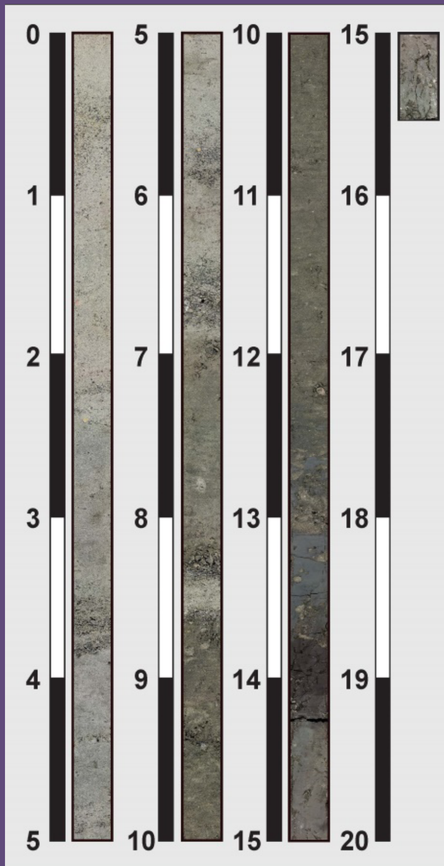

Amelia Island, Nassau County, FL Marine Geological Field Investigation for Offshore Geologic Model Support

BOEM
Notice of Scientific Research NA15-001

Submitted to:
Bureau of Ocean Energy Management (BOEM)

Florida Department of Environmental Protection (FDEP)

South Amelia Island Shore Stabilization Association (SAISSA)

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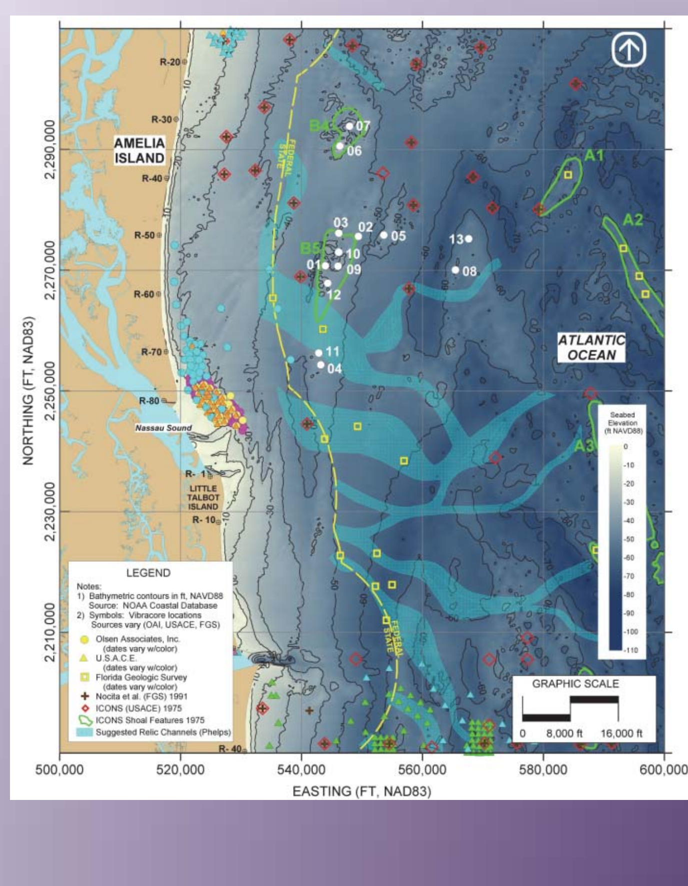

10 May 2016

olsen associates, inc.

Amelia Island, Nassau County, FL
Marine Geological Field Investigation for
Offshore Geologic Model Support

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EXECUTIVE SUMMARY

This report describes the collection and analyses of thirteen shallow seabed sediment Vibracores and supporting high-resolution multibeam hydrographic survey data acquired to describe limited areas of the seabed in Federal waters off Amelia Island, Nassau County, FL (**Figure 1.1**). The Vibracore data were collected by Athena Technologies, Inc. of McClellanville, SC, contracted by Olsen Associates, Inc. under the attached *Notice of Scientific Research NA15-001* (**Appendix A**) authorized by the Bureau of Ocean Energy Management (BOEM). Supporting hydrographic survey data were likewise collected by ARC Surveying and Mapping of Jacksonville, FL. Support for the research was provided by the South Amelia Island Shore Stabilization Association (SAISSA).

