91.44	0.00	7.00	0.10	0.20	
Dec	60.71	22.44	10.06	16.22	71.63	0.00	7.00	0.90	0.00	
Annual	**1373.38**	**27.61**	**15.83**	**21.72**	**1676.15**	**0.00**	**113.00**	**3.50**	**88.70**	

Monticello 3 W FL **85879**								Date Created:	4/6/07	Version 2007
								Last Modified:	10/22/14	
								Modified By:	Jessica Cook Hale	
	Precip mm	**Tmax C**	**Tmin C**	**Tmean C**	**Evap mm**	**Snow mm**	**Rain Days**	**Days < 0°C**	**Days > 40°C**	
Jan	123.19	16.67	3.06	9.86	0.7	0	9	0.10	0.00	
Feb	130.05	18.56	4.44	11.50	1.18	3	8	0.00	0.00	
Mar	127.00	22.39	8.28	15.33	1.64	0	8	0.00	0.10	
Apr	99.06	26.06	11.78	18.92	2.46	0	7	0.00	0.80	
May	104.90	29.61	15.67	22.64	2.45	0	7	0.00	8.70	
Jun	140.72	32.00	19.22	25.61	3.56	0	12	0.00	17.30	
Jul	166.12	32.67	20.67	26.67	3.56	0	15	0.00	20.10	
Aug	153.16	32.33	20.50	26.42	3.59	0	14	0.00	19.80	
Sep	102.87	30.67	18.22	24.44	2.26	0	9	0.00	12.90	
Oct	69.34	26.78	12.22	19.50	1.95	0	6	0.00	2.00	
Nov	85.85	20.89	6.67	13.78	1.49	0	6	0.00	0.00	
Dec	123.44	18.33	4.39	11.36	0.96	0	8	0.00	0.00	
Annual	**1425.96**	**25.72**	**12.17**	**18.94**	**25.8**	**3**	**110**	**0.10**	**81.80**	

Lisbon FL 85076								Date Created:	4/6/07	Version 2007
								Last Modified:		
								Modified By:	Jessica Cook Hale	
	Precip mm	**Tmax C**	**Tmin C**	**Tmean C**	**Evap mm**	**Snow mm**	**Rain Days**	**Days < 0°C**	**Days > 40°C**	
Jan	74.46	20.11	13.61	7.06	70.13	0.00	8.00	3.20	0.00	
Feb	86.45	21.11	14.56	7.94	84.15	0.00	7.00	1.50	0.00	
Mar	90.02	24.33	17.72	11.06	127.76	0.00	7.00	0.30	0.10	
Apr	59.67	27.39	20.78	14.17	168.05	0.00	5.00	0.00	1.40	
May	102.51	30.22	24.06	17.83	196.35	0.00	7.00	0.00	8.60	
Jun	149.18	32.11	26.67	21.11	192.53	0.00	14.00	0.00	16.60	
Jul	157.85	32.78	27.39	22.06	168.05	0.00	16.00	0.00	22.00	
Aug	156.83	32.72	27.44	22.17	150.96	0.00	16.00	0.00	22.10	
Sep	124.70	31.44	26.33	21.22	125.97	0.00	13.00	0.00	12.60	
Oct	55.08	28.39	22.67	16.89	125.97	0.00	8.00	0.00	2.00	
Nov	52.53	24.44	18.33	12.17	81.86	0.00	7.00	0.20	0.00	
Dec	65.54	21.22	14.89	8.50	68.60	0.00	8.00	1.70	0.00	
Annual	**1174.79**	**27.17**	**21.22**	**15.17**	**1560.35**	**0.00**	**116.00**	**6.90**	**85.40**	

Pensacola Airport FL **86997**								**Date Created:** **Last Modified:** **Modified By:**	4/6/07 12/6/14 Jessica Cook Hale	**Version 2007**
	Precip mm	**Tmax C**	**Tmin C**	**Tmean C**	**Evap mm**	**Snow mm**	**Rain Days**	**Days < 0°C**	**Days > 40°C**	
Jan	125.73	15.56	5.44	10.50	65.53	2.54	10	5.80	0	
Feb	135.38	17.44	7.06	12.25	82.80	0	9	3.00	0	
Mar	133.86	20.89	10.72	15.81	126.74	0	9	0.70	0	
Apr	91.44	24.61	14.56	19.58	158.75	0	7	0.00	0.1	
May	109.73	28.44	18.72	23.58	178.30	0	7	0.00	3.1	
Jun	155.96	31.39	22.06	26.72	179.83	0	10	0.00	13.7	
Jul	187.20	32.11	23.33	27.72	166.62	0	14	0.00	18.4	
Aug	195.07	31.72	23.22	27.47	153.67	0	13	0.00	17.9	
Sep	134.62	30.17	21.00	25.58	133.85	0	9	0.00	9	
Oct	96.52	26.17	15.39	20.78	119.38	0	5	0.00	0.6	
Nov	92.96	19.94	9.56	14.75	80.77	0	7	0.80	0	
Dec	111.76	17.22	7.00	12.11	58.92	0	9	4.10	0	
Annual	**1570.74**	**24.78**	**14.94**	**19.86**	**1505.21**	**0**	**109**	**14.40**	**62.8**	

Lake Alfred Experiment Station FL 84707								**Date Created:** **Last Modified:** **Modified By:**	4/6/07 Jessica Cook Hale	**Version 2007**
	Precip mm	**Tmax C**	**Tmin C**	**Tmean C**	**Evap mm**	**Snow mm**	**Rain Days**	**Days < 0°C**	**Days > 40°C**	
Jan	57.89	21.67	8.00	14.83	84.91	0	6	2.20	0.00	
Feb	79.05	22.67	8.89	15.83	99.70	0	6	1.10	0.10	
Mar	88.49	25.67	12.06	18.89	153.25	0	7	0.20	0.90	
Apr	35.19	28.50	14.50	21.56	187.93	0	5	0.00	3.80	
May	112.71	31.17	17.89	24.50	208.08	0	8	0.00	13.70	
Jun	177.99	32.67	21.11	26.94	184.36	0	13	0.00	20.90	
Jul	174.17	33.33	22.00	27.72	186.91	0	15	0.00	25.20	
Aug	187.94	33.33	22.11	27.72	176.46	0	15	0.00	25.80	
Sep	147.65	32.33	21.11	26.72	157.33	0	13	0.00	19.50	
Oct	64.26	29.50	17.11	23.28	135.15	0	7	0.00	5.80	
Nov	54.32	25.89	12.89	19.39	99.45	0	5	0.30	0.20	
Dec	49.22	22.83	9.33	16.11	78.79	0	5	1.40	0.00	
Annual	**1228.85**	**28.28**	**15.61**	**21.94**	**1752.36**	**0**	**105**	**5.20**	**115.90**	

Vero Beach 4 FL **89219**								**Date Created:**	4/6/07	**Version 2007**
								Last Modified:		
								Modified By:	Jessica Cook Hale	
	Precip mm	**Tmax C**	**Tmin C**	**Tmean C**	**Evap mm**	**Snow mm**	**Rain Days**	**Days < 0°C**	**Days > 40°C**	
Jan	55.85	22.56	10.06	16.33	71.4	0	9	1.30	0.00	
Feb	74.21	23.17	10.67	16.89	91.8	0	8	0.50	0.00	
Mar	80.07	25.44	13.44	19.44	138.72	0	8	0.10	0.30	
Apr	51.51	27.72	15.61	21.72	169.32	0	7	0.00	1.40	
May	116.28	29.83	18.56	24.22	180.28	0	10	0.00	4.40	
Jun	169.83	31.33	21.17	26.28	169.83	0	14	0.00	11.00	
Jul	163.46	32.39	22.00	27.22	169.32	0	14	0.00	18.50	
Aug	166.52	32.39	22.28	27.33	161.16	0	15	0.00	19.30	
Sep	189.72	31.39	21.94	26.67	128.26	0	16	0.00	10.70	
Oct	147.39	29.00	19.00	24.00	122.65	0	13	0.00	2.10	
Nov	84.15	26.06	15.11	20.61	84.40	0	10	0.00	0.10	
Dec	54.57	23.44	11.50	17.50	67.32	0	8	0.60	0.00	
Annual	**1353.54**	**27.89**	**16.78**	**22.33**	**1554.48**	**0**	**132**	**2.50**	**67.80**	

Loxahatchee FL 93271								Date Created: Last Modified: Modified By:	4/6/07 3/13/16 Jessica Cook Hale	Version 2007
	Precip mm	**Tmax C**	**Tmin C**	**Tmean C**	**Evap mm**	**Snow mm**	**Rain Days**	**Days < 0°C**	**Days > 40°C**	
Jan	63.50	24.50	11.00	17.94	80.83	0	6	0.90	0.00	
Feb	62.48	25.22	11.11	18.33	97.15	0	6	0.30	0.20	
Mar	82.55	27.22	13.17	20.39	134.64	0	6	0.20	1.50	
Apr	61.72	29.22	14.94	22.06	159.88	0	6	0.00	4.50	
May	140.46	31.00	17.72	24.39	176.97	0	10	0.00	10.60	
Jun	230.89	32.06	20.39	26.33	157.33	0	15	0.00	18.00	
Jul	184.91	32.89	21.33	27.17	153.25	0	16	0.00	24.00	
Aug	163.07	33.11	21.44	27.33	150.70	0	16	0.00	25.80	
Sep	209.04	32.11	21.06	26.72	131.58	0	16	0.00	18.00	
Oct	137.41	29.89	18.72	24.39	116.02	0	12	0.00	5.10	
Nov	86.87	25.78	14.06	21.28	86.7	0	7	0.00	0.30	
Dec	53.34	25.44	12.44	18.78	71.65	0	7	0.60	0.10	
Annual	**1476.25**	**29.17**	**16.56**	**22.94**	**1516.74**	**0**	**123**	**2.00**	**108.10**	

St. Mark's 5 SSE FL **87867**								**Date Created:**	4/6/07	**Version 2007**
								Last Modified:	10/21/14	
								Modified By:	Jessica Cook Hale	
	Precip mm	**Tmax C**	**Tmin C**	**Tmean C**	**Evap mm**	**Snow mm**	**Rain Days**	**Days < 0°C**	**Days > 40°C**	
Jan	128.02	16.33	5.06	10.69	0.70	0	8	5.60	0.00	
Feb	110.74	17.78	6.33	12.06	1.18	0.5	7	4.20	0.00	
Mar	120.40	21.67	10.00	15.83	1.64	0	8	1.40	0.00	
Apr	95.76	25.94	14.06	20.00	2.46	0	5	0.00	0.00	
May	89.92	29.33	17.72	23.53	2.45	0	6	0.00	0.00	
Jun	130.30	32.11	20.83	26.47	3.56	0	9	0.00	0.00	
Jul	190.50	32.67	22.17	27.42	3.56	0	13	0.00	0.00	
Aug	167.64	32.56	22.11	27.33	3.59	0	12	0.00	0.00	
Sep	132.33	31.28	20.22	25.75	2.26	0	9	0.00	0.00	
Oct	78.23	27.39	14.67	21.03	1.95	0	5	0.10	0.00	
Nov	69.60	20.83	8.56	14.69	1.49	0	6	2.00	0.00	
Dec	111.51	18.00	6.44	12.22	0.96	0	7	5.80	0.00	
Annual	**1424.94**	**25.61**	**14.11**	**19.86**	**25.80**	**0**	**96**	**19.00**	**0.00**	

Savannah GA **WSO Airport NOAA weather station**								**Date Created:**	4/6/07	**Version 2007**
								Last Modified:	10/30/14	
								Modified By:	Jessica Cook Hale	
	Precip mm	**Tmax C**	**Tmin C**	**Tmean C**	**Evap mm**	**Snow mm**	**Rain Days**	**Days < 0°C**	**Days > 40°C**	
Jan	91.19	15.39	9.78	12.58	0.00	1.016	9	0.10	0.00	
Feb	81.79	16.89	11.72	14.31	0.00	4.572	8	0.00	0.00	
Mar	96.01	21.17	18.06	19.61	0.00	0.508	8	0.00	0.10	
Apr	76.96	25.28	21.56	23.42	0.00	0	7	0.00	1.20	
May	103.89	28.89	26.33	27.61	0.00	0	8	0.00	6.50	
Jun	143.76	31.56	29.33	30.44	159.00	0	11	0.00	15.50	
Jul	162.05	32.83	29.94	31.39	195.07	0	13	0.00	21.50	
Aug	189.48	32.06	29.89	30.97	166.11	0	13	0.00	18.90	
Sep	113.54	29.56	27.17	28.36	147.32	0	10	0.00	7.50	
Oct	60.71	25.28	22.00	23.64	130.55	0	6	0.00	0.50	
Nov	55.63	21.11	16.83	18.97	75.18	0	6	0.00	0.00	
Dec	75.18	16.83	12.44	14.64	76.96	1.778	8	0.00	0.00	
Annual	**1250.19**	**24.72**	**23.67**	**24.19**	**950.214**	**8.636**	**109**	**0.20**	**0.00**	

Tifton GA								**Date Created:**	4/6/07	**Version 2007**
								Last Modified:	10/31/14	
								Modified By:	Jessica Cook	
	Precip mm	**Tmax C**	**Tmin C**	**Tmean C**	**Evap mm**	**Snow mm**	**Rain Days**	**Days < 0°C**	**Days > 40°C**	
Jan	111.00	15.50	2.50	9.00	51.56	2.54	9	0.20	0.00	
Feb	110.49	17.72	3.61	10.67	83.82	2.54	8	0.00	0.00	
Mar	114.30	21.78	7.11	14.44	121.41	0	9	0.00	0.00	
Apr	82.80	25.94	11.28	18.61	132.33	0	6	0.00	0.80	
May	92.20	29.61	15.67	22.64	143.76	0	7	0.00	7.90	
Jun	109.98	32.28	19.11	25.69	152.65	0	9	0.00	18.70	
Jul	127.51	33.44	21.00	27.22	150.62	0	10	0.00	24.50	
Aug	127.00	32.78	20.89	26.83	110.23	0	10	0.00	22.50	
Sep	83.06	30.44	18.17	24.31	150.36	0	7	0.00	10.60	
Oct	57.91	26.44	12.50	19.47	106.68	0	5	0.00	1.10	
Nov	61.21	20.22	6.33	13.28	80.26	0	6	0.00	0.00	
Dec	99.31	17.22	3.78	10.50	66.04	0	8	0.10	0.00	
Annual	**1176.78**	**25.39**	**11.89**	**18.64**	**1349.75**	**5.08**	**94**	**0.30**	**86.20**	

Ailey GA **90090**								**Date Created:**	4/6/07	**Version 2007**
								Last Modified:	10/31/14	
								Modified By:	Jessica Cook	
	Precip mm	**Tmax C**	**Tmin C**	**Tmean C**	**Evap mm**	**Snow mm**	**Rain Days**	**Days < 0°C**	**Days > 40°C**	
Jan	111.00	15.50	2.50	9.00	51.56	2.54	9	0.20	0.00	
Feb	110.49	17.72	3.61	10.67	83.82	2.54	8	0.00	0.00	
Mar	114.30	21.78	7.11	14.44	121.41	0	9	0.00	0.00	
Apr	82.80	25.94	11.28	18.61	132.33	0	6	0.00	0.80	
May	92.20	29.61	15.67	22.64	143.76	0	7	0.00	7.90	
Jun	109.98	32.28	19.11	25.69	152.65	0	9	0.00	18.70	
Jul	127.51	33.44	21.00	27.22	150.62	0	10	0.00	24.50	
Aug	127.00	32.78	20.89	26.83	110.23	0	10	0.00	22.50	
Sep	83.06	30.44	18.17	24.31	150.36	0	7	0.00	10.60	
Oct	57.91	26.44	12.50	19.47	106.68	0	5	0.00	1.10	
Nov	61.21	20.22	6.33	13.28	80.26	0	6	0.00	0.00	
Dec	99.31	17.22	3.78	10.50	66.04	0	8	0.10	0.00	
Annual	**1176.78**	**25.39**	**11.89**	**18.64**	**1349.75**	**5.08**	**94**	**0.30**	**86.20**	

Homerville, GA GA **94429**								**Date Created:**	4/6/07	**Version 2007**
								Last Modified:	10/30/14	
								Modified By:	Jessica Cook Hale	
	Precip mm	**Tmax C**	**Tmin C**	**Tmean C**	**Evap mm**	**Snow mm**	**Rain Days**	**Days < 0°C**	**Days > 40°C**	
Jan	110.74	16.22	2.78	0.43	0.00	0	10	5.95	0.00	
Feb	111.00	18.00	3.78	1.33	46.73	2.54	9	3.90	0.00	
Mar	120.40	22.00	7.33	3.43	81.53	0	9	1.70	0.00	
Apr	92.71	26.06	11.00	5.15	120.65	0	6	0.10	0.55	
May	95.50	29.39	14.89	6.85	150.62	0	8	0.00	4.10	
Jun	137.67	32.11	18.83	8.67	146.05	0	12	0.00	9.55	
Jul	161.80	33.00	20.33	9.38	139.70	0	1	0.00	12.35	
Aug	167.39	32.50	20.44	9.19	115.82	0	13	0.00	11.35	
Sep	107.70	30.39	18.72	7.48	88.64	0	10	0.00	6.05	
Oct	57.40	26.06	12.50	4.77	73.40	0	6	0.25	0.50	
Nov	66.04	21.61	7.44	2.64	42.16	0	7	2.10	0.00	
Dec	107.44	17.67	3.94	1.12	19.81	0	8	5.40	0.00	
Annual	**1335.79**	**25.44**	**11.83**	**18.44**	**1059.688**	**2.54**	**99**	**19.40**	**44.45**	

Columbus airport GA **92166**								**Date Created:**	4/6/07	**Version 2007**
								Last Modified:	12/6/14	
								Modified By:	Jessica Cook Hale	
	Precip mm	**Tmax C**	**Tmin C**	**Tmean C**	**Evap mm**	**Snow mm**	**Rain Days**	**Days < 0°C**	**Days > 40°C**	
Jan	105.16	14.22	2.50	8.36	26.92	7.62	10	12.60	0.00	
Feb	114.30	16.39	3.83	10.11	44.81	2.54	9	8.10	0.00	
Mar	143.76	20.50	7.28	13.89	79.50	0	10	3.10	0.00	
Apr	101.09	25.06	11.22	18.14	117.34	0	8	0.20	0.40	
May	95.25	28.93	16.17	22.55	153.16	0	8	0.00	6.10	
Jun	99.57	32.11	20.39	26.25	164.84	0	10	0.00	16.80	
Jul	134.11	33.11	22.17	27.64	155.19	0	13	0.00	21.90	
Aug	101.09	32.83	21.83	27.33	135.38	0	10	0.00	20.80	
Sep	83.82	30.06	19.00	24.53	97.53	0	8	0.00	9.90	
Oct	57.91	25.11	12.39	18.75	72.89	0	6	0.20	0.70	
Nov	91.95	19.83	6.78	13.31	36.57	0	8	3.90	0.00	
Dec	115.06	15.22	3.39	9.31	14.47	17.78	9	10.60	0.00	
Annual	**1242.57**	**24.44**	**12.22**	**18.33**	**1098.65**	**27.94**	**109**	**38.70**	**76.60**	

Calhoun Experiment Station GA **91474**							**Date Created:**	4/6/07	**Version 2007**
							Last Modified:		
							Modified By:	Jessica Cook Hale	
	Precip mm	**Tmax C**	**Tmin C**	**Tmean C**	**Evap mm**	**Snow mm**	**Rain Days**	**Days < 0°C**	**Days > 40°C**
Jan	132.35	9.56	3.11	-3.33	0	20.4	11	20.70	0.00
Feb	129.29	12.33	5.44	-1.44	0	7.65	10	16.20	0.00
Mar	164.22	17.28	10.22	3.11	118.06	12.75	11	9.80	0.00
Apr	123.17	22.39	14.89	7.39	146.62	2.55	9	2.30	0.10
May	123.93	26.39	19.17	11.89	154.02	0	9	0.00	2.40
Jun	103.79	30.33	23.39	16.39	184.62	0	9	0.00	10.30
Jul	124.19	31.83	25.22	18.56	184.87	0	10	0.00	17.20
Aug	87.72	31.44	24.83	18.22	166.77	0	8	0.00	15.60
Sep	105.32	28.28	21.50	14.67	133.36	0	8	0.00	5.80
Oct	83.13	22.78	14.94	7.00	107.61	0	6	2.90	0.10
Nov	106.34	17.28	9.94	2.61	76.50	0	8	11.80	0.00
Dec	128.01	11.61	5.17	-1.28	76.50	2.55	10	18.60	0.00
Annual	**1411.43**	**21.78**	**14.83**	**7.83**	**1348.95**	**45.9**	**109**	**82.30**	**51.50**

