1-1-2019

Archaeological Computer Modeling of Florida's Pre-Columbian Dugout Canoes: Integrating Ground-Penetrating Radar and Geographic Information Science

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Abstract

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Document Type

Thesis

Degree Name

M.A.

Department

Anthropology

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Keywords

Dugout canoes, Florida archaeology, Geographic information system, Ground penetrating radar, Network analysis, Underwater ground penetrating radar

Subject Categories

Anthropology | Archaeological Anthropology

ARCHAEOLOGICAL COMPUTER MODELING OF FLORIDA'S PRE-COLUMBIAN DUGOUT CANOES: INTEGRATING GROUND-PENETRATING RADAR AND GEOGRAPHIC INFORMATION SCIENCE

A Thesis
Presented to
the Faculty of Social Sciences
University of Denver

In Partial Fulfillment
of the Requirements for the Degree
Master of Arts

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by
Brandon Charles Ackermann
March 2019
Advisor: Lawrence B. Conyers

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The focus of this research is the application of two computational methods in modeling pre-Columbian dugout canoe use on Florida's ancient transportation network. Ground-penetrating radar (GPR) was used to locate what appear to be multiple unexcavated canoes inundated in the lake-bottom of Lake Santa Fe, a lake in close proximity to Newnans Lake, which contains the largest number of ancient canoes in the world. The identification of multiple canoes in Lake Santa Fe supported the recent idea that this lake may have served as a transit point within Florida's pre-Columbian transportation network. A Geographic Information System (GIS) was then used to model this navigation network, using metrics derived from previously recorded canoes. Florida's canoes with both spatial coordinates and radiometric dates were then placed into this navigation network by calculating transportation routes between canoe locations and contemporaneous archaeological sites interpreted as aggregation centers. These analyses help to demonstrate how archaeological canoes represent more than isolated artifacts, positing an alternative perspective that links canoes to anthropological regarding place and landscape.

ACKNOWLEDGEMENTS

A special thank you to Dr. Lawrence Conyers for seeing me through the many rabbit holes I went down throughout the course of graduate school. His perspectives on academia, economics, and contemporary life were vital in my formation as both a better scholar and better man than I was when I arrived in Denver. I am forever grateful. A big thank you to Drs. Estaban Gomez and Frédérique Chevillot for agreeing to serve on my committee. Computer modeling, geophysics, and ancient canoes are certainly not everybody's cup of tea, and I appreciated their time and attention.

I owe a great deal to Julie Duggins, who let me run with canoes and whose friendship and mentoring were truly vital in all phases of this project. A big thank you to Dr. Ryan Duggins, as well. His encouragement and participation in the fieldwork aspects of this work were crucial. Thank you to Dr. Dean Goodman for providing a trial of *GPRSLICE*, without which none of the GPR simulation would have been possible. Many thanks to Josh Goodwin, Jason O'Donoghue, Paulette McFadden, Nicholas Yarbrough, and Mary Glowacki, my friends and colleagues at the Florida Bureau of Archaeological Research whose enthusiasm, encouragement, and patience as I finished this thesis was extraordinary.

None of this would have been possible without the love and support of my family. A special thanks to my parents John and Michele and siblings Joe and Mandie. And to Kristen, whose love has meant everything.

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CHAPTER ONE: INTRODUCTION

This thesis is about dugout canoes (Figure 1.1), the earliest known watercraft in the global archaeological record (Kandare 1983, Meide 1995, Hartmann 1996). Through this work I develop a methodology for locating canoes and provide a spatiotemporal context for previously recorded canoe sites in the state of Florida. The goal of this work was to generate a spatial model of canoes, their ages, and the relationship between canoes and terrestrial archaeological sites across the peninsula, which led to the computational modelling of pre-Columbian transportation and exchange networks from 6910 B.P. to European contact. This was done to model the relationship between the locations of canoe sites and gathering places that aggerated people from across the landscape during discrete time periods in the past.

This study began by using ground-penetrating radar (GPR), a geophysical method, to model potential canoes in Lake Santa Fe, Florida (Figure 2). I located multiple clusters of subsurface reflections that appear to be dugout canoes, and their locations along the margins of that lake prompted a broader examination of canoe sites regionally. Specifically, I was influenced by project collaborator Julie Duggins' (2019) call to contextualize specific canoe sites as transit points within a broad-scale regional network of human movement.

Duggins (2019) mapped the locations of all canoes with geographic coordinates and noticed that the locations with the greatest number of canoes were near the boundary of water drainages, which ultimately lead to either the Gulf of Mexico, Atlantic Ocean, or south towards the Everglades. In her analysis, Duggins interpreted large numbers of clustered canoes within some individual sites as transit points, places where people intentionally left their canoes to either begin or end one mode of multimodal travel across the Florida landscape. This perspective posits that some canoe locations are within a primary archaeological context and were placed in that context as part of a well-planned mobility strategy. When canoes are related to nearby other archaeological sites of the same age, they are likely related to the people whose activities resulted in the deposition of the corresponding archaeological record. This means that canoes and contemporaneous sites can be viewed within Tobler's (1970) first law of geography: "everything is related to everything else, but near things are more related than distant thing." When Tobler's law is coupled with anthropological interpretations of human activities during certain time-periods, the spatial distributions of canoes and other archaeological sites provide an insight into the patterned movements of pre-Columbian economic activities such as the transportation of goods and ideas across the landscape.

Figure 1.1. Seminoles and their dugout canoes on the Miami River, Florida. State Library and Archives image number RC00208A

The theoretical view of some canoe locations as a proxy for transit points led me to create a spatial model of the locations of Duggins (2019) transit points in conjunction with individual canoe sites within a Geographic Information System (GIS). This software platform was used to study the locations of all canoe sites, hypothesizing that even singular canoe sites could be examined within the context of human networks of movement. By taking this view, I was able to examine not only the cached canoes hypothesized to be transit points, but also reconstruct where singular canoe sites were likely travelling to and from across Florida's pre-Columbian transportation network. In the process of doing this I was also able to discern the specific routes people would have taken to and from important gathering places where they engaged in cultural activities related to social interaction and economic exchange. With access to a personal computer (PC) with high-performance components including an Intel I7 quadcore central processor unit (CPU) and an NVDIA graphical processing unit (GPU), I was able to harness these components' respective abilities to execute multiple complex algorithms and render high-resolution graphics to computationally model

The computational modelling of canoes in GIS began by mapping previously recorded canoe sites documented in the Florida master log-boat database to reproduce Duggins (2019) results, and then led to extending her analysis to include further analytical techniques available in the GIS. The first of these analyses generated a spatial representation of Florida's natural hydrology (Figure 1.2), representing the aquatic network in which canoes could have been used in the past. This conduit for the movement of people and goods across the landscape was then used to model specific canoe routes across cultural periods, linking canoe sites with major archaeological sites of the same age. The navigation network was created as a spatial framework in which to calculate the most time-efficient canoe routes, allowing me to determine where there was likely movement by canoe in the past.

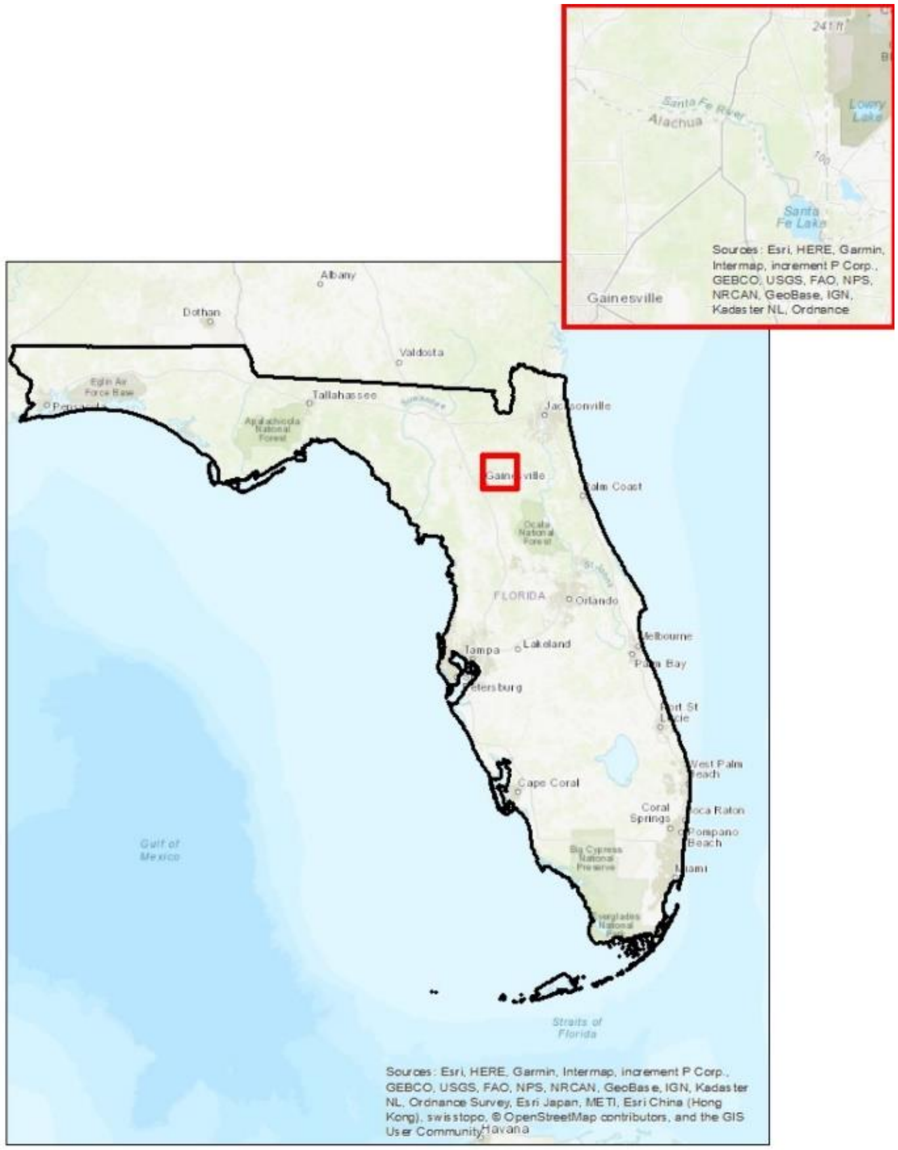


Figure 1.2: Map of Florida with inset of Lake Santa Fe, the location of the GPR survey conducted for this study

Before the relationship between major archaeological sites and canoes could be modeled, a subset of canoe records containing radiometric dates was extracted and then calibrated, tying these canoes to their respective archaeological time-period. This was important because by knowing when these canoes were used, the associated cultural components of the people who used these canoes could be used in interpreting the patterns revealed in the route analyses. These data allowed me to compare the distribution of canoes across time and to make interpretations about both cultural phenomena associated with specific cultural periods. In this way, canoes, routes and the network in which they were used could be analyzed within the anthropological contexts of trade, transportation, technology, and pre-Columbian economies.

Once the canoes were placed within their temporal contexts in the GIS database, canoe locations were examined in tandem with contemporaneous archaeological sites interpreted as gathering places to model pre-Columbian patterns of human mobility. The results of these analyses allowed me to reconstruct Florida's regional-scale network of humans, goods, and the likely movement of ideas over time. In addition, these results provided a framework for interpreting canoes as they are found throughout the state, placing them within an anthropological context that helps to clarify how canoes facilitated intraregional interaction.

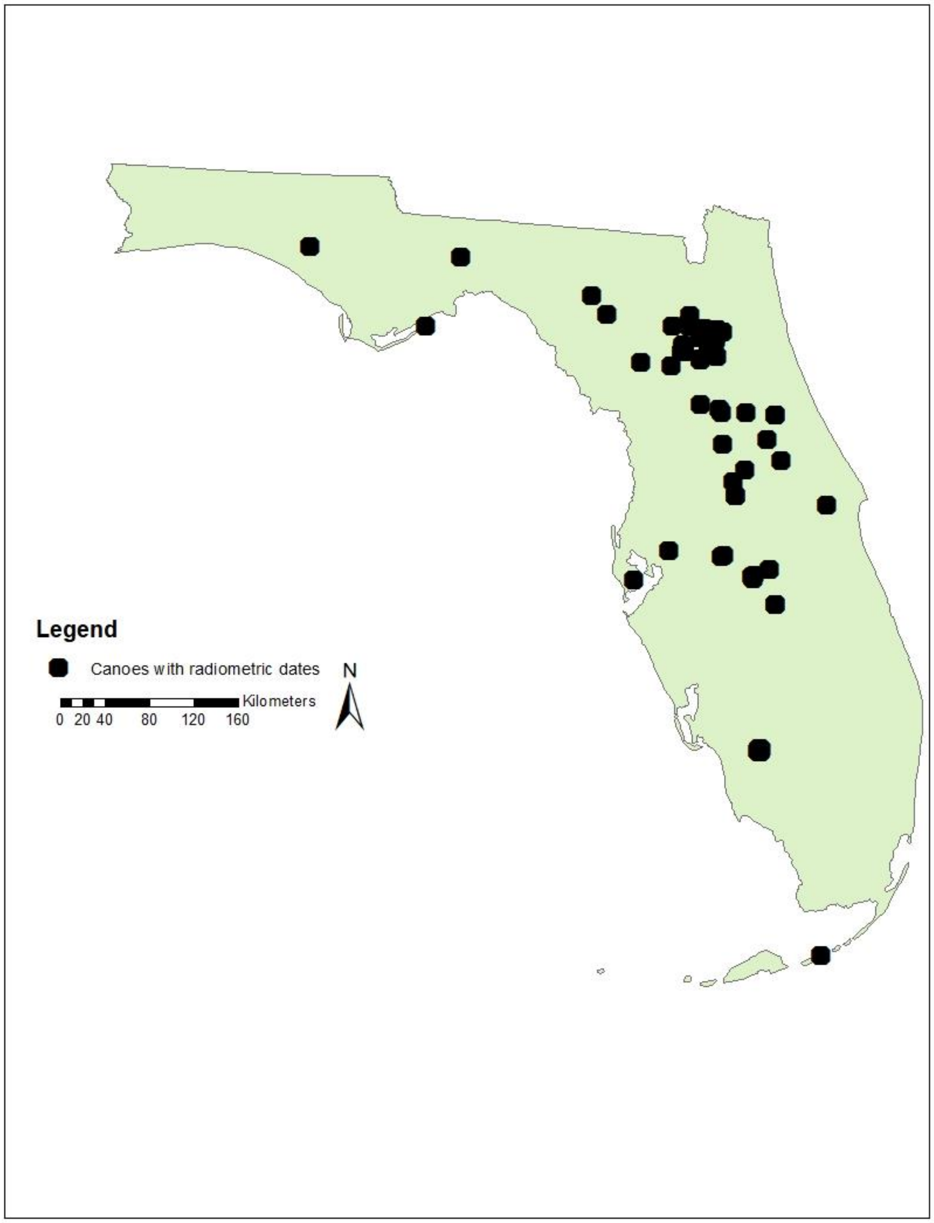


Figure 1.3: Map of previously recorded canoes with radiometric dates

Background

Research on dugout canoes over the past three decades has revealed that the State of Florida contains the largest collection of dugout canoes found anywhere in the world (Ruhl and Purdy 2005), the largest number of canoes located at a singular site (Wheeler et al. 2003), and the oldest dated canoe in the western hemisphere (Hartmann 1996). Over 400 canoes and their attributes have been recorded in the state, resulting in a robust database maintained at the Florida Bureau of Archaeological Research (BAR). This database is what is used in this study, as it contains radiometric dates and spatial coordinates, which were used within a GIS framework to analyze the distribution of canoes through both time and space.

Starting with the compilation of Florida's dugout canoe information into a singular database (Newsom and Purdy 1990), some archaeologists have called for dugout canoes to be interpreted as dynamic archaeological sites instead of curated objects (Hartmann 1996; Wheeler et al 2003; Ruhl and Purdy 2005). Duggins (2019) offers an additional perspective, viewing some sites that have been found along the edges of drainage basins as transit points. In her analysis, transit points are analogous to portages, places where a boat and its people and goods traveled overland between navigable waterways. The importance of portages in prehistory is widely documented (Holyoke and Hrynick 2015; Westerdahl 2006) and Duggins' analysis shows where pre-Columbian Florida peoples intentionally cached their canoes at the beginning or end of one mode of movement across the peninsular landscape. At some point, these cached canoes were abandoned and subsequently became part of the archaeological record. While the mechanism for the inundation of canoe is unknown, Ruhl and Purdy (2005) interpreted the location of the canoes at Newnan's Lake as a relict shoreline, which became submerged as a result of variation in lake water levels over millennia. Because people likely stored their canoes at the edges of waterbodies, places where multiple submerged canoes at drainage boundaries have been located are interpreted as cached canoes.

The hypothesis that people cached their canoes at the end of waterways is important to this study because it provides a model for where canoes were located within a broader network of non-random, patterned human movement. As Kvamme (2006) notes, despite tremendous variability among peoples, "human behavior is patterned with respect to the natural environment and to social environments created by humanity itself."

Ethnographic evidence exists for intentional canoe caching elsewhere in North America and provides support for the idea that the quantity of canoes at some sites is the product of intentional human behavior. Duggins (2019) uses these ethnographic examples from the northeast and great lakes regions to support her idea that the concentration of canoes at both Newnan's Lake, the largest singular canoe site in the world, as well as other canoe sites are a result of intentional canoe caching. She hypothesized that based on Lake Santa Fe's positioning at the interchange between two Gulf and Atlantic drainages, a cache of canoes like those found at other sites may be present within this lake. The GPR survey conducted for this thesis was carried out to test Duggins' hypothesis that Lake Santa Fe contains a cache of canoes, and therefore is a transit point. In the process of analyzing those GPR data I realized that archaeological computer modelling offered a solution to not only helping Duggins test her hypothesis, but also could be used to analyze the thirty-year-old canoe database in a new way. Specifically, I recognized that the GIS framework could be used to explore human mobility across time and space by using attributes already present in this database. Furthermore, I recognized that coupled with location data contained in the Florida Master Site File (FMSF), canoe data could be used to explore not only where people were going, but also the relationship between human movement and geographic centers of human activity that aggregated Florida's pre-Columbian populations.

The movements of people by canoe facilitated not just people traveling, but also the transportation of goods and ideas across what was a dynamic natural and cultural landscape from the fifth century B.C. through European contact in the early 16th century. From about 7000 cal B.P. onward, people who were already living in Florida adapted to environmental changes and developed canoe technology, which was used to exploit aquatic resources and traverse across the rivers, streams, and lakes which today characterize the Florida landscape (Hartmann 1996). While canoe technology may have appeared in Florida as a result of environmental adaptation, the use of canoes quickly reverberated into other aspects of pre-Columbian life, becoming "entangled" within the complex system of human culture (Hodder 2011). Canoe manufacture required organized labor and technical specialization, and the use of canoes facilitated the long-distance transportation of people, goods, and ideas across the landscape. Therefore, canoes can be used to explore the mechanism for many aspects of pre-Columbian life (Hartmann 1996).

The perspective I take for this thesis hypothesizes that much like the driveways, garages, and parking lots of today, some canoe sites represent both a terminus and launching point for travel across a broad-scale multimodal network of human movement, while others are traces of activity along this network. People traveled across the lakes and rivers, which characterize Florida's aquatic landscape, to engage in trade, attend social gatherings, transport goods between population settlements, and building economies during a time when populations were growing, and cultures were becoming increasingly complex. Using this framework, Florida's networked pre-Columbian economic, cultural, and transportation landscape, if reconstructed by first placing canoes into their spatial and temporal contexts, can reveal patterns in human mobility that facilitated the transportation of goods and people, social interaction, and economic activities in the past.

Methods

The spatial analyses of recorded canoe and terrestrial archaeological sites were executed using the computational power of GIS to create models of the well-dated canoes and archaeological site distributions across the Florida peninsula. As knowing their ages was important to produce models during different times, the radiometric dates for 128 well-dated, previously recorded dugout canoes had to first be calibrated and incorporated into the GIS models.

Once the radiometric-dated canoes were categorized by their archaeological time-period, these results were also input as metadata in the dataset of canoes that contained spatial coordinates. An important attribute for the data modeling is a hydrological network consisting of rivers and lakes. A final dataset incorporated into the models is the location of major archaeological sites that have been interpreted as aggregation centers.

An integration of these data was then used to construct models of the routes between canoe sites and places where people were gathering on the landscape. The GIS computer platform is especially applicable to this study as it can be used to search for specific data corresponding to an archaeological time-period and then place those data within a regional landscape model of human movement. This allows for the creation of a dynamic model of pre-Columbian settlement, mobility, and interaction.

Results and Conclusions

The results of the computer modeling support the idea that Lake Santa Fe was an important transit point on the ancient landscape. When the locations of canoes with radiometric data was fused with contemporaneous archaeological sites, with routes calculated between them, it became evident that many canoe routes persisted over time, indicating that these routes were *persistent places* on the landscape (Schlanger 1992). Moreover, the modeling done here calculates the physical link between the movement of people, goods, and ideas across the landscape. These results show that intraregional interaction and exchange was likely facilitated by canoe travel from 7000 years ago forward.

CHAPTER TWO: BACKGROUND

Between eight and six-thousand years ago, sea-level rise and a corresponding elevation of the water table resulted in the development of numerous wet environments across the Florida landscape (Brenner et al. 1990). These included shallow lakes, estuaries, numerous streams and rivers, as well as corresponding floodplains and forested swamps that replaced prairie grasses (Grimm et al. 2001). As wetland ecosystems developed, humans took advantage of the newly available biotic communities of plants and animals by hunting, gathering, and fishing these resources (Milanich 1994).

In tandem with the human exploitation of new wetland environments beginning around eight thousand years ago, important cultural devlopments that emerged included the innovation of new technologies, a hallmark of humankind (White 1949, Sahlins and Service 1960, Oakley 1968). One of those developments in technology during this time was the adoption of dugout canoes, the earliest known watercraft in the Western Hemisphere (Hartmann 1996). Using these dugout canoes, pre-Columbian peoples traveled along Florida's newly formed vast hydrological network to procure aquatic resources, access diverse environments, and interact with contemporaneous peoples on the peninsula and elsewhere in North America (Brose 1990, Newsom and Purdy 2005).

As dugout canoes facilitated transportation throughout the peninsula, people who had previously been separated geographically participated in different social arrangements, and complex networks of trade and interaction were formed and maintained. What had previously been scarce resources in one area could be transported and traded with others who may have had an abundance of other items, creating trading networks that benefited all (Milanich 1994, Anderson and Sassaman 2012). This naturally led to population increases as people were able to settle for extended periods of time, and possibly permanently, in one spot and no longer had to rely on a mobility strategy dictated solely by the seasonal availability of resources (Russo 2008). The general population increase also led to heightened settlement density, which naturally changes the social dynamics as food resources required management to prevent overexploitation (Anderson and Sassaman 2012, Milanich 1994). This can be seen in Florida through large-scale mounded shell deposits, which in some areas have been interpreted as the remnants of feasting events that drew distributed groups together for political and ceremonial undertakings (Russo 2004). One instrument that facilitated these interactions was the canoe, which was the primary technology for moving goods, people, and ideas across the newly created wetland landscape. This became especially prevalent during the Late Archaic Period (Table 2.1) and persisted from this time forward.

The research presented here develops a methodology for locating these ancient canoes, and then places previously recorded canoes into a spatiotemporal context to model the movement of humans and goods across Florida. This is done to explore how pre-Columbian peoples within Florida may have been interacting with each other during discrete culture periods by canoe travel, and also to generate new hypotheses regarding this mechanism of transportation and exchange in the past.

Geological Background

In order to model the movement of people of goods by canoe across the Florida landscape, it was neccesary to first understand how this landscape developed. Many of the geological processes that shaped Florida's landscape are evident in its contemporary geomorphology (Figure 2.1). These include remnant shorelines, terraces, and scarps, as well as the karst topography, which dominates a majority of the peninsular landscape (Hine 2013). These surface features, in tandem with Florida's diverse ecosystems, such as rivers, lakes, springs, upland forests, and pine-dominated flatlands, comprise the landscape in which humans dwelled since at least 14000 years ago (Milanich 1994, Dunbar 2017).

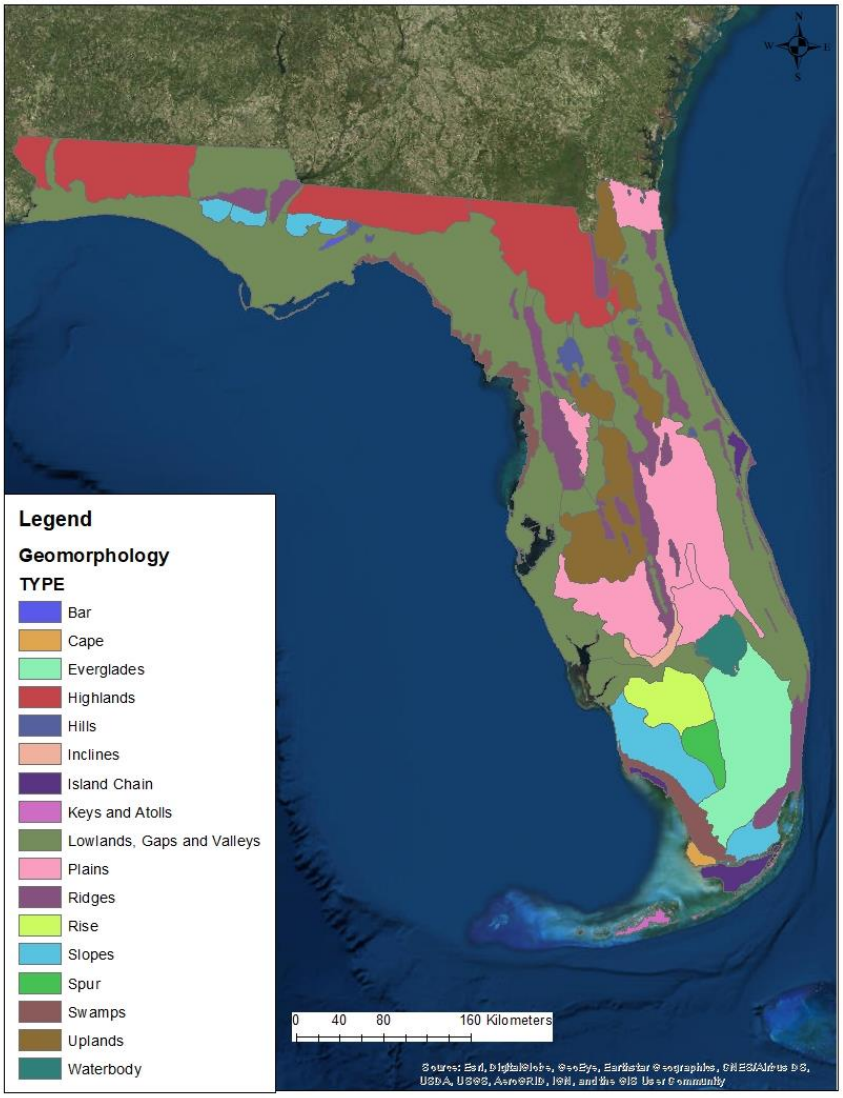


Figure 2.1: Geomorphology of the Florida Peninsula showing markers of past sea-level change such as Hills, Ridges, and Uplands, among others

After the breakup of two mega continents 250 million years ago (MYA), the Florida platform's basement rocks formed. These rocks are distinguishable, as they derived from the Gondwana continent, while the majority of North America's bedrock originated in the Laurentia continental craton, the geological precursor to modern North

America. This is notable because as the Florida platform fused to continental North America around 180 MYA, a failed rift basin formed in the southern portion of what is now the state of Georgia extending southward to the Florida panhandle. This rift basin formed a topographically low area that for tens of million years was occupied by the Georgia Channel Seaway Complex, a marine current system that flowed during seawater high-stands as Florida was forming (Figure 2.2). The Georgia Seaway flowed perpendicular to the Florida platform, which now existed in submerged and emerged parts, and the orientation of the complex relative to the Florida platform shielded the landform from the eroding sediments of the Appalachian Mountains and Piedmont to the north. Because the channel system protected the submerged basement rocks from these nutrient-rich sediments, clear water conditions persisted for much of the Mesozoic Era through the middle Oligocene Epoch. With the basement rocks existing then as a large, flat, and shallowly-submerged landmass in a subtropical latitude, the ideal conditions for the development of a carbonate platform existed. This carbonate platform is now overlaid on the basement rocks and comprises the second component of Florida's geology (Hine 2013).

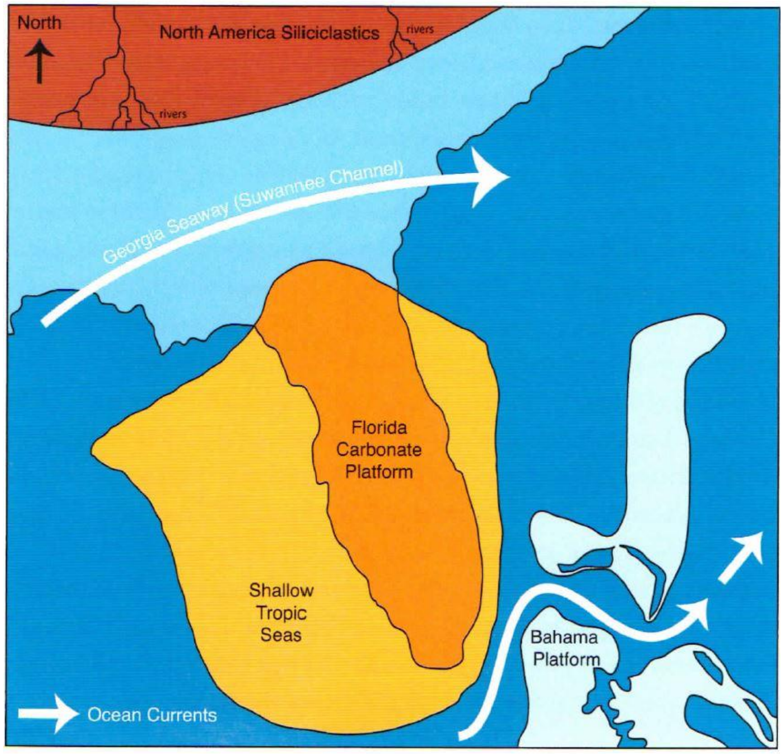


Figure 2.2: Illustration showing the Georgia Seaway Complex, which served as a barrier against eroding sediments for tens of millions of years from the Mesozoic Era to the middle Oligocene Epoch, allowing the Florida platform to develop the carbonate platform that comprises the second component of its geologic structure. Hine 2013

Carbonate sediments served as the parent material for the second layer of the contemporary Florida platform and derive from the skeletal material of plants, animals, and micro-organisms in a clean and shallow marine environment (Hine 2013). These sediments were of varying grain sizes, which, when mechanically transformed and sorted via current and wave action, were deposited in place and are recognizable in distinct stratigraphic layers (Hine 2013). Over time, the individual carbonate grains fused through a process called *cementation*, in which dissolved materials in the water filled in the small spaces between grains and formed laterally extensive rock units. These units underwent further chemical and mechanical transformations that resulted in a karstic landscape, the distinctive topographic characteristic that comprises the majority of the Florida landform.

Following the development of carbonate rocks on the Florida platform basement during the Middle Jurassic period around 174 MYA, chemical and mechanical processes transformed the carbonate rocks into a karst terrain. Karst is a distinct type of terrain whose morphology is determined by the dissolution of underlying carbonate rocks (Hine 2013:117). As slightly acidic waters permeated Florida's carbonate system, the water preferentially dissolved some of the surface and near-surface carbonate rock. This dissolution created voids within the bedrock structure, resulting in a morphologically variable surface and subsurface that is charachterizerd by an abundance of sinkholes, springs, caverns, and undergound rivers (Hine 2013:118). Florida's porous bedrock is directly related to the water table, and therefore related to the hydrological network that humans have exploited since their arrival.

The wide-spread dissolution of rocks in Florida's carbonate system created a network of voids, many of which contain freshwater. These, in general, comprise the Floridan aquifer system, which is one of the most extensive freshwater systems in the world, supplying water for Florida's past peoples as well as its contemporary populations (USGS 2013). With Florida's basement rocks and the carbonate platform in place, siliciclastic sediment cover, the third component of the geological platform, began to develop, eventually resulting in the modern-day ground surface.

The third and final element of Florida's geologic structure is the package of siliciclastic sediments, which comprises much of the modern ground surface and confines the Floridan aquifer. Beginning around 28 MYA in the middle Oligocene Period during a sustained sea level low stand, prograding river deltas produced by rivers flowing from the north filled in the Georgia Seaway Complex. During the following sea-level high-stand, quartz-rich sediment was deposited across the seaway where it reached the northernmost portion of the Florida platform, effectively creating the Florida peninsula. Once this occurred, during sea level high-stands sediment was deposited via longshore drift in a southward direction, resulting in the formation of sandy deposits along coastlines, which can be seen today as elevated inland ridges parallel to Gulf and Atlantic coasts (Hine 2013, Scott 2011, O'Donoghue 2015). During sea-level low-stands, these clastic sediments were carried by rivers within the interior of the peninsula, toward the outer margins of the emerged continental shelf far offshore from the modern coastline and created the shorelines that bound the contemporary Florida peninsula.

Cultural Chronologies

Figure 2.3: Location of archaeological sites mentioned in this chapter

Table 2.1: Culture-historical chronology of pre-Columbian Florida. After Anderson and Sassaman 2012

Cultural Period	**Calendrical date**	**Conventional Radiocarbon date (Years before present)**	**Calibrated Radiocarbon date**
Mississippian	950 A.D.	1,100 RCYBP	1,000 cal B.P.
Woodland	1,200 B.C.	3,000 RCYBP	3,200 cal B.P.
Late Archaic	3,800 B.C.	5,000 RCYBP	5,800 cal B.P.
Middle Archaic	5,900 B.C.	7,000 RCYBP	7,800 cal B.P.
Early Archaic	9,550 B.C.	10,000 RCYBP	11,500 cal B.P.
Paleoindian	12,000 B.C.	12,000 RCYBP	14,000 cal B.P.

Paleoindian

Florida's archaeological record indicates that biologically modern humans have been utilizing the Peninsula for at least 14,550 years, as evidenced by the currently oldest absolute-dated archaeological site in North America (Halligan et al. 2016). The first Americans, called Paleoindians arrived at the end of the Pleistocene Era and found themselves in a climate and natural environment much different than that of today. Although Florida was never glaciated, glacial masses elsewhere contained much of the Earth's water and the sea-level was approximately 100 meters lower than present (Dunbar 2017). With the sea level and water table significantly lower than it is today, Florida's land area was about double the size. In addition, the climate was much cooler and drier than today (Dunbar 2017). Around 15,000 cal. year B.P. at the end of the Ice Age glaciers began melting and induced a rise in sea level that pushed shorelines inland and began the shift from a glaciated North America to today's landscape (Milanich 1994; Miller 1998). In these arid conditions, the locations of freshwater resources necessary for human survival provided geographic constraints on both humans and the animals they hunted. This was a time when Florida was arid, and with the lower sea level and corresponding deep-water table, the Florida peninsula would have been a harsh and difficult environment for people. Specifically, the locations of fresh water within the deep springs of the karst terrain dictated the subsistence regimes and migratory paths of both people and animals because these freshwater resources existed only in certain locations (Miller 1998:45; Milanich 1994).

Archaeological evidence at sites such as Wakulla and Little Salt Springs (Figure 3), suggests that the highly-mobile hunter-gatherer Paleoindians stalked megafauna and small mammals at these geographically restricted water-sources (Milanich 1994). Elsewhere, the close association between Paleoindian sites and waterbodies is widely demonstrated in predictive models of archaeological site locations (Anderson and Sassaman 2012) and indicates that from the onset of human migration into North America, a pattern of settlement around water was established. This was the case in Florida throughout the Paleoindian period.

These Paleoindians were highly mobile because they depended on the migration patterns established by the animals they hunted. And therefore, their tool-kit was limited in size as they had to move on foot between resource areas. They manufactured multi-use tools as opposed to the more time-intensive specialized tools that would become widespread in later times (Milanich 1994:48). Paleoindians are most frequently identified in the archaeological record by their distinctive bifacial lanceolate-formed points, which were hafted to large spears and fashioned out of stone, ivory, and bone (Milanich 1994:48). Although the demography of Florida's Paleoindians is unknown, a population dispersion is inferred from the geographically isolated bifacial stone tool traditions at the end of the Paleoindian period (Thulman 2006:219).

By the end of the Pleistocene, multiple groups of Paleoindians likely existed within the Peninsula that were probably bands of kin-related individuals no larger than an extended family, with an estimated maximum number of individuals between thirty and fifty (Kelly 1995). Although no canoes are known from the Paleoindian Period, recent revelations that the first human migrations into North America occurred via a coastal route (Potter et al. 2018) open the possibility that watercraft were at least understood at this time but have just not been found yet.

Archaic

Succeeding the Paleoindian Period is the Archaic, a period spanning eight-thousand years (Table 2.1). Bookended by the beginning of the Holocene geological epoch at the end of the Ice Age and the emergence of modern environmental conditions around 3,200 years ago, the Archaic Period saw a marked increase in population and the innovation of new technologies such as stone and ceramic vessels, wood-working tools, and canoes. Even though it is the most extended period in eastern North American pre-Columbian history, the Archaic Period is vastly understudied (Sassaman 2010).

Early Archaic

Marked by the end of the Younger Dryas climatic event ca. 11,500 cal B.P. and contemporaneous with an abrupt increase in global temperature, the Early Archaic Period (Table 1) can be characterized as a time of population growth and a continued reliance on the hunter-gathering subsistence strategy prevalent in the Paleoindian Period (Anderson and Sassaman 2012). Marked technological changes during the Early Archaic included a shift in lithic technology from lanceolate forms to smaller bifacial projectile points. This shift coincides with the extinction of Pleistocene megafauna and suggests the transition from big-game hunting to the systematic killing of smaller game, primarily deer (Anderson and Sassaman 2012). The Early Archaic Period is also the first archaeological period with known mortuary data, providing a glimpse into the health, ideology, and demographic components of hunter-gatherer life in Florida. Most notable of these sites is Windover (Figure 2.3), where bioarcheological data derived from 168 individuals has been utilized to infer the health and mortality of Florida’s Early Archaic peoples.