The data described herein were collected to supplement existing marine geotechnical data in the region, dating back to the late 1960's and 1970's, and to contribute to the understanding of both the spatial characteristics of the existing seabed sediments in the area and the underlying paleochannel morphology of the seabed. The data describe areas not previously sampled and add to the marine geologic model proposed by Phelps et al. (2007). This model, further described by Zarillo et al. (2009), theorizes that the nearshore seabed consists of infilled river channels and adjacent higher-elevation shoals, both created during lower sea levels. The higher elevation shoals are hypothesized by these researchers to be comprised of coarser reworked sediments, versus finer, siltier sediments that have infilled the paleochannels.

The present data collection focuses on these higher elevation shoal areas, those previously unsampled but identified by Meisburger and Field (1975) from the earliest marine geotechnical field work in the area. In particular, the current work focused on a long, nearly shore-parallel ridge lying four to miles offshore of the Amelia Island shoreline in Federal Waters. This ridge contains the B4 and B5 shoals identified, but not sampled, by Meisburger and Field.

In general, along the shore-parallel ridge and on the B4 and B5 shoals, a lens of muddy sands (5 to 15% fines, SP-SM or SM material in the USCS classification scheme) is typically found at an elevation of -45 to -47 ft NAVD88 (approx.). At deeper depths, a clay layer (CH or CL material) was found in many Vibracores, beginning at elevations of -51 to -53 ft NAVD88.

Above the silty SP-SM layer, up to -30 ft NAVD88 in limited areas, the higher elevation shoals do contain coarser sand (SP) sediments with varying levels of carbonate (shell) material and much lower levels of silts and fines (less than 2% passing the #230 sieve). The color of these sediments is likewise much lighter, typically average a Munsell Value of 6 or 7. These coarser sediments, however, are still comprised of relatively fine quartz sand, with typical median grain diameters of 0.14 to 0.18 mm and mean diameters of 0.18 to 0.23 mm. The increased mean values are the result of the presence of varying levels of carbonate (shell) material that exists in broken, hash-like form in the quartz sand. There is very little evidence of any medium or coarse quartz sand in the samples collected.

The high-resolution multibeam bathymetric data collected at the B4 and B5 shoals reveals that the shallower features, above the clay and silty sand levels, exist in irregular, broken small ridges and smaller sub-shoal features that sit atop the larger shore-parallel ridge. These features appear to be oriented in a slightly oblique angle to the ridge and the shoreline, lying more in a NE-SW orientation, but in scattered fashion. Comparison of the Vibracore locations to the high-resolution bathymetry confirms that the sand material lies in these higher elevation ridges, mounds, and sub-shoals.

<u>Discussion of Geologic Model Applicability</u> The thirteen Vibracore samples collected in October 2015 for this study supplement the existing dataset and potentially support the geological model proposed by Phelps et al. (2007) and further discussed by Zarillo et al. (2009), although the support is somewhat subjective and limited by the small number of data points. These limited results do indicate areas of coarser and cleaner sand deposits in the higher elevation areas adjacent to some of the identified paleochannel locations. The new Vibracores do not, however, completely differentiate the sediments collected within identified paleochannel areas from the sediments collected at the same absolute elevations in the adjacent areas of higher elevation shoals.

All the Vibracores, in a paleochannel or upon a shoal, seem to indicate a silty SP-SM or SM layer beginning at approximately -45 ft to -47 ft NAVD88 and extending down-core to -51 to -53 ft NAVD88, where the sediments transition to clay in nearly every core investigated. The specific sample characteristics of the silty sediment layers in either dataset are not readily available for comparison, but inspection of the photographs of the two Vibracore sets does suggest that perhaps the paleochannel sediments are finer/siltier/muddier, and darker, than the corresponding samples collected adjacent to the channels. This would support the paleochannel model, albeit only from a subjective, visual standpoint. Again, the Vibracores do indicate that above a certain elevation, roughly -45 ft NAVD88, sediments exist that are principally sandy in content. A more detailed sub-bottom sonar survey, collected at high resolution along the length of the ridge (N-S) and with a focus on only the upper 20 to 30 feet of the seabed might better identify the existence of these paleochannels.