Experiment GA 93271								**Date Created:** **Last Modified:** **Modified By:**	4/6/07 Jessica Cook Hale	**Version 2007**
	Precip mm	**Tmax C**	**Tmin C**	**Tmean C**	**Evap mm**	**Snow mm**	**Rain Days**	**Days < 0°C**	**Days > 40°C**	
Jan	124.44	10.83	-0.61	5.11	65.535	7.65	11	14.40	0.00	
Feb	120.87	13.28	0.78	7.06	79.05	5.1	10	10.90	0.00	
Mar	143.82	18.11	5.22	11.67	121.89	2.55	10	5.20	0.00	
Apr	113.99	22.78	9.56	16.17	159.63	0	8	0.70	0.00	
May	110.93	26.56	13.94	20.28	192.01	0	9	0.00	2.40	
Jun	102.77	30.06	18.06	24.11	202.98	0	10	0.00	9.70	
Jul	124.19	31.33	19.83	25.61	193.29	0	12	0.00	13.80	
Aug	108.63	30.94	19.44	25.22	177.22	0	10	0.00	12.30	
Sep	78.54	28.22	16.33	22.28	143.05	0	8	0.00	5.30	
Oct	77.78	23.22	9.50	16.39	110.16	0	6	0.50	0.40	
Nov	89.25	18.22	5.39	11.83	77.52	2.55	8	5.50	0.00	
Dec	117.81	13.06	1.17	7.11	60.18	2.55	10	12.70	0.00	
Annual	**1313.00**	**22.22**	**9.89**	**16.06**	**1582.53**	**20.4**	**112**	**49.90**	**43.90**	

Allatoona Dam 2 GA **90181**							**Date Created:**	4/6/07	**Version 2007**
							Last Modified:		
							Modified By:	Jessica Cook Hale	
	Precip mm	**Tmax C**	**Tmin C**	**Tmean C**	**Evap mm**	**Snow mm**	**Rain Days**	**Days < 0°C**	**Days > 40°C**	
Jan	128.01	9.39	3.39	-2.61	70.38	25.5	11	19.70	0.00	
Feb	116.79	12.06	5.50	-1.06	81.6	0	10	15.40	0.00	
Mar	148.67	17.67	10.61	3.50	122.91	0	11	8.30	0.40	
Apr	127.50	22.50	15.39	8.22	156.06	0	9	1.20	0.10	
May	113.99	26.11	19.56	13.06	181.81	0	9	0.00	1.80	
Jun	91.55	29.78	23.67	17.56	190.99	0	9	0.00	9.10	
Jul	120.11	31.33	25.44	19.56	194.56	0	11	0.00	14.40	
Aug	99.96	30.89	25.17	19.39	174.16	0	9	0.00	13.50	
Sep	93.08	27.39	21.83	16.28	143.82	0	8	0.00	4.20	
Oct	80.58	21.89	15.50	9.11	107.35	0	7	0.80	0.10	
Nov	97.67	16.94	10.78	4.61	77.26	0	9	7.20	0.00	
Dec	112.46	11.44	5.61	-0.28	64.51	0	10	17.80	0.00	
Annual	**1330.34**	**21.44**	**15.22**	**8.94**	**1565.44**	**25.5**	**113**	**70.40**	**43.60**	

Sapelo Island GA **97808**								**Date Created:** **Last Modified:** **Modified By:**	4/6/07 10/20/14 Jessica Cook Hale	**Version 2007**
	Precip mm	**Tmax C**	**Tmin C**	**Tmean C**	**Evap mm**	**Snow mm**	**Rain Days**	**Days < 0°C**	**Days > 40°C**	
Jan	96.52	15.94	4.83	10.39	33.02	0	9	0.00	0.00	
Feb	97.79	17.50	5.94	11.72	47.75	0	8	0.00	0.00	
Mar	99.57	20.94	9.61	15.28	84.83	0	8	0.00	0.00	
Apr	76.20	24.50	13.33	18.92	126.49	0	6	0.00	0.70	
May	79.25	27.72	17.61	22.67	161.54	0	7	0.00	2.90	
Jun	125.73	30.33	20.94	25.64	166.11	0	10	0.00	9.40	
Jul	153.67	31.89	22.56	27.22	168.40	0	11	0.00	16.80	
Aug	188.47	31.33	22.56	26.94	134.11	0	11	0.00	13.50	
Sep	165.35	29.28	20.94	25.11	101.85	0	11	0.00	4.20	
Oct	81.28	25.44	15.78	20.61	79.75	0	7	0.00	0.40	
Nov	69.09	19.94	9.56	14.75	43.68	0	6	0.00	0.00	
Dec	86.61	17.39	6.61	12.00	19.05	2.54	8	0.10	0.00	
Annual	**1319.53**	**24.50**	**14.28**	**19.39**	**1166.62**	**2.54**	**102**	**0.10**	**47.80**	

Table 6.1:Early Archaic sites, all environmental variables

FID	To_springs	To_water	To_karst	To_chert	To_20mcoas	To_Aucilla	NPP	Precip_var
0	5.68	1.54	12.10	0.00	104.37	1.54	1904.43	23.27
1	9.98	3.65	17.92	0.00	108.23	3.65	1902.40	22.87
2	6.82	5.11	17.10	0.37	126.11	5.11	1920.74	25.58
3	6.47	4.66	17.86	1.00	126.17	4.66	1920.33	25.60
4	6.91	4.94	16.92	0.22	126.10	4.94	1920.84	25.57
5	2.29	0.42	4.77	0.00	97.76	0.42	1908.02	23.64
6	5.49	1.52	13.76	0.00	113.46	1.52	1898.12	22.71
7	8.16	3.92	16.01	0.18	126.87	3.92	1920.71	25.51
8	9.03	1.85	13.82	0.00	125.75	1.85	1922.31	25.49
9	1.05	0.17	6.38	0.00	99.29	0.17	1906.94	23.57
10	22.74	6.90	6.77	0.00	139.48	16.06	1893.26	21.44
11	4.98	0.27	22.37	0.00	125.35	0.27	1919.78	25.77
12	2.69	0.04	9.69	0.00	102.64	0.04	1919.38	23.47
13	1.23	0.03	8.25	0.00	101.23	0.03	1916.17	23.77
14	1.11	0.05	8.12	0.00	101.09	0.05	1915.09	23.75
15	0.68	0.01	7.68	0.00	100.66	0.01	1913.67	23.75
16	0.47	0.01	7.50	0.00	100.50	0.01	1915.13	23.86
17	3.46	0.05	10.49	0.00	103.47	0.05	1926.13	23.43
18	10.59	1.26	18.05	0.00	109.07	1.26	1901.24	22.96
19	1.04	0.05	8.04	0.00	101.01	0.05	1914.45	23.74
20	0.97	0.00	7.95	0.00	100.92	0.00	1913.45	23.71
21	0.41	0.05	7.43	0.00	100.43	0.05	1916.70	23.98
22	49.38	3.72	10.58	1.27	169.28	3.72	1886.84	23.51
23	5.06	1.28	11.86	0.00	104.55	1.28	1910.14	23.32
24	7.99	5.21	14.91	2.70	108.94	12.47	1904.60	22.43
25	21.04	0.02	8.84	10.84	79.04	0.02	1919.85	24.24

FID	To_springs	To_water	To_karst	To_chert	To_20mcoas	To_Aucilla	NPP	Precip_var
26	17.20	0.33	3.65	7.18	83.02	0.33	1932.82	24.39
27	2.40	0.20	4.64	0.00	97.64	0.20	1908.04	23.66
28	1.76	0.01	5.28	0.00	98.28	0.01	1907.57	23.63
29	5.76	5.53	4.50	0.00	119.77	10.70	1896.51	22.03
30	2.44	0.07	4.61	0.00	97.62	0.07	1908.03	23.67
31	2.31	0.29	4.73	0.00	97.73	0.29	1908.00	23.65
32	9.21	1.12	6.22	0.97	128.78	1.12	1907.69	23.63
33	2.25	0.53	4.83	0.00	97.80	0.53	1908.02	23.64
34	2.04	0.03	5.01	0.00	98.02	0.03	1907.71	23.65
35	3.26	0.08	3.78	0.00	96.80	0.08	1908.39	23.70
36	16.89	0.01	3.23	6.82	83.37	0.01	1937.06	24.47
37	19.58	0.43	5.91	9.63	80.57	0.43	1918.34	24.32
38	0.42	0.04	7.46	0.00	100.46	0.04	1915.81	23.91
39	0.41	0.04	7.45	0.00	100.45	0.04	1916.18	23.94
40	2.17	0.63	5.19	0.00	98.04	0.63	1907.97	23.60
41	31.06	0.21	3.34	0.03	150.04	20.26	1907.99	23.88
42	20.29	0.47	7.45	0.00	128.40	19.68	1895.47	21.24
43	5.35	3.22	8.37	0.00	98.93	3.22	1908.18	23.38
44	28.22	3.50	16.51	3.09	114.62	53.37	1915.57	20.68
45	9.99	0.98	8.44	0.74	118.24	14.93	1899.51	21.92
46	11.93	1.28	10.92	0.01	117.07	17.42	1901.52	21.87
47	41.10	1.79	10.77	0.00	108.30	75.57	1940.90	20.48
48	14.57	12.45	21.19	0.47	114.56	30.15	1906.69	21.47
49	7.96	5.19	14.93	2.71	108.92	12.50	1904.62	22.43
50	2.48	0.06	9.50	0.00	102.47	0.06	1920.73	23.56
51	30.84	1.30	22.48	0.00	101.25	81.12	1901.89	30.86
52	8.88	0.87	0.78	0.00	91.40	0.87	1927.09	25.05

FID	To_springs	To_water	To_karst	To_chert	To_20mcoas	To_Aucilla	NPP	Precip_var
53	15.86	0.01	8.46	0.00	94.67	25.91	1942.66	27.70
54	1.72	0.03	5.32	0.00	98.32	0.03	1907.54	23.63
55	2.04	0.08	5.02	0.00	98.03	0.08	1907.69	23.65
56	3.27	0.13	3.78	0.00	96.79	0.13	1908.37	23.70
57	2.00	0.33	9.04	0.00	102.04	0.33	1924.31	23.86
58	2.39	0.49	9.43	0.00	102.43	0.49	1926.07	23.74
59	1.88	0.47	8.89	0.00	101.90	0.47	1925.98	24.00
60	0.47	0.00	7.52	0.00	100.51	0.00	1915.42	23.88
61	15.64	0.24	8.65	0.00	94.84	26.20	1942.49	27.70
62	0.95	0.02	7.94	0.00	100.91	0.02	1913.72	23.72
63	0.69	0.04	7.70	0.00	100.69	0.04	1914.07	23.77
64	1.21	0.07	8.24	0.00	101.22	0.07	1916.42	23.79
65	1.10	0.08	8.12	0.00	101.09	0.08	1915.49	23.77
66	0.43	0.02	7.45	0.00	100.46	0.02	1916.98	23.99
67	22.94	5.45	18.10	7.85	130.73	42.11	1902.56	26.47
68	0.15	14.62	12.66	0.00	92.81	35.31	1922.08	22.24
69	5.66	4.83	13.83	0.00	74.76	28.97	1931.03	23.17
70	0.44	14.18	13.38	0.00	92.20	34.93	1922.37	22.28
71	8.64	0.42	0.32	0.00	91.53	0.42	1921.59	24.63
72	20.87	0.17	8.81	10.59	79.21	0.17	1919.85	24.23
73	17.33	0.36	3.76	7.32	82.88	0.36	1932.09	24.38
74	19.66	0.44	6.01	9.72	80.49	0.44	1918.40	24.32
75	50.21	0.05	5.00	38.78	51.18	26.11	1889.76	24.41
76	18.98	0.04	0.00	5.21	84.19	7.17	1958.40	27.78
77	18.99	0.07	0.00	5.20	84.20	7.20	1958.38	27.78
78	18.93	0.04	0.00	5.15	84.25	7.17	1958.34	27.78
79	16.88	1.20	5.67	5.37	83.71	4.09	1917.57	23.95

FID	To_springs	To_water	To_karst	To_chert	To_20mcoas	To_Aucilla	NPP	Precip_var
80	18.13	0.07	4.20	8.05	82.14	0.07	1932.52	24.51
81	21.04	0.02	8.84	10.84	79.04	0.02	1919.85	24.24
82	17.20	0.33	3.65	7.18	83.02	0.33	1932.82	24.39
83	17.55	0.35	3.90	7.52	82.67	0.35	1931.67	24.40
84	16.89	0.01	3.23	6.82	83.37	0.01	1937.06	24.47
85	18.72	0.13	4.80	8.67	81.53	0.13	1927.94	24.31
86	17.98	0.30	4.20	7.94	82.26	0.30	1930.49	24.39
87	25.12	0.31	8.13	14.87	74.92	0.31	1922.76	24.45
88	25.59	0.12	7.74	15.32	74.46	0.12	1923.11	24.47
89	25.97	0.21	7.35	15.50	74.08	0.21	1923.56	24.48
90	19.36	0.60	5.75	9.42	80.79	0.60	1918.19	24.30
91	19.03	0.19	5.15	9.00	81.20	0.19	1924.81	24.32
92	19.77	0.62	6.29	9.89	80.34	0.62	1918.53	24.31
93	19.58	0.43	5.91	9.63	80.57	0.43	1918.34	24.32
94	19.50	0.18	5.67	9.50	80.70	0.18	1920.24	24.33
95	18.84	0.41	5.08	8.84	81.36	0.41	1923.46	24.30
96	18.61	0.74	0.70	5.44	84.03	6.27	1958.96	27.77
97	22.27	2.74	3.32	1.49	88.80	21.39	1949.28	27.90

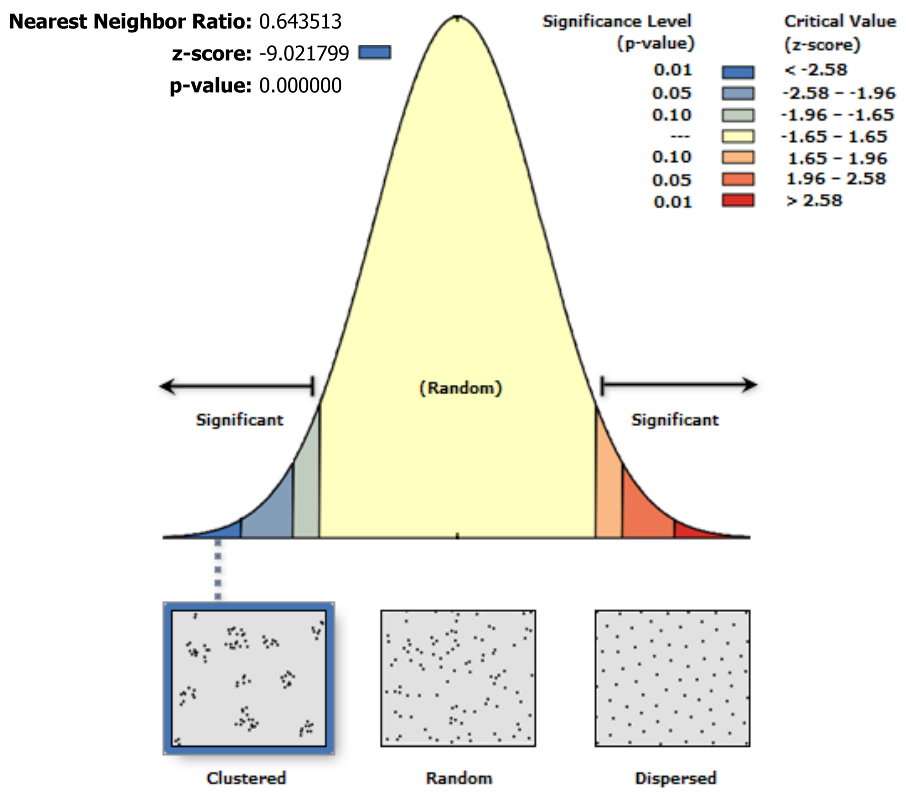
Table 6.2: Middle Archaic sites all variables

FID	To_water	To_Springs	To_karst	ToChert	To_m_coast	AnnualNPP	Precip_var	To_Aucilla
0	2.74	22.27	3.32	1.49	4.34	2995.28	10.38	21.39
1	670.21	8.04	9.65	1309.57	0.00	2985.53	7.14	9.55
2	701.29	22.74	0.47	0.00	0.00	2604.06	6.92	16.06
3	963.04	0.19	3.03	8.56	0.00	2795.56	7.05	8.12
4	2484.63	5.78	7.94	1464.68	0.00	2894.26	7.07	10.81
5	1309.41	10.27	2.63	469.06	0.00	2781.19	6.95	12.52
6	1462.33	10.08	2.66	624.28	0.00	2780.47	6.95	12.35
7	2208.78	8.87	3.68	519.29	0.00	2789.54	6.97	11.84
8	1935.76	9.02	3.83	278.23	0.00	2794.56	6.97	12.15
9	1934.11	5.76	4.43	0.00	0.00	2807.45	7.01	10.70
10	273.82	23.27	0.02	0.00	0.00	2596.62	7.63	16.24
11	5094.00	40.65	12.65	4317.78	0.00	2588.05	8.00	23.83
12	179.64	31.06	2.11	25.91	0.00	2566.07	8.55	20.26
13	1319.42	10.49	2.72	943.10	0.00	3000.00	7.08	42.49
14	7670.34	34.25	6.55	0.00	0.00	2604.96	7.40	27.56
15	9424.76	44.69	11.81	0.00	0.00	2703.81	7.21	41.59
16	878.21	28.22	5.70	2675.91	0.00	2935.44	6.86	53.37
17	319.02	20.31	1.65	2.56	0.00	2850.07	6.86	26.94
18	1398.99	21.87	2.12	0.00	0.00	2724.81	6.80	20.38
19	24.57	0.12	11.06	0.00	0.00	3000.00	7.15	20.04
20	126.25	26.46	3.16	682.76	0.00	2924.45	6.84	46.87
21	3479.01	41.94	4.75	0.00	0.00	2781.19	7.33	46.12
22	426.95	17.67	2.03	0.00	0.00	2854.40	6.90	23.73
23	75.52	17.11	0.36	6098.62	0.00	3000.00	7.02	49.20
24	7530.42	34.00	1.28	1117.56	0.00	2819.86	6.70	40.86
25	4042.86	15.36	0.70	0.00	0.00	2938.61	6.94	29.34
26	4540.16	16.24	0.49	0.00	0.00	2931.79	6.93	29.76
27	5296.55	29.28	2.53	205.09	0.00	2803.39	6.74	33.39
28	1763.99	24.70	1.14	655.48	0.00	2731.89	6.77	23.28
29	978.30	22.95	3.04	1701.33	0.00	2952.46	6.89	45.40
30	4826.60	28.02	1.95	0.00	0.00	2805.99	6.76	32.16
31	102.48	23.57	1.92	0.00	0.00	2869.70	6.83	33.04

FID	To_water	To_Springs	To_karst	ToChert	To_m_coast	AnnualNPP	Precip_var	To_Aucilla
32	436.13	18.68	1.68	0.00	0.00	2860.38	6.88	25.83
33	770.20	19.55	2.68	455.46	0.00	2810.35	6.88	21.24
34	339.84	17.99	1.11	5661.65	0.00	3000.00	6.98	47.29
35	209.71	22.14	0.32	0.00	0.00	2937.44	6.88	39.60
36	21.83	22.69	0.02	0.00	0.00	2932.90	6.87	39.92
37	2375.36	25.37	2.28	398.29	0.00	2913.29	6.84	41.79
38	2833.44	9.47	7.22	1748.68	0.00	2966.93	7.01	23.99
39	100.30	19.64	4.29	0.00	0.00	2747.81	6.84	19.13
40	87.30	40.23	24.68	124.54	0.00	2916.47	6.90	74.45
41	1154.33	36.43	20.60	524.18	0.00	2929.76	6.91	70.20
42	2016.02	11.02	9.57	184.11	0.00	2906.79	7.00	18.78
43	1103.95	11.93	8.36	27.77	0.00	2886.39	7.00	17.42
44	2191.16	37.90	0.99	0.00	0.00	2840.48	6.80	50.36
45	758.83	11.88	8.04	187.15	0.00	2880.79	7.00	16.97
46	1200.25	24.11	8.81	9987.30	0.00	3000.00	7.02	58.68
47	367.00	25.53	2.56	257.83	0.00	2927.44	6.85	45.47
48	3508.06	16.31	0.59	189.66	0.00	2964.68	6.95	32.77
49	9201.91	45.15	12.65	0.00	0.00	2699.95	7.20	41.90
50	8863.40	45.66	13.20	0.00	0.00	2698.42	7.19	42.35
51	2149.11	8.42	7.08	0.00	0.00	3000.00	7.08	31.20
52	787.03	18.18	1.16	7067.02	0.00	3000.00	7.01	50.30
53	8767.94	45.28	11.46	0.00	0.00	2709.36	7.21	42.38
54	899.19	21.40	8.74	11166.74	0.00	3000.00	7.09	57.11
55	925.58	20.68	6.68	10205.61	0.00	3000.00	7.06	55.87
56	512.22	21.37	6.85	10713.89	0.00	3000.00	7.05	56.36
57	9715.10	37.35	1.84	1276.57	0.00	2765.73	6.95	38.96
58	1264.04	34.52	3.53	1403.85	0.00	2696.99	7.19	31.43
59	1098.93	23.90	0.43	0.00	0.00	2599.23	7.16	17.05
60	3169.81	14.82	1.80	0.00	0.00	2901.67	6.94	24.90
61	36.37	17.61	1.62	5220.81	0.00	3000.00	6.98	46.40
62	477.37	17.10	1.41	4836.03	0.00	3000.00	6.99	46.39
63	689.03	18.75	1.26	6502.67	0.00	3000.00	6.98	48.57
64	3735.75	17.93	9.10	51.50	0.78	2753.53	11.60	65.60