Located in Brevard County on the Atlantic coast, the Windover site (Figure 2.3) is an exceptionally rich data source for studies of the Early Archaic. At this early mortuary center, 168 individuals were intentionally buried at the bottom of a shallow pond, now covered by peat (Doran 2002). Due to the anaerobic properties of the peat deposits, the burials at Windover Pond contained human brain matter and gastric contents, providing some of the first bioarchaeological data from pre-7000 B.P. human remains (Doran 2007). These data have allowed scientists to glean insight into the health, demography, and diets of this ancient population.

At Windover, archaeologists uncovered the remains of individuals of both sexes with an age range between infancy through about 60 years (Doran 2002). Bioarchaeological evidence at Windover indicates that subadults had a high-degree of interrupted bone growth, likely the result of malnutrition, and many of the adult skeletons showed signs of bone disease, including osteoporosis and osteoarthritis. These data indicate that this early population endured many physical and nutritional hardships (Doran 2002). This is interesting because it shows that during this period basic nutritional needs were unmet, with a majority of community labor likely being invested into tasks related to the meeting of these needs, including food aqcuisition (Doran 2007). Despite the precense of nutritional hardships, many organic grave goods including intricately woven baskets and fabrics were found at Windover, indicating that the ceremonial treatment of the dead was an important aspect of Early Archaic life (Doran 2002).

At Windover, special attention was not only reserved for the dead, but also for the living and specifically children. One of the most remarkable findings at Windover pond are the remains of a 15-year-old boy with *Spina Bifida* who was likely paralyzed from the waist down and missing his right foot yet, he lived long enough to have had it heal into a stump below his knee. This individual would likely not have survived to adolescence without the investment of care on a community level, which shows that the investment of time and energy into the care of children was particularly important to this community (Doran 2002). Mortuary ponds like Windover are present elsewhere in the state and their use into the Middle Archaic Period indicates a shared cultural behavior at least with respect to the burial of the dead among the various band-level populations across Florida.

Middle Archaic

The Middle Archaic Period coincides with a time of environmental change that deeply impacted multiple aspects of pre-Columbian culture. Contemporaneous with this period is the Mid-Holocene climatic interval, also referred to as the Altithermal, Hypsithermal, Atlantic, or Climatic Optimum (Anderson and Sassaman 2012). The environment during this time is characterized as one of extremes in precipitation and temperature relative to the early Holocene, with hotter and wetter summers, as well as cooler and drier winters. In addition, continued sea-level rise resulted in the establishment of large estuarine systems where river valleys were flooded, as well as the gradual emergence of inland wetland systems, including the lakes and rivers of today's landscape (Anderson and Sassaman 2006, Schulderein 1996, Milanich 1994). As these new wetlands and rivers developed, people began to adapt to this changing environment by taking advantage of newly-available aquatic fauna, such as freshwater and marine shellfish (Randall 2015, Schulderein 1996:3, Hale et al. 2018). The oldest dugout canoes in Florida date to this period, providing another line of evidence for the importance of the newly formed aquatic landscape, and which shows that people easily adapted to and exploited these new environments. Dugout canoes provided access to resource-rich wetland areas and also facilitated the transportation of people and goods across the peninsula (Hartmann 1996).

The changing environment during the Middle Archaic also influenced mobility and the production of technology. Russo (2008) notes that with the emergence of waterways community effort was required to produce new technologies for resource exploitation, such as dugout canoes, fishing nets, and fishing weirs. The organization of these activities necessitated leadership to prevent overexploitation, a need Russo (2008) argues resulted in stratified social systems for the first time. In addition, Russo (2008) notes that this may also have resulted in economic specialization, with individuals and groups concentrating on producing a limited variety of goods and technologies for the first time. The technological specialization that occurred during the Middle Archaic also affected mobility and transportation.

With the production and use of canoes, Middle Archaic people gained the ability to travel longer distances in a day and procure a greater quantity of resources than by foot travel alone. Because of the increased efficiency available with canoe use, people who used canoes during this time were able to move their home camps less frequently than in the Early Archaic. While it is believed that the day-to-day activities of Middle Archaic peoples were confined to river valleys, exotic tools such as greenstone derived from the Appalachian Mountains are present in Middle Archaic site assemblages, indicating that people were engaging in trade and interacting with people who lived beyond their home base and even the peninsula (Anderson and Sassaman 2012).

During this period, mortuary practices continued to be an important aspect of culture. Middle Archaic peoples continued to inter their dead in ponds, however, an important transition to earthen burials can be seen at the end of this period. This change in burial practice may be attributed to the deepening of the ponds and lakes as the water table rose, which may have restricted access to the pond cemeteries first used in the Early Archaic Period (Sassaman 2013). As with the Windover site (Figure 2.3) bioarchaeological data from a mortuary context has contributed greatly to the knowledge of the Middle Archaic Period, particularly with regards to trade and interaction.

At the Harris Creek site (Figure 2.3), isotope analysis on human teeth from human burials revealed four non-local individuals interred in what appears to be the earliest non-pond-burial mortuary context. It appears that some of the people interred at the Harris Creek site came from the Atlantic seaboard, likely from as far away as Tennessee or Virginia (Quinn et al. 2008). These data further support the idea that people at Harris Creek (and more generally) Middle Archaic Florida populations participated in long-distance exchange networks, which could have led to inter-mating with groups from far away.

In summary, the Middle Archaic Period in Florida can be characterized by increased technological innovation, decreased residential mobility, widespread exchange, economic specialization with respect to subsistence technologies, and the beginnings of social stratification. All of these activities may be related to the use of canoes beginning at this time, and underly the importance of canoe technology in the formation of pre-Columbian cultures from this time forward.

Late Archaic

The defining attribute of the Late Archaic Period (Table 2.1) was the adoption of pottery at around 3700 cal B.P. (Sassaman 2004). The advent of ceramic technology indicates that food storage provided enough nutritional stability during this time to exert more energy on activities unrelated to subsistence. With ceramic technology changes in settlement and exchange are also present in the Late Archaic. Permanently-settled villages are appear for the first time during this period and are reflected in coastal shell ring sites, which consist of large piles of shells in semi-circular form encircling a level plaza area (Russo 2006). At these sites, people deposited the refuse from their daily meals behind their households and participated in periodic ritual feasting events, which likely involved interaction with non-local communities (Russo 2008).

The appearance of non-local materials, such as steatite (or soapstone) derived from the Appalachian Mountains and transformed into vessels is also evidence for extensive interaction and exchange, and steatite is believed to have been traded widely throughout the southeast at this time (Anderson and Sassaman 2012). One outstanding question in Florida archaeology is the degree to which Florida populations were interacting with and influenced by the people of Poverty Point in Louisiana. Extensive research at Poverty Pointy over the years has revealed it to be the largest and most elaborate expression of prehistoric culture in North America (Milanich 1994). At Poverty Point, community-built earthworks, monumental architecture, and an abundance of non-local materials indicate that it was the center of a widespread exchange network with reaches into the lower Southeast and Midwest (Kidder 2010). Included in the assemblage from Poverty Point is a wealth of Florida-made St. Johns pottery, demonstrating a link between Florida populations with this early metropolis (Hays and Weinstein 2004).

Canoes from the Late Archaic period are known in Florida, with the highest concentration of these ancient canoes appearing at Newnan's Lake in the northcentral highlands (Figure 2.3) (Wheeler et al. 2003). It is entirely possible that the canoes at Newnan's Lake were the mechanism in which some Florida populations interacted with the people of Poverty Point. The locations of these ancient canoes relative to sites of the same age offer insight into the spatial dimensions of the distribution of humans and goods across the Florida landform.

Early Woodland

During the Woodland Period from 1,200 B.C. to 950 A.D. (Table 2.1), the widespread adoption of pottery, intensive cultivation of crops, mound construction, ceremonialism, and well-defined village life became common-place among the inhabitants of pre-Columbian Florida (Anderson and Mainfort 2002). The Woodland

Period is the first in which archaeologists have distinguished regional cultures, as defined by specific stylistic and manufacturing techniques visible in ceramics. This variability in ceramic styles shows geographically-bound groups of people who shared cultural attributes, and has allowed for the cross-cultural comparison of early economies by examining the artifact assemblages of sites with different ceramic styles (Milanich 1994).

In Florida, the Deptford series of sand-tempered pottery (Figure 2.4) is the most common material marker of Early Woodland culture. Sand-tempered pottery replaced the fiber-tempered ceramics of the Late Archaic, which is meaningful because it allows archaeologists to distinguish Early Woodland sites from the Late Archaic, and also to determine sites that were occupied across time periods (Milanich 1994). Deptford sites have frequently been recorded on both the Gulf and Atlantic coasts and exist sparsely within the interior peninsula. The settlement pattern for this period indicates that mobility was likely seasonal, with coastal occupation occurring during most of the year with populations moving inland during the late fall and early winter to harvest acorns and hickory nuts, as evidenced by specialized nut processing tools at these sites (Milanich 1971,1994:117-118). During the Early Woodland, mortuary practices suggest there was cultural continuity across the region, with sand burial mounds become pronounced at Early Woodland sites (Stephenson et al. 2002).

Figure 2.4: Deptford ceramics, the primary diagnostic ceramic type for the Early Woodland. Florida Museum of Natural History

Middle to Late Woodland

During the Middle Woodland Period from approximately 200 B.C. to A.D 400 (Table 2.1) (Anderson and Mainfort 2002), evidence suggests that communities across North America participated in a widespread network of ceremonialism and exchange which resulted in the movement of people and goods across the landscape. This "Hopewellian" interaction sphere was centered in the Midwestern portion of North America, and manifested itself first through the Swift Creek culture, defined by distinguishible complicated-stamped vessels (Figure 2.5) present at several burial mound sites such as Block-Sterns and Crystal River (Figure 2.3) (Stephenson et al. 2002). Around A.D. 200, the Weeden Island series of ceramics (Figure 2.6) superseded the Swift Creek tradition, suggesting the influx of new ideas into the region (Anderson and Sassaman 2012).

Figure 2.5. Swift Creek complicated stamped ceramics, which replaced Deptford ceramics in the early to mid-Woodland Period. Florida Museum of Natural History

Figure 2.6. Weeden Island series ceramics, which superseded Swift Creek ceramics in the Middle Woodland. Florida Museum of Natural History

Although sometimes referred to as a single culture, the Weeden Island series of ceramics is representative of many cultures who shared many religious ideas (Willey 1949, Milanich 2002). During this period, Pre-Columbian populations across the peninsula participated in a shared sociopolitical structure and ideology, yet exhibited different environmental adaptations and economies expressed at the local level, as inferred from varying faunal assemblages found at these sites (Milanich 2002). For example, Weeden Island coastal communities continued to rely on shellfish and other marine resources, while inland communities subsisted off the upland game and freshwater species found in interior lakes (Milanich 2002, Willey 1949). While subsistence regimes varied throughout the peninsula during this time, settlement patterns were similar, with villages centered around earthen mounds. Many villages around mounds have been identified, with the density of adjacent Weeden Island village sites used to support population increase (Milanich 2002).

By about AD 750, during the Late Woodland Period, another shift in ceramic technology occurred across the region. The elaborate, well-decorated vessels commonplace at the beginning of the Middle Woodland period were replaced by non-decorated utilitarian wares, indicating the end of the shared ideological and political system that dominated earlier times. While the causes of this culture change are unknown, after A.D. 600 the use of the bow and arrow provided an increased hunting efficiency, which when coupled with an increased use of utilitarian pottery may have afforded greater local autonomy to populations, reducing the need for interconnectivity (Anderson and Mainfort 2002). Alternatively, rapid population growth and the overhunting of game with the bow and arrow may have put a strain on resources and led to an increase in warfare, thereby contributing to the decline of Woodland ceremonialism (Anderson and Mainfort 2002).

Mississippian

The Mississippian period describes the time between the Late Woodland period and the first European contact with Florida's indigenous peoples in the sixteenth century (Table 1). Deriving its name from the large river valley in which the observations about these cultures were initially made, what it means to be "Mississippian" has been questioned in the last couple of decades (Anderson and Sassaman 2012, Marrinan and White 2007). Traditionally, the defining traits of Mississippian peoples have included a reliance on maize agriculture, the presence of shell-tempered ceramics, flat-topped pyramidal mounds, and a likely shared ceremonial system that has been inferred from iconographic depictions. Mississippian ideology is thought to have originated near Cahokia in what is now Illinois, and likely depended largely on the transportation of people, ideas, and goods via canoe across the many interconnected rivers to maintain the connections between settlements during this time (Anderson and Sassaman 2012, Alt and Puketat 2011). Today, Mississippian period peoples are recognized as diverse cultures with varied subsistence economies and practices, who, nonetheless, exhibited similarities such as participation in a shared mortuary program. Mississippian period peoples are most readily characterized as living within hierarchal societies that built massive monumental architecture, maintained burgeoning populations by agricultural intensification, and participated in a shared ideology as inferred from artifact assemblages and iconography. Especially noteworthy was their treatment of the dead, with the construction of distinct mortuary mounds organized around a central plaza (Anderson and Sassaman 2012).

As in the Middle Woodland, there was a continuity in ideology and ceremony throughout Mississippian Period Florida. This continuity was independent of subsistence regimes. In Florida, some peoples practiced maize agriculture later in this period, while others, who shared similar iconographic and sociopolitical structures, never did (Marrinan and White 2007). Exchange and interaction are evident in the iconography of Mississippian material culture, with many artifacts produced from exotic materials, including copper from the Great Lakes, and other finely-crafted objects circulating throughout the region at this time (Anderson and Sassaman 2012). Coinciding with the onset of the Little Ice Age about A.D. 1300, a cooling trend that persisted through the mid-19th century, Mississippian peoples increasingly engaged in warfare and, in many cases, ceased monumental construction (Anderson and Sassaman 2012, Livingood 2010). One hypothesis is that these environmental changes resulted from reduced harvest yields and therefore caused an economic strain on populations. By the time Europeans arrived in North America, many Mississippian Period sites were abandoned, and what were one-time nucleated populations had spread across the Peninsula, as evident in the archaeological record and in accounts from the first European explorers (Anderson and Sassaman 2012).

Florida's Dugout Canoes

At the time of European contact, dugout canoes were ubiquitous across Florida indigenous cultures. Despite the historical knowledge of canoes, the existence of these watercraft in the archaeological record was not realized until 1961 when Ripley Bullen and Harold Brook's discovered the Zellwood canoe fragments in Lake Apopka (Figure 2). Three years later, Bullen and Brooks excavated another canoe in Lakeland, Florida (Figure 2), publishing their results in 1968 (Bullen and Brooks 1968). Their work showed that the dates for these canoes coincided with those from sites with steatite vessels originating in Appalachian Mountains, concluding that water transportation was likely a key component of the diffusion of goods, people, and ideas from the Late Archaic period forward (Bullen and Brooks 1968).

Although dugout canoe finds occurred sporadically throughout the following two decades, intentional canoe research did not occur until the 1980s when Barbara Purdy and her graduate students at the University of Florida aggregated records of canoe finds within the state (Newsom and Purdy 1990). Newsom and Purdy (1990) sought the public's help in recording canoes, placing newspaper ads and writing letters to landowners requesting information on dugout canoes found on private lands. This tactic proved successful and, by the mid-1980s, canoes were being reported an average rate of one per month. By 1990, Newsom and Purdy had enough information to make preliminary observations regarding the geographic distribution of canoes, noting a concentration in the northeastern highland physiographic region (Newsom and Purdy 1990) (Figure 2.7).

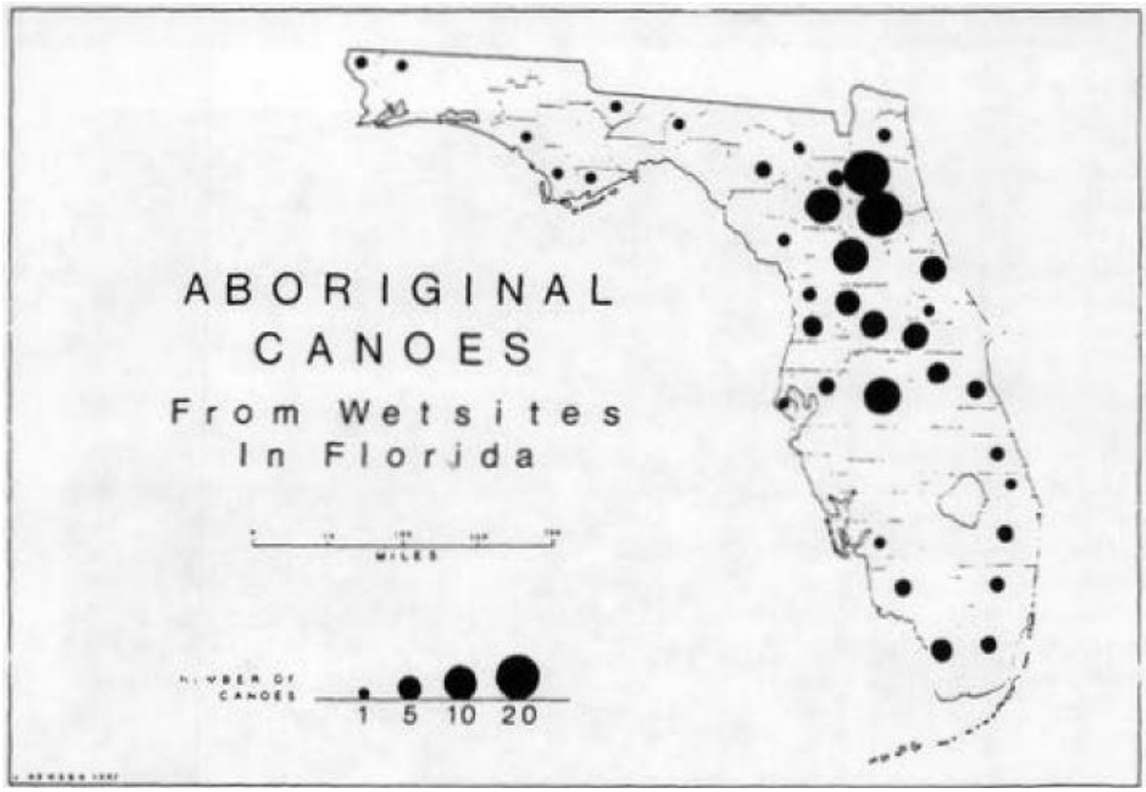


Figure 2.7: Density of pre-Columbian canoes in 1987. Newsom and Purdy 1990

One of the most significant contributions of the Newsom and Purdy's work is the classification of canoe types by morphological attributes. They observed morphological variations in the ends and sides of the reported canoes that appear to show they gradually became more refined throughout time. This work also produced a typing system, assigning the numerals one through four corresponding with what they interpreted as early, simple forms (1) through refined later forms (4) (Newsom and Purdy 1990). While this ordinal ranking system has since been determined as having no chronological continuity, Bullen and Brooks (1968), and then Newsom and Purdy's (1990) observations of the differences in canoe construction techniques may prove useful in years come as it can possibly show differences in canoes related to different activities, such as trade canoes vs fishing canoes (Ruhl and Purdy 2005).

Following this initial work (Newsom and Purdy 1990), canoe research was followed in 1996, by a dissertation on the development of prehistoric watercraft in the Southeast United States (Hartmann 1996). Included in this research were the Florida canoe data including the De Leon II canoe, now recognized as the oldest watercraft in the western hemisphere (Hartmann 1996). This canoe is notable because it shows that people were using watercraft almost as soon as wetland environments formed 8000 years ago (Schulderein 1996). One of the most notable aspects of Hartmann's overall work on watercraft was the call to view dugout canoes not as static artifacts, but as objects with dynamic use histories (Hartmann 1996). In this way he suggested that ancient dugout canoes have more to teach us then just that people were using boats, but rather that canoes are directly related to important aspects of pre-Columbian life such as subsistence, interaction, trade, and warfare.

In 2000, canoe research saw new life with the fortuitous discovery of 101 canoes in Newnan's Lake, located in North Central Florida (Figure 2.3). Drought conditions that year left the lake-bed exposed, revealing numerous fragmentary and complete dugout canoes (Wheeler et al. 2003). A team led by then-State Archaeologist Ryan Wheeler responded to this phenomenon and initiated as much data recovery as was possible. All canoes were described *in situ* (partially excavating some), recording the GPS coordinates of all, and selectively sampling 55 canoes for radiometric dating. The results of the dating were surprising, with 41 of the 55 canoes dating to the Archaic period. Before the discovery of the Newnan's Lake canoes, only a handful of Archaic period canoes were known in the state (Wheeler et al. 2003). The team concluded that early canoes shared no morphological differences from later canoes. These findings refuted the model of the typology model first proposed by Bullen and Brooks (1968) and later refined by Newsom and Purdy (1990) that indicated more refined manufacturing over time. The discoveries also reinvigorated interest in dugout canoes, and the state was able to take custody of the paper files first generated by Newsom and Purdy in the 1980s on these artifacts. The files that were digitized include extracted measurements, provenience, and other attributes, and a yet-to-be published tabular database was created. This database is currently maintained by the Florida Bureau of Archaeological Research (BAR) within the Division of Historical Resources (DHR), Department of State (DOS), and serves as the repository for all Florida canoe data.

Coinciding with the creation of the canoe database, Wheeler successfully petitioned the Florida Master Site File, the repository for all archaeological site information, to recognize canoes as recordable archaeological sites and create a separate canoe-specific form for the standardization of recorded data (Appendix I). This was used as a database for this thesis.

Today, the canoe database has been expanded to record various attributes that have been recorded over the years such as canoe measurement fields, water type where they were found, radiocarbon dates, and the percent of the canoe that is complete. One of the more useful fields in the canoe database is the geographic coordinates of the recorded canoe, allowing canoes with these attributes to be imported and queried within a Geographic Information System (GIS), which is the software used here to model the spatiotemporal distribution of canoes across the landscape.

When Wheeler left BAR in 2009, he left behind a framework for recording, reporting, and analyzing canoe data. The database has been continuously used to record subsequent canoe finds, and today contains records for 424 canoes from 199 individual sites. In 2015, Julie Duggins, then a staff archaeologist at BAR, initiated another revival in canoe research after plotting the canoe data in a GIS and recognizing a pattern in some canoe sites (Duggins 2018). She noticed that mapped canoes tended to cluster at the boundaries of second-level watersheds (Duggins 2018). This observation, coupled with ethnographic data on caching behavior of canoes at portages (Kari and Fall 2003, Swanton 1922), led Duggins to hypothesize that multiple dugout canoes were likely to be found in Lake Santa Fe, located north of Newnan's Lake (Figure 2.8).

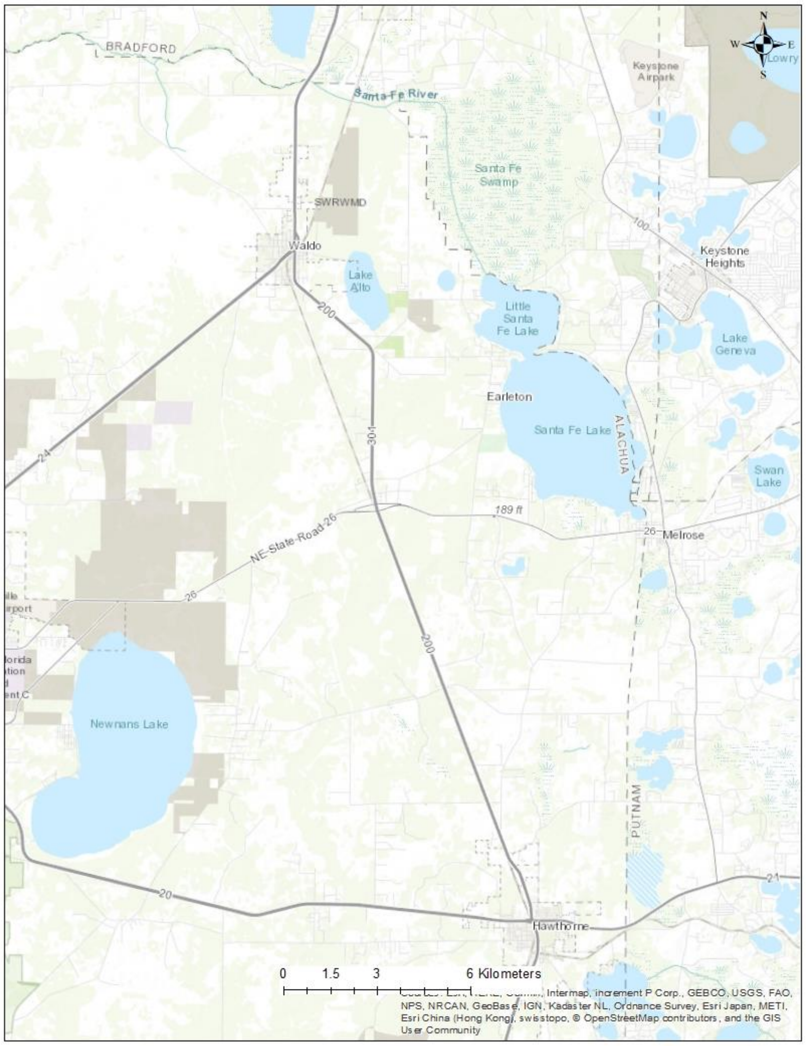


Figure 2.8: Location of Lake Santa Fe north of Newnans Lake

Interested in performing experimental fieldwork, Duggins contacted me in 2015 to inquire as to whether I thought ground-penetrating radar could detect dugout canoes. It was this project that spurred the applications of GPR discussed here. Those data were further integrated with the spatial and temporal data from the Florida database so that both the dugout canoes and pre-Columbian cultures can be compared, providing insight into dugout canoe use across the landscape in conjunction with cultural attributes.

Despite the unparalleled collection of canoes and canoe sites in the state, most of Florida's known canoes (and sites) have been found by chance, often in the wake of natural disasters (Hurricane Irma Canoe 2017) or extreme environmental conditions, such as the 2000 drought (Newnan's Lake canoes). When dugout canoes are found accidentally, frequently the attention of attending archaeologists is focused solely on the documentation and preservation of these objects. This is often pragmatic, as the fragile nature of waterlogged wood, which when exposed to air, rapidly dries out and collapses, results in the canoe's ultimate destruction if preservation is not swiftly employed (Renfrew and Bahn 1996:66). Unfortunately, a side effect of this record-before-destroyed-approach is that the anthropological context of dugout canoes is often only thought about intermittently as individual canoes are uncovered by chance. A recent ongoing effort by BAR to locate dugout canoe sites actively (as with the GPR described here), as well as placing these sites within a broader anthropological context has served as the impetus for this thesis research.

CHAPTER THREE: METHODS

This project modeled parts of Florida's pre-Columbian canoe distribution and use of waterways by these vessels using archaeological computing methods. The goal of this work was to develop a methodology for locating archaeological canoes, and to integrate the temporal and spatial attributes of previously recorded canoes into a geospatial database to explore about how canoes may have facilitated transportation, interactions between people, and the exchange of goods and ideas in the past. To accomplish these goals, two methods were integrated. First, ground-penetrating radar (GPR) was used to model submerged canoes located in Lake Santa Fe where there was previous evidence of their existence. Second, reported canoe locations and archaeological sites elsewhere in Florida were analyzed in a Geographic Information System (GIS) to model navigable waterbodies and calculate specific canoe routes across the Florida landscape during specific time-periods.

The impetus for this work was a renewal in canoe research initiated by then-Florida Bureau of Archaeological Research (BAR) archaeologist Julia Duggins (2019). In 2015 she hypothesized that Lake Santa Fe may contain a cache of canoes similar to those found in Newnan's Lake, located just 12.5 km away. She contacted me to inquire whether I thought GPR could be used to locate these canoes. I agreed to participate in the project. This decision was made in-part to the knowledge that GPR has produced detailed data sets in freshwater contexts (Conyers 2012), including submerged logs (Jol and Albrecht 2004) and I hypothesized that submerged canoes encased in lake sediments would result in similar results.

The outcome of the GPR work conducted for this project was a model of potential canoes in Lake Santa Fe for later identification by the BAR underwater dive team. Because the GPR detection of canoes has been understudied, it was necessary to critically evaluate the potential of this method before producing the Santa Fe model. It was essential to first conceive how a submerged dugout canoe may appear in a GPR data set. To address this, a comparative GPR data set consisting of reflection profiles was collected over the locations of known canoes at Newnan’s Lake. In addition, a computer-simulated model was created using metric inputs derived from previously recorded canoes in the canoe database in order to produce a “forward model” of what these artifacts would look like in profile. These datasets then allowed for the identification of reflections that may be submerged canoes at Lake Santa Fe, resulting in a map of these reflections for future target-verification.

Despite the method’s name, ground-penetrating radar is not limited to ground investigations. Instead, multiple environments lend themselves to survey using the GPR method, including concrete, ice, and freshwater environments (Utsi 2017, Daniels 2004, Conyers 2012). Ground-penetrating radar was chosen for this study because it has the proven ability to produce highly-detailed data sets in freshwater lakes, successfully imaging data of geological and cultural origins (Conyers 2012, 2016; Jol and Albrecht

2004). Although the data potential for GPR in freshwater is well-established, previous archaeological applications of this method are scarce (Conyers 2016:93). Here I present one of the first applications of the GPR method for this purpose.

Ground-Penetrating Radar Fundamentals

Ground-penetrating radar is a near-surface geophysical method that operates by transmitting pulsed electromagnetic energy in waveform through an antenna into the subsurface. Once the radar waves propagate within the ground, energy is reflected, refracted, and dissipated by media including soil and sedimentary packages, geological discontinuities, and anthropogenic artifacts and features (Conyers 2013:27). As a portion of the transmitted energy is reflected by materials with differing magnetic and electrical properties within the surrounding subsurface matrix, the energy returns to the surface where it is received by a second antenna within the GPR unit. The returned electromagnetic waves are then transferred electronically to a computer control unit to be modulated, digitized and recorded as digital data, where they can then be later processed and interpreted.

Returned wave data are recorded as composite *traces*, which are aggregated wavelets, defined as a single oscillating sine wave of both positive and negative variance from the mean amplitude, measured in voltages (Conyers 2013:26). Each wavelet is characterized by recorded time and amplitude attributes within a broad band of frequencies (Figure 3.1). These are then recorded as traces and stacked linearly to produce a reflection profile image. When this is done buried objects that may be anthropogenic in origin, as well as natural sedimentary units can be inferred from the geometries of amplitude changes within adjacent reflection traces across the generated profile image.

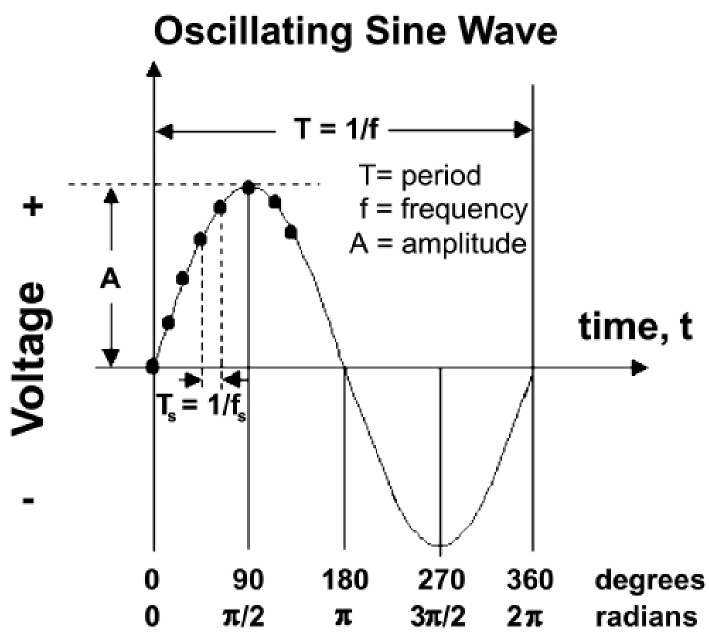


Figure 3.1 Attributes of an oscillating sine wave, the energy form of propagating radar waves.

Ground-penetrating radar generated electromagnetic waves do not travel at a constant velocity, but rather move at differing velocities depending upon the medium through which they are traveling. For this reason, GPR does not measure the depth of subsurface media directly but instead collects data in the time-domain (measured in nanoseconds or one billionth of a second). Ground-penetrating radar systems measure time using two-way travel time (twtt), which is the elapsed time-window between the transmission of a radar pulse to an interface in the ground (or water in this case), and the pulse’s return to the receiving antenna. Because GPR measures both the time it takes for the radar wave to reach an interface and the return time from the interface to the surface, measured depth (d) equals one half of twtt (t). When the velocity of propagating radar waves in a given medium are known, the time domain can be converted to an accurate depth measurement, making the GPR method capable of recording the depth of subsurface objects and interfaces within a three-dimensional (x,y,z) coordinate system (Daniels 2004, Conyers 2013).

The most critical differentiator of GPR systems and therefore an important element of survey design is the selection of a GPR antenna frequency. The frequency of GPR-generated electromagnetic waves is a measurement of the oscillating electrical current (quantified as cycles per second) applied to the transmitting antenna (Conyers 2013:24). Ground-penetrating radar systems are largely designated by their operating frequency e.g. 400, 900 MHz, which are usually within the ultra-high frequency radio spectrum (Daniels 2004). Most often, the designated frequency of a GPR unit is reported as the center frequency of the transmitting antenna, as GPR impulse generators output frequencies across a wide spectrum. However, the frequency designation for GPR antennas more accurately refers to the output frequency, which uses the maximum energy generated by the antenna. This measurement is referred to as the “peak energy” (Utsi 2017) (Figure 3.2). Frequency is an important factor in the design of a GPR survey because there are direct relationships between frequency, wavelength, the minimum size of detectable objects (resolution), and depth of penetration, which are variables that directly affect the success of any survey (Conyers 2012).

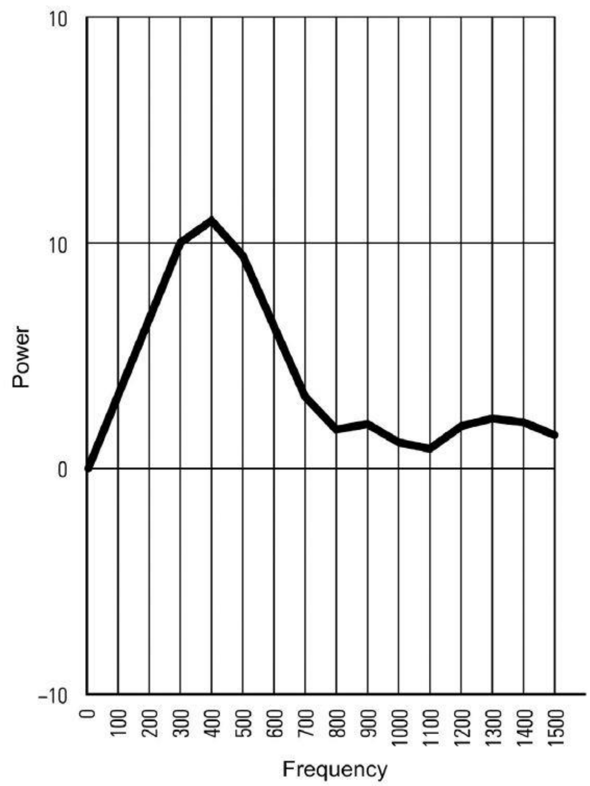


Figure 3.2 Power to Frequency spectrum of a 400 MHz GPR antenna illustrating the peak energy designation of GPR antennas. (Utsi 2017)

A fundamental aspect of GPR antenna frequency is that this measurement determines the wavelength of a propagating radar wave. There is a linear relationship between the frequency and wavelength of propagating radar waves, with higher frequency energy characterized by shorter wavelengths and lower frequency energy characterized by longer wavelengths (Conyers 2012:24) (Figure 3.3). Understanding this relationship is vital when planning a GPR survey because wavelength is one factor, which determines both the resolution as well as the depth of penetration into the ground or lake sediment of GPR waves. For this discussion I define resolution as the minimum size object or interface detectable by propagating energy at any given time. Wavelength is a primary factor in the minimum size object detectable by the GPR method. As a rule of thumb, to be detectable, an object must be at least 10% or greater of the size of the radar wavelength (Utsi 2017, Daniels 2004), although some references report a minimum of 40% (Conyers 2013). For this reason, it is crucial that when prospecting for archaeological materials of a known size, a GPR system that operates within a frequency range that corresponds to wavelengths of an appropriate resolution is chosen. Radar wavelengths are not a constant, but rather vary on the velocity of radar waves in various media. However, as with the time to depth calculation, when the velocity of radar waves in a specific medium are known, wavelengths can be calculated (Equation 3.1).

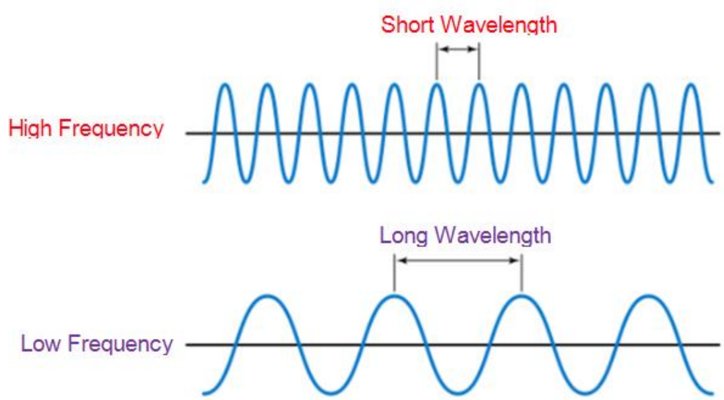


Figure 3.3: Illustrates relationship between the frequency and wavelength of a propagating radar wave. Higher frequency waves have short wavelengths and the inverse is also true

$$\boldsymbol{\lambda} = \mathbf{v} \div \mathbf{f}$$

Equation 3.1: Equation for determining the wavelength of a propagating radar wave where wavelength equals velocity divided by frequency.