Amelia Island, Nassau County, FL
Marine Geological Field Investigation for
Offshore Geologic Model Support

10 May 2016

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Marine Geological Field Investigation for Offshore Geologic Model Support

10 May 2016

Prepared for:

Bureau of Ocean Energy Management
Marine Minerals Program
Notice of Scientific Research NA15-001

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1.0 INTRODUCTION

This report describes the collection and analyses of thirteen shallow seabed sediment Vibracores and supporting high-resolution multibeam hydrographic survey data acquired to describe limited areas of the seabed in Federal waters off Amelia Island, Nassau County, FL (**Figure 1.1**). The Vibracore data were collected by Athena Technologies, Inc. of McClellanville, SC, contracted by Olsen Associates, Inc. under the attached *Notice of Scientific Research NA15-001* (**Appendix A**) authorized by the Bureau of Ocean Energy Management (BOEM). Supporting hydrographic survey data were likewise collected by ARC Surveying and Mapping of Jacksonville, FL. Support for the research was provided by the South Amelia Island Shore Stabilization Association (SAISSA).

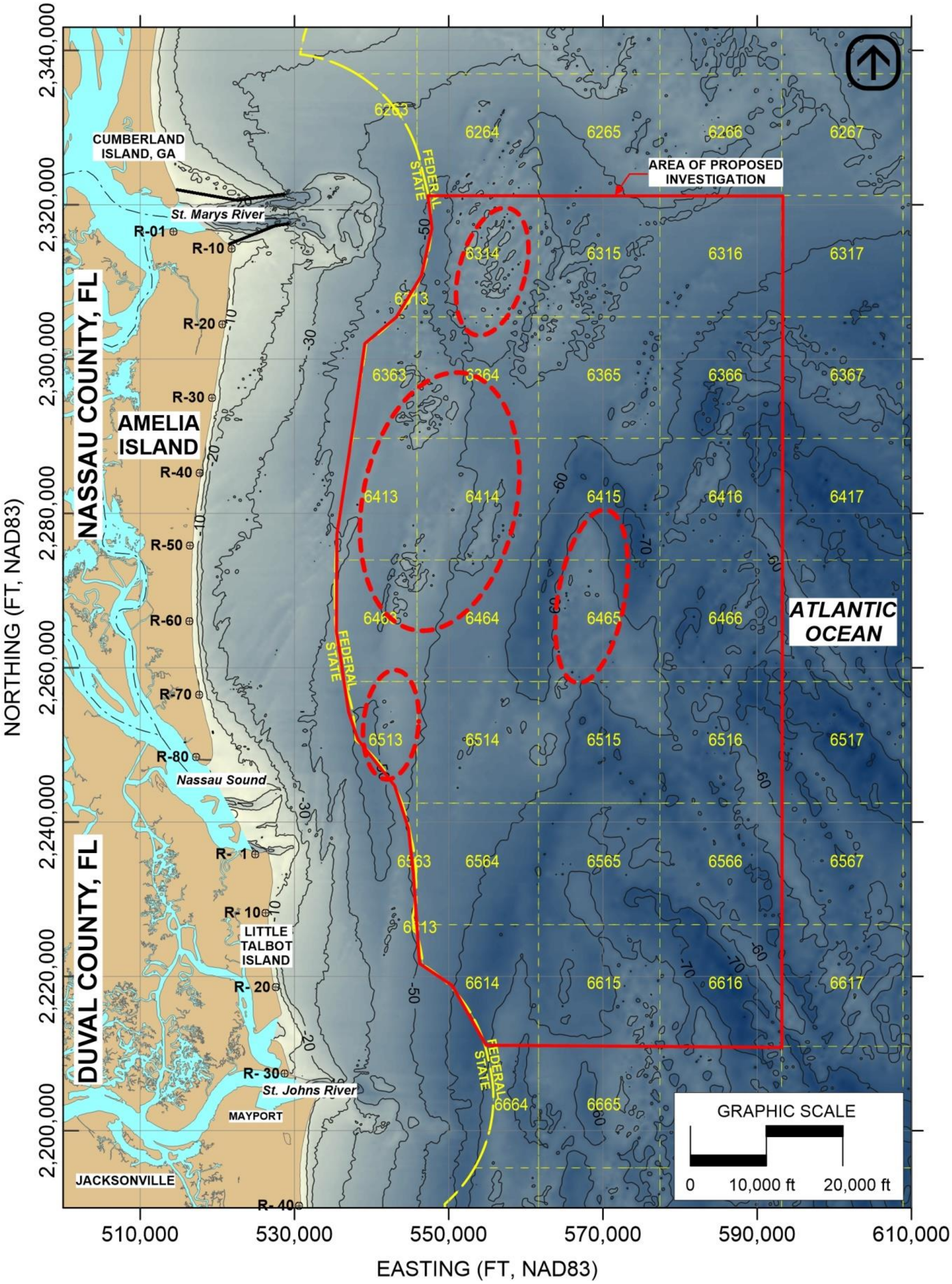

Figure 1.1 Location map of the NE Florida study area. The study focuses on the shoals in Federal Waters off Nassau County. The red ovals highlight the primary areas of interest relative to the yellow BOEM OCS block numbers. Contour elevations in feet, NAVD88.

The data described herein were collected to supplement existing marine geotechnical data in the region, dating back to the late 1960's and 1970's, and to contribute to the understanding of both the spatial characteristics of the existing seabed sediments in the area and the underlying paleochannel morphology of the seabed. The data describe areas not previously sampled and add to the marine geologic model proposed by Phelps et al. (2007). This model, supported by Zarillo et al. (2009), theorizes that the nearshore seabed consists of infilled river channels and adjacent higher-elevation shoals, both created during lower sea levels. The present data collection focuses on the higher elevation shoal areas, those previously unsampled but identified by Meisburger and Field (1975) from the earliest marine geotechnical field work in the area.

1.1 Location

Figure 1.1 depicts the overall study area for the investigation. Amelia Island is a 14-mile long barrier island extending from the jettied entrance to the St. Marys River at the Florida/Georgia State Line southward to Nassau Sound, where the Amelia and Nassau Rivers converge to meet the Atlantic Ocean. The Nassau/Duval County Line runs through Nassau Sound, which is an unstabilized inlet that separates Amelia Island from Little Talbot Island. Amelia Island lies roughly 25 miles northeast of Jacksonville, FL.

