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MAPPING THE SUBMERGED LANDSCAPE OF NORFOLK CANYON , VA USING ACOUSTIC TECHNIQUES AND THE SEARCH FOR SUBMERGED PREHISTORIC ARCHAEOLOGICAL SITES

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BY

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Abstract

Archaeologists have long debated the circumstances surrounding the initial peopling of North and South America. Two of the most hotly contested facets of this debate have been the timing of this event and the route that people took into the New World, whether inland or along the coast. However, without including data from parts of the continental shelf surrounding the Americas that are now submerged but were formerly a subaerially exposed coastal landscape, an important part of the equation is missing. By expanding the search for early archaeological sites onto this largely unexplored terrain, it may be possible to obtain some degree of resolution to this debate. If it is possible to locate sites on the deeper parts of the continental shelf, they could provide evidence of human occupation of the Americas before the Clovis period, which began approximately 13,250 years ago. Radiocarbon dates from sites on land that predate this horizon have been vehemently challenged by "Clovis-first" proponents. If it is possible to locate sites on a landscape that would have already been submerged by the beginning of the Clovis period, they would be very difficult to refute.

The landscape surrounding Norfolk Canyon, a submarine feature on the continental shelf off the coast of Virginia, has great potential to be a site of early human habitation. Norfolk Canyon is one of a series of submarine canyons that line the edge of the continental shelf of the eastern United States. Importantly, it may have represented the point at which the Susquehanna River, which today terminates at the head of Chesapeake Bay, would have intersected the Atlantic Ocean during the low

stand in sea level associated with the Last Glacial Maximum (LGM). Today, Chesapeake Bay is a very productive estuary that is an important resource for the occupants of the surrounding region. Certainly, if similar conditions existed in parts of Norfolk Canyon during a period of lower sea level, they would have been of similar importance for any human populations that lived nearby. On top of that, they would almost certainly have attracted people to the surrounding landscape. Therefore, if humans were in the New World at the time that the head of Norfolk Canyon was subaerially exposed, it is extremely likely that they would have included these resources within their subsistence strategies and it is quite possible that evidence of such activities could remain on the landscape.

However, whether the Americas had been colonized before the outermost parts of the continental shelf, including the head of Norfolk Canyon, were submerged by rising water levels is a subject of intense debate. One of the eventual goals of the search for submerged sites on the continental shelf is to test this question. In order to justify this project, I argue only that humans could possibly have entered the New World and reached the mid-Atlantic region of the United States by the LGM. This is supported by three past discoveries. The first is Meadowcroft Rockshelter, a site in western Pennsylvania that has yielded several radiocarbon dates predating the Clovis period. This site has been the subject of intense debate for more than a three decades. The second is Cactus Hill, a site in southeastern Virginia that has yielded radiocarbon and sediment luminescence dates predating Clovis from a stratigraphic layer below Clovis. And the third is a projectile point that was previously recovered by a scallop dredge from the continental shelf near Norfolk Canyon but was only recently rediscovered in a local museum collection. This point, which appears to bear some resemblance to those of the Solutrean tradition of southwestern Europe, was recovered from the same dredge material as megafaunal remains and other organic material dating to 22,000 years ago.

As a first step to potentially locate evidence of human occupation within our study area on the continental shelf near the head of Norfolk Canyon, we conducted an acoustic survey using side scan, multibeam, and singlebeam sonars. This survey was part of a larger underwater archaeological project called the Virginia Capes Archaeology Project that was comprised of a series of four oceanographic cruises that took place during the summers of 2006, 2007, and 2008. Other objectives of this project included a general survey for historic shipwrecks as well as a more specific search for an individual sixteenth century wreck that is believed to be in the area. In order to accomplish the other goals, a magnetometer survey and video groundtruthing with remotely operated vehicles were also performed. Specific survey areas within the overall study area were chosen with all three objectives in mind.

Based on the acoustic data, I argue that there is strong evidence to suggest that had humans been living in the New World at the time that the landscape surrounding the head of Norfolk Canyon was subaerially exposed, there are several areas within the study area that represent excellent places to look for submerged sites. In particular, there are three features that are especially promising and demand further investigation. The first is a relatively steep portion of a possible shoreline feature that is evident in the singlebeam and multibeam data. The shoreline would have remained in the same place for a relatively long period of time, allowing people to occupy the same location on the landscape for an extended time, potentially increasing the size and archaeological visibility of any nearby sites. The second feature is a terrace immediately adjacent to a topographic valley that may represent a segment of a submerged river, possibly the ancestral Susquehanna River. Such features are commonly the location of known terrestrial Paleoindian sites in the mid-Atlantic United States. Finally, the third is a series of potential river mouths and shallow estuaries surrounding the head of Norfolk Canyon. These undoubtedly would have been attractive to human populations due to the abundant resources they would have provided. Although these results are promising, they are useful only upon completion of further research, including the collection of core, rock, and organic samples and more extensive acoustic surveys, including with sub-bottom sonars. However, the outcome of this thesis and the Virginia Capes Archaeology Project represent an important step in the quest to locate submerged archaeological sites on the continental shelf off the coast of Virginia and throughout the Americas as a whole.

Acknowledgements

I would first like to thank my advisor, Dr. Robert Ballard, not only for his assistance with this project, but for all of the opportunities he has provided me with during my time at URI. It was his vision that brought the idea of archaeological oceanography into existence and I was fortunate enough to have had the opportunity to be a part of this new and exciting program. In my four years as Dr. Ballard's student, I have participated on seven different oceanographic cruises, each of them unique. These experiences have truly helped me grow as both an oceanographer and an archaeologist, and will be of great benefit to me in the future. Second, I would also like to thank Dr. Rod Mather. In addition to being on my thesis committee for this project, he was also my advisor for the History MA component of the joint degree program. Also, Rod was one of the co-chief scientists for the Virginia Capes Archaeology Project and he worked very closely with me to complete this project. I would like to acknowledge Dr. Chris Roman, my third committee member. I have been to sea with Chris several times and I have learned much from him, particularly with respect to ROVs and AUVs. Finally, I would like to thank Dr. Kristine Bovy for serving as the chair of my thesis defense committee. Like Rod, Kris served on my MA committee as well as on this one, and neither project would have been nearly as successful without her input.

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Introduction

One of the most interesting questions in human history concerns the timing and circumstances surrounding the earliest human colonization of North and South America. There is evidence that as early as the late sixteenth century, the European explorers of the New World believed that Native Americans had descended from migrants who had traversed a hypothetical land bridge from northeastern Asia into northwestern North America (de Acosta 1604 in Fiedel 2000). With few exceptions, including Bradley and Stanford (2004) who argue that people may have immigrated to the Americas from southwestern Europe across the frozen North Atlantic during the Last Glacial Maximum (LGM) approximately 21,000 years ago, the idea that the New World was first colonized from Asia remains almost universally accepted by the archaeological community (e.g. Meltzer 1995; Fiedel 2000; Waters and Stafford 2007; Goebel et al. 2008). However, any further details regarding this event, including its timing and the specific migration routes that were taken are much less well established. There has been a longstanding debate between those archaeologists who argue that the people of the Clovis cultural tradition, which had an initial date of about 13,250 years ago (Fiedel 1999, 2000; Waters and Stafford 2008), were the first inhabitants of the New World and those that believe that there were earlier, pre-Clovis populations in North and South America. Additionally, there has also been a debate as to whether people entered the continent along the coast or via an inland route.

Due to rising water levels throughout North America, those regions that would have been on the coast at the time that humans first settled the continent are now under water. Obviously, how deeply submerged they are is contingent on when colonization occurred, but whenever that was, it is clear that only focusing on sites in regions that are now terrestrial neglects the coastal piece to the puzzle. Nevertheless, to date, relatively little work has been done to search for submerged formerly coastal sites (e.g. Stright 1990; Merwin, Lynch, and Robinson 2003). The work that has been done, particularly on individual sites, has primarily been focused on shallow water areas that can be accessed easily by scuba divers. To be fair, there are logistical reasons for this, as relatively few archaeologists have access to the necessary technologies or funding to conduct the large scale oceanographic cruises that would be required to investigate deeper areas. Nonetheless, if humans entered the New World as early as the LGM, it is possible that most of the continental shelf was exposed at the time. This is a huge area that may have played an important role in settlement strategies.

An extensive survey of parts of the shelf could address the questions of when and by what route people entered the Americas. If evidence of human occupation is found anywhere on the continental shelf under a water depth greater than the local amount of sea level rise in the past 13,250 years, it would suggest that people would have been in the area prior to the Clovis period, and this would therefore refute the "Clovis-First Theory," which I will discuss in greater detail in Chapter 2. Whether the question of migration routes can be tested is more site specific. For example, if evidence of human occupation can be found on the continental shelf off the western coast of Canada and the northwestern United States that predates the earliest archaeological sites from the interior, it would suggest a coastal migration route. Sites located elsewhere on the shelf, however, would be less telling.

The seaward edge of the continental shelf off the eastern coast of the United States is lined by a number of submarine canyons. These canyons represent interesting topographic features that, if subaerially exposed at any time during which humans occupied the region, could have attracted people to live there or utilize the resources that they may have provided. Additionally, there is reason to believe that during the sea level low stand of the LGM, several of the major rivers of the mid-Atlantic region of the United States, which today terminate at large estuaries such as the Hudson River, Chesapeake Bay, and Delaware Bay, extended out to the canyons that are present along the edge of the continental shelf (e.g. Edwards and Merrill 1977). One of these rivers is the Susquehanna, which currently terminates at Chesapeake Bay, but potentially extended to Norfolk Canyon when the sea level was much lower. Today, Chesapeake Bay is an extremely productive system that is a very important resource for the local human population. If a similar system was present at the edge of the continental shelf, presumably at the head of Norfolk Canyon, it would certainly have drawn human populations to settle nearby, assuming they were in the Americas at all at the time.

Because of this possibility, we decided to initiate an effort to search for evidence of human activity near the head of Norfolk Canyon. The first stage of this quest would be to gain a better understanding of the topography of the landscape in order to decide where to focus more intensive testing. To do this, we conducted an extensive multibeam, singlebeam, and side scan sonar acoustic survey of the head of Norfolk Canyon and certain other nearby survey grids as part of a larger underwater archaeological project called the Virginia Capes Archaeology Project, which consisted of four oceanographic cruises during the summers of 2006, 2007, and 2008. Other components of this project included a general survey for historic shipwrecks and a more specific survey for a sixteenth century shipwreck that is believed to be in the area. These surveys in part dictated where we placed some of our survey grids. In any case, I intended to address the question of where on the landscape surrounding Norfolk Canyon would have been the most likely locations for people to have occupied, again assuming that they had arrived in the Americas before rising water levels submerged the study area. As this represents only a first step in locating sites, the goal was simply to generate a predictive model to determine where to concentrate future surveys, potentially including the collection of core, rock, or organic material samples, which were not possible during this project.

To address these questions, this thesis contains five major sections. Chapter 1 is a presentation of the geological background that is necessary to place the study area into appropriate context. This includes a discussion of submarine canyons as a whole, as well as one specific to the canyons of the mid-Atlantic United States and Norfolk Canyon in particular. Importantly, it also addresses the timing of the last glaciation and the varying interpretations among geologists and geological oceanographers regarding sea level rise curves, rates of sea level rise, and the total amount that sea level has risen, both globally and locally off the coast of Virginia. Chapter 2 contains three major sections. The first is a discussion of the Paleoenvironmental conditions near Norfolk Canyon during the Late Pleistocene and Early Holocene. This was specifically focused on how environmental conditions would have affected the habitability of the region, both with respect to comfort and resource availability. The second section is the archaeological background for the thesis, including a discussion of what is currently known about the peopling of the Americas. It also includes a synopsis of settlement and land use patterns among known archaeological sites on land in the mid-Atlantic region for periods of prehistory that can be potentially extrapolated to better understand the way that people may have occupied the landscape during periods of lower sea level. Finally, the third section is a presentation of the hypothesis and expectations for the fieldwork and associated data processing. Chapter 3 is a discussion of the field methods used to collect data for this thesis, as well as the methods used to process and mosaic the data into interpretable maps.

The second half of the thesis is a presentation of the results of research and a discussion of their archaeological and oceanographic implications. Chapter 4 includes the results of the processed data, as well as a series of maps generated from the side scan, multibeam, and singlebeam sonar data. This chapter also contains a preliminary description of the potential topographic features that appear to be evident within the data. Chapter 5, then, is a discussion of the results of the data and their implications for our understanding of the various features on the landscape and how people might have interacted with them at the time they were subaerially exposed. This chapter also includes suggestions as to how the results of this project can be expanded upon with future work, as well as the conclusion to this thesis, which is primarily an attempt to update the definition of the field of archaeological oceanography and apply it to the current project.

Despite the fact that this project was only a first step in the attempt to locate evidence of human occupation of the continental shelf near the head of Norfolk Canyon, it was nonetheless highly successful. Based on the acoustic data that we collected, there are at least three areas on the landscape that appear to be promising and can be labeled high priority for any future sampling project. One is a possible shoreline segment that is relatively steep where the shoreline would have remained in place for a longer period of time than elsewhere. The second is a terrace above a potential river feature that may be part of the ancestral Susquehanna River. And the third feature is a series of potential river mouths and estuarine components near the head of Norfolk Canyon. Assuming these topographic features are what they appear to be, each could very likely be associated with human settlement for reasons that I will outline in Chapter 2. In any case, I argue that this thesis and the Virginia Capes Archaeology Project as a whole are together a very important first step in our understanding of human land use on the continental shelf. This project represents only the initial stages of our attempt to locate evidence of human occupation on the shelf, but its results are nonetheless very encouraging. The quest to locate relatively deep submerged sites is a difficult one, but this thesis represents an important early step and will hopefully lead to more intensive investigations and eventually the realization of the goal of locating submerged archaeological sites.

Chapter 1 - Geological Background

Norfolk and Other Submarine Canyons

A primary objective of this study is to generate high-resolution acoustic images of Norfolk Canyon, a submarine canyon along the edge of the continental shelf of the eastern United States near Chesapeake Bay, the Virginia Capes, and the Delmarva Peninsula (which includes parts of the states of Delaware, Maryland, and Virginia). Similar features can be found throughout the world and have been the subject of intensive study by oceanographers and geologists for more than a century (e.g. Dana 1863; Lindenkohl 1885; Shepard and Beard 1938; Veatch and Smith 1939; Kuenen 1953; Shepard and Dill 1966; Uchupi and Emery 1967; Uchupi 1968; Kelling and Stanley 1970; Keller and Shepard, 1978; Mitchell 2004; Perkins 2005). These canyons are not only interesting as submarine features, however, as many can also be exposed subaerially and represent very different components of the landscape during low stands in sea level accompanying glacial periods. Large parts of what is today the continental shelf of North America were exposed most recently during the late Wisconsin glacial maximum (e.g. Curray 1965; Emery et al. 1967; Whitmore et al. 1967; Kraft 1971; Weil 1977; Emery and Uchupi 1972; Belknap and Kraft 1977; Twichell et al. 1977; Peltier 1990; Uchupi et al. 2001). Most glacial geologists currently place the timing of the last glacial maximum (LGM) at about 21,000 years ago (Stone and Borns 1986; Boothroyd 2001), although recent evidence suggests that it may have been even earlier (Peltier and Fairbanks 2006). This will be discussed in

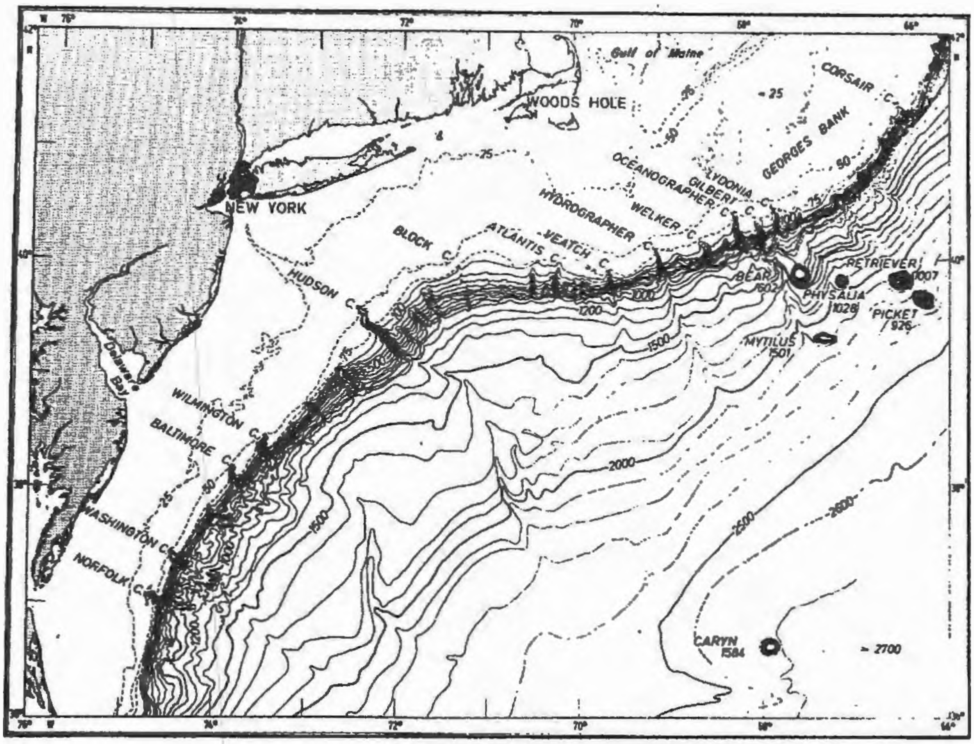


Figure 1.1 - Submarine Canyons of the Northeastern United States (Keller and Shepard 1978)

more detail later in this chapter. Importantly, it seems likely that the continental shelf around Norfolk Canyon was subaerially exposed at this time.

Submarine canyons line the entire edge of the continental shelf of eastern North America (Veatch and Smith 1939; Shepard and Dill 1966; Uchupi 1970; Swift et al. 1972; Keller and Shepard 1978) (Figure 1.1). The most prominent of these canyons is Hudson Canyon, which represents the endpoint of the Hudson River at the time of the last lowstand in sea level (Veatch and Smith 1939; Ewing et al. 1963; Uchupi 1970; Keller and Shepard 1978). This marks a transition between a region to the north in which canyons densely line the edge of the continental shelf and one to the south in which canyons are more sparsely distributed (Shepard and Dill 1966; Keller and Shepard 1978). Another transitional area occurs between Veatch and Hydrographer Canyons to the south-southeast of Nantucket Island. The canyons to the west and south of Veatch are relatively inactive and contain primarily fine-grained sediments, with the exception of their uppermost reaches. Hydrographer and the canyons to the northeast, however, appear to be undergoing active erosion and are lined with either bare rock or coarse sands. This dichotomy is due in large part to the relative currents present in the canyons. To the northeast of Hydrographer Canyon, currents as high as 70 to 75 cm/sec are common, whereas to the southwest, maximum values are closer to 30 cm/sec (Keller and Shepard 1978). This has clear implications for landscape preservation, as the southwestern canyons are more likely to retain relict features from periods of exposure.

A similar pattern is present on the shelf as a whole. There is a transition zone between Hudson and Block Island Canyons. To the south of Hudson Canyon, the heavy mineral assemblage consists of an abundance of easily eroded minerals like garnet and amphibole, whereas to the north, off Georges Bank and the Scotia Shelf, staurolite and other erosion-resistant minerals are more common (Milliman et al. 1972; Keller and Shepard 1978). This furthers the interpretation that submerged landscapes and shorelines are more likely to be preserved to the south of Hudson Canyon, particularly those on the outer shelf. Additionally, the shelf from Georges Bank to Chesapeake Bay is relatively smooth compared to the northern region (Veatch and Smith 1939; Uchupi 1970). This too aids in the possibility of locating relict features and shorelines, which are more likely to stand out on a flat background. Keller and Shepard (1978) note different source areas for the sediments deposited on the shelf to the north and south of Hudson Canyon. This may be one of the important factors affecting the relative smoothness and currents for the two areas.

There is another transition in the continental shelf near Cape Hatteras, North Carolina. To the north, the shelf is immediately adjacent to the continental slope. To the south, the shelf is either separated from the slope by a marginal plateau or is cut in two by a marginal trough (Uchupi 1970) (Figure 1.2). For this reason, there are very few canyons of the type of interest in this study south of Cape Hatteras and the adjacent Hatteras and Pamlico Canyons (Veatch and Smith 1939; Kuenen 1953; Shepard and Dill 1966; Emery and Uchupi 1972). I will argue in the next chapter that the landscape surrounding the canyons of the northeastern United States and Norfolk Canyon in particular may have provided ideal locations for human occupation and natural resource exploitation during periods of subaerial exposure. Therefore, because of the presence of such canyons and the higher currents and erosion rates among those further to the northeast, the region of the United States continental shelf between Hudson Canyon and Cape Hatteras represents an excellent place to search for evidence of early human occupation of the Atlantic coast of North America.

Among the features of interest for this thesis are relict shorelines that represent low stands in sea level. Although a major goal of this project is to locate features such as these on a small scale using high-resolution acoustic data, there are several shorelines that can be traced throughout the mid-Atlantic continental shelf and must also be taken into account. In particular, the Nicholls, Franklin, and Block Island (or Atlantis when southwest of Hudson Canyon) Shorelines have been observed near

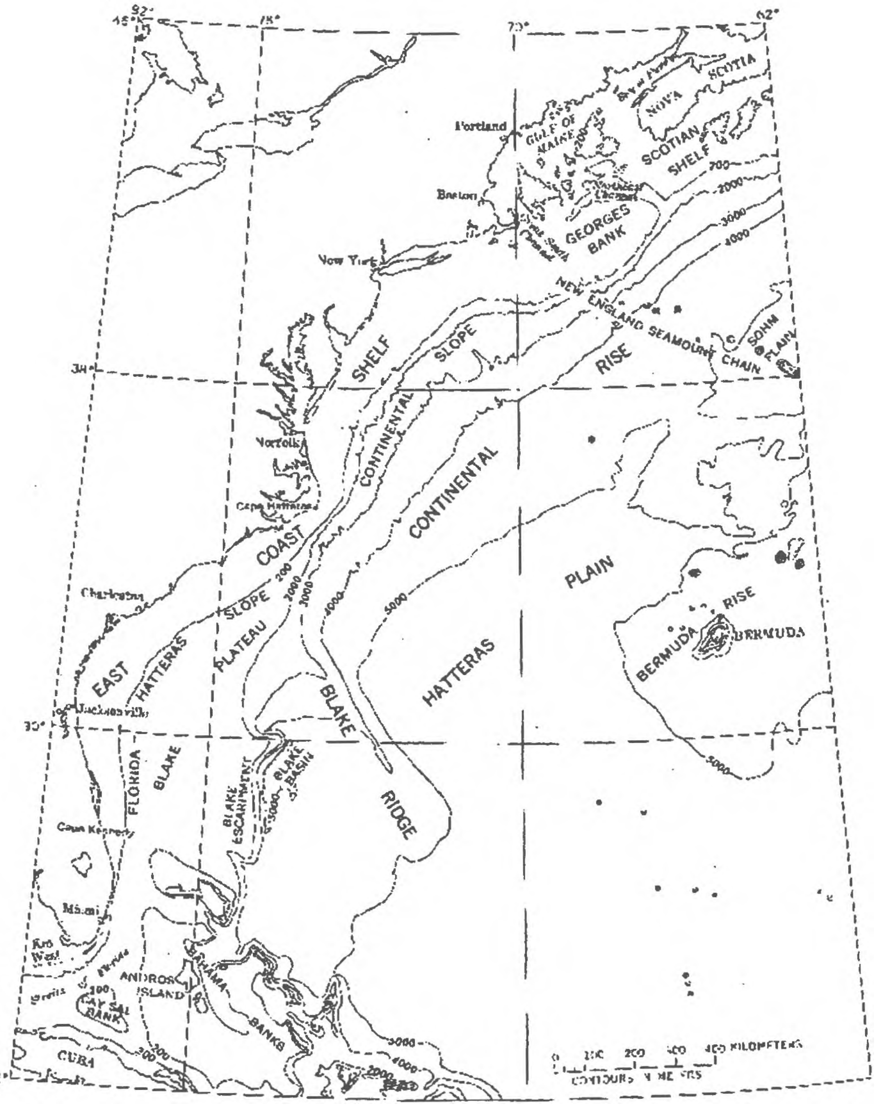


Figure 1.2 - The Continental Margin off the East Coast of the United States (Uchupi 1970)

Norfolk Canyon, and a fourth, the Fortune Shore, is evident near Hudson Canyon (Veatch and Smith 1939; Ewing et al. 1960, 1963; Knott and Hoskins 1968; Kelling and Stanley 1970; Emery and Uchupi 1972; Dillon and Oldale 1978) (Figure 1.3). The Nicholls Shore is the furthest from land, and appears to trace the shelf break near Norfolk, Washington, and Baltimore Canyons. Littoral shells from a core collected at a depth of 132m from the Nicholls Shore were radiocarbon dated to more than 35,000 years ago (Ewing et al. 1963; Emery and Uchupi 1972). However, for reasons that

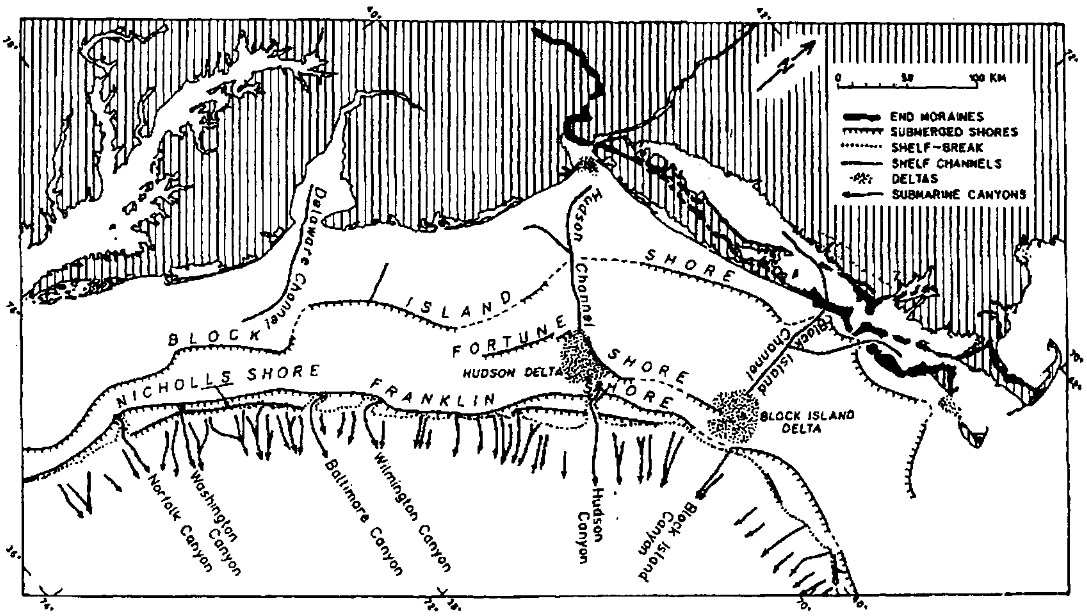


Figure 1.3 - Submerged Shorelines of the Northeastern United States (Emery and Uchupi 1972)

will be discussed later in the chapter, this date is almost certainly a great underestimate of the age of the shoreline. This was recognized quickly as such, and Emery and Uchupi (1972) have therefore suggested an Illinoian (300-130 ka) date for the terrace.

The Franklin Shore, however, is shallower and further inland than the Nicholls Shore. Importantly, it intersects the head of Norfolk Canyon and therefore is within the geographic range included by this study. Additionally, it is more likely to be associated with a still stand in sea level during the most recent glaciation of the late Wisconsin (Veatch and Smith 1939; Emery and Uchupi 1972). Ewing et al. (1960) have cautioned that both of these shorelines have been completely or partially buried by more recent deposition of sediment. However, the fact that they are present at all is promising for the search for other similar features nearby. There is also a third shoreline that may be of interest for this thesis. The Block Island/Atlantis Shore is substantially shallower and further inland than the Franklin Shore in most places.

However, to the south, particularly near Washington and Norfolk Canyons, it is present much further from land than it is to the north (Emery and Uchupi 1972) (Figure 1.3). Importantly, it represents a nearby shoreline that is much more likely to date to a still stand in sea level associated with the melting and retreat of the Laurentide Ice Sheet following the LGM. In any case, the presence of the Block Island/Atlantis and Franklin Shores gives hope for the possibility that other relict features are still intact and can be observed near the head of Norfolk Canyon.

The Canyons and Channels of the Mid-Atlantic Continental Shelf

There are many canyons that line the edge of the continental shelf between Hudson Canyon and Cape Hatteras. However, most of these are relatively small, with their heads either at the shelf edge or on the slope a short distance below the break in slope (Shepard and Dill 1966; McGregor et al. 1979). Only four cut into the continental shelf: Wilmington, Baltimore, Washington, and Norfolk. The head of each of these canyons is approximately 10 miles from the shelf edge (Veatch and Smith 1939; Kuenen 1953; Shepard and Dill 1966; Uchupi and Emery 1967; Uchupi 1968, 1970; Kelling et al. 1975; Keller and Shepard 1978). I will also include Hudson Canyon in this discussion because it shares many similarities with the other four and it has been the subject of more extensive research than any of the other canyons on the east coast of the United States (e.g. Shepard and Dill 1966). All of these canyons, as well as those further north, were formed as a result of erosion, which Keller and Shepard (1978) argue was a much more forceful agent on the continental slope during lower stands in sea level (also Kuenen 1953; Ewing et al. 1960; Uchupi 1968, 1970; Swift et al. 1972; McGregor et al. 1979; Mitchell 2004). It is possible that some of the erosion of the uppermost parts of the canyon occurred during periods of subaerial exposure, although this would not have been necessary for them to form.

In general, the submarine canyons of the eastern United States extend in a straight line down the slope with only widely rounded bends. This differs from similar canyons elsewhere, which typically exhibit much sharper bends. Additionally, many of the east coast canyons extend down to the bottom of the slope, a feature that is less common elsewhere (Kuenen 1953; Shepard and Dill 1966). The five canyons between Hudson Canyon and Cape Hatteras each have a deflection in course inside the break in slope (Kuenen 1953). All five generally trend downslope to the southeast, and all but Norfolk Canyon bend to the north near their heads (Shepard and Dill 1966; Kelling and Stanley 1970). For Wilmington and Baltimore Canyons, Kelling and Stanley (1970; also Veatch and Smith 1939) attribute the southeast-trending portions to drainage emanating from the vicinity of Delaware Bay during a late Tertiary lowstand. The north-hooked, shallow portion of each canyon head, they argue, was subsequently carved by a glacially enhanced, south-flowing drainage system during Pleistocene lowstands. Although Hudson and Washington canyons exhibit a similar northward hook, and therefore their shapes may have been formed by a similar mechanism, Norfolk Canyon instead bends to the west (Shepard and Dill 1966). This may still be due to a glacially-enhanced drainage system, but it may have instead been derived from the ancestral Susquehanna River and the region that is today Chesapeake Bay to the west.

The interiors of the canyons themselves are unlikely to preserve relict features for several reasons. Most obviously, it is unlikely that any parts of the canyons with the possible exception of the uppermost parts of the canyon heads have been exposed for any period of time. The average gradient of the east coast canyons is about 5 percent, with the walls even steeper (Shepard and Beard 1938; Ewing et al. 1963). For comparison, the continental shelf near Hudson canyon dips seaward at an angle of 0.4-0.5 degrees (Ewing et al. 1960). In addition, Kelling and Stanley (1970) found that the heads of Wilmington and Baltimore Canyons experienced episodes of filling and excavation. Based on data collected using seismic profilers, Uchupi (1968) estimates that several hundred meters of sediment fill may be present in the center of Wilmington and Norfolk Canyons. For reasons that will be discussed later in this section, it is possible that estuarine conditions may have existed in parts of the canyons (Weil 1977; Swift 1973, 1976).

Another factor influencing the interior of the east coast canyons is the occurrence of turbidity flows, the mechanism in large part responsible for the formation of the canyons. According to Perkins (2005), initially sediments build up in the head of the canyons. Eventually, the pile becomes unstable and the material breaks free, resulting in an erosive turbulent flow. Mitchell (2004) has observed some similarities between these turbidity currents and subaerial rivers. Namely, "in both turbidity currents and rivers, the driving force is gravity acting on a body of water of anomalous density compared with its ambient fluid." Both act as agents of erosion through the "plucking or quarrying of coarse material and abrasion by particles within the flow." Additionally, turbidity currents can carve channels into the floors of broader canyons, just as rivers can carve channels through wide valleys (Perkins 2005, citing Posamentier). Submarine canyons also behave like rivers in that numerous small ravines begin at the edge of the continental shelf and, like river tributaries, meet and feed into larger canyons further downslope (Mitchell 2004; Perkins 2005).

However, there are several important differences between turbidity currents and rivers. First, the density contrast between the flow and ambient fluid is less for a turbidity current than for a river current. Therefore, changes in the solid load have a greater effect on flow power and erosive potential underwater. Turbidity currents also usually are thicker than rivers, incorporate ambient water, and experience friction with the overlying fluid (Mitchell 2004). As a result of these factors, not only is erosion associated with turbidity currents more pronounced than that associated with rivers, so is the construction of underwater features. For example, Posamentier (in Perkins 2005) finds that while river floods on land can create natural levees a few meters tall, the levees formed by turbidity currents can grow up to 100 meters tall. Certainly then, there are mechanisms that serve to alter the submarine landscape inside the canyons themselves. However, we are also interested in relict features on the shelf adjacent to the canyons. Namely, if there is evidence of human occupation within the study area, it would be on the shelf rather than in the canyons. Although there has been some sedimentation on the outer continental shelf, current rates are minimal, as most sediments entering the marine environment are deposited in the present-day estuaries and nearshore areas (Curray 1960; Uchupi 1970; Swift et al. 1972; Hollister 1973; Swift 1973; Keller and Shepard 1978; Perkins 2005). This is particularly true on the east coast of the United States, where the edge of the shelf is much further from shore than on the west coast, explaining the relative inactivity of the canyons of the Atlantic continental shelf (Sommerfield in Perkins 2005).