Depth of penetration is also affected by wavelength and, thus, frequency. When radar waves are transmitted into the ground (or another medium), a portion of the propagating waves are either reflected by objects and/or interfaces or the energy is lost as it is absorbed into the medium. In general, higher frequency (shorter wavelengths) have a shallower depth of penetration while lower frequency (longer wavelengths) have a greater depth of penetration (Conyers 2013:25). This is partly because of the depth threshold for wavelength characterization. Although the empirical evidence is scarce, it has been reported that even in ideal environmental conditions the maximum depth of penetration will be no longer than twenty wavelengths and many times it is even less (Daniels 2004, Utsi 2017). This threshold is particularly useful when both the depth of interest and the properties of the survey medium are known ahead of time, as a survey antenna frequency can be chosen, which meets this depth of penetration threshold.

The largest influencing factor in whether any object/discontinuity is detectable using the GPR method is the degree of difference between the electrical/magnetic properties of the discontinuity and its surrounding matrix (Conyers 2013). This is true of both the subsurface media in which radar waves propagate, as well as the objects/discontinuities the GPR user is attempting to detect. The degree in which the electric field of GPR-generated electromagnetic waves can travel through a given medium, like any form of electric current, is largely dependent on the medium's ability to either conduct (transmit) or resist (store) an electric charge (Daniels 2004). The general measurement of the electrical susceptibility of a material is called the relative dielectric permittivity (RDP), though it is also referred to as the dielectric constant (Conyers 2006).

RDP is often used as a proxy for the velocity of radar wave propagation (Conyers 2013:49). In general, the higher the RDP of a given medium the slower the velocity of a propagating radar wave. The baseline measurement for RDP is air (RDP=1), with radar waves traveling at the speed of light, the highest velocity.

Pre-Collection Parameters

Many of the variables discussed in this section, including antenna frequency, collection time-window, and RDP can be optimally calculated ahead of a survey and further defined within the computer control unit software at the time of collection. Because the alteration and control of GPR collection settings varies by manufacturer I will now only discuss pre-collection parameters specific to the SIR-3000 manufactured by Geophysical Survey Systems, Inc. (GSSI), the GPR system used for this thesis work.

The SIR-3000 control unit allows several settings, which can be customized by the user prior to survey. The number of samples, frequency filters, time zero, range, gains, scn/unit and collection mode are all options that GSSI has programmed into the operating system of the SIR-3000 control unit and are discussed below.

The core measurement unit of the GPR system is the reflection trace, which is a compiled series of wavelets generated at one location on the collection surface (Conyers 2012:28). The SIR-3000 produces pulsed wavelets at a much higher rate than the onboard digitizer can process (Conyers 2012:32). For this reason, the SIR-3000 uses an incremental sampling method to capture values over one reflection trace. The denser the sampling size the more detailed the data. However, denser data comes at a file-size cost, which is particularly true of data collected over long transect lines. Generally, 512 samples provide a good compromise between waveform resolution and data-size, although the SIR-3000 has the ability to collect trace data comprised of 1012 samples. On one of the first tests runs for this thesis I collected a profile comprised of 27,000 traces each characterized by 1012 samples. Despite the high resolution of this profile, the denser data resulting from collecting with 1012 samples was not practical, as data would have had to have been continuously transferred to an external memory unit during collection as the data size of multiple profiles exceeded the onboard disk space. Therefore, I used 512 samples for this thesis work.

Another modifiable setting within the SIR-3000 is filters. These include both high-pass and low-pass frequency filters. Although the antenna frequency designation refers to the frequency corresponding to the peak energy of the antenna in use, it is by using the high-pass and low-pass filters that the frequency designation becomes the often-reported mean frequency measurement (Utsi 2017:194). A high-pass filter deletes radar waves below a specific frequency measurement and allows waves higher than the specified frequency to “pass by.” Conversely, the low-pass filter deletes radar waves emitted at a frequency higher than a specified value, maintaining waves with energy values lower than the specified cut off value (Conyers 2012:104). The antenna used in this thesis research is a 400 MHz antenna manufactured by GSSI. To achieve a 400 MHz center frequency, I used a high-pass filter set to 200 MHz, and a low-pass filter with 800 MHz as its cutoff.

The next customizable setting is time-zero. To accurately convert two-way travel time to depth, it is vital that the GPR control unit is calibrated so that the first recorded reflection is of the ground surface (Conyers 2012:98). This first reflection is called the direct-wave and is visible as the first high-amplitude wavelet in the digital oscilloscope programmed into GSSI's system (Figure 3.4). Conyers (2012:99) recommends that time zero be set to -1, or roughly 3.31 samples to accurately capture the ground surface and this was the setting used for this study.

Viewing the onboard oscilloscope in real time during setup can be useful not only for visualizing the direct wave, but also for setting an appropriate time-window. As demonstrated in Figure 4, the onboard oscilloscope can be used to determine the time interval in which the GPR waveforms are attenuated within the subsurface, where they appear as noise. By examining the digital oscilloscope, it is possible to adjust your time-window in real time to assure you are collecting data within a range that results in definable waveforms. The time-window setting in GSSI's system is called range. For my study I used a range of 300 ns, which was determined in the field in real-time.

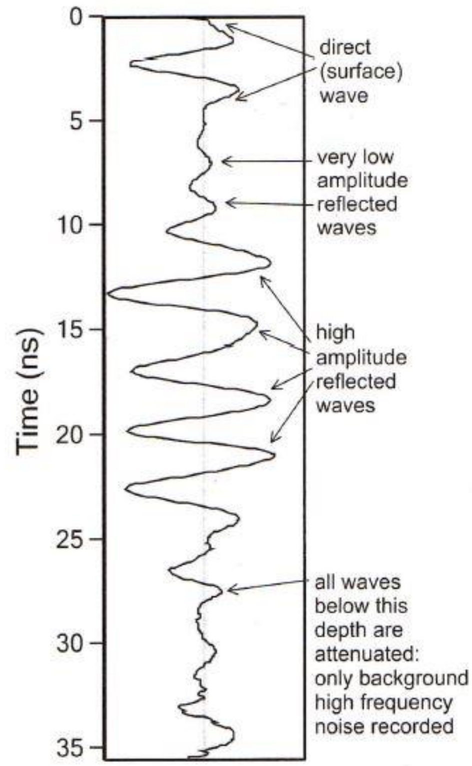


Figure 3.4: A GPR trace as it appears on the onboard oscilloscope, annotated to show varying amplitudes and noise (Conyers 2004)

Radar waves spread conically as they propagate into the subsurface, losing energy as they are attenuated with increasing depth. As a result, radar waves recorded deeper in the subsurface often have amplitude values, which may appear faint in the onboard oscilloscope (Conyers 2012:99). These waves can be adjusted within the collection unit software using gain control, which artificially increases (or decreases) the amplitudes for waves recorded deeper in the time-window.

Before data collection can commence, the scan sampling interval over the GPR line of travel must be set. This option is labeled scn/unit in the GSSI system. This setting is particularly important in resolving the accurate size of features of interest within the subsurface. If the physical space between one trace and the next exceeds the size of an object within the ground, then the entirety of that object will not be captured in the resulting GPR profile (Utsi 2017:74). The scn/rate for this survey was set at 60 traces collected per meter.

The last customizable setting that must be set prior to beginning a survey is the collection mode. During data collection many traces are compiled together to generate a reflection profile image. To accurately place data within the context of the real world, spatial data must be collected in tandem with each trace. This is one area where the collection of data on water bodies differs significantly from terrestrial survey. In most terrestrial applications, a calibrated survey wheel connected to an odometer encoder is utilized to record the length of the survey transect, which is then recorded in the header of each GPR profile. To collect data in this way the distance collection mode is specified in the GSSI system. Since a survey wheel cannot be used in water, my data were collected in the time collection mode, which activates the transmitting antenna in timed pulses, and in this case, was linked to a real-time global positioning system (GPS) utilizing the RS232 serial port embedded in the SIR-3000 hardware. By collecting in this way, I was able to merge the GPS and GPR data sets during post-collection processing to place these data into geographic space, which allowed me to effectively map reflections that may be dugout canoes so that these reflections may be field verified by the dive team at a later point.

Data Collection

Traditional terrestrial GPR surveys are conducted by pushing (or pulling) the GPR unit along closely-spaced transects within a local grid. This is done so that subsurface reflectors oriented perpendicular to the GPR direction of travel and larger than the footprint of the transmitting antenna can be identified in the data set during post-collection data processing. The collection of data in grids also means that the GPR data set can be processed through a standard procedure that generally consists of "slicing" amplitudes at discrete time-intervals along the z axis, digitally gridding these data with the same dimensions as the grid the collection grid, interpolating amplitude values between collected transects, and then creating color relief maps that illustrate the variability of amplitude values at a discrete depth in the subsurface (Conyers 2012).

Anticipating following the standard processing procedure outlined above, the GPR data collected at Lake Santa Fe and Newnan's Lake was done so in grids with planned one-meter intervals between transect lines. To collect data on top of the water-surface at both lakes, the GPR antenna was placed in a Zodiac Zoom inflatable boat tethered to the RV Workhorse, BAR's 21 ft collection vessel (Figure 3.5). Connected to both the RV Workhorse and the GPR unit was a Trimble SPS 351 DGPS unit, allowing all collected reflection traces to be placed within geographic space during the data-processing and analysis phases.

Figure 3.5: Collecting data at Newnan's Lake. The GPR unit is located in the stern of Zodiac Zoom inflatable boat (far right)

The collection of GPR data occurred in late 2015 and early 2016. At Newnan's Lake twenty-six transects were collected over the locations of known canoes within a grid measuring approximately 119 by 45 meters (Figure 6). At Lake Santa Fe, data were collected in nine areas (Figure 7) adjacent to the modern shoreline. For each survey area at Lake Santa Fe, the decision was made to contain the transects within the 3 to 4 ft contour lines, which correspond both to the depth in which the Newnan's canoes were located, and the depth in which a previously recorded canoe was located in Lake Santa Fe.

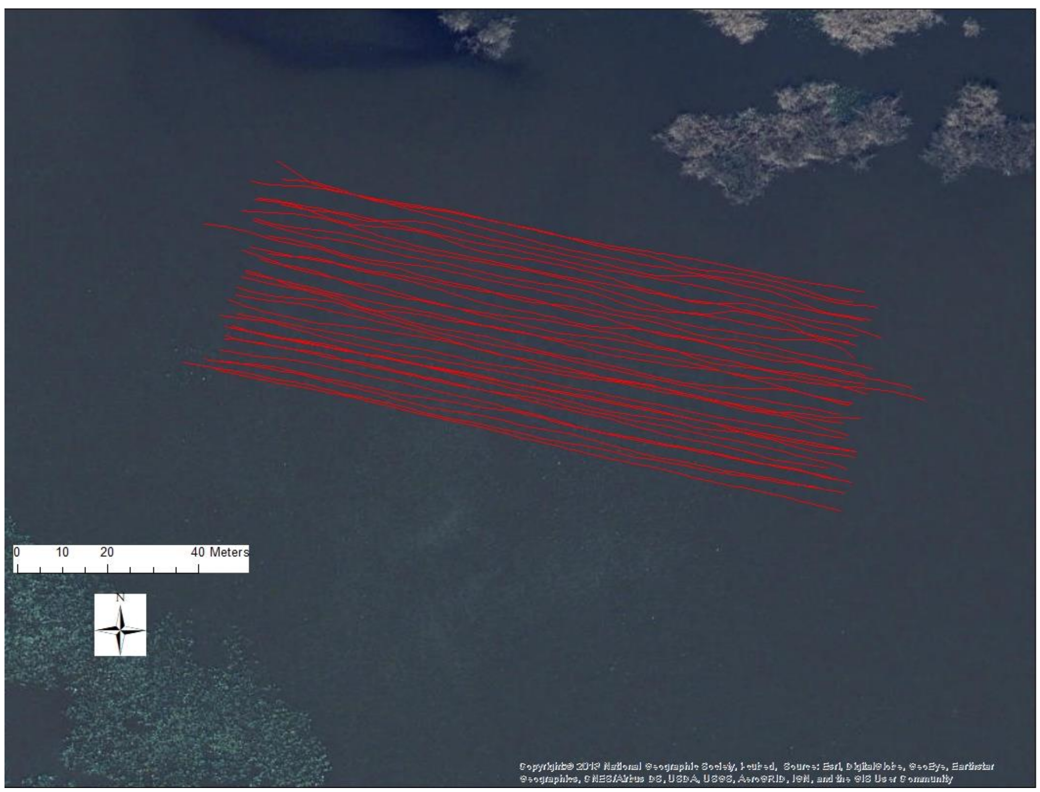


Figure 3.6: Transects over the locations of known canoes at Newnan's Lake

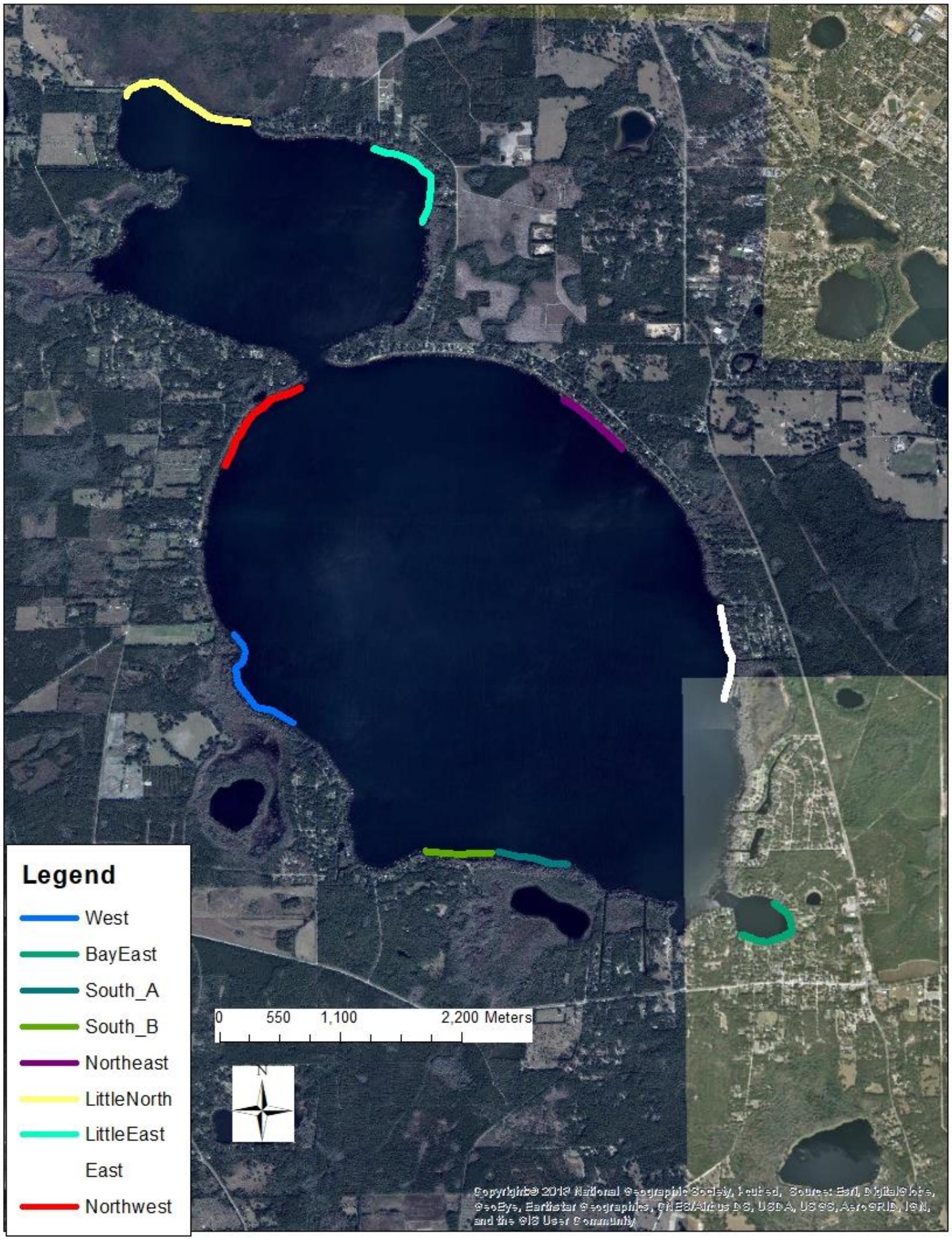


Figure 3.7: The locations of the GPR survey areas at Lake Santa Fe

Conclusion – Ground-Penetrating Radar

Ground-penetrating radar (GPR) was the first computational method used in the study of archaeological canoes for this thesis. The goal of the GPR work was to exploit this method's capability to detect buried objects in submerged contexts and apply this technology in locating archaeological canoes. Because the use of GPR for archaeological applications has generally been confined to terrestrial contexts, a detailed approach was necessary, which required me to critically evaluate the appropriateness of this technology to my application. To do this, GPR was used to collect proxy data over the locations of known canoes at Newnan's Lake, and a "forward model" of canoe reflections was produced synthetically using computer software. The culmination of these processes was the collection of GPR data at Lake Santa Fe, where prior evidence of canoe use existed, to map reflections that may be indicative of canoes in that lake.

The detection and mapping of potential canoes at Lake Santa Fe was sparked by Duggins (2019) hypothesis that Florida's largest recorded canoe sites, and possibly Lake Santa Fe, were places people intentionally stored their canoes at the edges of watersheds. This led me to consider how these portages fit within a broader intraregional canoe transportation network that linked people and goods with places on the landscape. Proceeding, I turned my attention to the computational capabilities of Geographic Information Systems (GIS), and the analyses that could be executed within them to explore these types of data at the regional scale.

Geographic Information Science (GISci)

Following the modelling and mapping of the GPR data interpreted as potential canoes in Lake Santa Fe, I harnessed the capabilities of ArcMAP, a geographic information system (GIS) to execute multiple analyses. These analyses were implemented to model the pre-Columbian movement of people, goods, and ideas by canoe across the Florida landscape. At its core, a GIS is a software framework that can store and manipulate data with geographic coordinates stored in a relational database (Connolly and Lake 2006).

The structure of this framework allows these data to be accurately displayed as a two-dimensional representation of a geometric ellipsoid, in this case planet Earth, with each datum containing multiple user-defined attributes that can be acted upon mathematically by the software (Connolly and Lake 2006). For example, spatial data representative of archaeological site locations (as is used here) can contain attribute information for multiple cultural affiliations, with each affiliation stored in a separate column within the data. A GIS software can then detect statistical clusters of archaeological sites with shared cultural affiliations (Connolly and Lake 2006).

Since the inception of commercial GIS software and personal computers in the 1980s, archaeologists have frequently used the capabilities of GIS software to map and analyze archaeological materials at the regional scale, following the research paradigm of “settlement pattern analysis” first developed by Gordon Willey four decades prior (Willey 1953). Using a GIS, we now have the ability to analyze datasets at the regional scale in increasingly nuanced ways (Kantner 2007, Verhagen 2018).

The various spatial analyses executed within a GIS are collectively known as “Geographic information science” (GISci), distinguishing these analytical techniques from the software platform in which they are implemented (Kantner 2018). For this thesis, GISci network analysis was used to calculate routes between archaeological canoes and important archaeological sites of the same age. This was done to visually analyze where and how contemporaneous groups may have used canoes to interact with each other in the past while integrating the temporal aspects of well-dated previously-recorded canoes.

To begin this process, a network dataset was created within ArcMap that modeled the hydrological network on which transportation by canoe could have occurred. Following the creation of this network, radiometric dates of known canoes in the canoe database (Florida canoe database) were calibrated outside of the GIS to determine when people were using canoes, which allowed me to analyze the spatiotemporal aspects of canoe transportation for specific time periods. After the time periods when people were presumably using canoes was defined, the Network Analysis GISci toolbox was utilized in ArcMap to calculate travel time by canoe, and therefore ease of movement across the transportation network, revealing places of potential interaction between pre-Columbian populations of the same age.

Modelling the Pre-Columbian Transportation Network in GIS

Before I could model how canoes facilitated transportation and interaction in the past, it was necessary to first determine where pre-Columbian people could have used canoes. To do this, I followed Livingood (2012) in utilizing the National Hydrology Dataset Plus (NHDPlus), a joint product of the United States Environmental Protection Agency (EPA) and United States Geological Survey (USGS) to model pre-Columbian rivers and other waterbodies that were likely navigable in the past. One of the most useful aspects of the NHDPlus is that it contains a subset of data that models the natural flow of waterbodies, effectively mitigating the effects of modern impoundments and reservoirs on the geometry of watercourses (McKay et al. 2017). In this way, I could model the movement of canoes along this network even in the case of lakes created by damming rivers, and lakes that were likely interconnected in the past. These data provided a good starting place for modelling navigable waterways, however, the data contained within the NHDPlus includes small creeks and streams that were likely not navigable by canoe (Figure 8) and further filtering was required on this data set to model pre-Columbian navigation for this project (Livingood 2016).

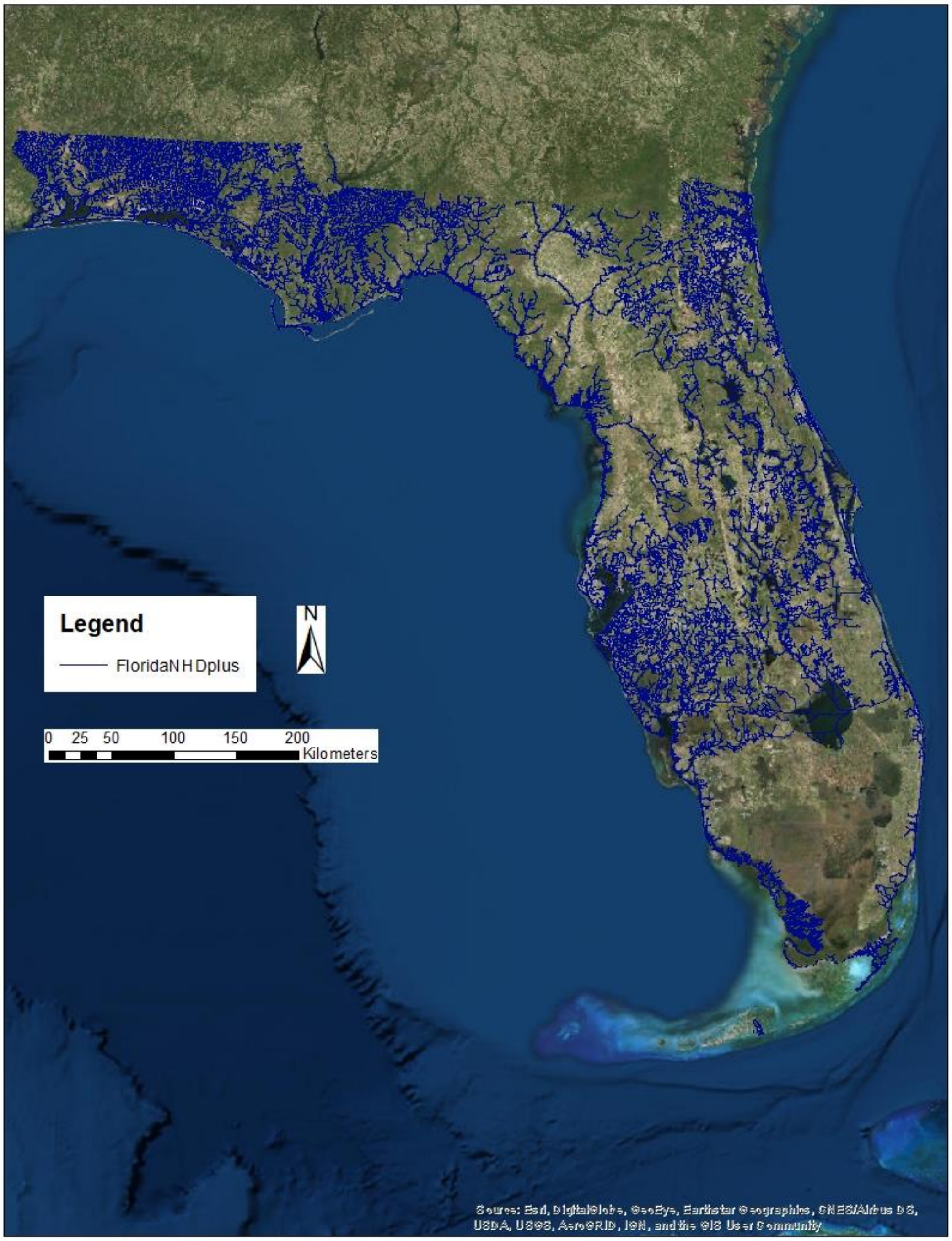


Figure 3.8. Locations of natural flowing waterways contained within the NHDPlus dataset. Many of the waterways depicted on this map are very small creeks and streams, which would not have been navigable by canoe.

To extract natural waterways that would have been navigable in the past, I first needed a way to determine what criteria to use in defining navigability. This determination was made by querying the canoe database and extracting metric data on previously recorded canoes whose provenience was the result of movement by navigation. All watercraft can be characterized by a basic set of measurements (Figure 9), which have direct bearing on how much water is required to float a canoe (Hayler and Keever 2003). While advanced calculations exist for determining this criterion for individual watercraft, for this study I took a more general approach, only concerning myself with the beam (width) and height variables (recorded as "height" in the database and presumed to be the cumulative measurement of both freeboard and draft).

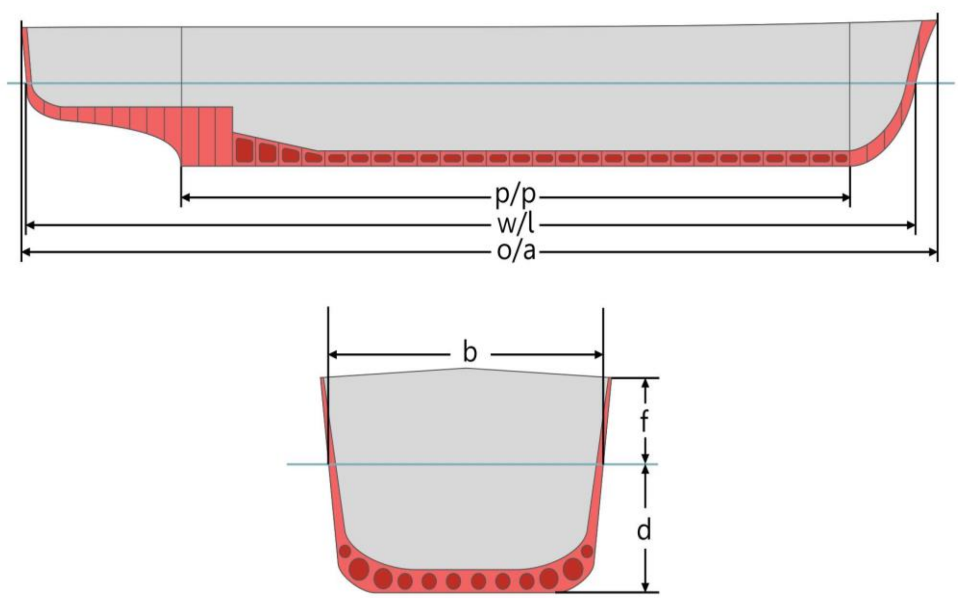


Figure 3.9: All watercraft can be described by a basic set of measurements where p/p = length between perpendiculars w/l = length at waterline o/a = length overall b = beam f = freeboard d = draught

The mean beam and height measurements for canoes in the database are .52 meters and .34 meters, respectively. Because the beam measurement is the larger of the two measurements, I decided to take a conservative approach to determining navigable waterways and only include waterways in the NHDPlus data set that have a volume measurement greater than or equal to this value. Within the NHDPlus dataset, volume of water flow is measured in cubic feet per second (CFS), and so I only extracted those data that were greater than or equal to 18 CFS (the approximate conversion from meters to cubic feet), or those data that were classified as coastline. This is important because it mandates that those streams wide enough to facilitate canoe travel could also float the canoe. The result of this filtering is a dataset of natural flowing waterways that could have supported canoe navigation in the past, and also includes the Florida coastline as it was navigable (Figure 3.10).

Figure 3.10. Locations of flowing waterways within the NHDPlus dataset that were likely navigable by canoe. These data have a mean volume that is greater than or equal to the mean beam of previously recorded canoes

Because I was interested in modelling travel-time (and therefore ease of movement) by canoe including coastal routes I edited the dataset to include a modified shoreline with straight line connectors to streams and rivers that terminated at the coast (Figure 3.11). This was done to reduce the complex geometry of the coastline, providing a more linear coastal route in the network analysis.

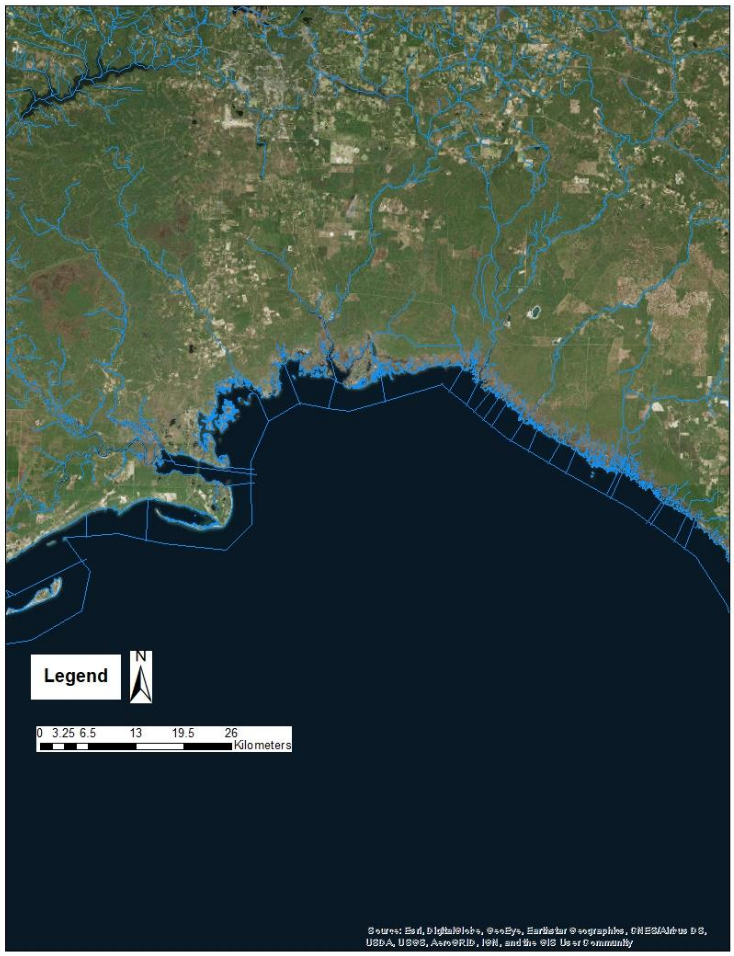


Figure 3.11: In order to model a more direct coastal route I created a coastal pathway that eliminates the complex geometry of the Florida coastline

Once I extracted the navigable waterways and modified the coastline, it was necessary to create a network dataset in ArcMap that contained values to be utilized by the Network Analyst toolbox. This was done because network analyses in GIS are an implementation of a subset of the branch of mathematics called *graph theory* (Wheatley and Gillings 2002). In graph theory, systems of lines are assigned variables in which mathematical algorithms are used to calculate how these lines connect to *nodes* within a network. With this structure in place, users can calculate least-cost routes along the riverine and coastal network with user-defined variables as costs. For this thesis I was principally concerned with travel-time because both ethnographic (Harrison 2007) and experimental (Burnett 1978; Gooledge and Zanaras 1973) studies indicate that travel-time is the major factor in a travelers' evaluation of distance, as opposed to the objective distance measurement itself.

To model canoe travel-time I followed Livingood (2012) in assigning a base-rate of 4 kilometers per hour (KPH) plus or minus the mean current speed of a particular line as defined in the navigable NHDPlus data. Livingood (2012) at this value after compiling the travel-time values and calculating the adjusted current speeds for a number of historic canoe trips. One of the most useful features in the NHDPlus data is that each line feature is digitized in the direction of water flow (McKay et al. 2012). This allowed me to program into the network dataset a formula that calculated different travel times depending on whether a canoe was travelling upstream or downstream. Hypothesizing that the non-navigable waterways in the NHDPlus could also have served as natural interfluvial portages (places where people carried their boats and cargo from one navigable stream to another), I also programmed in travel times for these portages by assigning all flowing water features under 18 CFS a value that identified these features to the software. This doubled the travel time along these stretches of the network. Because the portage time was chosen arbitrarily and is less objective than the base rate for navigable waterways, I made portages optional in the menu to solve routes along the network.

Table 1 is the attribute schema for the network with example data, and Equation 1 is the formula I used to implement travel-time in the network dataset.

Table 3.1. Attribute schema for the navigable waterways network with sample data. UNIQUEID is a unique identifier used by the software to reference each line, LENGTHKM is the length of each line feature in kilometers. Q0001C is the mean volume of water in each line measured in CFS. V0001C is the mean velocity of water in each segment measured in feet per second (FPS). MFACT is the multiplication factor used by the programmed algorithm in determining travel time. Segments that are navigable are assigned a multiplication factor of 1, while segments that are hypothesized as interfluvial portages are assigned a multiplication factor of 2, doubling the travel time. INTPORT is the column that lets the software know that a segment is unnavigable by canoe and instead is an optional interfluvial portage. 1 = unnavigable and 0 = navigable.

UNIQUEID	LENGTHKM	Q0001C	V0001C	MFACT	INTPORT
1	3	18	4	1	0
2	3	9	4	2	1

$$\left(\frac{L}{B \pm (V * C)}\right) * M$$

Equation 3.2. The equation used by the Network Dataset to implement travel time by canoe where L = Length in Kilometers (LENGTHKM), B = the base rate for canoe travel (4,) V= Velocity (V0001C), C= Conversion factor (V0001C is measured in feet per second, for this analysis C=1.097 to convert feet per second to kilometers per hour), M = multiplication factor (MFACT)

Once the network dataset was generated I used the Network Analysis toolbox to explore potential transportation routes and exchange networks for archaeological periods with known canoes. This was possible as I had extracted age-dates from the canoe database and calibrated them, thereby allowing me to assign each canoe a culture period designation. An example of a route analysis can be seen in figure 12, which shows calculated routes between Woodland Period canoes and the Crystal River (CI1) and Fort Center (GL23) sites, two major centers of interaction and exchange during this period.

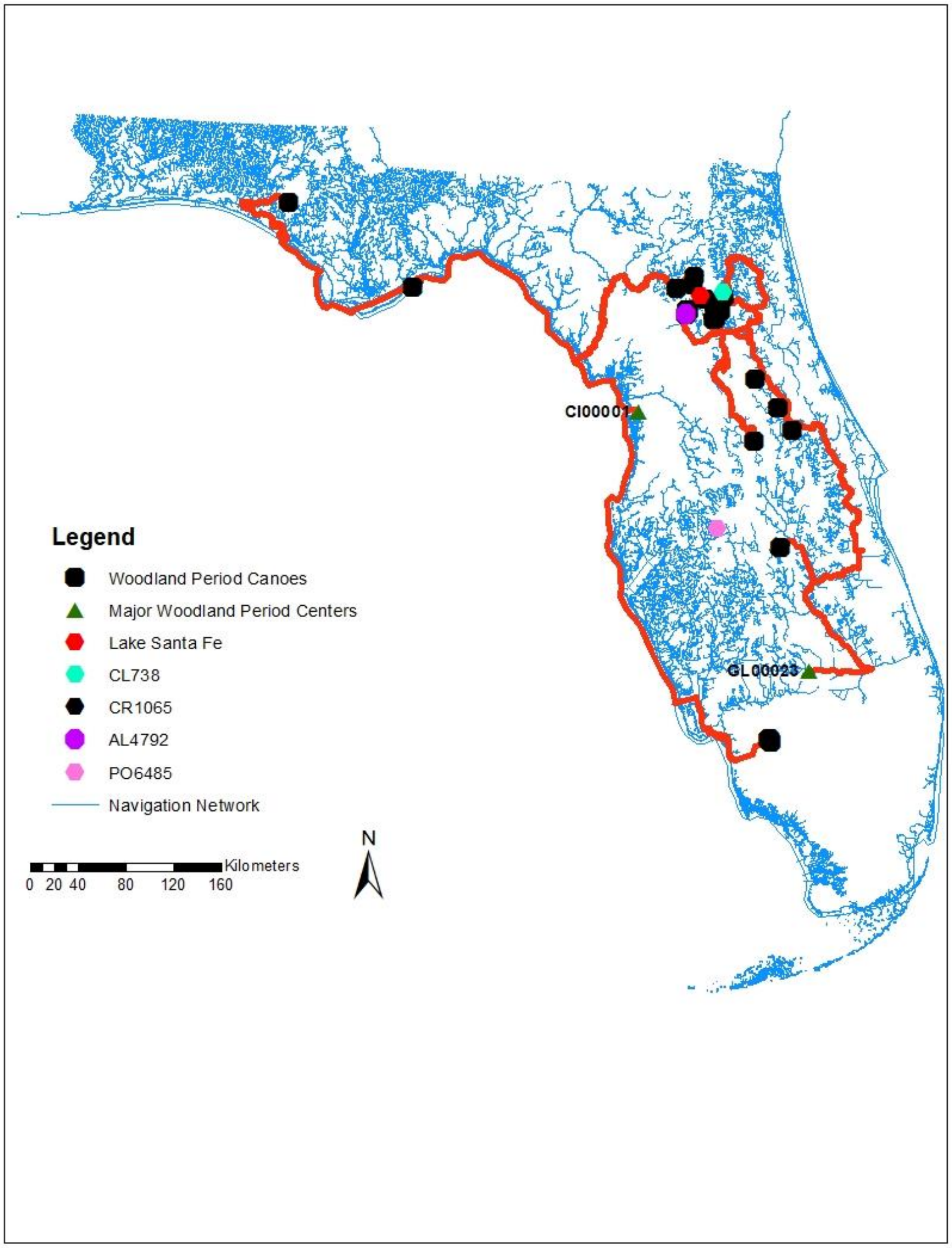


Figure 3.12: An example route analysis showing the calculated canoe routes between Woodland Period canoes and two contemporaneous centers of interaction and exchange.

Conclusion – Geographic Information Science (GISci)

Ground-penetrating radar (GPR) was used for this project to detect and map archaeological canoes that have not-yet been excavated. Following this work, I broadened my scope of analysis and examined canoes at the scale of the entire Florida landform, integrating terrestrial archaeological sites, their periods of occupation, and well-dated canoes. This was done using a Network Analysis, a Geographic Information Science (GISci) method. This method was used to model the spatial dimensions of Florida's pre-Columbian canoe use and isolate transportation corridors and places of interaction. By using the Network Analysis technique, I was able to establish where in pre-Columbian Florida people could have used canoes and then calculate specific routes and travel-times.