Following the standard BOEM study guidelines, the area bounded in red defines the broader limits of the field work, defined on its western edge by the three-nautical mile boundary between Federal waters offshore and waters of the State of Florida inshore to the shoreline of Amelia Island. The numbered squares in yellow represent outer continental shelf (OCS) block numbers for BOEM. BOEM uses these identifying blocks to locate studies and leases of material. The northern and southern limits of the study were selected to cover the Federal offshore area of Nassau County and northern Duval, without venturing northward into waters seaward of the State of Georgia. The eastern offshore boundary was selected to sufficiently bracket the areas of interest, which are highlighted by the red-dashed ovals, and to allow for the potential expansion of the study area from those primary areas if the data collection scheme indicated it was warranted. As will be described in Chapter 2, the red-dashed oval areas of interest were developed from the existing literature and data, guided in large part by the research of Meisburger and Field (1975) and the geologic model theory of Phelps et al (2007).

2.0 PREVIOUS WORK

This chapter summarizes the nearshore and offshore work conducted off the coast of Amelia Island in Nassau County, FL. Numerous investigators, including Olsen Associates, Inc., have conducted geotechnical studies in the region over the last 50 years.

2.1 Geologic Background

Henry (1971) provides a narrative of the geologic history of the Nassau Sound coastal area, and a description of the geologic makeup of Amelia Island and the nearshore waters of the Atlantic Ocean. Henry describes how Amelia Island was formed in two distinct time periods. The core of the island formed during the late Pleistocene Epoch as a series of sea level change cycles extending from roughly present day levels down to as much as 300 to 450 feet below present day levels over three main cycles, terminating the epoch at the lowest levels. During these cycles, marshes and lagoons formed landward of sandy alongshore strands, eventually forming the core of the island. According to Henry, late Pleistocene Silver Bluff sediments (up to 40,000 to 50,000 years before present) comprise the central core of the island extending from south of the Egan's Creek area at Fernandina southward beyond Fletcher Avenue and American Beach. This core area also lies over a thousand feet or more landward of the present day Mean High Water Line (MHWL). In the later portions of the Pleistocene Silver Bluff period (beginning roughly 25,000 years before present) sea level dropped significantly, ultimately marking the end of the Pleistocene Epoch. Rivers and creeks extended their reach across the exposed area east of the older shoreline, cutting channels down through the previously submerged sediments.