Not only do some features of the submarine canyons of the Atlantic Continental Shelf resemble those of rivers, but some also may have been affiliated with major river systems during low stands in sea level. Hudson Canyon is an excellent example of this. There is a clear valley that crosses the continental shelf from near New York City, where the present Hudson River empties into the Atlantic Ocean, to the head of Hudson Canyon, which cuts further into the shelf than any of the other east coast canyons (Veatch and Smith 1939; Shepard and Dill 1966; Uchupi 1970) (Figure 1.1). Uchupi (1970) argues that during the Pleistocene, this valley, Hudson Channel, was the main stream that carried runoff from the New York-New Jersey region. During Wisconsin glaciation, the Hudson valley was deepened by glacial erosion (Uchupi et al. 2001). Water flowed from the series of glacial lakes that occupied the Hudson Valley through Hudson Channel, especially as the topography changed and these glacial lakes drained to the shelf. In that way, the channel acted as an extension of Hudson River until it was submerged. Uchupi et al. (2001) observe that the marine flooding of Hudson River took place 11,500 years ago, soon after the lakes in the valley drained more than 12,000 years ago.

Although they differ from Hudson Channel in some ways, there are also similar channels that appear to connect some of the other canyons of the mid-Atlantic region to present day river-estuary systems (Uchupi 1970; Swift et al. 1972; Edwards and Merrill 1977; Twichell et al. 1977; Kraft and John 1978; McGregor et al. 1979; Colman et al. 1990). There appear to be two channels and corresponding canyons associated with the present day Delaware River and Delaware Bay estuary. The Great Egg Channel extends from the Great Egg Harbor Inlet in southeastern New Jersey, north of the present day Delaware Bay, to near Baltimore Canyon (Swift et al. 1972). The Delaware Channel, however, extends from the present day entrance to the Delaware Bay to Wilmington Canyon (Twichell et al. 1977). Interestingly, these two channels cross about two-thirds of the way out to the shelf edge (Edwards and Merrill 1977). It seems that the Delaware Channel was formed during the late Pleistocene and is likely associated with the most recent low stand in sea level (Twichell et al. 1977). The Great Egg Channel, however, is likely associated with another, earlier paleochannel of the ancestral Delaware River. This would not be unique, as Colman et al. (1990; Colman and Mixon 1988; also Hack 1957) have observed evidence of three paleochannels for the ancestral Susquehanna River. The most recent dates to the low stand associated with the LGM, and the two others are progressively older to the north. Knebel and Circé (1988) have observed an analogous southward migration of the ancestral drainage systems beneath Delaware Bay. The Great Egg Channel may date to the same time as one of the Chesapeake Bay paleochannels; the younger of the two dates to the low stand in sea level approximately 150,000 years ago (Colman and

Mixon 1988; Colman et al. 1990). In general, Mixon (1985) has observed southwestward deflections of the Potomac, Susquehanna, and Delaware Rivers due to the downwarping of the inner edge of the Coastal Plain.

There is also a submerged channel associated with Norfolk Canyon, the feature of interest for this thesis. Although Uchupi (1970) argues that it is less well-developed than those off Delaware Bay and Hudson River, it nonetheless likely represents the extension of the ancestral Susquehanna River from present day Chesapeake Bay to Norfolk Canyon (Swift et al. 1972; Edwards and Merrill 1977; McGregor et al. 1979; Colman and Mixon 1988; Colman et al. 1990). However, Swift (1973) has argued that the shelf valleys of the North American Atlantic Shelf are not simply the result of the drowning of the master streams of the Atlantic slope by postglacial transgression, and therefore intact relict topography. Instead, he claims that they are "flood-channel retreat paths." Using the example of Delaware Bay, Swift (1973; also Weil 1977) argues that the channel represents the retreat path of the estuary as it was encroached upon by the rising sea level. This can certainly be translated to Chesapeake Bay and Norfolk Channel. Therefore, it seems that although estuarine conditions did not exist in the region of present day Chesapeake Bay until about 5,000 years ago (e.g. Blanton 1996), it is quite possible that estuarine conditions and the highly productive ecosystems that they provide were present along the Susquehanna River, but further out along the slope. Of particular interest for this thesis, it is possible that estuarine conditions may have existed in parts of Norfolk Canyon at the time of the LGM. This is particularly true given the evidence that sea levels may have been relatively stable for 5,000 to 7,000 years during this period (Peltier and Fairbanks 2006).

Sea Level Change and the Timing of the Last Glaciation

A central goal of this thesis is to reconstruct submerged landscapes off the coast of Virginia. In order to do that, however, it is necessary to better understand the evolution of sea level in the area and its impact on the location of the coastline at various stages of time. The major driving force for these changes was the most recent advance and retreat of the Laurentide Ice Sheet, which covered most of Canada and parts of the northern continental United States. It, along with other ice sheets throughout the Northern Hemisphere, locked up large amounts of water, thereby causing global sea levels to fall. Conversely, as the ice sheets melted following the end of the LGM, water reentered the oceans, raising global sea levels (for more detail, see Pirazzoli 1996; Benn and Evans 1998; Hughes 1998). As such, most experts estimate the global rate of eustatic sea level rise to have been between 120 and 130 meters since the low stand associated with the LGM (e.g. Emery and Garrison 1967; Emery et al. 1967; Whitmore et al. 1967; Milliman and Emery 1968; Belknap and Kraft 1977; Kraft 1977; Edwards and Emery 1977; Fairbanks 1989; Peltier 1990, 1994; Pirazzoli 1996; Hughes 1998; Peltier and Fairbanks 2006), although more conservative estimates have also been presented (e.g. CLIMAP Project Members 1976).

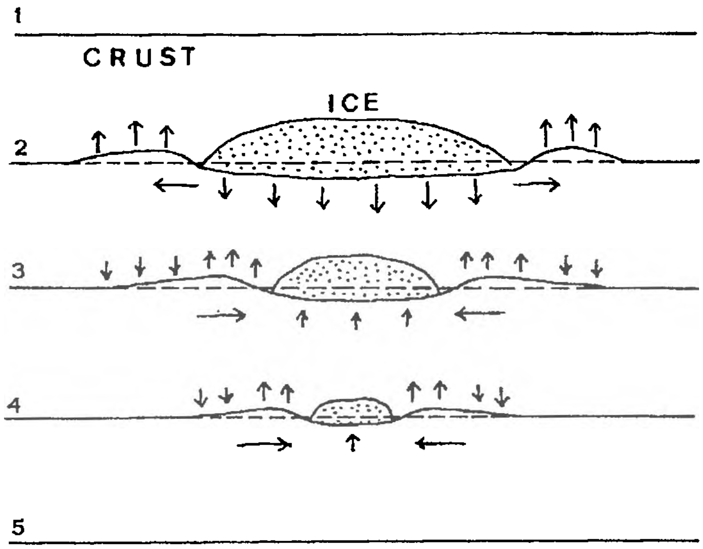
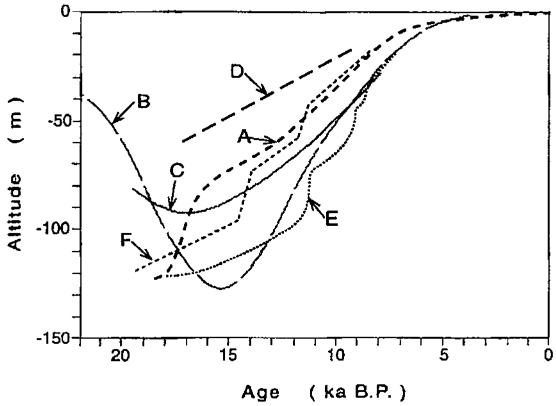


Figure 1.4 - Vertical Movements of Continental Crust Associated with Deglaciation (Pirazzoli 1996)

Certainly, however, there are other, more local forces affecting changes in sea level in various places in the world. Among the most important of these are isostatic depression and rebound associated with the loading and unloading of heavy ice sheets on the continental crust. The area around the ice sheet bulges around the ice margin. As the ice sheet melts, uplift of previously depressed areas occurs, and the marginal rim will tend to subside and move toward the center of the vanishing load (Pirazzoli 1996) (Figure 1.4). Therefore, as an ice sheet retreats, land that it previously covered first rebounds upward, and depending on rates of retreat and uplift, may then bulge as a result of depression on adjacent parts of the landscape still depressed by ice. This land surface is therefore moving up, then down as sea level rises eustatically. There are other factors that affect local changes in sea level, but it is not of particular relevance to discuss them here. However, it is important to note that sea level curves can be quite complicated, particularly for those regions that were near or under ice



Curve	Location	Reference
A	U.S. continental shelves	Curray, 1965
B	U.S. Atlantic shelf	Milliman & Emery, 1968
C	Eastern U.S. shelf	Dillon & Oldale, 1978
D	Southeast U.S. Atlantic shelf	Blackwelder *et al.*, 1979
E	Barbados	Fairbanks, 1989
F	Barbados	Bard *et al.*, 1990 b

Figure 1.5 - Relative Sea-Level Curves for North America (Pirazzoli 1996)

sheets during glacial periods, and that local sea level curves must be employed to understand changes in the landscape due to encroaching shorelines.

Unfortunately, however, it is not easy to generate high resolution relative sea level curves and as a result, there are great differences between different models. This is particularly pronounced the further one travels back in time as data becomes more scarce. Pirazzoli (1996; see also Bloom 1983a) compiled different relative sea level curves for various parts of North America (Figure 1.5). Two of the most widely accepted relative sea level curves are those of Milliman and Emery (1968) and Dillon and Oldale (1978). We can disregard for now the ages at which they observe the minimum in sea level, as the general consensus of the date of the LGM has been pushed back since they developed their models. This will be discussed later in this section. Nonetheless, Milliman and Emery (1968) observe a low stand in sea level of approximately 130 meters below present, whereas the value for the same event obtained by Dillon and Oldale (1978; also CLIMAP Project Members 1976) is closer to 85 meters below present.

This difference between the two models is even more pronounced when considering the minimal slope of the continental shelf (e.g. Ewing et al. 1960). These values are significant in their relation to the known shorelines in that region of the shelf. Namely, the Nicholls Shore is at a depth of about 132 meters (Ewing et al. 1963; Emery and Uchupi 1972). In the Milliman and Emery (1968; also Emery et al. 1967; Emery and Garrison 1967) model, this interpretation might then associate the Nicholls Shore with the LGM, suggesting a problem with the early radiocarbon date from this feature obtained by Ewing et al. (1963). Additionally, Dillon and Oldale (1978) project the current depth of the stretch of Nicholls Shore closest to Norfolk Canyon at approximately 105 meters below sea level. Their own estimate of 85 meters for the low stand, on the other hand, is quite close to where they project the Franklin Shore to presently be. Curray's (1965) curve is similar to that of Milliman and Emery (1968), although it is shifted back in time by about four millennia. Other researchers such as Blackwelder (1980) project the sea level rise to be even less dramatic than that represented by the curve of Dillon and Oldale.

Other estimates have been made as well for the amount of sea level rise since the LGM. Based on recovered mastodon and mammoth teeth, as well as radiocarbon dates from shallow-water shellfish species, peat deposits, and relict sands, Whitmore et al. (1967) argue that the outer part of the Atlantic continental shelf must have been exposed for about 10,000 years and the inner part for about 20,000 years. They compiled a database of known mastodon and mammoth teeth recovered by fishermen during dredging of the shelf. The average depth of recovery for the teeth was 36 meters, and the maximum was about 120 meters, although the nature of the recovery method renders their provenience inexact. Still, one of the three clusters of recovered teeth is not only near Chesapeake Bay, but it is along the edge of the shelf, quite near to Norfolk Canyon (Whitmore et al. 1967). Assuming that these teeth date to the most recent low stand in sea level, as the authors do, this suggests that the edge of the continental shelf near Norfolk Canyon would have been habitable by humans at this time. Additionally, Uchupi et al. (2001) place the sea level for southern New England at the time of the LGM approximately at the shelf break. Because the known shorelines on the northeastern continental shelf are continuous between Chesapeake Bay and southern New England (Emery and Uchupi 1972), it is not unreasonable to extrapolate the interpretation of Uchupi et al. (2001; see also Belknap and Kraft 1977) to the region around Norfolk Canyon.

Perhaps the greatest concern regarding whether a landscape could have been occupied during the most recent low stand is whether it was actually subaerially exposed at the time. Although I have primarily discussed the relative sea level height with respect to the continental shelf, the depth at which the canyons themselves are located is also important. Edwards and Merrill (1977) list the present-day depth at which each of the principal canyons of the northeastern United States becomes an obvious topographic feature (to the nearest 20 meter isobath). In general, Hudson Canyon and the four along the mid-Atlantic shelf are among the shallowest of the topographic features. Additionally, Norfolk Canyon is the only one of the fourteen canyons to be listed at under 100 meters. It is evident at 80 meters and the immediately adjacent Washington Canyon is evident at 100 meters. Although isostatic effects have caused differences in the amount of sea level rise across the continental shelf, the relative shallowness of Norfolk Canyon is nonetheless promising.

To this point, I have discussed the various estimates of sea level on the mid-Atlantic continental shelf while for the most part avoiding associating a date with this event. This is primarily because the best estimate of the timing of the LGM has been pushed back in time since the sea level curves that I discussed in the preceding paragraphs were generated. Although there was some variation, prior to the past two decades, the general consensus was that late Wisconsin glacial maximum occurred around 18,000 years ago (e.g. Curray 1960, 1965; Emery and Garrison 1967; Emery et al. 1967; CLIMAP Project Members 1976; Gates 1976; Edwards and Merrill 1977; Peltier 1990). As a result, this date is the one that appears most frequently in archaeological literature regarding the peopling of North America (see Meltzer 1995 and Fiedel 2000 for a discussion of the previous literature). This will be discussed in more detail in the next chapter, along with the implications of the greater antiquity of the LGM on the understanding of the earliest inhabitants of the Americas.

In the past two decades or so, however, the date of 21,000 years ago has replaced 18,000 years ago as the likely date of the LGM (e.g. Stone and Borns 1986; Peltier 1994; Boothroyd 2001; Uchupi et al. 2001). Additionally, rather than sea level reaching a low stand and immediately beginning to rise again, it seems more likely that it may have been somewhat stable at its minimum level for several thousand years before starting to rise. Mickelson et al. (1983) argue that the Laurentide Ice Sheet reached its maximum position by about 21,000 years ago and began retreating by about 18,000 years ago. Recent studies have sought to push back the date of the LGM even further. Hughes (1998) claims that sea level reached 125 meters below present by 23,000 years ago, but remained close to this level until 14,000 years ago. The CLIMAP Project Members (1976) observed relative stability in sea level from 24,000 to 14,000 years ago as well. More recently, Peltier and Fairbanks (2006) used a new model to find that although sea level was close to the widely supported estimate of 120 meters below present at 21,000 years ago (118.7 meters in their model), it was an additional 4 meters lower at 26,000 years ago. Although this would push the date of the low stand back 5,000 years, it does not really impact previous interpretations of when sea level began to rise to present levels. They instead argue that this means that the LGM was between 5,000-7,000 years long. This has important archaeological impacts that will be discussed in the next chapter.

In general, the rate of sea level rise has not been constant over time. Rather, there has been fluctuation since the LGM (e.g. Curray 1960; Kraft 1971; Weil 1977; CLIMAP Project Members 1976; Belknap and Kraft 1977; Bloom 1983b). As I mentioned in the previous paragraph, Peltier and Fairbanks (2006) observed a sea level rise of 4 meters from 26,000 to 21,000 years ago, a rate of 0.8 meters per 1,000 years. Most studies do not address rates of sea level rise until the Holocene (10,000 years ago to the present), but those that include the preceding period generally find that sea level was relatively stable for several millennia following the LGM (e.g. CLIMAP Project Members 1976; Hughes 1998; Peltier and Fairbanks 2006). An exception to this is

Curray (1960), who observed a rise from 65 to 45 fathoms (119 to 82 meters) below present from 18,000 to 16,000 years ago, and then a still stand at about 48 fathoms (88 meters) below present from 16,000 to 12,000 years ago. More researchers, however, argue that rapid deglaciation and sea level rise began around 14,000-15,000 years ago (Milliman and Emery 1968; Bard et al. 1990). In any case, Oldale and O'Hara (1980) place sea level off southern New England at about 70 meters below present at 12,000 years ago, and claim that it rose at a rate of 1.7 meters per century to about 33 meters below present at 9,500 years ago. This level of about 30-40 meters below present is common for the beginning of the Holocene (Milliman and Emery 1968; Dillon and Oldale 1978; Bloom 1983b). Since that time, Belknap and Kraft (1977) argue that sea level rise was 0.296 meters per century until about 5,000 years ago, 0.207 meters per century from 5,000 to 2,000 years ago, and then 0.125 meters per century since about 2,000 years ago. Custer (1986b) and others have argued that the slowing of sea level rise at about 5,000 years ago was instrumental in the formation of the Chesapeake Bay and Delaware Bay estuaries. Kraft (1971) and Oldale and O'Hara (1980) present curves with analogous changes in the rates of sea level, although that of Oldale and O'Hara is notable for having a rate of sea level rise in the last 2,000 years that is an order of magnitude less than Belknap and Kraft. These changes in rates of sea level rise and the relative position of the coastline around the Americas through time had strong influences on human occupation of these continents throughout the period since the LGM, as will be discussed in the next chapter.

Chapter 2 - Paleoenvironments, Archaeological Background, and Hypotheses

Late Pleistocene and Early Holocene Paleoenvironmental Conditions Near Norfolk Canyon

To better understand which parts of a landscape humans occupied at various points in prehistory, it is first necessary to understand the environmental conditions that were present there and how they changed over time. Certainly, the inhabitants of the mid-Atlantic region of the United States during the LGM not only encountered very different coastal topography than today, but they also were exposed to a different climate and distribution of natural resources as well. These factors are all tied together. For example, climate affects food resources, as do sea level and topography. However, each must be understood to draw a picture of the conditions faced by human occupants of the region and speculate how they addressed them. Bonnichsen et al. (1987) discuss the importance of environment as a catalyst for change in human adaptive systems, arguing that "humans may respond through their adaptive systems to environmental extremes by reorganizing the structure of their settlement, subsistence, and procurement systems, by creating or adopting innovations to enhance chances of survival, and/or by dispersion." Such environmental extremes include those resulting from cyclical changes such as those associated with cycles of glaciation and deglaciation.

Glaciation affected the climate of various parts of the United States in different ways. For example, during the LGM, the southwest was generally moister than today whereas the southeast was drier (Baker 1983). There were also some differences between the northeast, which was close to the ice sheet, and the southeast. Kutzbach (1987) found that during the LGM, the northeast was 6 degrees C colder than present and the southeast was 2 degrees C colder than present. Estimates by Gates (1976) are even more extreme, as he argues that parts of North America and Europe immediately to the south of the ice sheets may have been as much as 10 to 15 degrees C colder than today. Kutzbach (1987) also found the northeast to be slightly wetter than present from 18,000 to 15,000 years ago (assuming a date of 18,000 years ago for the LGM) due to increased storminess along the border of the sea-ice and the ice sheet. Like Baker (1983), however, he argues that the southeast was substantially drier than today from 18,000 to 12,000 years ago, due in large part to reduced summer precipitation. Although Virginia is in somewhat of a transitional location between the northeast and southeast, its climate appears to have been more in line with the south, as it experienced about 20-50 percent less precipitation than today, with a higher percentage falling as snow (Conners 1986). However, Conners (1986) did find that that the climate of the coastal regions of southeastern Virginia was more moderate than the mountainous regions of the western part of the state.

Although North America was in general colder than today, there is evidence to suggest that the ice sheet may have had a moderating affect on seasonal climates. Summers would have been cooler due to the proximity to the ice and winters more mild due to the blockage of arctic air masses by the ice sheets (Wright 1987). It has also been suggested that adiabatically heated air descending from glacial surfaces raised temperatures along the ice front, although Fladmark (1983) challenges this hypothesis. In any case, as the ice sheets retreated during the LGM, it seems that the climate may have worsened before getting better, at least with respect to seasonal extremes in temperature (Wright 1987). This climatic shift and greater seasonality may have been in large part responsible for the great extinction event of large mammals that occurred in the closing millennia of the Pleistocene (e.g. Bonnichsen et al. 1987; Wright 1987). McLean (1986) has also argued that there may be a connection between higher ambient air temperatures and reproductive dysfunction among these species. This event will be discussed in greater detail in the next section as part of the debate over the role of human hunting on the extinction of these large mammals.

Despite the effects of increased seasonality, however, there was a general warming trend through the late Pleistocene following the LGM and the beginning of the Holocene (e.g. Gardner 1981). According to Custer (1986a), the environmental changes in eastern Virginia during the late Pleistocene and early Holocene were substantial, with a clear trend toward warm and dry conditions between 9,000 and 7,000 B.C. on the Delmarva Peninsula. However, just before this time, there was a notable climatic event that reversed some of the changes of the previous millennia. The Younger Dryas, from about 12,890-11,680 cal BP, was a sudden and major glacial readvance that, according to Anderson and Faught (2000; Faught 2004; also Kennett et al. 2009), "led to pronounced colder conditions, changes in the distribution of floral and faunal communities, and possibly a significant lowering of sea level." Onset of this event was quite rapid and it was characterized by dramatic short-term temperature fluctuations. Kennett et al. (2009) have argued that it may have been triggered by a swarm of comets or carbonaceous chondrites that produced multiple air shocks and possible surface impacts at approximately 12.9 thousand cal. years B.P. According to Delcourt and Delcourt (1986), the Younger Dryas was part of a period from 13,000 to 10,000 years ago that was characterized by vegetational disequilibrium and disharmonious faunal assemblages. Nonetheless, this was only a minor setback in the longer-term shift toward warmer temperatures and drier conditions that resumed immediately following the Younger Dryas (Edwards and Merrill 1977; Gardner 1981; Custer 1986a).

Certainly, factors such as relative temperatures, precipitation, and their seasonality are important by themselves; a warmer climate is more physically comfortable for humans and more precipitation decreases the possibility of droughts. However, equally important are their impacts on the natural resources available for human exploitation, namely the local flora and fauna. Meltzer (1988; Meltzer and Smith 1986) divides eastern North America of the late Pleistocene into two major environmental regions. The first, periglacial tundra or open spruce parkland was characterized by humans hunting species like caribou. The second, complex boreal or deciduous forest was much more species rich, allowing human populations to be generalists that exploited a wide variety of subsistence resources. In the full to late glacial, tundra vegetation was restricted to high altitudes or proximity to the ice margin (Davis 1983; Watts 1983; Meltzer 1988). According to Meltzer (1988; also Watts 1983), "the tundra habitat was both a climatic and successional phenomenon. Tundra vegetation was the first to colonize new landscapes exposed by glacial retreat." According to Dent (1981) these conditions existed in the northeastern United States until about 8,000 B.C. However, because it met none of the conditions mentioned above, it is most likely that the coastal plain of Virginia, including the now submerged continental shelf, fell into the second category, the complex boreal or deciduous forest, during and immediately following the LGM. At that time, Delcourt and Delcourt (1980) argue, the region was primarily dominated by Jack Pine Forest. Throughout the southeastern United States, pine/spruce forest or woodland was the most prevalent type (Watts 1983). Coastal Virginia almost certainly fell in line with this trend rather than that of the periglacial regions to the north (e.g. Fairbridge 1977).

However, Whitehead (1965) did notice appreciable differences in vegetation between southeastern Virginia and southeastern North8 Carolina during the full glacial period. Virginia was more boreal than North Carolina and was dominated by spruce and pine, with lesser percentages of fir and birch. There was a shift during the late glacial period to a pine dominated system with spruce, birch, and alder as associates. At this time, oak and hickory, two important members of the deciduous forest environment, began to appear. During the early postglacial period, the importance of these species began to grow as there was a gradual transition from northern hardwoods to an environment dominated by oak, hickory, sweet gum, and many other deciduous forest species. Whitehead (1965) argues that this environment reached maximum development around 7,000 years ago. Custer and Wallace (1982; Custer 1986a, 1990), however, suggest a slightly different chronology, although their focus area is just to the north of Virginia, in the Piedmont Uplands of southeastern Pennsylvania, northern Delaware, and northeastern Maryland. They extend the period of spruce-pine boreal forest cover through 8,000 B.C., although they also noted that at this time, low-lying areas would have included many small, poorly-drained settings that would represent game-attractive locales and good hunting locations. They argue that between 8,000 and 6,500 B.C., there was an increase in boreal forest cover, and although patterns of resource distributions would be similar to the previous period, resource locations would be fewer and more widely dispersed. It is not until 6,500 B.C., in their model, that oak-hemlock forests become more prevalent. Along with the development of these deciduous forest environments, Custer and Wallace (1982; Custer 1986a, 1990) argue, was an increase in the number of habitats for white-tailed deer in upland habitats and an increase in favorable hunting locales in all physiographic settings. They also note that gathered resources would have been more numerous and would have had a wider distribution during this period. Despite their differences, however, the models of Whitehead (1965) and Custer and Wallace (1982; Custer 1986a, 1990), along with those of other researchers (e.g. Carbone 1976; Edwards and Merrill 1977; Fairbridge 1977; Sirkin 1977; Delcourt and Delcourt 1980, 1986; Gardner 1981; Johnson 1983; Watts 1983; Conners 1986), all suggest a spruce-pine dominated boreal forest environment in coastal Virginia or similar nearby locations during and immediately following the LGM, and an eventual shift to deciduous forest species in the first several millennia of the Holocene.

The Virginia coastal plain, although a distinct physiographic region, is not ecologically uniform throughout. Turner (1978) describes three broad geographically and topographically defined ecological zones in the present day coastal plain. Along the Chesapeake and Atlantic coasts, there is a coastal zone characterized by pine forests. This zone extends inland along the major rivers until reaching brackish waters. A transition zone is located in the region in places where freshwater and saltwater meet. This zone is characterized by deciduous forests, although there is some merging with coastal pine forests. The third zone is further inland along the freshwater portions of the rivers, and is dominated by deciduous forests. Although the components of these zones were likely different at various times during the late Pleistocene and the Holocene, similar patterns were likely present among natural resources. Importantly, because sea levels were lower and parts of the present day continental shelf were exposed as part of the coastal plain during the late Pleistocene, the locations of these zones were shifted (i.e. regions that are now coastal were inland). Turner (1978) found that the best zone for the exploitation of wild fauna in the Virginia coastal plain was in the vicinity of the freshwater-saltwater transition. During the LGM, when parts of Norfolk Canyon may have exhibited estuarine characteristics, our study area at the canyon head may have represented such a resource rich transitional zone.

In general, estuaries are characterized by very high productivity. Barber (1979) has argued that lower estuaries are the most productive environments on earth. In addition, upper estuaries represent ideal locations to exploit transient species such as anadromous fish (Turner 1978; Barber 1979). Also of great importance are shellfish, which are most abundant and available in freshwater-saltwater transition zones (Turner 1978). Chesapeake Bay is an appropriate example of the importance of estuaries for marine resources. Before the estuary formed around 5,000 B.P., Blanton (1996) argues that the Chesapeake Bay basin would not have been unique among major stream valleys in the area. The subsequent formation of the modern estuary distinguished the area as a zone that yielded resources that were richer, more predictable, and more extensively distributed than they were before. A similar shift occurred at roughly the same time near Delaware Bay (Custer 1986b; Blanton 1996).

Custer (1986b, 1988) has argued that the primary cause of the formation of stable estuaries following 5,000 B.P. in the Chesapeake region was the dramatic reduction in the rate of sea level rise. This is very similar to the pattern observed in Narragansett Bay, Rhode Island, where Kerber (1984) argues that estuarine succession did not develop until after 6,000 B.P. and that protected coastal areas favorable for the development of shellfish beds and other resources were not abundant before 3,000 B.P. Like Custer, he too attributes this to a reduction in the rate of sea level rise. Both use this argument to explain the apparent lack of large-scale shellfish exploitation by humans in their respective study areas before the time of estuarine succession. Still, there can be no doubt that shellfish were present before this time, as many of the sea level curves that I discussed in the previous chapter were generated using radiocarbon dates taken from shellfish at various depths on the continental shelf, including the oyster *Crassostrea virginica*, that was an important part of prehistoric subsistence (e.g.

Kerber 1984; Brennan 1977; Bernstein 1993). If estuarine conditions existed in Norfolk Canyon during the LGM it is quite likely that shellfish could have been available there. Additionally, because sea level may have remained around the low stand for 5,000-7,000 years (Peltier and Fairbanks 2006), the concerns posed by Custer and Kerber regarding rapid rates of sea level rise would not have been applicable. Additionally, Custer (1988) speculates that the Hudson River may have been more likely to contain shellfish beds than the other estuaries, and was in fact the site of the earliest clear evidence for shellfish exploitation in the northeast around 5,000 B.C. (Brennan 1977) because of its fjord-like structure. Its steep sides led to less lateral disruption of environments with sea level rise. The canyons of the edge of the continental shelf also have steep walls, allowing the coastline to have remained relatively stable as well (Shepard and Beard 1938; Ewing et al. 1963). Together, these factors suggest that parts of submarine canyons such as Norfolk Canyon may have been ideal locations to exploit marine resources, especially shellfish, during the LGM. Norfolk Canyon in particular may have been the Pleistocene counterpart of Chesapeake Bay, a vitally important cornerstone for the subsistence of local groups (Blanton 1996), and therefore may represent a promising search area in the quest to understand the circumstances surrounding the earliest occupation of eastern North America.

The "Clovis-First" Debate and the Colonization of the Americas

One of the archaeological questions most central to whether or not people occupied the landscape near Norfolk Canyon is whether people were even in the Americas at the time that it was subaerially exposed. The date of the initial peopling of the Americas has been the subject of intense debate for much of the twentieth century and earlier, and today remains a contentious issue in American Archaeology (see Meltzer 1995, Fiedel 2000, and Goebel et al. 2008 for recent summaries). In this section, I will present both sides of the debate: those that argue that the people of the Clovis cultural tradition, with a date of about 13,250-12,800 calender years B.P. (Waters and Stafford 2007), were the first inhabitants of the New World and those that believe that there were earlier, pre-Clovis populations in North and South America. It is not necessary for this thesis that I argue conclusively which of the two sides is correct. Rather, I argue that the evidence for a pre-Clovis occupation is sufficient to give credence to the possibility that people could have been in coastal Virginia and the adjacent continental shelf at the time that Norfolk Canyon was exposed. Although this would require a date for the initial peopling of the Americas earlier than even some pre-Clovis advocates would be comfortable with, I will demonstrate that the existing evidence allows for the possibility of the necessary early occupation of eastern North America.

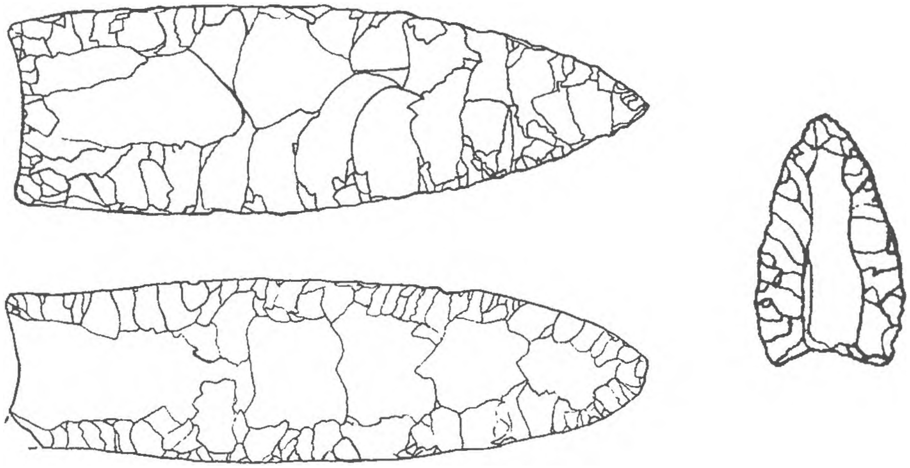


Figure 2.1 - Examples of Projectile Points from the Clovis Tradition (Not to Scale) (Justice 1987)

The Clovis Cultural Tradition and the Clovis-First Theory

Regardless of whether it represents the earliest evidence of human occupation of the New World, the Clovis cultural tradition is extremely important because it "stretched coast to coast as the first (and perhaps only) truly continental archaeological horizon" (Meltzer 1993). Foremost, the Clovis tradition is defined by its distinctive stone tool assemblage. The most notable technology of the Clovis tradition is the bifacial lanceolate fluted point, which does not appear to have any clear predecessor, especially with respect to the flutes near the base of the point (Figure 2.1). However, other tool types have been found associated with fluted points, including blades, burins, large bifaces, endscrapers, sidescrapers, and gravers, as well as a few tools of bone and ivory (Stanford 1991; Meltzer 1995; Fiedel 2000). Kelly and Todd (1988) suggest that in general, "Paleoindians used a lithic technology that was designed to be transportable, have long-term utility, and be of use in areas where only a limited number of stone sources might have been known."

Prior to the discovery of the Clovis tradition, there was another fluted point complex that was believed to represent the earliest human occupation of the Americas. In 1926, obviously man-made spear points were found embedded in the skeletons of extinct giant bison near Folsom, New Mexico. This was important because it associated humans with megafaunal species that were known to have become extinct during the Pleistocene, substantially pushing back the estimated earliest date of human occupation of North America, which had previously been estimated at about 5,000 years ago (Fiedel 2000). Less than a decade later, similar points were found alongside mammoth bones in Dent, Colorado and Blackwater Draw, near Clovis, New Mexico (Cotter 1937). Subsequent fieldwork at Blackwater Draw revealed the Clovis points to be stratigraphically below Folsom points, placing them as the earliest clear evidence of human occupation of the Americas at the time (Sellards 1952; Haynes 1964; Meltzer 1995; Fiedel 2000). It was not long before sites associated with Clovis were found throughout the United States (Haynes 1964). Certainly, the advent of radiocarbon dating technology was of vital importance for refining the Clovis and Folsom chronology. During the 1950s, a date of 10,780 ± 135 rcbp (uncalibrated radiocarbon years ago) was obtained for the Folsom component of the Lindenmeier site in Colorado (Fiedel 2000). In 1959, the Lehner Clovis site in Arizona was dated to 11,290 ± 500 and 11,180 ± 140 rcbp (Haury et al. 1959). As I mentioned in the introduction to this section, the current estimate for the timing of Clovis is from approximately 13,250 to 12,800 years ago (11,050-10,800 rcbp) (Waters and Stafford 2007).