CHAPTER FOUR: DATA ANALYSIS

The analyses of the data presented in this thesis were undertaken in order to provide a holistic perspective of Florida's archaeological canoes at a scale only possible through the use of modern computing.   As described in the previous chapter, the methods of ground-penetrating radar (GPR) and geographic information science (GISci) were employed in order to detect canoes embedded in sub-bottom sediment at Lake Santa Fe, and then to place these canoes and others recorded in the state within an anthropological context that emphasizes the movement of people and goods across the landscape. Here I analyze the GPR data collected at Lake Santa Fe to reveal the presence of what appears to be multiple canoes in that lake, and then incorporate those data into an analysis that calculates specific canoe routes between known canoe locations and contemporaneous archaeological sites of major importance.

Model-Making 1 - Analogs and Hypothesis Testing

Before the design and implementation of a data collection strategy (Chapter 3), GPR was chosen for this research partly because of the successful application of the GPR method in detecting submerged logs, which are analogs for canoes in lake sediment (Jol and Albrecht 2004). Working in a lake in Wisconsin, Jol and Albrecht (2004) used GPR to locate submerged logs both on the lake bottom and within lake bottom sediment. The major advance outlined in their work was the determination that submerged logs create an identifiable geometric reflection in the GPR dataset referred to as a point-source reflection hyperbola (Figure 4.1).

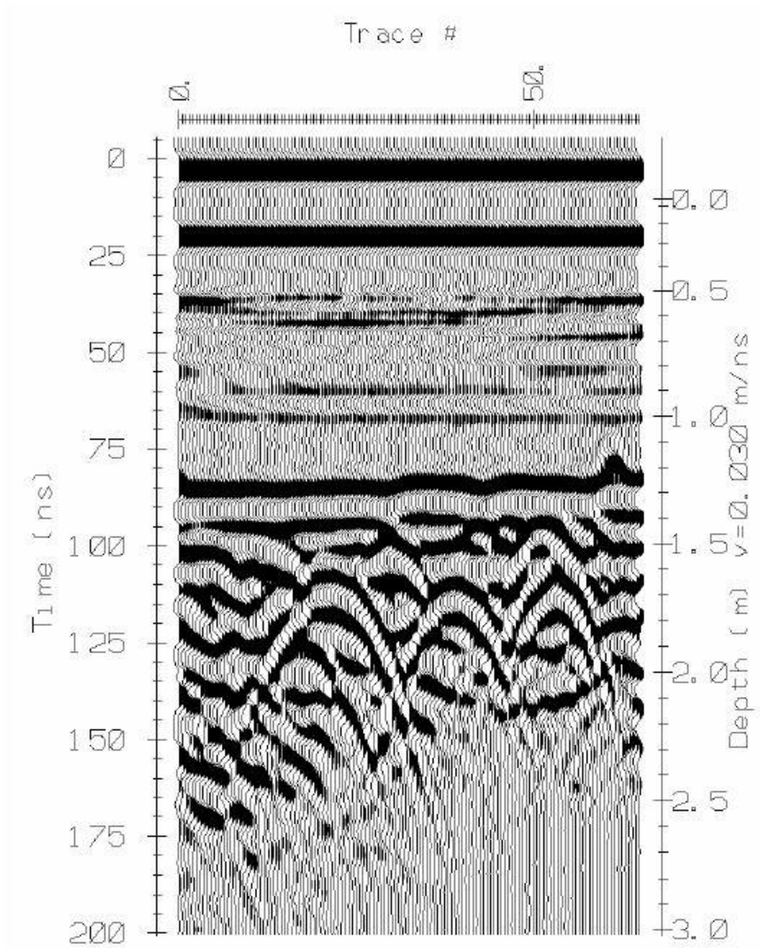


Figure 4.1: Point-source hyperbolas generated from submerged logs in sub-bottom sediment (Jol and Albrecht 2004).

Point-source hyperbolas are important reflection patterns in GPR datasets, because a hyperbola contains information regarding the approximate spatial extent of a buried object as well as the object's orientation. Point-source hyperbolas are reflections generated from objects of restricted size, which are situated generally perpendicular to the travel direction of a GPR antenna (Conyers 2013:58). Knowing that these two attributes are inherent in hyperbolic reflections means that hyperbolas, which sometimes occur in successive GPR reflection profiles both parallel and perpendicular to each other in space can be mapped to determine the extent of the object generating the reflection.

Hyperbolic reflections occur when ground-penetrating radar energy propagates downward in a conical pattern, expanding outward with increased depth (Figure 4.2). As the radar approaches a buried object along the line of travel, the widest edge of the conical energy contacts the object before the antenna is directly over the object. It is then reflected and moves back to the surface antenna. However, it is recorded by the system as if it were below. As a result, reflections are recorded by the GPR control unit before the antenna is directly over the object. Because GPR data are collected in the time-domain, reflections are recorded closer in time (shallower) as the antenna nears the top of the object, and subsequently are recorded farther in time (and thus appear deeper) as the antenna moves over and away from the object (Conyers 2013:60) (Figure 4.2).

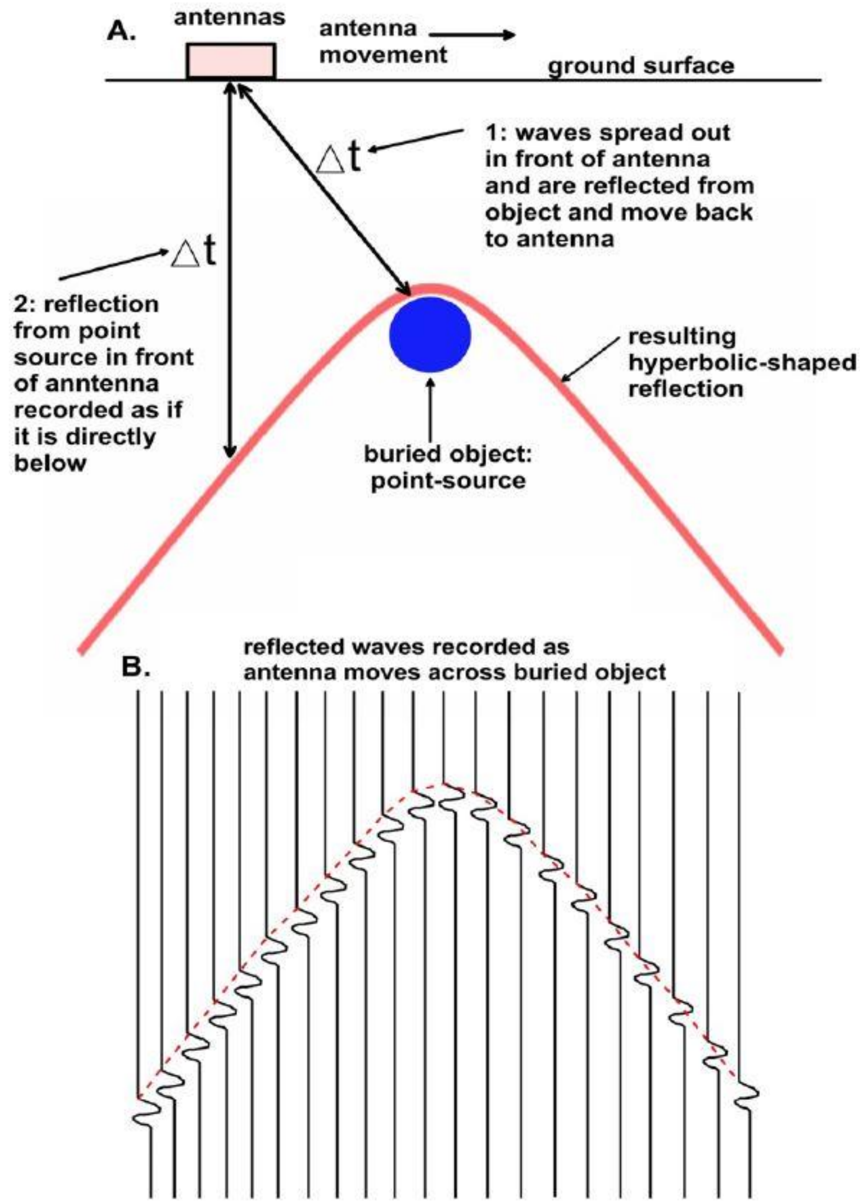


Figure 4.2 Hyperbolic-shaped reflections occur when the footprint of the GPR antenna encounters a subsurface object before the antenna in directly above the reflector (Conyers 2013:61).

Because Jol and Albrecht (2004) demonstrated that submerged logs generate point-source reflection hyperbolas I hypothesized that dugout canoes, which are at essence, modified logs (Hartmann 1996) would also produce these reflections in some form. To test this hypothesis two experiments were conducted. First, GPR data were collected over the known location of a recorded dugout canoe in Newnans Lake. Second, a "forward model" of a canoe was generated in GPRSIM, a ground-penetrating radar reflection modelling software package to synthetically model a canoe reflection for comparison against the Newnans data. By collecting data over a known canoe, and then integrating the interpretation of these data with a computer-derived model, I was able to critically analyze the data collected from Lake Santa Fe. This allowed me to identify multiple reflection features believed to be canoes in this lake, and by doing so confirming Lake Santa Fe's importance in the pre-Columbian transportation network.

Model-Making 2 - GPR at Newnans Lake

In 2000, a prolonged drought exposed 101 canoes in the lakebed at Newnans Lake (Wheeler et al. 2003). As part of their field procedure, those researchers collected a GPS coordinate at the center-point of each recorded canoe before the water rose again. Because they had the foresight to collect this GPS dataset, as part of the study for this thesis, I was able to collect GPR transect lines at the location of known canoes. Although there were four known canoes in our survey area, variability in the spacing of collection transects due to the nature of the collection watercraft, resulted in only one transect line directly crossing a perpendicular canoe.

Analysis of the GPR profile collected over the known canoe at Newnans Lake (Figure 4.3) indicates that submerged dugout canoes in sub-bottom sediment will produce a series of reflections where two tails of a hyperbola flank a central hyperbolic reflection. These reflections appear to have been generated by the antenna first encountering the side of the canoe and creating with it an independent reflection that is analogous to a single axis of a hyperbola. This can be seen in Figure 3 and is labeled as a left hyperbola axis. The central hyperbolic reflection appears to have been generated from the bottom of the canoe, likely as the antenna moved directly over the canoe. Finally, the right hyperbola axis was generated as the antenna moved away from the canoe and was produced in the same manner as the left hyperbola axis.

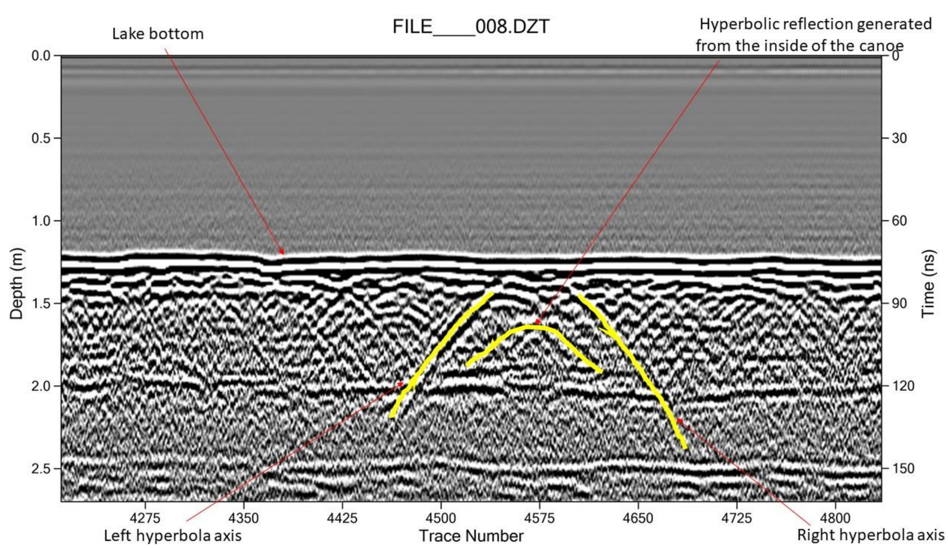


Figure 4.3. GPR reflection profile collected over the location of a known canoe at Newnans Lake. The canoe produced two hyperbolic reflections.

"Forward" Modelling of a Submerged Canoe

To generate an additional line of evidence that canoes create hyperbolic reflections I created a "forward" model of a canoe within *GPRSIM*. *GPRSIM* is a GPR reflection modelling software, which allows researchers to simulate radar reflections by calculating the paths radar waves will take in the ground given a set of conditions (Goodman 1994, Conyers 2013).

To create a model in *GPRSIM* I first used the mean beam and height metrics of known canoes (as discussed in Chapter 3) to create a two-dimensional cross section of an idealized canoe. Next, it was necessary to determine the relative dielectric permittivity (RDP) of the materials to be included in the model. Relative dielectric permittivity is the general measure of the electromagnetic properties of a material and is most often used as a proxy measurement for the velocity of propagating radar waves (Conyers 2013). The difference in RDP between two subsurface media ultimately determines whether a velocity shift, and therefore, a significant velocity change can occur within the electromagnetic wave and become detectable in a GPR data set (Conyers 2012:36). For this model three RDP determinations were necessary, two of them requiring calculation. The antenna and inflatable boat were coupled with freshwater, and this was the first RDP selected. Freshwater is almost entirely resistive and therefore does not impede the travel of a propagating radar wave, but significantly reduces its velocity. Freshwater has a known RDP value of 80 and this what was programmed into the model (Conyers 2013).

The next RDP requiring selection was the lake bottom itself. Lakes in Florida, including both Newnans Lake and Lake Santa Fe are characterized by sandy bottoms (Pirkle and Brooks 1959). It is known that dry sand has an RDP of 3 (Conyers 2012:36). However, modelling saturated sand present on the bottom of a lake requires an adjustment to the RDP value, since the unconsolidated sand in these conditions is fully saturated by water, which results in an increased RDP. The greatest changes in radar velocity, and thus, RDP are a function of a material's ability to retain water (Conyers 2012:34). This means that when the porosity of a dry material is known, the RDP of the saturated material can be calculated by multiplying the percentage of the material's pore spaces by the RDP of freshwater (80) and adding that value to the remaining nonporous material percentage multiplied by its dry RDP. Unconsolidated or cemented sand porosity is estimated to be around 30% (Conyers 2012:36). Therefore, to calculate the RDP of fully saturated sand 30% of the sand will have an RDP of 80, and the remainder of the sand will have an RDP of 3 (Equation 1). The resulting RDP for fully saturated sand is 26.1 and this was set for the lake bottom.

Equation 4.2: Equation for determining the RDP of a saturated object or substance. Value 1 is the percentage of porosity for a given object or substance, which is then multiplied by the RDP of water. These values are then added to the remainder of the substance that is not pore spaces, which is multiplied by the original RDP. The values shown here are for determining the RDP of saturated sand**.**

$$(0.3 \times 80) + (0.7 \times 3) = 26.1$$

After the RDP for the lake bottom was estimated, it was necessary to determine the RDP of the canoe itself. In all species of wood, prolonged exposure to water induces physical and chemical changes within the wood structure that directly affects its RDP. These changes occur as water soluble substances, as well as bonding materials are leached from the wood over time (Unger et al. 2013). Through a process called hydrolysis, the cellulose in the cell walls disintegrates, leaving behind lignin, a complex organic polymer, which serves as the skeleton for all fibrous plants (including wood). As the structural components of wood disintegrate, the wood becomes porous and permeable to water, resulting in the wood becoming waterlogged. When wood becomes waterlogged the remaining lignin structure and water preserves the shape of the wood, but the wood becomes incredibly fragile. This is why archaeologists must take extreme caution when preserving excavated waterlogged wooden objects, as once the submerged wood is exposed to air the water will evaporate and result in the collapse of the wooden object (Unger et al. 2013). This is useful information, as it can be used to estimate pore spaces filled with water and allow an RDP calculation also.

Since waterlogged wood is wood in which water has permeated the inner structure of wood, the RDP for waterlogged wood must be calculated in the same way as the saturated sand. I did this, using 2.85 as baseline RDP for dry wood (Torgovnikov 2012) and a 66% porosity value (Unger et al. 2013). When calculated using the same formula that was used for calculating the RDP of saturated sand, the RDP of saturated wood was determined to be 53. Once the RDP of saturated wood was determined I programmed the model to replicate a 400 MHz antenna and initiated the model (Figure 4.4).

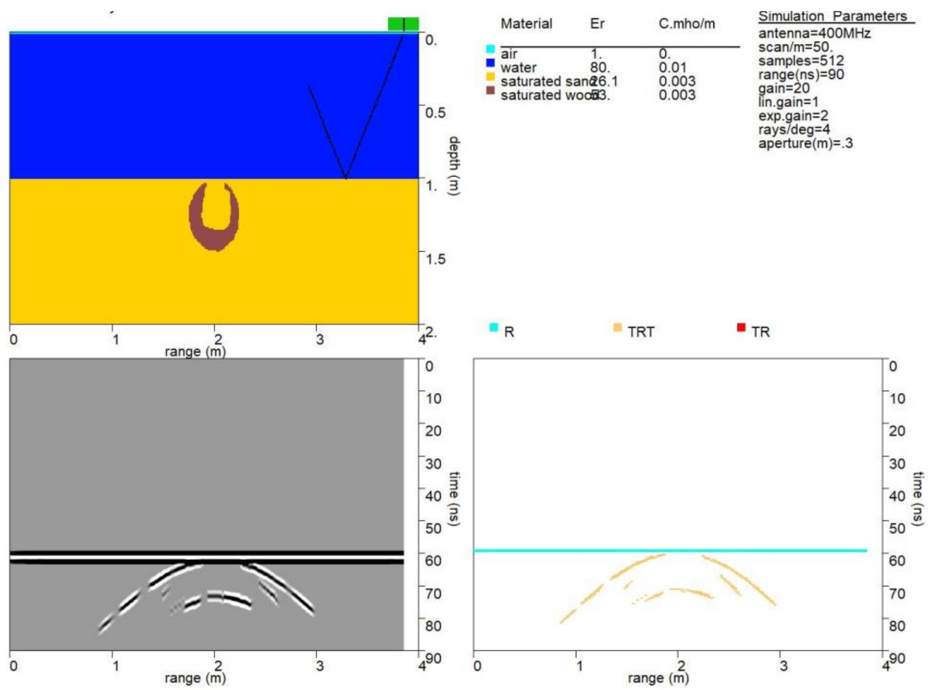


Figure 4.4. Synthetic computer model of a GPR reflection generated by a submerged canoe. The results of this model are nearly identical to the reflection generated from a known canoe. These two reflections in tandem provided a template from which I could identify reflections in the GPR data collected at Lake Santa Fe.

Ground-Penetrating Radar Data Processing – Lake Santa Fe

Having established that dugout canoes will produce a set of hyperbolic reflections I now had an identifiable reflection pattern, which I could extract from the GPR dataset collected at Lake Santa Fe. To look for reflections that may be representative of canoes I visually analyzed the over 47,210 meters of GPR data at Lake Santa Fe (Figure 4.5).

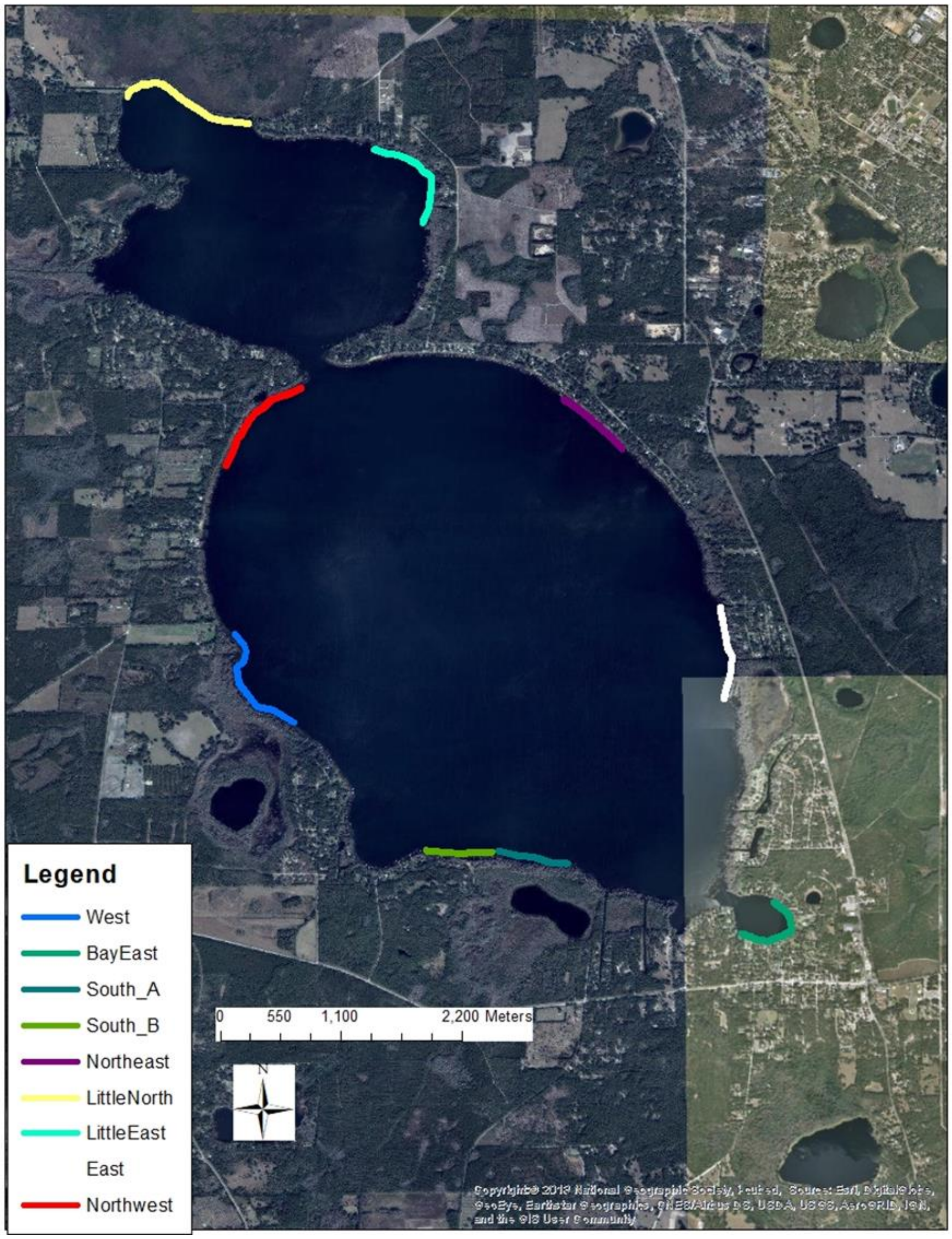


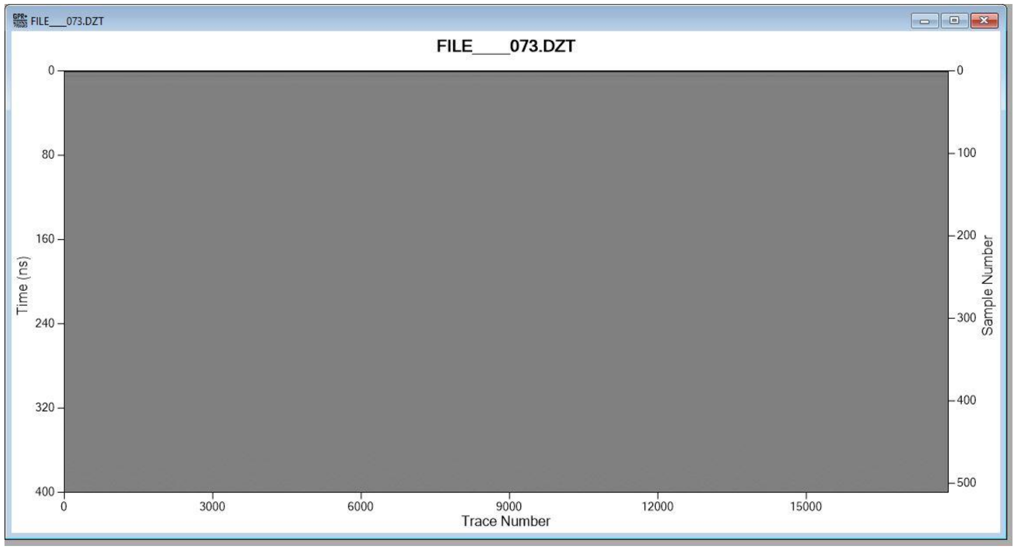
Figure 4.5. GPR data was collected in nine survey areas at Lake Santa Fe

The GPR data collected at Lake Santa Fe consists of profiles composed of in excess 27,000 traces and it was vital that analysis occurred using a software, which allows the resizing of the image window as well as the ability to manually zoom in on a selected portion of the profile for detailed analysis. While many GPR reflection profile analysis packages exist for inspecting GPR profiles, the software used for this thesis was *GPRVIEWER* (Lucius and Conyers 2016), written by Jeff Lucius of the United States Geological Survey (USGS).

GPRVIEWER is a Windows application built on the .NET platform that is designed solely for the visualization of 2D GPR profile data. Using *GPRVIEWER* I worked my way through the profiles at multiple scales and isolated areas where reflections were present. In all cases the synthetic model was used as an interpretation tool and these reflection features were then identified. While a variety of reflections were visible in the dataset, including many small objects and even fish, I only targeted reflections that matched the model data. In this way, I only chose reflections, which are most likely to be dugout canoes.

The first step in analysis once the data were loaded into *GPRVIEWER* was the removal of background noise in the data using the interactive "remove background" icon. This was a necessary first step because as GPR data are collected in the field, often unwanted radio waves transmitted in the same frequency range as the GPR are inadvertently received and recorded by the GPR unit (Conyers 2012:96). These unwanted signals obfuscate true subsurface reflections and must be removed from individual profiles upon loading into a software program to visualize reflections in detail.

The next step in analysis was adjusting the range-gains, artificially enhancing the strength of reflections (Conyers 2013). This allowed me to enhance the visualization of reflections that were not immediately clear and identify important features in the data set. The gains adjustment helped me identify the water column and lake bottom, a crucial first step. In GPR data sets collected on lakes the lake bottom can be identified as a high-amplitude planar reflection spanning the length of the profile (Conyers 2012:37), as was seen here (Figure 4.6)



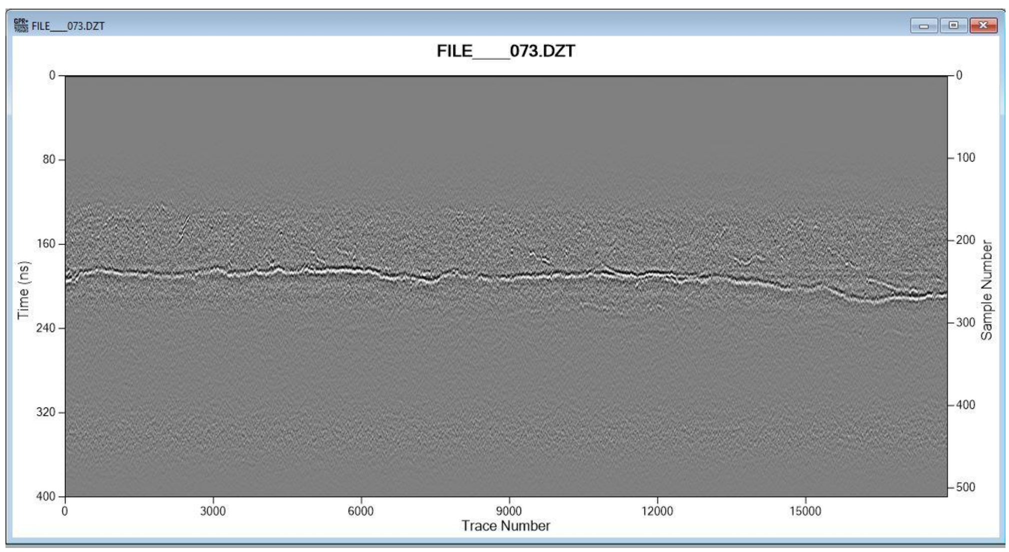


Figure 4.6 Screenshots from the GPR-Viewer software package showing a before and after image of the background removal and gains adjustment procedure. These procedures were vital, as they allowed me to identify the lake bottom and water column as is clear in the bottom image

Once I identified the water column and lake bottom in the data I reformatted the image scale so that the bottom axis of the profile was marked in 1000 trace increments, equal to about 43 meters. By changing the scale in this way, I was able to isolate 2000 traces at a time and methodically examine the lake bottom and sub-bottom in sections to identify reflections that may be submerged canoes, looking specifically for reflections like those generated by the GPR data over the known canoe, as well as the synthetic computer modelling.

For this thesis I only recorded hyperbolas situated within the top 50 cm of the sub-bottom sediment, ignoring any reflections that were on or above the lake bottom. This choice was made because the majority of archaeological canoes in Florida have been found embedded within sub-bottom sediment (Bullen and Brooks 1968; Wheeler et al. 2003). Moreover, ethnographic data suggests that many indigenous groups intentionally buried their canoes, the core of Duggins (2019) hypothesis that pre-Columbian people cached their canoes at watershed boundaries. Therefore, I was only selecting reflections that met the contextual attributes of previously recorded canoes.

After I visually identified a reflection that might be a canoe, I placed the mouse cursor over the reflection to retrieve its attributes. In *GPRVIEWER* the cursor position allows the software to return the trace number, sample number, and depth of the reflection of interest. Because I was able to retrieve these attributes I could use these data to reference the reflections of interest in another software package that was better suited for geographic mapping.

Once all reflections in the dataset were identified it was necessary to adjoin these reflections with their spatial coordinates so that they could be mapped and then filtered to identify reflections that are most likely to be canoes. To accomplish this, I used the *GPR-SLICE* software package authored by Dean Goodman of the Archeogeophysics Laboratory. While *GPR-SLICE* does contain the ability to view GPR profiles, I found that *GPRVIEWER* provided a better platform for this purpose, as discussed previously. One area, however, where *GPR-SLICE* excels is in the ability to integrate spatial and GPR data.

Because the data collected for this thesis occurred on water, there was no stationary grid datum, as is common with terrestrial data (Conyers 2012). Therefore, to place each GPR trace into geographic space, a separate GPS dataset was collected concurrent with the GPR data. These data existed as a separate entity then the GPR dataset and required manual action to associate them with the GPR data. To append a GPS data set to a GPR profile in *GPR-SLICE* it is necessary that the folder containing the raw GPR file includes two other files. The first is a time marker file with a .tmf extension and the second is the GPS file formatted with a .txt extension. All three of these files must share a name, with the only variation being their file extension. The time marker file is a binary file generated by the SIR 3000 system, which records the spatial coordinates of the first trace collected in the file (GSSI 2016). The GPS file is the collected log of spatial coordinates along the line of travel recorded by the GPS data logger. The GPS logger used for this thesis recorded the file extension with the proprietary .DEP extension. When the GPS data set was collected in tandem with the

GPR data the saved file name associated with each transect was recorded. This allowed me to associate each .DEP file with the appropriate GPR file and adjoin these data. Once the .DEP files were renamed and converted to .TXT files the data were ready for spatial joining in *GPR-SLICE*, and therefore I could place each reflection in geographic space.

To associate the recorded hyperbolas with their real-world spatial coordinates in *GPR-SLICE* I used the XYPOINTS function within the software package. This function allows a user to manually select a georeferenced reflection trace in the profile and save an ASCII computer file with the spatial coordinates of the selected trace. Since my analysis of the two-dimensional profiles in *GPRVIEWER* resulted in the recording of each reflection's central trace number, I used the trace number as the sole selection criterion in the XYPOINTS dialogue and created a file for each reflection.

Once I exported the georeferenced reflections in GPR-SLICE I was ready to map the data in GIS. The files exported from GPR-SLICE are in ASCII format, which can easily be converted to a text format by changing the file extension to .TXT. I did this for each file and then imported the data as point features in ArcMap. Since the XYPOINTS function in GPR-SLICE saved all the hyperbolas in a single GPR profile in one file I changed the display properties of the point features so that they were colorized by collection profile number. Figure 7 shows the result of this procedure for a section of the East survey area.

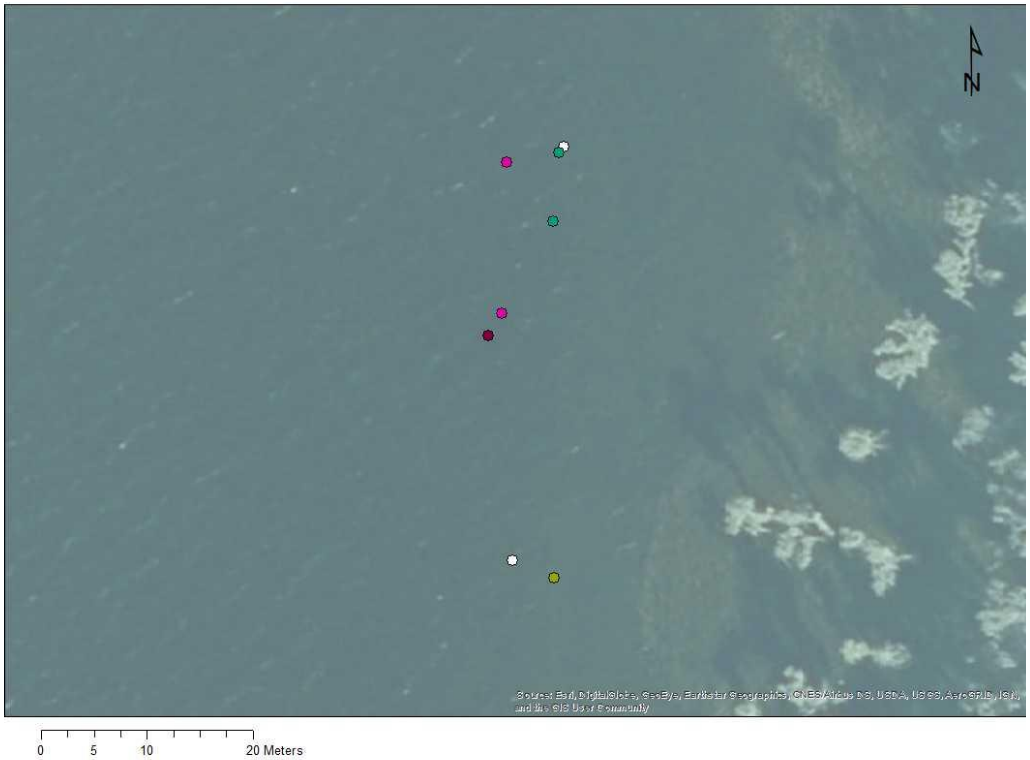


Figure 4.7: Once spatial coordinates were adjoined to the reflections I identified as potential submerged canoes, they were loaded in ArcMap and colorized by their collection line. By displaying the data in this way, I could easily distinguish the transect that generated each reflection.

Data Mapping and Criteria Determination Using the Florida Canoe Database

After the recorded reflections in the GPR dataset were mapped as point features in ArcMap the next step was generating criteria to “connect the dots” and determine which reflections were generated from submerged dugout canoes, and which reflections may be singular objects imbedded within the lake sub bottom and therefore should be removed as candidates in my model. Taking this additional filtering step was crucial because hyperbolic reflections in GPR datasets are generated by any objects perpendicular to the direction of travel of the GPR antenna and therefore adjacent reflections that are situated at 90° or 360° to each other cannot usually be generated from the same object (Conyers

2013). In addition, the length component of elongated objects perpendicular to the radar antenna is not captured in a single GPR profile, but rather can only be estimated by associating hyperbolas that appear in adjacent parallel profiles. Therefore, only reflections, which are within a specified distance and angle to each other were candidates for dugout canoes.

To determine these distance criteria, I generated descriptive statistics of canoe lengths using the *max length* variable within the canoe database. However, before I could generate the descriptive statistics for the *max length* field further filtering was required to capture appropriate data values. One of the categorical variables in the canoe database is the *part* of the canoe recorded. This column exists so that if, for example, just a portion of a canoe is discovered it can be notated as such in the database. Since the max length of a canoe fragment will skew the mean of the *max length* variable for all recorded canoes I queried the data to only include canoes where the *part* variable was recorded as "complete," indicating that the canoe was not fragmentary. In this way it was possible to extract appropriate length values from known canoes to generate criteria from which the GPR data from Lake Santa Fe could be compared.

Once my dataset consisted of the max lengths of complete canoes the mean and max values of this variable were extracted. Because the closest canoe site to Lake Santa Fe is Newnans Lake I also generated the mean and max lengths for all canoes reported to be complete at Newnans Lake. The results of these two analyses are presented in Table 1.

Table 4.1. Results and sampling universe of canoe lengths as recorded in the canoe database. By extracting these data, I was able to "connect the dots" on the reflections that may be canoes

Mean value of *max length* field	Maximum value of *max length* field	Sampling universe
5.6 meters	15 meters	All entries in master log boat database where *part* field equals “complete”
6.6 meters	8.6 meters	All entries in master log boat database where *part* field equals “complete” AND *SiteID* equals AL4792

To utilize the mean and max values for canoe lengths in ArcMap I turned to the multiple ring buffer tool within the Proximity toolset (Esri 2017). The multiple ring buffer tool allows the user to create a new shape feature consisting of multiple spatial buffers at specified distances around input features. For each point representing a possible canoe reflection I generated a multiple ring buffer feature consisting of 5.6,6.6,8.6, and 15-meter buffers (Figure 4.8). Because I grouped the point features according to their GPR profile name, the creation of the buffer features followed the same naming scheme.