The second phase in the development of Amelia Island begins in the current Epoch, the Holocene, which began approximately 18,000 years before present and is marked by a slow rise in sea levels up to the present day condition. As the sea level rose, the river channels that extended across the Pleistocene coastal plain now met the sea and were shortened, causing deposition of sediments in various areas across the present day continental shelf. As sea levels rose to match those of the early Pleistocene Silver Bluff, sediments were deposited along the interface between the two. Henry describes this interface as a lagoon that later developed into the Egan's Creek salt marsh and the lower areas and ponds that run parallel to the beach down the island (roughly 1,000 to 1,500 ft landward of the present day MHWL). In the now-submerged offshore areas, the river channels infilled, typically with finer sediments, over this rising-sea portion of the Holocene, and the coarser sediments deposited by the truncated river mouths were submerged in place in numerous areas. The offshore ridges seen in **Figure 1.1** may be formations left in place (i.e., buried 'temporary' shorelines or nearshore areas) during short pauses in sea level rise during the Holocene period.

2.2 Previous Investigations

Meisburger and Field (1975)

The first significant offshore sand resource study in Federal waters off the coast of northeast Florida was published in 1975 by the Coastal Engineering Research Center (CERC) of the U.S. Army Corps of Engineers' (USACE). Meisburger and Field (1975) conducted shallow seabed sub-bottom sonar reflection profiling, coupled with 20-ft sediment cores, to characterize the offshore geology. The study was part of the Inner Continental Shelf Sediment and Structure (ICONS) program, which collected similar data all along the Atlantic coast of Florida. **Figure 2.1** summarizes the field efforts off Nassau and Duval Counties. The Vibracore and sub-bottom data were evaluated to describe various areas of interest, characterized as follows:

- 'A' – areas of best potential for beach compatible sand
    - Determined with some level of sampling
- 'B' – areas not sampled, but possibly containing beach compatible sand
- 'M' – areas of no interest for beach compatible sand

The 'A' shoals off Nassau County were identified 12-14 miles offshore, within the area of the NW-SE trending ridge field seen in **Figure 1.1** near the eastern edge of the red boundary box. Very limited Vibracore sampling of these 'A' shoals revealed gray to light gray 'clean quartz' fine sand in lenses of 2 to 9 ft or more in thickness[1]. It is noted that the 'A' shoals in neighboring Duval County were used to develop the borrow areas used for the Duval County Shore Protection Project (shoals A4 and A5 in **Figure 2.1**).

Numerous 'B' shoals were identified along the generally shore-parallel ridges much closer to shore, but no additional data were collected on those features at that time to establish their sediment quality. One objective of the October 2015 field investigation was to determine the composition of the material within the B4 and B5 shoal features identified by Meisburger and Field (1975). **Figure 2.2** depicts the shoal features identified in the 1975 study, and a compilation of the other geotechnical investigations in the area discussed below, including the Vibracores collected in 2015. It is of interest to note in **Figure 2.1** that of the numerous cores collected in the ICONS work, the vast majority fell in areas of lower seabed elevation, versus the higher ridge and shoal features. As such, these sediments, if analyzed, would typically reveal finer, siltier sediments (which is generally the case for those samples that were studied).

[1] Only a subset of the Meisburger and Field (1975) Vibracores were sampled to any great level of detail, and very few of them were sampled off Nassau County.