Among the first to synthesize this information into a story of human colonization of the New World was C. Vance Haynes (1964, 1966; Dincauze 1984; Fiedel 2000). He postulated that during the time of the LGM, sea level was low enough that Beringia, a land bridge that connected eastern Asia with western Alaska and is now submerged by the Bering Strait, was exposed and allowed passage between the two continents. However, the Cordilleran and Laurentide Ice Sheets, which covered the western and eastern parts, respectively, of North America as far south as the northern parts of the continental United States, were adjoined and blocked passage to the rest of the continent. As the climate warmed and the ice sheets melted, they separated, opening an "ice-free corridor" between them that allowed the population stranded on the Alaskan side of the Bering Strait access to the rest of the New World. Despite this, Haynes never expressly ruled out the possibility that there were earlier occupants of the Americas. In fact, he even speculated about their presence, despite remaining skeptical of the most of the supporting evidence that existed (Haynes 1969; Dincauze 1984). Still, Haynes has been among the first to challenge sites that are candidates for pre-Clovis occupation, demanding indisputable evidence of their date of occupation (e.g. Haynes 1980). It was not until he visited Monte Verde in the late 1990s that he finally was willing to accept any evidence at all for pre-Clovis occupation of the Americas (Fiedel 2000).

Expanding on Haynes's model by attempting to explain the role of Clovis points in the colonization of the New World was Paul S. Martin. He agreed that humans entered the Americas through the ice-free corridor between the Cordilleran and

Laurentide Ice Sheets and found that the relative timing of this event and the large-scale extinction of numerous species of Pleistocene megafauna was not a coincidence, particularly when considering the ubiquitous appearance of fluted spear points at the same time (Martin 1973; Meltzer and Mead 1985; Fiedel 2000; Fiedel and Hughes 2004). Martin (1973; Martin et al. 1985) argues that upon the opening of the ice-free corridor, the first Americans swept through the Western Hemisphere and decimated its fauna within 1,000 years. In his model, humans killed off "inexperienced" prey before it had an opportunity to learn defensive behaviors. This explained the relative lack of kill sites found in many parts of the Americas, as humans would not have needed to develop more elaborate hunting techniques that may have been more archaeologically visible. As human populations entered new and favorable habitats, their numbers would "unavoidably explode" and hunt to a degree proportional to their growing population. Within a decade, the population of large fauna on the front of the wave of advancing humans would have been severely reduced or entirely obliterated. As prey would have become less readily abundant, the front would have swept on, eventually reaching the southern tip of South America by 10,500 years ago (Martin 1973). After publishing his generalized model in Science in 1973, Martin proceeded to defend it using more specialized models and specific evidence for individual species (e.g. Martin et al. 1985).

Despite its elegance, there are serious problems with Martin's overkill model, and at this point, it has been rejected by many members of the archaeological community (e.g. Meltzer 1995; Grayson and Meltzer 2003, 2004). Notably, problems with the relative chronology of the appearance of Clovis and the disappearance of megafauna have been exposed (Meltzer 1993, 1995; Grayson and Meltzer 2003, 2004). As I mentioned in the previous section, other researchers have attributed the extinction of megafauna to climatic changes during the late Pleistocene and early Holocene (Meltzer and Mead 1983; Bonnichsen et al. 1987; Wright 1987; McLean 1986; Grayson and Meltzer 2003, 2004). Additionally, the premise that Paleoindians were universally dependent on hunting of large game has come under attack. Instead, it appears that they were more likely to be generalized foragers and those that were more reliant on hunting usually targeted smaller species like deer rather than large megafauna (Dent 1981, 1996; Gardner 1981, 1989; Custer et al. 1983; Custer 1984, 1986b, 1988; Nicholas 1987; Kelly and Todd 1988; Meltzer 1988, 1993; Bryan 1991; Lepper and Meltzer 1991; Adovasio 1993; Anderson and Faught 1998). Bryan (1991) argues that the specialized big-game hunting economy developed only in those areas of North America having naturally limiting ecosystems. Nonetheless, as Meltzer (1995) notes, rejecting the overkill hypothesis does not imply an outright rejection of the Clovis-first model. Hunter-gatherers and foragers could have entered North America as the ice-free corridor opened without hunting megafauna. They also likely did not flood the New World as quickly as was suggested by Martin (Meltzer 1995). Nonetheless, some members of the archaeological community do still reject the alternate explanations for the peopling of the Americas and continue to accept a modified version of the overkill model (e.g. Fiedel and Haynes 2004). Regardless, Clovis remains important because it represents the earliest undisputed evidence of a human presence in the Americas.

Evidence for a Pre-Clovis Occupation of the Americas

Although there remains a faction of the archaeological community who still refuse to accept the presence of a pre-Clovis population in the Americas, evidence for an earlier population has been mounting over the course of the second half of the twentieth century and the early twentieth century. Alan Bryan (1977, 1991) has claimed that the Clovis-first "myth" was due in large part to the "historical accident" that the first recognized early sites were kill sites and the first verified association of artifacts with extinct fauna was in New Mexico rather than Central or South America. He further argues that had there been over the course of the twentieth century as many archaeologists working in South America as in North America and that had the first definite association of artifacts with extinct fauna been found at Tibitó rather than Folsom, neither the Clovis-first theory nor the idea that the earliest colonists were primarily big-game hunters would have ever gained widespread acceptance (Bryan 1991). Similarly, the skeptics who took it upon themselves to challenge all pre-Clovis contenders would not have existed.

As I mentioned in the previous section, archaeologists like C. Vance Haynes, as well as others such as Paul Martin and Dena Dincauze, were very critical of any sites that appeared to be pre-Clovis contenders (Fiedel 2000). As Adovasio (1993) argues, the criteria to establish the age of allegedly early sites in the New World have changed little since they were first established by Hrdlička and Holmes about 90 years ago. They include "(1) artifacts of indisputable human manufacture in primary depositional contexts; (2) clearly defined, that is, unambiguous stratigraphy with a precise knowledge of the emplacement mechanisms, overall context, and all associations of recovered artifactual and ecofactual materials; and (3) multiple radiocarbon determinations that are internally consistent and/or an equivalent chronology established by some other equally reliable and widely accepted chronometric method" (Adovasio 1993). Adovasio (1993) rejects two other commonly cited criteria, "replicability" and "high visibility," arguing that they allow for the possibility of sites unfairly being ruled out as anomalies. In general, the arguments over the antiquity of many early sites center around whether they meet these criteria. To date, only Monte Verde, a site that I will discuss later in this section, has been accepted by the skeptics (Fiedel 2000). In any case, while Clovis provides a mostly uniform technological adaptation that is confined to a relatively short and well-established period of time, candidates as pre-Clovis sites have much more diverse and poorly-defined artifact assemblages and have a wide range of radiocarbon dates. At the very least, their existence challenges the long held belief that humans only first entered the Americas through the ice-free-corridor as the North American ice sheets separated following the LGM.

In order to justify the early dates for a pre-Clovis presence in the New World, alternate models for the peopling of the Americas to the traditional ice-free corridor model have been proposed (Bryan 1991). Perhaps the most simple of these is the suggestion that people entered through the corridor before it closed prior to the LGM rather than after it reopened following the LGM. This would have required much earlier dates for the entrance to the New World than are currently believed. Nonetheless, the idea of a very early colonization of the continents has been present for decades. MacNeish (1976), for example, has argued that migrating bands crossed the Bering Strait some 70,000 ± 30,000 years ago and slowly moved southward reaching North America move than 40,000 years ago and South America more than 20,000 years ago. Willey (1966) has also suggested that humans may have come over from Asia 30,000 or more years ago, but such populations would have been part of a "pre-projectile point horizon," making them somewhat difficult to distinguish in the archaeological record. Additionally, it has also been suggested that there may have been two separate Pleistocene "penetrations" into the New World, one before 30,000 years ago unassociated with Clovis, and then a second about 15,000 years ago that lead to the fluted point tradition (Butzer 1991; Fiedel 2000; also Chard 1963; Willey 1966). However, as one might anticipate, there is not nearly enough evidence for these theories to convince the skeptics.

An interesting alternative to the ice-free corridor model is one of coastal migration. Among the strongest proponents of this hypothesis is Knut Fladmark (1983). Fladmark argues that even during during the LGM, there were scattered ice-free areas around the northern Pacific Coast of North America. This could have resulted in a discontinuous strip of outer coastal headlands, uplands, and islands capable of sustaining relatively complex and diverse flora and even terrestrial game near sea level. Fladmark (1983) contends that it would have been possible to travel between these coastal refugia either by boat or on foot over short stretches of ice. He further suggests that if people had the ability to cross a distance of 10-20 km of water, they may have been able to cross the Bering Strait during the period from 60,000 to 25,000 B.P. which he believes may have been a favorable interval for population expansion throughout the Americas. Nonetheless, Fladmark's model of coastal migration is in large part theoretical, as it lacks substantive archaeological support. Any evidence of human occupation of the coastal refugia that he postulates would have been subsequently submerged by rising water levels, and has yet to be discovered. Goebel et al. (2008) argue based on geological data that people likely colonized the Americas along the Pacific Coast as soon as it was deglaciated. Still, the possibility of traversing the Pacific Coast of North America by boat is not entirely out of the question, as there is clear evidence of the occupation of the Santa Barbara Channel Islands of California, which were never connected to the mainland and were therefore necessarily settled by boat, by 12,000 to 13,000 B.P. (e.g. Erlandson and Rick 2002). Goebel et al. (2008) also argue that boats were likely used in the process of entering the continent along the coast.

Despite the lack of archaeological evidence supporting the coastal migration model, it has been bolstered by the results of linguistic studies, although these have been challenged to some degree (e.g. Goebel et al. 2008). Rogers (1985) and Gruhn (1988) have approached the linguistic analysis of the peopling of the New World in two different ways, but both arrived at the same conclusion: that people were in the

Americas earlier than would be predicted in the Clovis-first model. Rogers (1985) argues that North America must have been inhabited prior to the Wisconsin glaciation due to the present day distribution of Native American languages. He claims that the longer a land area is free from ice, the more time there is for human colonization. As a result, glacial conditions, particularly those at the time of the LGM, would have had an impact on the current linguistic distribution. Rogers (1985) found that areas deglaciated after 12,000 B.P. are dominated by languages extending into areas deglaciated before 12,000 B.P., whereas those areas deglaciated before 12,000 B.P., including those to the south of the ice sheets, were dominated by languages exclusive to those areas. He also found that the greatest linguistic diversities were found on the periphery, but not the core of the deglaciated regions or the ice-free corridor. Additionally, the lack of any languages related to the Algonquian linguistic group in or near Beringia, Rogers argues, would dispute the possibility that this was the source of its spread throughout North America. Finally, the greatest diversity in the Na-Dene language group, which originated north of the ice sheets, is concentrated along a narrow strip of land on the Pacific coast of southeast Alaska, supporting the idea that it may have been a coastal refugium during the LGM.

Gruhn (1988) more strongly argues for a coastal migration route in her study. She too bases her analysis on linguistic diversity, but unlike Rogers, does not relate it directly to the position of the ice sheets at the LGM. Gruhn notes the great linguistic diversity of the Pacific Coast of North America, presenting it as evidence that people entered the continent along that route. Additionally, she argues that there is no linguistic evidence in support of the notion that interior northern North America or the Great Plains were the earliest populated zones. Rather, both Gruhn (1988) and Rogers (1985) argue that the interior areas were colonized relatively late and from the south. Gruhn (1988) is very hesitant to employ the problematic technique of glottochronology to obtain absolute dates for the divergence of related languages. However, she (Gruhn 1977, 1988) argues that her research in conjunction with archaeological evidence is consistent with a minimal possible date of 40,000 years ago for the earliest human entry into North America. As summarized by Meltzer (1989, 1995; also Fiedel 2000), there are critics of Rogers's and Gruhn's linguistic models who have argued that linguistic diversity could have resulted from a large number of factors that they did not take into account. Namely, they argue that a high diversity of languages could have resulted that geographic, economic, and other factors that had nothing to do with glacial events. Additionally, they find the lack of archaeological support at the least troubling, but Meltzer (1995) does not rule out the possibility of a coastal migration.

A recently proposed but highly controversial model for the colonization of the Americas posits that rather than entering the New World from Asia, the earliest inhabitants traveled over the frozen North Atlantic from southwestern Europe (Bradley and Stanford 2004). The authors argue that there is a general lack of data supporting an Asian connection and the origin of Clovis culture and technology remains a mystery, despite the fact that it has been treated as a given that people first entered the New World via Beringia. To support their argument, Bradley and Stanford note that

Figure 2.2 - Map of North America with the Sites in Question Highlighted (Modified from Adovasio 1993)

Upper Paleolithic Solutrean technologies of southwestern Europe are more similar to and are therefore more likely direct antecedents of Clovis than anything that is present in northeastern Asia or Beringia. This theory is very highly controversial in large part due to genetic evidence which strongly associates present-day Native Americans and DNA collected from early American skeletal remains and human coprolites with an Asian origin, and not at all with Europe (Goebel et al. 2008; Gilbert et al. 2008).

Nonetheless, the potentially pre-Clovis assemblages from Meadowcroft Rockshelter, Cactus Hill, and Page-Ladson, three east coast sites with pre-Clovis radiocarbon dates, could be interpreted to support the Solutrean hypothesis, as they are located in the United States Northeast and contain artifacts with technological characteristics of developmental Clovis technology. Additionally, a projectile point that was originally recovered by a scallop dredge boat about 40 miles off the coast of Cape Charles, Virginia has recently come to light in an Eastern Shore museum collection. This point, which appears to be very morphologically similar to typical Solutrean points, was recovered in the same dredge as megafaunal remains and other organic material dating to about 22,000 B.P. (I.R. Mather, personal communication 2009). This find is especially interesting for this study, as its proximity to Norfolk Canyon supports the idea that the nearby shelf was occupied during the low stand in sea level of the LGM. It also provides tentative support for Bradley and Stanford's (2004) hypothesis that the Americas were discovered by ice age European seal hunters who traveled further and further out to sea to exploit ice-edge resources until eventually reaching and establishing camps on the Atlantic Coast of North America.

There are three potentially pre-Clovis sites that are of particular relevance to this study (Figure 2.2). First, even though it is located in southwestern South America, Monte Verde is of great importance to any study of pre-Clovis settlement of the Americas. As I mentioned before, this site represents the first time that many skeptics accepted any evidence of pre-Clovis occupation of the Americas (Fiedel 2000). Radiocarbon dating places human occupation of the site at about 14,220 - 12,500 B.P. (Dillehay 1987, 1989, 1997; Dillehay et al. 2008; Adovasio 1993; Meltzer 1997; Fiedel 2000). This component of the site is a streamside settlement sealed beneath a peat layer that formed after abandonment, aiding in determining the stratigraphy of the site. This site appears to represent a single human occupation of several seasons' duration in which inhabitants exploited small game, paleollama, and mastadon, as well as a wide diversity of plants (Dillehay 1987, 1997; Adovasio 1993; Fiedel 2000). There is even a layer that suggests the site's inhabitants used seaweeds from distant beaches and estuarine environments for food and medicine. At the least, Dillehay et al. (2008) argue, the inhabitants of the site were accustomed to frequently exploiting coastal resources, and this may provide evidence that an early settlement of South America was present along the coast. There is also another, seemingly older component of Monte Verde. Two possible hearths have been found containing carbonized wood that has been dated to about 35,000 B.P. These features were found about 80 cm deeper than the later occupation and are associated with about two dozen pebbles of basalt that may have been human-modified (Tuross and Dillehay 1995; Fiedel 2000). Nonetheless, this date has not been nearly as universally accepted, and even Dillehay has doubts about its accuracy (Fiedel 2000).

The second site of interest is Meadowcroft Rockshelter, along with other nearby related sites. The rockshelter is located on the north bank of Cross Creek, a minor west-flowing tributary of the Ohio River about 47 km southwest of Pittsburgh, Pennsylvania. Despite stern opposition by Haynes and others (e.g. Haynes 1980, 1991; Mead 1980), Adovasio (1983, 1993; Adovasio et al. 1977, 1978a, 1978b, 1983, 1985) has vehemently defended the radiocarbon dates from the site that extend as far back as almost 20,000 B.P. The validity of these dates has been at the center of the longstanding debate which has not been fully resolved (Adovasio 1993; Meltzer 1995; Fiedel 1999). Haynes (1980) has contended that the charcoal that was dated was contaminated, rendering the dates untrustworthy. Still, the apparently proto-Clovis tool assemblage present at the site including lanceolate bifaces and small, prismatic blades detached from small, prepared cores are consistent with an early date for the site, and have helped to convince some researchers of its antiquity (Adovasio 1993; Fiedel 1999).

The third site of interest, Cactus Hill, is a relative newcomer to the debate, as it was only discovered in 1993 (Wagner and McAvoy 2004). This site is particularly interesting for this thesis due to its proximity to Norfolk Canyon, as it is located in a sand deposit rising above an alluvial terrace of the Nottoway River in the Coastal Plain of southeastern Virginia (Wagner and McAvoy 2004; Feathers et al. 2006). It is of great importance for the Clovis-first debate because unlike Monte Verde and Meadowcroft, Cactus Hill contains a cultural layer stratigraphically below a layer of Clovis artifacts. Charcoal from the lower cultural layer, which is primarily characterized by quartzite blades, has been dated to between 20,000 and 18,000 years ago (McAvoy and McAvoy 1997; Wagner and McAvoy 2004; Goebel et al. 2008). Additionally, optically stimulated luminescence ages obtained from sediment samples place the deposit containing the pre-Clovis artifacts at about 18,000 years ago (Feathers et al. 2006). All of these dates, which are certainly going to be subjected to intense scrutiny (e.g. Fiedel 1999), as well as the blade industry, which is typical of what many estimate proto-Clovis to have been, suggest a pre-Clovis occupation of Virginia that would likely have extended onto the then-exposed continental shelf.

One final factor that influences our understanding of the timing of the peopling of the Americas is the fact that the estimated date of the LGM has been pushed back from 18,000 years ago to at least 21,000 years ago and possibly as early as 26,000 years ago in the past two decades or so (e.g. Stone and Borns 1986; Peltier 1994; Boothroyd 2001; Uchupi et al. 2001; Peltier and Fairbanks 2006). Clovis itself has been well dated by a large number of radiocarbon samples from many sites throughout North America. However, an earlier date for the LGM could mean an earlier date for the opening of the ice-free corridor and therefore more time for people to enter the continent via this route prior to Clovis. Similarly, if people colonized the New World via a Pacific coastal route during the LGM, the dates for this could have been earlier than previously thought as well. In either case, this could lend credence to the possibility that some of the proto-Clovis sites could have been direct antecedents to Clovis while still having been occupied by people who entered the Americas via the traditionally cited mechanisms. Conversely, if the New World was colonized by occupants of what is today southwestern Europe during the LGM, this would allow for an earlier potential date of entry, perhaps putting that theory in line with the early dates obtained from Meadowcroft and Cactus Hill.

Finally, there remains the possibility that more than one of the colonization models is true. I am hesitant to doubt the curiosity and ingenuity of our ancestors, and I keep an open mind to the possibility of the theories of the settlement of the New

World by a Pacific coastal route or from Europe. It seems quite possible that the first colonization of the New World could have come via Beringia before the LGM. Later, there could have been a second group of colonists from Europe during the LGM, who brought with them the technology that evolved into Clovis. Although there is no genetic evidence to support this, it could explain the apparent lack of direct predecessors to Clovis technology in Alaska and its somewhat sudden appearance with only a few known examples of proto-Clovis tool assemblages. Additionally, Mason (1962) suggested the idea that Clovis originated in the United States southeast, a theory that has been echoed by many since then (e.g. Brennan 1982; Bryan 1991; Stanford 1991; Anderson and Faught 2000). Waters and Stafford (2007) have recently argued that there was a rapid spread of Clovis technology throughout the preexisting population of North America, but that the exact point of origin was not clear. However, the purpose of this section has not been to argue either side of the Clovis-first debate. Rather, it has been to demonstrate that it is quite possible that the mid-Atlantic region of the United States, especially the parts of the Virginia Coastal Plain that are now submerged, could have been inhabited during the period of a low stand in sea level associated with the LGM.

<u>Paleoindian Site Patterns and Land Use in the Mid-Atlantic United States</u>

In order to best predict which parts of the landscape near Norfolk Canyon were most likely to have been occupied by humans during the LGM, it is first necessary to understand the patterning of known nearby contemporaneous sites. As I made clear in the preceding section, there are very few sites in the eastern United States that potentially date to that time, and the dates of those that do have been called into question. The earliest time period with a large number of confirmed sites is the Paleoindian period, beginning with Clovis and ending around 10,000 B.P. Although it is an imperfect analog, the site distribution from this period likely provides the best reference for that of the preceding millenia, including the time of the LGM. Certainly, land use changed over time, particularly in the face of the changing topography, vegetation, and climate associated with deglaciation and associated sea level rise. Still, I argue in this section that in the absence of data from contemporaneous sites, Paleoindian site distribution is an acceptable substitute for the purpose of generating a predictive model of where people may have lived on the landscape.

Meadowcroft Rockshelter and Cactus Hill, two of the sites described in the previous section as containing pre-Clovis components, also both have evidence of continued occupation through the Paleoindian period and later (Adovasio 1983, 1993; Adovasio et al. 1977, 1978a, 1978b, 1983, 1985; Wagner and McAvoy 2004; Feathers et al. 2006). However, a number of very large sites in the mid-Atlantic region have been dated to this period, including the Williamson site in Dinwiddie County, Virginia (McCary 1951, 1976, 1983; Haynes 1972; Benthall and McCary 1973), the Thunderbird and Fifty sites in Warren County, Virginia, which make up Gardner's (1977, 1981, 1983, 1989) Flint Run Complex, the Hopewell and Point-of-Rocks sites in Chesterfield County, Virginia (McAvoy and Bottoms 1965; McAvoy 1979), the Shoop Site in eastern central Pennsylvania (Witthoft 1952), the Shawnee-Minisink Site in northeastern Pennsylvania (Crowl and Stuckenrath 1977; Foss 1977; McNett et al. 1977; Dent 1981), and the Plenge Site in northwestern New Jersey (Kraft 1973, 1977). Similar sites are also present throughout New England, including the Bull Brook Site in Ipswich, Massachusetts (Byers 1954, 1955), the Reagan Site in northwestern Vermont (Ritchie 1953), the Whipple Site in southwestern New Hampshire, and the Vail Site in northwestern Maine (Gramly 1984). McCary (1983) describes several other Paleoindian sites in Virginia, including the Isle of Wight County Site, the Dime Site, the Quail Springs Site, the Richmond or Kingsland Creek Site, the Bourne or Rockville Site, and the Mitchell Plantation Site. In general, however, the number of sites associated with fluted points has grown far too numerous to mention all of them, especially when taking small sites and isolated finds of projectile points into account (see McCary 1951, Mason 1962, Brennan 1982, Custer et al. 1983; Turner 1989; Anderson and Faught 1998, 2000).

Of these fluted point sites, by far two of the largest and most extensive are the Williamson Site, which runs for about one mile along a flat-top ridge spreading about 200 yards at its widest (McCary 1951, 1983), and the Thunderbird Site, which is approximately 300 feet wide and extends for slightly less than a mile along a Late Pleistocene-Early Holocene terrace (Gardner 1983). Clearly, sites of this size are far easier for an archaeologist to find than small ephemeral occupation sites and isolated artifacts. This is particularly true underwater, where surveying and testing for sites is much more difficult and expensive. Therefore, the fact that such large sites existed at such an early date is promising for our search for earlier submerged sites, demonstrating that large sites were not confined to the latest periods of prehistory.

Despite the geographic variability in the location of many of these sites, they possess a number of commonalities, particularly with respect to their placement on the landscape. In particular, many of the sites are clearly associated with rivers or creeks. In his study of the Delmarva Peninsula, for example, Custer (1984) observed two main categories of site settings: "1) poorly-drained swampy environments, which may be swampy frequent floodplains of major and minor drainage, bay/basin features, sinkholes, or drainage divide swamps; and 2) well-drained floodplains or terraces of the major drainages." He further found that those sites associated with poorly-drained swampy settings are primarily hunting/processing sites and related base camps, whereas those associated with well-drained settings are more often base camp sites associated with outlying hunting sites or quarry-related activities. Both environments can be affected by the presence of freshwater. In regard to the first group, swamps are formed by the poor drainage of water. However, sites of the second group, while better drained, are similarly dependent on resources made available by nearby rivers or creeks. This not only includes the water itself, but also cryptocrystalline rocks such as chert, flint, jasper, and chalcedony, which were commonly used as source material for stone tools. Erosion due to running water could have exposed previously buried outcrops. Additionally, the most widespread source of these lithic materials is riverine transported boulders, cobbles, and pebbles. Rather than being confined to isolated outcrops, this material occurs along the course of the river on fans, terraces, and colluvial slopes (Gardner 1983).

As I mentioned previously, both the Williamson and Thunderbird Sites are long and narrow. In each case, this is partially due to the presence of a nearby river or creek. The Williamson Site extends along a ridge running parallel along the south side of Little Cattail Creek (McCary 1951, 1976, 1983; Haynes 1972; Benthall and McCary 1973). The Thunderbird Site and the nearby Fifty site are located along the inner edge of the floodplain of the South Fork of the Shenandoah River. The former is located on a Late Pleistocene-Early Holocene terrace, whereas the latter is situated on an alluvial fan which overlooked a slough or abandoned channel of the braided south fork at the time of occupation (Gardner 1983). All three sites contain available primary (in situ outcrops) and secondary (river transported materials) cryptocrystalline rocks that were clearly important resources for the inhabitants (McCary 1951, 1976, 1983; Haynes 1972; Benthall and McCary 1973; Gardner 1977, 1981, 1983, 1989).

Other major Paleoindian sites have riverine foci as well. In Virginia, the Hopewell site is located on the top of a fifty-foot bluff overlooking the Appomattox River (McAvoy and Bottoms 1965) and the nearby Point-of-Rocks site is located several hundred yards north of the same river (McAvoy 1979). Additionally, both sites have lithic components, although the one at the Hopewell Site is much more extensive, as it contains local sources of quartzite and chalcedony, the latter of which is present in the river bed below the site. The Point-of-Rocks Site, however, is typical of small Paleoindian camp sites without abundant naturally occurring chert resources, as it has produced a relatively small number of artifacts and a limited collection of debitage (McAvoy and Bottoms 1965; McAvoy 1979).

Another site of particular relevance to this study, despite its greater distance from the Virginia Capes, is the Shoop Site in eastern central Pennsylvania. This site is of interest because of its location adjacent to the Susquehanna Valley on the west, although the closest water body is Armstrong Creek, a tributary of the Susquehanna. As was the case with the Williamson and Thunderbird Sites, the Shoop Site is long and narrow, situated on a plateau, and bounded to the north by Armstrong Creek (Witthoft 1952). Unlike those other sites, however, it seems that many of the artifacts present at the site are made from a variety of exotic rather than local lithic materials. Still, Witthoft (1952) observed that the majority of the lithic material present at the site is of mottled bluish western New York Onondaga chert, pebbles of which can be found in river gravels of the Susquehanna all the way to the Chesapeake Bay. Nonetheless, in the initial work done at the site, he did not observe any direct evidence that river pebbles were the source of the chert used for these tools. Meltzer (1988) has argued that the Shoop Site was unique among Paleoindian sites in the region of eastern North America that was never glaciated in that it was the only one that was dominated by exotic lithic types. Nonetheless, it is clear that the area near the Susquehanna River, which during the LGM would likely have extended to Norfolk Canyon, was occupied during the Paleoindian period, and that it may have carried important chert resources that could have been available along its course.

Other important Paleoindian sites throughout the northeastern United States have a similar riverine focus (see map in Funk 1978). Elsewhere in the mid-Atlantic region, the Plenge Site and the Shawnee-Minisink Site fit the same pattern. The Plenge Site is located on a gently sloping terrace about 200 feet from the Musconetcong River, a tributary of the Delaware River in northwestern New Jersey, and 15 to 18 feet above the silted river flats. Additionally, although there are no nearby chert outcrops or quarries, there are abundant shale, chert, jasper, and chalcedony pebbles and cobbles available on the site (Kraft 1973, 1977). The Shawnee-Minisink Site is located on the western side of the Delaware, at its confluence with Brodhead Creek. It is in alluvial sands of the second terrace above the Delaware River (Crowl and Stuckenrath 1977; McNett et al. 1977). "Black flint" that was found at the site was obtained both from quarries and surface-collected cobbles (McNett et al. 1977). Additionally, the exotic materials present at the site may have been carried as cobbles by natural transport (Marshall 1985; Meltzer 1988). In New England, the Bull Brook Site is located on a kame terrace on the south side of Bull Brook (Byers 1954, 1955), the Reagan Site is located at an elevation of about 300 feet above the Missisquoi River about three-quarters of a mile away (Ritchie 1953), the Whipple Site is situated on a gently sloping terrace or deltaic deposit 180 meters from the modern Ashuelot River course (Curran 1984), and the Vail Site is located immediately adjacent to an ancient channel of the Magalloway River (Gramly 1984). Clearly, then, throughout the northeast, large Paleoindian sites are frequently found associated with rivers and streams.

As I mentioned in the first section of this chapter, Meltzer (1988; Meltzer and Smith 1986) has divided eastern North America of the late Pleistocene into two major environmental regions which were associated with human settlement and subsistence patterns. The boundary between them was delineated by the maximum extent of the Laurentide Ice Sheet during the LGM. To the north of this line was the glaciated region, which during the Late Pleistocene was primarily a periglacial tundra or open spruce parkland (Meltzer 1988). The Paleoindians that occupied this region were highly mobile, possibly specialized hunters, exploiting caribou. Kelly and Todd (1988) have argued that this mobility required a highly portable technology which could fulfill all tool needs, such as bifaces. Additionally, most Paleoindian tools were manufactured from high quality cryptocrystalline raw materials which were in many cases transported long distances. This could have been due both to the greater selectivity in choosing the highest quality raw materials for the maximum utility and use-life of the tools and to the frequent range shifts of the people who used them (Kelly and Todd 1988). In the Eastern United States, Meltzer (1988) has argued that this pattern of a reliance on exotic lithic materials is confined to the northern zone that was glaciated during the LGM. South of the maximum extent of the ice sheet, with the exception of the Shoop Site, as I mentioned previously, there was a greater reliance on local, but nonetheless generally high quality, cryptocrystalline rock (e.g. McCary 1951, 1976, 1983; Witthoft 1952; McAvoy and Bottoms 1965; Haynes 1972; Benthall and McCary 1973; Kraft 1973, 1977; McNett et al. 1977; McAvoy 1979; Gardner 1977, 1981, 1983, 1989; Marshall 1985; Meltzer 1988).

During the Late Pleistocene, the region to the south of the LGM ice margin, according to Meltzer (1988), was an extensive complex boreal/deciduous forest. Also unlike the north, he found that the inhabitants of these forests were generalists who exploited a variety of subsistence resources with a less mobile settlement system. Therefore, while in the north, some large sites may have been reoccupied many times because they were ideal hunting locations on seasonal migration routes, in the southern, boreal/deciduous forests, stone was probably the only resource to promote reuse of a particular location (Meltzer 1988; Kelly and Todd 1988). In the decades following their initial discovery, it was generally accepted that the Folsom and Clovis traditions were primarily used for big game hunting of presently extinct megafauna (e.g. Martin 1973). The flaws in Martin's overkill model do not by themselves force a rejection of the idea that the Pleistocene inhabitants of North America were big game hunters. However, despite the fact that the earliest fluted point sites that were found were associated with megafaunal remains, most such sites that have since been studied have not had such an association. This is particularly true in the eastern United States, where the possible "kill site" associated with the Vail Site in Maine is a rare exception to the rule (Bryan 1977; Gramly 1984; Meltzer and Smith 1986; Meltzer 1988, 1995; Lepper and Meltzer 1991).

Currently, the consensus among archaeologists is that rather than big game hunters, Paleoindians were primarily generalized foragers, utilizing a wide range of resources (e.g. Lepper and Meltzer 1991). Kelly and Todd (1988; also Meltzer 1993) have argued that early Paleoindians were probably generalists in relation to large terrestrial faunal resources and opportunists in relation to all other food resources. This certainly appears to be true in eastern North America, particularly in the boreal/ deciduous forest zone (Dincauze and Mulholland 1977; Gardner 1977, 1981, 1983, 1989; Custer et al. 1983; Custer 1984; Kelly and Todd 1988; Meltzer 1988, 1993, 1995; Turner 1989; Adovasio 1993; Dincauze 1993; Anderson and Faught 1998; Fiedel 2000). Some advocates of the theory that Paleoindians were primarily big-game hunters have tried to argue that the absence of sites of this type is due to poor conditions for the preservation of organic materials due to the acidic conditions of the wet and humid forests of eastern North America (see Meltzer 1993). Although he does concede that preservation is relatively poor in the area for these reasons, Meltzer (1993) has effectively dispelled the idea that it is the reason that "kill sites" have not been found, citing that perhaps thousands of Pleistocene fossil localities of extinct megafauna have been found throughout North America in a variety of environmental settings, but none yield associated artifacts. The fact that Paleoindians were likely generalists is both beneficial and detrimental to our search for submerged sites, assuming their predecessors followed similar subsistence patterns, as Adovasio's (1993) research at Meadowcroft Rockshelter suggests they might have. This is beneficial for the current study, in that resources would have been relatively stationary and therefore people could have revisited the same sites many times, contributing to their archaeological visibility. It is detrimental, on the other hand, because many sites within such a subsistence pattern would have been very ephemeral and nearly impossible to relocate.