FID	To_water	To_Springs	To_karst	ToChert	To_m_coast	AnnualNPP	Precip_var	To_Aucilla
65	1145.89	22.01	2.15	6165.89	0.00	2703.94	8.93	20.58
66	1167.17	22.18	5.24	6260.63	0.00	2698.54	8.91	23.64
67	1041.92	22.90	9.22	0.00	0.00	2695.52	10.86	69.54
68	2734.81	20.28	8.71	4819.84	0.00	2698.50	9.32	36.53
69	1231.33	18.34	0.28	1750.25	0.00	2709.33	9.48	43.05
70	345.68	18.97	0.23	1964.95	0.00	2707.65	9.49	44.07
71	213.05	19.30	0.96	1820.25	0.00	2707.23	9.50	44.80
72	62.51	0.09	7.65	0.00	0.00	2803.26	9.81	32.12
73	1747.96	23.01	17.10	176.48	0.00	2711.03	11.34	73.00
74	64.41	0.20	8.22	0.00	0.00	2932.35	9.94	9.43
75	3078.97	0.17	11.23	0.00	0.00	2800.12	10.34	50.23
76	197.01	7.97	11.25	0.00	0.00	3000.00	10.15	10.48
77	121.78	13.65	4.78	0.00	0.29	3000.00	10.31	9.61
78	274.72	12.65	5.68	0.00	0.00	3000.00	10.29	9.18
79	636.03	22.32	6.45	6241.53	0.00	2690.97	9.33	41.84
80	746.20	13.48	0.40	0.00	0.00	3000.00	7.51	15.27
81	1311.49	23.19	0.67	3762.34	0.00	3000.00	7.64	37.26
82	415.85	28.69	15.52	10487.44	0.00	3000.00	7.21	63.13
83	21.57	0.74	6.05	0.00	0.00	3000.00	7.30	30.02
84	291.52	0.28	8.51	0.00	0.00	3000.00	7.23	33.95
85	178.06	0.04	8.24	0.00	0.00	3000.00	7.22	35.19
86	475.23	0.24	7.60	0.00	0.00	3000.00	7.21	33.55
87	1442.85	0.84	9.12	0.00	0.00	3000.00	7.25	30.43
88	555.32	0.49	2.15	0.00	0.00	3000.00	7.26	21.17
89	318.70	22.53	10.47	12125.70	0.00	3000.00	7.10	58.45
90	319.42	23.07	11.63	12416.27	0.00	3000.00	7.11	59.14
91	266.33	33.59	11.11	126.99	0.00	3000.00	7.57	52.85
92	549.26	20.95	10.58	10514.36	0.00	3000.00	7.13	57.09
93	2547.99	33.79	22.12	8638.38	0.00	2986.91	7.11	70.05
94	317.12	21.49	11.02	10824.49	0.00	3000.00	7.14	57.73
95	3125.51	1.87	8.03	0.00	0.00	3000.00	7.40	30.57
96	552.33	0.44	8.67	0.00	0.00	3000.00	7.23	34.93

Average Nearest Neighbor Summary



Given the z-score of -9.02179872157, there is a less than 1% likelihood that this clustered pattern could be the result of random chance.

Average Nearest Neighbor Summary

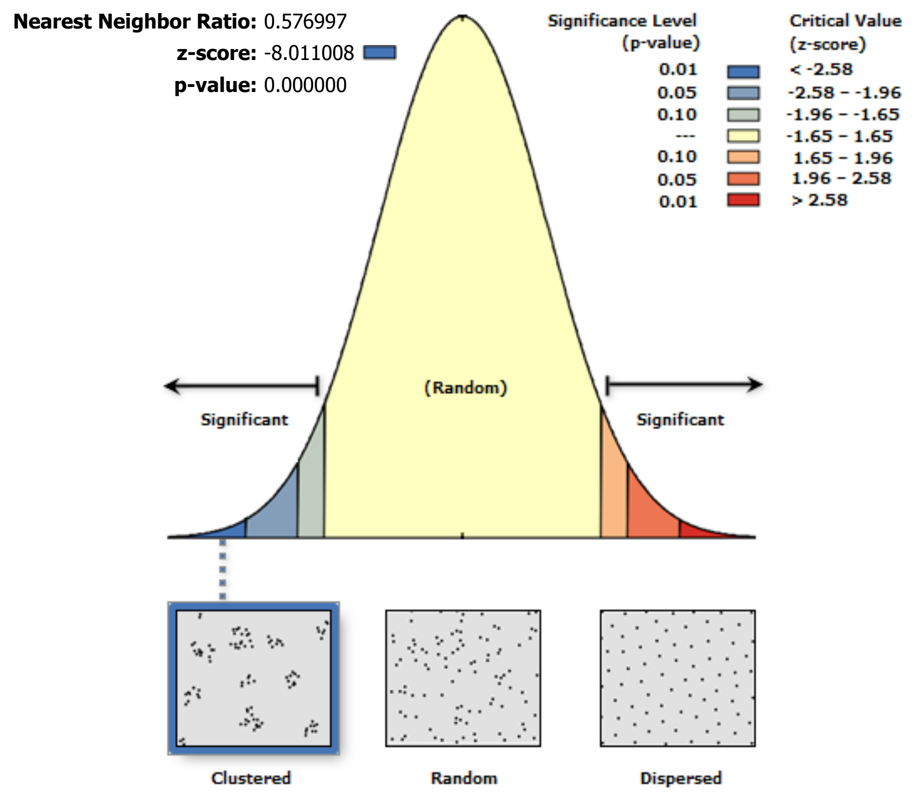
Observed Mean Distance:	3082.5020 Meters
Expected Mean Distance:	4790.1132 Meters
Nearest Neighbor Ratio:	0.643513
z-score:	-9.021799
p-value:	0.000000

Dataset Information

Input Feature Class:	MA_terrestrial_submerged
Distance Method:	EUCLIDEAN

Figure 6.1: Average nearest neighbor summary, Middle Archaic period sites

Average Nearest Neighbor Summary



Given the z-score of -8.01100811703, there is a less than 1% likelihood that this clustered pattern could be the result of random chance.

Average Nearest Neighbor Summary

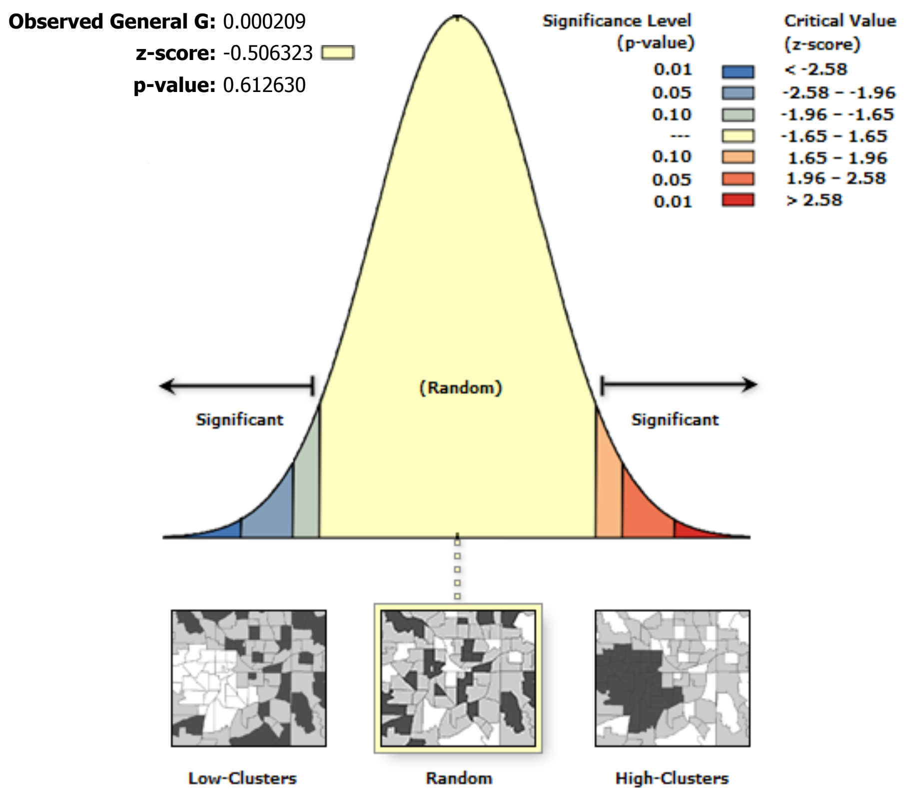
Observed Mean Distance:	3408.5734 Meters
Expected Mean Distance:	5907.4350 Meters
Nearest Neighbor Ratio:	0.576997
z-score:	-8.011008
p-value:	0.000000

Dataset Information

Input Feature Class:	EA_terrestrial_submerged
Distance Method:	EUCLIDEAN

Figure 6.2: Average nearest neighbor summary, Early Archaic period sites

High-Low Clustering Report



Given the z-score of -0.506323008143, the pattern does not appear to be significantly different than random.

General G Summary

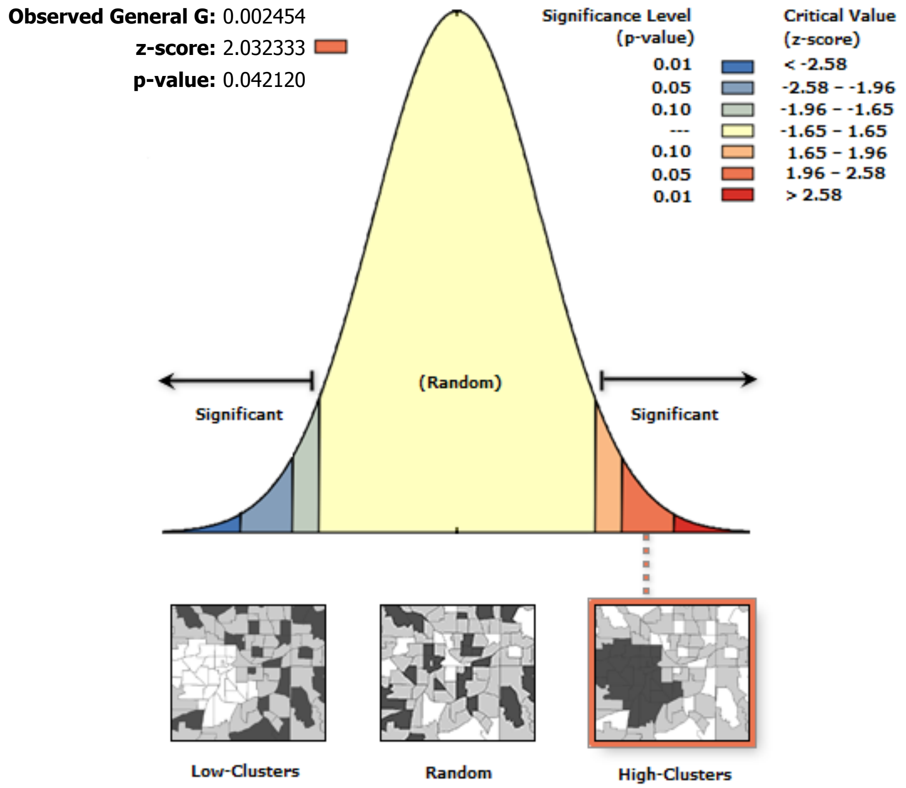
Observed General G:	0.000209
Expected General G:	0.001147
Variance:	0.000003
z-score:	-0.506323
p-value:	0.612630

Dataset Information

Input Feature Class:	EA_terrestrial_submerged
Input Field:	TO_WATER

Figure 6.3: Getis Ord General G, Early Archaic period site proximity to water

High-Low Clustering Report



Given the z-score of 2.03233273723, there is a less than 5% likelihood that this high-clustered pattern could be the result of random chance.

General G Summary

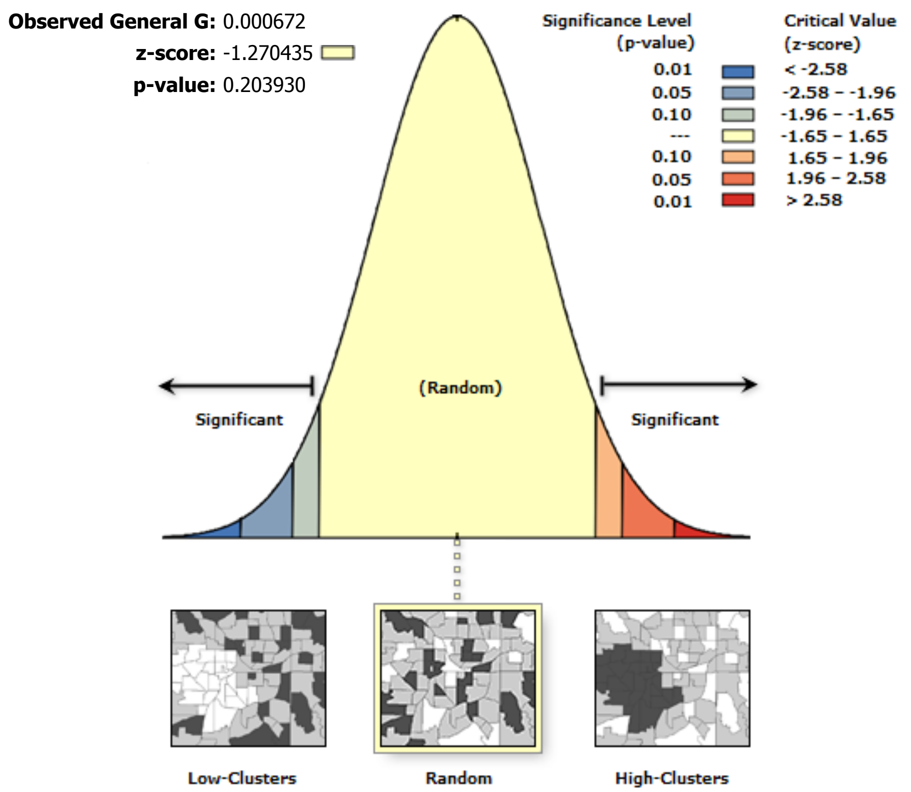
Observed General G:	0.002454
Expected General G:	0.001147
Variance:	0.000000
z-score:	2.032333
p-value:	0.042120

Dataset Information

Input Feature Class:	EA_terrestrial_submerged
Input Field:	TO_SPRINGS

Figure 6.4: Getis Ord General G, Early Archaic period site proximity to springs

High-Low Clustering Report



Given the z-score of -1.27043511279, the pattern does not appear to be significantly different than random.

General G Summary

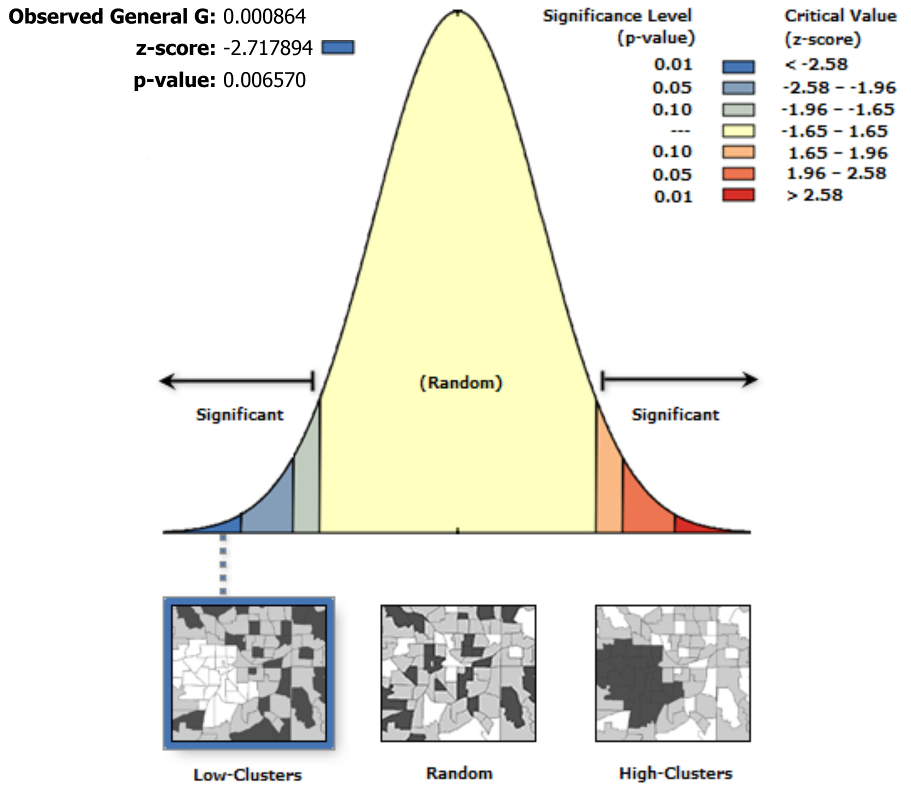
Observed General G:	0.000672
Expected General G:	0.001147
Variance:	0.000000
z-score:	-1.270435
p-value:	0.203930

Dataset Information

Input Feature Class:	EA_terrestrial_submerged
Input Field:	TO_KARST

Figure 6.5 Getis Ord General G, Early Archaic period site proximity to karst

High-Low Clustering Report



Given the z-score of -2.71789444724, there is a less than 1% likelihood that this low-clustered pattern could be the result of random chance.

General G Summary

Observed General G:	0.000864
Expected General G:	0.001147
Variance:	0.000000
z-score:	-2.717894
p-value:	0.006570

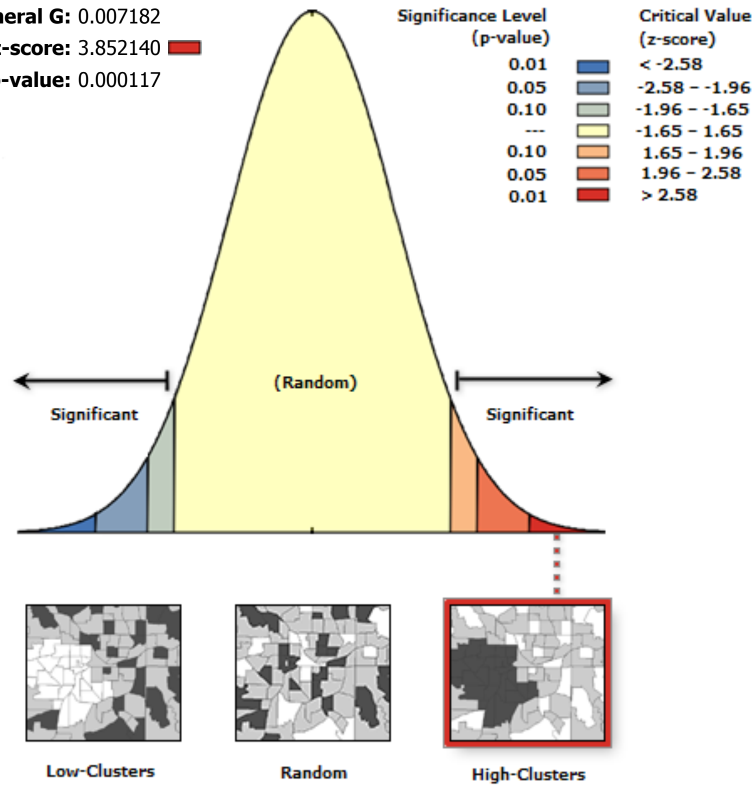
Dataset Information

Input Feature Class:	EA_terrestrial_submerged
Input Field:	TO_20MCOAS

Figure 6.6: Getis Ord General G, Early Archaic period site proximity to the coastline

High-Low Clustering Report

Observed General G: 0.007182
z-score: 3.852140
p-value: 0.000117



Given the z-score of 3.85214047418, there is a less than 1% likelihood that this high-clustered pattern could be the result of random chance.