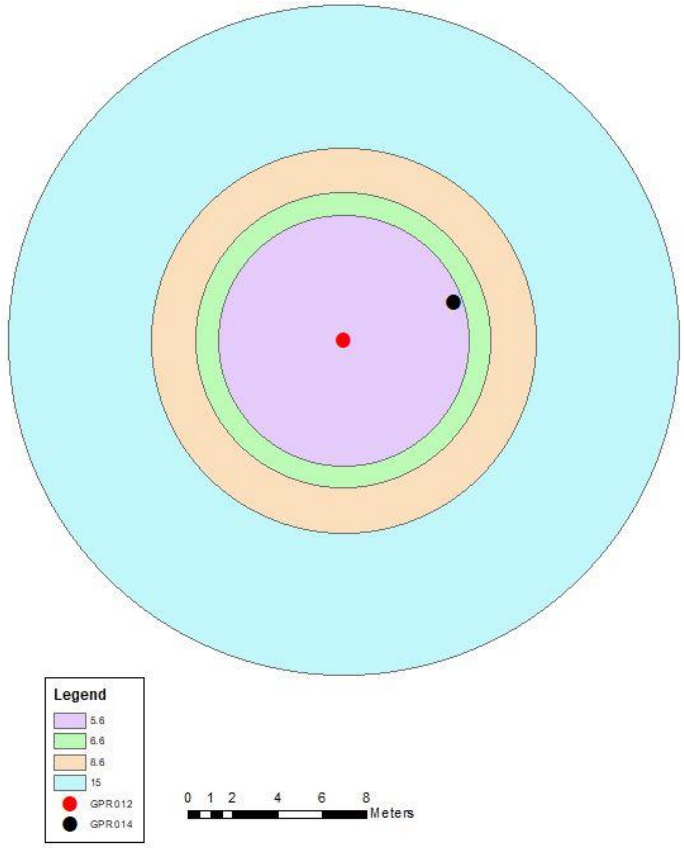


Figure 4.8: The results of the buffer analysis, which was used to draw concentric rings around identified reflections to examine the lengths of the reflector. In this figure each point represents an identified reflection in separate GPR profile lines. The points are within 5.6 meters of each other, the mean length of canoes at Newnans lake

After the buffer features were created I then examined the buffers for each point representing a possible canoe and "connected the dots" by creating a new line feature between points within these distance criteria. The line features were generated using the criteria outlined in Table 2. The creation of line features using these criteria effectively concluded the modelling of potential canoes in Lake Santa Fe, as I know had a map of the identified features in this lake.

Table 4.2. Line feature name and distance criteria used to generate the model of potential canoes in Lake Santa Fe

Line feature name	Distance Criteria
Targetslessequal5_6	Reflections, which were less than or equal to 5.6 meters away from each other
Targetslessequal6_6Great5_6	Reflections, which were less than or equal to 6.6 meters and greater than 5.6 meters away from each other
Targetslessequal8_6Great6_6	Reflections, which were less than or equal to 8.6 meters and greater than 6.6 meters away from each other
Targetslessequal15Great8_6	Reflections, which were less than or equal to 15 meters and greater than 8.6 meters away from each other

Results: Ground-Penetrating Radar Data at Lake Santa Fe

Of the nine areas surveyed at Lake Santa Fe, four contained likely reflections generated from submerged canoes (Figure 4.9). Chapter 267 of the Florida Statutes prohibits the disclosure of the specific locations of individual archaeological sites and therefore, the precise locations of the canoes identified in the GPR dataset collected at Lake Santa Fe are not presented in this thesis. Instead, I present the maps and results of this work by an arbitrary survey area number and do so without base maps that could be used to locate these data in space. In this way I visualize where in this lake the canoes are without comprising their exact locations.

Figure 4.9: Out of the nine areas surveyed at Lake Santa Fe, four produced what appear to be canoes

Survey Area 1

Survey area 1 (Figure 4.10) shows six features that appear to meet the criteria for submerged canoes. Of these six features five of them are clustered together, with one isolated feature. Four of these features are between 8.6 and 15 meters and length, making them longer than most canoes known in Florida. Two of these features are between 5.6 and 6.6 meters, making them about the average length of known canoes.

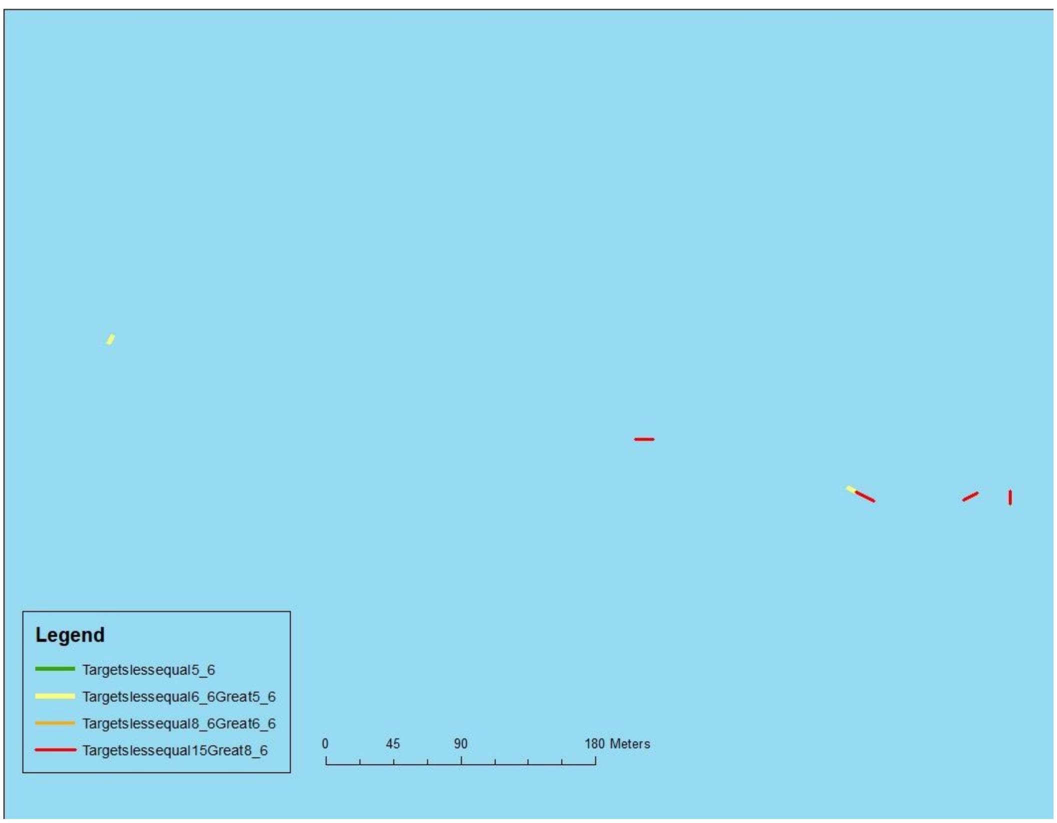


Figure 4.10: Potential submerged canoes in Lake Santa Fe as classified by length

Survey Area 2

Survey area 2 (Figure 4.11) contained 14 objects that may be submerged canoes. Of these reflections, 3 are less than or equal to 5.6 meters, the mean length of all previously recorded canoes in Florida. One object is between 5.6 and 6.6 meters in length. Three objects are between 8.6 and 6.6 meters, and the rest of the objects are between 8.6 and 15 meters in length.

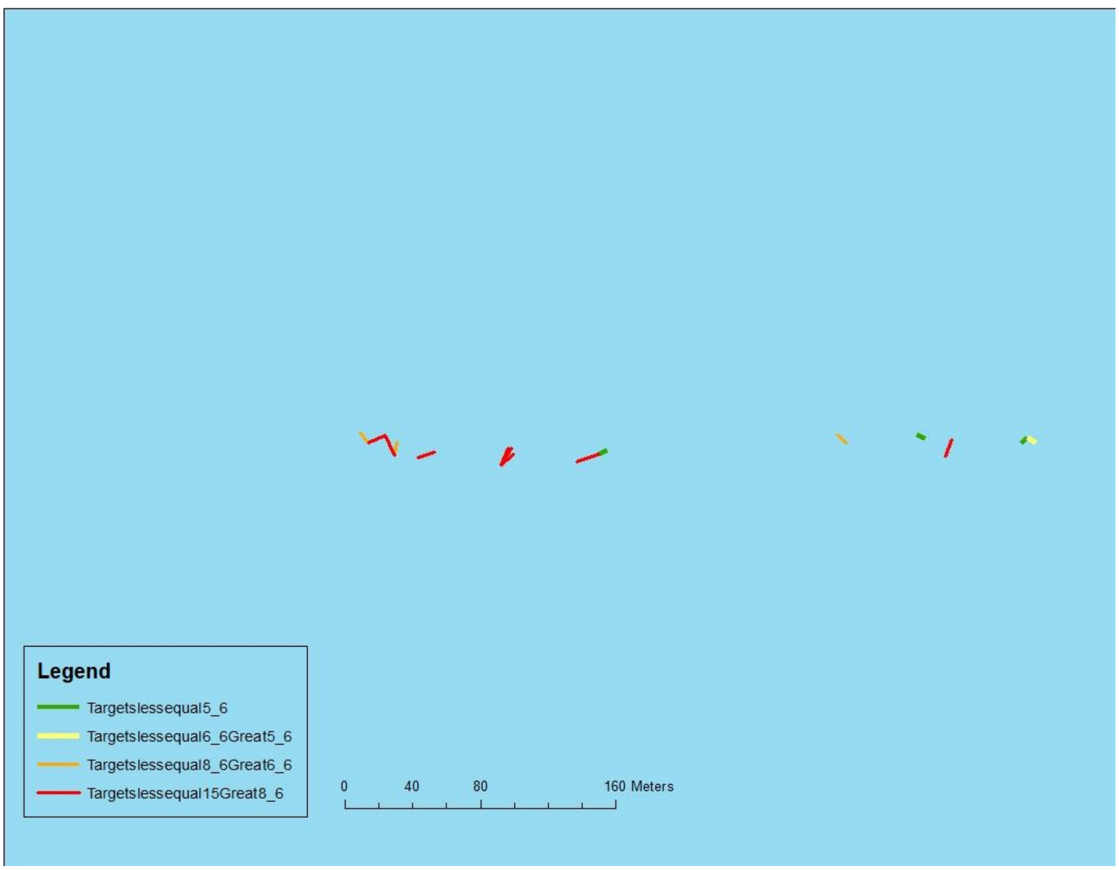


Figure 4.11: Objects in survey area 2 that may be submerged canoes in Lake Santa Fe

Survey Area 3

Survey area 3 (Figure 4.12) contained 7 objects that may be submerged canoes at Lake Santa Fe. Of these objects 3 were less than or equal to 5.6 meters in length, and the rest were between 8.6 and 15 meters long. These objects occur in two clusters.

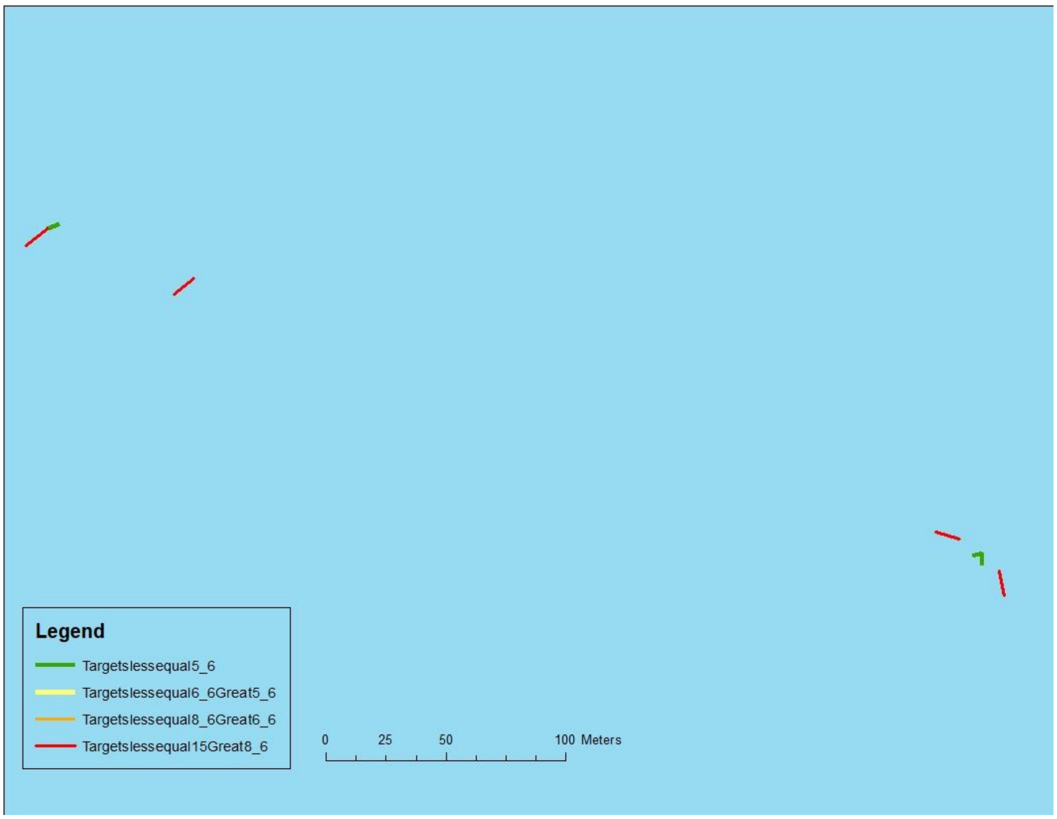


Figure 4.12: Survey area 3 at Lake Santa Fe with 7 possible submerged canoes

Survey Area 4

Survey area 4 (Figure 4.13) is the final survey area with objects that may be submerged canoes at Lake Santa Fe. This area has 14 objects that may be canoes, the same number as Survey area 2. In this area, 7 objects were less than 5.6 meters in length, 1 object is between 5.6 and 6.6 meters, 4 objects are between 8.6 and 15 meters long. Interestingly, these objects appear in three discrete clusters.

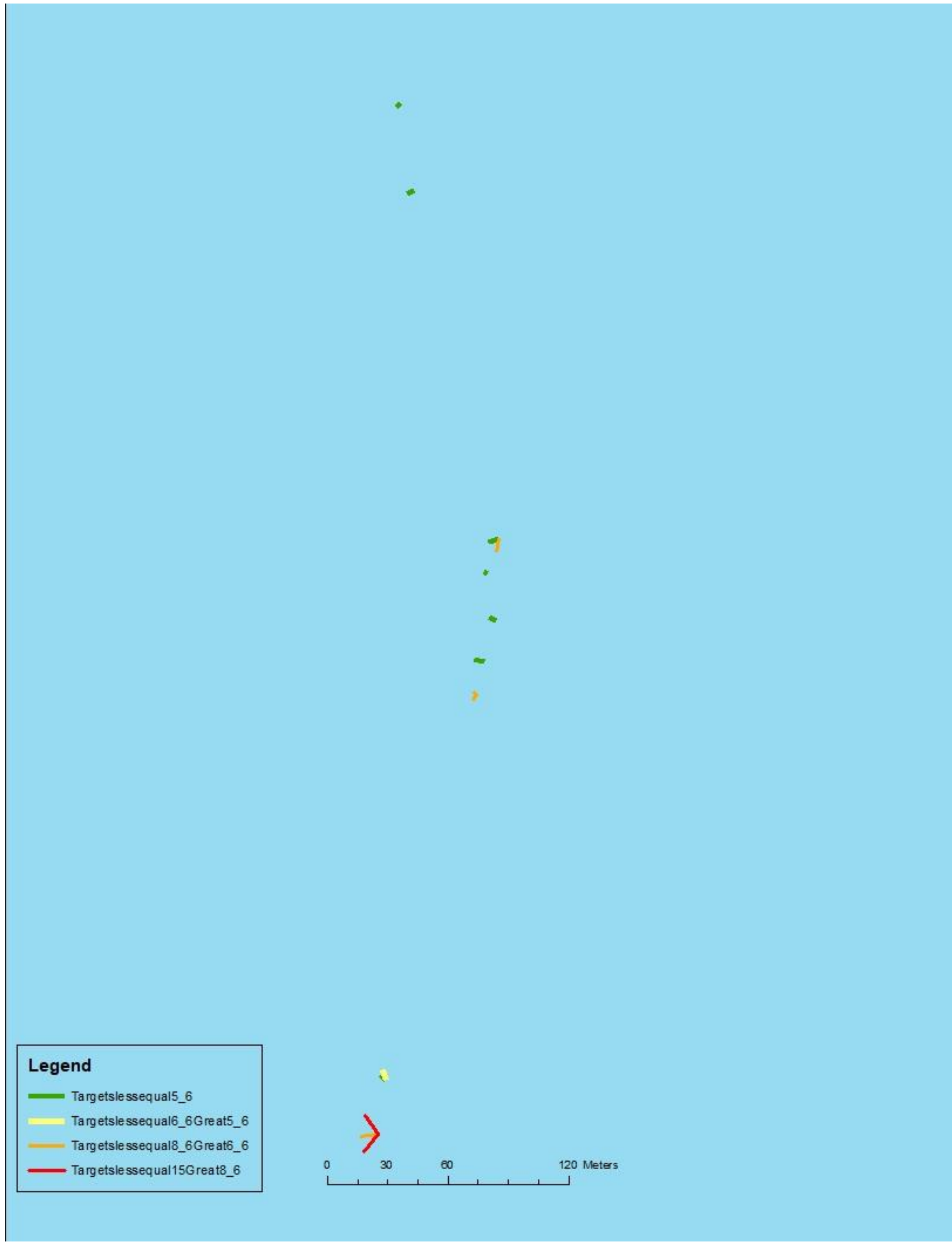


Figure 4.13: Survey area 4 at Lake Santa Fe with 14 objects that may be canoes

Conclusion – Ground-Penetrating Radar at Lake Santa Fe

The results of the analysis of GPR data at Lake Santa Fe show what are likely to be many canoes submerged in this lake. In total, 41 features were identified that generated similar reflections to the synthetic model and known canoe and met the length criteria of previously recorded canoes in the canoe database. While it is likely that some of these features are false positives, perhaps fallen trees, their presence under the lake-bottom, as well as their length make these features ideal candidates for canoes. Moreover, because they are classified by length, I hypothesize that the features, which are within the mean length range for previously recorded canoes are the best candidates for canoes. Those features, which measure between 2 and 6 meters comprise 22 of the total features identified.

The presence of what appear to be many canoes in this lake preliminarily support Duggins (2019) hypothesis that Lake Santa Fe may have been an important portage in the pre-Columbian transportation network. This idea, and its support by the GPR data provide an excellent opportunity to consider why there appear to be so many canoes in this lake, and how these canoes may have been used in the past. The next stage in the data analysis process was to then place these portages and other canoe sites into the overall landscape by examining the timing and mechanism of their use.

Model-Making 3 – When and Where

With the GPR work showing that there are likely many canoes within the sub-bottom sediment at Lake Santa Fe, my focus turned from whether there were canoes in this lake to how these canoes got there and even more so, how Lake Santa Fe may have functioned in Florida's pre-Columbian transportation system. In this way the identification of canoes led to further hypothesis about how portages and canoe sites can be used to explore how Florida's pre-Columbian transportation system facilitated the movement of people, goods, and ideas across the landscape.

In her most recent work, Duggins (2019) identified Lake Santa Fe as a possible major portage where travelers across Florida may have cached their canoes for later use. Her hypothesis, in brief, stems from an observation that Florida's four largest canoe sites (Figure 14) are situated at the boundaries of watersheds. Furthermore, she recognizes the continued use of these portages through time (as evident in radiometric dates from three of these sites) as evidence of their significance in the pre-Columbian transportation network. By adopting this perspective, I could then extend the location modelling of canoes with GPR to a study of the spatial and temporal aspects of these canoes within an anthropological context of landscape. Specifically, I could utilize the computational powers of GIS explore when and where people were using canoes in relationship to important archaeological sites of the same age.

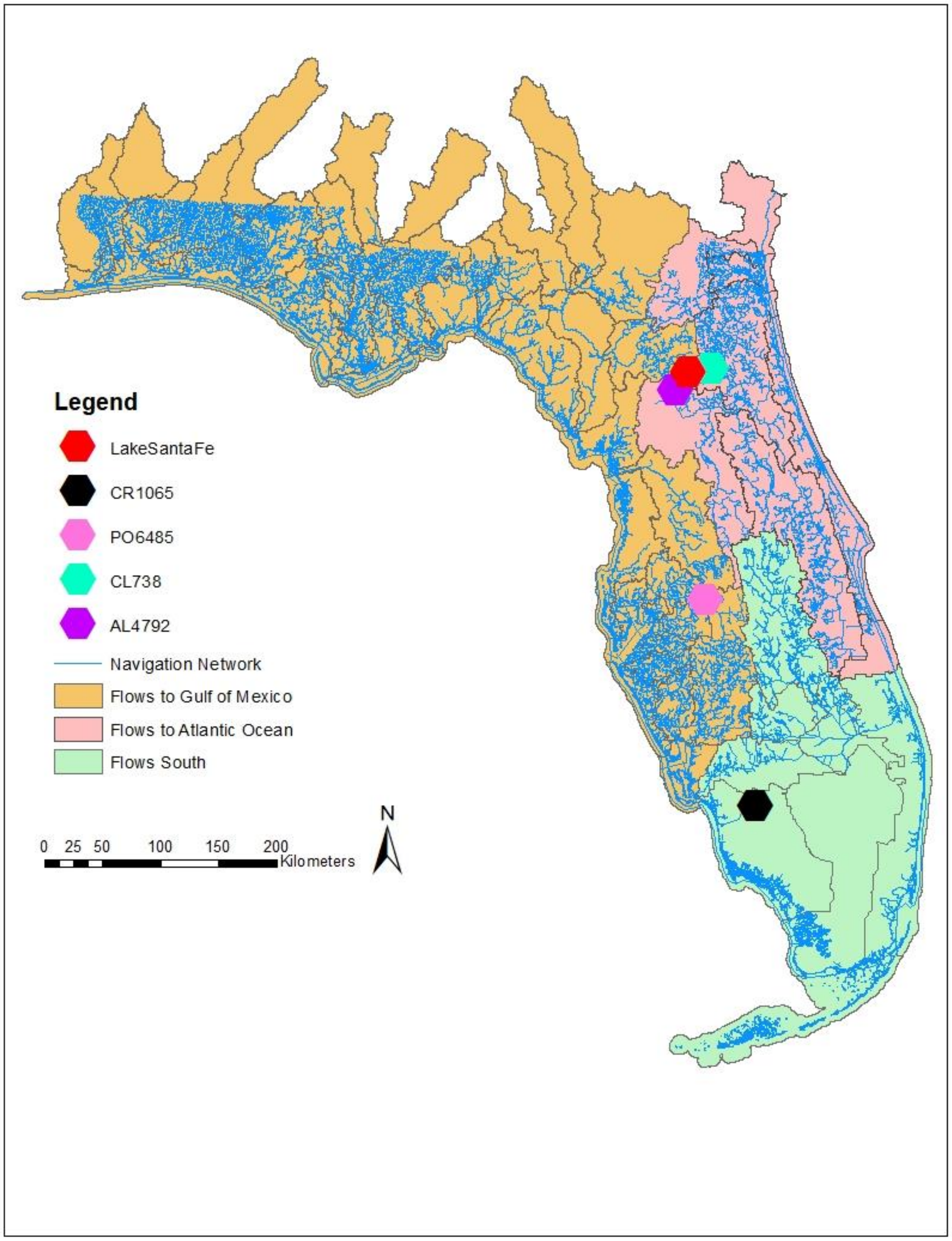


Figure 4.14: The locations of sites Duggins (2019) hypothesized to be portages in the pre-Columbian transportation network. Each one of these sites contains over 10 canoes. Lake Santa Fe is also included as a portage in this figure

.

To explore the spatial and temporal distribution of Florida's pre-Columbian canoes, I first extracted canoes with both raw radiometric dates and spatial coordinates from the canoe database (BAR Canoe Database). While Florida's well-dated canoes have been reported piecemeal (Wheeler et al. 2003, Ruhl and Purdy 2005, Hartmann 1996), the database contains many unreported data, with the most recent synthesis of all canoe dates appearing before the discovery of numerous early canoes at Newnans Lake in the year 2000 (Hartmann 1996, Ruhl and Purdy 2005). This provided an opportunity to calibrate these dated canoes with the most up-to-date IntCal13 atmospheric curve (Reimer et al. 2013), revealing when they were used in a more precise way, and then assign them an appropriate culture-period classification, following the most common scheme for archaeological sites (Anderson and Sassaman 2012).

Of the 424 canoes recorded in the database, 127 have both radiometric dates and spatial coordinates (BAR Canoe Database). After extraction, these dates were imported into the OxCal online calibration program to analyze their temporal probability distributions at the 95% confidence level (Bronk Ramsey 2017). This was important because by calibrating the conventional radiocarbon dates I accounted for fluctuating levels in 14C in the past, and therefore was able to better pinpoint when these canoes were manufactured. Once this analysis was complete I exported the data into an excel spreadsheet (Appendix 2) and classified each canoe by its culture-period according to its mean date, following the example of Smith and Stephenson (2017) (Figure 4.15). The results of this analysis (Figure 4.15) are a culture-period assignment for 119 of these canoes.

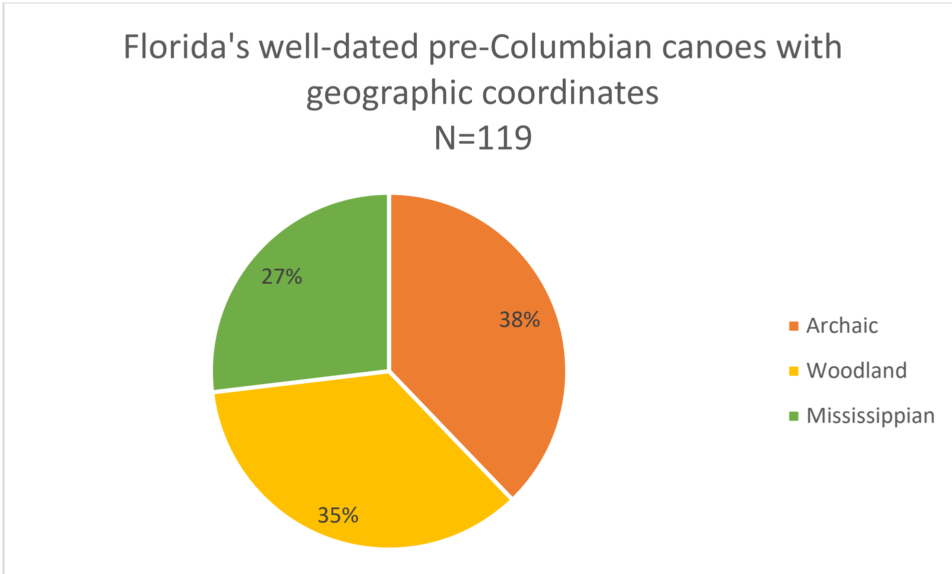


Figure 4.15: After the well-dated canoes were calibrated to reveal their time of use, they were assigned a culture period as depicted in this figure

The analysis of the canoes with radiometric ages determined when people were using these canoes, but in order to explore how these canoes were used for transportation across the pre-Columbian Florida landscape, I needed a way to incorporate the spatial attributes of these data with the locations of archaeological sites of the same age. To do this I analyzed how Duggins' (2019) hypothesized portages, as well as smaller well-dated canoe sites can be used to reveal canoe specific routes that people would have taken to arrive at centers of social interaction in pre-Columbian Florida.

Portages are significant interchanges on the transportation network as they are places where one mode of travel originates or terminates, much like modern bus stations or airports (Duggins 2019, Rodrigue et al. 2016). As such, they represent important locations on the network infrastructure because for some trips they served as obligatory gateways or hubs for travel. These gateways, as well as other stops along the transportation network can best be thought of as nodes connected by the network infrastructure (in this case flowing water) (Figure 16).

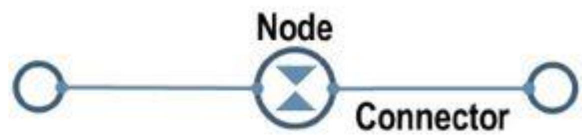


Figure 4.16: Nodes are a basic element of all transportation networks.

In addition to portages, smaller canoe sites can also be thought about as nodes, which are valuable because they represent places where people were once using canoes along specific routes. Moreover, all archaeological sites in close proximity to the network's infrastructure are nodes. Some sites, however, served as particularly important places for "social and material interaction by gathering diverse people" (Gilmore 2016). These sites, at the continental level, include well known archaeological sites that where people engaged in complex systems of trade and social interaction. Some of the better-known ones in North America include Chaco Canyon, New Mexico (Lekson 2007, Lekson and Cameron 1995), Cahokia, Illinois (Alt 2006, Pauketat and Bernard 2004) and Poverty Point, Louisiana (Kidder 2011, Spivey et al. 2015). At the regional scale, these famous sites can be recognized through their status as persistent places with monumental constructions, which served as aggregation centers for an extended period of time (Thompson and Pluckhan 2012). While not at the scale of these famous sites, many sites in Florida likely served the same function at least locally, becoming centers for trade and social interaction (Wallis 2014). When portages, well-dated smaller canoe sites, and the locations of important centers of social interaction are analyzed holistically, a nuanced perspective of the pre-Columbian transportation network can be formulated.

To reveal these nuances, I utilized the network dataset described in the previous chapter to calculate the least cost paths between canoe locations and important archaeological sites from the same time-period. In all the analyses travel time is the cost being aggregated and the software is programmed to calculate the routes that take the least amount of time. As described in the previous chapter, this model includes hypothesized overland portage routes, which “cost” more than canoe travel alone. In this way, the model is designed to calculate ease of travel across the landscape.

Only those Florida sites that have been recognized in the archaeological literature as persistent places on the landscape are incorporated in these analyses. This is partly because of the lengthy time-periods, which comprise the culture-periods assigned to each canoe. While no doubt many places served as aggregate centers for distinct traditions within these culture periods (Weeden Island mortuary complexes in the Woodland Period being a prime example) only those sites that have been interpreted as having enduring importance are utilized. The exception to this rule is in the first analysis (Figure 4.17), which calculates the routes from the earliest canoes to two major shell rings, which have been interpreted as places of elaborate feasting events six-thousand years ago (Russo 2002, Saunders and Russo 2011). This analysis demonstrates that both the Lake Santa Fe and Newnans Lake portages would have been utilized in the movement between the locations of the earliest-known canoes and shell-rings on the Gulf coast of Florida.

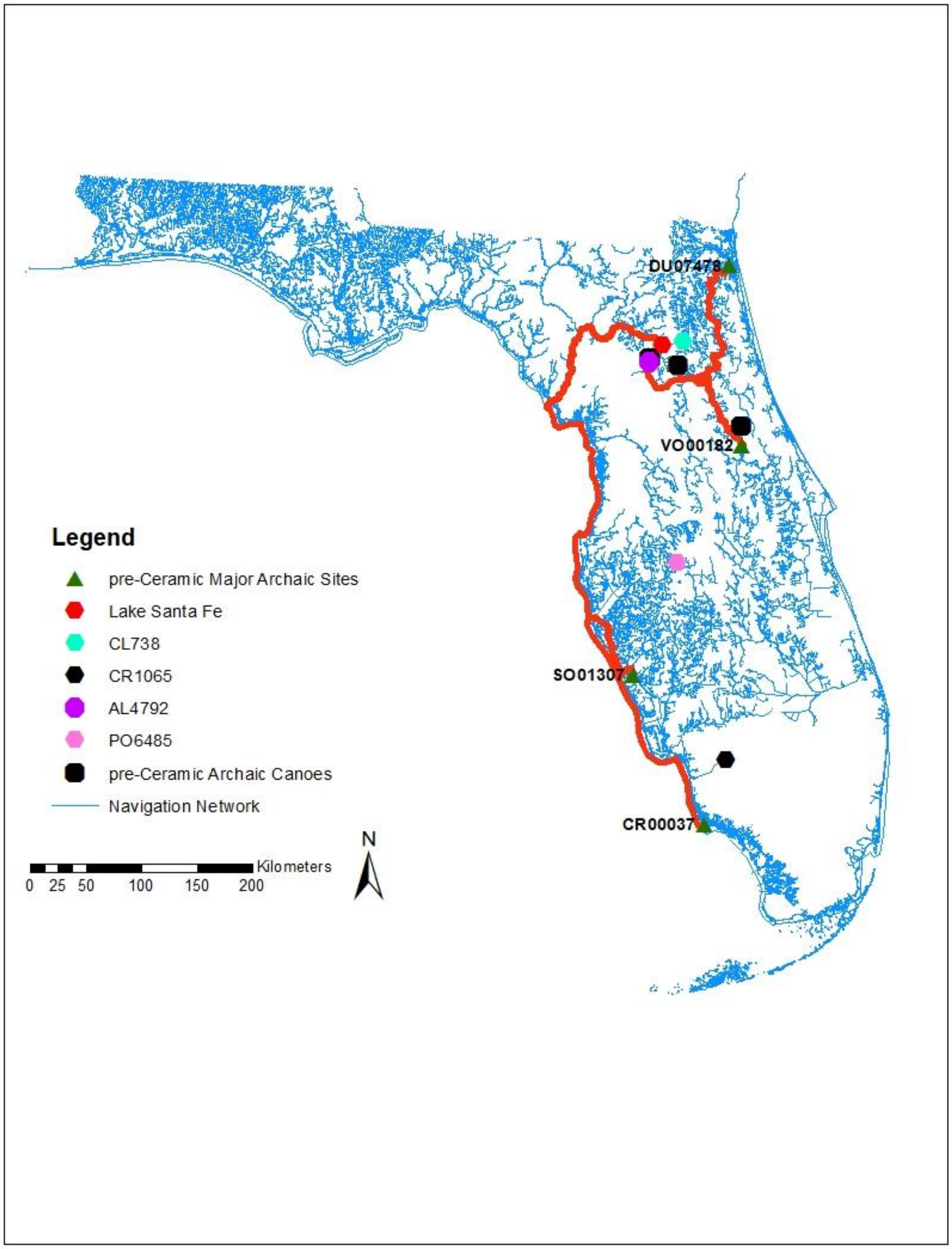


Figure 4.17: The least-cost routes between the earliest canoes in Florida and sites where the people who used these canoes likely traveled

The second analysis (Figure 4.18) demonstrates the routes for canoes assigned to the Archaic period, with dates ranging from Cal. 3790 B.C to Cal. 1680 B.C (Appendix 3). This analysis shows that the same routes and portages used to connect the earliest canoe sites to major feasting centers were still being used during this time, with additional routes emerging with the presence of expansive shell-mound centers during the Late Archaic. At these centers large amounts of fiber-tempered ceramics, the first ceramic technology in the southeast, was traded heavily, with clearly complex systems of trade and interaction in place (Gilmore 2016, O'Donoghue 2017).

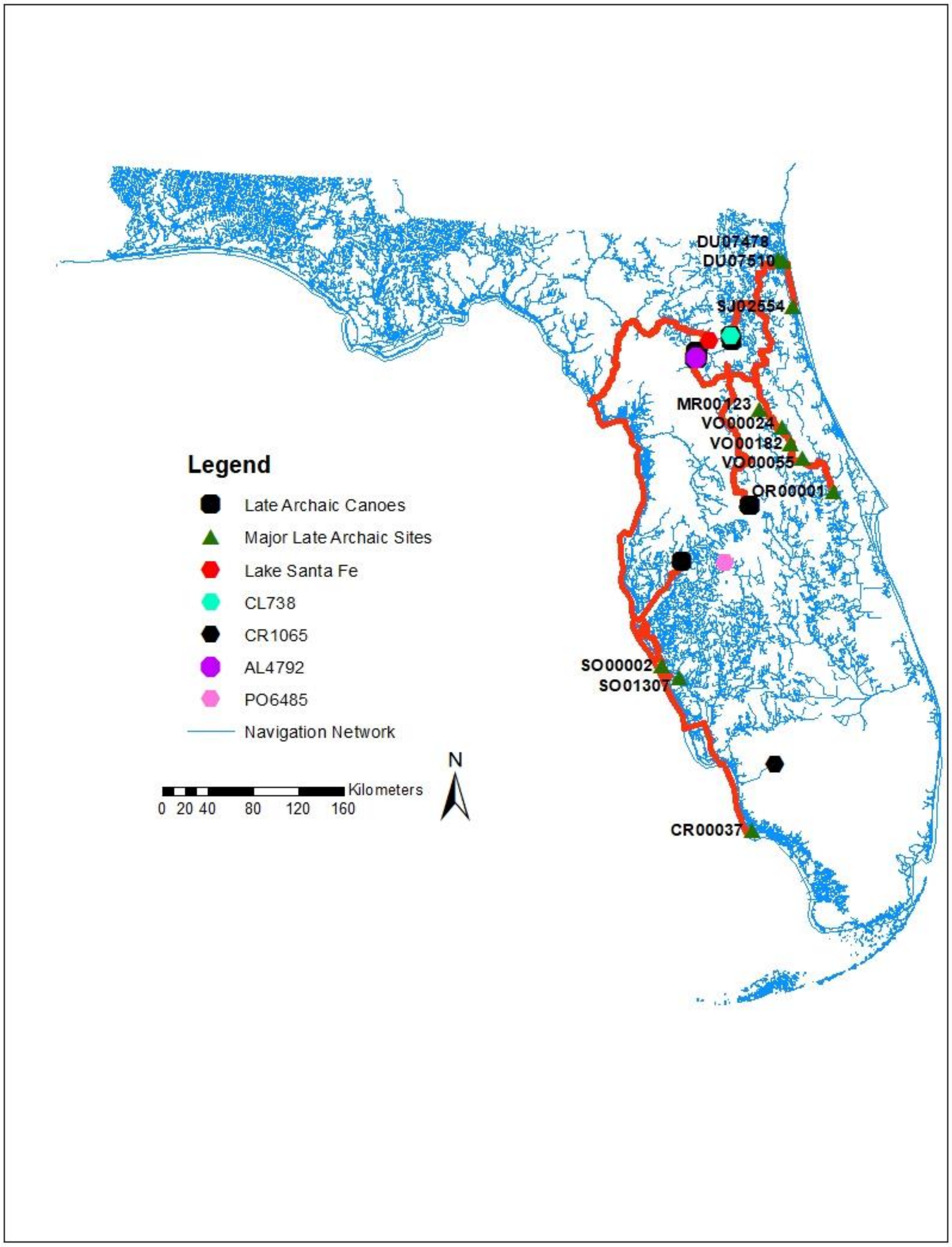


Figure 4.18: Locations of Late Archaic canoes and routes to important gathering places during this time

The third analysis (Figure 4.19) examines the routes between the locations of Woodland Period canoes (Cal. 1200 B.C to A.D 950) and the Crystal River (CI01) and Fort Center (GL23) sites. These are both places that had continued occupation and importance through the Woodland period while many other places in North Florida held only brief tenures (Pluckhahn et al. 2015, Thompson and Pluckhahn 2012). At both of these centers an abundance of non-local materials has been recovered, suggesting that they were hubs for the exchange of both goods and ideas during the duration of the Woodland period.