Such a stationary resource that appeared to play a major role in Paleoindian settlement patterns, particularly in the boreal/deciduous forest region of eastern North America, was cryptocrystalline rock. Gardner (1977, 1981, 1983, 1989; see also Custer et al. 1983; Custer 1984, 1990; Turner 1989) generated a model of Paleoindian settlement based on what he termed the Flint Run Complex, which included the Thunderbird and Fifty Sites in the Shenandoah Valley of northern Virginia. Central to this model is the distribution of lithic resources on the landscape. Gardner observes six types of sites within the Flint Run Complex: quarry sites, quarry reduction stations, quarry related base camps, base camp maintenance stations, outlying hunting sites, and isolated point finds. The large Thunderbird Site was the only example of a quarry related base camp within the complex, and the Fifty Site was one of the several base camp maintenance stations near Thunderbird (Gardner 1981). In any case, the first four site types, and certainly the largest and most complex sites, appear to be associated with quarries and other available sources of chert and other cryptocrystalline materials. Custer (1984; Custer et al. 1983) extends Gardner's interpretations about the importance of lithic materials within Paleoindian settlement patterns to the Middle Atlantic Coastal Plain. In particular, he looks at the Delmarva Peninsula, notable for its proximity to the study area for this thesis. Custer et al. (1983) argue that on the Delmarva Peninsula, cryptocrystalline resources are concentrated in a few locales, and settlement patterns are cyclical and oriented around specific sources. However, he also asserts that prime hunting and gathering settings are important foci for Paleoindian settlements as well. In any case, it is clear that chert outcrops, which may be visible in side scan sonar data, would have likely been central to the settlement patterns of the inhabitants of the nearby landscape. Similarly, if relict river paths are evident in the acoustic data, it is possible that lithic and other resources may have been available nearby, and they too could have represented a preferred place on the landscape.

Post-Pleistocene Settlement Patterns and the Formation of Chesapeake Bay

Aiding in our understanding of Paleoindian and earlier settlement patterns in regard to features of the landscape is the fact that many of the resources that they highly valued are similar and in the same location as they are today. Outcrops of cryptocrystalline rock are an excellent example of this. As I argued in the previous section, such lithic materials were central in Paleoindian site distributions, and likely were of great importance in previous periods as well. While the landscape has changed since then, adjacent sites have maintained the same spatial relationship to the stationary outcrops. Similarly, most rivers and creeks, and the resources that they would have provided, have remained relatively stable since the LGM, particularly in the unglaciated regions of the eastern United States (e.g. Swift 1973; Mixon 1985; Colman et al. 1990). This too allows for our understanding of the relationship of these features with nearby sites, as I discussed in the previous section.

Nonetheless, there is one type of feature that has been of vital importance in the past 5,000 years that would not have had any analogs from the Pleistocene that have not since been submerged. There is a series of large estuaries along the East Coast of the United States that exist where major rivers meet the Atlantic Ocean, including Hudson River, Delaware Bay, and Chesapeake Bay. As I discussed in Chapter 1, at the time of the LGM, each of these rivers would have continued to one of submarine canyons that line the edge of the continental shelf (Shepard and Dill 1966; Uchupi 1970; Swift et al. 1972; Edwards and Merrill 1977; Twichell et al. 1977; Colman et al. 1990). Consequently, there is reason to believe that at that time, parts of some of the canyons may have exhibited estuarine characteristics (Swift 1973; Weil 1977). In the first section of this chapter, I argued that during the LGM, Norfolk Canyon in particular may have been the Pleistocene counterpart of Chesapeake Bay, a vitally important cornerstone for the subsistence of local groups (Blanton 1996). Therefore, the purpose of this section is to analyze the trends in land use directly associated with Chesapeake Bay and how this information can be used to better predict how people would have occupied the landscape surrounding Norfolk Canyon if it was an estuary during the LGM.

Mouer (1991b) has argued that of all of the environmental changes that occurred in Virginia during the Archaic period (10,000 - 3,000 B.P.), none was more important than the formation of Chesapeake and Delaware Bays about 5,000 years ago. Before this event, Blanton (1996) argues, what is now the Chesapeake Bay would not have been unique among major stream valleys before 5,000 B.P. It was the creation of the estuary at this time that distinguished the area as a resource rich zone. Although there is some validity to that statement, it overlooks the fact that the Chesapeake Bay basin would have included the continuation of the Susquehanna River. Prior to inundation of the bay, all of the rivers and streams that today empty into it would have been tributaries of the Susquehanna, suggesting that the basin may have played a somewhat more important role on the landscape than some of the other river valleys. To date, a number of submerged sites have been found in present day Chesapeake Bay, which Blanton (1996) attributes to the shallowness of the embayment (which makes the sites easier to find and study) and the many flooded stream channels that drained the area. In any case, it is clear that the parts of the ancestral Susquehanna River that are now submerged by Chesapeake Bay provided viable and an many places preferred locations on the landscape for human occupation. This characteristic almost certainly continued along the river as it extended onto the continental shelf.

Following the slowing of sea level rise after about 5,000 B.P., Custer (1986b; 1988; also Whyte 1990) observes a marked increase in the intensity of utilization of coastal resources. He argues that prior to this time, extensive shell middens are not present or likely to be found due to the lack of stable water conditions. Custer (1986b) does acknowledge that occasional opportunistic use of shellfish, fish, or sea mammal resources was certainly possible and likely occurred before 5,000 B.P., but argues that any estuarine settings that would have made many of these resources available were very ephemeral. Gardner (1982) has argued that the mouth of the present-day Chesapeake Bay was inundated about 8,800 B.C., allowing for some estuarine settings to exist at this early date. However, the only sites that he or Custer (1986b) observed in those coastal settings are small procurement sites or transient camps with no associated shell middens. It was not until sea level rise slowed and Chesapeake Bay reached a state roughly approximating its present position, they found, that sites associated with coastal resources began to rival interior sites in size or complexity.

Custer (1986b, 1988) has argued that beginning in the Late Archaic period (5,000 - 3,000 B.P.), coinciding with the conditions described in the previous paragraph, there was a shift in settlement patterns and site distributions, which extended through the Early Woodland period (3,000 - 1,600 B.P.) to the end of the Middle Woodland period (1,600 - 1,000 B.P.). He characterizes this shift as an emphasis on the rich and predictable resources on the major river valley floodplains and the estuarine marsh settings (Custer 1988; also Kavanaugh 1983; Whyte 1990; Hodges 1991; Klein and Klatka 1991; Mouer 1991a). Certainly, river valley floodplains were important before this period as well, but estuarine marshes were a new addition to the settlement system. Both were the subject of greater focus than they had been before (Hodges 1991). Importantly, because Custer (1986a, 1986b, 1988; Custer and Wallace 1982) has argued that the only reason that estuaries were not a highly ranked resource before this time was because they were either nonexistent or unstable, there is no reason to believe that they would not have been an important component of human settlement and subsistence patterns during the LGM, when rates of sea level rise were slower and estuaries were likely more stable. Therefore, it is possible that shell middens could be present on the submerged landscape of the continental shelf, particularly near the head of Norfolk and the other submarine canyons. This is particularly true considering, as I demonstrated in the previous section, that Paleoindians were likely opportunistic generalists rather than big-game hunters. The same was likely the case for pre-Clovis occupants of the Americas as well (e.g. Gruhn 1988; Adovasio 1993).

Reinhart (1979) analyzed the cultural sequence of the James River and its tributaries on the Virginia Coastal Plain. He observed that during the Middle and Late Archaic in particular, sites were generally located strategically to maximize subsistence potential and minimize subsistence effort. This has an important implication for this study. Namely, Reinhart (1979) argues that preferred site locations are often found at the junction of several ecological zones, allowing the inhabitants easy access to several different resources. This makes logical sense, and could be extended to earlier periods as well. More explicitly, Reinhart (1979) observed several Middle and Late Archaic sites on river or creek banks in close proximity to a freshwater swamp. Certainly, intersections of rivers and their associated floodplains with estuaries fit this model as well (see Turner 1978).

Klein and Klatka (1991) found that the population of Virginia tripled from the Middle to Late Archaic. At the same time, there was a decrease in mobility and increase in sedentism that accompanied this expansion in population (Barber 1991; Klein and Klatka 1991). Both of these can be beneficial in the search for sites, as they typically lead to larger and denser sites. If one is to attribute both of these developments to the presence of Chesapeake Bay, it bodes well for the possibility of finding sites near Norfolk Canyon, assuming that parts of it contained estuarine conditions during the LGM. Not only would an estuary have been present, but a major river and its associated floodplain would have been present as well. Of course, it is overly short-sighted to attribute all of the changes in settlement and subsistence patterns that occurred during the Late Archaic to the formation of Chesapeake Bay. Similar changes, particularly with regard to dramatic increase in population size, occurred throughout the northeastern United States during this period (e.g. Snow 1980; Mulholland 1988). As I discussed at the beginning of this chapter, climate and other associated environmental changes certainly played a major role in the increase in population at this time (e.g. Whitehead 1965; Dincauze 1974; Carbone 1976; Gates 1976; Edwards and Merrill 1977; Fairbridge 1977; Sirkin 1977; Mulholland 1979, 1984, 1988; Davis et al. 1980; Delcourt and Delcourt 1980; Snow 1980; Dent 1981; Gardner 1981; Custer and Wallace 1982; Davis 1983; Fladmark 1983; Johnson 1983; Watts 1983; Connors 1984; Custer 1986a, 1990; Kutzbach 1987; Wright 1987; Bonnichsen et al. 1987; Lavin 1988; Meltzer 1988). Still, some changes in settlement and subsistence patterns that occurred at the time of the formation of the Chesapeake can be extrapolated to the LGM, particularly those associated with exploitation of coastal resources, and they must be included, however cautiously, in the model generated in this thesis.

Hypothesis

There is one central hypothesis that drove all of the field and laboratory work done as a part of this project: that the landscape surrounding Norfolk Canyon would have been an ideal location for human settlement and subsistence during the periods that it was subaerially exposed. I will discuss this hypothesis in greater detail later in this section. However, there is another "sub-hypothesis" that I have addressed implicitly over the course of this chapter that is vital to the relevance of the main hypothesis. In the title of this chapter, I label the central part the "archaeological background." This is certainly what it was. However, in that section, I also presented the argument that not only was it possible that people had arrived in the New World by the time Norfolk Canyon was exposed during the LGM, but that they could have been living in the Mid-Atlantic region of the present-day United States.

As I attempted to convey, this argument is certainly non-trivial and has been, in one form or another, the subject of intense debate for the better part of the last century. Nonetheless, by this point, enough evidence has mounted for a pre-Clovis occupation of the Americas that despite the fact that some skeptics remain unconvinced, the possibility of an early colonization cannot be dismissed. Additionally, despite the fact that the early dates obtained for many pre-Clovis contender sites have been successfully challenged, a number of other sites have withstood such attacks, and as Adovasio (1993) argues "will not go away." Of these, three of the most promising candidates are at Monte Verde, Meadowcroft Rockshelter, and Cactus Hill. The fact that two of these are in the Mid-Atlantic region is only more promising for the possibility that sites are present on the continental shelf off the coast of Virginia. Similarly, the projectile point that was recovered near Norfolk Canyon in a scallop dredge with organic material that has been dated to 22,000 B.P. also supports this possibility (I.R. Mather, personal communication 2009).

Now that it has been established that people *could* have been living on the landscape surrounding Norfolk Canyon during the LGM, it becomes necessary to ask whether they *would* have lived there. That is, based on the available evidence and the data collected as a part of this thesis, did the canyon and adjacent parts of the continental shelf provide sufficient desirable resources to attract humans to live there as opposed to other places on the landscape? This first requires that we ask what resources were important to the potential inhabitants of this region. Unfortunately, as I have argued in this chapter, this is difficult to assess directly, as there are very few sites that potentially have the same antiquity as those that would be present near Norfolk Canyon. Those that do exist (Meadowcroft, Cactus Hill), would have been much further inland and therefore different environmental conditions and natural resources may have been present. For this reason, to best understand which parts of the landscape would have been preferred, we must turn to other periods of prehistory that are better represented in the archaeological record.

As I discussed in the previous sections of this chapter, the periods chosen to extrapolate settlement and subsistence patterns to the one in question had both temporal and topographic similarities. In regard to temporal similarities, it makes sense that there could be some degree of continuity over time, although the introduction of the fluted point, possibly from Paleolithic people from Europe (see Bradley and Stanford 2004) may have been disruptive to this. Still, patterns from the Paleoindian period must be considered. Additionally, the earliest clear analog to what could have been estuarine conditions in Norfolk Canyon at the time of the LGM would have been during the Late Archaic, coinciding with the formation of Chesapeake and Delaware Bays. Certainly, a number of cultural and environmental changes had by this point made indelible changes on the way people interacted with the landscape. Still, many of the available resources were likely the same, thereby creating similarities in where people lived to exploit them. In any case, although data from other periods of prehistory can be quite useful, it must be considered with some degree of cautiousness.

At the time of exposure, the head of Norfolk Canyon would have been the site of the intersection of a major river, the Susquehanna, and possibly an estuary. As Turner (1978) has argued, shellfish are most abundant and available in such freshwater-saltwater transition zones. In addition, Barber (1979) has found upper estuaries such as this to be ideal locations to exploit transient species such as anadromous fish. Clearly then, the head of Norfolk Canyon, which is the study area for this thesis, represents an excellent location to find submerged sites, both because of the access it would provide to this transition zone, but also as Reinhart (1979) emphasizes, it would have been close to several ecological zones and the resources they would have provided. Similarly, it seems likely that other smaller rivers or creeks may have intersected the canyon further downstream, creating similar environments, particularly with regard to the availability of shellfish, there as well. Additionally, our study area also extends to the west of the head of the canyon. This certainly would have included parts of the floodplain of the river and any river terraces, both of which were of great importance within Paleoindian settlement systems. In regions of lesser sedimentation or disturbance, these features may be evident in the acoustic data that we collected. Also of great importance for Paleoindian settlement patterns was the availability of high-quality cryptocrystalline rock. Although it is somewhat of a long-shot, larger outcrops may be evident in side scan sonar data, particularly in river terraces where they may have been exposed by erosion, as appears to be the case on many Paleoindian sites on land (e.g. Gardner 1981).

Ideally, it would be of great utility to be able to estimate the position on the landscape of Norfolk Canyon at various times as it retreated following the LGM. Unfortunately, as I discussed in Chapter 1, the relative sea level curves and estimates for sea level height at various times vary widely. This uncertainty is only exacerbated by the flat continental shelf, causing small fluctuations in sea level height to translate to large changes in the position of the shoreline. For this reason, I do not seek in this thesis to associate various positions of the shoreline and locations of probable habitation with absolute dates. This is particularly the case considering the fact that we did not collect any core, rock, or radiocarbon samples. My goal is therefore to attempt to associate potential habitation locations with the low stand in sea level that occurred during the LGM as well as any still stands in sea level that occurred as the shoreline was retreating. In any case, the acoustic data that we collected for this project could reveal evidence of past shorelines, some of which may be related to previously known shorelines in the region.

Hypothesis: Parts of the landscape surrounding Norfolk Canyon would have been preferred locations for human habitation during periods of lower sea level, particularly during the Last Glacial Maximum. In particular, features that are associated with temporally or topographically similar archaeological sites on land are present on the landscape. Importantly, this hypothesis does not test whether the presence of these features actually translates to the existence of submerged archaeological sites.

Expectations

1. Topographic features associated with the period that the study area was subaerially exposed are clearly evident in the multibeam and/or side scan sonar data that were analyzed for this study.

2. Features that are associated with temporally or topographically similar archaeological sites on land are present on the landscape. This includes rivers or creeks with associated floodplains and well-drained river terraces.

3. There is evidence of a large river, namely the ancestral Susquehanna, intersecting the head of Norfolk Canyon.

4. Potentially cryptocrystalline rock outcrops may be evident in the side scan sonar data. However, it is unlikely that rock type can be distinguished without visual ground-truthing or the collection of samples.

5. Relict shorelines associated with the low stand in sea level that occurred during the LGM or later still stands may be evident in the acoustic data. These may or may not correspond to some of the previously recognized shorelines that extend throughout the continental shelf of the northeastern United States.

Null Hypothesis

This hypothesis addresses the possibility that the submarine landscape surrounding Norfolk Canyon does not resemble any of the preferred settlement locations as determined based on the archaeological record of Paleoindian sites in the Mid-Atlantic region and Late Archaic, Early Woodland, and Middle Woodland sites near Chesapeake Bay. As such, Norfolk Canyon did not represent an attractive locale for human occupation during periods that it was exposed subaerially. The purpose of this hypothesis then, is to enumerate the features that would suggest that the landscape might not have provided the appropriate resources to support a large or long-term human population. Importantly, like the hypothesis, the null hypothesis does not address the arguments that I made earlier in this chapter regarding how certain features translate to the availability of resources for human populations. Rather, it only suggests that such features either did not exist or were too sparse to make large-scale human occupation of the region viable.

Null Hypothesis: The landscape surrounding Norfolk Canyon would have contained very few if any preferred locations for human habitation during periods of lower sea level. In particular, features that that are associated with temporally or topographically similar archaeological sites on land are not present on the landscape. During the

LGM, occupants of the Mid-Atlantic region of the United States either lived further inland or in other coastal locations.

Null Hypothesis: Expectations

1. Topographic features associated with the period that the study area was subaerially exposed are not evident in the multibeam and/or side scan sonar data that were analyzed for this study. They may have not existed during low stands in sea level or they may have since been obscured by erosion or sedimentation.

2. Features that are associated with temporally or topographically similar archaeological sites on land are not present on the landscape.

3. It is unclear where the ancestral Susquehanna River would have intersected Norfolk Canyon.

4. No potentially cryptocrystalline rock outcrops are evident in the side scan sonar data.

5. As was the case with the first hypothesis, relict shorelines associated with the low stand in sea level that occurred during the LGM or later still stands may be evident in the acoustic data. These may or may not correspond to some of the previously recognized shorelines that extend throughout the continental shelf of the northeastern United States. This hypothesis does not challenge the contention that the landscape surrounding Norfolk Canyon was exposed during the LGM.

Conclusion

The purpose of the fieldwork done as a part of this project and the upcoming data analysis is, as presented by the hypothesis, to better understand the potential for human occupation of the landscape of the continental shelf near Norfolk Canyon. However, the possibility that people could have lived there is entirely dependent on the question of whether or not humans were even in the Americas, particularly in the Mid-Atlantic region of the United States, during the periods that the outermost reaches of the shelf were subaerially exposed. In this chapter, I addressed this "sub-hypothesis," arguing that it is quite possible that people occupied this region, and that they would have been available to access Norfolk Canyon, provided that it contained desirable resources that drew them there. Despite the fact that substantial work has been done to address our understanding of the earliest inhabitants of the New World, much remains to be done, particularly with regard to formerly coastal regions that are now submerged. As such, the main hypothesis addressed in this thesis has broader implications than whether Norfolk Canyon itself could have been part of the subsistence strategy of the earliest settlers of eastern North America. This study, particularly if followed up by future research cruises that focus on and sample regions determined to have likely been highly ranked in a pre-Clovis settlement and subsistence pattern, can have important applications to our understanding of coastal settlement and the exploitation of coastal resources during the LGM and possibly earlier.

Chapter 3 - Methods

Field Methods

In general, underwater archaeology is much more logistically challenging than terrestrial archaeology. This is certainly due in large part to the presence of water above the cultural surface. Not only does the water body make the cultural materials more difficult to access, it limits the time that can be spent on site, reduces visibility on site, and can also be detrimental to the possibility of keeping stratigraphy intact while excavating. Importantly, particularly for this project, the presence of overlying water has made submerged archaeological sites and other cultural materials much more difficult to find. In order to highlight the dearth of known underwater sites in North America, I (Jazwa 2008) previously compared the total number of known archaeological sites on Anacapa Island, the smallest of California's four northern Channel Islands, to that of the entire continental shelf of North America. Anacapa Island, despite having an area of only 1.8 km^2, has 27 recorded archaeological sites (see Rick 2006). In 1990, Stright (1990), could list only 35 inundated sites on the continental shelf, and only "a few" have been found since that time (Merwin et al. 2003). Of course, this is due both to the difficulty of finding underwater sites and the fact that much less effort has been put into searching for them, because of both the inherent practical and financial challenges.

The difficulty of finding submerged sites becomes greater the further one travels onto the continental shelf and into deeper water. In shallow water, scuba divers can be employed to survey for and investigate sites. In deeper water, this is not the case and the only option is to employ technologies and methodologies that are native to the fields of oceanography and ocean engineering. This is certainly true in the region of interest for this study, as it is located near the outermost edge of the Atlantic continental shelf of the United States. Additionally, such techniques have the benefit of being able to survey large areas relatively efficiently, undoubtedly much more so than scuba divers. Still, individual sites and the cultural components that they contain are very small in relation to the overall landscape and importantly, to the typical resolution of the acoustic instruments used by oceanographers. As such, rather than attempting to find individual sites, the current frontier in underwater archaeology is to locate drowned landscapes using remote sensing techniques and look for environmental features favorable for human settlement. As I discussed in Chapter 2, this is the goal for this thesis. Its purpose is foremost to determine which parts of the landscape surrounding Norfolk Canyon are most likely to have been the site of human habitation during periods of lower sea level.

The fieldwork done for this thesis is part of a larger archaeological oceanographic field project called the Virginia Capes Archaeology Project. Fieldwork for this project consisted of four oceanographic cruises that took place in the summers of 2006, 2007, and 2008. Two cruises each were conducted on the University-National Oceanographic Laboratory System (UNOLS) ship *R/V Endeavor* (Figure 3.1) and the National Oceanographic and Atmospheric Association (NOAA) ship *Thomas Jefferson* (Figure 3.2). The Virginia Capes Archaeology Project and the four associated cruises were under the direction of co-chief scientists Dr. I. Roderick Mather of the University

Figure 3.1 - R/V Endeavor

Figure 3.2 - NOAA Ship Thomas Jefferson

of Rhode Island (URI), Dr. Dwight Coleman of URI, and Dr. Gordon Watts of the Institute for International Maritime Research. This fieldwork was funded by the NOAA Office of Ocean Exploration, the Rhode Island Endeavor Program, and the Institute for Exploration (IFE).

There were three major archaeological objectives to the Virginia Capes Archaeology Project. The first was a side scan sonar survey of the region around the head of Norfolk Canyon with the purpose of locating any historic shipwrecks that may have been present in the area. Also included in this objective was video groundtruthing of any promising sonar targets using a remote operated vehicle. The

Figure 3.3 - A Klein 5000 Side Scan Sonar Towfish

second goal of the Virginia Capes Archaeology Project was to find a sixteenth century shipwreck that may have been present within the study area. A cannon dating to that century had been recovered in fishing nets, and as a part of our study, we collected magnetometer data in a grid surrounding the location where it was reportedly found in an effort to possibly find more iron artifacts from the same wreck. Finally, the third objective of the Virginia Capes Archaeology Project is the one that is directly related to this thesis. This was to generate a geological and archaeological topographic map of the landscape around the head of Norfolk Canyon. The side scan data that was collected as a part of the first objective was also used for this one as well. Additionally, to generate a high resolution map of the landscape, we collected multibeam sonar data. Finally, singlebeam sonar data was collected during the first cruise on the *Thomas Jefferson*. The approximate boundaries for the rectangular area from which data were collected were 37°3'N 75°6'W, 37°21'N 75°6'W, 37°21'N 74°30'W, and 37°3'N 74°30'W.

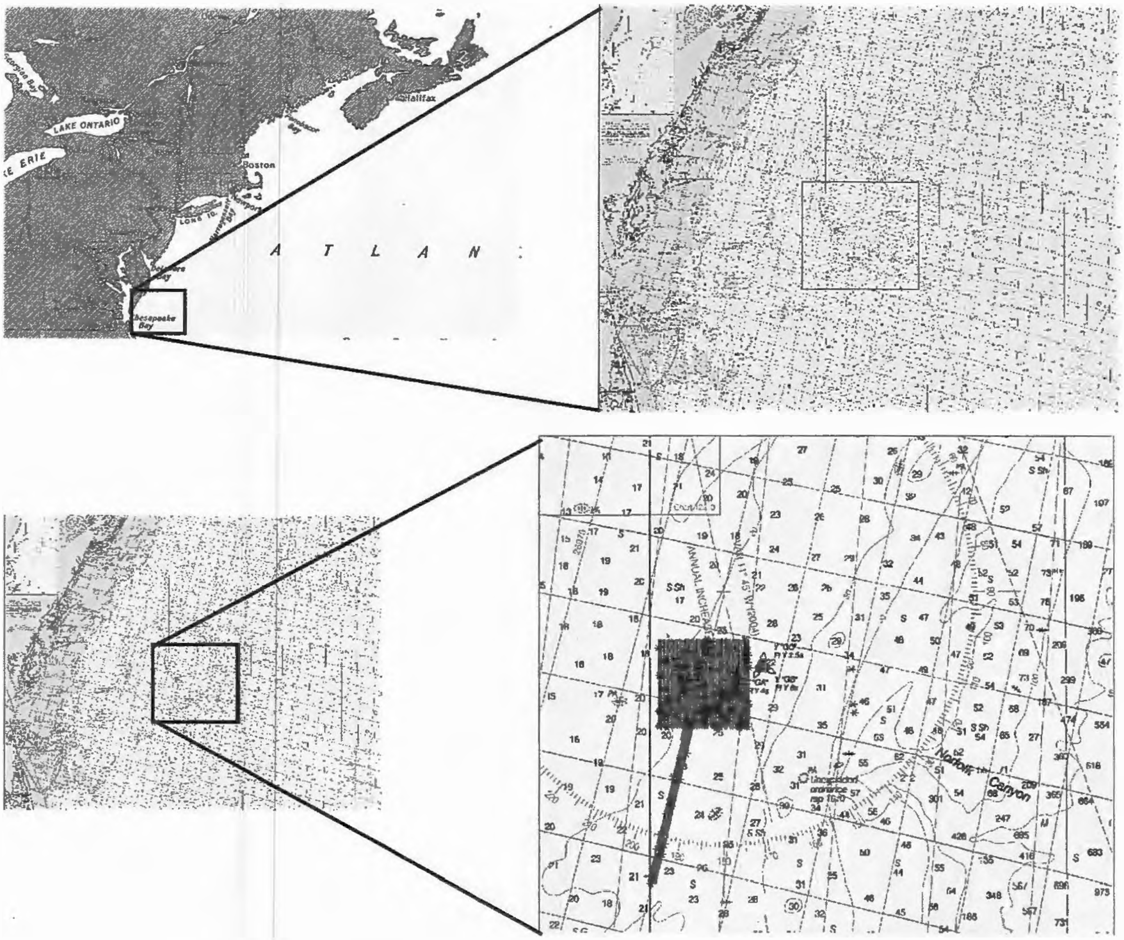


*Figure 3.4 - Upper Images: The Context of the Survey Area within the Northeastern United States
Lower Images: Tracklines for the 2006 Side Scan Survey, First Pass*

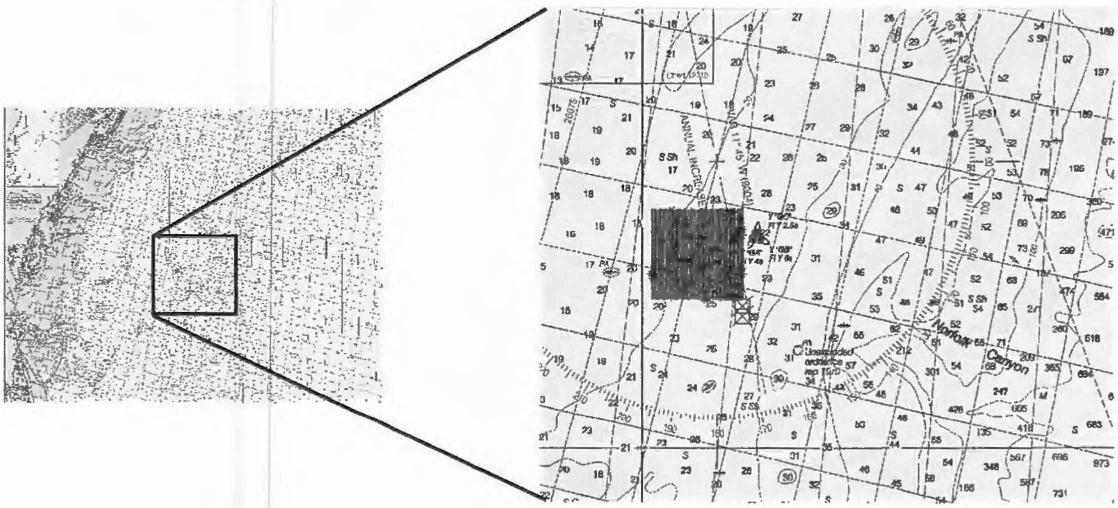


Figure 3.5 - Tracklines for the 2006 Side Scan Survey, Second Pass

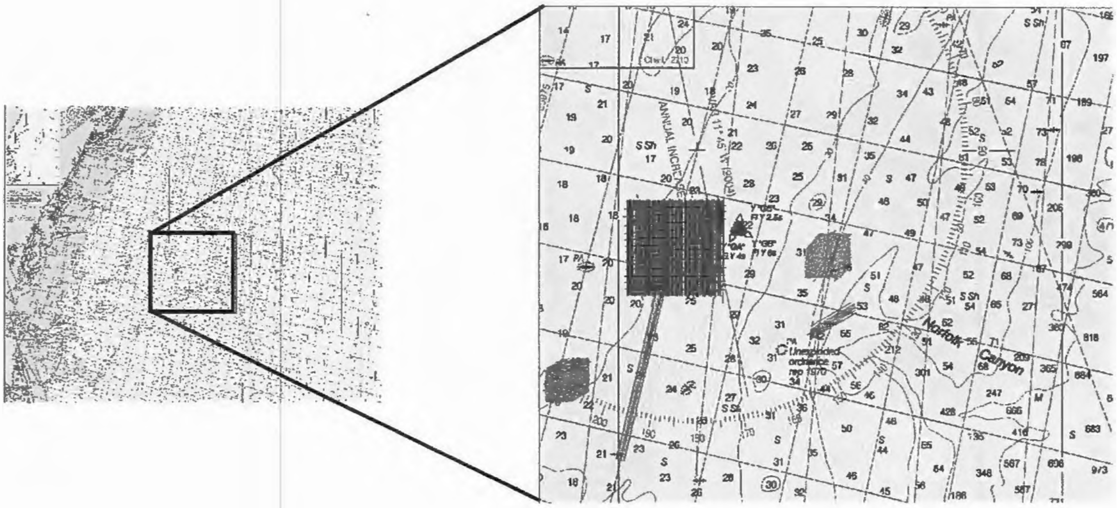


Figure 3.6 - Tracklines for the 2006 Multibeam Survey

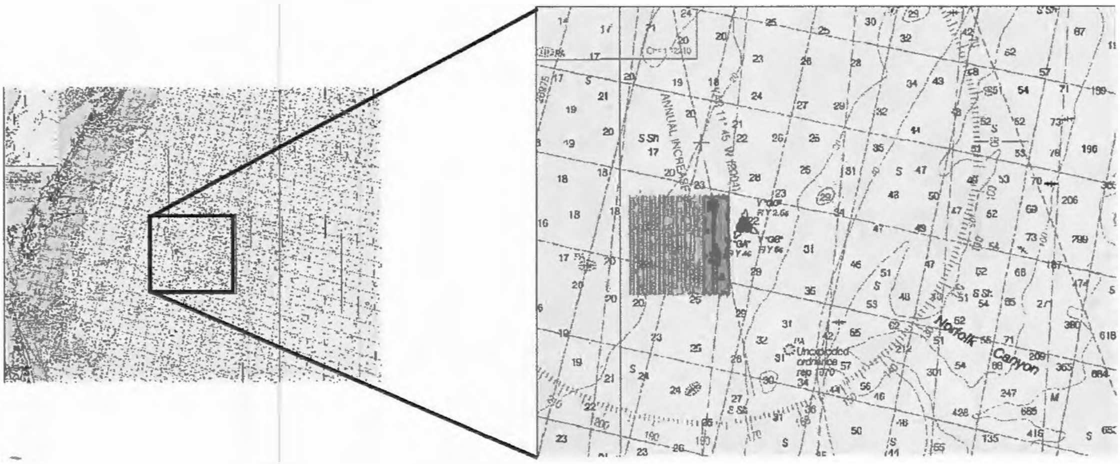


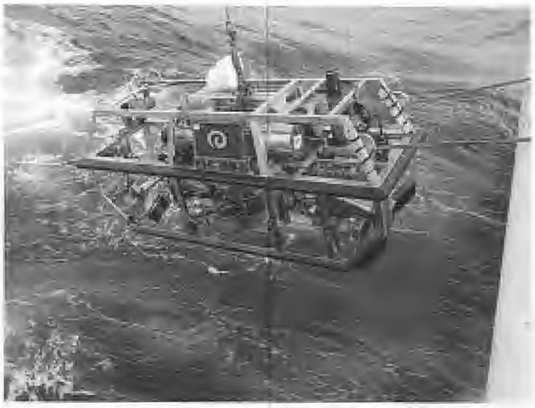
Figure 3.7 - Tracklines for the 2006 Singlebeam Survey

The first research cruise of the Virginia Capes Archaeology Project took place in June of 2006. Three different types of acoustic data were generated during this cruise. Side scan sonar data was collected using a Klein 5000 towfish towed behind the *Thomas Jefferson* (Figure 3.3). This system collected high frequency data at 455 kHz with an error of 1 percent. Additionally, multibeam sonar data was collected using a RESON 7125 multibeam sonar at a frequency of 400 kHz and single beam data was collected using an ODOM Echotrac DF3200 MKII, which operates at nominal

Figure 3.8 - One of NOAA Ship Thomas Jefferson's Survey Launches

frequencies of 200 and 24 kHz or 210 and 33 kHz. Both were hull mounted. Tracklines for the side scan sonar were run in a rectangular grid about 12.5 km to the northwest of the head of Norfolk Canyon with dimensions 9,500 m by 9,800 m and a spacing of 160 m. We surveyed the grid twice with the tracklines offset by 80 m in order to ensure a 200 percent coverage for the side scan data. During the first pass, we also collected data from six additional tracklines extending 17 km to the south-southwest of the grid and several smaller lines within the grid as a second pass on some of the potential targets (Figures 3.4 and 3.5).