General G Summary

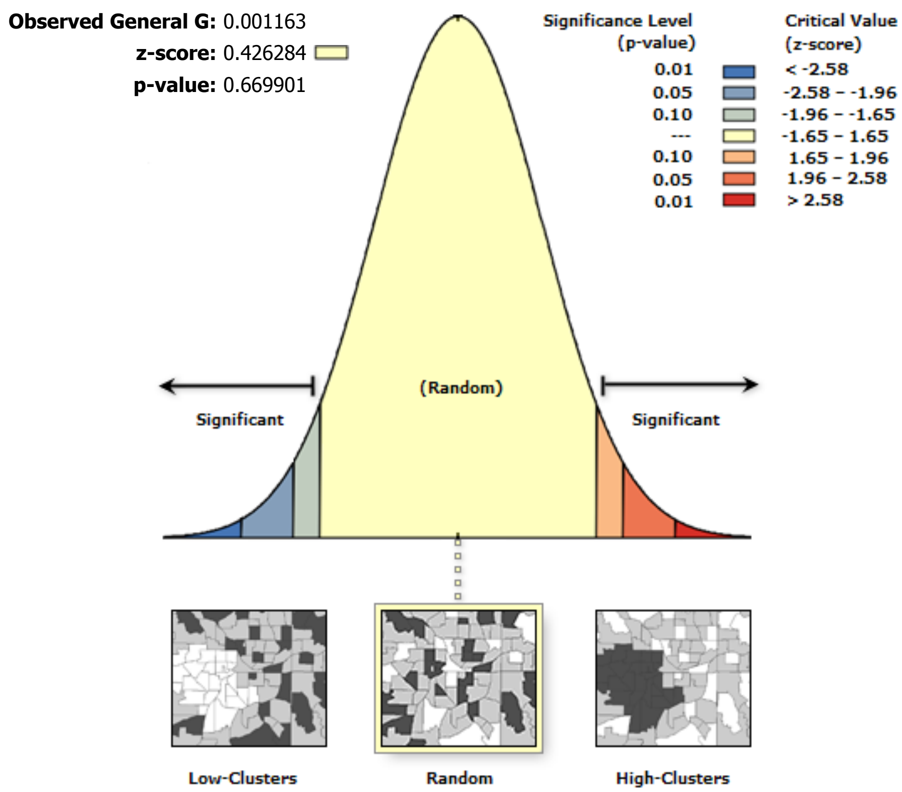
Observed General G:	0.007182
Expected General G:	0.001147
Variance:	0.000002
z-score:	3.852140
p-value:	0.000117

Dataset Information

Input Feature Class:	EA_terrestrial_submerged
Input Field:	TO_CHERT

Figure 6.7: Getis Ord General G, Early Archaic period site proximity to chert

High-Low Clustering Report



Given the z-score of 0.426283728472, the pattern does not appear to be significantly different than random.

General G Summary

Observed General G:	0.001163
Expected General G:	0.001147
Variance:	0.000000
z-score:	0.426284
p-value:	0.669901

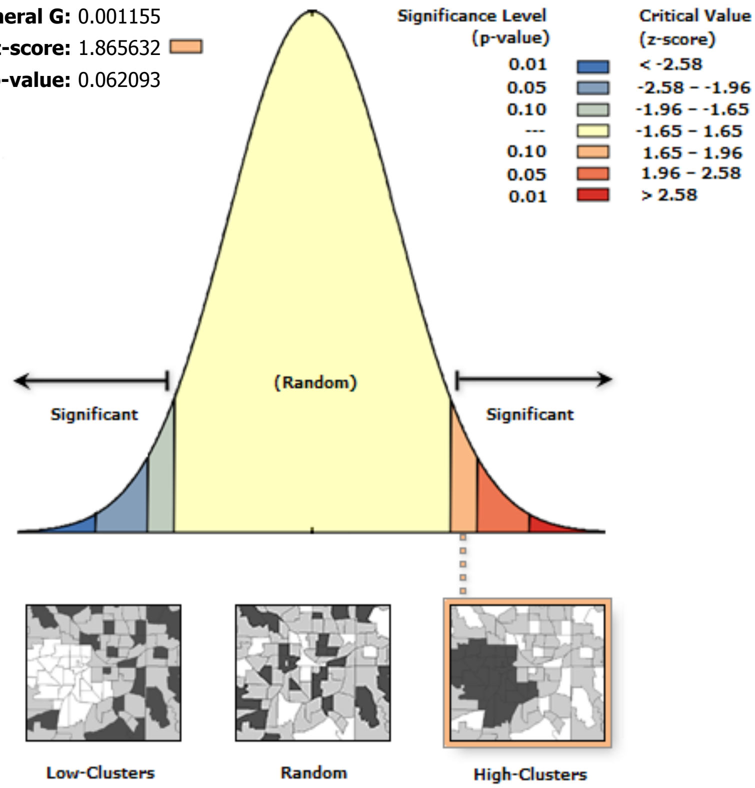
Dataset Information

Input Feature Class:	EA_terrestrial_submerged
Input Field:	PRECIP_VAR

Figure 6.8: Getis Ord General G, Early Archaic period site proximity to areas with high variation in precipitation

High-Low Clustering Report

Observed General G: 0.001155
z-score: 1.865632
p-value: 0.062093



Given the z-score of 1.86563207426, there is a less than 10% likelihood that this high-clustered pattern could be the result of random chance.

General G Summary

Observed General G:	0.001155
Expected General G:	0.001147
Variance:	0.000000
z-score:	1.865632
p-value:	0.062093

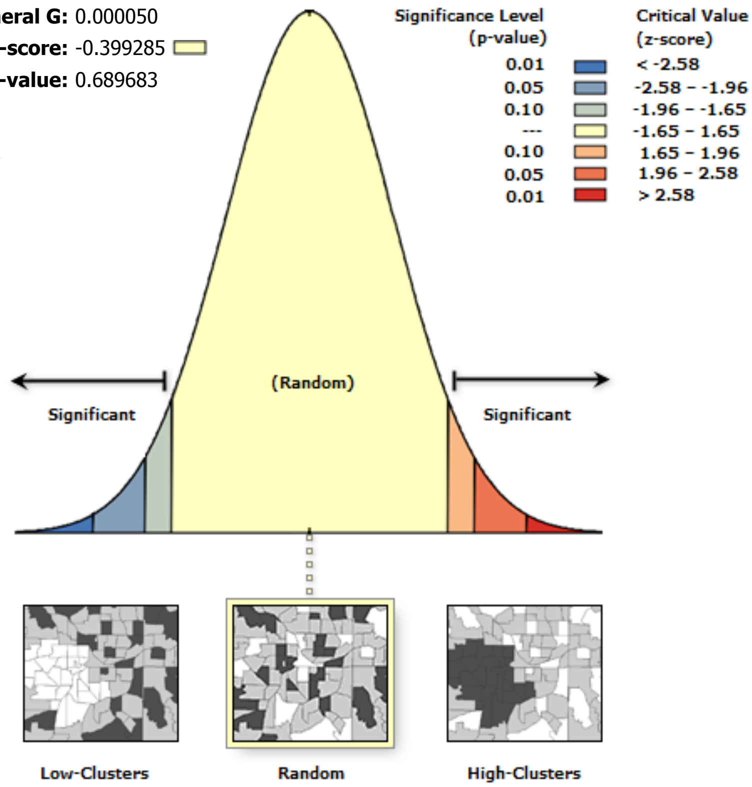
Dataset Information

Input Feature Class:	EA_terrestrial_submerged
Input Field:	NPP

Figure 6.9: Getis Ord General G, Early Archaic period site proximity to areas with high NPP

High-Low Clustering Report

Observed General G: 0.000050
z-score: -0.399285
p-value: 0.689683



Given the z-score of -0.399285451544, the pattern does not appear to be significantly different than random.

General G Summary

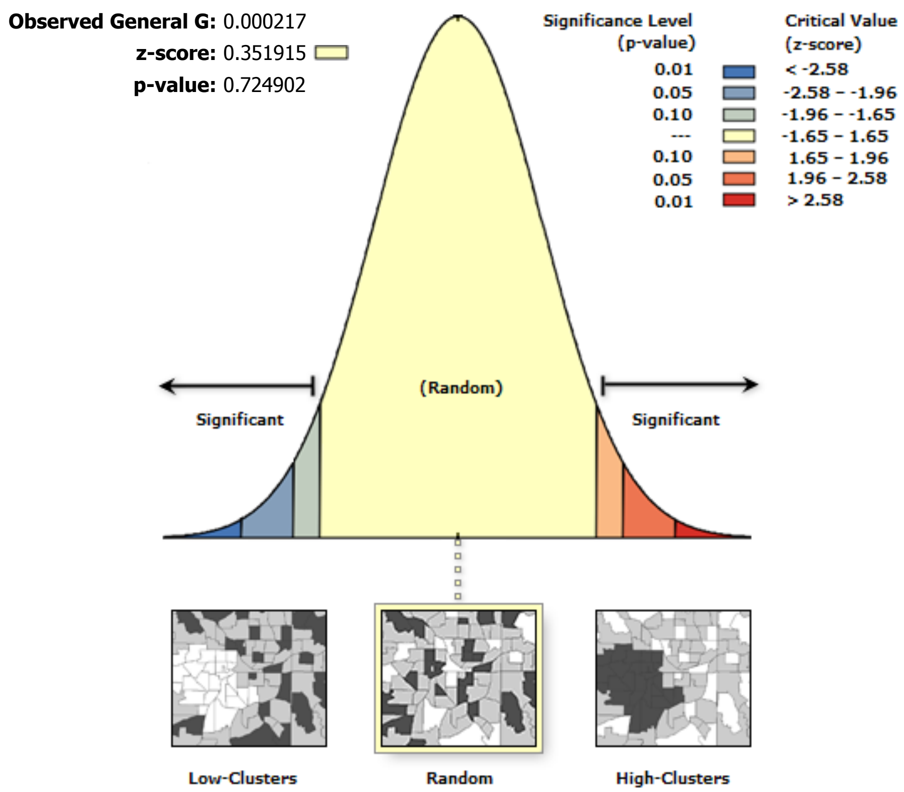
Observed General G:	0.000050
Expected General G:	0.000180
Variance:	0.000000
z-score:	-0.399285
p-value:	0.689683

Dataset Information

Input Feature Class:	MA_terrestrial_submerged
Input Field:	TO_WATER

Figure 6.10: Getis Ord General G, Middle Archaic period site proximity to water

High-Low Clustering Report



Given the z-score of 0.351915207676, the pattern does not appear to be significantly different than random.

General G Summary

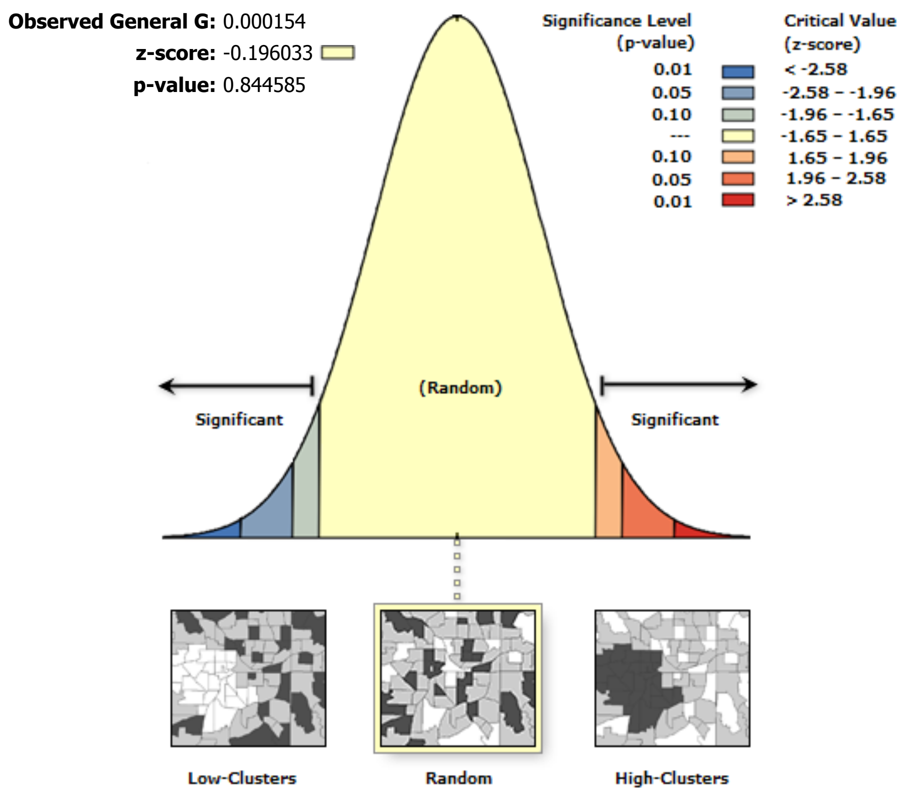
Observed General G:	0.000217
Expected General G:	0.000180
Variance:	0.000000
z-score:	0.351915
p-value:	0.724902

Dataset Information

Input Feature Class:	MA_terrestrial_submerged
Input Field:	TO_SPRINGS

Figure 6.11: Getis Ord General G, Middle Archaic period site proximity to springs

High-Low Clustering Report



Given the z-score of -0.19603260185, the pattern does not appear to be significantly different than random.

General G Summary

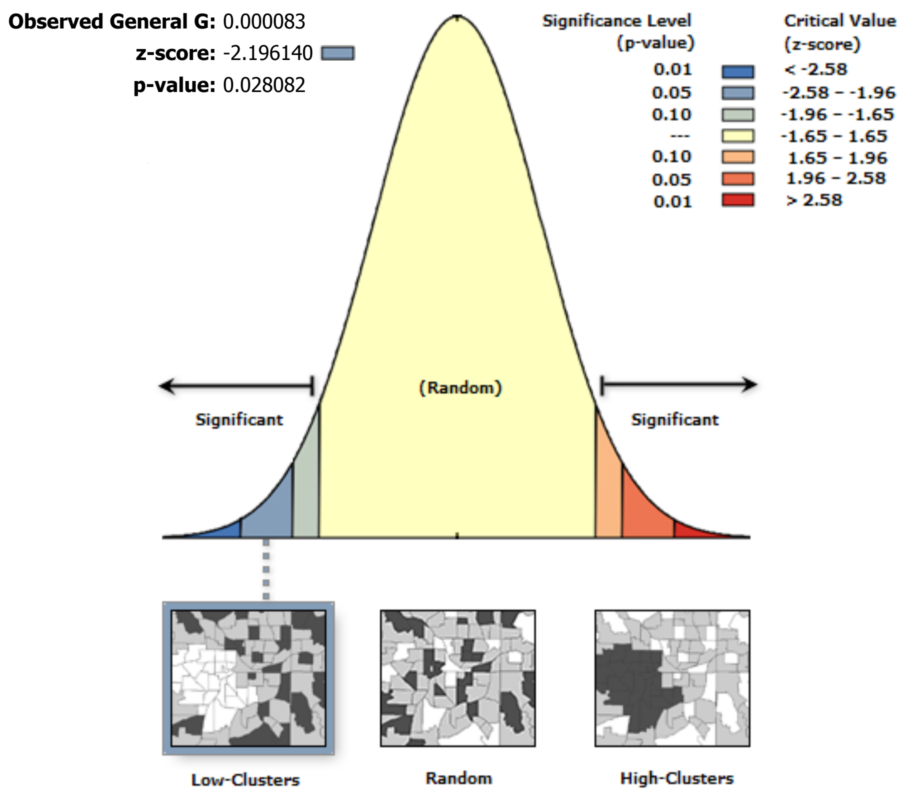
Observed General G:	0.000154
Expected General G:	0.000180
Variance:	0.000000
z-score:	-0.196033
p-value:	0.844585

Dataset Information

Input Feature Class:	MA_terrestrial_submerged
Input Field:	TO_KARST

Figure 6.12: Getis Ord General G, Middle Archaic period site proximity to karst

High-Low Clustering Report



Given the z-score of -2.196140167, there is a less than 5% likelihood that this low-clustered pattern could be the result of random chance.

General G Summary

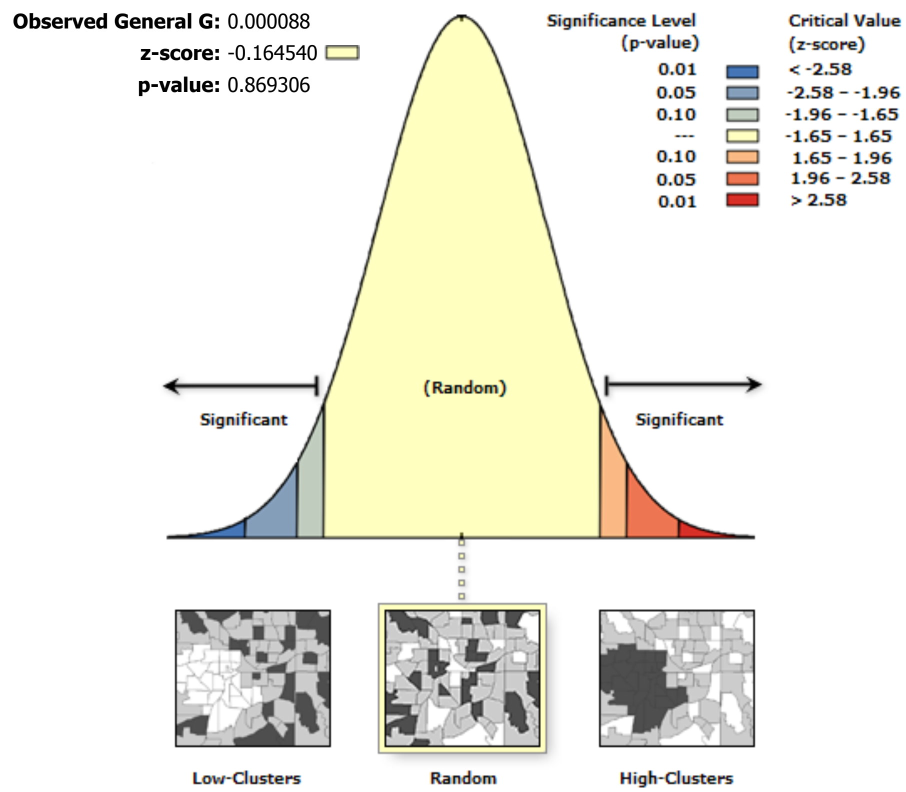
Observed General G:	0.000083
Expected General G:	0.000180
Variance:	0.000000
z-score:	-2.196140
p-value:	0.028082

Dataset Information

Input Feature Class:	MA_terrestrial_submerged
Input Field:	TO_COAST

Figure 6.13: Getis Ord General G, Middle Archaic period site proximity to the coast

High-Low Clustering Report



Given the z-score of -0.16453973222, the pattern does not appear to be significantly different than random.