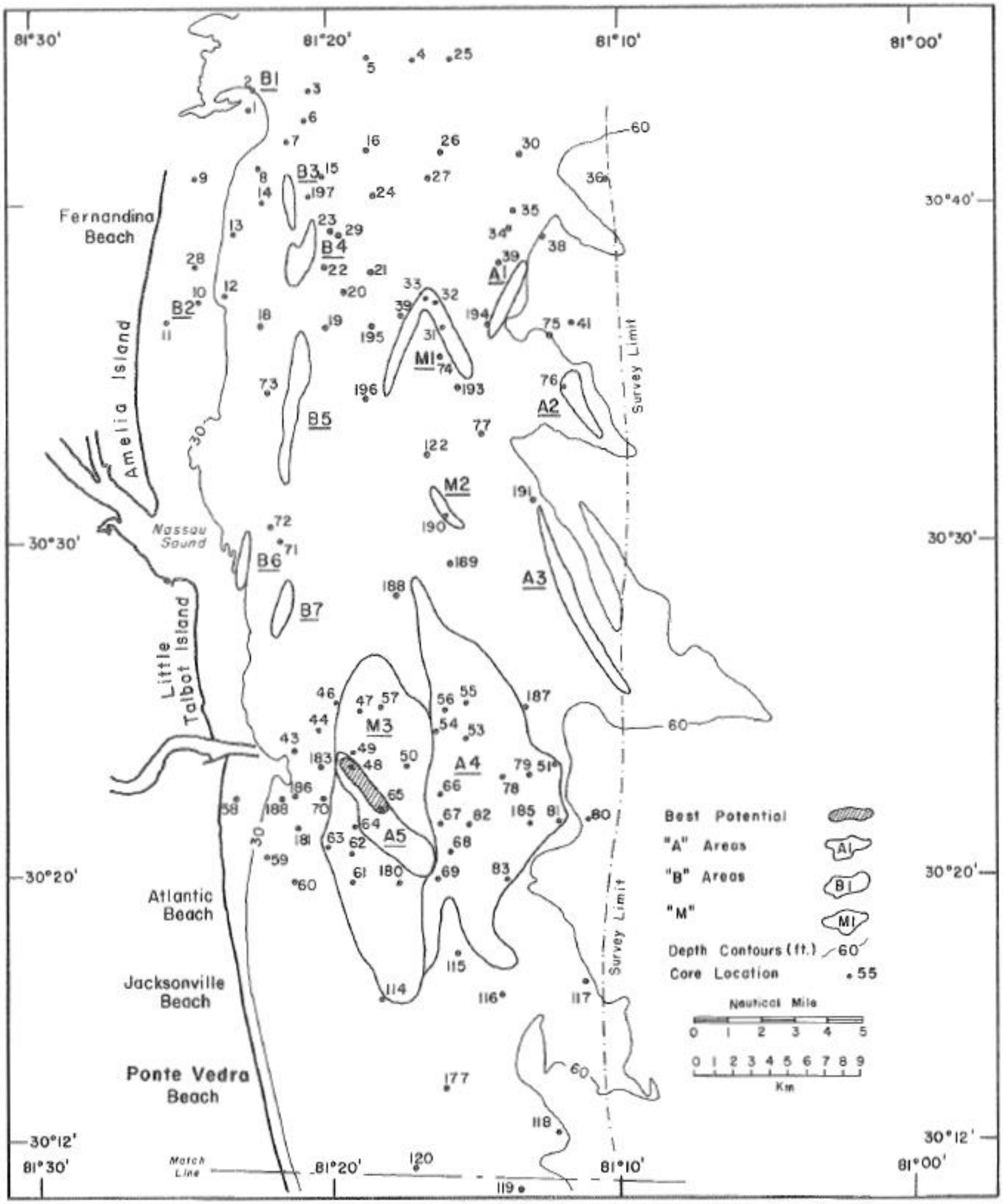

Figure 2.1 Locations of Vibracore samples and identified shoal features off Nassau and Duval Counties, as determined by Meisburger and Field (1975).