Multibeam sonar data was also collected at the same time as side scan during the first pass over the grid, as well as in three other sets of tracklines to the southwest, east, and southeast. These grids had northeast-southwest trending tracklines with line spacings of about 100 m, 130 m, and 140 m, and had dimensions of approximately 4,300 m by 4,400 m, 4,400 m by 4,600 m, and 1,200 m by 5,300 m, respectively (Figure 3.6). Singlebeam sonar data was also collected from a single grid in the same area that received 200 percent coverage by side scan sonar. Line spacing for these tracklines was primarily 160 m, with spacing of 80 m in the eastern 2,500 m of the



Figures 3.9 and 3.10 - Remotely Operated Vehicles Argus and Little Hercules

survey area, which had overall dimensions of about 9,500 m by 9,800 m (Figure 3.7). Also during this cruise, magnetometer data was collected about 19 kilometers to the west-northwest of the head of Norfolk Canyon using a Geometrics G882 Marine Cesium Vapor Magnetometer towed off the back of *Thomas Jefferson's* survey launches 1301 and 1302 (Figure 3.8). While all three types of acoustic data are of relevance for this thesis, the purpose of the magnetometer survey was to locate iron artifacts potentially related to the sixteenth century cannon that had been found in the area.

The second cruise was much different from the first. In July of 2006, the team went back to the Virginia Capes aboard the *R/V Endeavor*. No acoustic data was collected during this expedition. Instead, we used the remotely operated vehicle (ROV) systems Argus and Little Hercules (Figures 3.9 and 3.10) to ground-truth side scan sonar targets from the previous cruise aboard the *Thomas Jefferson*. The video generated during this cruise was not collected for the purpose of mapping Norfolk Canyon, but rather to determine whether sonar targets were shipwrecks or shipwreck refuse. I will not be including the video that was collected during this cruise as a

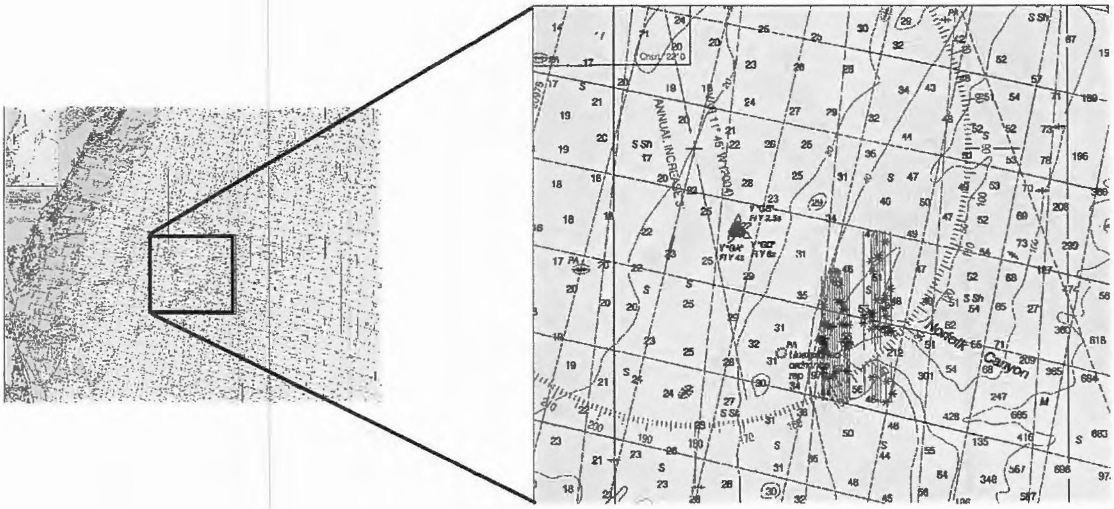


Figure 3.11 - Tracklines for the 2007 Side Scan Survey

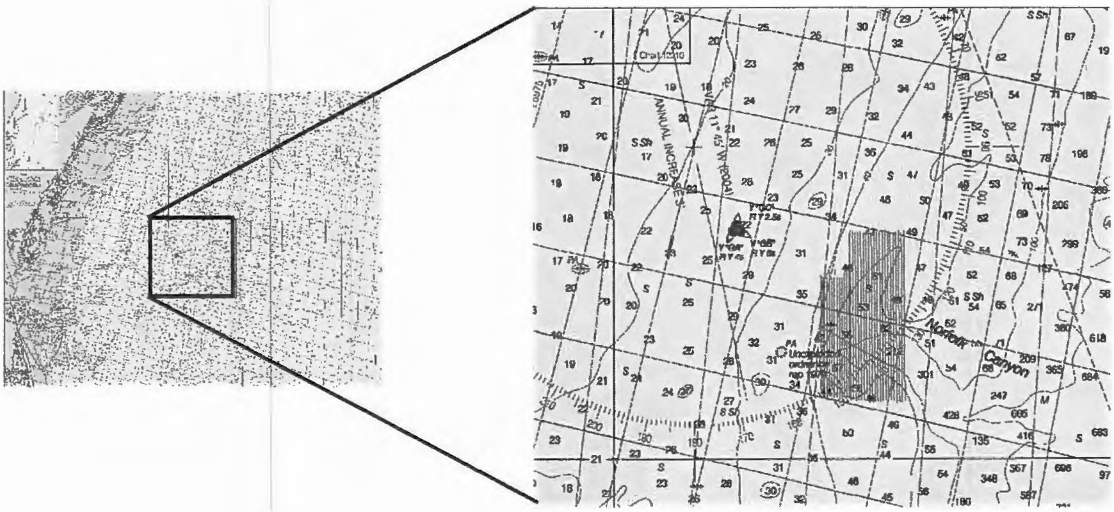


Figure 3.12 - Tracklines for the 2007 Multibeam Survey

part of this study, as it primarily consists of attempts to ground-truth targets that were believed to potentially be shipwrecks. However, in the future, ROVs and the video that they provide can be of great use in the search for individual sites, as they provide the most efficient way to image the seafloor.

In August of 2007, we returned to Norfolk Canyon on the *Thomas Jefferson* and used the same side scan sonar system as the previous year at 100 percent coverage.

Figures 3.13, 3.14, and 3.15 - The Autonomous Underwater Vehicles Atalanta and MARV and the Side Scan Sonar Echo, Respectively

We collected side scan sonar data from two rectangular grids that encompassed the head of Norfolk Canyon. These grids had dimensions of approximately 12,500 m by 2,800 m and 17,000 m by 2,800 m, and had spacings of 230 m and 260 m, respectively. We also ran two short tracklines in the 2006 survey area to get a better image of one of the previously identified targets (Figure 3.11). Also during this cruise, we collected data using the same RESON 7125 multibeam sonar system from 2006, but supplemented it with a Kongsberg 1002 multibeam sonar system as well, which operated at a frequency of 95 kHz. Data collected by the RESON sonar was limited to two short tracklines within the 2006 survey area, but the Kongsberg data encompassed a rectangular grid area of about 16,500 m by 8,200 m with a line spacing of 260 m at

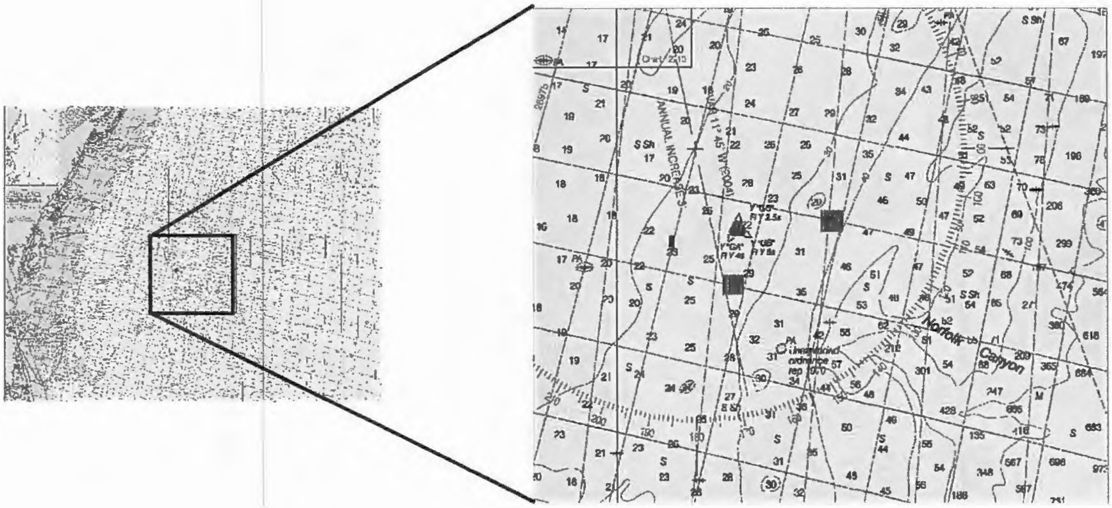


Figure 3.16 - Tracklines for the 2008 MARV Side Scan Survey

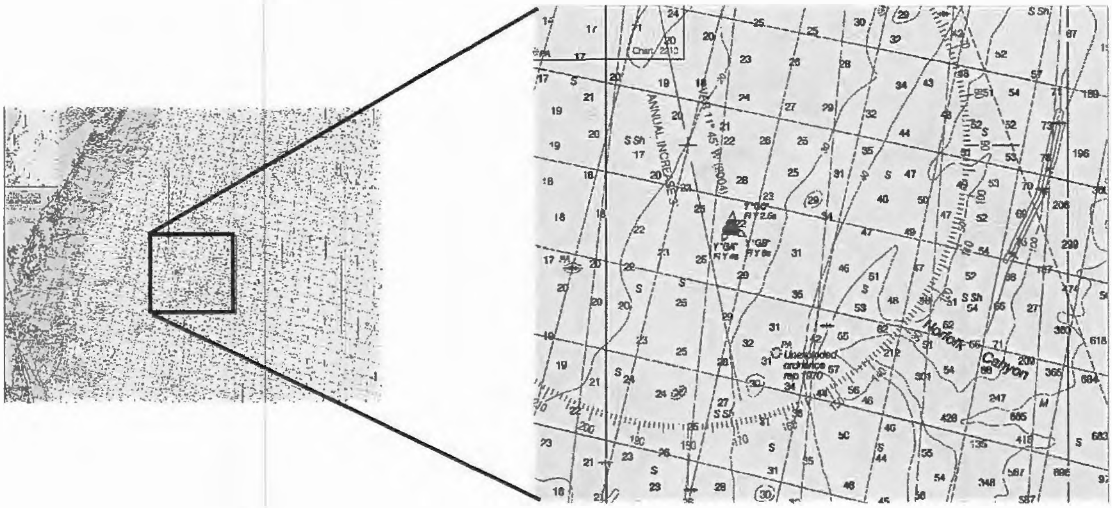


Figure 3.17 - Tracklines for the 2008 Echo Side Scan Survey

the head of Norfolk Canyon (Figure 3.12). At the same time, we also collected magnetometer data using the same method and for the same purpose as the previous year.

The final oceanographic cruise related to this project took place in July of 2008 aboard the *R/V Endeavor*. Unlike during the previous expeditions, data was collected primarily using autonomous underwater vehicles (AUVs). We used two AUVs:

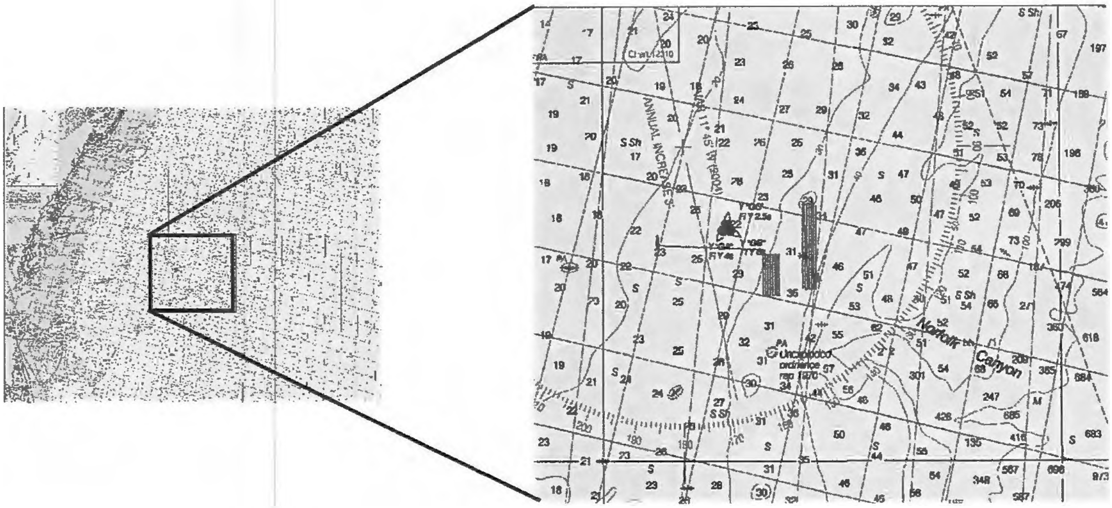


Figure 3.18 - Tracklines for the 2008 Atalanta Side Scan Survey

Atalanta, owned by URI and IFE (Figure 3.13), and MARV, owned by the Naval Undersea Warfare Center (NUWC) (Figure 3.14). Both collected side scan sonar data. Atalanta collected data using an Edgetech 2200-M Chirp with 840 kHz high frequency and 230 kHz low frequency. MARV collected data at the dual frequencies of 600 kHz high and 300 kHz low. We also collected data using IFE's side scan sonar system Echo (Figure 3.15), which operated at 100 and 400 kHz. MARV data was collected primarily from two smaller grids with dimensions 2,000 m by 2,000 m and 2,000 m by 2,100 m, with a line spacing of 140 m. Data from a smaller set of tracklines of dimensions 1,000 m by 450 m was collected within the 2006 survey area in the same area as 2007 as well (Figure 3.16). Additionally, Echo was used to collect data from three long (~ 16 km) tracklines to the east of the other study areas but to the north of Norfolk Canyon (Figure 3.17). Finally, Atalanta data was collected from three grids with approximate dimensions 1,000 m by 160 m, 4,000 m by 1,600 m, and 8,350 m by 1,350 m, with a line spacing of 220 m (Figure 3.18).

Laboratory/Data Processing Methods

All of the data collected during the four oceanographic cruises described above has been processed using the computer program CARIS HIPS and SIPS version 6.1, service pack 2. The program, which is designed to process acoustic sonar data, was able to handle the various types of side scan, multibeam, and singlebeam data generated at sea. It allows the user to not only view and process the data, but also to mosaic it into larger maps. Unfortunately, however, there are problems with HIPS and SIPS's treatment of 16-bit side scan data that render the output lower resolution than the raw data. In order to view the data in HIPS and SIPS, it is first necessary to import the raw data and convert it to the format that the program can use. This allows options for preserving 16-bit data and converting to 8-bit data. If the first option is chosen, the amplitude of the data is decreased to the point that some is lost. Conversely, data is also lost with the second option, as it converts 16-bit data to 8-bit by scaling the values (CARIS 2008). CARIS is currently working to correct the problem with data loss when preserving 16-bit data and it should be mitigated when the next version is released. However, this was not available at the time that I was processing the data for this project.

Upon importing data into HIPS and SIPS, the first step is to inspect it and remove any clearly outlying points. These are evident either by looking at the image of the tracklines or by searching for anomalies in the vessel speed and distance between data points in the Navigation Editor. Each type of data then has different filters that must be applied to improve its appearance and aid with interpretation. For example, when processing side scan sonar data, the nadir, the area between right and left swaths containing no data, must first be removed. Next, the beam pattern, the horizontal patterning in the intensity of the return that is intrinsic to the sonar, must be corrected for. Finally, any further anomalies in the intensity of the data must be corrected for, and the data must be smoothed to make any features that are present more clear. It is not necessary to include details as to how this was done in the HIPS and SIPS software, but this discussion should make clear the detailed process necessary to process each line. In total, I processed more than 1,000 lines for this thesis. Although much of the data collected aboard the *Thomas Jefferson* was processed in the field by lab technicians that were members of the ship's crew, when viewing it later in HIPS and SIPS, it was apparent that it was not sufficiently processed for the purposes of this thesis, and as such, it was reprocessed. All instruments that collected side scan data collected both high and low frequency data. I processed all of the available side scan data with the exception of the low frequency side scan data from 2006. This data was not processed due to time constraints and the fact that it would not have included any additional parts of the shelf that were not covered by the high frequency data, due to the 200 percent coverage that year. Multibeam and singlebeam data were somewhat more straightforward than side scan data, but required similar steps to be processed.

Upon processing each of the individual lines of data, the next step was to combine them into mosaics that allowed for larger parts of the landscape to be viewed together. The size and resolution of these mosaics were limited by the memory of the computer used to process the data. This is not to say that the computers used for data processing were insufficient for the task, but rather that a decision had to be made between relatively low resolution mosaics of large areas or relatively high resolution mosaics of small areas. Therefore, the first step was to create a somewhat lower resolution map of the entire area for each of the different data types. Because there is no area that was covered by the low resolution side scan sonar data that wasn't covered by the high resolution data, for the analysis, I primarily used the high resolution data. The only exceptions to this were the data collected by Echo, as a problem with the system rendered the high resolution data not viable, and Atalanta, which did not have sufficient density of coverage to use the more narrow high frequency tracklines. Next, I created smaller, higher resolution mosaics of the various survey regions of the study area.

As I mentioned in the previous chapter, there are limits to this study in that it is heavily reliant on acoustic data and does not include visual groundtruthing or sample collection in the analysis. As such, what I am able to do at best is to create a predictive map of some of the most likely sites for human habitation. However, some of the important features that would have been attractive to human populations, such as cryptocrystalline rock outcrops, are very difficult, if not impossible to distinguish from less attractive features without this type of groundtruthing. Similarly, the collection of core samples would allow us to better assess the viability of human habitation of certain areas before submergence and marine sedimentation. In rare cases, and with a lot of luck, such cores could potentially even recover small cultural materials, verifying that the landscape had been occupied by humans during a lower stand in sea level. Despite this, the current study provides an excellent first attempt to model human habitation of the region surrounding Norfolk Canyon. Additionally, for the reasons that I outlined in Chapter 2, particularly with regard to the archaeological potential of the region in question, this study also represents a promising early step in our understanding of human use of the now submerged continental shelf of North America during the LGM, and addresses the question of the nature of the earliest colonists of the New World, one that is of tremendous interest and debate in the field of American Archaeology.

Chapter 4 - Processed Data and Results

As I outlined in the previous chapter, the methods that we employed to collect and process data were most effective for locating topographic features that may have represented preferred habitation sites or other types of sites on the landscape. We were able to collect data from several small areas near Norfolk Canyon, including two substantial ones at the head of the canyon and about 12.5 kilometers to the northwest of the canyon head. The location of these survey areas was dictated by all three archaeological objectives of the Virginia Capes Archaeology Project. This lead to a somewhat patchy coverage of the overall survey area, but it it is nonetheless possible to observe topographic features on the landscape that may have represented preferred human habitation sites at the time that the shelf was subaerially exposed. On the same note, none of the data that we collected explicitly indicates that sites were not present in the study area, even though it is not possible from the data that we collected to definitively determine the location of individual sites. Additionally, the presence of likely relict shorelines is particularly promising for our understanding of past landscapes and how they may have been utilized by early inhabitants of North America.

Three types of data have been processed as a part of this thesis. The most substantial of these is side scan sonar data, which covered nearly all of the study area (Figure 4.1). Also covering much of the study area was the multibeam sonar data (Figure 4.2). The third type of data that I will include in this analysis is singlebeam sonar data, but it was collected over a relatively small area that overlaps with the other

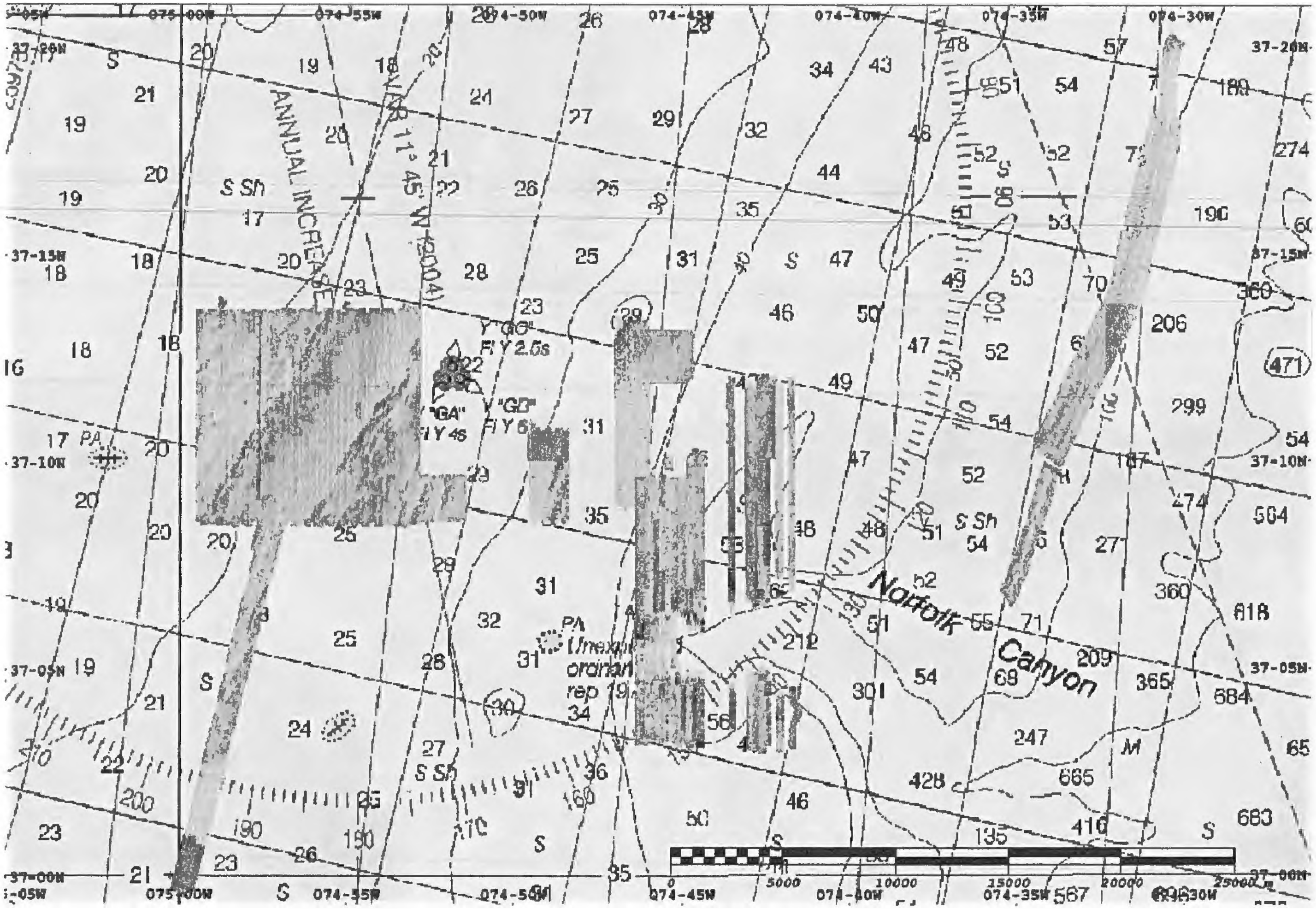


Figure 4.1 - The Side Scan Sonar Data Collected During the Virginia Capes Archaeology Project

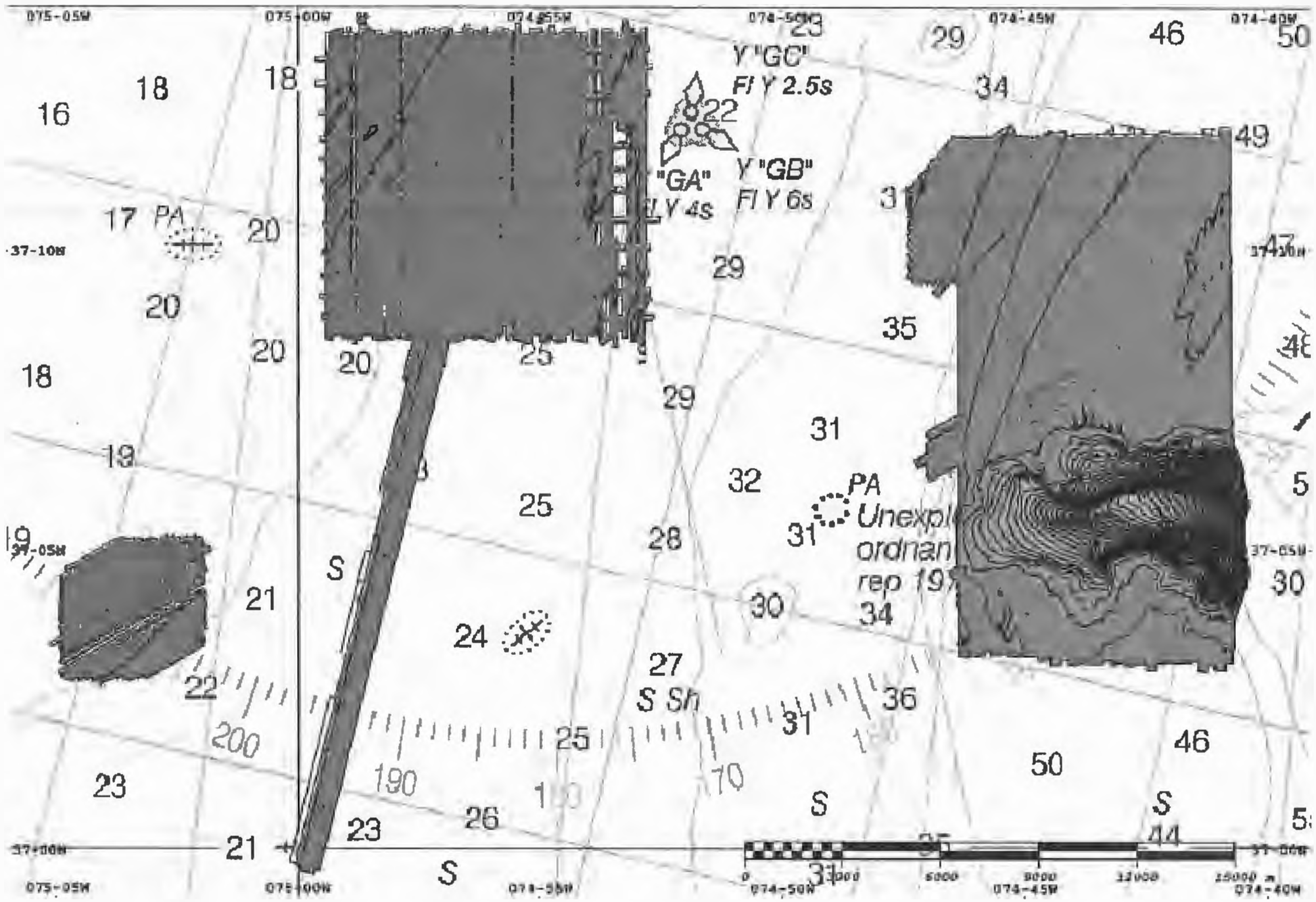


Figure 4.2 - The Multibeam Sonar Data Collected During the Virginia Capes Archaeology Project (10 Meter Contours)

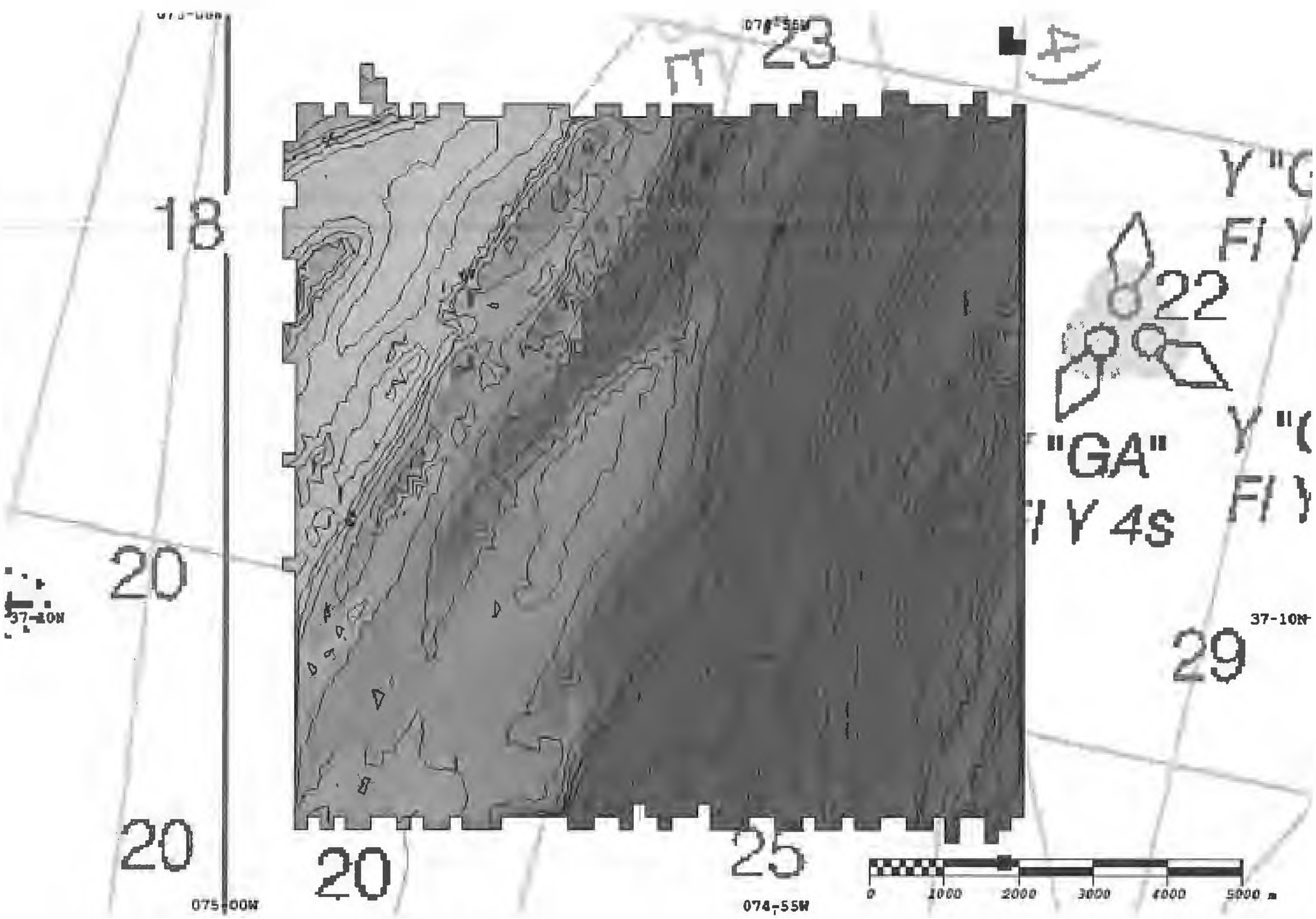


Figure 4.3 - The Singlebeam Sonar Data Collected During the Virginia Capes Archaeology Project (1 Meter Contours)

data that was collected and therefore serves primarily as support for the interpretations derived from the side scan and multibeam sonar data (Figure 4.3). Although both magnetometer and video data were also collected over the course of the research cruises that comprised the Virginia Capes Archaeology Project, they were not done so systematically nor were they collected over large areas, as they were focused on locating or identifying individual targets, none of which were directly related to the objectives of this thesis. As such, in this chapter, I will present only the processed side scan, multibeam, and singlebeam data and the results of their analysis.