General G Summary

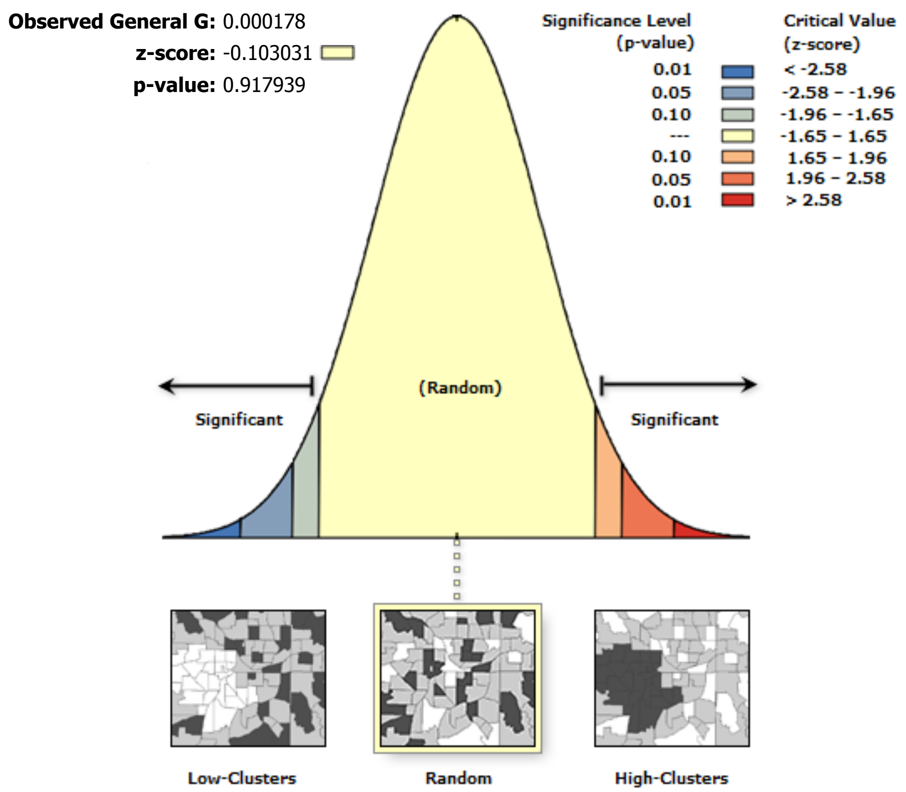
Observed General G:	0.000088
Expected General G:	0.000180
Variance:	0.000000
z-score:	-0.164540
p-value:	0.869306

Dataset Information

Input Feature Class:	MA_terrestrial_submerged
Input Field:	TOCHERT

Figure 6.14: Getis Ord General G, Middle Archaic period site proximity to chert

High-Low Clustering Report



Given the z-score of -0.103030722323, the pattern does not appear to be significantly different than random.

General G Summary

Observed General G:	0.000178
Expected General G:	0.000180
Variance:	0.000000
z-score:	-0.103031
p-value:	0.917939

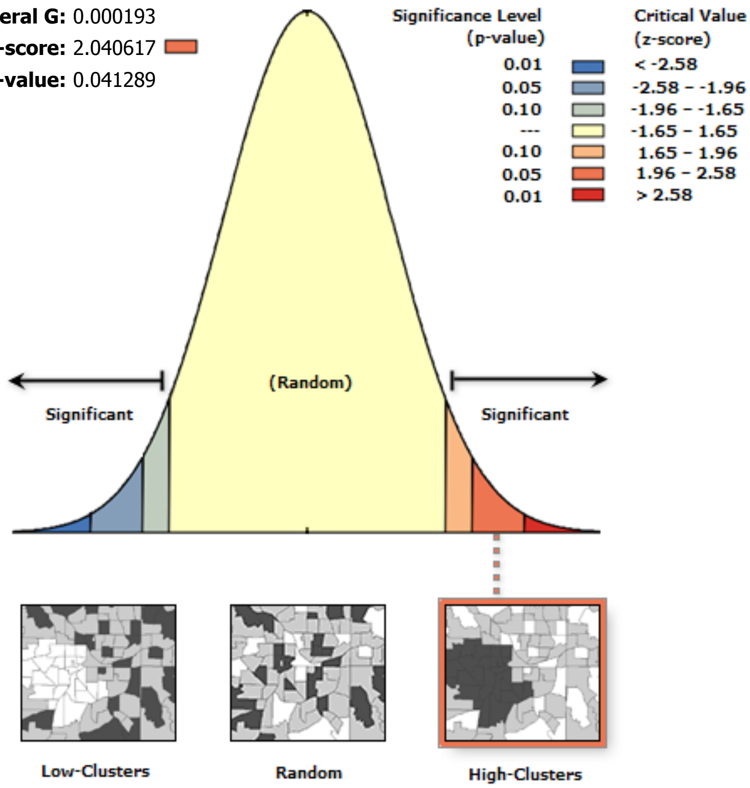
Dataset Information

Input Feature Class:	MA_terrestrial_submerged
Input Field:	PRECIP_VAR

Figure 6.15: Getis Ord General G, Middle Archaic period site proximity to areas with higher variability in precipitation

High-Low Clustering Report

Observed General G: 0.000193
z-score: 2.040617
p-value: 0.041289



Given the z-score of 2.04061731289, there is a less than 5% likelihood that this high-clustered pattern could be the result of random chance.

General G Summary

Observed General G:	0.000193
Expected General G:	0.000180
Variance:	0.000000
z-score:	2.040617
p-value:	0.041289

Dataset Information

Input Feature Class:	MA_terrestrial_submerged
Input Field:	ANNUALNPP

Figure 6.16: Getis Ord General G, Middle Archaic period site proximity to NPP

APPENDIX C: Lithics and sediments, Econfina Channel site

Item	Weight (g)	Length (mm)	Description
2016-10-19-001	1.00	13.00	Debitage
2016-10-19-001	1.00	19.60	Debitage
2016-10-19-004	4.00	24.70	Debitage
2016-10-19-004	2.00	19.10	Debitage
2016-10-19-004	164.00	79.30	Debitage
2016-10-19-004	111.00	94.30	Debitage
2016-10-19-004	67.00	69.30	Debitage
2016-10-19-004	13.00	45.50	Debitage
2015 unit 2	193.00	98.90	Debitage
2015 unit 2	183.00	114.50	Debitage
2015 unit 2	156.00	106.80	Debitage
2015 unit 2	142.00	81.90	Debitage
2015 unit 2	81.00	69.90	Debitage
2015 unit 2	77.00	77.90	Debitage
2015 unit 2	72.00	73.50	Debitage
2015 unit 2	60.00	54.50	Debitage
2015 unit 2	57.00	50.20	Debitage
2015 unit 2	45.00	64.00	Debitage
2015 unit 2	36.00	61.90	Debitage
2015 unit 2	31.00	53.60	Debitage
2015 unit 2	16.00	41.00	Debitage
2015 unit 2	4.00	27.00	Debitage
2015 unit 2	2.00	26.80	Debitage
2015 unit 2	189.00	84.50	Debitage
2015 unit 2	11.00	37.60	Debitage
2015 unit 2	26.00	61.90	Debitage
2015 unit 2	37.00	61.60	Debitage
2015 unit 2	3.00	24.40	Debitage
2015 unit 2	21.00	58.10	Debitage
2015 unit 2	13.00	40.70	Debitage
2015 unit 3	148.00	81.50	Debitage
2015 unit 3	80.00	86.00	Debitage
2015 unit 3	206.00	95.60	Debitage
2015 unit 3	177.00	92.90	Debitage
2015 unit 3	114.00	98.20	Debitage
2015 unit 3	76.00	81.40	Debitage
2015 unit 3	61.00	88.10	Debitage
2015 unit 3	75.00	67.10	Debitage
2015 unit 3	30.00	42.50	Debitage
2015 unit 3	16.00	52.40	Debitage
2015 unit 3	5.00	40.00	Debitage
2015 unit 3	31.00	61.50	Debitage
2015 unit 3	31.00	42.10	Debitage
2015 unit 3	11.00	53.50	Debitage

Item	Weight (g)	Length (mm)	Description
2015 unit 3	12.00	41.30	Debitage
2015 unit 3	11.00	40.10	Debitage
2015 unit 3	13.00	48.90	Debitage
2015 unit 3	25.00	43.40	Debitage
2015 unit 3	15.00	45.80	Debitage
2015 unit 3	5.00	35.10	Debitage
2015 unit 3	10.00	34.90	Debitage
N9	3.98	33.40	Debitage
W9	4.11	24.60	Debitage
W6	2.21	15.20	Debitage
E6	1.40	20.60	Debitage
W15	0.35	7.10	Debitage
N6	1.54	11.80	Debitage
E12	0.25	9.40	Debitage
E9	0.21	8.60	Debitage
E3	0.81	12.20	Debitage
E21	1.30	16.70	Debitage
E27	0.90	13.10	Debitage
Seep	106.00	82.70	Debitage
2016-10-19-004	24.00	33.20	Tool
2016-10-19-003	26.00	36.80	Tool
Seep	221.00	114.60	Tool
Midden	70.00	146.60	Tool

Primary/secondary debitage	Retouch/shatter	Tools
63	117	4

Table 6.3: Bulk sediment particle size analysis 2015 sediments

Sample Identity:	Date:	Initial Sample Weight:	Aperture (microns)						
			4000	2000	1000	500	250	125	63
N3	3/31/16	884	257.00	126.00	132.00	118.00	136.00	104.00	9.00
N6		799	170.00	128.00	120.00	241.00	0.00	128.00	11.00
N9		832	179.00	183.00	156.00	102.00	89.00	105.00	14.00
N12		841	131.00	185.00	187.00	138.00	105.00	84.00	9.00
N15		928	203.00	228.00	173.00	129.00	100.00	82.00	10.00
N18		562	97.00	120.00	122.00	95.00	61.00	57.00	8.00
N21		942	113.00	183.00	215.00	183.00	134.00	98.00	13.00
N24		735	115.00	140.00	150.00	131.00	101.00	88.00	9.00
N27		845	73.00	131.00	185.00	185.00	136.00	120.00	13.00
N30		942	63.00	136.00	226.00	239.00	163.00	105.00	9.00
W5		1735	341.00	215.00	240.00	194.00	323.00	398.00	21.00
W10		1173	282.00	138.00	166.00	143.00	197.00	230.00	14.00
W15		1121	141.00	127.00	133.00	115.00	209.00	366.00	25.00
S3		1628	514.00	127.00	143.00	108.00	248.00	455.00	26.00
S6		1148	192.00	60.00	59.00	73.00	262.00	456.00	38.00
S9		901	33.00	24.00	34.00	86.00	288.00	389.00	40.00
S12		916	5.00	37.00	43.00	84.00	248.00	420.00	55.00
E3		1151	497.00	165.00	90.00	84.00	129.00	164.00	17.00
E6		1373	200.00	176.00	198.00	157.00	243.00	362.00	31.00
E9		1261	192.00	187.00	187.00	155.00	233.00	284.00	20.00
E12		1016	193.00	168.00	161.00	121.00	155.00	200.00	15.00
E15		944	263.00	141.00	142.00	108.00	140.00	134.00	13.00
E18		1008	219.00	36.00	71.00	84.00	249.00	336.00	8.00
E21 Eel grass		991	137.00	44.00	37.00	67.00	258.00	395.00	44.00
E24		836	54.00	26.00	34.00	73.00	241.00	361.00	40.00
E27		945	95.00	33.00	35.00	77.00	250.00	401.00	45.00
E30		699	30	17	28	66	212	306	34