This analysis demonstrates that during the Woodland period people likely used canoe routes first utilized in the Archaic period to connect people across the peninsula. One observation is that a route linking the Everglades with the St. John's River Valley appears at this time. This is interesting, as it is believed the majority of cultural activity was centered around the northern Gulf Coast at this time, as expressed first through the Swift Creek culture and then through the Weeden Island cultures (Anderson and Mainfort 2002). A route connecting the Everglades and St. John's River Valley indicates that there may have been more activity outside of the Gulf Coast during this period than previously thought.

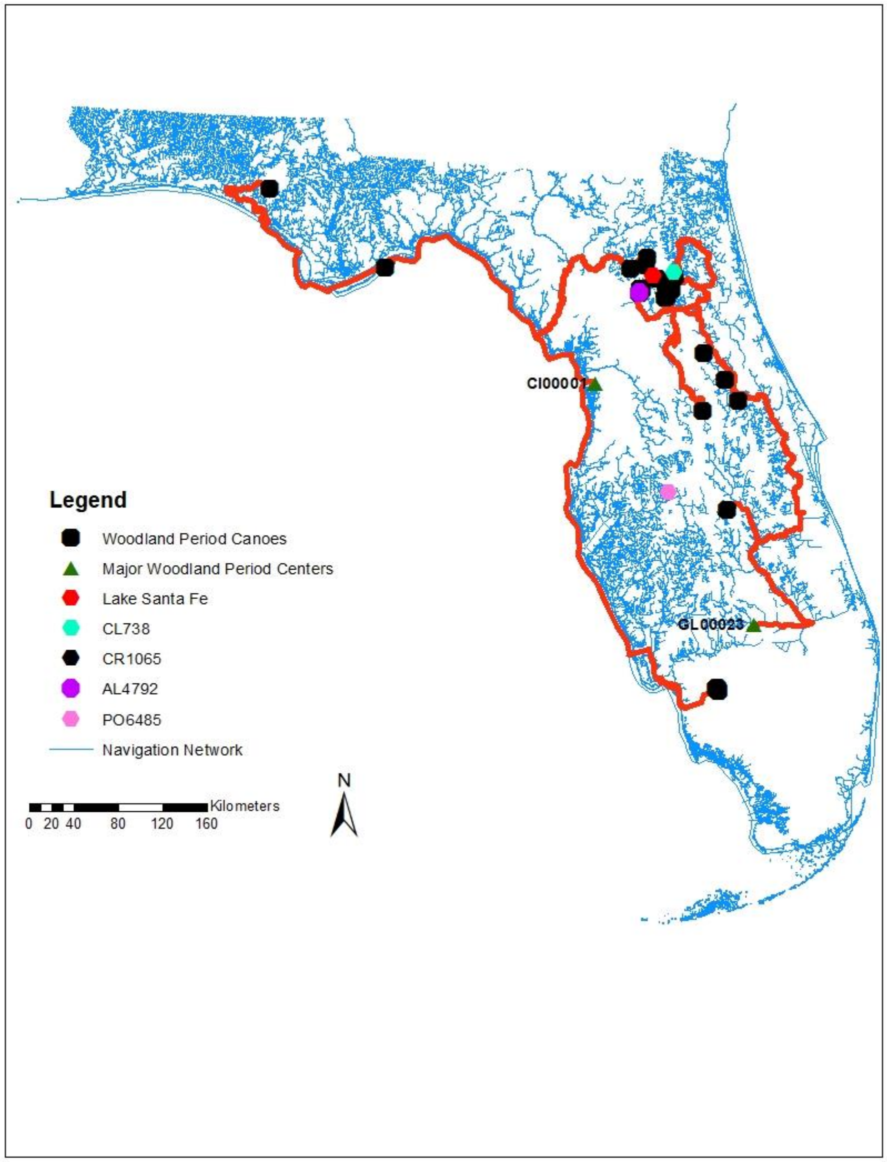


Figure 4.19: Locations of Woodland period canoes and the routes to Crystal River and Fort Center, two important places of interaction during this time

The fourth analysis (Figure 20) demonstrates routes between canoes dated to the Mississippian period and select major sites of the same age. As with the analyses that proceeded it, the routes taken during the Mississippian period were ones that were used in the past, clearly demonstrating that these paths were places used over long durations of time. A notable addition to the routes in the Mississippian period is the first use of Lake Hollingsworth (PO6485), one of the sites with multiple canoes that Duggins (2019) hypothesized to be a transit point. Interestingly, Lake Hollingworth is the only one of the hypothesized portage sites to not have any well-dated canoes and the results of this analysis indicate that these canoes may date to the Mississippian period.

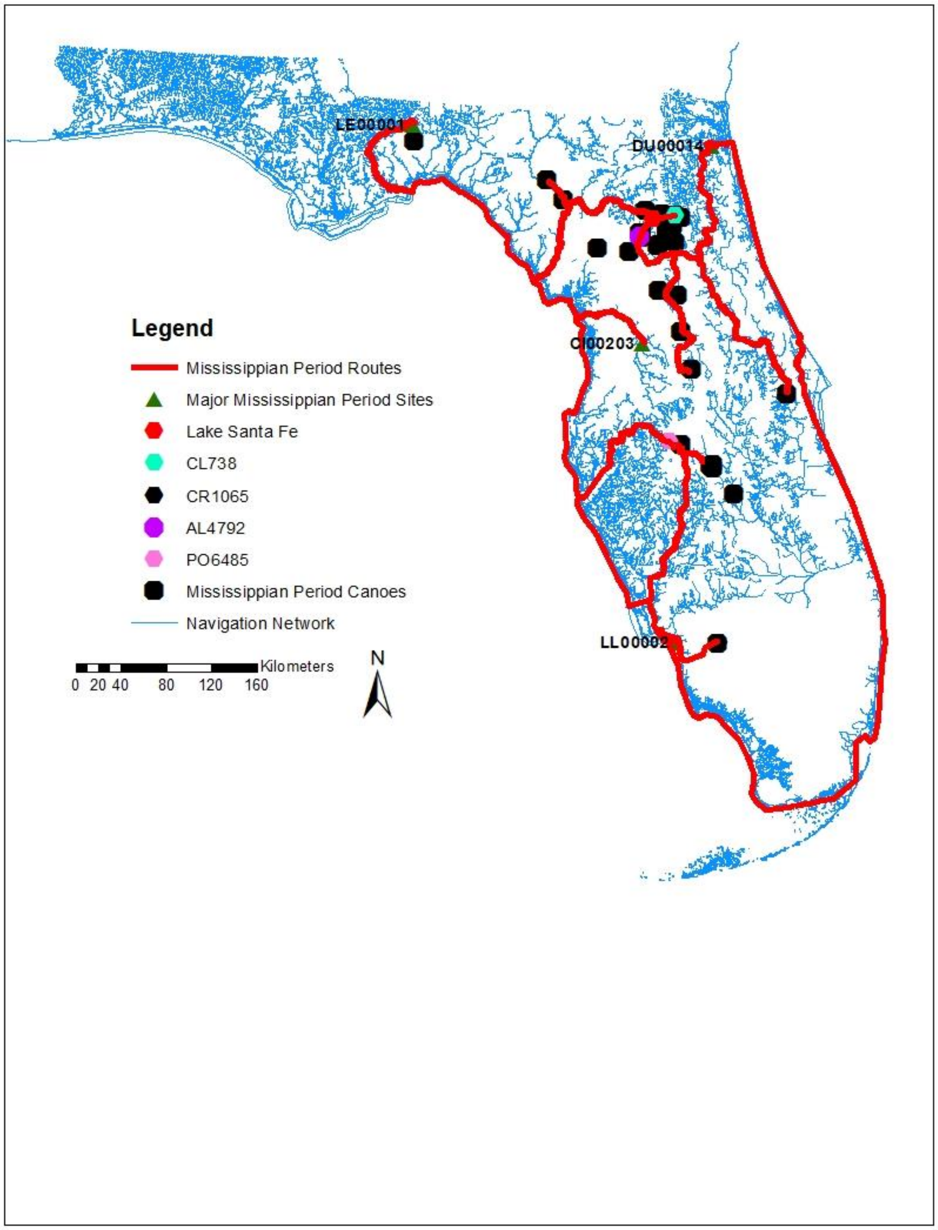


Figure 4.20: Locations of Mississippian Canoes and routes to select important sites during this time

Conclusion – GISci Modelling of Canoes Through Time and Space

The modelling of canoes in both time and space indicate that canoe technology was in use in Florida since at least Cal. 4961 B.C, during the Archaic Period. When navigable canoe routes were calculated between the locations of canoes and contemporaneous archaeological sites interpreted as major gathering centers, it became evident that portage locations served important roles as transportation hubs from the onset of canoe travel.

When the routes were calculated for the Woodland and Mississippian periods it became evident that while the locations of major centers shifted over time, the canoe routes stayed by and large intact, with only minor changes. The continuity in canoe routes over time has broader implications for social interaction and the exchange of goods and ideas. Notably, it is evident that if in fact groups from across the Florida peninsula aggregated at these centers as hypothesized, then their encounters with each other would likely to have occurred while in transit before they reached their destination. This, in turn, means that alliance-formation played an important role not only in the trading of goods, but also in the maintenance of access to sections of the transportation network. In this sense, the data analysis in this chapter indicates that canoe routes themselves may be best viewed as persistent places in the same way that the major sites utilized in the network analysis are. These “landscapes of movement” (Snead et al. 2009) are explored further in the following chapter.

CHAPTER FIVE: SYNTHESIS

This study began by using ground-penetrating radar (GPR) to locate submerged canoes in Lake Santa Fe, Florida. The identification of what appear to be multiple canoes in that lake led me to consider that lake's role as a natural portage in Florida's pre-Columbian navigation network as it is at the boundaries of two major watersheds in northcentral Florida. Lake Santa Fe is located 12 km northeast of Newnan's Lake, the largest singular canoe site globally (Wheeler et al. 2003) (Figure 2.8). The presence of 101 canoes within Newnan's Lake led Duggins (2019) to investigate other sites with multiple canoes, which sit at the boundary between major watersheds whose terminus is either the Gulf of Mexico, Atlantic Ocean, or south towards the Everglades (Figure 4.14). This led to the idea that these canoes were intentionally cached at important places on the ancient landscape, and their locations at watershed boundaries suggested that these sites were major portage locations for the movement of canoes, people, and goods to and from otherwise isolated geographic locales.

When this thesis research began at Lake Santa Fe, which also sits at a major watershed boundary, only 2 canoes were known from this lake (FMSF). However, the GPR results presented here indicate that additional canoes are present at Lake Santa Fe, further supporting Duggins (2019) idea that Lake Santa Fe served as a major transportation interchange on Florida's pre-Columbian transportation network. With Lake

Santa Fe now classified as a portage, I then looked at the locations of individual canoe sites and their ages across Florida and mapped major archaeological sites of the same age as the canoes. That analysis connected the dots between canoe sites, portages, and contemporaneous archaeological sites, and the research branched out to explore the movement of people, ideas, and goods by canoe over time and space. This was important because the function of canoes as transportation vessels means that they are most appropriately viewed within a context of movement across waterways, rather than as static locations.

The next step in the process was to simulate movement by canoe on the ancient landscape by producing a computer model of the navigable waterways that led from the locations of canoes to important sites of the same age. This was done by determining what waterbodies would have been navigable given the known dimensions of previously recorded canoes, the average depth of the water in this hydrological system, and then creating artificial overland paths to connect some portage locations to this network.

Once the navigation network was in place, connecting portages to rivers, and ultimately to the Gulf of Mexico, Atlantic Ocean, or Everglades, I calibrated the radiometric age-dates of canoes with this information contained in the database. This allowed me to analyze the temporal distribution of canoes and assign each canoe a culture period designation. This was important because it allowed me to place each canoe within its proper cultural context and associate canoe sites with important archaeological sites of the same age, and also the navigation network in which they would have traveled.

This dataset was then used as part of a network analysis within a Geographic Information System (GIS) that calculated specific canoe routes from canoe sites to important archaeological sites of the same age during the Archaic (11,500 – 3,200 cal B.P.), Woodland (3,200 – 1,000 cal B.P.), and Mississippian (1,000 cal B.P. – A.D. 1600) culture periods (Anderson and Sassaman 2012; Ashley and White 2012). That analysis showed that canoe routes through portages that connected the Atlantic and Gulf of Mexico watersheds were likely continuously in use from the onset of canoe technology six-thousand years ago forward.

To explore the implications of the computer modelling with respect to the movement of people, goods, and ideas through the calculated canoe routes, a holistic approach was utilized that integrates anthropological theory with abductive reasoning. This allowed me to consider generally the importance of human movement and the role of the canoe in connecting people and ideas across the pre-Columbian transportation network.

Abductive reasoning, also referred to as "inference to the best explanation" (Fogelin 2007) is an epistemological approach to archaeological inquiry that emphasizes the limited nature of the archaeological record to test ideas about the past. In this framework, the empirical observation of archaeological data is used as a generative tool for hypotheses and explanations that are not directly verified or refuted, but instead are posited as inferences to the best available conclusion (Helmreich 2007).

By using an abductive approach in this thesis, I acknowledge the experimental nature of my methods and their results, which can be tested later through intensive field survey. However, using this framework allowed me to integrate ideas from multiple schools of anthropological theory that are sometimes seen as in conflict with each other to provide a more holistic view than is often implemented (Fogelin 2007, Hegmon 2003). Namely, by using an abductive approach I was able to harness the computational and quantitative power of GIS while not being solely confined to those objective results in interpreting my datasets.

How To Think About Pre-Columbian Canoes: Theoretical Perspectives

A major objective of this thesis was to take archaeological canoes and place them within an interpretive context informed by anthropological theory. As Cassels (1997) notes, anthropological theories in archaeology can be divided, generally, into two types: *materialistic* and *ideational*. Materialistic theories focus on physical factors, such as technology, environment, and population, and the effect that these factors have on cultural development. Ideational theories are those theories, which posit that cultural development is primarily a product of how people think, and therefore it is these processes that are the object of study within this paradigm. These two divides in theory are analogous to debates in the field between the appropriateness of processual versus post-processual approaches (Fogelin 2007). It is my belief that archaeological theories are the most useful when materialistic and ideational perspectives are combined. In this sense, my application of archaeological theory in this thesis can be best categorized as "processual-plus," a term introduced by Hegmon (2003).

I propose that canoes are best viewed not as isolated objects in a museum or database, but instead as dynamic technologies that enabled important aspects of pre-Columbian culture. In the context of this thesis, I adopt Tyler's (1871:1) definition of culture as "that complex whole which includes knowledge, belief, arts, morals, law, custom, and any other capabilities and habits acquired by man as a member of society." While the inclusion of "man" in this definition is problematic in today's vernacular, I believe Tyler's definition is the most appropriate summation of culture because it encompasses both the material and mental aspects of culture.

My view is that human beings are first and foremost an adaptive biological species, and therefore a materialist perspective is the most appropriate place to start thinking about the role of canoes in the development of pre-Columbian culture. Harris (1979) posits that culture exists in three parts: the *infrastructure* (technology, environment, demography), the *structure* (sociocultural organization), and the *superstructure* (ideology). In Harris' view, the infrastructure determines the direction of cultural development, and thus, the structure and superstructure cede to the pressures of the infrastructure. In this paradigm, culture is a dynamic system that changes with human needs (Kuznar and Sanderson 2015). To this end, I agree with Macdonald and Purdy (1982:9) that canoes are best viewed as "adaptive mechanisms." This view of dugout canoes echoes cultural materialist Leslie White's (1949:365) standpoint that "man as an animal species, and consequently culture as a whole, is dependent upon the material, mechanical means of adjustment to the natural environment." It is no coincidence that the earliest canoes in the database (as confirmed in the age-calibrations) (Appendix 4) are coeval with the emergence of aquatic ecosystems during the Middle to Late Archaic Period because it was at this time the waterways became navigable as sea levels stabilized (Ruhl and Purdy 2005). Therefore, a functional perspective that views the advent of canoe technology in response to environmental change serves as an appropriate starting place for thinking about the canoes analyzed in this thesis.

The cultural materialist approach (Harris 1979) views adaptation to the environment and demographic pressures through technology as the most influential element of culture, but it does not ignore the implications that these adaptations have to the development of complex social systems. Others, (MacDonald and Purdy 1982:10) posit that "the efficiency of the canoe undoubtedly played a role in making possible the rise of complex societies." In addition, Hartmann (1996:41) further elaborates on this point, illustrating that the time and energy saved through canoe travel would have then been available to channel into activities such as earthwork or monument building, as well as ceremony. In the context of this thesis, these cultural materialist approaches provided a framework for viewing adaptation as "setting the stage" for complex social systems, without ignoring the intricacies and importance of social interaction. Here I have taken these earlier ideas about canoes and environmental adaptation and integrated them with ideational theories regarding the importance of place-making and landscape in shaping the human experience.

Those initial ideas about canoes and their importance in the development of pre-Columbian cultures were important, and here I have taken them and implemented them, along with more recent ideas in social theory, within a GIS-based spatial analysis that can place this important aspect of pre-Columbian culture into a regional-scale digital landscape model. I am looking at both the physical and social implications of canoe transportation, and therefore, this work can be best characterized as belonging within the recent paradigm of landscape archaeology. This kind of study explores “natural, built, and ideational environments” Henry and Wright (2013). In general, these new approaches to landscape in archaeology seek to incorporate how people thought about the environment along with how the environment aided or constrained them (Bender et al. 1998, Knapp and Ashmore 1999). While there are many different avenues of inquiry in landscape archaeology, this study is best described as examining the “landscape of movement,” a perspective that stresses the importance of the physical manifestation of movement through a landscape (Snead et al. 2009).

The radiometric date-calibrations of canoes analyzed for this thesis revealed that the earliest canoes in Florida date to the boundary between the Middle (7800 - 5800 cal B.P.) and Late (5800 – 3,200 cal B.P.) Archaic Periods (Anderson and Sassaman 2012) (Appendix 2). It is at this time that canoe technology was developed as changing environmental conditions resulted in navigable waterways and wetland environments. People in the Archaic used canoes to intensively-harvest shellfish in these new locales, with the exploitation and then management of these resources resulting in the development of the first complex societies in Florida. As these societies grew, communities hosted feasting events that aggregated disparate populations across Florida and perhaps beyond, with routes connecting the Atlantic and Gulf coasts. At these political and ceremonial gatherings, new ideas and diverse expressions of material culture were exchanged, and networks of interaction were formed and maintained. (Russo 2002; Randall 2015; O'Donoghue 2017; Gilmore 2016). These activities were imperative aspects of pre-Columbian culture, and the presence of canoes at this time suggests their importance as people and goods would have moved to these places for these kinds of interactions.

The evidence that people were likely moving around in Florida can be seen through the coincidence of canoes and the earliest shell-ring and mound sites on both the Atlantic and Gulf coasts (Figure 5.1). This was an important time in the past as people appear to have settled in one locale for extended periods of time for the first time and no longer traveled long distances to obtain food resources. While they were not agricultural, they were at least semi-sedentary as resources obtained from the sea and the productive estuaries and marsh environments were closer than in previous times. Shell-rings are an important component of this reduced mobility strategy as they are the remains of residential communities who hosted elaborate feasts that saw the integration of people both within and external to the Florida landform (Russo 2002). At these sites, people would have participated in ritual and political activities that would have required intricate social dealings instigated by the hosting community. Specifically, Russo (2002) posits that by attending these feasts, participants would become indebted to their hosts and leave these events with an increased social and economic obligation to the hosting community.

These obligations may have included “promises of marriage or other alliances, support in battle, labor or some other form of repayment” (Russo 2008).

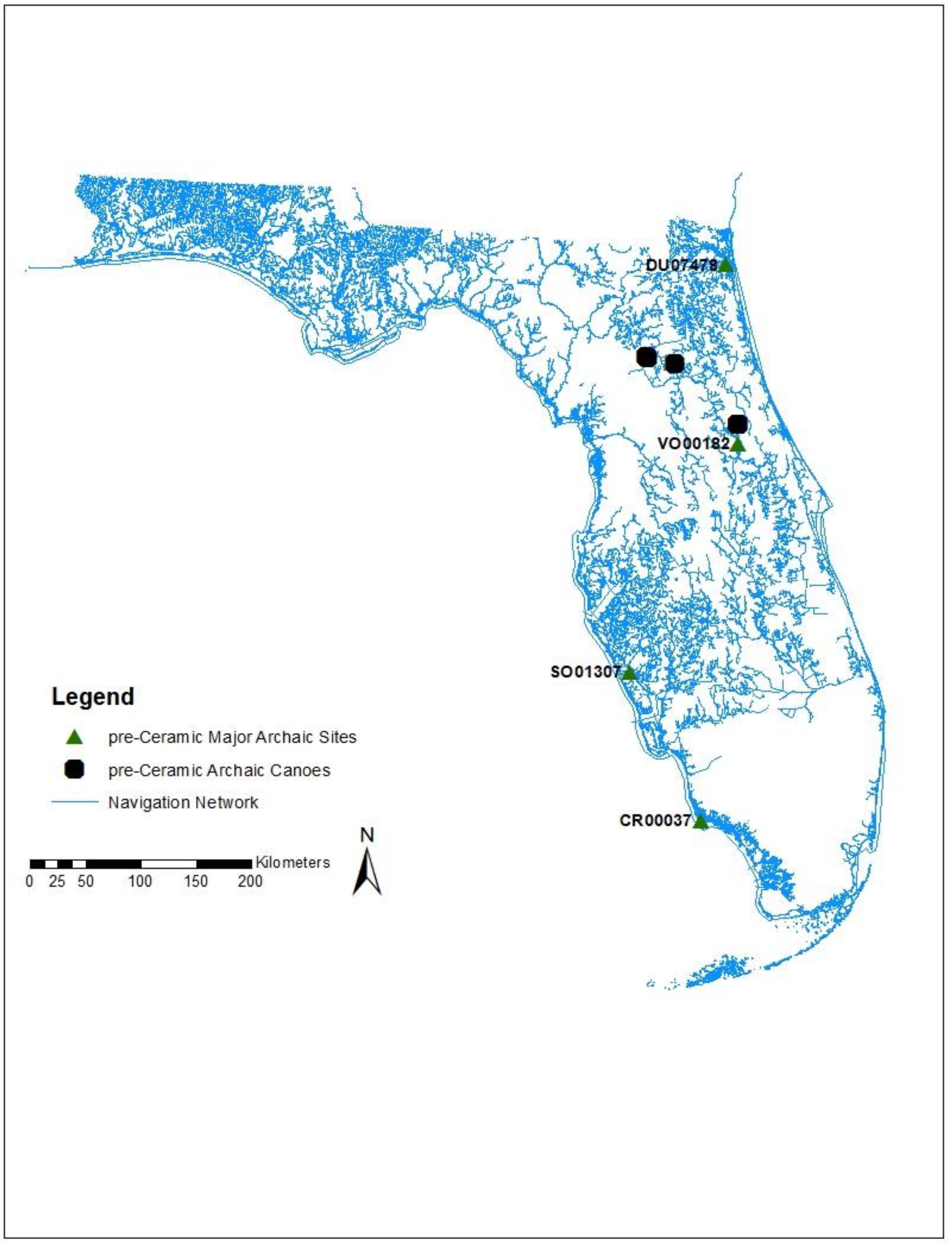


Figure 5.1: The locations of pre-Ceramic Archaic Period canoes and contemporaneous major archaeological sites

The calculated routes for this time (Figure 5.2) indicate that a route through the portage sites of Newnan's Lake (AL4792) and Lake Santa Fe was being used from the onset of Middle-Archaic canoe transportation. This model of the initial movement by canoe then provided an antecedent from which routes in succeeding time-periods could then be compared.

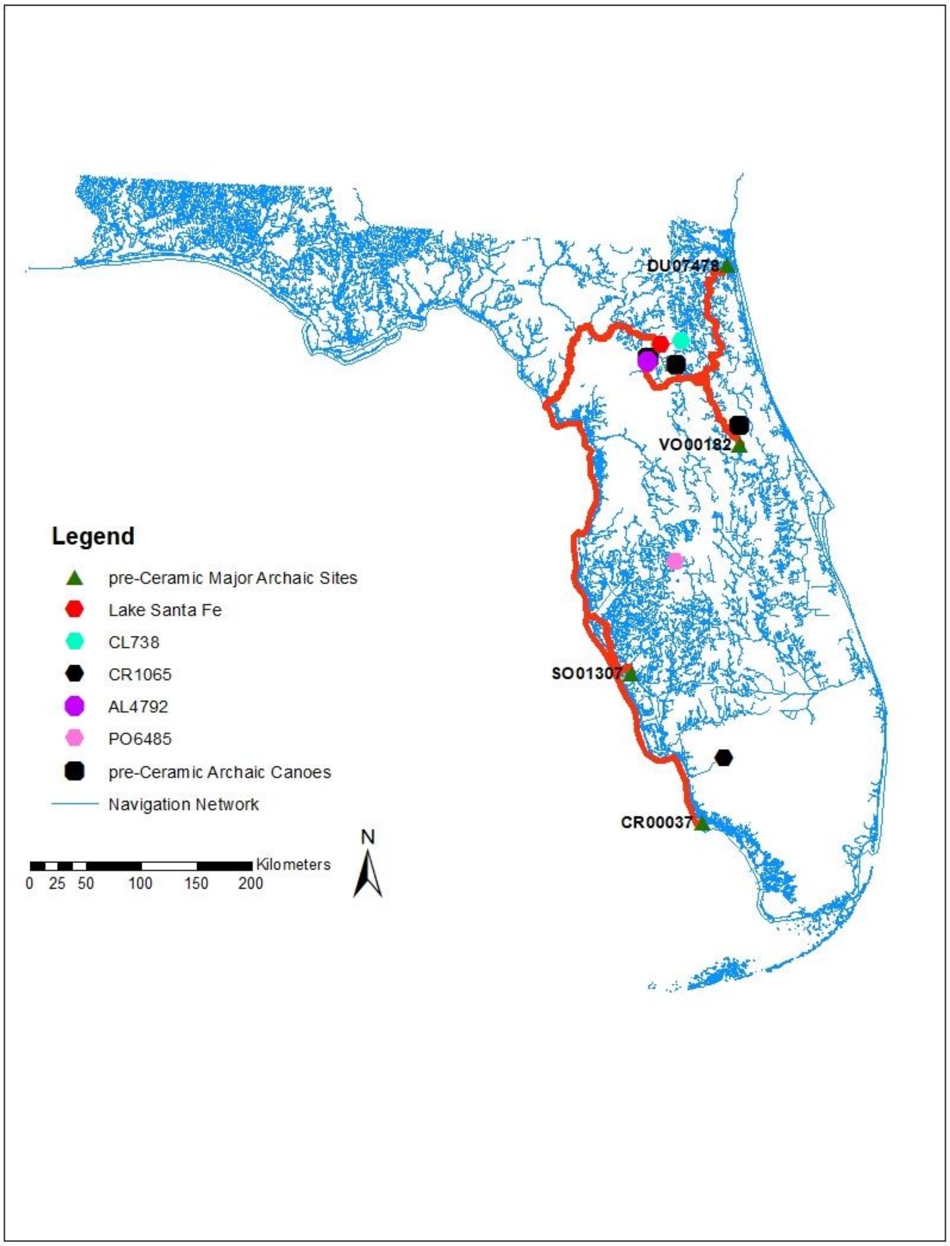


Figure 5.2. The locations of pre-Ceramic Archaic Period canoes and contemporaneous major archaeological sites and the routes between them

Following the modeling of the earliest canoes, contemporaneous major sites, and the routes that linked them, I calculated the routes for the remainder of the Archaic Period canoes (Figure 5.3). These canoes date exclusively to the Late Archaic Period (5800 – 3200 cal B.P.) (Appendix II). It was at this time that there appears to be a geographic expansion of numerous cultural traditions that were first initiated in the Middle Archaic (Anderson and Sassaman 2012). These traditions include an increase in economic specialization in resource procurement, the manufacturing of new technologies such as canoes and fishing nets, a decrease in residential mobility, an increase in widespread exchange, and expansive population growth (Gilmore 2016).

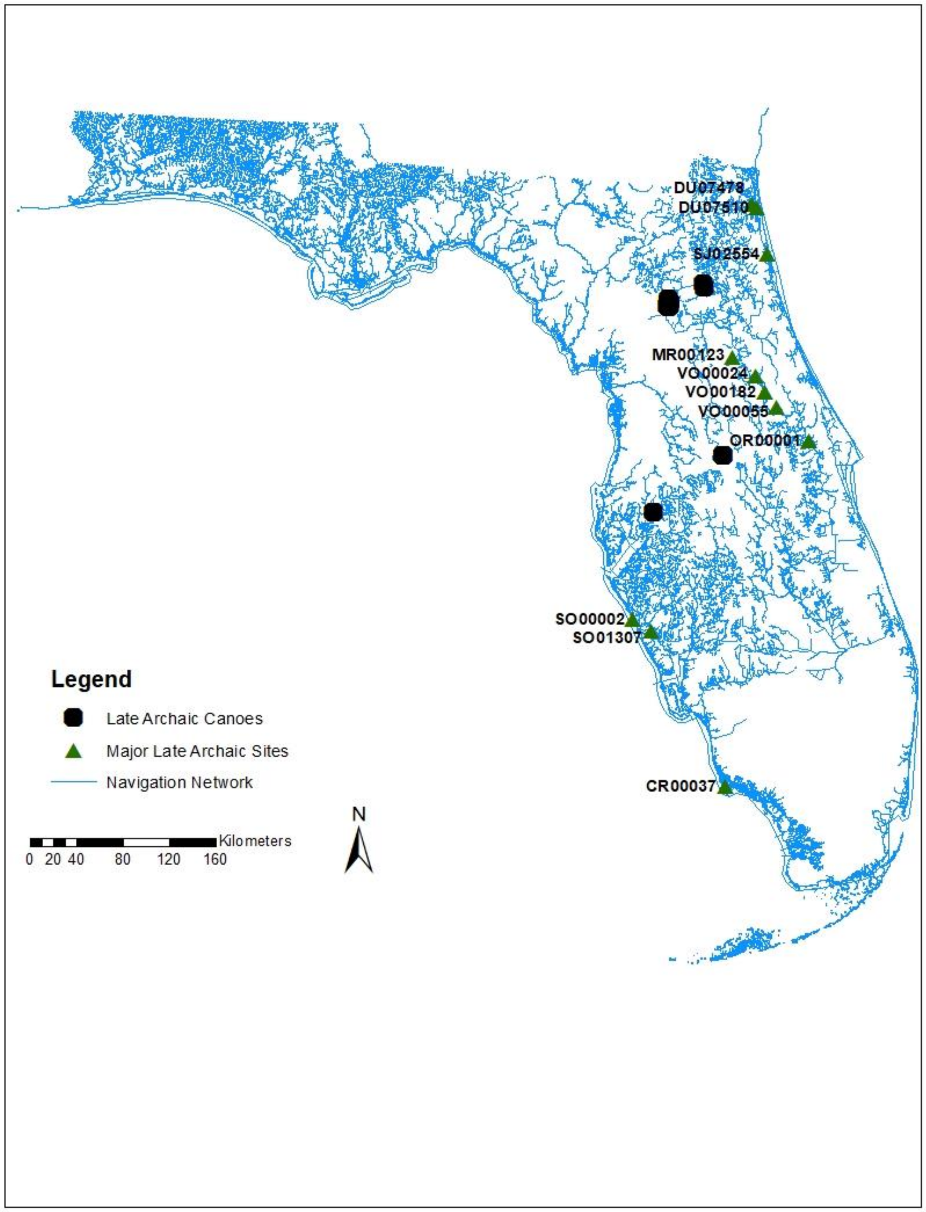


Figure 5.3. The locations of Late Archaic Period canoes and contemporaneous major archaeological sites

The most important development during this period was the adoption of the first pottery in Florida, which played in integral role in pre-Columbian culture from this time forward (Gilmore 2016, O’Donoghue 2017). Originating on the South Carolina and Georgia, ceramic technology first appeared in northeastern Florida around 4600 Cal. B.P

(Gilmore 2016, Sassaman 1993). Coeval with the arrival of ceramics was a rise in the construction of massive shell mounds and rings where pottery was traded for the first time in Florida. Among these places of monumental architecture was the Silver Glen complex in the middle St. Johns River Valley, a major center of interaction and exchange, at which diverse groups of people gathered in much the same way as their pre-ceramic predecessors (Gilmore 2016).

The network analysis modeled the canoe routes between the locations of Late Archaic canoes, the Silver Glen complex, and other contemporaneous sites that served as aggregation centers for pre-Columbian people during this time (Figure 5.4). When the canoe routes were calculated it became clear that the routes and portages used to connect the earliest canoe sites in the Atlantic watershed to major feasting centers along the Gulf coast were active during this period of important cultural developments. It is my interpretation that because routes that connected the Atlantic and Gulf watersheds were well-established at this time, these are the likely routes that facilitated the introduction of ceramics to the Gulf coast from the Atlantic.

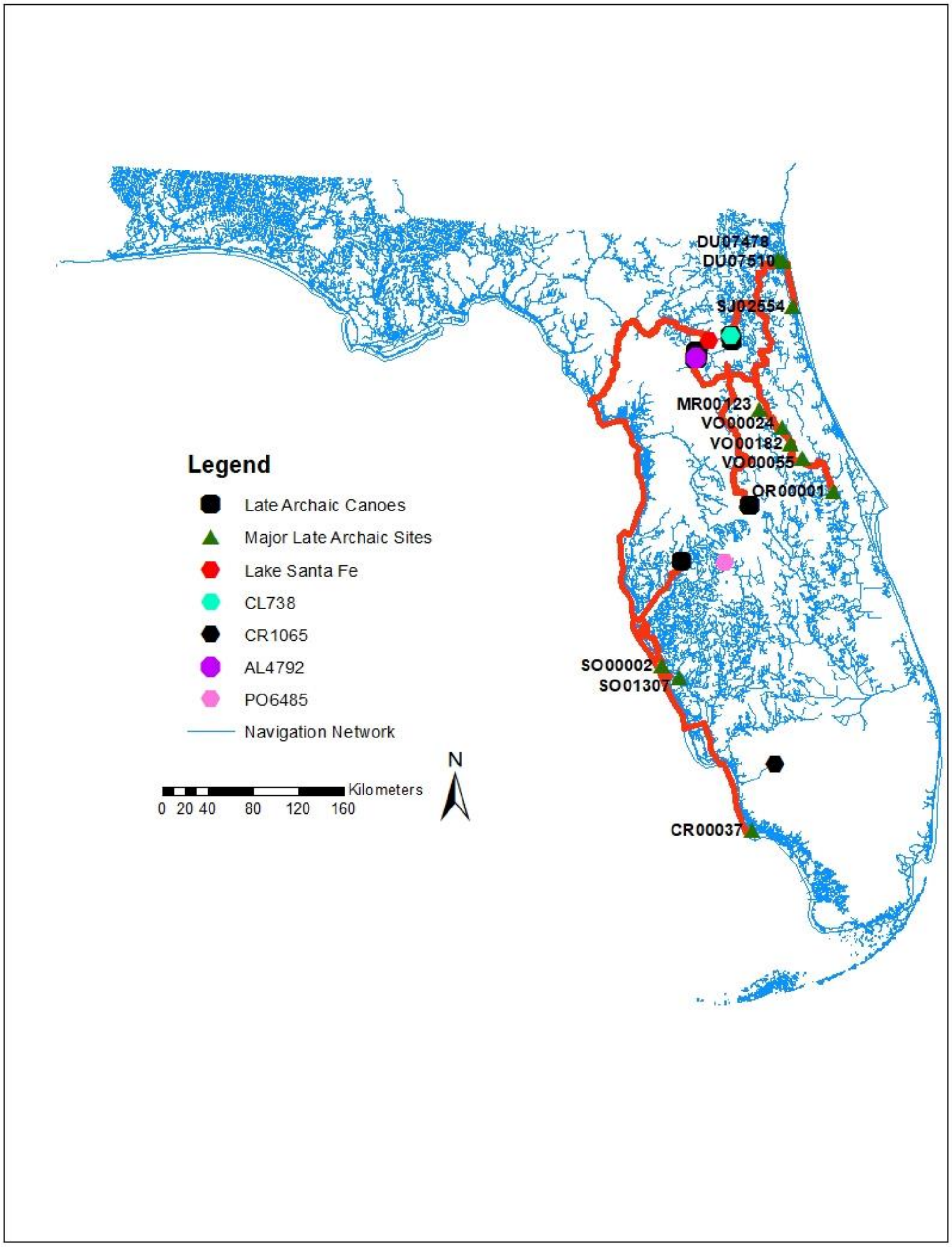


Figure 5.4. The locations of Late Archaic Period canoes and contemporaneous major archaeological sites and the routes between them

The movement by canoe between the Atlantic and Gulf watersheds along earlier routes was also, perhaps, the mechanism by which peoples in the St. Johns River Valley along the Atlantic coast of Florida connected to the Poverty Point site in Louisiana at this time. Poverty Point is located along the Mississippi River and was the largest physical expression of Archaic culture in the Southeast (Kidder 2006, Anderson and Sassaman 2012, Spivey 2015). The rise of Poverty Point coincided with the collapse of the Silver Glen complex around 3500 cal B.P., as Florida's networks of interaction and exchange reoriented towards Poverty Point (Gilmore 2016). This is evident through an abundance of Florida ceramics originating in Florida's St. Johns River Valley appearing at Poverty Point (Hays and Weinstein 2004). It is likely that the same Atlantic to Gulf coast route established with the first use of canoes in Florida was the mechanism for the movement of people, goods, and ideas to Poverty Point.

Between 4000 and 3000 cal B.P. stormy weather and flooding reconfigured the Mississippi River, ultimately resulting in the demise of Poverty Point and with it the interaction and exchange networks that it served (Kidder 2006). The collapse of Poverty Point is synchronous with the onset of the Woodland Period (3200 -1000 cal B.P.) (Anderson and Sassaman 2012).