Side Scan Sonar Data

Side scan data was collected throughout nearly all of the study area. However, it was not all collected with the same system. Rather, the overall map of side scan sonar data is an amalgamation of both high and low frequency data from four different systems (Figures 4.1, 4.4 - 4.7). Most of the data from the two major study areas at the head of Norfolk Canyon and the region to the northwest was collected by the Klein 5000 system aboard the NOAA ship *Thomas Jefferson* in 2007 and 2006, respectively (Figure 4.4). I have processed and included in this thesis the high frequency data collected by this system, as the tracklines were close enough together that there were be no gaps in the data that would not have been present in the low frequency data. AUV data was collected by two different systems in 2009, both from blocks between the two large survey areas of the previous years. Although I processed both the high and low frequency data from both systems, I include in this thesis only the high

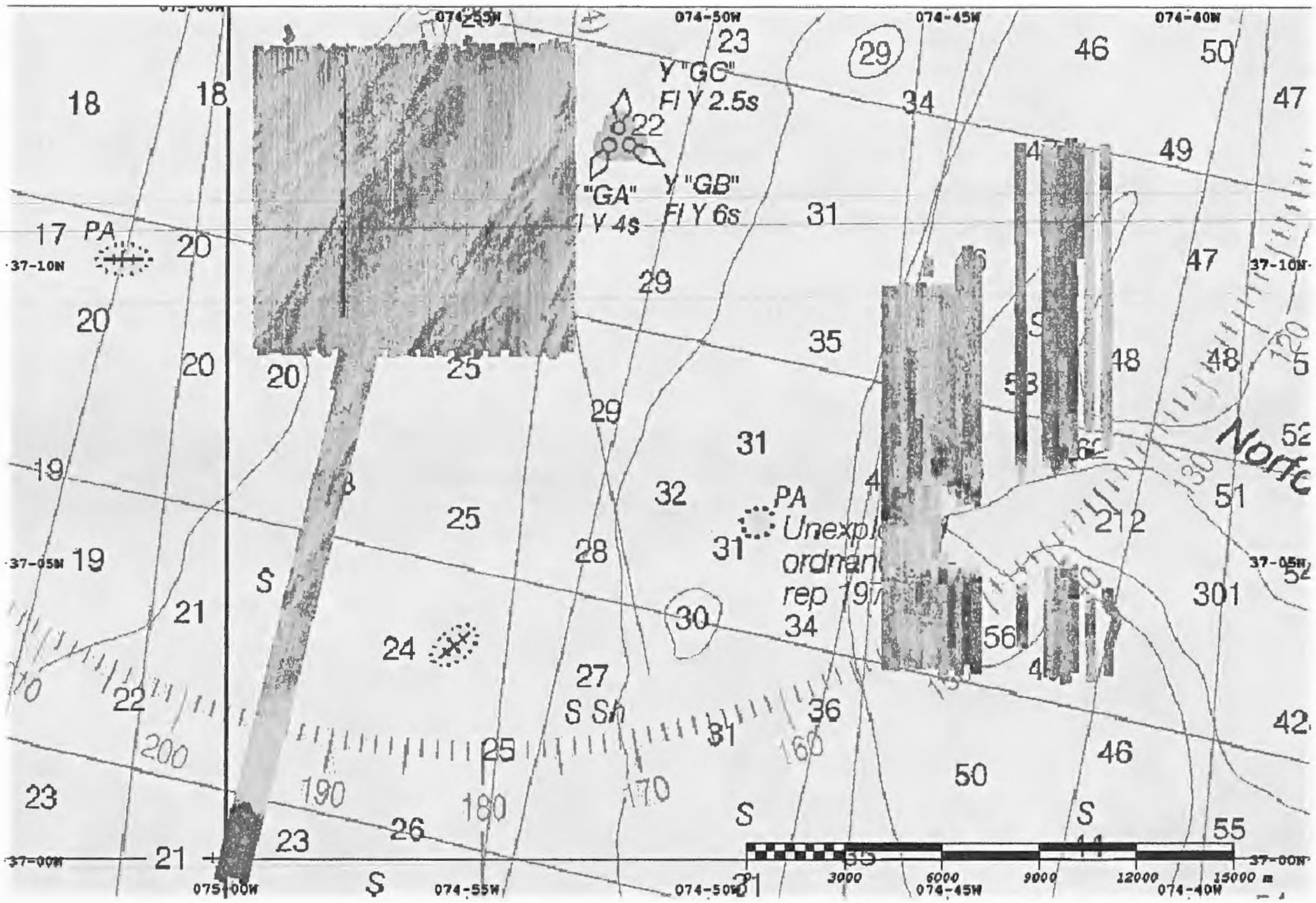


Figure 4.4 - The Side Scan Sonar Data Collected by the Klein 5000 Towfish

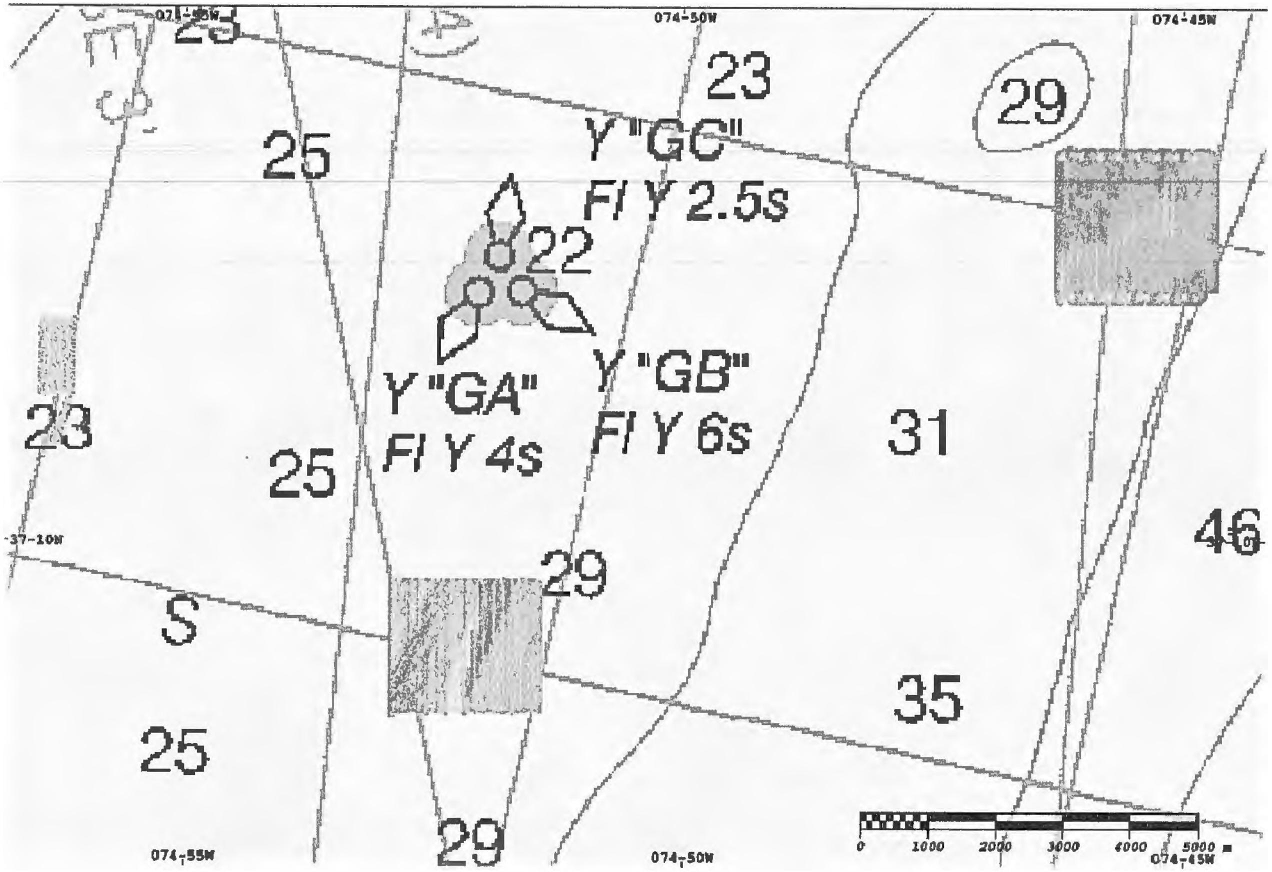


Figure 4.5 - The Side Scan Sonar Data Collected by the AUV MARV

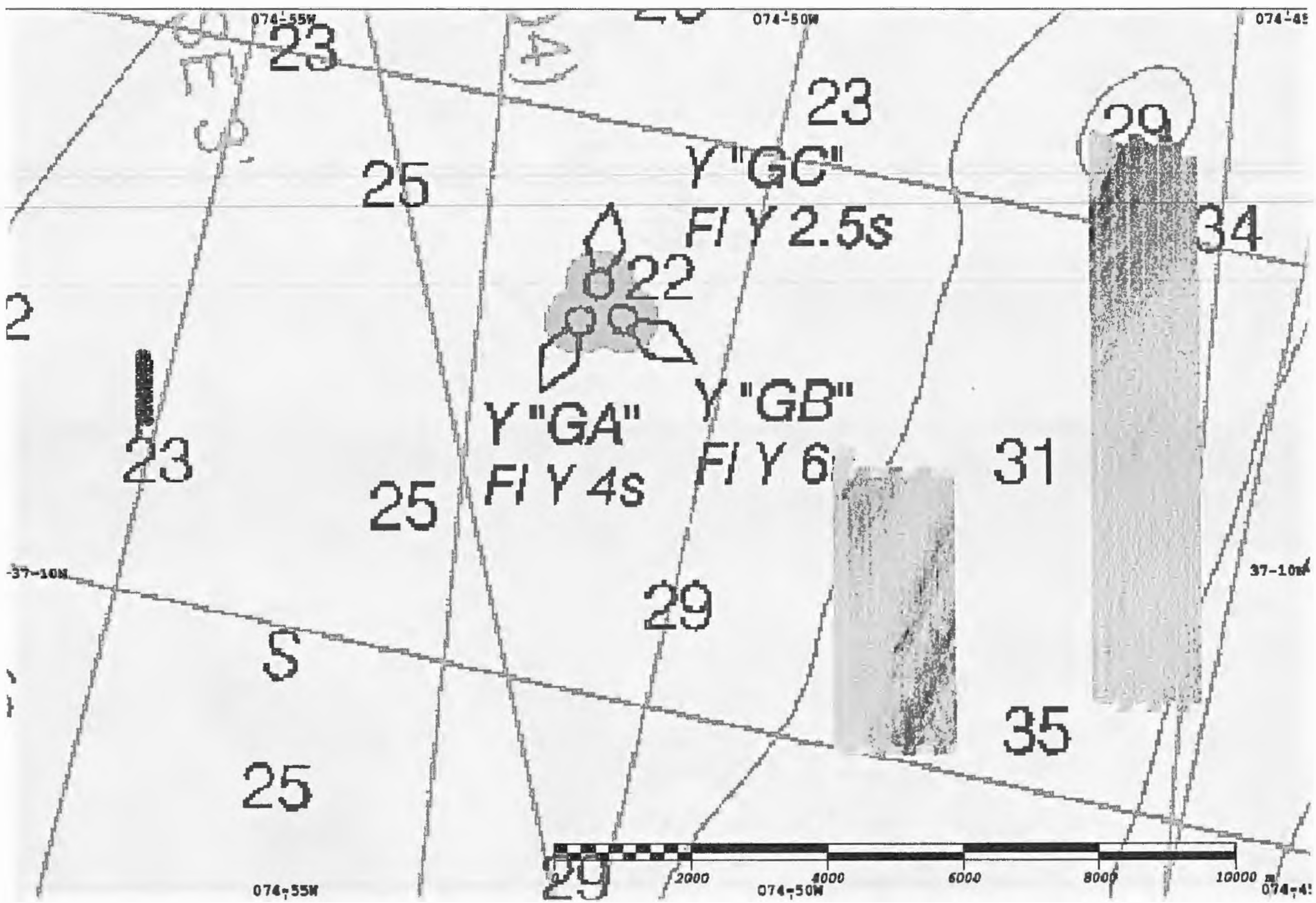


Figure 4.6 - The Side Scan Sonar Data Collected by the AUV Atalanta

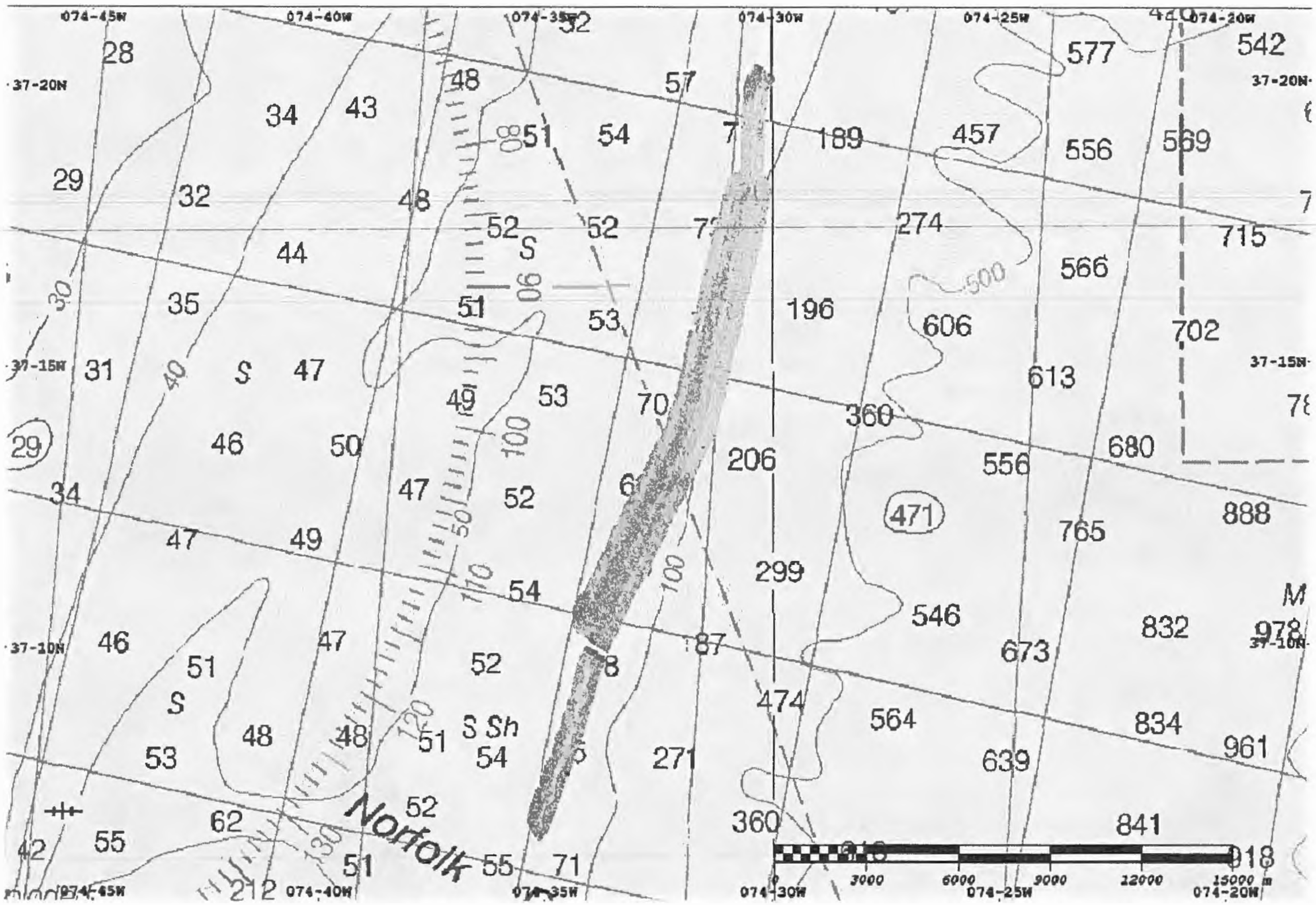


Figure 4.7 - The Side Scan Sonar Data Collected by the Towfish Echo

frequency data from the MARV AUV (Figure 4.5) and only the low frequency data from the Atalanta AUV (Figure 4.6). I chose the high frequency data for the former for the same reason as for the Klein 5000 system. However, it was necessary to use the low frequency data from Atalanta because the tracklines were not spaced closely enough to allow for full coverage with high frequency data. Finally, in 2008, data was collected nearer to the edge of the continental shelf to the northeast of the head of Norfolk Canyon using the towfish Echo towed behind the ship *R/V Endeavor*. Due to problems with the high frequency data, I have only included the low frequency data in this thesis (Figure 4.7).

The clearest features in the side scan data are what may be a series of relict shorelines from periods during which the rapidly transgressing shoreline either slowed or stopped for a period of time. In particular, there are at least two very clear such features in the sidescan data collected in 2006 (Figure 4.8). That they may be relict shorelines is supported by their orientation along a northeast-southwest trending line, approximately parallel to the edge of the continental shelf in the area. Additionally, there appear to be several less pronounced potential shorelines immediately to the southeast of the two very clear features. These extend beyond the block of data collected in 2006 onto a smaller block collected by MARV in 2008. Similarly, there is also evidence of other shorelines present to the east of these, as can be seen in the blocks of data collected by Atalanta in 2008. Unfortunately, it is difficult to make this assertion with a great degree of certainty, as the areas over which this data was collected are very narrow from east-west and they are separated by a region from

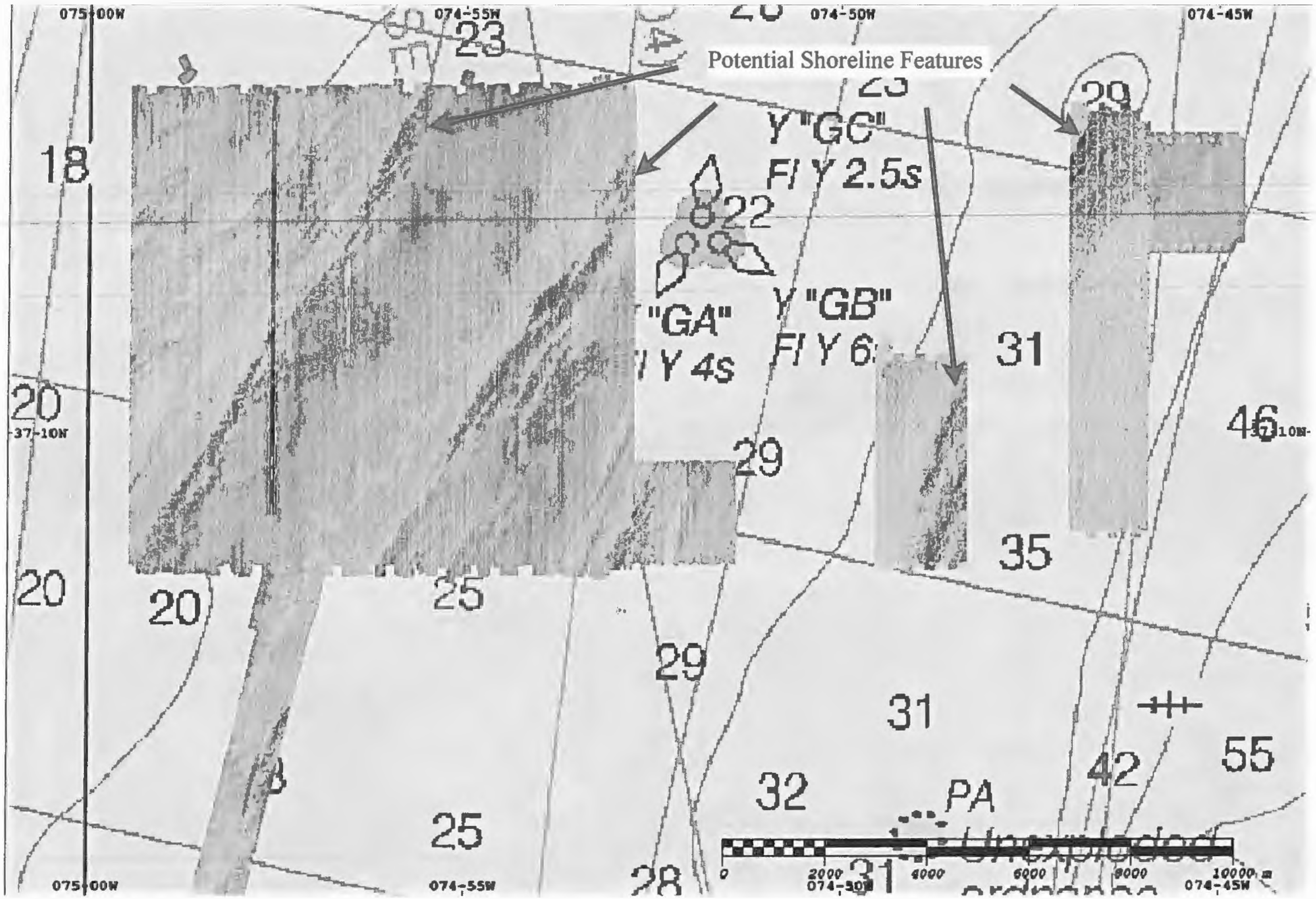


Figure 4.8 - Potential Shoreline Features that Are Evident in the Side Scan Data

which we collected no data. Still, a second block of MARV data immediately east of and overlapping the northern part of the Atatlanta data, while unclear, appears to substantiate and demonstrate a continuation of these potential shoreline features.

Unfortunately, there do not appear to be any clear possible shoreline features within the Klein 5000 data collected in 2007 around the head of Norfolk Canyon (Figure 4.9). This is due in part to the fact that there are gaps in the data between some lines. Another issue with the side scan coverage in this area is the fact that the canyon became deep quite quickly from the edges to the center and the towfish could not be lowered deep enough to collect data from the bottom of the feature. Despite this, even in the areas of good coverage, there do not appear to be any relict shorelines parallel to those observed in the data from the regions to the northwest near the head of the canyon. However, despite the fact that it is somewhat obscured, parts of the northern face of the head of Norfolk Canyon appear to be evident as well. In the final area from which side scan data was collected, to the northeast of the canyon head, by the towfish Echo, there do not appear to be any features evident at all, let alone shorelines (Figure 4.7).

Side scan sonar data is fundamentally different than either singlebeam or multibeam data in that rather than simply recording the depth of the seafloor, it detects the time and strength of the return of an array of signals reflecting off of the seafloor. It is for this reason that side scan sonars are particularly effective at locating discrete objects such as shipwrecks or large rock outcrops. Such objects have a higher chance of being found using side scan sonars both because they are made of a different

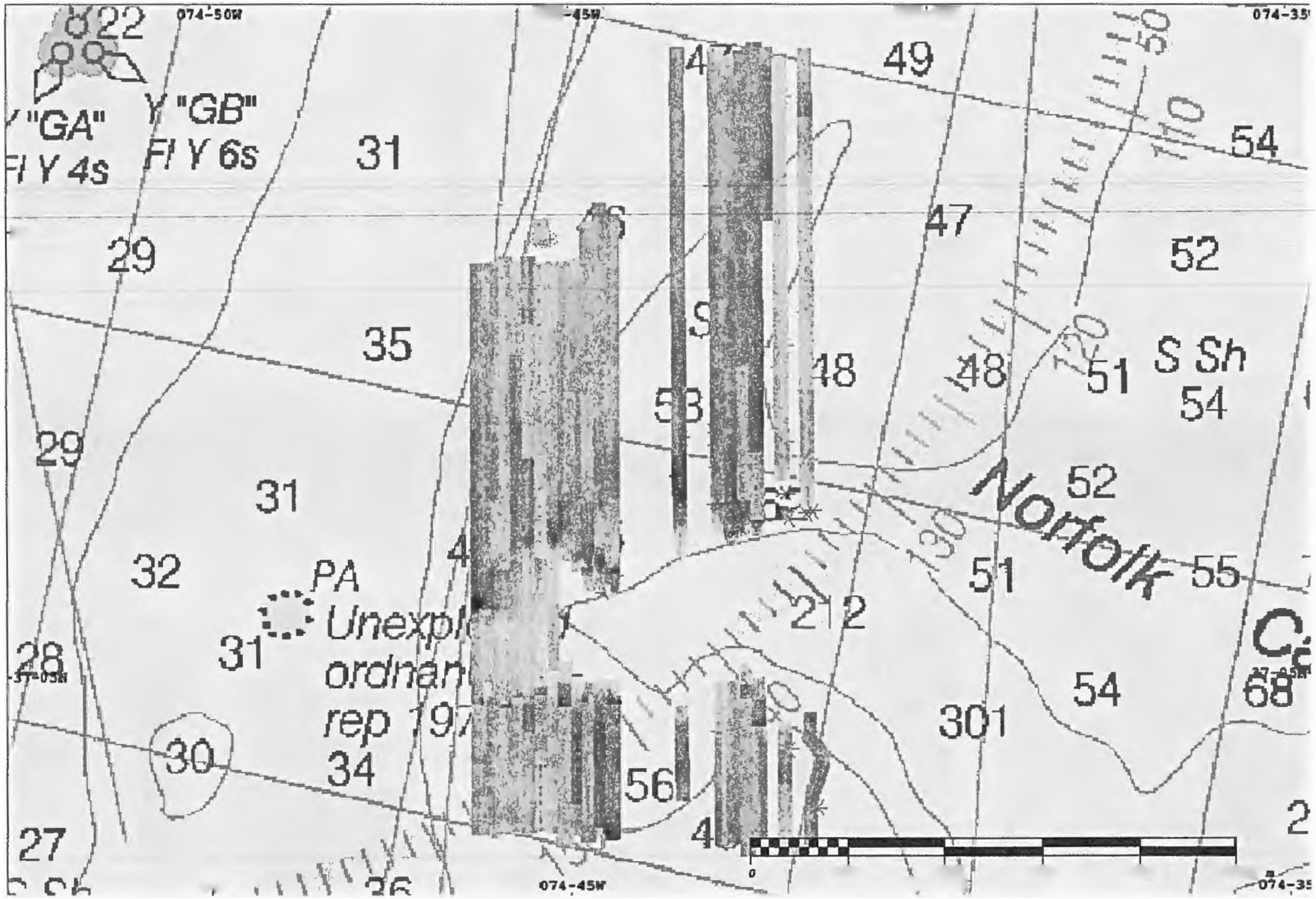


Figure 4.9 - Side Scan Sonar Data from the Area Immediately Surrounding the Head of Norfolk Canyon

material than the surrounding sea floor, often causing them to return a signal with a different intensity to the detector, and because their acoustic shadow can be seen as well, assisting with the determination of the size and shape of the object. As such, when we observe what appear to be relict shorelines in the side scan data, they may be apparent because they are relatively dramatic changes in depth that return a stronger signal due to the greater angle of the seafloor. Therefore, more gradual changes in sea floor depth, such as those that occur between the possible shorelines, are not typically apparent in side scan data. Because of this, the lack of shoreline features in side scan data does not necessarily mean a lack of shorelines in the area.

Similarly, large, shallow, gently-sloping topographic features may not be evident in this data as well. This may include shallow estuaries similar to present day Chesapeake Bay. Based on the side scan data that we collected as a part of the Virginia Capes Archaeology Project and that I processed for this thesis, no such features seem immediately apparent. Rather, the only clear features are the potential shorelines that I have previously discussed. Additionally, there does not appear to be any clear evidence in the side scan data that the ancestral Susquehanna River or other rivers or streams ran through the study area. Based on the work of previous researchers who traced the former path of this river, it is likely that it traveled to the south of the large study area surveyed in 2006 (e.g. Swift et al. 1972; Colman et al. 1990). Unfortunately, the seven tracklines that extend to the south-southwest from this region provide a map that is too narrow to determine whether the path of the ancestral Susquehanna is evident on the seafloor (Figure 4.4). Still, even if the survey region does include the former path of this river and any estuarine features that may have been associated with it, it is quite possible that they may not appear in the side scan data, as they may have been since been filled by more recent sedimentation.

One of the most common uses of side scan sonar data is to locate discrete objects, such as shipwrecks and large rock outcrops. For the purposes of this thesis, the presence of such rock outcrops could have been interesting. As I mentioned in Chapter 2, the presence of cryptocrystalline rock resources was an important factor in Paleoindian site distribution throughout the northeastern United States and the Mid-Atlantic region in particular. Due to the fact that we were unable to ground-truth any targets in our acoustic data by collecting cores or rock samples and that our use of visual ground-truthing in 2006 with the ROV *Little Hercules* was limited to potential shipwreck targets, it would not be possible to say for sure that any outcrops are comprised of any of the raw materials preferred by early inhabitants of North America. Regardless, there are no clear features of this type in the side scan data that we collected from 2006 to 2008 (Figure 4.1). Because of the lack of these features, as well as the absence of evidence for rivers, streams, or embayments, the major product of the side scan data, at least with regard to this project, is the evidence for several possible submerged shorelines.

Singlebeam Sonar Data

Unlike the side scan and multibeam sonar data, singlebeam data was collected from a very limited region of the study area. It was collected in 2006 at the same time that side scan and multibeam data were obtained from the large survey area to the northwest of the head of Norfolk Canyon. Unlike side scan data, singlebeam data does provide absolute depths of the seafloor, which allows for clearer determinations of depth changes. Similarly, with singlebeam data, it is possible to generate depth contours, which assist in determining the locations of submerged shorelines and other features (Figure 4.3). Unfortunately, however, singlebeam data is limited in that it collects a single data point rather than an array oriented perpendicular to the ship trackline every time it "pings" the seafloor. For this reason, because the tracklines were spaced to ensure there were no gaps in the side scan and multibeam data, substantial gaps in the singlebeam data were unavoidable. In order to achieve a coherent image, I used the tiling feature within the CARIS Hips and Sips software before adding the contour lines and generating the final product. I spread the data over square "bins" with 175 meter sides. This compensated for the gaps in the data, but decreased its resolution.

Nonetheless. the processed singlebeam data can be used to test the possible identities of the features that were evident in the side scan data, particularly when viewing the 1 meter contours. As was the case with the side scan data, there appear to be two clear northeast-southwest lines with relatively sharp changes in depth, potentially corresponding to previous shorelines (Figure 4.10). However, it seems that the one of these further to the southeast is not as coherent in the singlebeam data as it is in the side scan, appearing to split into two distinct features further to the northeast. If this is a submerged shoreline, it perhaps suggests that as the water level rose, it

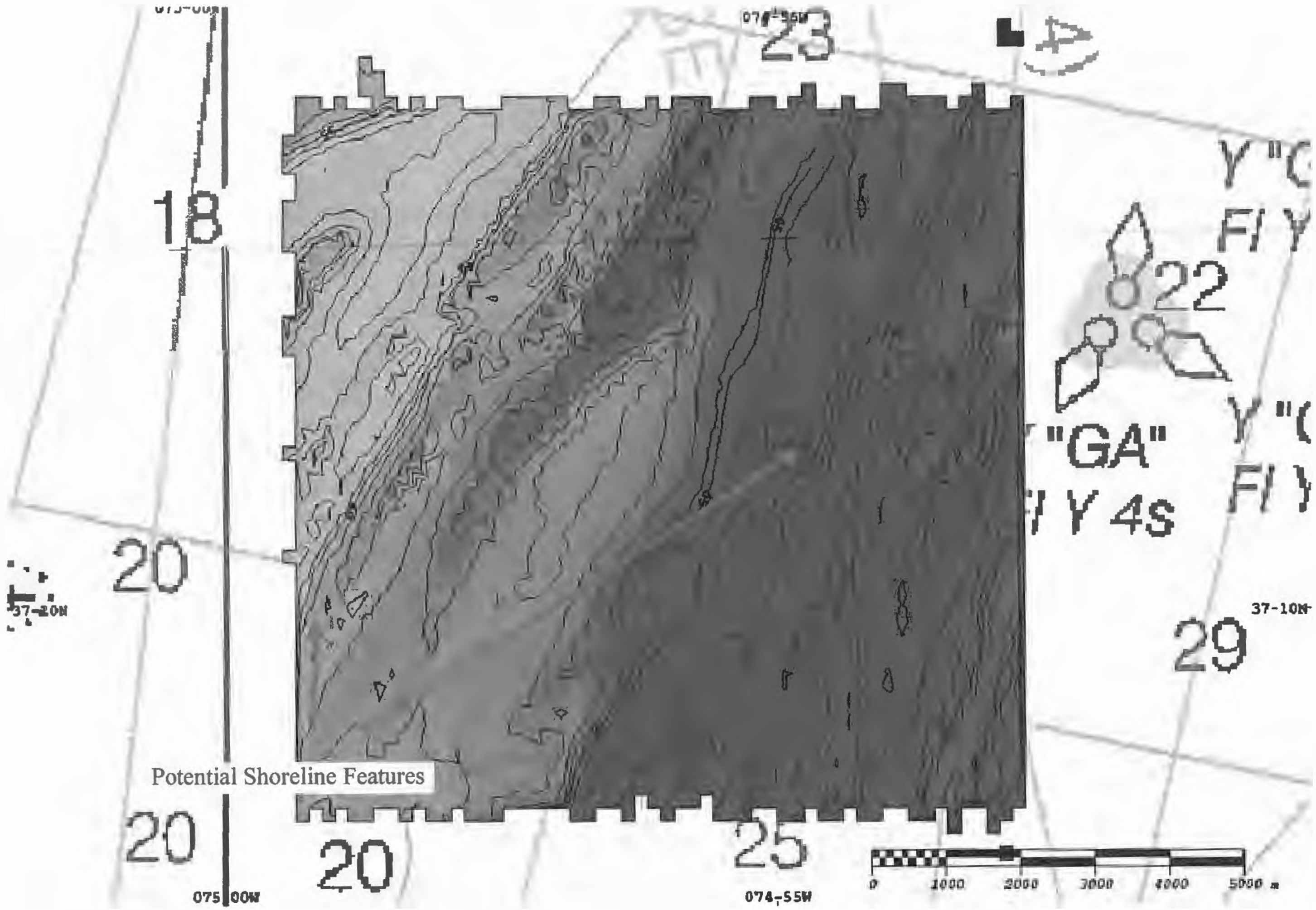


Figure 4.10 - Singlebeam Data with Potential Shoreline Features Indicated (1 Meter Contours)

remained at the southwestern part of the shoreline for a longer period of time, whereas further to the northeast, the shoreline was at one point for some amount of time before transgressing to another. This would suggest that the southwestern part might be a better prospect for locating evidence of human occupation, as the same coastal location could have been occupied for a longer period of time, and therefore sites could have become larger and more developed. This could make them more likely to be found.