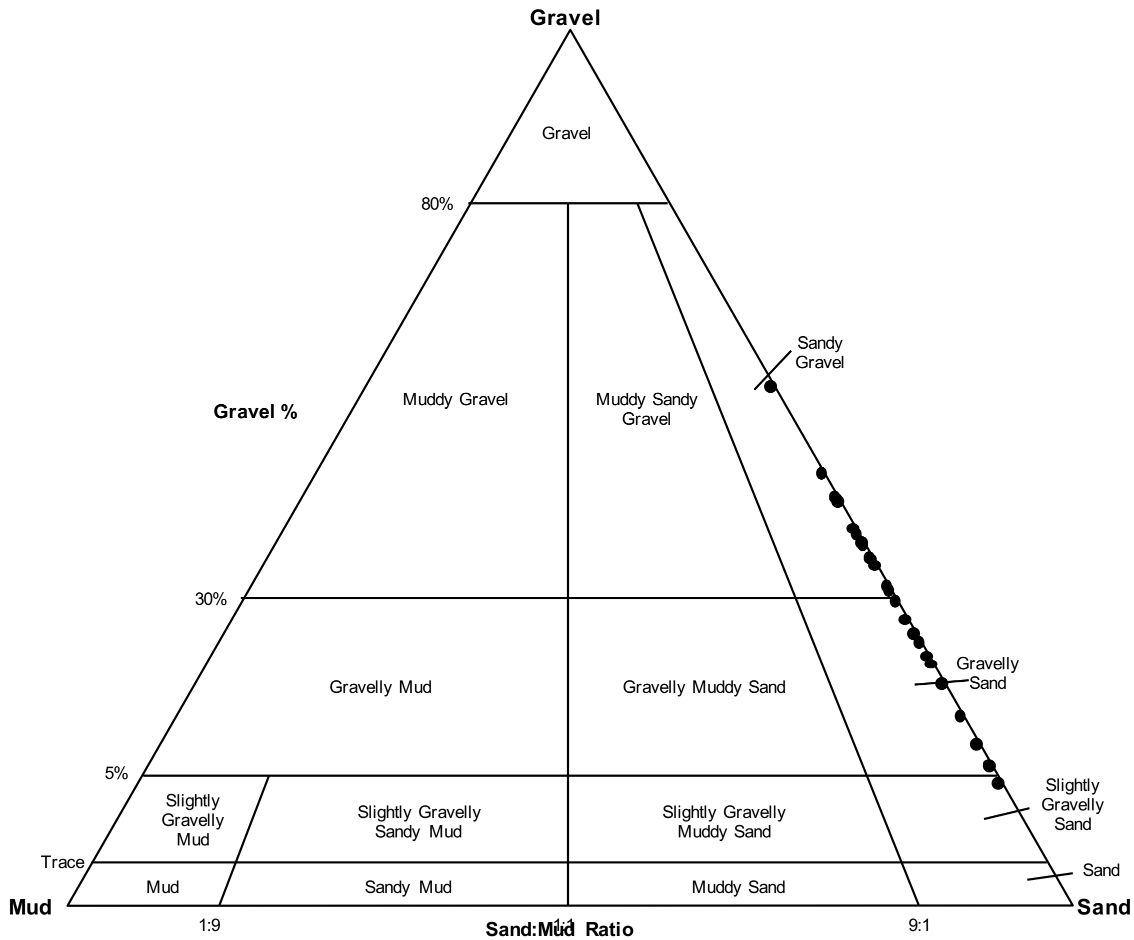


Figure 6.17: Folk classification, Econfina sediments, 2015 samples

APPENDIX D: XRD data

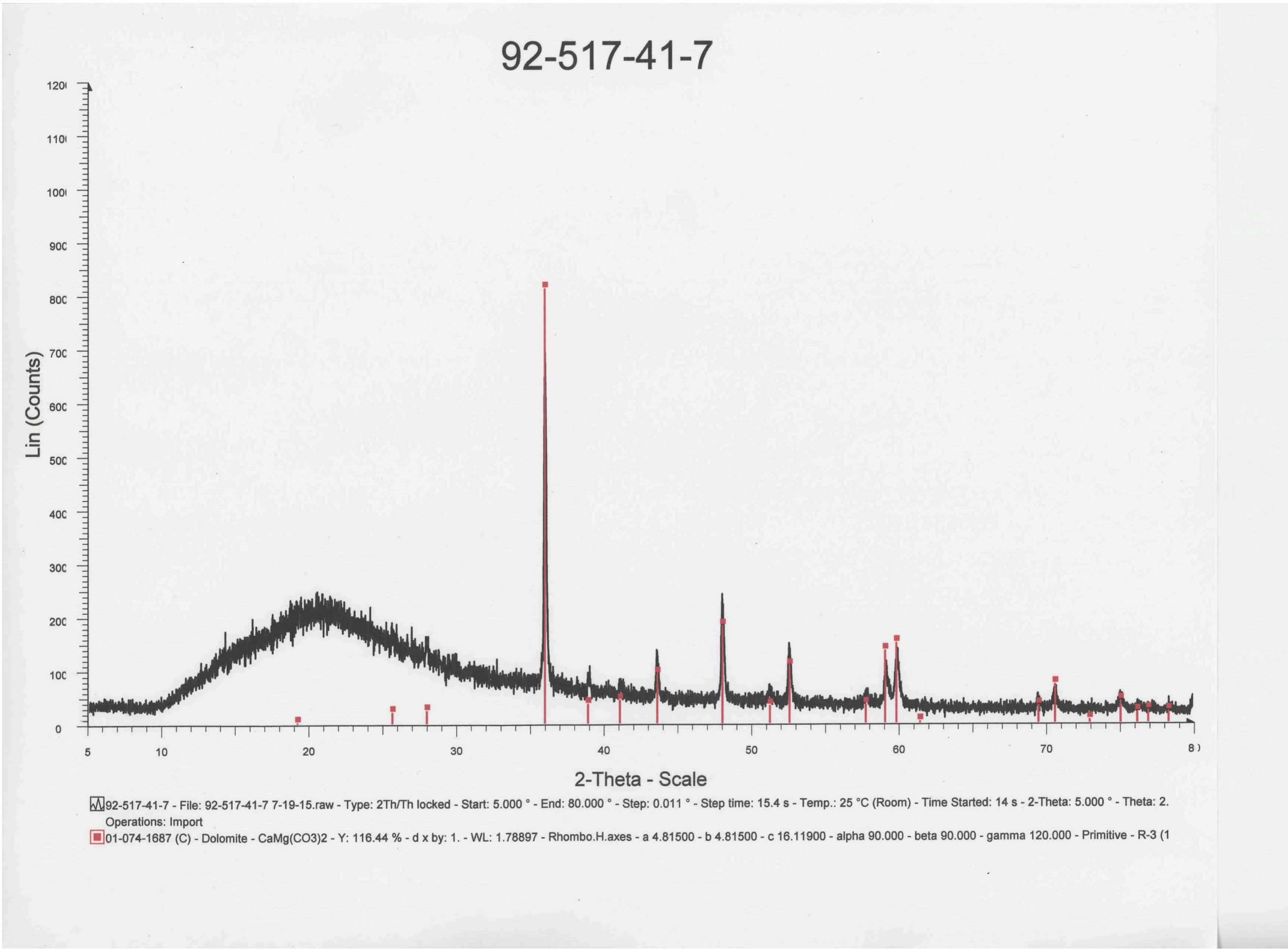


Figure 6.18: XRD spectrum 92-517-41-7

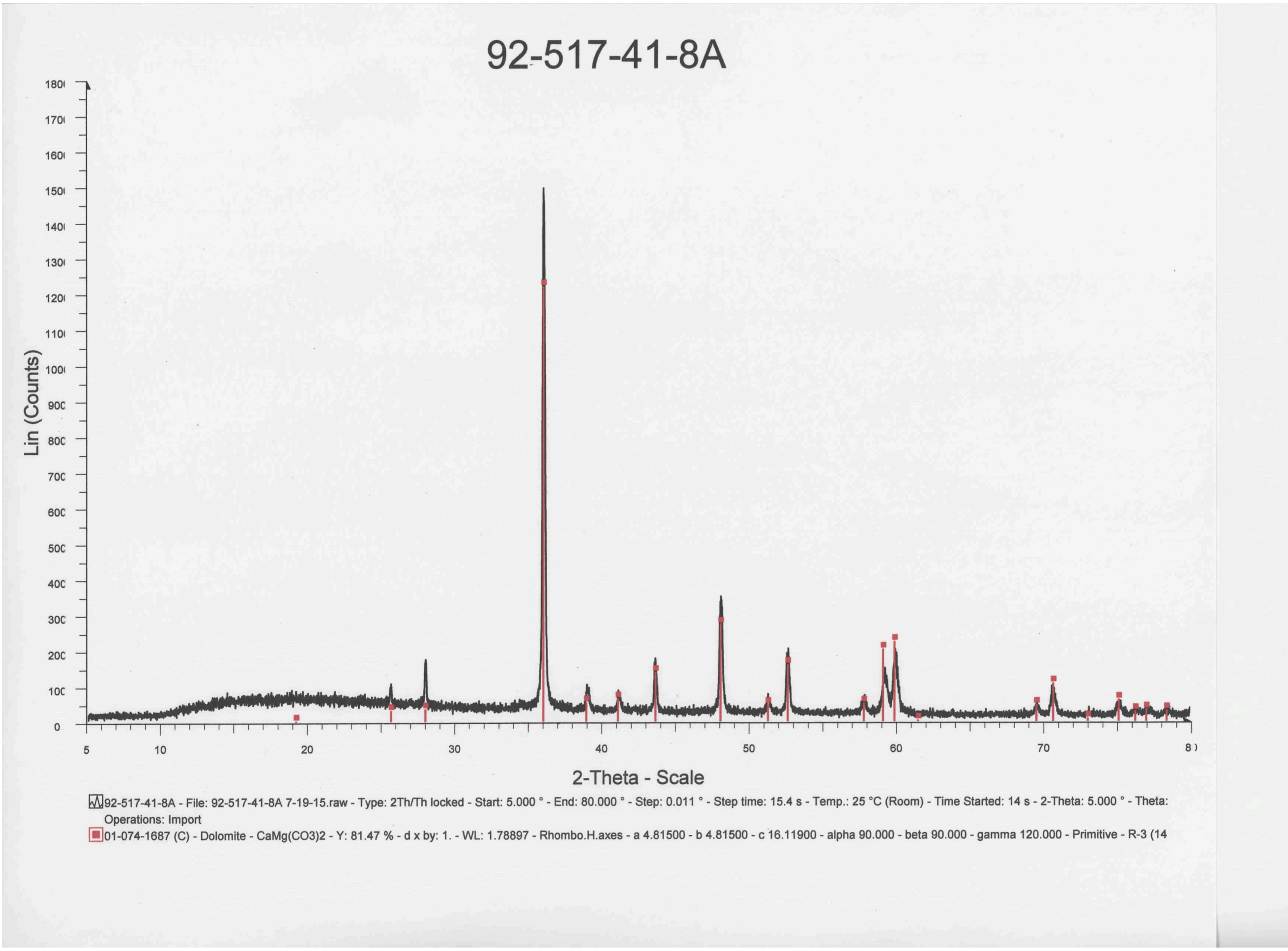


Figure 6.19: XRD spectrum 92-517-41-8A

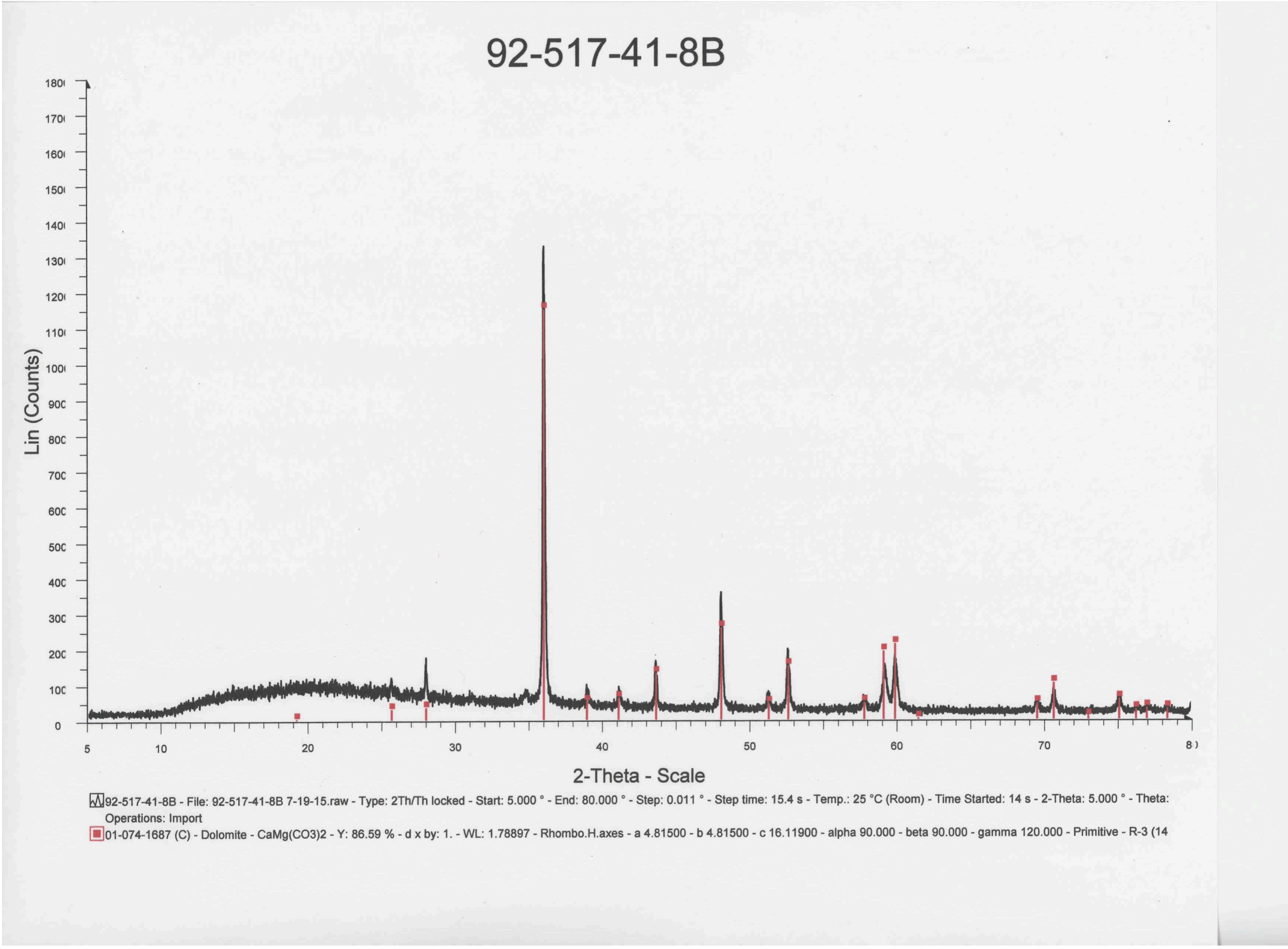


Figure 6.20: XRD spectrum 92-517-41-8B

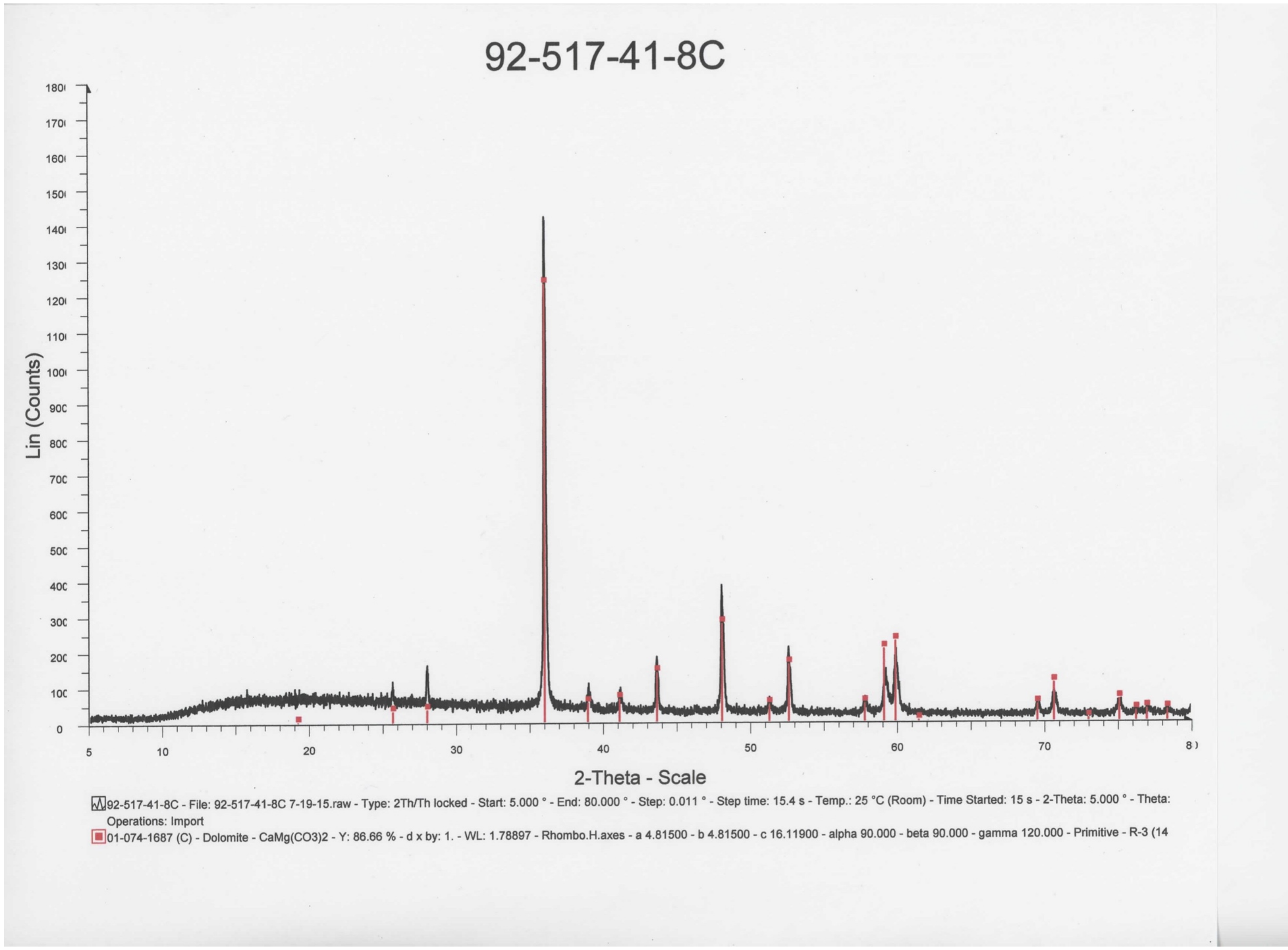


Figure 6.21: XRD spectrum 92-517-41-8C

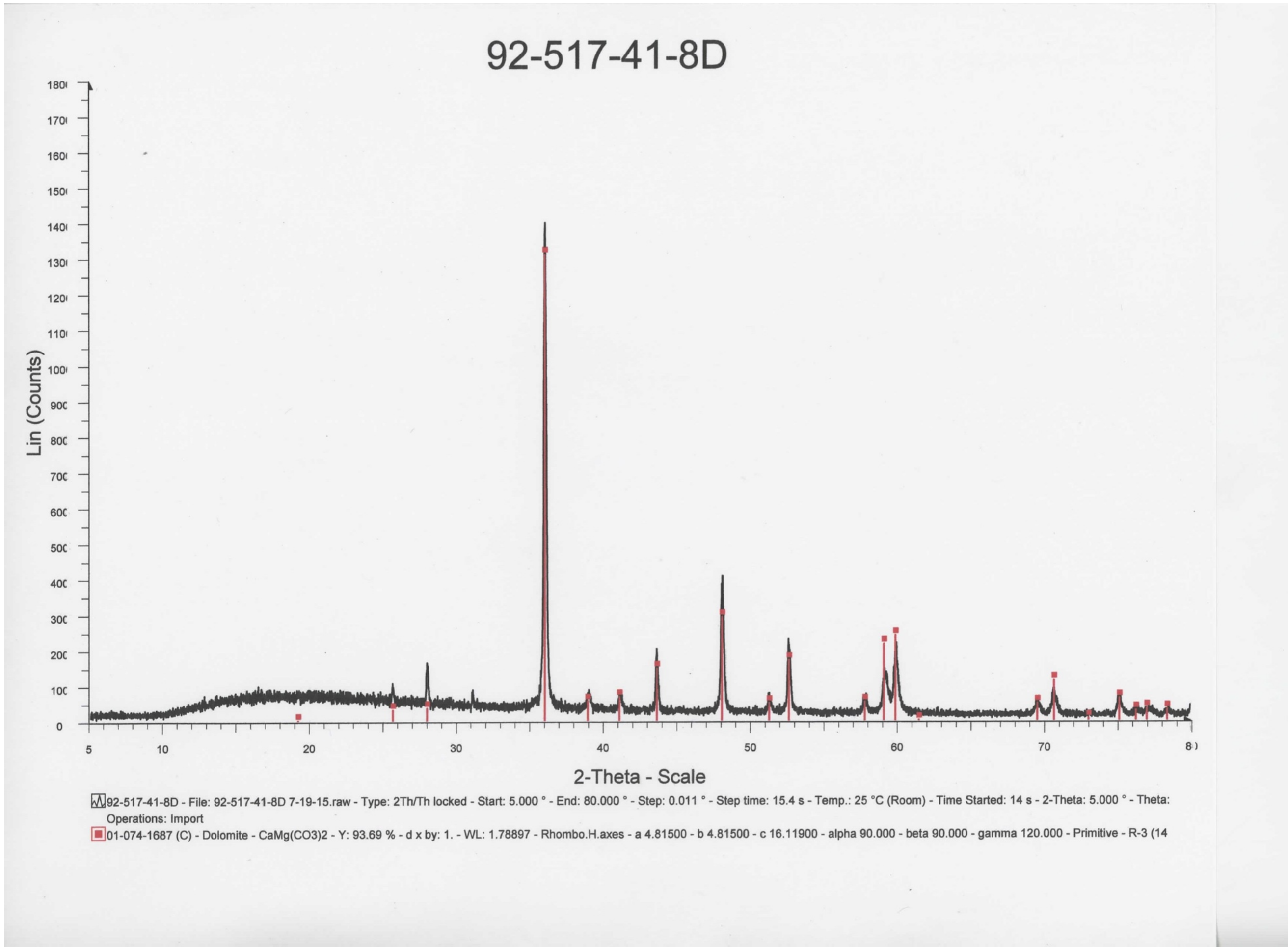