The Woodland Period (3200 to 1000 cal B.P.) is marked principally in the archaeological record by the ubiquitous adoption of ceramic technology, of which some types and forms were traded widely across Florida and the southeast (Anderson and Mainfort 2002). The canoe routes dating to the Woodland Period modeled the connections between these canoes and two centers of monumental architecture, Crystal River and Fort Center (Figure 5.5).

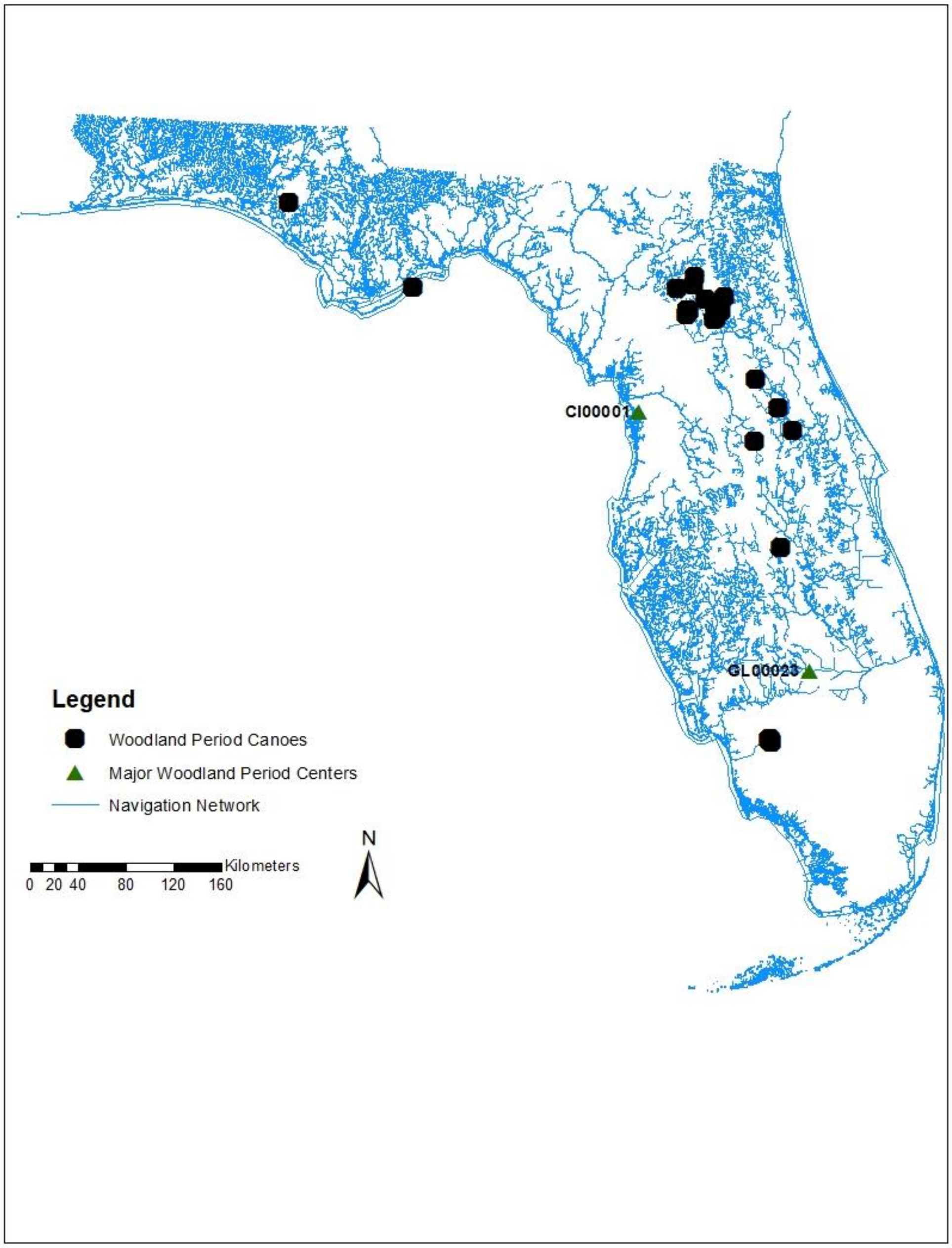


Figure 5.5. The locations of Woodland Period canoes and contemporaneous major archaeological sites

Both the Crystal River and Fort Center sites contained exotic materials, including copper from the Great Lakes region and steatite from the Appalachian Mountains, indicating they may have been centers for the exchange of goods and ideas throughout the Woodland Period (Pluckhahn et al. 2015, Thompson and Pluckhahn 2012). As with the Late Archaic, Woodland Period routes exploited by the first canoe-making tradition were utilized to connect populations from both the Atlantic and Gulf coasts of Florida with each other and, possibly, with peoples beyond the peninsula during this time (Wallis 2014). Notably, it is during this period that canoes in the Panhandle of Florida appear for the first time (Figure 5.6). The routes through the Panhandle may be related to their use in facilitating the movement of people by canoe to Poverty Point, Louisiana during the preceding Late Archaic Period.

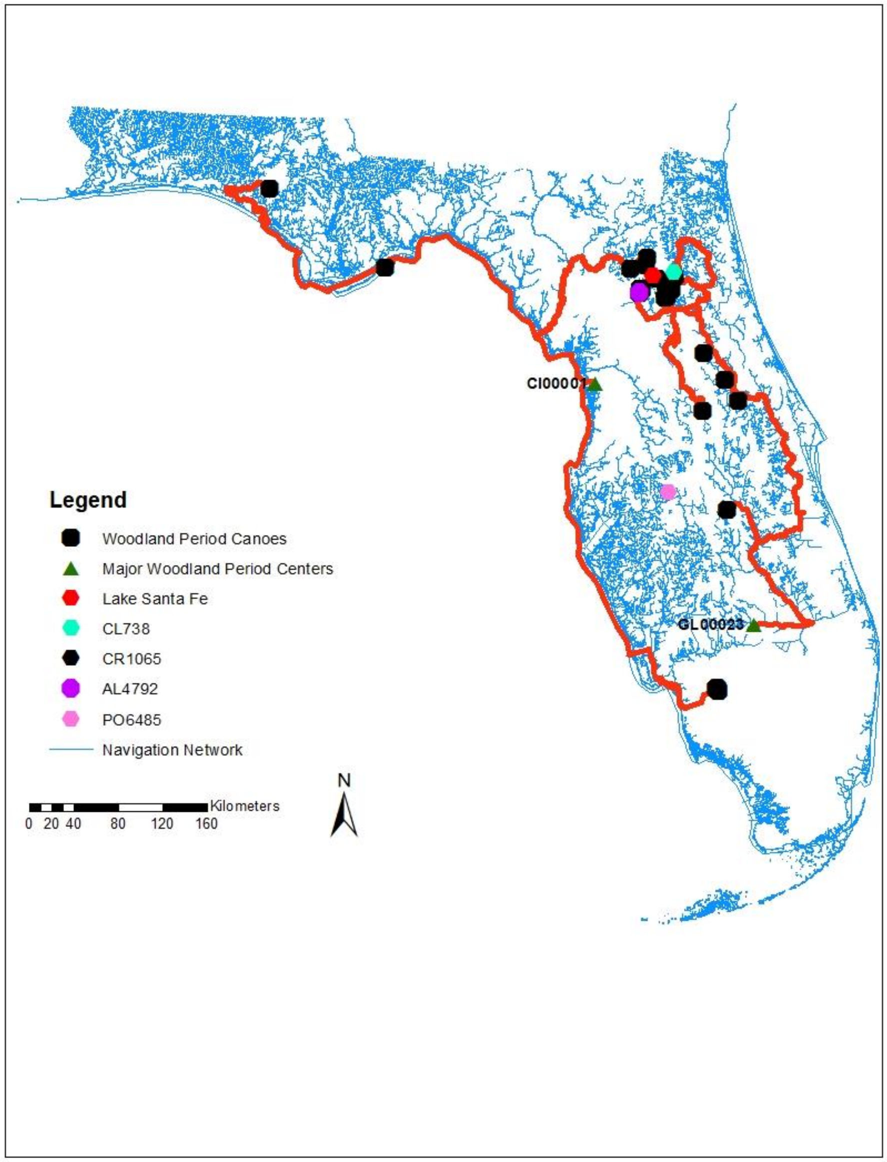


Figure 5.6. The locations of Woodland Period canoes and contemporaneous major archaeological sites and the routes between them

After the modeling of Woodland Period canoes, a network analysis was executed for canoes and sites dating to the Mississippian Period (1000 – 1500 cal B.P.) (Figure 5.7). This period is generally characterized by the adoption of maize agriculture and the presence of political chiefdoms, although recent work has shown that agriculture was likely not adopted in Florida until after European contact (Ashley and White 2013). What is clear during this period is that, as in the Woodland Period, multiple sites in Florida served as major places for the exchange of extralocal goods including copper from the Great Lakes and steatite from the Appalachian Mountains. Moreover, there is sufficient evidence that the people who utilized these sites harvested shell only available on the Gulf and Atlantic coasts and exchanged them with communities within the North American interior.

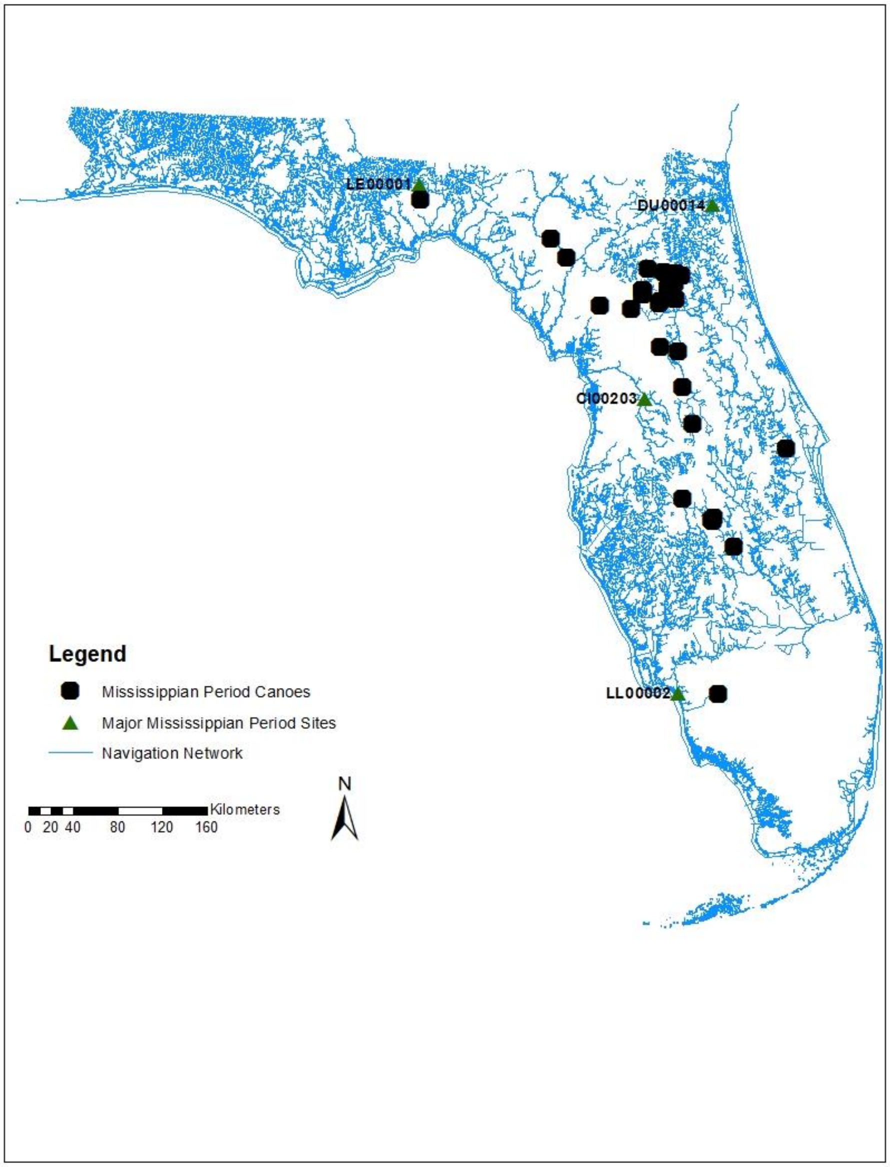


Figure 5.7. The locations of Mississippian Period canoes and contemporaneous major archaeological sites

The route analysis for this period (Figure 5.8) demonstrates that the routes utilized during the Woodland Period predominately stayed intact, indicating their continued usage and importance in the social lives of people during this time. A notable addition to these routes is a route through Lake Hollingsworth (PO6485). Lake Hollingsworth is a site with multiple canoes, and Duggins (2019) hypothesized that it may have been a portage. While no canoes from Lake Hollingworth have been subjected to radiometric dating, the results of the network analysis indicate that these canoes may belong to the Mississippian Period, further indicating that the Lake Hollingsworth portage developed at this time as pre-Columbian populations participated in complex economic arrangements that saw the movement of scarce resources throughout the Florida landform.

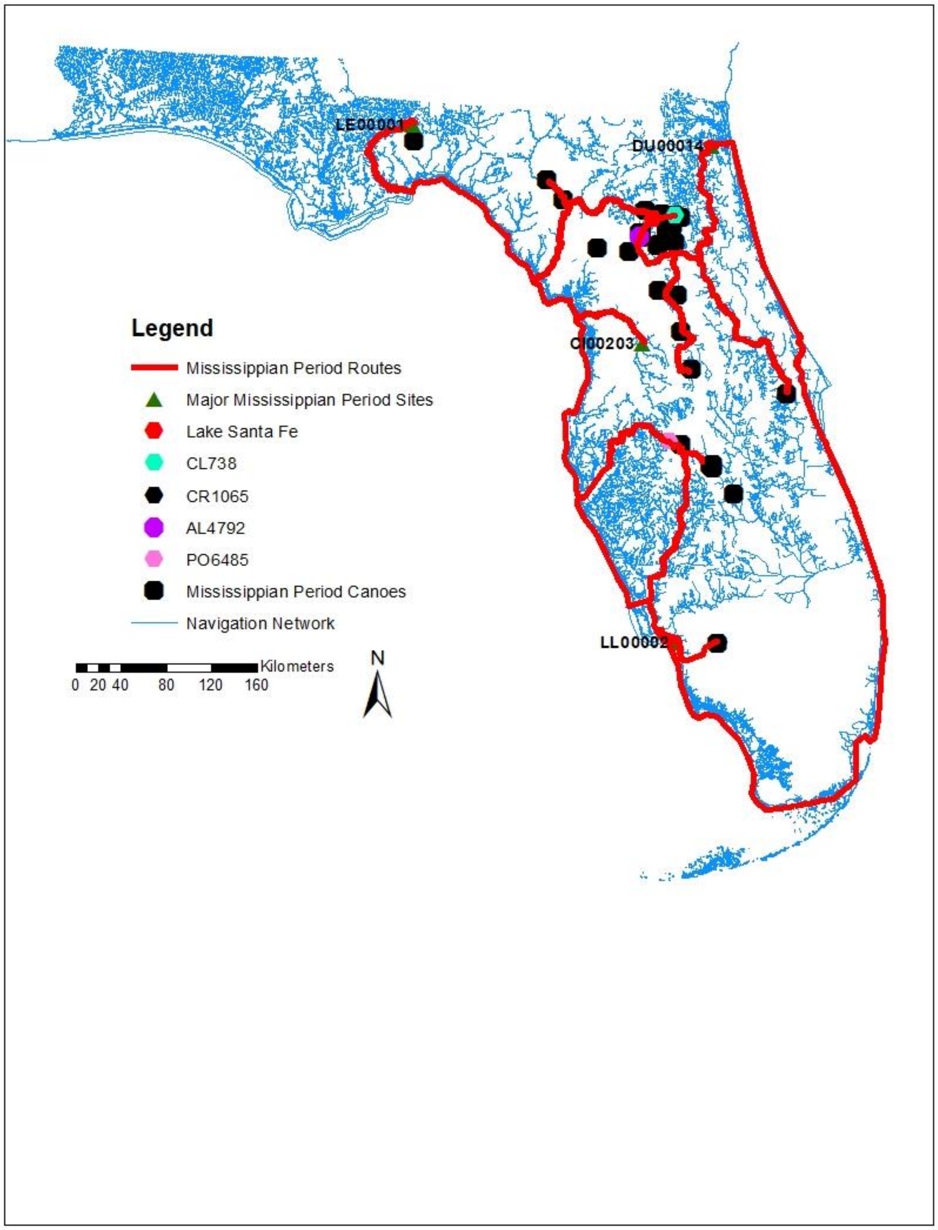


Figure 5.8. The locations of Mississippian Period canoes and contemporaneous major archaeological sites and the routes between them

Routes as Persistent Places

Through the analysis of the pre-Columbian canoe navigation network, it became apparent that some routes were used repeatedly throughout the Archaic, Woodland, and Mississippian Periods. Moreover, in each of these time-periods multiple canoes with age-differences of thousands of years were found to be located on the same routes. Based on their continued usage over time, these routes may be best conceptualized as *persistent places*, a term first introduced by Schlanger (1992). While archaeological sites have placed been within this framework, Florida's canoe routes have yet to be considered in this same context. Persistent places, as their title suggests, are places that are occupied repeatedly over time. Anthropologically, this concept articulates well with "place-making" as introduced by Basso (1996). In this schema, places exist as both physical and mental spaces that predicated on the interactions between people, things, and the world around them. "Places, along with the landscapes and regions into which they articulate, are products of the movements and interactions initiated by people" (Gilmore 2016: 6). Thinking about persistent places as linear versus disparate places, this definition can easily be extended to canoe routes. Canoe routes did not just channel human activity--they were important places in and of themselves as people moved to and from places of interaction. In this sense, routes as persistent places encompass more than just their reuse over time. Persistent routes themselves facilitated interactions and social relationships.

While the analysis of the nuances of these social relationships was beyond the scope of this thesis, I was able to execute an analysis that demonstrated the potential applicability of the network dataset in defining the importance of interaction in maintaining access to canoe routes. Milanich (1994, 2004) states that post-500 BC Florida's Pre-Columbian population can be recognized through 9 distinct culture areas (Figure 5.9) Each one of these culture areas represents geographically bounded groups whose identities and presence on the landscape has been reconstructed largely on the basis of distinct pottery types. When these culture areas are incorporated into the models of Pre-Columbian canoe routes, it is evident that where routes transcend more than one culture area, relationships, as facilitated by social interaction, were necessary to maintain access between culture areas. An example of this can be seen in Figures 1 and 2, which demonstrate a canoe route between Mount Royal (PU00035) and Mound Key (LL00002), two major centers during the Mississippian Period. The first analysis (Figure 5.9) shows an unimpeded route. The second analysis (Figure 5.10) adds a restriction to the route calculation that prohibits movement through the North Peninsular Gulf Coast area. The results of this analysis demonstrate how drastically routes can change when movement is prohibited through an area, thus, highlighting the importance of maintaining social relationships.

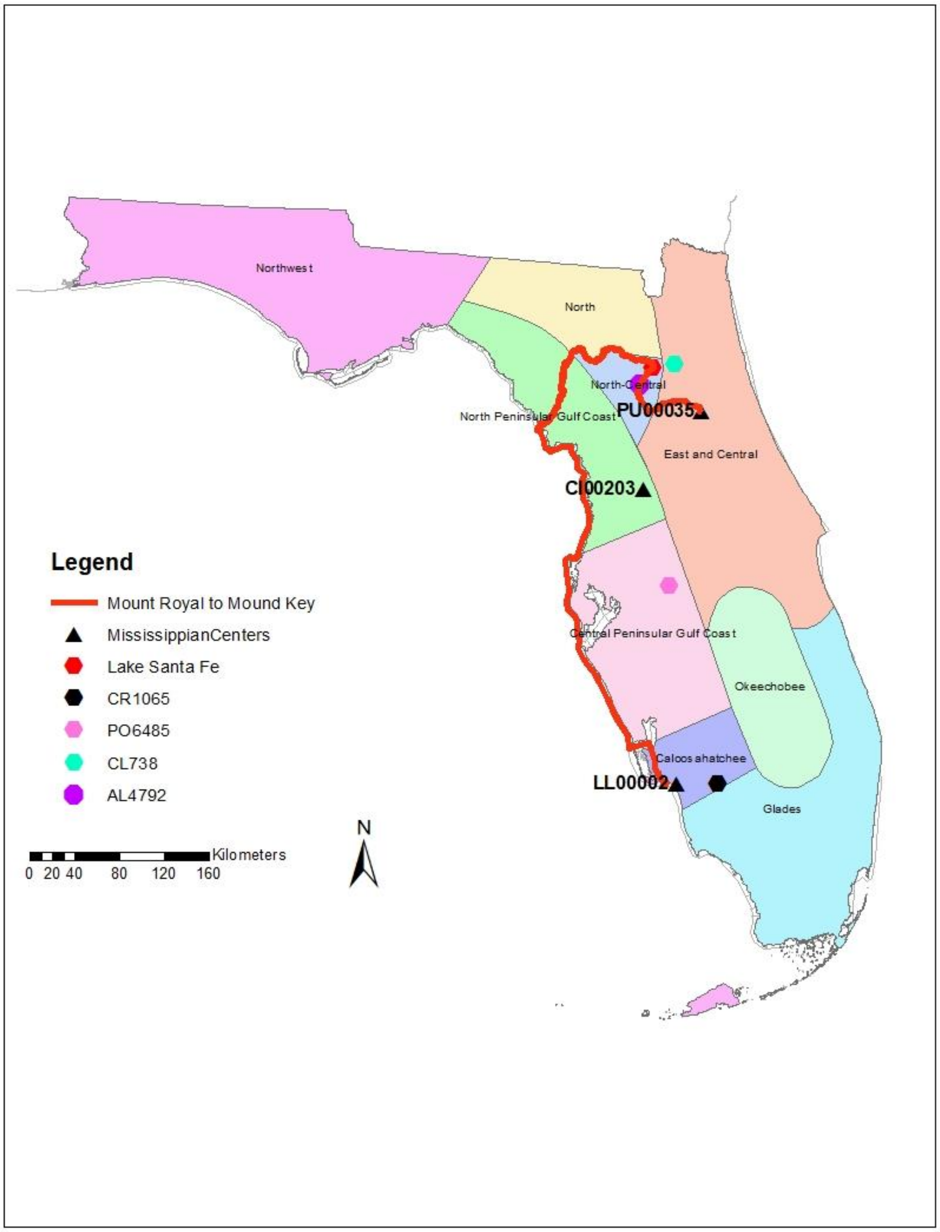


Figure 5.9. Culture Areas as defined by Milanich (1994) with a calculated route between Mount Royal and Mound Key, two important centers of interaction in the Mississippian Period

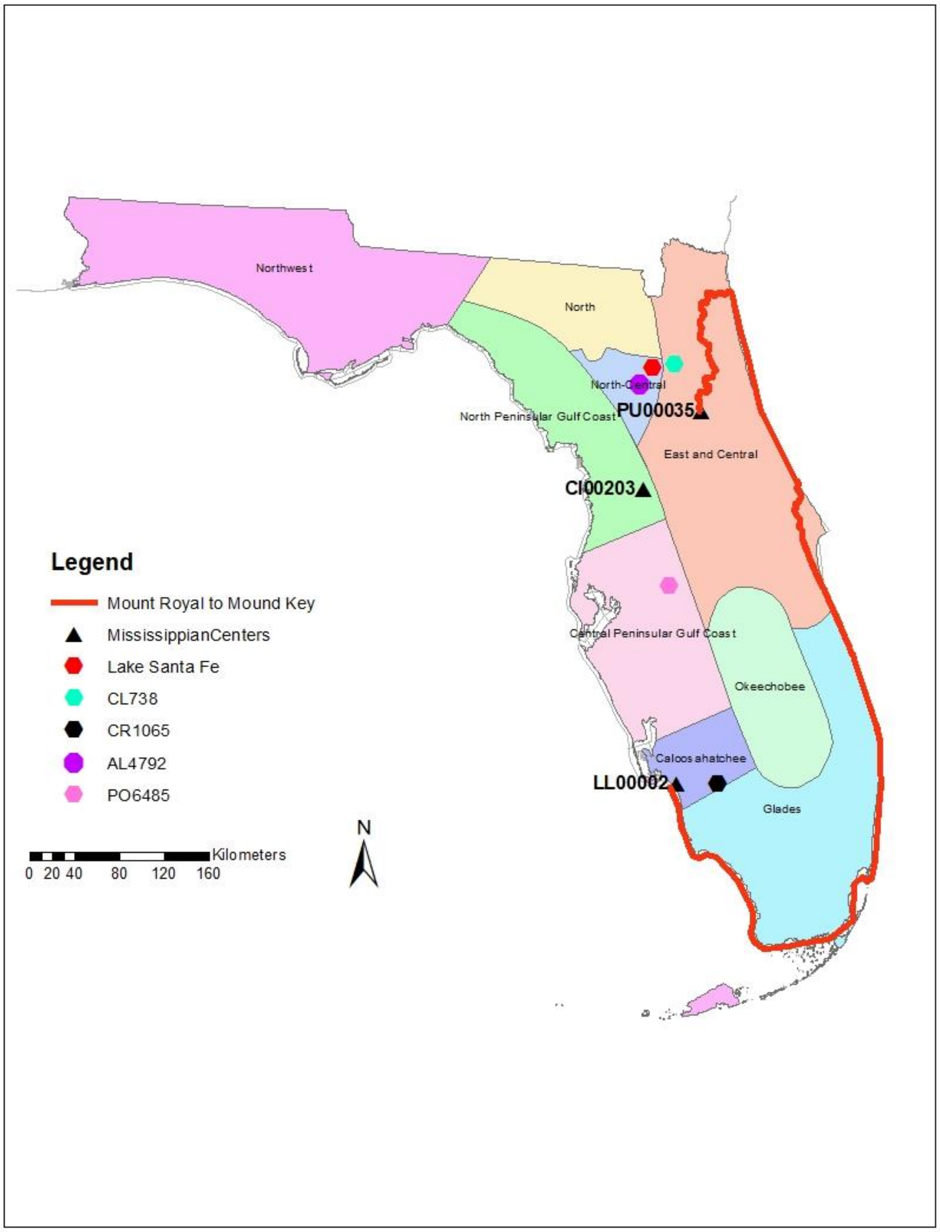


Figure 5.10: Culture Areas as defined by Milanich (1994) with a calculated route between Mount Royal and Mound Key, two important centers of interaction in the Mississippian Period. This figure shows the results of travel when transportation through the North Peninsular Gulf Coast is prohibited. These results demonstrate the need for positive social relationships in order to maintain access to routes

Conclusion

Canoe sites, portages, aggregation centers, and the routes between these places represent important aspects of the pre-Columbian physical and social landscape. People used canoe routes to connect to places of diverse social interaction, where they were introduced to new ideas, technology, and other aspects of material culture. Analysis of the locations of previously recorded canoes, their calibrated age-dates, and contemporaneous sites interpreted to be gathering places revealed that the development of canoes are directly related to the rise of complex societies and the networks of interaction and exchange in which these societies participated.

Through the calculation of canoe routes that connected canoe locations with important centers of population aggregation it became clear that some canoe routes persisted for millennia, themselves becoming persistent places on the landscape which facilitated their own set of social relationships and interaction. Moreover, familiarity with the earliest canoe routes that linked the Atlantic and Gulf watersheds may have been responsible for the diffusion of ceramic technology to Florida's Gulf coast, and most certainly served as a transit corridor for the movement of people, goods, and ideas to Poverty Point and other North American interior sites of importance. When archaeological canoes are viewed through a holistic viewpoint rooted in anthropological concepts of place and landscape, they become dynamic entities that represent more than entries in a database or objects in a museum.

CHAPTER SIX: CONCLUSION

Florida contains the largest known quantity of dugout canoes in the world, the largest singular canoe site in the world, and the oldest canoe in the Western Hemisphere. Despite the clear significance of the canoe in pre-Columbian Florida life, when found, canoes in the state have been traditionally viewed as isolated objects whose provenience is divorced from human agency. A recent renewal in canoe research led by Duggins (2019) has been implemented to place archaeological canoes within a cultural context that views their geographic locations as a product of strategic human movement across the ancient landscape. This renewal in canoe research began by Duggins' (2019) identification of certain sites with multiple canoes as transit points for travel across Florida's ancient transportation network that linked watersheds, which ultimately flow to the Gulf of Mexico, Atlantic Ocean, or south towards the Everglades (Figure 4.14). In her analysis, she identified four of these transit points based on their quantity of canoes and hypothesized that Lake Santa Fe may be a fifth. The hypothesis that Lake Santa Fe may also be a transit point was made based on that lake's geographic location at the boundary of two watersheds, however, prior to this thesis work only 2 canoes were known from that lake. This provided only limited evidence that Lake Santa Fe was a transit point where people intentionally stored their canoes.

Following Duggins (2018) work and in order to test the hypothesis that Lake Santa Fe was a transit point, GPR was used to detect additional canoes in that lake. Because no survey of this scale and type had been executed prior to this thesis work, it was necessary to critically examine the GPR method's utility in detecting submerged canoes. This was done by extracting metrics of previously recorded canoes contained within the Florida master canoe database and then creating a "forward" model of a canoe in a GPR simulation software. The reflections generated in this model were then compared against a GPR profile collected over the location of a known canoe at nearby Newnan's Lake. The results of that analysis demonstrated that the GPR method is well-suited to detecting submerged and inundated canoes in lake-bottom sediment. In addition, a byproduct of this analysis was an identifiable geometric reflection pattern generated from submerged canoes, which served as a model in the analysis of the GPR data collected at Lake Santa Fe.

The GPR survey at Lake Santa Fe resulted in the determination that there are likely many unrecorded canoes in that lake, preliminarily supporting the idea that it was also a major transit point in the pre-Columbian transportation network. Following this discovery and thinking more about transit points and portage locations between watersheds, ArcMap, a GIS software system was used to digitally construct the transportation network that linked the Gulf of Mexico to the Atlantic Ocean. This was done by extracting metrics on canoe morphology contained within the Florida master canoe database, which were then used to extract portions of the NHDPlus hydrological dataset that model the unimpeded natural flow of surface water. That analysis revealed a complex network of interconnected navigable water features in which canoes could have been used (Figure 3.10).

Following the creation of the navigable transportation network, this dataset was transformed into a “network dataset” in GIS by writing a script that calculated the travel-time by canoe across each segment of the network. To use that dataset in a meaningful way, I first extracted canoes from the master database that contained both radiometric dates and spatial coordinates (Appendix II). Those age-dates were calibrated and then assigned a culture-period designation based on their mean date. This analysis revealed that canoe technology was present in Florida by 6910 cal. B.P., which is coincident with the Middle to Late Archaic Period, a time of environmental change that facilitated the movement of people by canoe, and also massive social changes in the social structure of hunting and gathering groups. The locations of the well-dated canoes were then plotted in GIS, and the network dataset was used to calculate the routes between canoes and contemporaneous archaeological sites that have been interpreted as being aggregate population centers. Also included in these models was the locations of Duggins’ (2019) transit points, with the addition of Lake Santa Fe.

The calculation of the canoe routes from the earliest canoes forward revealed the interconnectedness of otherwise disparate canoe locations. Through the calculation of these routes several observations were made regarding the continuity of some routes over time. Notably, the first model from the horizon of the Middle and Late Archaic Periods (Figure 4.17) revealed that a route connecting the Atlantic and Gulf watersheds was likely used from the onset of canoe use. Further analysis (Figure 4.18) demonstrated that this same route was likely the mechanism in which ceramic technology first spread to the Gulf Coast during the Late Archaic Period. Moreover, the transportation interchange between the two watersheds at Newnan's Lake and Lake Santa Fe would have also have been the mechanism in which people in the St. John's River Valley on the Atlantic coast would have proceeded to Poverty Point, Louisiana, far to the west. The routes suggest this method of movement and can provide a support for the hypothesis for how Florida ceramics made it to Louisiana over three-thousand years ago.

Following the collapse of the aggregate center of Poverty Point, Louisiana around 3500 cal. B.P., the canoe transit model for the Woodland Period (Figure 4.19) indicates that canoe use in Florida expanded from the central Florida area to the panhandle, as well as Atlantic coast. These routes stayed predominately intact through the Mississippian Period (4.20), as complex and diverse economies flourished throughout Florida during a period of extensive population growth and social complexity.

The modeling of additional canoes in Lake Santa Fe, and then well-dated canoes, elsewhere in Florida that link contemporaneous aggregations centers, demonstrate that interconnectivity of Florida's pre-Columbian populations was facilitated by canoe. This model of intraregional interaction is based in concepts of place that emphasize the importance of human movement in the development and maintenance of complex social systems in the past. Through the modelling of routes, specifically, it became clear that canoe routes were important places on the landscape that once established persisted over millennia. This perspective of routes as persistent places is counter to the traditional viewpoint of canoe sites as isolated archaeological sites. Instead it emphasizes canoe travel as dynamic and shows that people and ideas, as well as materials that can be seen in the archaeological record were moving over tremendous distances, linking people from otherwise isolated locales.

Recommendations for Future Work

The experimental nature of the methods used for this thesis research points to the obvious need to improve the canoe route models. As the apocryphal saying goes "all models are wrong, but some are useful." To begin, it would be prudent to collect additional GPR data in grids with tighter spacing over the areas where there appears to be canoes at Lake Santa Fe. While I believe the broad-scale strategy used to identify these areas was an appropriate one, by collecting additional GPR data in a reduced area, it may be possible to process the data using the amplitude time-slice technique, as is standard for terrestrial surveys. This would likely aid in the identification of additional canoes that were not in close proximity to the GPR profiles that were collected during the first survey by generating a composite amplitude map at discrete depths in the lake-bottom.

Once the locations of canoes in Lake Santa Fe are further defined, the next step is to use diver survey to visually inspect the canoes identified here to verify or refute their status as canoes. This information should then be used to reexamine the two-dimensional GPR data and discern differences between those reflections that are canoes and those that are not.

For future applications of the GPR method for locating canoes, and general GPR work on water, it is recommended that a collection unit is used that records the full GPS string simultaneously to each GPR reflection so that all can be placed into space easily. While the methodology presented here works for the SIR-3000 manufactured by GSSI, this part of the data analysis process was one of the most time-consuming, as each GPS file had to be manually examined, renamed, and then merged with each GPR profile for spatial analysis. Newer systems, such as the SIR-4000 have the capability to read and write GPS data within the radar reflection file-structure, which would speed up the processing time.

Regarding the canoe route modeling, it would be interesting to examine the artifact inventories of the major population centers for each time period. This would be especially useful for determining pottery vessel forms and clay origins and therefore where the pottery was manufactured. I am particularly interested in tracing the origins of ceramics found at these sites to infer the movement of these artifacts from their production locations to where they were finally preserved. One of the interesting aspects of the modeled routes is that there were calculated using a “least cost” algorithm that minimized time of travel for paddling a canoe. While time of travel was a good baseline "cost," as evident in figures 5.9 and 5.10, when geographic restrictions are placed on the traveler such as forbidden territory, these routes can drastically change. By determining the origins of the ceramics at these sites, routes can be calculated with starting and ending points. Those calculated routes could then be compared to the routes calculated here to determine any deviances, which may be evidence of the degree of social cooperation with certain groups at specific points in time.

In addition to examining ceramic origins in formulating new routes, it may also be useful to supplement these routes with others calculated that use instead of time caloric values expanded as canoe paddlers moved up and down rivers, interconnected lakes, and coastal areas. This analysis could be refined to estimate the required caloric intake for passenger and cargo loads over a set amount of time, which may provide a model of overnight camp locations along specific canoe routes. Those locations could then be subjected to archaeological survey to test whether ceramics of the same origin are present at these sites.

Archaeological survey may also be useful in examining the validity of some of the modeled routes and stretches of the navigation network. The NHDPlus dataset from which the navigation network was generated is itself a model of the natural surface flow of water, which does not consider the effects of modern development on watercourses. In some instances, the navigation model consists of stretches of water that are not extant today. Where the calculated routes travel along these stretches, a combination of archaeological survey and sediment coring may be able to validate or refute the modeled navigation network itself. For example, if archaeological site density along these stretches match extant watercourses, and fluvial sediment is identified in the cores, then it is reasonable to accept that modeled portion of the route as valid in the past when those sediments were deposited.

Lastly, while the canoes, contemporaneous sites of importance, and their calculated routes focused on Florida for this thesis research, the methods and datasets used for the computational modeling could and should be extended to regions beyond Florida. By extending these analyses to neighboring states and regions, a complex model of the pre-Columbian transportation of people, goods, and ideas by canoe across might be generated.

The research presented in this thesis utilized modern computational methods to examine Florida's pre-Columbian dugout canoes at a scale not possible even 10 years ago. As computer technology becomes more advanced, it is my hope that others build upon this work to execute even more complex algorithms and analyses that may help shed light on these important aspects of ancient life. It is only by "connecting the dots" and integrating multiple and diverse datasets that canoes can be examined in their proper context as important places on the pre-Columbian landscape. Computational methods are extremely promising in their ability analyze the large datasets required to do this. We must look towards the future in order to analyze the past.

REFERENCES

Alt, Susan M.

2006 The Power of Diversity: Settlement in the Cahokian Uplands. In *Leadership and Polity in Mississippian Society*, edited by Brian M. Butler and Paul D. Welch, pp. 289-308. Occasional Paper No. 33. Center for Archaeological Investigations, Southern Illinois University, Carbondale.

Alt, Susan M., and Timothy R. Pauketat

2011 Why Wall Trenches? *Southeastern Archaeology* 30 (1):108-122.

Anderson, David G., and Kenneth E. Sassaman

2012 *Recent Developments in Southeastern Archaeology: From Colonization to Complexity*. Society for American Archaeology Press, Washington, D.C.

Anderson, David G., and Robert C. Mainfort, Jr. (editors)

2002 *The Woodland Southeast.* University of Alabama Press, Tuscaloosa.

Ashley, Keith, and Nancy M. White

2012 Late Prehistoric Florida: An Introduction. In *Late Prehistoric Florida: Archaeology at the Edge of the Mississippian World*, pp. 1-28. University Press of Florida, Gainesville.

Ashmore, Wendy, and A. Bernard Knapp (editors)

1999 *Archaeologies of Landscape: Contemporary Perspectives*. Wiley-Blackwell, Hoboken.