Despite the apparent similarities in potential shoreline features between the side scan and singlebeam data, when superposing the singlebeam contour lines on the side scan data, it is clear that they do not occur in the same location (Figure 4.11). Both of the images in the side scan data that appear to be shorelines are shifted to the southeast from the areas of steep slope in the singlebeam data. Because all that can be said from the side scan data is that the features represent something that causes a different intensity of the response of the acoustic signal from the surrounding sea floor, those that are observed in the singlebeam data are more likely to represent the actual submerged shorelines. The lines present in the side scan data could instead represent long outcrops of rocks or different sediments. It is also possible that these lines could have been trawl lines, which are usually long and straight. Additionally, this puts into question the features identified as potential shorelines in the side scan data that does not have overlapping singlebeam or multibeam data. However, this does not preclude similar features, particularly those in the southeastern corner of the side scan survey

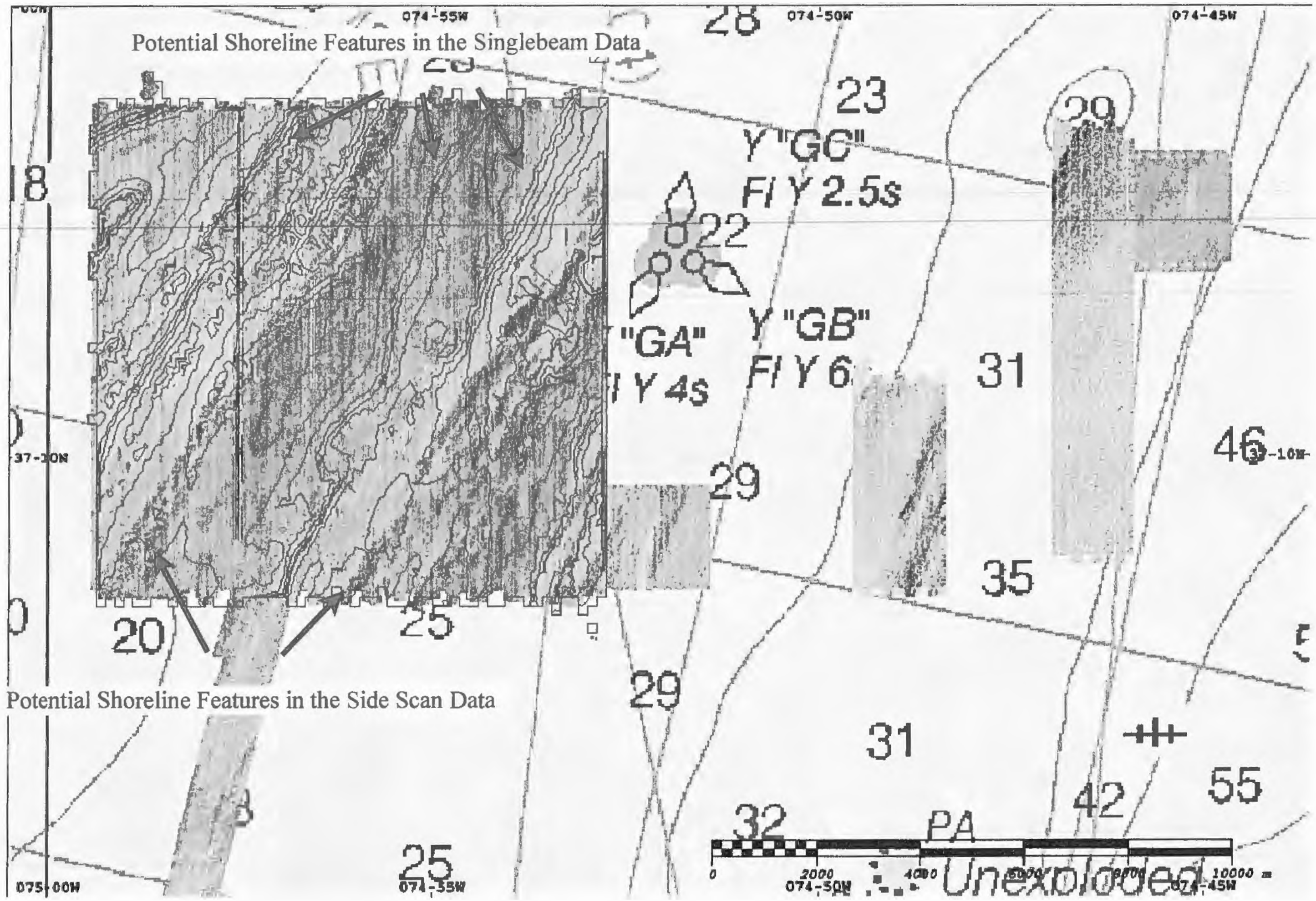


Figure 4.11 - Side Scan Data with 1 Meter Contour Lines from the Singlebeam Data Superposed

area, from potentially being shoreline features, although one must be wary if identifying them as such.

As was the case with the side scan data, there are other possible shorelines at the southeastern corner of the region from which data was collected. These are neither well defined enough nor long enough to be labeled shorelines with great levels of certainty. Similarly, there is another potential shoreline feature at the very northwestern corner of the survey area, but labeling it as such results in the same problems. Additionally, the resolution of the processed image precludes the identification of other features. In particular, despite the fact that contour lines were created from the data, there is no clear evidence, as was the case in the side scan data, of rivers, streams, or embayments within the survey area. Smaller features such as discrete objects like rock outcrops are even less likely to be evident in the data. Despite these drawbacks, however, the singlebeam data was very useful in testing and challenging the interpretations of the side scan sonar data from the same survey area.

Multibeam Sonar Data

The multibeam sonar data was collected from three discrete survey areas (Figure 4.12). The western survey area, the smallest of the three, was surveyed in 2006. It is the only multibeam survey area that does not correspond to a side scan sonar survey area. The central survey area corresponds to the large region to the northwest of the head of Norfolk Canyon from which we also collected side scan and singlebeam data. We collected this data in 2006 as well. Finally, the eastern survey area consists of

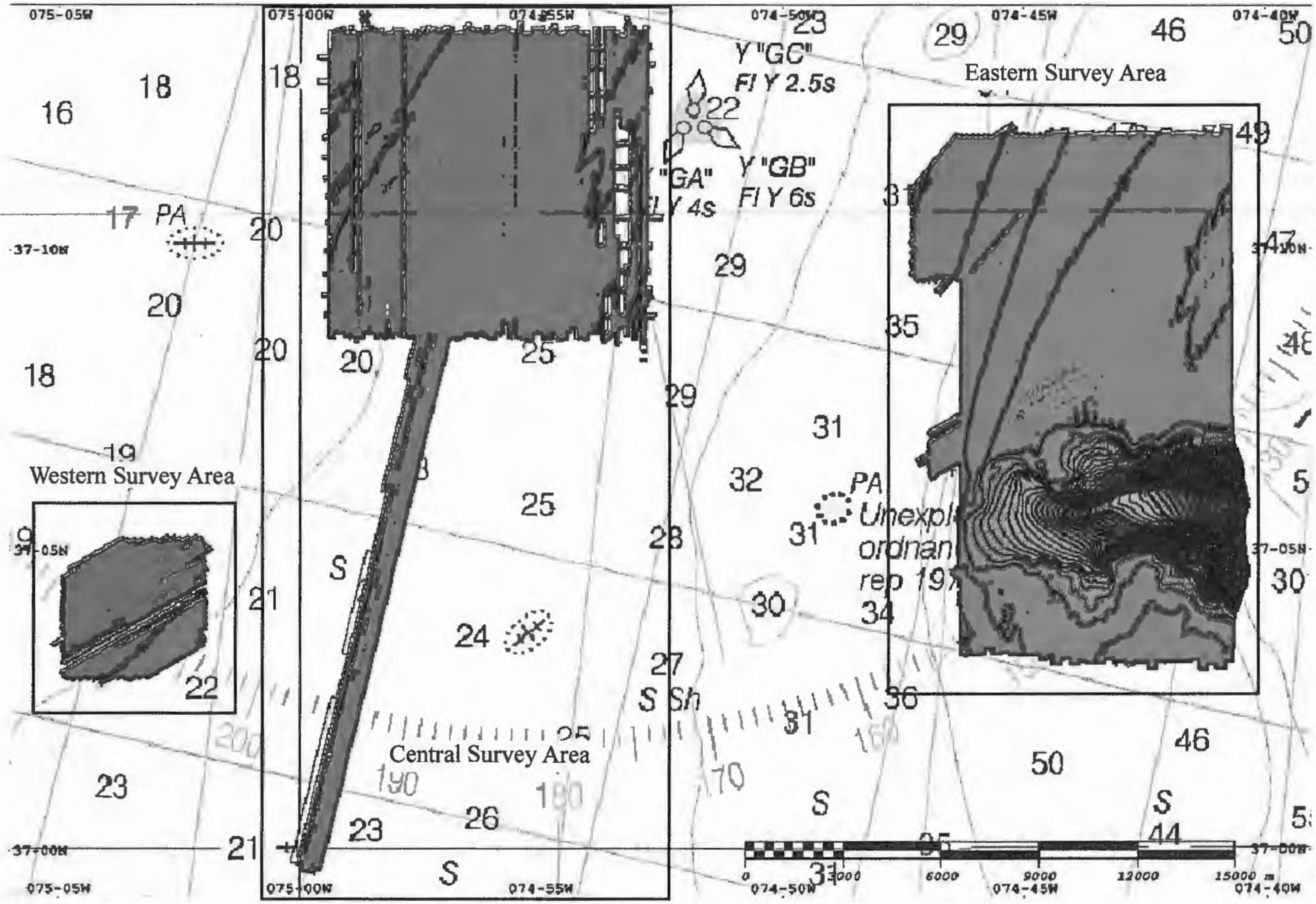


Figure 4.12 - Multibeam Data with the Western, Central, and Eastern Survey Areas Indicated (10 Meter Contours)

three components. A majority of the region, including the head of Norfolk Canyon and parts of the shelf to the north and south, was surveyed in 2007. However, two other blocks, including a series of eight southwest to northeast trending tracklines immediately to the northwest of Norfolk Canyon and a nearly square-shaped block of tracklines at the northwest corner of the 2007 survey area, were surveyed in 2006 along with the western and central survey areas.

Like the singlebeam data, multibeam data measures the actual depths of the seafloor. As such, it is possible to include contour lines and determine where rapid changes in sea level occur. On the other hand, multibeam data differs from singlebeam data in that while the former collects a single data point with each "ping," the latter collects an array of data oriented perpendicular to the ship's trackline. Because of this, there should theoretically be no gaps in maps of the multibeam data, as the tracklines were designed to give 100 percent coverage. Unfortunately, it seems that in some cases, primarily in the central survey area, but in the others as well, there were periods during which the multibeam data was either not collected or recorded. These gaps could be corrected for by using the tiling feature within CARIS Hips and Sips that I used to generate a map of the singlebeam data, but this would be done at the cost of resolution. Therefore, the final product maintains these gaps, although they do not appear to be greatly detrimental to the overall image. In any case, because multibeam data is collected in an array and therefore does not need to be extrapolated to generate a map, these images are much higher resolution than those created from singlebeam data and therefore they are theoretically more useful for the purpose of identifying topographic features.

The map of processed data from the central survey area contains evidence of similar topographic features to those I previously observed in the side scan and singlebeam data (Figure 4.13). Unfortunately, contours of less than 5 meters are too numerous in this region to yield clear and meaningful results. This is due in part to some of the gaps in the data as well as slight variations between individual tracklines, but it is not as much of an issue in the other survey areas. When viewing the 5 meter contours, however, lines are clearly present along the same lines that I interpreted to be the potential locations of submerged shorelines. Unfortunately, due to the lack of more frequent contour lines in the multibeam data and the relatively flat nature of the slope, only one contour line corresponds to each of these possible shorelines, so one must be careful not to read too much into their placement on their own merit. However, when taking into account the apparent features in the singlebeam data, the location of these contour lines seems more than coincidental. This includes not only the two potential shorelines that appeared most clearly in the singlebeam data, but others to the far northwest and southeast of the survey area as well (Figure 4.14). Like the singlebeam contour lines, when these contour lines are superposed on the side scan data for this area, they do not coincide with the linear features, supporting the interpretation that the features in the singlebeam data, and not the side scan data, represent the location of relict shorelines (Figure 4.15).

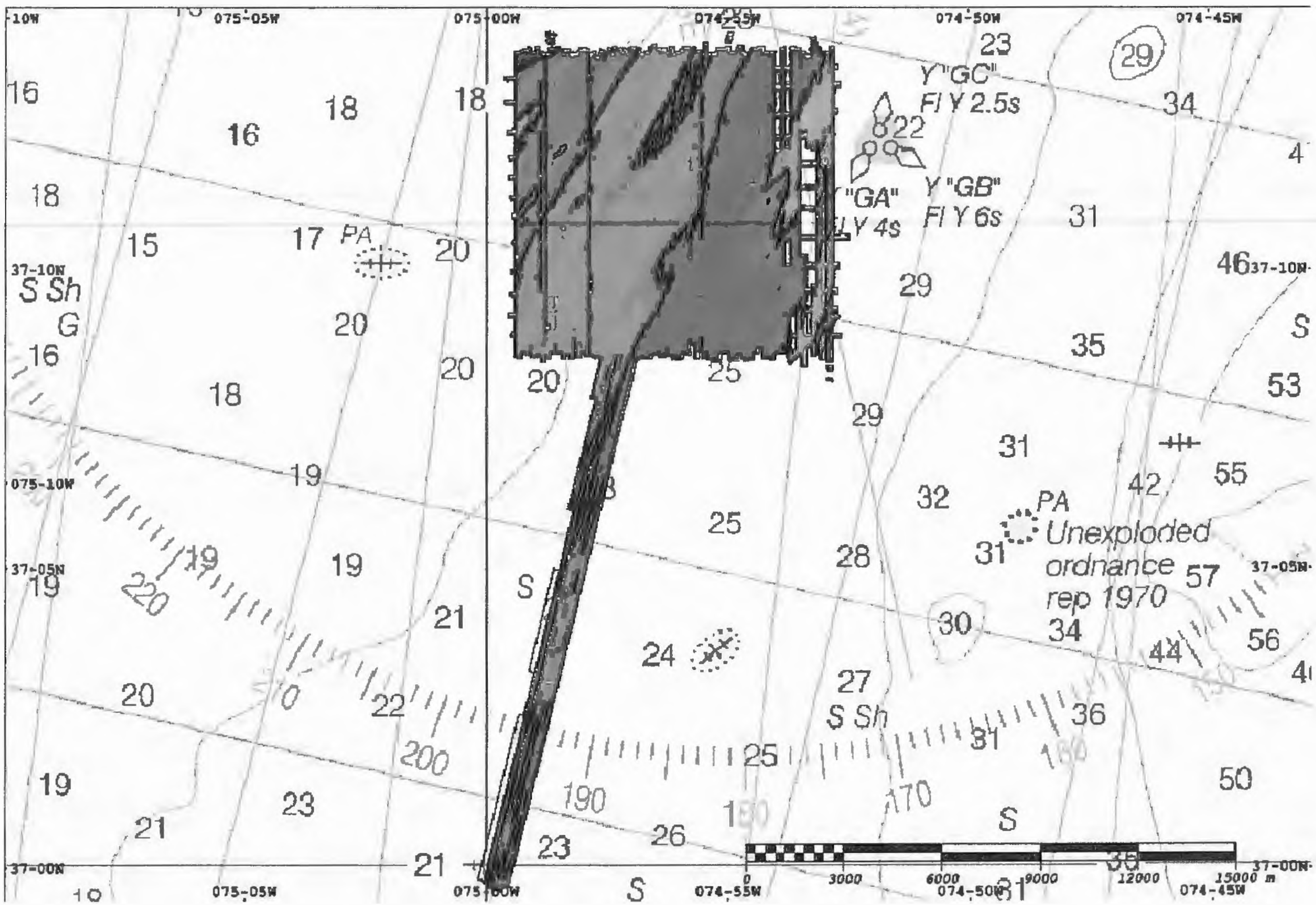


Figure 4.13 - The Central Multibeam Survey Area (5 Meter Contours)

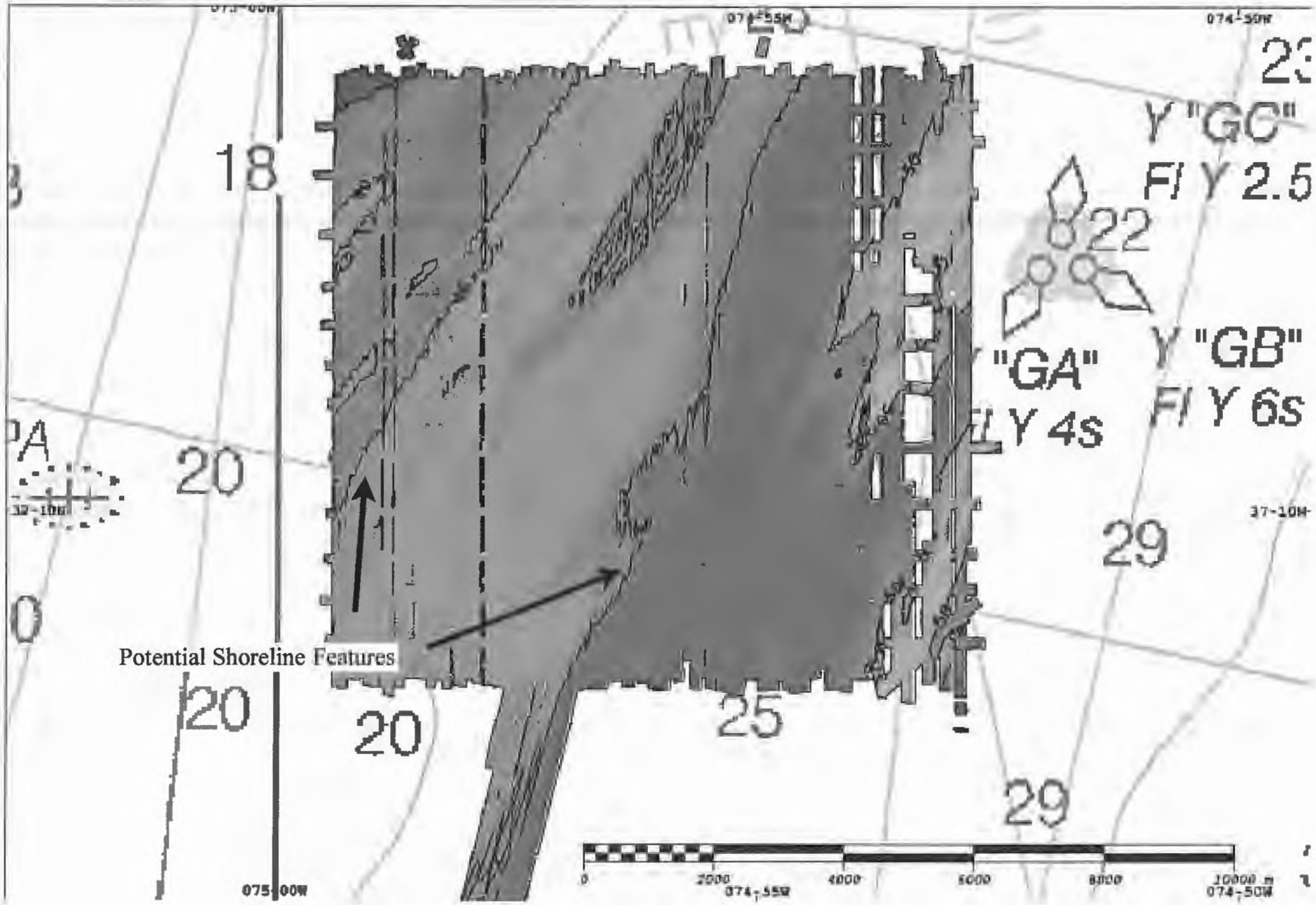


Figure 4.14 - The Central Multibeam Survey Area with Potential Shoreline Features Indicated (5 Meter Contours)

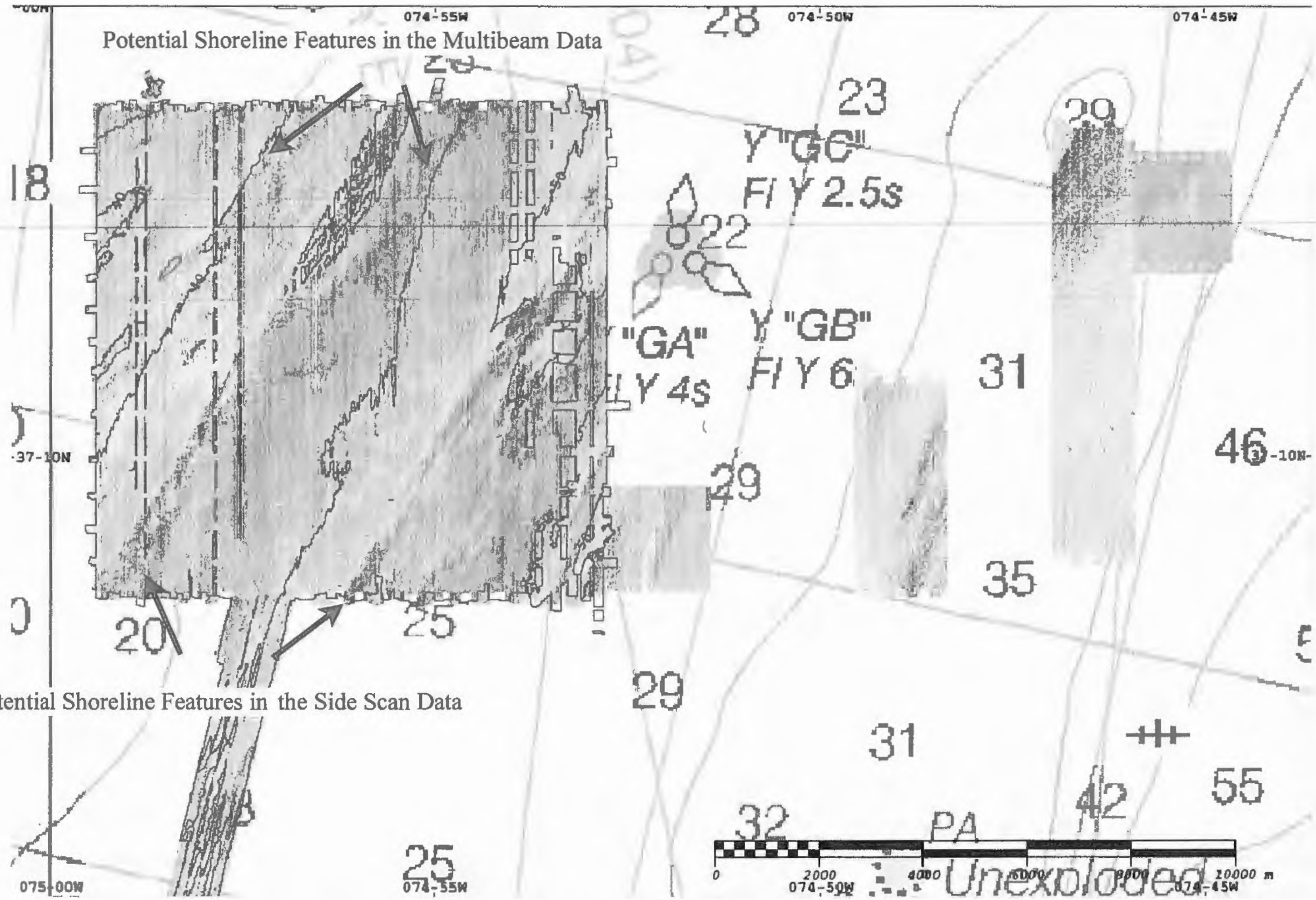


Figure 4.15 - Side Scan Data with 5 Meter Contour Lines from the Multibeam Data Superposed

Further enforcing the possibility that these features that are evident in the singlebeam and multibeam data are relict shorelines is the relative depth of the well-established Block Island Shoreline. Over its approximately 800 kilometer course from near Nantucket to southeast of Virginia, the depth of this shoreline ranges from between 36 to 48 meters in depth. In general, the slope of the feature is downward toward the southwest, which suggests that it is probably located at the deeper end of this range near Norfolk Canyon (Emery and Uchupi 1972). Therefore, it is very likely that the Block Island Shore intersects the central Multibeam Survey area. It is even quite possible that one of the two pronounced possible shorelines observed during this project could be this feature, as one is at roughly 40 meters depth and the other at approximately 45 meters depth. However, it is difficult to determine exactly which of these it is without a larger scale survey that traces their extent.

The higher resolution of the multibeam data allows for several features to be visible that are not in the singlebeam data or the side scan data. In particular, it is clear in the multibeam data that the regions between the possible shorelines are not mostly flat or gently sloping. For example, between the two lines that represent the two most pronounced possible shorelines, there is a slight valley along much of the southwest-northeast axis. There is a similarly trending valley in the far southeast corner of the survey area as well. The orientation of these valleys parallel to the potential shoreline, however, suggests that they are unlikely to have been rivers or streams. Similarly, there is no evidence to suggest that there were any embayments in this area at the time that parts of this region were subaerially exposed. Additionally, there is no evidence of any rivers or streams in the seven tracklines of data that extend south-southwest from the main part of this survey area, although it is likely that the ancestral Susquehanna River would have passed through it. Finally, despite the fact that the multibeam survey returned higher resolution data than did the singlebeam survey, there is no clear evidence of rock outcrops or any other similar features that may have served as potential attractants for early human occupants of the Americas.

The western survey area is substantially smaller than the other two and does not correspond with any of the data that was collected by either the side scan or singlebeam sonars. Unlike with the central survey area, contours of less than 5 meters do not clutter the map to the point that it becomes uninterpretable. For this reason, I have plotted this region with 1 meter contours (Figure 4.16). There is only one feature in this area of particular interest. Near the southeastern corner of the survey area, there is a narrow southwest-northeast trending valley with relatively steep sides. It is possible that this valley could represent a relict river or stream. Although it is oriented roughly parallel to most of the potential shorelines that we observed, this valley is slightly curved and is located along the trajectory that the ancestral Susquehanna likely would have followed. Unfortunately, this survey area only includes a small piece of the trough, so it is difficult to make such determinations with any great degree of certainty. Nonetheless, it represents an interesting possibility, particularly with respect to the goals of this thesis, as the Susquehanna or any other river would have represented a source of important resources and may have occupied an important place within the land use system of the early inhabitants of the Americas. Additionally, it is

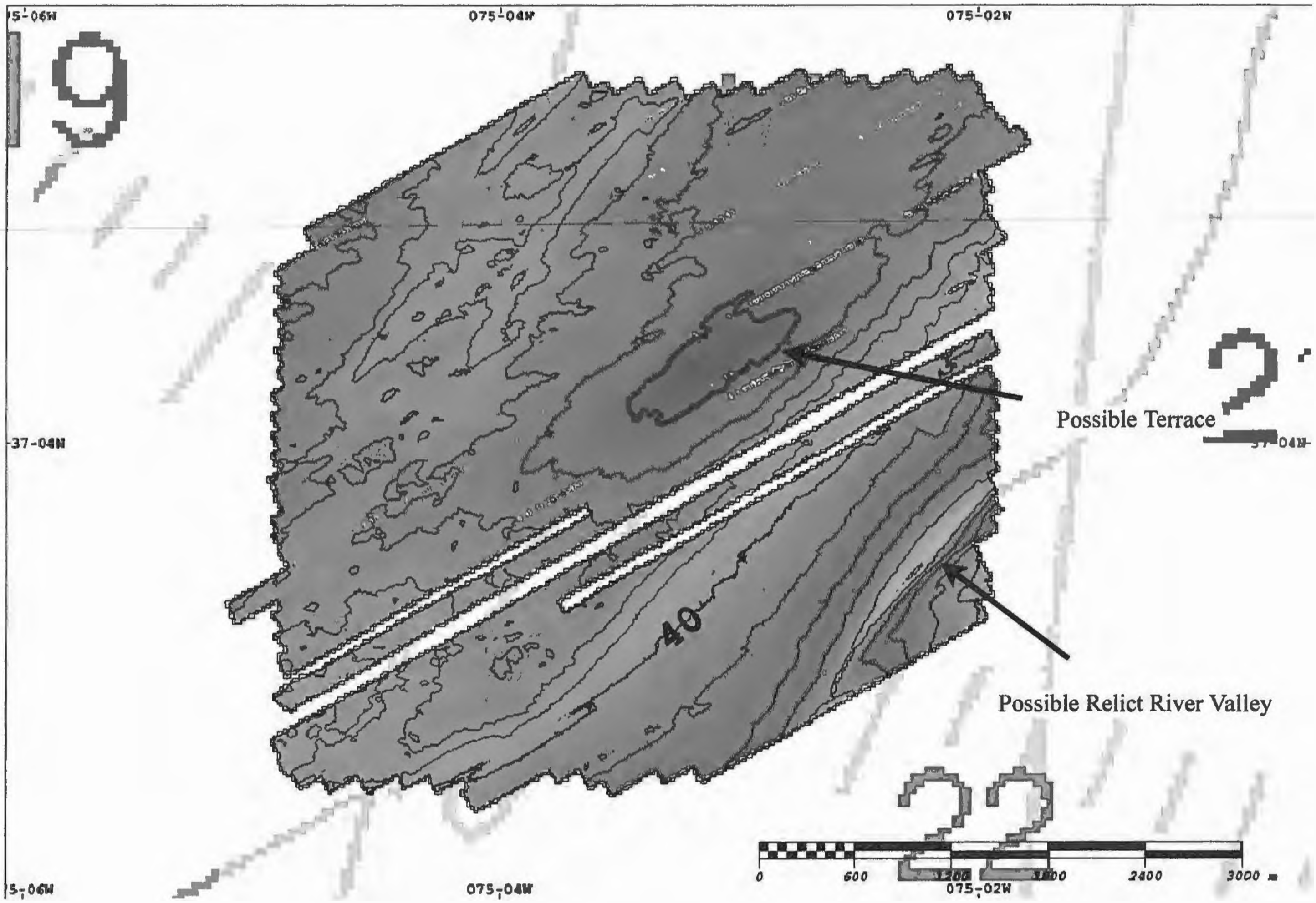


Figure 4.16 - The Western Multibeam Survey Area with the Features of Interest Indicated (1 Meter Contours)

also possible that the feature could be associated with the Block Island Shoreline, as the contours on the walls range from 40 to 44 meters deep.

Beyond this feature, there are not really any clear topographic features within this survey area. This includes other possible river or stream features or embayments. There is, however, a relative high point just to the northeast of the center of the survey area. By itself, this would not necessarily represent anything particularly important. However, if the valley in the southeastern corner of the survey area is in fact a relict river valley, the high point could be of great interest. As I argued in Chapter 2, many of the largest and most important Paleoindian sites in the northeastern United States are located on plateaus, terraces, bluffs, ridges, and other high points above nearby rivers or creeks. Because of this, based simply on the information that is available from our 2006, 2007, and 2008 surveys of the area, this feature and the relatively flat area surrounding it should be highly ranked in terms of the possibility of human occupation. Despite this, there is no direct evidence that cryptocrystalline rock such as chert, which was also one of the important factors influencing Paleoindian site distribution, was present in the area, as no such features are evident in the multibeam data. However, it is quite possible that such materials may have been carried from upstream and were available in the nearby river. Obviously, this is all speculation, but this survey area remains quite promising for our quest to find evidence of early human occupation on the continental shelf.

The eastern survey area is of particular interest for this thesis because it includes the head of Norfolk Canyon, a feature that I previously argued may have marked the intersection of the ancestral Susquehanna River with the Atlantic Ocean and may have experienced estuarine conditions during a period of lower sea level, possibly around the time of the Last Glacial Maximum. If this was the case, and humans were living in the Americas at this time, such an environment would certainly have provided preferred settlement locations on the landscape. Because of the intense slope of the edge of the canyon, I plotted 10 meter contours in this area rather than anything smaller (Figure 4.17). Upon doing this, no shoreline features in the area surrounding the head of the canyon become apparent. This is interesting because the Franklin Shoreline is located at a depth of approximately 85 meters near its southern extent just to the south of Norfolk Canyon, and should intersect the canyon head (Emery and Uchupi 1972). Additionally, Dillon and Oldale's (1978) estimate of an LGM sea level is also at 85 meters below present. No evidence of either can be observed in the multibeam or side scan data collected during this project. Milliman and Emery's (1968) estimate for the LGM sea level of 130 meters was outside of the survey area, with the exception of the 130 meter contour along the steep slope of the canyon.

There is no direct evidence to definitively determine where any rivers or streams would have entered the canyon, although at least the Susquehanna River and almost certainly others would have done so. However, there are several patterns in the contour lines that suggest where this may have occurred. In particular, there are two areas to the north and another to the south where depressions in the landscape extend a substantial distance from the main axis of the canyon (Figure 4.18). In addition, there are similar, much smaller features, many further from the canyon head, which also

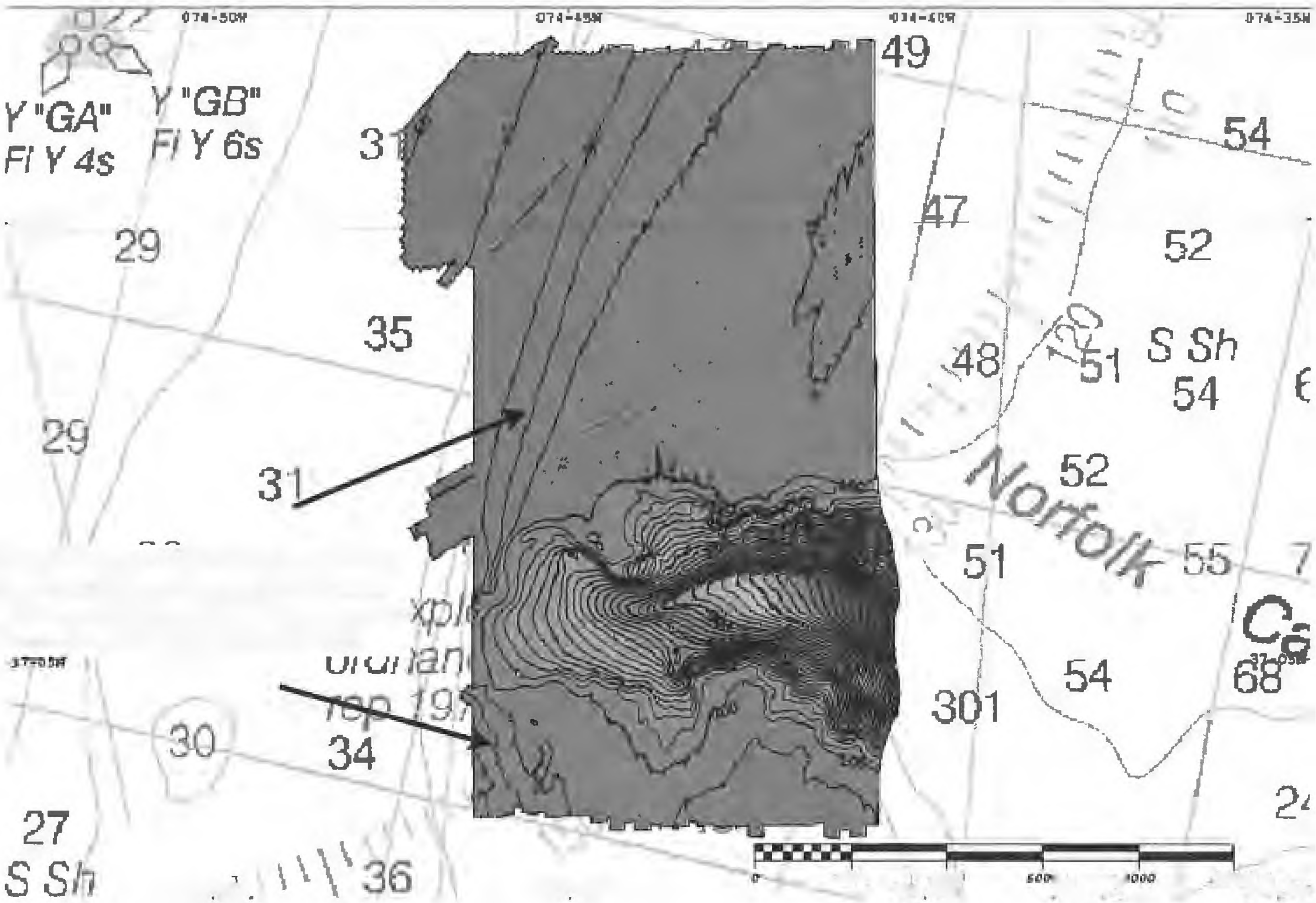


Figure 4.17 - The Eastern Multibeam Survey Area (10 Meter Contours)

may indicate the point of entry of a river or a stream. Certainly, however, this is highly speculative without core samples to test the location of possible relict river beds.