Figure 6.22: XRD spectrum 92-517-41-8D

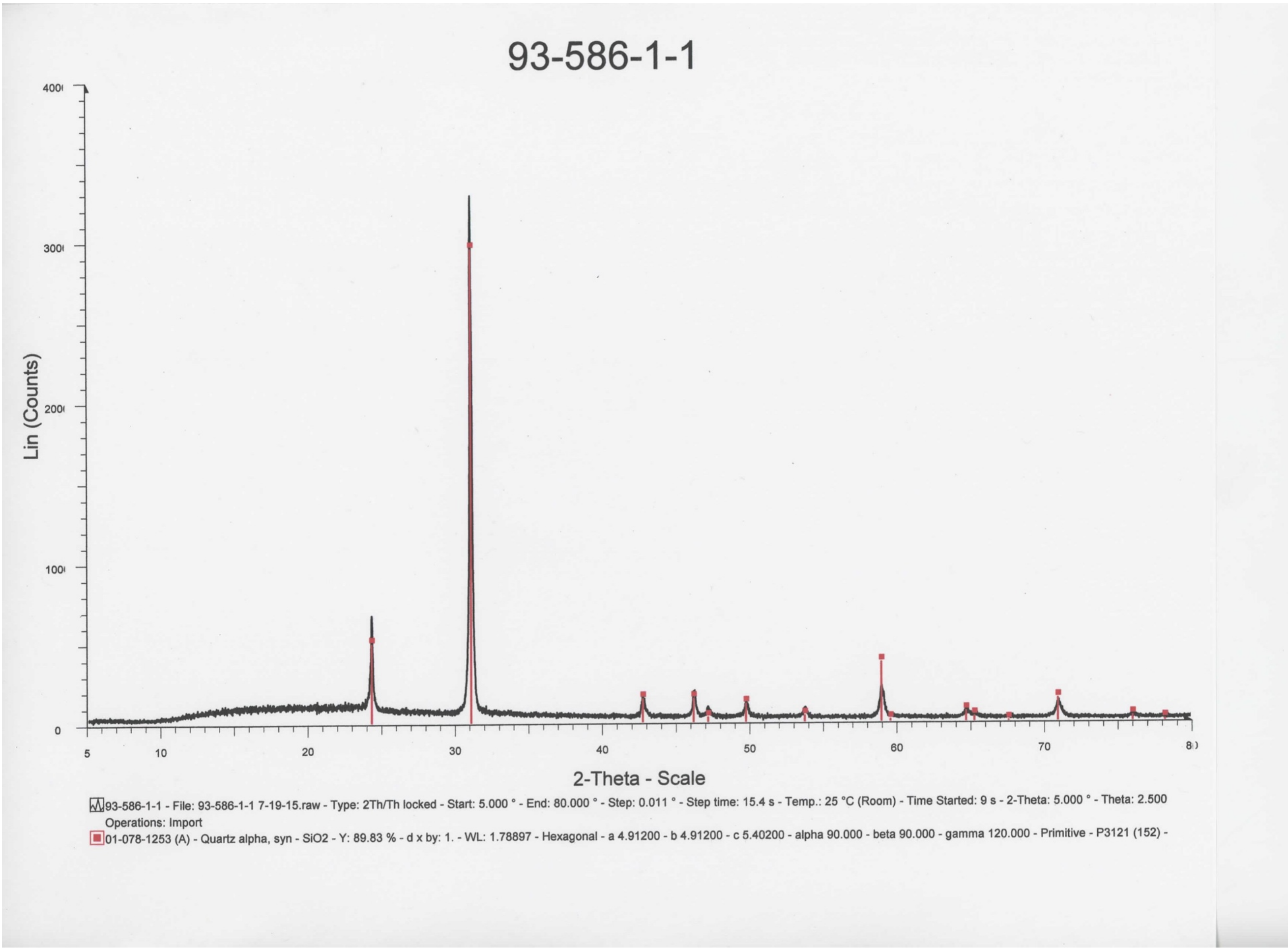


Figure 6.23: XRD spectrum 93-586-1-1

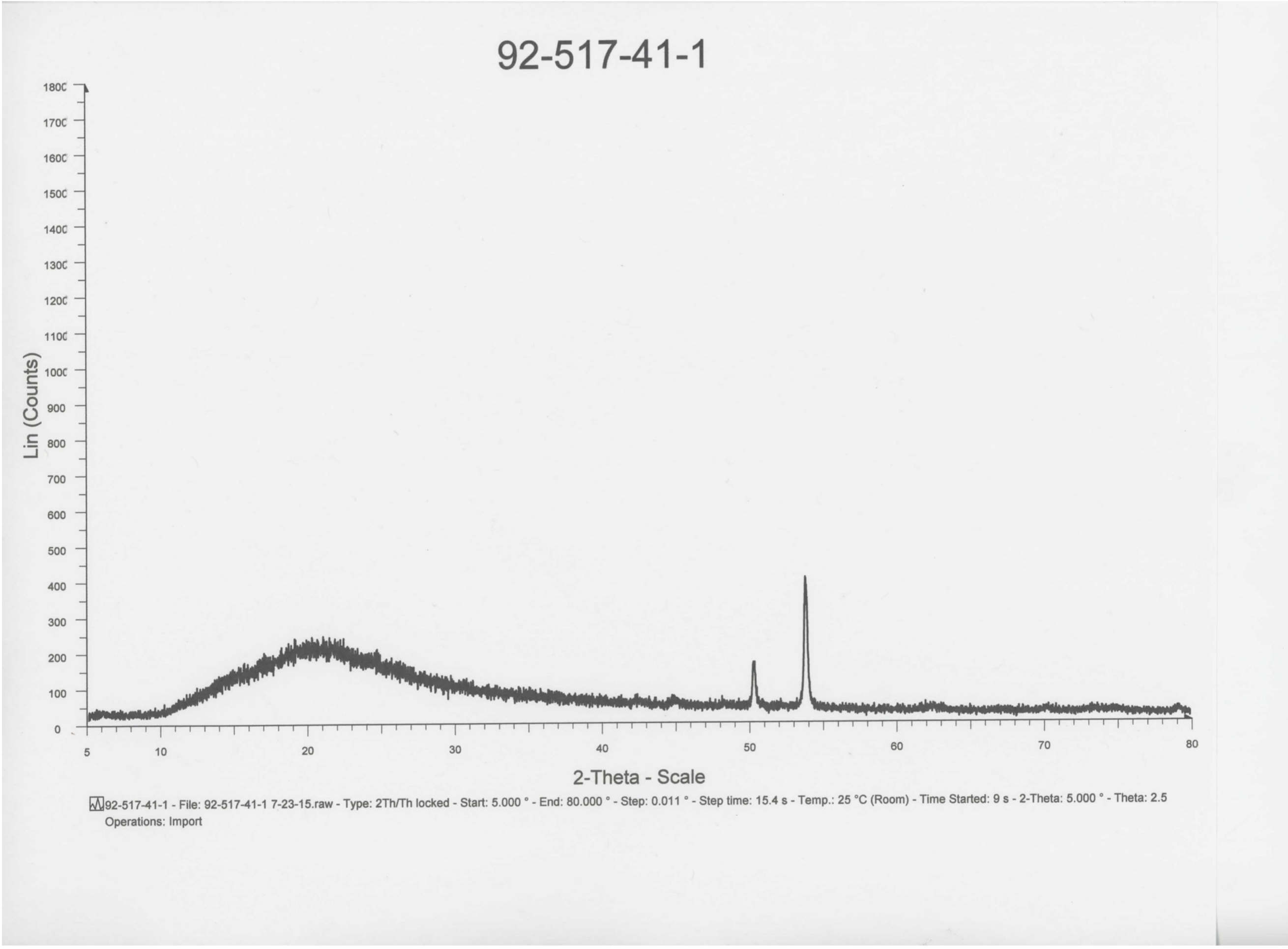


Figure 6.24: XRD spectrum 92-517-41-1

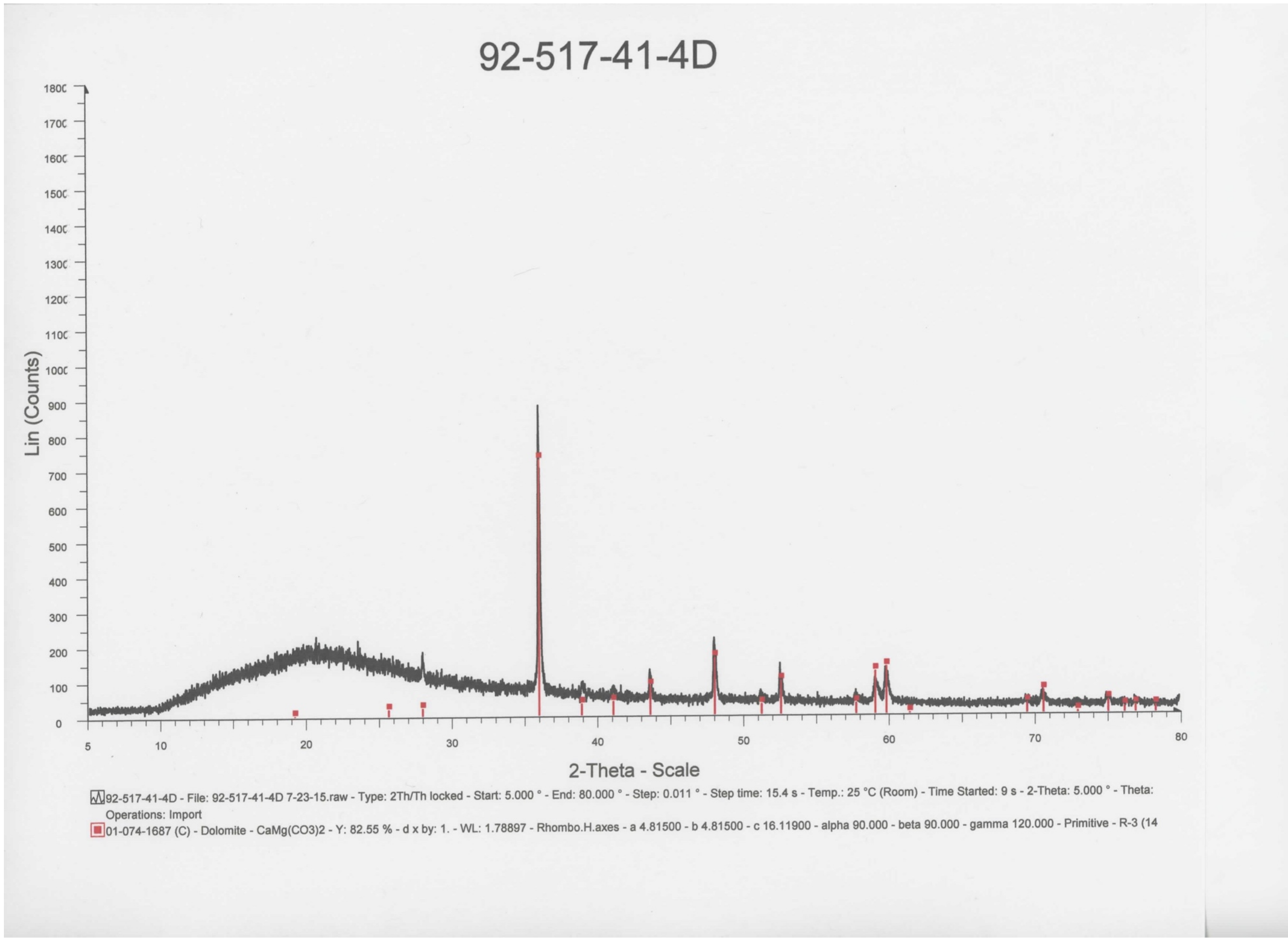


Figure 6.25: XRD spectrum 92-517-41-4D

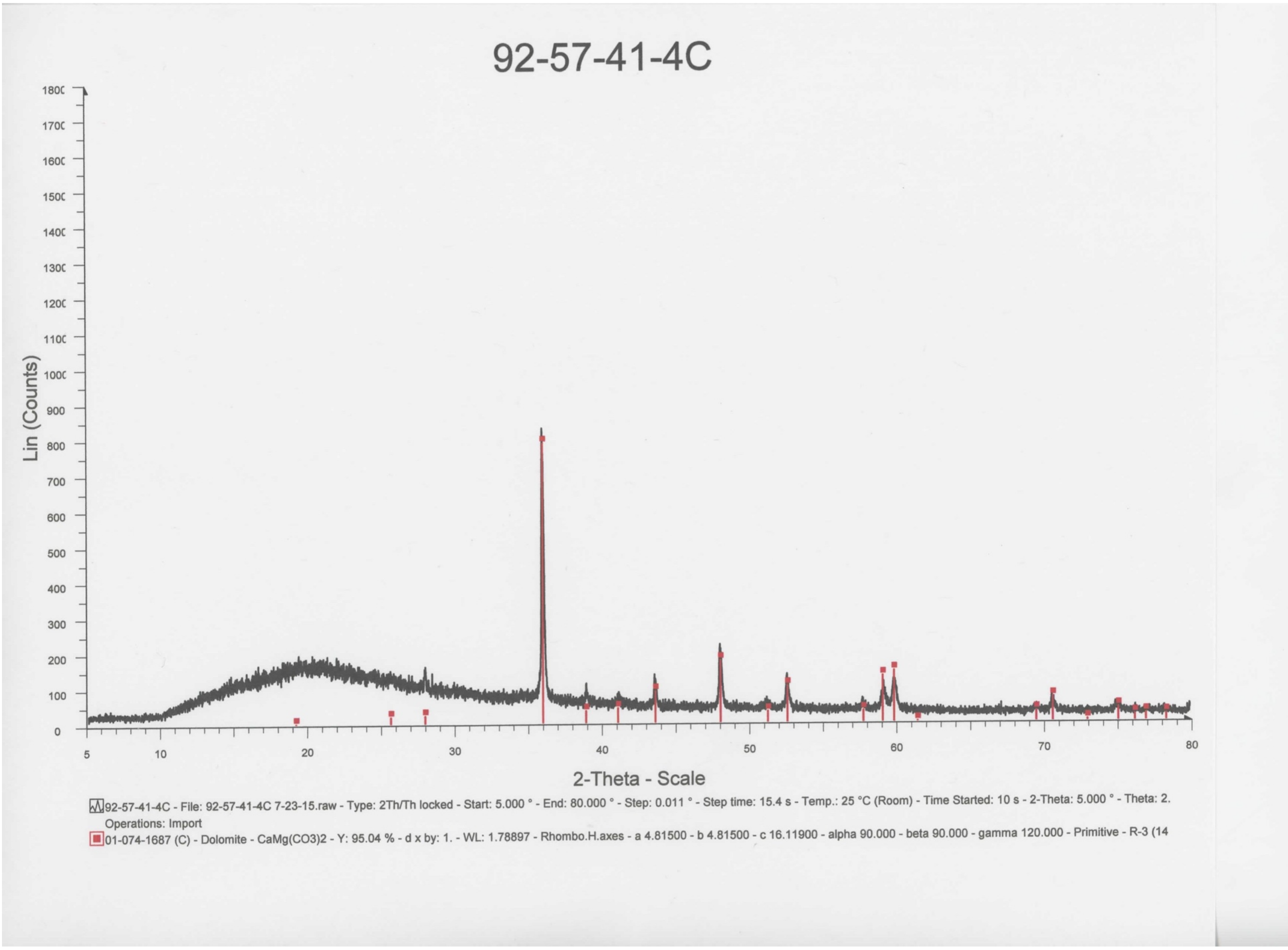


Figure 6.26: XRD spectrum 92-517-41-4C (label on scan has typo)

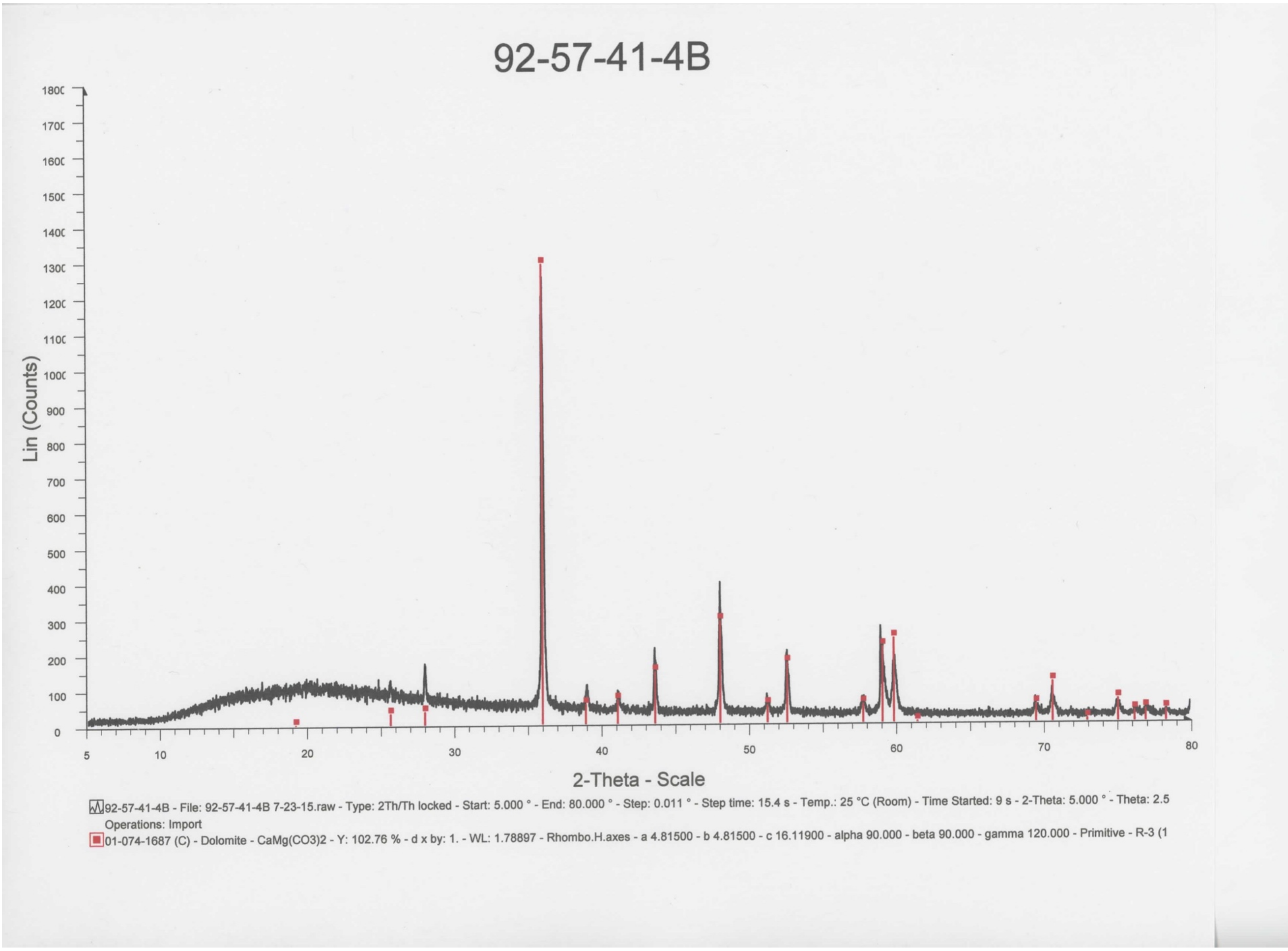


Figure 6.27: XRD spectrum 92-517-41-4B (label has typo)