Basso, Keith H.

1996 *Wisdom Sits in Places: Landscape and Language Among the Western Apache*.

University of New Mexico Press, Albuquerque.

Bender, Barbara, Paul Aitken (editor), Daniel Miller (editor), and Paul Gilroy (editor)

1998 *Stonehenge: Making Space*. Berg Publishers, Oxford.

Brenner, Mark, Barbara Leyden, and Michael Binford

1990 Recent Sedimentary Histories of Shallow Lakes in the Guatemalan Savannas. *Journal of Paleolimnology* 4 (3):239-252.

Brose, David S.

1990 Toward a Model of Exchange Values for the Eastern Woodlands. *Midcontinental Journal of Archaeology*:100-136.

Bullen, Ripley P., and Harold K. Brooks

1967 Two Ancient Florida Dugout Canoes. *Quarterly Journal of the Florida Academy of Sciences* 30 (2):97-107.

Burnett, Pat

1978 Markovian Models of Movement Within Urban Spatial Structures. *Geographical Analysis* 10 (2):142-153.

Cassells, E. Steve

1997 *The Archaeology of Colorado*. Johnson Books, Boulder.

Conolly, James, and Mark Lake

2006 *Geographical Information Systems in Archaeology*. Cambridge Manuals in Archaeology. Cambridge University Press, Cambridge.

Conyers, Lawrence B.

2006 Innovative Ground-penetrating Radar Methods for Archaeological

Mapping. *Archaeological Prospection* 13 (2):139-141.

2012 *Interpreting Ground-penetrating Radar for Archaeology*. Left Coast Press, Walnut Creek.

2013 *Ground-Penetrating Radar for Archaeology*. 3rd ed. Geophysical Methods for Archaeology, edited by Lawrence B. Conyers and Kenneth L. Kvamme. AltaMira Press, Lanham.

2016 *Ground-penetrating Radar for Geoarchaeology*. New Analytical Methods in Earth and Environmental Science. Wiley-Blackwell, Hoboken.

Cook Hale, Jessica W., Nathan L. Hale, and Ervan G. Garrison

2018 What is Past is Prologue: Excavations at the Econfina Channel Site, Apalachee Bay, Florida, USA. *Southeastern Archaeology*:1-22.

Daniels, David J. (editor)

2004 *Ground Penetrating Radar*. 2nd Ed. The Institution of Electrical Engineers, London.

Doran, Glen H.

2002 *Windover: Multidisciplinary Investigations of an Early Archaic Florida Cemetery*. Florida Museum of Natural History: Ripley P. Bullen Series, edited by Jerald T. Milanich. University Press of Florida, Gainesville.

2007 A Brief Continental View from Windover. *In Ancient Health: Skeletal Indicators of Agricultural and Economic Intensification*, edited by Mark Nathan Cohen and Gillian M. M. Crane-Kramer, pp. 35-51. University Press of Florida, Gainesville.

Drennan, Robert D.

2009 *Statistics for Archaeologists: A Commonsense Approach.* 2nd Ed. Springer, New York.

Duggins, Julie

2019 Canoe Caching at Transit Points: Inferring Florida's Ancient Navigation Routes Using Archaeology and Ethnohistory. In *Iconography and Wetsite Archaeology of Florida's Watery Realms*, edited by Wheeler, Ryan J., and Joanna Ostapkowicz. University of Florida Press, Gainesville.

Dunbar, James S.

2016 *Paleoindian Societies of the Coastal Southeast*. Florida Museum of Natural History: Ripley P. Bullen Series. University Press of Florida, Gainesville.

Esri

2018 Buffer. Electronic document, http://desktop.arcgis.com/en/arcmap/10.3/tools /analysis -toolbox/buffer.htm, accessed September 21, 2018.

Florida Museum

2018 Ceramic Technology Lab: Florida Galleries. Electronic document, https:// www.floridamuseum.ufl.edu/ceramiclab/galleries/, accessed August 07, 2018.

Fogelin, Lars

2007 Inference to the Best Explanation: A Common and Effective Form of Archaeological Reasoning. *American Antiquity* 72 (4):603-626.

Gilmore, Zackary I.

2016 *Gathering at Silver Glen: Community and History in Late Archaic Florida*.

University Press of Florida, Gainesville.

Golledge, Reginald G., and Georgia Zannaras

1973 Cognitive Approaches to the Analysis of Human Spatial Behavior. In *Environment and Cognition*, edited by W. H. Ittelson, pp. 59-92. Seminar Press, New York.

Goodman, Dean

1994 Ground-Penetrating Radar Simulation in Engineering and Archaeology. *Geophysics* 59 (2):224-232.

Grimm, Eric C., Socorro Lozano-García, Hermann Behling, and Vera Markgraf

2001 Holocene Vegetation and Climate Variability in the Americas. In *Interhemispheric Climate Linkages*, edited by Vera Markgraf, pp. 325-370. Elsevier, Amsterdam.

Halligan, Jessi J., Michael R. Waters, Angelina Perrotti, Ivy J. Owens, Joshua M. Feinberg, Mark D. Bourne, Brendan Fenerty, Barbara Winsborough, David Carlson, Daniel C. Fisher, Thomas W. Stafford, and James S. Dunbar

2016 Pre-Clovis Occupation 14,550 Years Ago at the Page-Ladson Site, Florida, and the Peopling of the Americas. *Science Advances* 2 (5):e1600375.

Harris, Marvin

1979 *Cultural Materialism: The Struggle for a Science of Culture*: Random House, New York.

Harrison, K. David

2008 *When Languages Die: The Extinction of the World's Languages and the*

Erosion of Human Knowledge. Oxford University Press, New York.

Hartmann, Mark

1996 Development of Watercraft in the Prehistoric Southeastern United States, edited by Donny L. Hamilton. ProQuest Dissertations Publishing, Ann Arbor.

Hayler, William B., and John M. Keever (editors)

2003 *American Merchant Seaman's Manual*. Schiffer Publishing, Limited, Atglen.

Hays, Christopher T., and Richard A. Weinstein

2004 *Early Pottery at Poverty Point: Origins and Functions*. University of Alabama Press, Tuscaloosa

Hegmon, Michelle

2003 Setting Theoretical Egos Aside: Issues and Theory in North American Archaeology. *American Antiquity* 68 (2):213-243.

Helmreich, Stefan

2007 Induction, Deduction, Abduction, and the Logics of Race and Kinship. *American Ethnologist* 34 (2):230-232.

Hine, Albert C., and Carlie Williams

2013 *Geologic History of Florida: Major Events that Formed the Sunshine State*. University Press of Florida, Gainesville.

Hodder, Ian

2011 Human-Thing Entanglement: Towards an Integrated Archaeological Perspective. *Journal of the Royal Anthropological Institute* 17 (1):154.

Holyoke, Kenneth, and Gabriel Hrynick

2015 Portages and Lithic Procurement in the Northeastern Interior: A Case Study from the Mill Brook Stream Site, Lower Saint John River Valley, New Brunswick, Canada. *Canadian Journal of Archaeology* 39 (2):1.

Jol, Harry M., and Arlen Albrecht

2004 Searching for Submerged Lumber with Ground Penetrating Radar: Rib Lake, Wisconsin, USA. In *Proceedings of the Tenth Internaitonal Conference on Ground Penetrating Radar*: *June 21-24, Delft, The Netherlands*, edited by Evert Slob, Alex Yarovoy and Jan Rhebergen. Delft University of Technology, The Netherlands and the Institute of Electrical and Electronics Engineers, Inc., Piscataway, New Jersey: 601-604.

Kandare, Richard P.

1983 *A Contextual Study of Mississippian Dugout Canoes: A Research Design for the Moundville Phase*. University of Arkansas, Fayetteville.

Kantner, John

2008 The Archaeology of Regions: From Discrete Analytical Toolkit to Ubiquitous Spatial Perspective. *Journal of Archaeological Research* 16 (1):37-81.

Kari, James, and James A. Fall

2003 *Shem Pete's Alaska: The Territory of the Upper Cook Inlet Dena'ina*. University of Alaska Press, Fairbanks.

Kelly, Robert L.

1995 *The Foraging Spectrum: Diversity in Hunter-Gatherer Lifeways*. Smithsonian Institutional Press, Washington, D.C.

Kidder, Tristram R.

2006 Climate Change and the Archaic to Woodland Transition (3000–2500 Cal BP) in the Mississippi River Basin. *American Antiquity* 71 (2):195-231.

2010 Chapter 1. Trend, Tradition, and Transition at the End of the Archaic. In *Trend, Tradition, and Turmoil: What Happened to the Southeastern Archaic?: Proceedings of the Third Caldwell Conference, St. Catherines Island, Georgia, May 9-11, 2008 (Anthropological Papers of the American History Museum of Natural History, no. 93),* edited by David Hurst Thomas and Matthew C. Sanger*, pp. 23-32.* American Museum of Natural History, New York.

2011 Transforming Hunter-Gatherer History at Poverty Point. *Hunter-Gatherer Archaeology as Historical Process*, edited by Kenneth E. Sassaman and Donald H. Holly Jr., pp. 95-119. University of Arizona Press, Tucson.

Kuznar, Lawrence A., and Stephen K. Sanderson (editors)

2015 *Studying Societies and Cultures: Marvin Harris's Cultural Materialism and Its Legacy*. Routledge, Abingdon.

Kvamme, Kenneth L.

2006 Integrating Multidimensional Geophysical Data. *Archaeological Prospection* 13 (1):57-72.

Lekson, Stephen H. (editor)

2007 *The Architecture of Chaco Canyon, New Mexico.* University of Utah Press, Salt Lake City.

Lekson, Stephen H., and Catherine M. Cameron

1995 The Abandonment of Chaco Canyon, the Mesa Verde Migrations, and the Reorganization of the Pueblo World. *Journal of Anthropological Archaeology* 14 (2):184-202.

Livingood, Patrick

2012 No Crows Made Mounds: Do Cost-Distance Calculations of Travel Time Improve our Understanding of Southern Appalachian Polity Size? *Least Cost Analysis of Social Landscapes: Archaeological Case Studies*, edited by Devin A. White and Sarah L. Surface-Evans, pp. 174-187. University of Utah Press: Salt Lake City.

2018 Making Better Maps of PreModern Rivers. Electronic document, http://patricklivingood.oucreate.com/projects/making-better-maps-of-premodern-rivers/, accessed July 17, 2018.

Lucas, Gavin

2012 *Understanding the Archaeological Record*. Cambridge University Press, New York.

Lucius, Jeffrey E., and Lawrence B. Conyers

2016 U. S. Geological Survey Open-Source Ground Penetrating Radar Software. In *Developing Integrated Methods to Address Complex Resource and Environmental Issues* (1413), edited by Kathleen S. Smith, Jeffrey D. Phillips, Anne E. McCafferty and Roger N. Clark. U. S. Geological Survey, Reston, VA.

MacDonald, George F., and Barbara A. Purdy

1982 Florida's Wet Sites: Where the Fragile Past survives. *Early Man* 4 (4):4-12.

Marrinan, Rochelle A., and Nancy M. White

2007 Modeling Fort Walton Culture in Northwest Florida. *Southeastern Archaeology* 26 (2):292-318.

McKay, Lucinda, Timothy Bondelid, Tommy Dewald, Craig Johnston, Richard Moore, and Alan Rea

2012 NHDPlus Version 2: User Guide. National Operational Hydrologic Remote Sensing Center, Washington, D.C.

Meide, Chuck

1995 The Dugout Canoe in the Americas: An Archaeological, Ethnohistorical, and Structural Overview. *Florida State University*, Tallahassee.

Milanich, Jerald T.

1971 *The Alachua Tradition of North-Central Florida*. Contributions of the Florida State Museum: Anthropology and History, No. 17. University of Florida, Gainesville.

1994 *Archaeology of Precolumbian Florida.* University Press of Florida, Gainesville.

2002 Weeden Island Cultures. In *The Woodland Southeast*, edited by David G. Anderson and Robert C. Mainfort Jr, pp. 352-372. University of Alabama Press, Tuscaloosa.

2004 Prehistory of the Lower Atlantic Coast After 500 BC. *Handbook of North*

American Indians, Volume 14: Southeast, edited by Raymond Fogelson and William Sturtevant, pp. 229–238. Smithsonian Institution Press.

Miller, James J.

1998 *An Environmental History of Northeast Florida*. Florida Museum of Natural History: Ripley P. Bullen Series. University Press of Florida, Gainesville.

Newsom, Lee Ann, and Barbara A Purdy

1990 Florida Canoes: A Maritime Heritage from the Past. *The Florida Anthropologist* 43 (3):164-180.

O'Donoughue, Jason M.

2017 *Water from Stone: Archaeology and Conservation at Florida's Springs.* Florida Museum of Natural History: Ripley P. Bullen Series. University Press of Florida, Gainesville.

Oakley, Kenneth P.

1968 *Man the Tool-maker*. University of Chicago Press, Chicago.

Pauketat, Timothy R., and Nancy S. Bernard

2004 *Cahokia Mounds.* Oxford University Press, New York

Sahlins, Marshall D., and Elman R. Service (editors)

1960 *Evolution and Culture*. The University of Michigan Press, Ann Arbor.

Snead, James E., Clark L. Erickson, and J. Andrew Darling (editors)

2009 *Landscapes of Movement: Trails, Paths, and Roads in Anthropological Perspective.* Penn Museum International Research Conferences, Vol. 1. University of Pennsylvania Museum of Archaeology and Anthropology, Philadelphia.

Pirkle, E. C., and H. K. Brooks

1959 Origin and Hydrology of Orange Lake, Santa Fe Lake, and Levys Prairie Lakes of North-Central Peninsular Florida. *The Journal of Geology* 67 (3):302-317.

Pluckhahn, Thomas J., and Victor D. Thompson

2012 Integrating LiDAR Data and Conventional Mapping of the Fort Center Site in South-Central Florida: A Comparative Approach. *Journal of Field Archaeology* 37 (4):289-301.

Pluckhahn, Thomas J., Victor D. Thompson, and Alexander Cherkinsky

2015 The Temporality of Shell-Bearing Landscapes at Crystal River, Florida. *Journal of Anthropological Archaeology* 37:19-36.

Potter, Ben A., James F. Baichtal, Alwynne B. Beaudoin, Lars Fehren-Schmitz, C. Vance Haynes, Vance T. Holliday, Charles E. Holmes, John W. Ives, Robert L. Kelly, and Bastien Llamas

2018 Current Evidence Allows Multiple Models for the Peopling of the Americas. *Science Advances* 4 (8):eaat5473.

Quinn, Rhonda L., Bryan D. Tucker, and John Krigbaum

2008 Diet and Mobility in Middle Archaic Florida: Stable Isotopic and Faunal Evidence from the Harris Creek Archaeological Site (8Vo24), Tick Island. *Journal of Archaeological Science* 35 (8):2346-2356.

Ramsey, Christopher Bronk

2017 Methods for Summarizing Radiocarbon Datasets. *Radiocarbon* 59 (06):1809-1833.

Randall, Asa R.

2015 *Constructing Histories: Archaic Freshwater Shell Mounds and Social Landscapes of the St. Johns River, Florida.* University Press of Florida, Gainesville.

Reimer, Paula J., Edouard Bard, Alex Bayliss, J. Warren Beck, Paul G. Blackwell, Christopher Bronk Ramsey, Caitlin E. Buck, Hai Cheng, R. Lawrence Edwards, Michael Friedrich, Pieter M. Grootes, Thomas P. Guilderson, Haflidi Haflidason, Irka Hajdas, Christine Hatte, Timothy J. Heaton, Dirk L. Hoffmann, Alan G. Hogg, Konrad A. Hughen, K. Felix Kaiser, Bernd Kromer, Sturt W. Manning, Mu Niu, Ron W. Reimer, David A. Richards, E. Marian Scott, John R. Southon, Richard A. Staff, Christian S. M. Turney, and Johannes van der Plicht

2013 IntCal13 and Marine13 Radiocarbon Age Calibration Curves 0-50,000 Years cal BP. *Radiocarbon* 55 (4):1869-1887.

Renfrew, Colin and Paul Bahn

1996 *Archaeology: Theories, Methods, and Practice*. 2nd ed. Thames and Hudson, Ltd., London

Rodrigue, Jean-Paul, Claude Comtois, and Brian Slack

2016 *The Geography of Transport Systems*. 4th ed. Routledge, Abingdon.

Ruhl, Donna L., and Barbara A. Purdy

2005 One Hundred-one Canoes on the Shore – 3–5,000 year old Canoes from

Newnans Lake, Florida. *Journal of Wetland Archaeology* 5 (1):111-127.

Russo, Michael

2004 *Measuring shell rings for social inequality*.

2008 Ancient Shell Ring Sites. *Archaeology in America: An Encyclopedia [4 Volumes]: An* Encyclopedia, edited by Francis P. McManamon, Linda S. Cordell, Kent G. Lightfoot, and George R. Milner. Greenwood Publishing Group, Westport.

Sahlins, Marshall D. and Elman R. Service

1975 Evolution and Culture. Reprinted. Originally published 1960.Ann Arbor: The University of Michigan Press. (Reprint 1970). A vol. in-8°, xvi + 136 pp., bibl. Bound $3°95." *Journal of Human Evolution* 4 (4):327-327.

Sassaman, Kenneth E.

1993 *Early Pottery in the Southeast: Tradition and Innovation in Cooking Technology*. The University of Alabama Press, Tuscaloosa.

2004 Complex Hunter-Gatherers in Evolution and History: A North American Perspective. *Journal of Archaeological Research* 12 (3):227-280.

2010 *The Eastern Archaic, Historicized*. AltaMira Press, Lanham.

2013 Drowning Out the Past: How Humans Historicize Water as Water Historicizes Them. *Big Histories, Human Lives: Tackling Problems of Scale in Archaeology* (School for the Advanced Research Advanced Seminar Series), edited by John Robb and Timothy R. Pauketat, pp. 171-191. School for Advanced Research Press, Santa Fe.

Saunders, Rebecca, and Michael Russo

2011 Coastal Shell Middens in Florida: A View from the Archaic Period. *Quaternary International* 239 (1-2):38-50.

Schlanger, Sarah H.

1992 Recognizing Persistent Places in Anasazi Settlement Systems." In *Space, Time, and Archaeological Landscapes*, edited by Jaqueline Rossignol and LuAnn Wandsnider, pp. 91-112. Springer, New York.

Schuldenrein, Joseph

1996 Geoarchaeology and the Mid-Holocene Landscape History of the Greater Southeast. In *Archaeology of the Mid-Holocene Southeast*, edited by Kenneth E. Sassaman and David G. Anderson, pp. 3-27. University Press of Florida, Gainesville.

Scott, Thomas M.

2011 Geology of the Florida Platform. *Gulf of Mexico Origin, Waters, and Biota: Volume 3, Geology*:17.

Smith, Karen Y., and Keith Stephenson

2018 The Spatial Dimension of the Woodland Period. *Southeastern Archaeology* 37 (2):112-128.

Spivey, S Margaret, Tristram R Kidder, Anthony L Ortmann, and Lee J Arco

2015 Pilgrimage to Poverty Point. *The Archaeology of Events: Cultural Change and Continuity in the Pre-Columbian Southeast*, edited by Zackary I. Gilmore and Jason M. O’Donoughue, pp. 141-159. University of Alabama Press, Tuscaloosa.

Stephenson, Keith, Judith A Bense, and Frankie Snow

2002 Aspects of Deptford and Swift Creek of the South Atlantic and Gulf Coastal Plains. In *The Woodland Southeast*, edited by David G. Anderson and Robert C. Mainfort Jr., pp. 318-351. University of Alabama Press, Tuscaloosa.

Swanton, John R.

1922 Early History of the Creek Indians and Their Neighbors. *Bureau of American Ethnology Bulletin* 73:1–492.

Thulman, David

2006 A Reconstruction of Paleoindian Social Organization in North Central Florida, edited by William Parkinson. ProQuest Dissertations Publishing, Ann Arbor.

Tobler, Waldo R.

1970 A Computer Movie Simulating Urban Growth in the Detroit Region. *Economic Geography* 46:234.

Torgovnikov, Grigoriy I.

1993 *Dielectric Properties of Wood and Wood-Based Materials*. Springer Series in Wood Science. Springer-Verlag, Berlin.

Tylor, Edward B.

1871 *Primitive Culture: Researches into the Development of Mythology, Philosophy, Religion, Art, and Custom*. John Murray, London.

Unger, Achim, Arno Schniewind, and Wibke Unger

2001 *Conservation of Wood Artifacts: A Handbook*. Springer-Verlag, Berlin.

Utsi, Erica C.

2017 *Ground Penetrating Radar: Theory and Practice*. Butterworth-Heinemann, Oxford.

Verhagen, Philip

2018 Spatial Analysis in Archaeology: Moving into New Territories. In *Digital Geoarchaeology: New Techniques for Interdisciplinary Human-Environmental Research*, edited by Christoph Siart, Markus Forbriger, and Olaf Bubenzer, pp. 11-25. Springer International Publishing AG, Cham.

Wallis, Neill J., and Asa R. Randall (editors)

2014 *New Histories of Pre-Columbian Florida*. University Press of Florida, Gainesville.

Westerdahl, Christer

2011 The Maritime Cultural Landscape. *In Oxford Handbook of Maritime Archaeology*, edited by Alexis Catsambis, Ben Ford, and Donny Hamilton. Oxford University Press, New York.

Wheatley, David and Mark Gillings

2002 *Spatial Technology and Archaeology: The Archaeological Applications of GIS.* Taylor & Francis, London.

Wheeler, Ryan J., James J. Miller, Ray M. McGee, Donna Ruhl, Brenda Swann, and Melissa Memory

2003 Archaic Period Canoes from Newnans Lake, Florida. *American Antiquity* 68 (3):533-551.

White, Leslie A.

1949 *The Science of Culture, A Study of Man and Civilization*. Grove Press, New York.

Willey, Gordon R.

1949 *Archeology of the Florida Gulf Coast.* Smithsonian Institution, Washington, D.C.

1953 Prehistoric Settlement Patterns in the Vird Valley, Peru. *Smithsonian Institution Bureau of American Ethnology Bulletin 155*. U.S. Government Printing Office, Washington, D.C.

Wright, Alice P., and Edward R. Henry (editors)

2013 *Early and Middle Woodland Landscapes of the Southeast*. Florida Museum of Natural History: Ripley P. Bullen Series. University Press of Florida, Gainesville.

APPENDICES

Appendix I

FLORIDA BUREAU OF ARCHAEOLOGICAL RESEARCH
LOG BOAT RECORDING FORM

Canoe Name or #: ______________________________

Field Date: __________

FMSF Site #: ______________________________

Form Date: __________

□ Previously recorded site

Recorder: ________________________

Setting: □ Lake/pond □ River/Stream/Creek □ Saltwater Name: ________________________

GPS: ____ □ Lat/Long □ UTM

□ NAD27 □ NAD83 □WGS

□ Meters/cm □ Feet/in □ Feet/t enths

Max Length: ___________________________

Max Width: ___________________________

Max Height: ___________________________

Max Inside Depth: ______________________

Girth of Bow: __________________________

Girth of Stern: _________________________

Thickness of Sides: _____________________

Bottom Thickness: ______________________

Intact: □ 75-100% □ 50-75% □ <50%

Part: □ Complete □ Deck fragment

□ End Fragment □ End fragment with Deck

□ Wood Sampled *PLEASE MARK ON SKETCH

From Location: _________________________

____

□ C-14 Sampled *PLEASE MARK ON SKETCH

From Location: _________________________

____

Appendix II

Database ID	Conventional C14 Age	Conventional C14 Plus or Minus	2sig from Calendrical	2sig to Calendrical	Mean Calendrical	BC/AD	2sig from BP	2sig to BP	Mean BP	Assigned Period
259	6050	60	-5207	-4793	-4961	BC	7156	6742	6910	Archaic
258	5140	100	-4231	-3708	-3944	BC	6180	5657	5893	Archaic
210	4990	50	-3943	-3659	-3790	BC	5892	5608	5739	Archaic
408	4370	80	-3338	-2880	-3055	BC	5287	4829	5004	Archaic
399	4210	60	-2917	-2620	-2779	BC	4866	4569	4728	Archaic
388	4090	60	-2872	-2489	-2677	BC	4821	4438	4626	Archaic

Database ID	Conventional C14 Age	Conventional C14 Plus or Minus	2sig from Calendrical	2sig to Calendrical	Mean Calendrical	BC/AD	2sig from BP	2sig to BP	Mean BP	Assigned Period
418	3990	70	-2855	-2291	-2519	BC	4804	4240	4468	Archaic
402	3970	80	-2853	-2208	-2484	BC	4802	4157	4433	Archaic
419	3970	80	-2853	-2208	-2484	BC	4802	4157	4433	Archaic
97	3950	70	-2831	-2206	-2445	BC	4780	4155	4394	Archaic
411	3880	50	-2474	-2204	-2357	BC	4423	4153	4306	Archaic
320	3880	80	-2573	-2136	-2348	BC	4522	4085	4297	Archaic
392	3870	60	-2487	-2145	-2342	BC	4436	4094	4291	Archaic

Database ID	Conventional C14 Age	Conventional C14 Plus or Minus	2sig from Calendrical	2sig to Calendrical	Mean Calendrical	BC/AD	2sig from BP	2sig to BP	Mean BP	Assigned Period
415	3800	70	-2464	-2037	-2248	BC	4413	3986	4197	Archaic
414	3750	60	-2400	-1972	-2166	BC	4349	3921	4115	Archaic
389	3730	60	-2333	-1949	-2136	BC	4282	3898	4085	Archaic
383	3690	50	-2268	-1938	-2080	BC	4217	3887	4029	Archaic
425	3680	60	-2273	-1898	-2069	BC	4222	3847	4018	Archaic
424	3660	70	-2280	-1786	-2045	BC	4229	3735	3994	Archaic
401	3650	60	-2201	-1884	-2031	BC	4150	3833	3980	Archaic

Database ID	Conventional C14 Age	Conventional C14 Plus or Minus	2sig from Calendrical	2sig to Calendrical	Mean Calendrical	BC/AD	2sig from BP	2sig to BP	Mean BP	Assigned Period
409	3620	60	-2194	-1777	-1991	BC	4143	3726	3940	Archaic
428	3620	60	-2194	-1777	-1991	BC	4143	3726	3940	Archaic
405	3600	80	-2197	-1745	-1962	BC	4146	3694	3911	Archaic
420	3600	70	-2141	-1754	-1962	BC	4090	3703	3911	Archaic
387	3570	60	-2127	-1746	-1916	BC	4076	3695	3865	Archaic
406	3570	60	-2127	-1746	-1916	BC	4076	3695	3865	Archaic
391	3540	60	-2032	-1696	-1873	BC	3981	3645	3822	Archaic

Database ID	Conventional C14 Age	Conventional C14 Plus or Minus	2sig from Calendrical	2sig to Calendrical	Mean Calendrical	BC/AD	2sig from BP	2sig to BP	Mean BP	Assigned Period
394	3540	60	-2032	-1696	-1873	BC	3981	3645	3822	Archaic
395	3530	70	-2113	-1686	-1863	BC	4062	3635	3812	Archaic
403	3520	60	-2020	-1692	-1847	BC	3969	3641	3796	Archaic
365	3505	60	-2014	-1685	-1830	BC	3963	3634	3779	Archaic
407	3500	60	-2010	-1667	-1825	BC	3959	3616	3774	Archaic
396	3480	60	-1947	-1644	-1804	BC	3896	3593	3753	Archaic
410	3480	60	-1947	-1644	-1804	BC	3896	3593	3753	Archaic

Database ID	Conventional C14 Age	Conventional C14 Plus or Minus	2sig from Calendrical	2sig to Calendrical	Mean Calendrical	BC/AD	2sig from BP	2sig to BP	Mean BP	Assigned Period
397	3470	60	-1936	-1641	-1793	BC	3885	3590	3742	Archaic
417	3450	70	-1949	-1566	-1771	BC	3898	3515	3720	Archaic
385	3440	60	-1908	-1616	-1760	BC	3857	3565	3709	Archaic
416	3430	60	-1903	-1566	-1748	BC	3852	3515	3697	Archaic
117	3400	60	-1881	-1534	-1708	BC	3830	3483	3657	Archaic
118	3380	60	-1877	-1526	-1680	BC	3826	3475	3629	Archaic
373	3320	60	-1746	-1454	-1604	BC	3695	3403	3553	Archaic

Database ID	Conventional C14 Age	Conventional C14 Plus or Minus	2sig from Calendrical	2sig to Calendrical	Mean Calendrical	BC/AD	2sig from BP	2sig to BP	Mean BP	Assigned Period
398	3310	60	-1741	-1451	-1593	BC	3690	3400	3542	Archaic
412	3290	70	-1741	-1428	-1576	BC	3690	3377	3525	Archaic
390	3140	60	-1531	-1233	-1399	BC	3480	3182	3348	Archaic
393	3090	60	-1498	-1208	-1341	BC	3447	3157	3290	Archaic
321	2965	55	-1383	-1013	-1180	BC	3332	2962	3129	Woodland
382	2610	60	-908	-543	-756	BC	2857	2492	2705	Woodland
372	2570	50	-827	-540	-699	BC	2776	2489	2648	Woodland

Database ID	Conventional C14 Age	Conventional C14 Plus or Minus	2sig from Calendrical	2sig to Calendrical	Mean Calendrical	BC/AD	2sig from BP	2sig to BP	Mean BP	Assigned Period
386	2400	60	-756	-390	-544	BC	2705	2339	2493	Woodland
413	2370	70	-765	-236	-511	BC	2714	2185	2460	Woodland
31	2250	60	-407	-171	-294	BC	2356	2120	2243	Woodland
214	1635	60	255	557	422	AD	1695	1394	1528	Woodland
197	1580	40	397	565	481	AD	1553	1386	1469	Woodland
21	1560	30	420	565	488	AD	1530	1386	1462	Woodland
74	1420	50	541	682	617	AD	1410	1269	1333	Woodland

Database ID	**Conventional C14 Age**	**Conventional C14 Plus or Minus**	**2sig from Calendrical**	**2sig to Calendrical**	**Mean Calendrical**	**BC/AD**	**2sig from BP**	**2sig to BP**	**Mean BP**	**Assigned Period**
280	1350	50	604	770	683	AD	1347	1180	1267	Woodland
384	1260	60	655	891	767	AD	1295	1059	1183	Woodland
28	1240	60	660	944	785	AD	1290	1007	1165	Woodland
81	1240	80	654	968	793	AD	1296	982	1157	Woodland
235	1225	70	663	967	802	AD	1287	984	1148	Woodland
42	1210	40	687	940	811	AD	1263	1010	1139	Woodland
241	1200	40	689	950	822	AD	1261	1001	1128	Woodland

Dat aba se ID	Conve ntional C14 Age	Conventio nal C14 Plus or Minus	2sig from Calend rical	2sig to Calen drical	Mean Calen drical	B C/ A D	2sig fro m BP	2si g to BP	M ea n BP	Assig ned Perio d
168	1185	85	669	995	839	A D	128 2	95 6	11 11	Woo dland
26	1180	50	696	976	843	A D	125 5	97 5	11 07	Woo dland
426	1170	60	691	989	853	A D	125 9	96 1	10 97	Woo dland
243	1160	80	689	1015	859	A D	126 1	93 5	10 91	Woo dland
279	1160	70	691	1013	861	A D	126 0	93 7	10 89	Woo dland
204	1160	65	693	1011	862	A D	125 8	94 0	10 88	Woo dland
404	1140	70	700	1021	879	A D	125 5	92 9	10 71	Woo dland

Database ID	Conventional C14 Age	Conventional C14 Plus or Minus	2sig from Calendrical	2sig to Calendrical	Mean Calendrical	BC/AD	2sig from BP	2sig to BP	Mean BP	Assigned Period
284	1140	60	725	1017	883	AD	1226	933	1067	Woodland
105	1130	65	722	1022	890	AD	1229	928	1060	Woodland
322	1135	50	772	1011	893	AD	1179	939	1057	Woodland
115	1120	50	776	1015	909	AD	1174	936	1041	Woodland
421	1090	60	775	1030	933	AD	1176	920	1017	Woodland
225	1090	45	778	1025	942	AD	1173	925	1008	Woodland

Database ID	Conventional C14 Age	Conventional C14 Plus or Minus	2sig from Calendrical	2sig to Calendrical	Mean Calendrical	BC/AD	2sig from BP	2sig to BP	Mean BP	Assigned Period
236	1070	60	776	1147	955	AD	1175	804	995	Mississippian
62	1060	50	780	1148	968	AD	1171	802	982	Mississippian
378	1040	40	893	1119	992	AD	1058	832	958	Mississippian
500	1010	22	985	1117	1018	AD	965	833	932	Mississippian
185	1010	50	901	1156	1037	AD	1050	794	913	Mississippian

Database ID	Conventional C14 Age	Conventional C14 Plus or Minus	2sig from Calendrical	2sig to Calendrical	Mean Calendrical	BC/AD	2sig from BP	2sig to BP	Mean BP	Assigned Period
30	1000	60	895	1168	1049	AD	1055	783	901	Mississippian
351	1000	60	895	1168	1049	AD	1055	783	901	Mississippian
374	1000	50	901	1161	1051	AD	1049	789	899	Mississippian
209	990	55	901	1181	1062	AD	1050	769	888	Mississippian
189	990	45	975	1160	1064	AD	975	790	886	Mississippian

Database ID	Conventional C14 Age	Conventional C14 Plus or Minus	2sig from Calendrical	2sig to Calendrical	Mean Calendrical	BC/AD	2sig from BP	2sig to BP	Mean BP	Assigned Period
376	950	40	1016	1183	1093	AD	935	767	857	Mississippian
18	945	35	1021	1163	1095	AD	930	787	855	Mississippian
283	930	40	1022	1189	1103	AD	929	761	847	Mississippian
379	920	40	1026	1206	1108	AD	925	745	842	Mississippian
380	910	40	1030	1210	1115	AD	920	741	835	Mississippian

Database ID	Conventional C14 Age	Conventional C14 Plus or Minus	2sig from Calendrical	2sig to Calendrical	Mean Calendrical	BC/AD	2sig from BP	2sig to BP	Mean BP	Assigned Period
157	880	45	1035	1246	1143	AD	915	704	807	Mississippian
237	870	50	1040	1257	1152	AD	911	694	798	Mississippian
400	850	60	1040	1270	1167	AD	911	680	783	Mississippian
231	845	65	1040	1274	1169	AD	911	677	781	Mississippian
64	855	45	1043	1264	1170	AD	907	686	780	Mississippian

Database ID	Conventional C14 Age	Conventional C14 Plus or Minus	2sig from Calendrical	2sig to Calendrical	Mean Calendrical	BC/AD	2sig from BP	2sig to BP	Mean BP	Assigned Period
255	850	50	1043	1268	1172	AD	908	682	778	Mississippian
113	840	55	1043	1275	1179	AD	908	676	771	Mississippian
227	825	50	1046	1280	1197	AD	904	671	753	Mississippian
186	800	70	1040	1297	1204	AD	911	653	746	Mississippian
34	790	50	1059	1292	1227	AD	891	658	723	Mississippian

Database ID	Conventional C14 Age	Conventional C14 Plus or Minus	2sig from Calendrical	2sig to Calendrical	Mean Calendrical	BC/AD	2sig from BP	2sig to BP	Mean BP	Assigned Period
51	765	50	1163	1377	1245	AD	788	573	705	Mississippian
203	750	55	1164	1387	1257	AD	787	564	693	Mississippian
361	740	60	1164	1391	1266	AD	787	560	684	Mississippian
116	720	55	1194	1395	1288	AD	757	555	662	Mississippian
218	690	50	1228	1398	1317	AD	722	553	633	Mississippian

Database ID	Conventional C14 Age	Conventional C14 Plus or Minus	2sig from Calendrical	2sig to Calendrical	Mean Calendrical	BC/AD	2sig from BP	2sig to BP	Mean BP	Assigned Period
354	630	100	1190	1453	1338	AD	761	498	612	Mississippian
381	640	60	1271	1414	1341	AD	680	537	609	Mississippian
13	630	50	1281	1409	1344	AD	670	542	606	Mississippian
19	630	50	1281	1409	1344	AD	670	542	606	Mississippian
216	610	50	1285	1414	1350	AD	665	536	600	Mississippian

Database ID	Conventional C14 Age	Conventional C14 Plus or Minus	2sig from Calendrical	2sig to Calendrical	Mean Calendrical	BC/AD	2sig from BP	2sig to BP	Mean BP	Assigned Period
230	590	45	1293	1419	1355	AD	657	532	595	Mississippian
56	575	50	1295	1429	1360	AD	655	521	590	Mississippian
234	575	60	1290	1435	1361	AD	660	516	589	Mississippian
232	500	50	1307	1477	1410	AD	644	473	540	Mississippian
254	470	80	1302	1635	1459	AD	649	315	491	Mississippian

Database ID	Conventional C14 Age	Conventional C14 Plus or Minus	2sig from Calendrical	2sig to Calendrical	Mean Calendrical	BC/AD	2sig from BP	2sig to BP	Mean BP	Assigned Period
377	460	60	1318	1633	1463	AD	632	318	487	Mississippian
94	440	40	1409	1620	1468	AD	541	331	482	Mississippian
123	430	40	1413	1624	1480	AD	537	326	470	Mississippian
188	425	50	1412	1633	1497	AD	538	317	453	Mississippian
184	380	50	1441	1637	1533	AD	510	314	417	Historical

Dat aba se ID	Conve ntional C14 Age	Conventio nal C14 Plus or Minus	2sig from Calend rical	2sig to Calen drical	Mean Calen drical	B C/ A D	2sig fro m BP	2si g to BP	M ea n BP	Assig ned Perio d
95	370	40	1446	1635	1537	A D	505	31 5	41 3	Histo rical
178	340	50	1453	1645	1553	A D	497	30 6	39 7	Histo rical
287	340	50	1453	1645	1553	A D	497	30 6	39 7	Histo rical
350	320	80	1431	...	1585	A D	520	...	36 5	Histo rical
286	250	50	1483	...	1672	A D	468	...	27 8	Histo rical
141	190	110	1494	...	1739	A D	457	...	21 1	Histo rical
158	30	50	1682	1931	1828	A D	268	19	12 2	Histo rical