Of great importance for our quest to determine where humans may have decided to settle near the head of Norfolk Canyon is the possible location of regions experiencing estuarine conditions, particularly those that may have been able to support large shellfish populations during periods that the rate of sea level rise was not so rapid as to prohibit their growth. Such regions would include relatively flat parts of the edge of the canyon. There are two such areas, one on the northern face of the canyon and another on the south (Figure 4.18). The one to the north is particularly promising, as it is between what I previously labeled as potential points of riverine entry into the canyon and it marks a larger flat area than anywhere else surrounding the canyon head. The flat area to the south is also adjacent to a potential point of riverine entry. Such areas would have been preferred for human occupation because people would have been able to access both marine and freshwater resources within relative short distances of each other, as well as those resources unique to the estuarine environment, as I discussed in Chapter 2. Other smaller flat areas exist along both the northern and southern face of the head of Norfolk Canyon. These are all between the two extreme estimates of 85 meters and 130 meters below present-day sea level given by Dillon and Oldale (1978) and Milliman and Emery (1968) for the depth of the sea level during the LGM. This enforces the idea that these flat areas could have been submerged under shallow water during a period when sea level and shorelines were

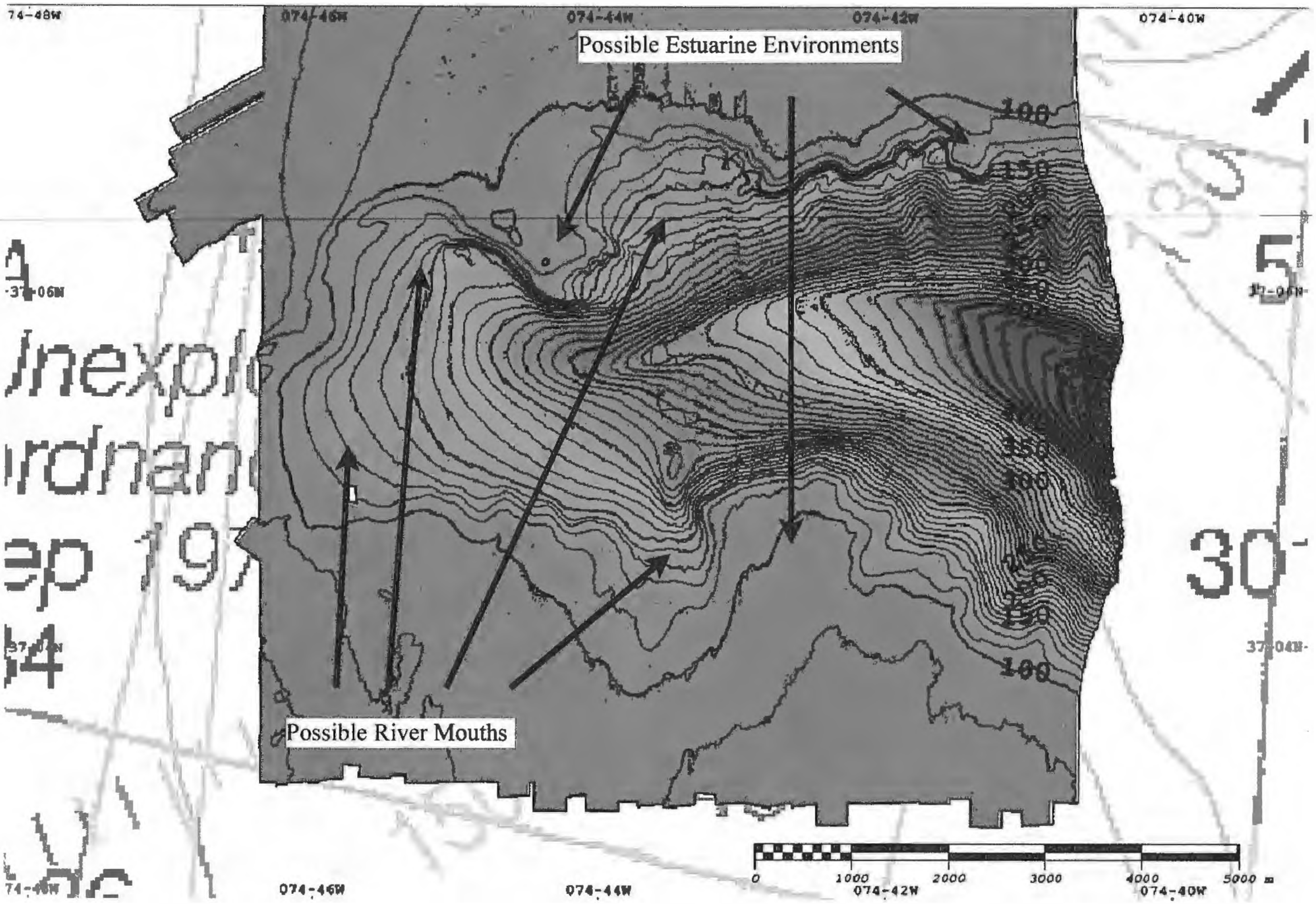


Figure 4.18 - The Eastern Multibeam Survey Area with Features of Interest Indicated (10 Meter Contours)

relatively stable, allowing for the formation of estuarine conditions and associated shellfish beds.

The eastern survey area can be divided in half. The southern half is comprised mostly of the head of Norfolk Canyon, whereas the northern half is not associated with the canyon, and topographically is more similar to the western and central survey areas. As such, I generated a separate map of the northern half so as to not wash out the apparent fluctuations in topography there within the color scheme by the much greater depths present within the canyon (Figure 4.19). In general, however, there are not many topographic features in the northern half of the survey area to speak of. 1 meter contour lines are relatively evenly spaced throughout the region, suggesting that the slope was relatively constant. This in turn argues against the presence of submerged shorelines remaining within the study area. This is similar to what we found in the side scan data from 2007. In the northwestern corner of the region, there is an area where the contour lines are closer together, although the line segments are much too small to make definitive interpretations. Additionally, the shape of the contour lines do not suggest the presence of rivers or streams. Finally, there is no evidence of any other discrete features throughout the eastern survey area.

Conclusion

In general, it is clear that the observations and interpretations included in this chapter are promising for the search for submerged sites on the United States Atlantic continental shelf. The fieldwork and data collection for this thesis was centered

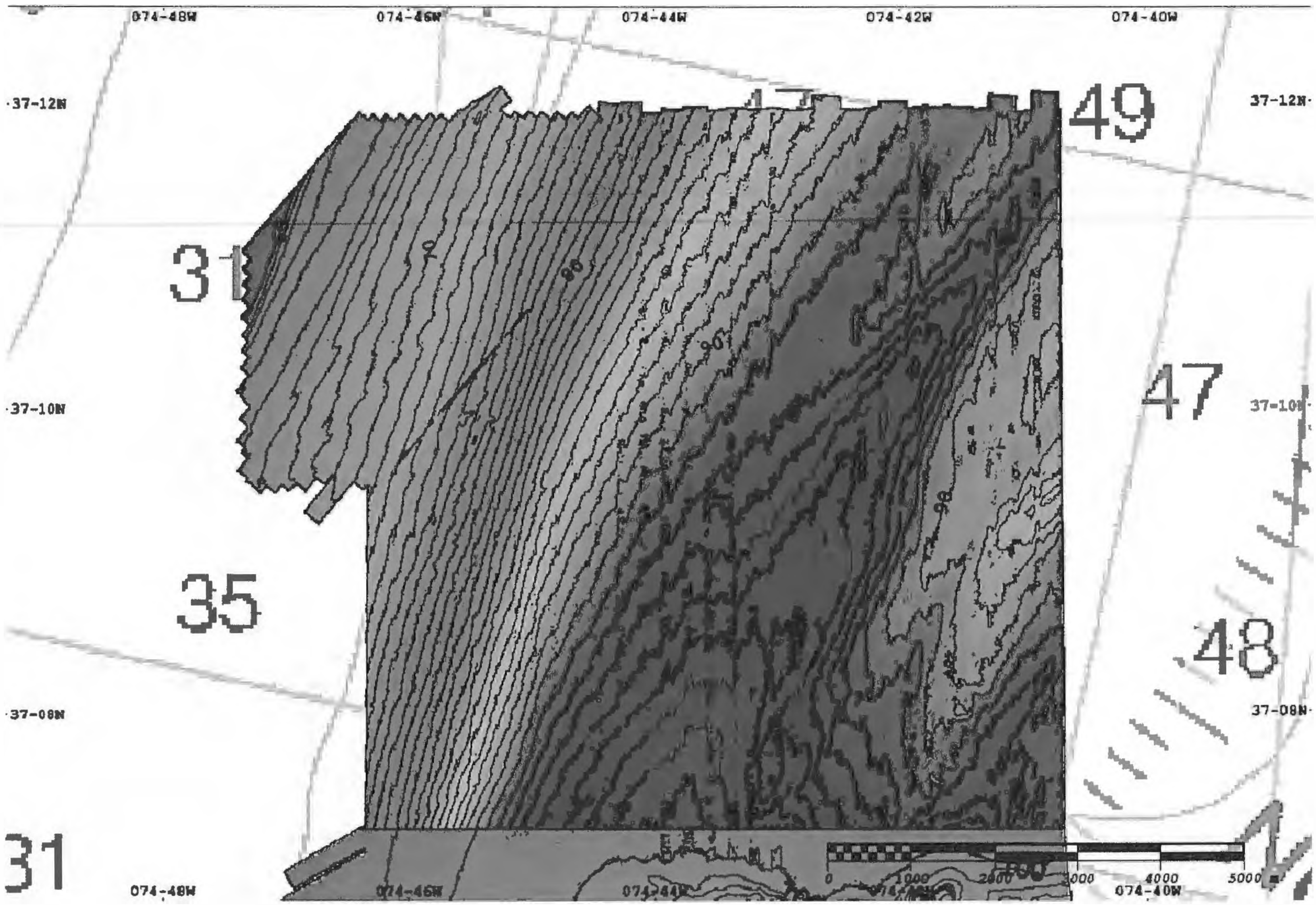


Figure 4.19 - The Northern Half of the Eastern Multibeam Survey Area (1 Meter Contours)

around acoustic data obtained during a series of research cruises that were shared with several disparate archaeological objectives as a part of the Virginia Capes Archaeology Project. Because of this, more research is necessary to make any concrete determinations about where submerged sites may be located. This project represents a first step in generating predictive maps of where such sites may be. As I briefly described earlier, and I will discuss in more detail in the next chapter, there are certain areas that should receive further study, particularly with core samples, before we can make legitimate guesses as to where to start looking for sites. Additionally, there would be some value in continuing the acoustic survey of the area, particularly between the head of Norfolk Canyon and the western multibeam survey area, in an attempt to locate any traces of the ancestral Susquehanna River. In any case, in the next chapter, I will expand on the results obtained from processing the current data set and tie this project into the greater understanding of the early prehistory of the Mid-Atlantic United States and the Americas as a whole.

Chapter 5 - Discussion and Conclusion

Discussion

The data set from which I made the interpretations described in Chapter 4 provides an important step toward our understanding of human occupation of the North American continental shelf. Logistical and financial concerns, as well as the longstanding debate over the antiquity of human settlement of the Americas, have stifled the ability of archaeologists to explore the shelf to any substantial degree. Even on land, it can be difficult to survey for and locate archaeological sites, particularly within a large survey area. Certainly, any difficulties encountered on land are multiplied underwater. This is true at any depth, but they are especially pronounced the greater the depth. As the edge of the continental shelf, including our survey area, is located under at least tens of meters of water and in many cases more than 100 meters, the costs to search for archaeological sites are relatively high. On top of that, the continental shelf represents a very large search area. Therefore, one of the major objectives of this thesis was to reduce this area to something a bit more palatable.

The first step in doing this was to choose a survey area. I argued in Chapters 1 and 2 that the submarine canyons that line the Atlantic continental shelf of North America, and in particular Norfolk Canyon, are ideal locations to begin looking for evidence of human occupation. On top of that, a survey of the head of Norfolk Canyon could easily be tied in to the Virginia Capes Archaeology Project, which also included a general shipwreck survey and the search for an individual sixteenth century wreck that is potentially located in the survey region. This was beneficial in that it assisted with funding the project, but at times it forced a compromise in exactly where acoustic data would be collected.

Still, we were able to survey the head of Norfolk Canyon in greater detail than anybody had done previously. Although the sidescan coverage of the canyon head was a bit disappointing, we were able to generate an excellent map with the multibeam data that we collected. This feature is of great interest not only archaeologically, but also oceanographically. Purely with respect to the latter, the map created from the data collected during the Virginia Capes Archaeology Project provides much greater insight into the morphology of the canyon than was available previously, certainly compared to the much more geographically extensive survey of Uchupi (1970) in the mid-1960s. While Uchupi's seismic reflection study, which covered the outer edge of the entire Atlantic Continental Shelf from Nova Scotia to Key West, was important in that it provided a relatively good look at all of the submarine canyons on the edge of the shelf, there is no way that it could possibly have been conducted to the resolution provided by an intensive survey of a single canyon. To do so for all of the canyons on the shelf would have required astronomical costs, both with respect to funding and time.

This decade, Mitchell (2004) compiled the results of a series of multibeam sonar surveys of a much smaller survey region off the coast of Virginia, North Carolina, and the Delmarva Peninsula, which included Washington and Norfolk Canyons. While much higher resolution than the one conducted by Uchupi, Mitchell's study was not as focused as ours, as he was looking not only at the major canyons, but the much smaller ones between them as well. Again, this study and the surveys that contributed to it, while beneficial to the overall field of oceanography in a number of ways, cannot offer the insight into the head of Norfolk Canyon that an intensive study such as the current project can. This includes but is certainly not limited to the ability to detect topographic features that suggest where rivers or streams may have entered the canyon, areas that my have represented estuarine environments, and evidence of submarine processes within the canyon. As I mentioned previously, the first two of these would have had a dramatic impact on where humans would have decided to occupy the landscape, and the third could influence the preservation or burial of sites.

Although the fieldwork itself can be fit entirely into the field of oceanography, as it was entirely conducted using methods that would traditionally be viewed as belonging to oceanographers, it was driven in major part by archaeological questions and its results have clear archaeological implications. In general, the continental shelf is a relatively flat feature and Norfolk Canyon, if nothing else, represents something topographically different that would have stood out to the early occupants of the region, if they were present at the time that the canyon was subaerially exposed. Additionally, for reasons that I outlined earlier, Norfolk Canyon and its possible estuarine resources, as well as the likely associated Susquehanna River and the resources that it would have provided, including food resources and cryptocrystalline rocks, would certainly have been attractive to human populations.

The projectile point that was recently rediscovered in a museum collection is of tremendous importance both for the overall understanding of human settlement of the

Americas and this project in particular. The point, which was recovered from dredge material that also contained megafaunal remains and other organic materials that have been dated to about 22,000 B.P. (I.R. Mather, personal communication 2009), is fundamentally important in that it can place human occupation in the New World at this early date. On top of this, the fact that the point was originally recovered off the coast of Virginia near Norfolk Canyon has important implications for this thesis. First, the presence of a human artifact on the continental shelf near Norfolk Canyon at all lends support to the idea that humans occupied the area at a time during which it was subaerially exposed. Second, the projectile point typology is of a pre-Clovis type, contributing credibility to the idea that humans were in the area before Clovis and the claims that terrestrial sites in the region, including Cactus Hill and Meadowcroft Rockshelter, also predate Clovis. Finally, the date of 22,000 B.P. obtained from the organic material associated with the projectile point corresponds roughly with the period that sea levels would have been at their lowest point during the LGM. Placing human occupation at the LGM associates it with the period of exposure of the continental shelf during which the Susquehanna River was most likely to have extended to Norfolk Canyon. This lends some degree of validation to some of the interpretations I made earlier, particularly those that were dependent on Norfolk Canyon having been the LGM counterpart of the present day Chesapeake Bay.

The central hypothesis of this thesis is that parts of the landscape surrounding the head of Norfolk Canyon would have been preferred locations for human habitation during periods of lower sea level, particularly during the LGM and the early stages of sea level rise. Of course, the data that was collected during the cruises of the Virginia Capes Archaeology Project was insufficient to conclusively demonstrate that humans lived on this landscape, as it was limited to acoustic surveys. However, I argue that we were able to locate several features on the landscape that can be correlated with similar terrestrial features, which in turn are often associated with evidence of human occupation. Certainly, the eventual goal of underwater archaeologists who are addressing the early human settlement of the Americas is to locate individual archaeological sites. In this project, it was not our goal to do so, as such a discovery is, without an unbelievable stroke of luck, at best several years, research cruises, and theses away. Still, I argue that this thesis and the associated prehistoric component of the Virginia Capes Archaeology Project were successful in our goals and the data collected and processed for them uphold the central hypothesis that I outlined above. We have reason to believe that people could have occupied parts of the continental shelf surrounding the head of Norfolk Canyon and that features remain on the landscape that at the time of their exposure would have served as attractants for human settlement.

Aside from Norfolk Canyon itself, the most obvious features on the landscape are the potential submerged shoreline features that are evident in both the singlebeam and multibeam data. These features are clearest in what I called the central multibeam survey area. There are at least two of these features that are very pronounced and can be unambiguously observed in the same location in the singlebeam and multibeam data, although what initially appeared to be similar features in the side scan data are shifted to the southeast. These features all run from southwest to northeast, roughly parallel to the edge of the shelf and the angle that the shoreline would have formed as it was retreating. In the singlebeam and multibeam data, these possible shorelines can be observed directly from the contour lines, which were derived from depth data. Particularly in the case of the singlebeam data, contour lines appear to bunch around these potential shorelines, suggesting a relatively dramatic change in elevation. This is less pronounced in the multibeam data, in part due to the lower resolution of the contour lines, but the lines that do exist occur in roughly the same location. In addition to the two most obvious possible shoreline features outlined in the previous chapter, there were several less clear possibilities that appeared in all three data types in the central multibeam survey area, and in the side scan data collected by AUVs further to the east.

The task then becomes to translate the position of these potential shoreline features into a series of predictions as to where people may have lived at the time the continental shelf was subaerially exposed. The most effective way to do this would be to search for other topographic features near the shorelines. In particular, possible rivers, ponds, and bays could have provided important resources that would have drawn people to live nearby. Where they would have intersected the shoreline, and therefore the ocean, would have provided the inhabitants with access to multiple types of resources. This would likely have increased the total abundance of resources and almost certainly increased their diversity, allowing for human survival during a wider variety of environmental events and conditions. Not only would this have attracted people to live there during a greater percentage of prehistory, it would also have allowed them to remain in one place for a longer period of time, thus increasing the archaeological visibility of consistently inhabited sites.

Unfortunately, however, there do not appear to be any such features associated with any of the potential shorelines. Still, this may just be due to a limited and patchy survey area. We have images for relatively small segments of these features. Only by collecting data from a larger part of our overall survey area can we determine if features such as these are not present, or present but located outside of the region that has been surveyed. There is also one other possibility, that they have been buried by marine sediment. To test for this, it would be necessary to either collect sub-bottom sonar data or a series of core samples.

In any case, there is something to be gained by looking at the morphology of the shorelines by themselves. For example, steeper shorelines that may have remained in place for longer periods of time would have allowed people to live in the same coastal locations for longer periods of time and therefore increased the archaeological visibility of the sites. I discussed in Chapter 4 a promising location along the further east of the two most probably shoreline features in the central multibeam survey area. The northeastern half of that shoreline segment appears to be split into two separate shorelines, while the southwestern half is a single feature. This suggests that the latter is overall a steeper feature and that part of the shoreline remained in place for a relatively longer period of time while the sea level transgressed over the relatively flat area between the two northern shoreline segments. Therefore, it would seem that the southwestern half of the shoreline segment would be a good place to start to look for sites, as people had more time to live there, assuming they were living on or near the coast, and they could have remained in the same area for relatively longer periods of time, thereby increasing the archaeological visibility of those sites. Therefore, this segment of the potential shoreline could be an ideal location to collect a series of cores in a further narrowing of the strategy I presented in the previous chapter.

With the exception of the region around the head of Norfolk Canyon, the feature that is most likely to be associated with human habitation is the topographic high point adjacent to a possible river bed within the western multibeam survey area. The potential river bed is a unique feature within all of the data that we collected during the Virginia Capes Archaeology Project. It is unfortunate for our quest to locate evidence of human habitation of the region that no other such features were observed, as many of the largest and most important Paleoindian sites in the northeastern United States are riverine in focus. In particular, sites such as Williamson and Thunderbird, along with numerous others, are long and narrow and located on terraces adjacent to rivers or creeks. In studying Paleoindian site distribution on the Delmarva Peninsula, Custer (1984) observed that one of the two main categories of site settings was "well-drained floodplains and terraces of major rivers." Obviously, any human occupation of the area for this thesis would have predated the Paleoindian period by at least several millenia. However, as I argued in Chapter 2, in many cases, Paleoindian settlement patterns represent the best analogs that we have for understanding those of prior periods. Therefore, the high topographic point overlooking the adjacent possible river bed is a location on the landscape of great interest (Figure 4.16) and any more extensive study of the survey area, with coring or otherwise, should include this feature. Unfortunately, the image that we have represents only a small segment of the valley, making it difficult to make concrete determinations as to whether it in fact represents a river, and if so, whether it is the ancestral Susquehanna River. Further acoustic surveys of the study area must be focused on trying to locate the path of the Susquehanna, as if evidence of it remains in the topography, it could provide very important clues as to where to begin looking for evidence of human habitation.

The most prominent topographic feature in the study area for this thesis is of course the head of Norfolk Canyon itself. As I argued in Chapter 2, there are reasons to believe that parts of the canyon head could have possessed characteristics similar to many of the estuaries that today occur at the intersection of the major rivers of the northeastern United States with the Atlantic Ocean. The Susquehanna River, which likely extended out to Norfolk Canyon at the time that the continental shelf was subaerially exposed, today terminates at Chesapeake Bay, a large and very productive estuary. Ever since the Chesapeake formed about 5,000 years ago, it has been of tremendous importance for the subsistence of the human occupants of the region (Blanton 1996). Had similar conditions existed at any point of prehistory, it is certain that they would have played an equally vital role in human subsistence. Barber (1979) has argued that upper estuaries such as what the head of Norfolk Canyon would have been are ideal locations to exploit transient species such as anadromous fish. Similarly, they frequently contain shellfish, which are most abundant at freshwater-saltwater transition zones (Turner 1978). For these reasons, in Chapter 4, I used the map generated from the processed multibeam data to determine where two important types of features may have existed. The first type includes rivers and streams that may have emptied into the canyon, the point of intersection of which would have allowed inhabitants to easily access both freshwater and marine resources. The second includes relatively flat areas that may have contained estuarine conditions during parts of prehistory and would have allowed access to shellfish resources.

As was the case throughout the survey area, with the single exception in the western multibeam survey area, there was little topographic evidence for the presence of rivers or streams near the head of Norfolk Canyon. However, there are several intriguing protrusions from the edge of the canyon that may represent where water bodies such as those may have intersected the canyon. The landscape around these features may have been the site of intensive human settlement for reasons mentioned in the previous paragraph. Additionally, I also noted several flatter sections of the landscape immediately surrounding the canyon that may have contained estuarine conditions soon after they were submerged. These areas may have been very productive, particularly with respect to shellfish populations. Only through taking core samples of these areas can it be determined whether they in fact were estuarine at any point. If so, they will represent a major clue as to where people would have lived on the landscape during the LGM, when it would theoretically have been subaerially exposed.

For all of the reasons that I have outlined so far in this chapter, the results of the fieldwork and data processing conducted for this thesis tentatively uphold the hypothesis that I presented in Chapter 2. Although I did not by any means find conclusive evidence of human occupation of the study area, the goal of this project was not to do so. Rather, the goal was to locate topographic features that potentially correspond to places that could have been highly attractive to human populations. Using side scan, multibeam, and singlebeam sonar data, it was possible to identify three features in particular that fit this criterion and should be investigated further. First is a segment of a potential shoreline feature to the northwest of the head of Norfolk Canyon. The second is a potential terrace above a relict river valley possibly corresponding to the ancestral Susquehanna River to the west of Norfolk Canyon. And the third includes several potential river mouths and estuaries that surround the head of Norfolk Canyon.

In general, this project has taken a very constructive first step toward a greater understanding of the head of Norfolk Canyon and the surrounding landscape, as well as the way humans may have interacted with the landscape. Because sea levels have risen possibly 100 meters or more since the LGM, any evidence of coastal human activity from that time is currently submerged. This project and others like it represent an important step in our quest to understand the circumstances surrounding the peopling of the Americas and the eastern United States in particular.

Future Work

There are several strategies that should be pursued during future surveys of the survey area in order to take this study to the next level. The most obvious is to collect side scan, multibeam, and singlebeam data from a larger region. In particular, it would be valuable to fill in some of the gaps between the western, central, and eastern multibeam survey areas. Hopefully, this would allow for the identification of more possible river features, including the Susquehanna. This would also provide the opportunity to obtain a larger view of the features that were evident in the current data, and test whether the interpretations that I made in this thesis were valid. More extensive side scan data of this area could be valuable as well, as it could help to better identify the features that were at first interpreted to be possible shoreline features in this study. Finally, more extensive survey of the region surrounding where the projectile point was recovered with the scallop dredge could potentially reveal more information about where this point may have existed in situ, particularly with respect to topographic features.

One acoustic technique that was not explored for the current project but could prove quite valuable for the objective of locating relict topographic features on the submerged landscape is high resolution sub-bottom sonar. Since the landscape has been submerged, there has been some amount of marine sedimentation that may have covered and obscured important features like river beds, valleys and estuaries. However, a high-resolution sub-bottom survey should allow such features to be found relatively easily if they are present. Perhaps the most important use of this technology would be to search for the path of the ancestral Susquehanna River. The most effective way to do so would likely be to run survey tracklines directly to the west of the head of the canyon, where the river would presumably have intersected this feature. As we were collecting the data for the current project aboard the *Thomas Jefferson*, sub-bottom data was continuously collected, but unfortunately, it was not recorded, preventing it from being used in this thesis.

Another way that the interpretations presented in this thesis could be tested and expanded upon is through the collection of core samples. In particular, sediment cores collected from areas that I identified as possible estuarine environments could very easily test this theory, as estuarine sediments would certainly be evident in them. Additionally, a series of cores should be collected along the edge of one or more of the possible shorelines that I described in this thesis in an attempt to locate evidence of coastal sediments or vegetation. Finally, sediment core samples, if taken in the right places such as swamps, lakes, or ponds, could provide general information about paleoclimate and vegetation patterns. Techniques for doing so are well established (e.g. Whitehead 1965; Davis 1969, 1983).

Finally, although visual survey using ROVs was included within the Virginia Capes Archaeology Project, it was mainly confined to ground-truthing potential shipwreck targets, and it was only conducted during the first year of the project. It is possible that this technology could be used to obtain images of the possible shoreline features, as determined by the acoustic data collected during the current project. Similarly, the potential river and estuary features near the head of Norfolk Canyon could be tested in this way as well, although it is unclear as to how effective such tests would be. Also, despite the fact that it would require a large financial commitment, as well as a larger research team, the use of the Institute for Exploration's flagship ROV Hercules would provide the use of manipulator arms to collect rock and sediment samples, as well as to move small amounts of overlying marine sediment to determine what is below the top layers. In any case, there are several directions that future work could take, all of which could make a substantial contribution to the quest to locate evidence of human occupation of the United States Atlantic continental shelf.

Conclusion

For my concluding remarks, I think it is appropriate to discuss the oceanographic sub-discipline of archaeological oceanography. This thesis is the second in this still young academic field and the first in six years. In his PhD dissertation, Coleman (2003) simply wrote that the new science of archaeological oceanography "involves the study of human history under the sea." He then expands on this definition to specify a focus on the deep sea, particularly parts that are too deep to practically investigate using scuba divers and therefore require the use of techniques and technologies that have been traditionally associated with the other, more mainstream sub-disciplines of oceanography. In his introduction to a recent book surveying the scope of archaeological oceanography, Ballard (2008) argues that an archaeological oceanographer is an archaeologist working in the ocean, just as a geological oceanographer is a geologist working in the ocean. He describes oceanography as a whole as not a separate academic discipline in itself, but rather an arena in which various disciplines such as physics, chemistry, biology, and geology work "bonded together by common needs such as the need for unique facilities that are required to carry out these separate lines of research." This can certainly be expanded to the social sciences of maritime history, archaeology, and anthropology under the umbrella of archaeological oceanography.

Because I am in the unique position of having the opportunity to write one of the first theses in this young field and because it has grown substantially since Coleman (2003) wrote his dissertation, I would like to take this opportunity to revisit the definition of archaeological oceanography. In general, a multidisciplinary field is one in which one or more of the disciplines contribute their tools, methodologies, and thought processes to answer questions posed by one or more of the disciplines. In the most simplified case of archaeological oceanography, there are two disparate possibilities. Either (a) traditionally oceanographic techniques are used to answer archaeological questions or (b) archaeological sites or traditionally archaeological techniques are used to answer oceanographic questions. Of course, no project is really one or the other, but rather (a) and (b) form a spectrum, somewhere along which each project falls. For example, the current project is in large part using oceanographic techniques to ask an archaeological question: where did people live when the shelf was exposed? Still, it was necessary to understand the existing archaeological record and the site distribution on land to fully answer these questions. Additionally, I also addressed some oceanographic questions, particularly with regard to the structure of the underwater landscape, although to a lesser extent.

In defining archaeological oceanography, I took a somewhat different approach than either Coleman (2003) or Ballard (2008). They opted to define it broadly and in doing so include within it much of what would be classified as the somewhat more traditional field of underwater archaeology. They include in their definition all archaeology done in the ocean, which puts at the forefront the similarities between the deep water work done at the Graduate School of Oceanography at the University of Rhode Island (URI-GSO) and the shallow water work done within history, anthropology, and archaeology departments at other institutions. There is a great value to this in that it also implicitly distinguishes what we do from Odyssey Marine Exploration and other marine salvage companies that do not uphold the accepted standards of archaeological ethics and can at best be described as looters and treasure hunters. While we use many of the same tools to excavate underwater sites as these companies, we share moral and ethical codes with archaeologists operating within more traditional academic institutions. It is important to stress these associations as we attempt to demonstrate to the greater archaeological community that underwater archaeology can be done using ROVs, AUVs, and other underwater technologies native to oceanography and held to the rigid standards of archaeology on land.

I chose a more narrow definition for archaeological oceanography not to eschew the associations and distinctions implied by the broader definition; they are certainly very important to maintain. Rather, I think it is important to stress the uniqueness of what we do here at URI-GSO and in particular the interdisciplinary nature of archaeological oceanography. While other universities have strong programs in underwater archaeology and in some cases may even be proficient in the oceanographic techniques that we use, no other program has the resources available to them that we do by being native to an entire campus of oceanographers and ocean engineers. Most, if not all, of the students within the archaeological oceanography program would describe ourselves first as archaeologists (and of course second as oceanographers), while earning a degree in oceanography and interacting with dyed in the wool oceanographers on a daily basis. Still, we are capable of operating in both worlds and seamlessly use the tools of each to address whatever questions we may encounter. Finally, although this may seem counterintuitive, my definition does not confine archaeological oceanography to always be done underwater. Although this particular project is confined to an underwater environment, there are oceanographers who study volcanology and other terrestrial geologic deposits that were formed underwater. Therefore, a geochemical sourcing project of cherts or other similar cryptocrystalline rocks that were used by human groups for tools could be considered a branch of archaeological oceanography. It is clear then that by combining archaeology with oceanography, what is formed is a very powerful academic discipline that is equipped to address a great number of important questions.

This thesis is a clear example of this. The peopling of the Americas is a question that has challenged archaeologists for well over a century. Although there is debate over the relative importance of the coast in this process, to not survey the coast would be missing a large piece of the puzzle. Since the LGM, when humans potentially could have entered the Americas, likely from northeastern Asia, water level has risen enough that regions that were coastal then are now too deep for human divers to access comfortably and productively. Therefore, oceanographic techniques and the new field of archaeological oceanography offer the best opportunity to study those parts of the continental shelf. I think that this thesis, while no means a conclusive study, is a useful first step in understanding human occupation of the continental shelf, not only near Norfolk Canyon, but throughout the Americas. Although the study area would not have been an entry point to the New World, the techniques and ideas that we have experimented with can be modified and translated to other parts of the continental shelf. Therefore, the results of this thesis offer a promising first step toward locating submerged evidence of human occupation of the continental shelf and more generally, an important step in the quest to understand the peopling and early human habitation of the Americas.

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