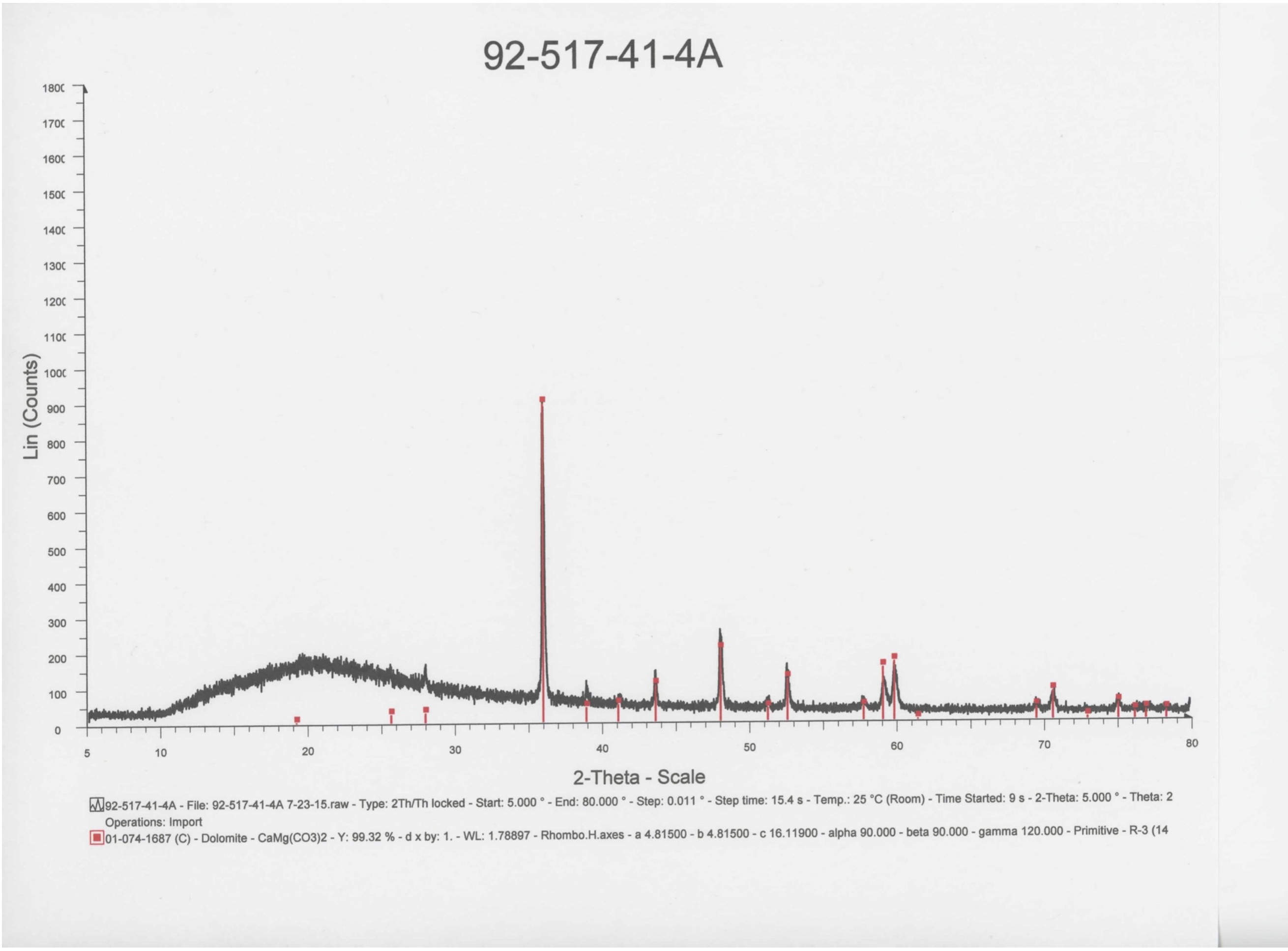


Figure 6.28: XRD spectrum 92-517-41-4A

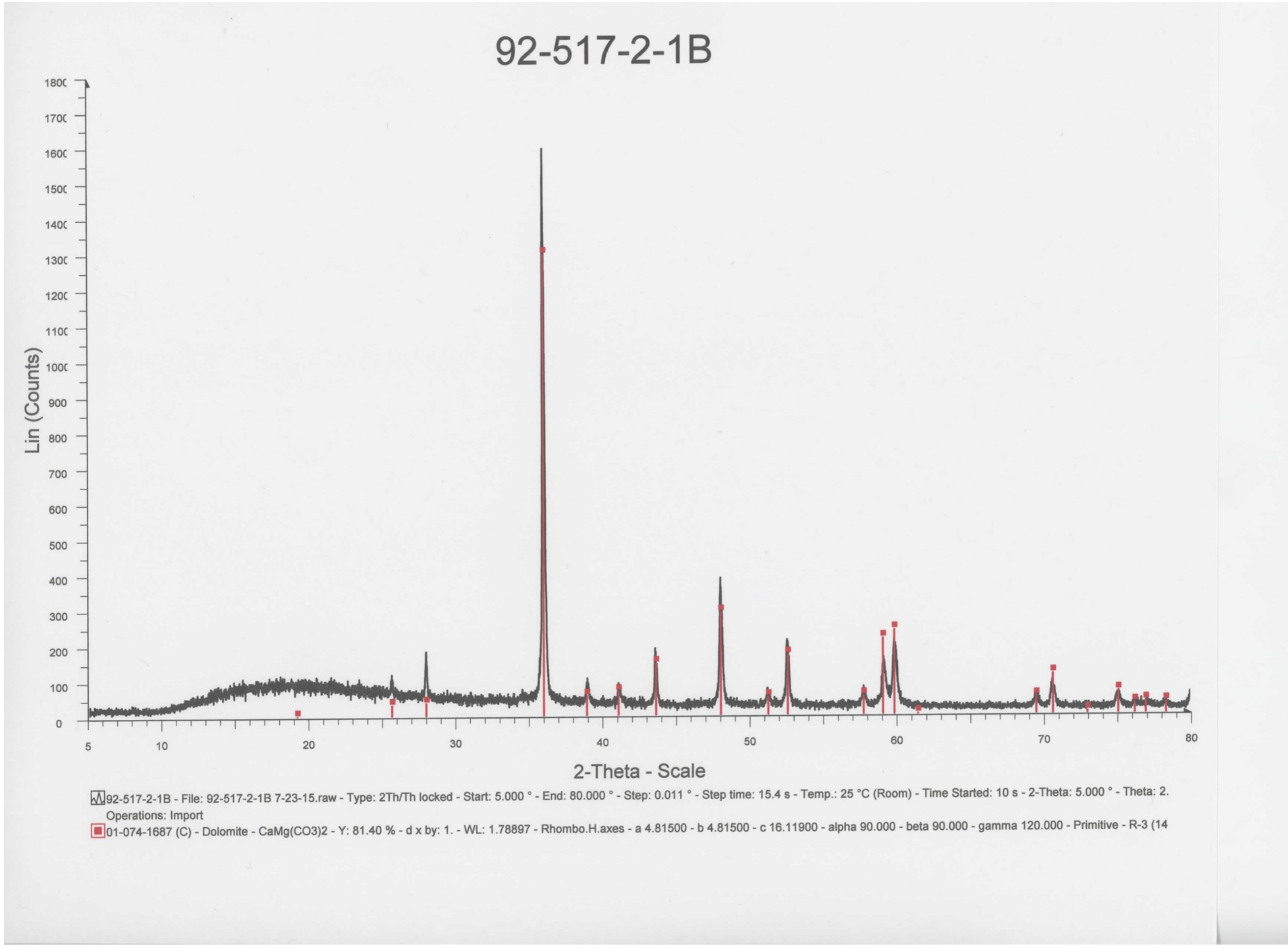


Figure 6.29: XRD spectrum 92-517-2-1B

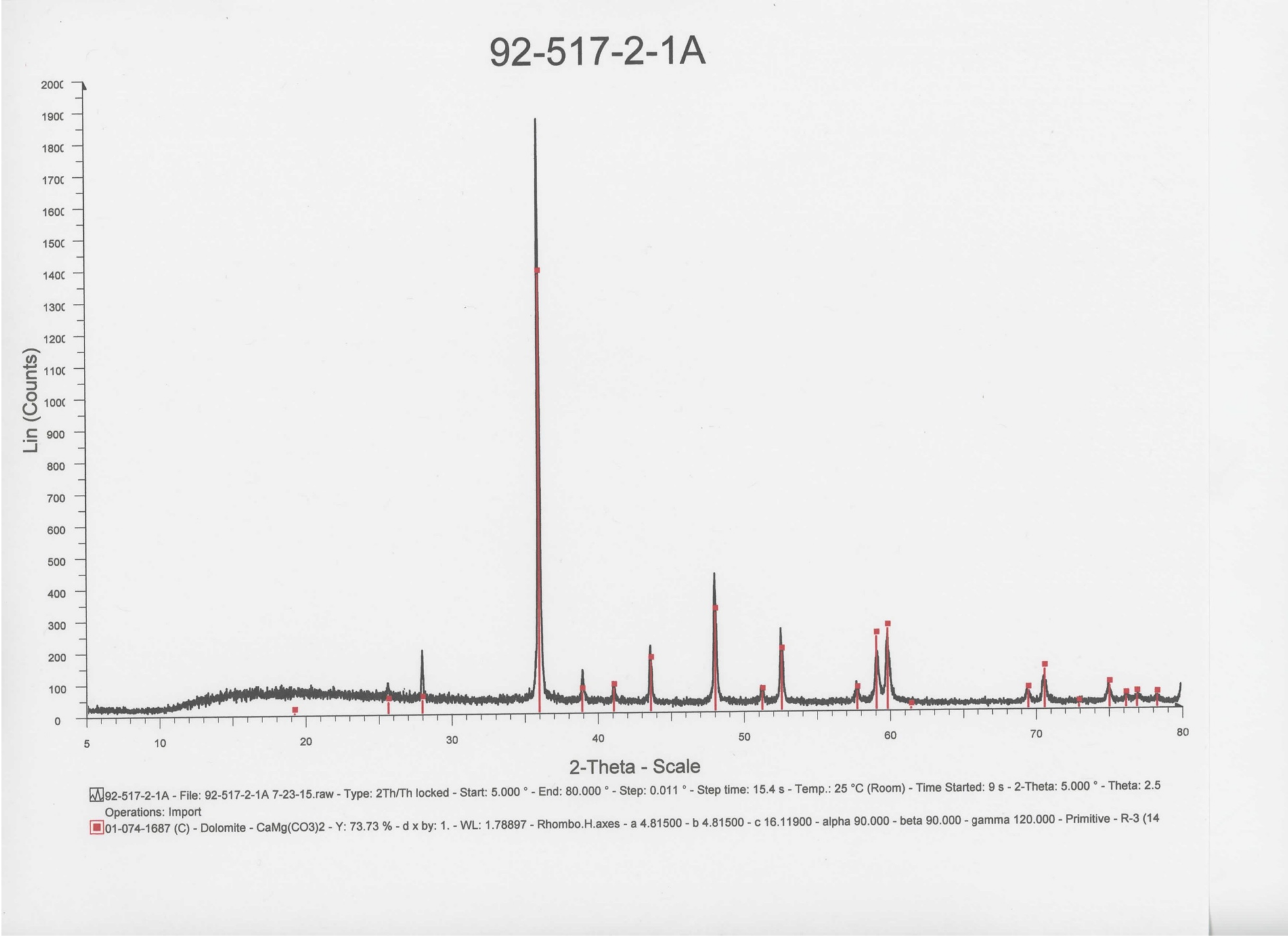


Figure 6.30: XRD spectrum 92-517-2-1A

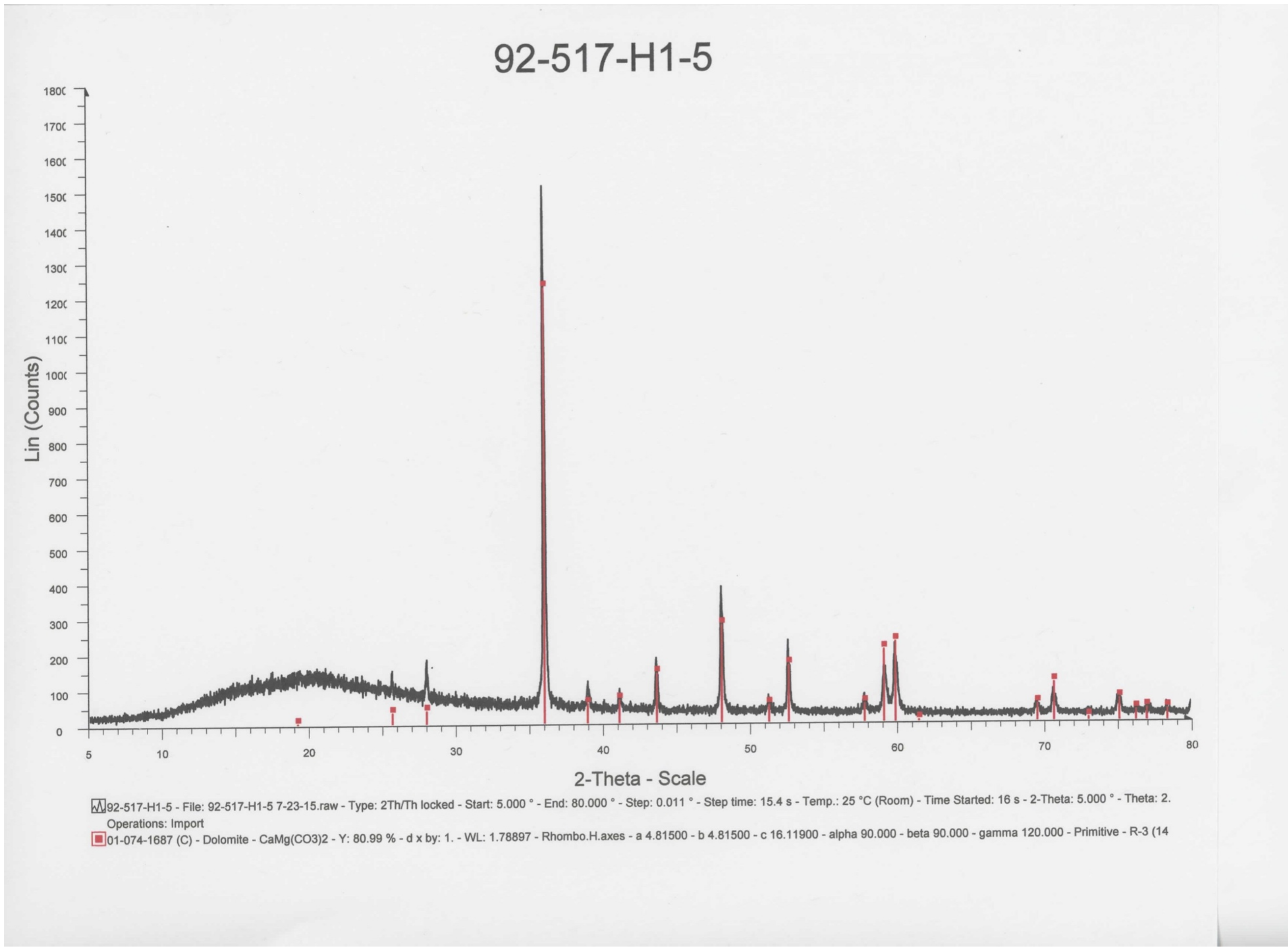


Figure 6.31: XRD spectrum 92-517-41-5 (label has typo)

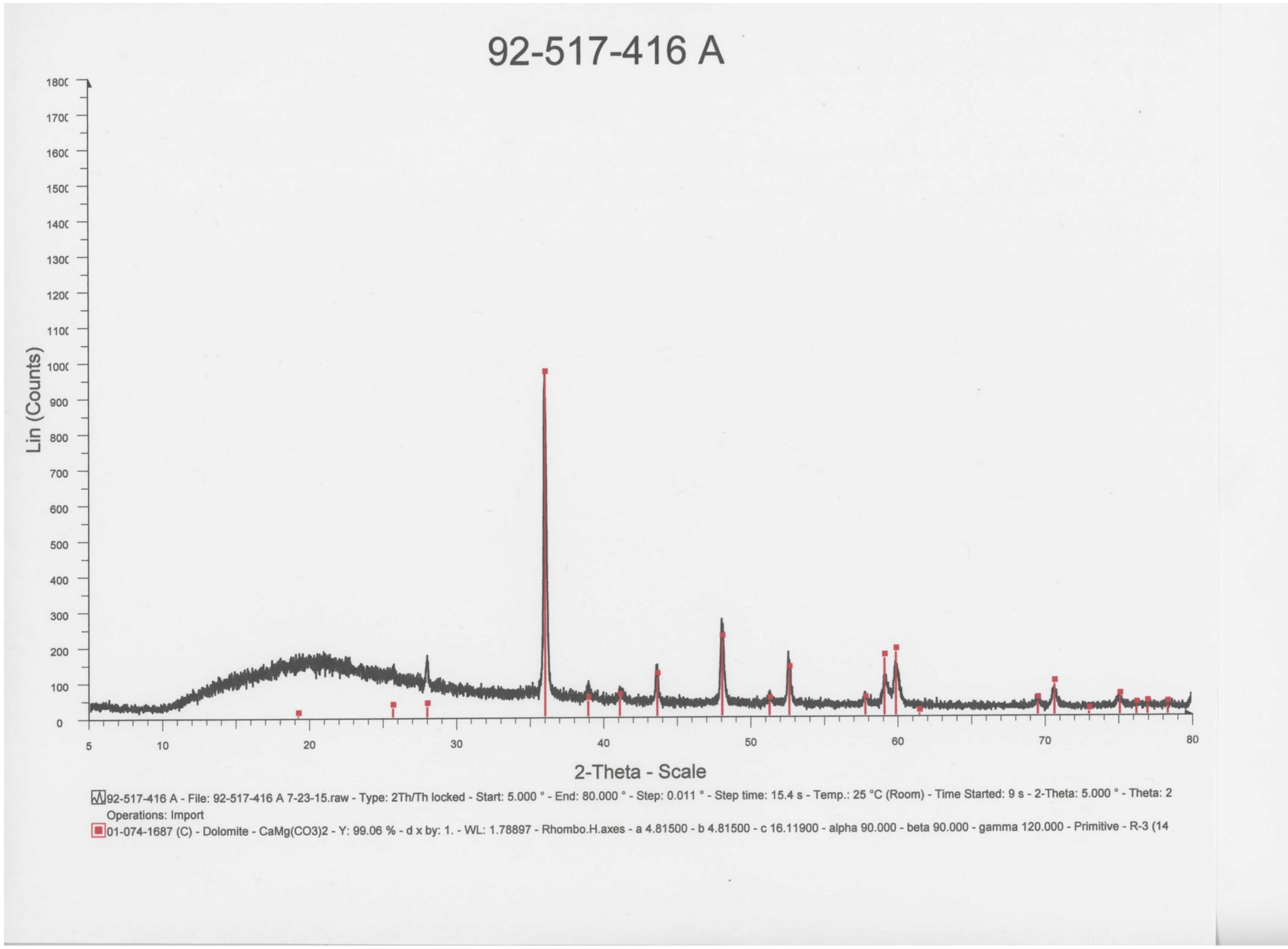


Figure 6.32: XRD spectrum 92-517-41-6A (label has typo)

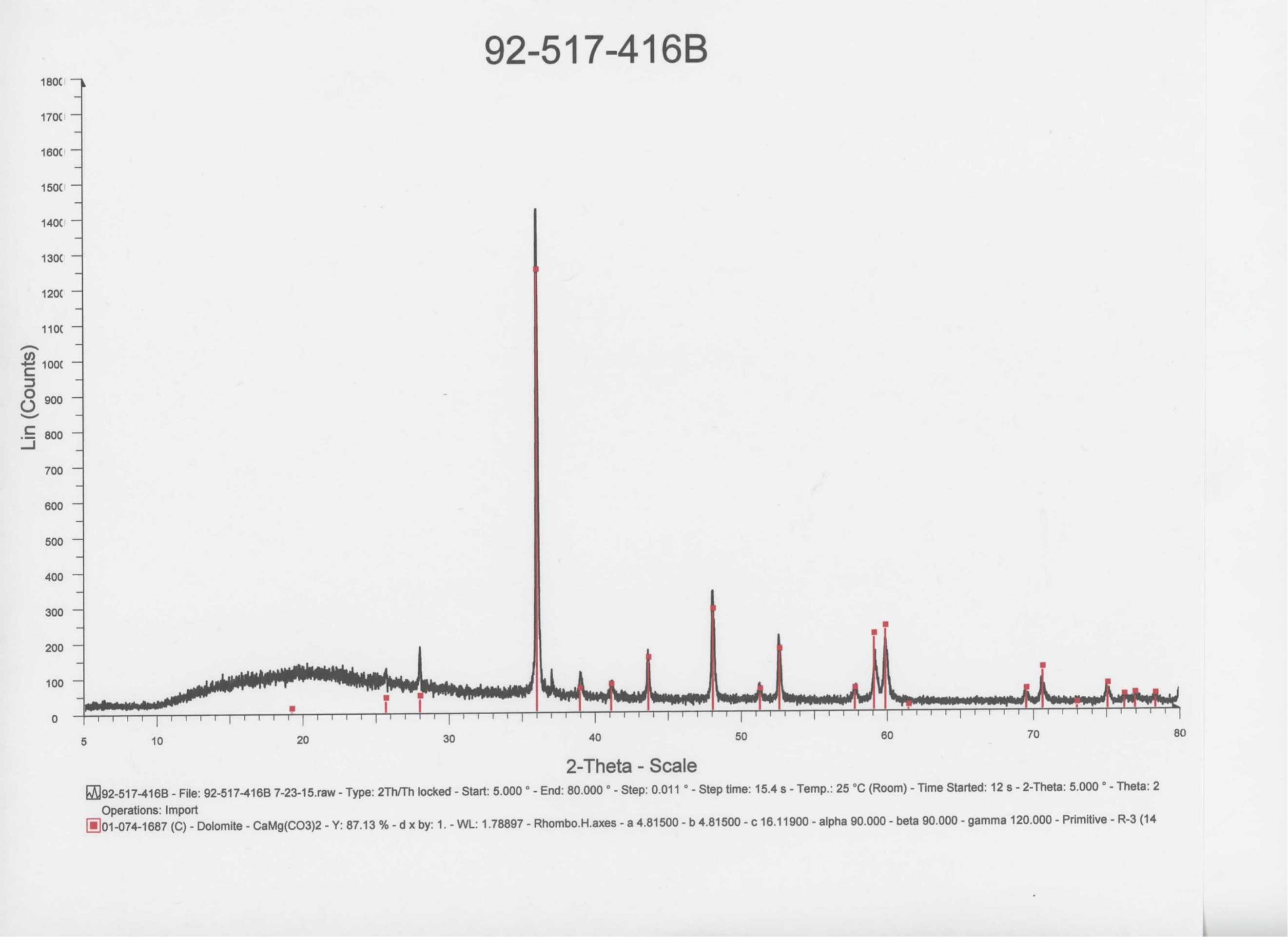


Figure 6.33: XRD spectrum 92-517-41-6B (label has typo)

APPENDIX E: XRF data

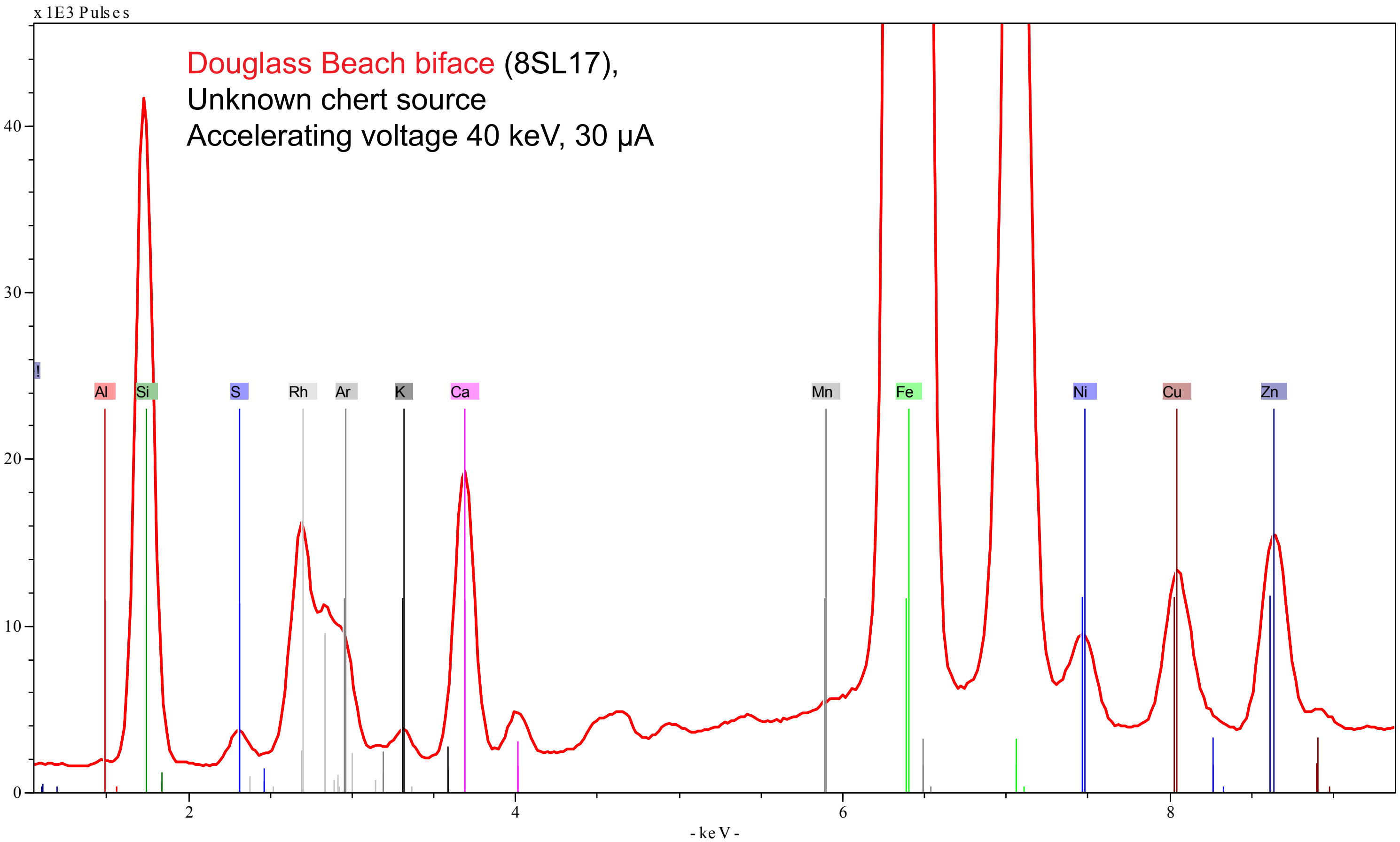


Figure 6.34: Douglass Beach biface pXRF scan, no filter

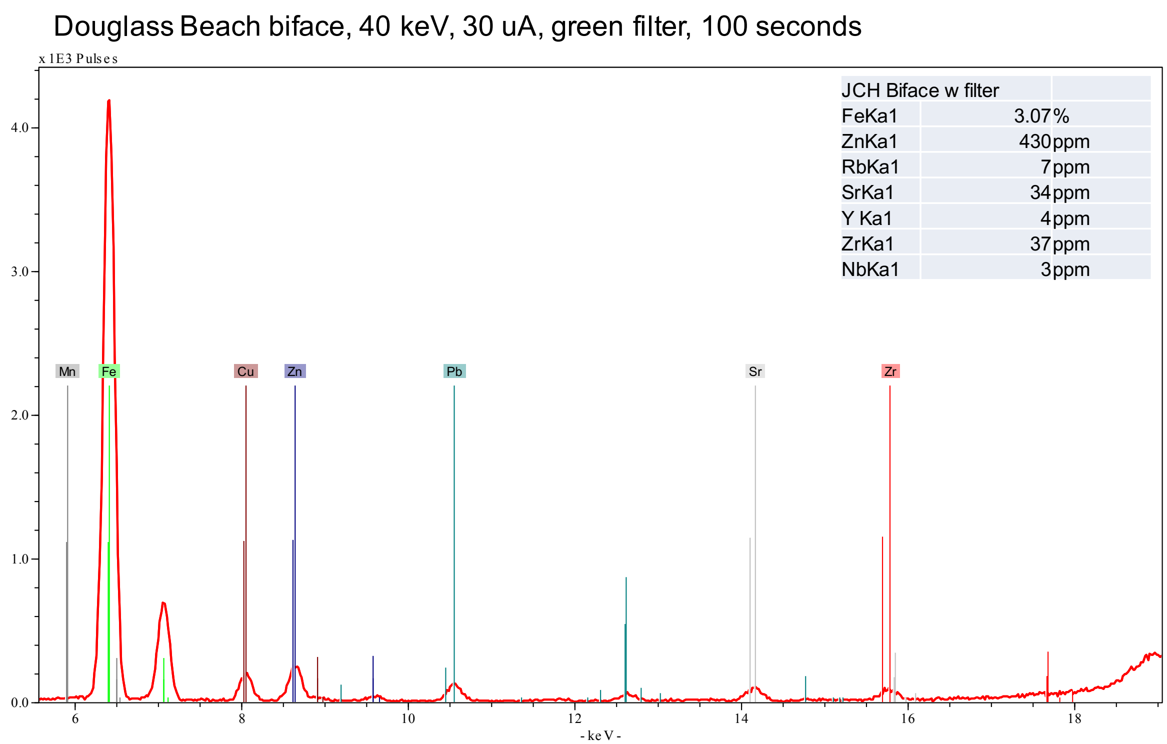


Figure 6.35: Douglass Beach biface pXRF scan, green filter showing elemental composition