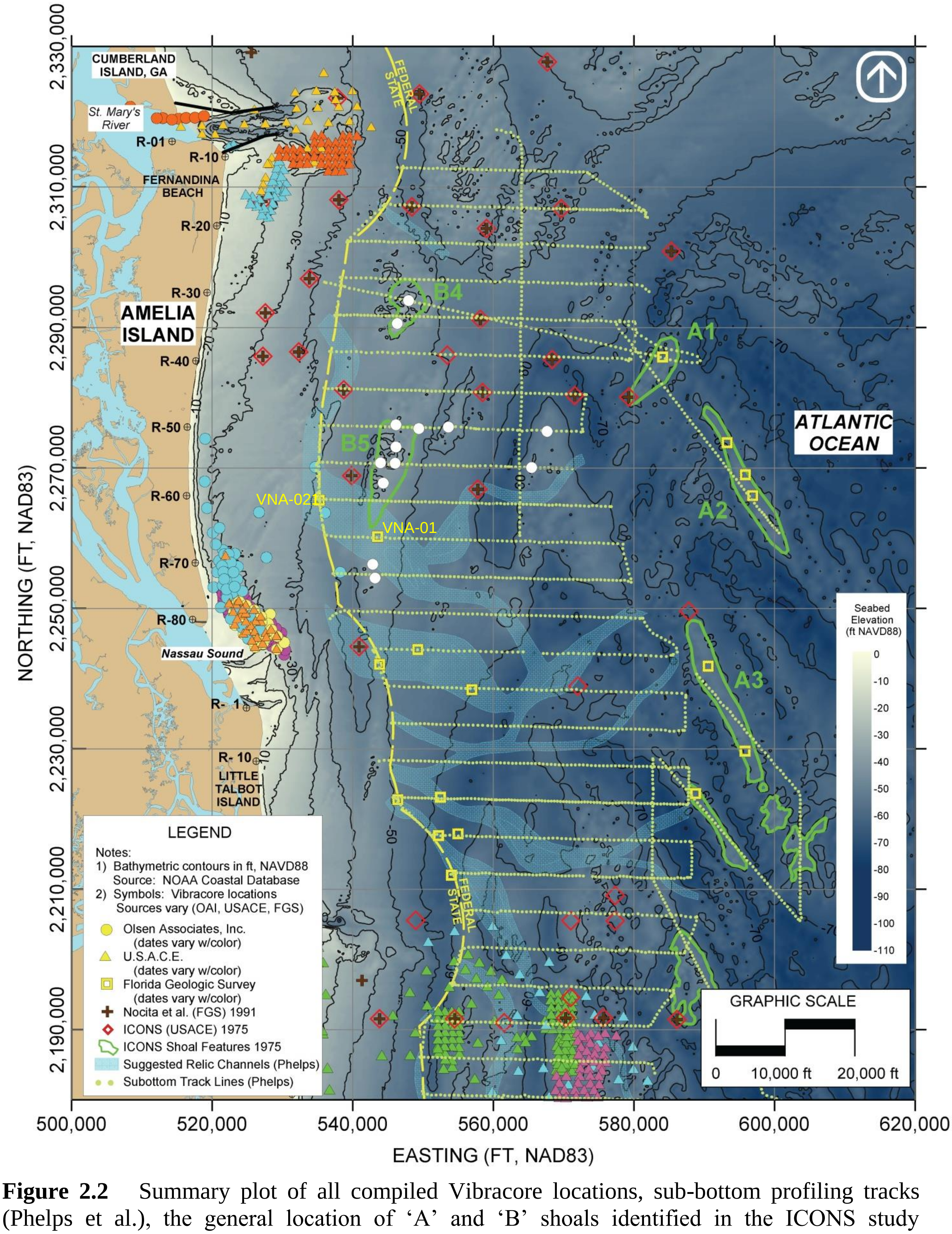

Figure 2.2 Summary plot of all compiled Vibracore locations, sub-bottom profiling tracks (Phelps et al.), the general location of 'A' and 'B' shoals identified in the ICONS study (Meisburger and Field, 1975), and the location and extent of the hypothesized paleochannel locations (Phelps et al., 2007). The white circles indicate the location of the 2015 Vibracores described herein.

U.S. Army Corps of Engineers (USACE, 1977)

In 1976, the U.S. Army Corps of Engineers acquired 19 irregularly-spaced Vibracores off Amelia Island between the south jetty at the St. Marys Entrance and the southern tip of Amelia Island, principally in State waters, for the Nassau County Shore Protection Project (USACE, 1977 – orange triangles). All Corps of Engineers Vibracores are depicted with triangle symbols in **Figure 2.2**.

Nocita et al. (1991)

Nocita et al. further examined selected Vibracore samples previously collected in the ICONS study, with a primary focus on the heavy mineral composition of the samples. Nocita et al. (1991) documented the weight percentage of sand, mud, and shell-gravel in each sample. They found excessively high mud (silt or fines) percentages, up to 70%, in numerous samples.

Olsen Associates, Inc. (OAI, 1993, 2001, 2007)

Olsen Associates, Inc. conducted geotechnical investigations in 1993, 2001, and 2007 for the purpose of finding beach quality sediments for the construction of beach nourishment projects along the southern shoreline of Amelia Island. The locations of the OAI Vibracores are depicted with filled circles in **Figure 2.2**. The light blue circles show the cores taken off the southern tip of the island in 1993, the yellow circles show the 2001 investigation along the edge of the ebb tidal platform of Nassau Sound, the magenta circles indicate the nearshore sampling of 2007, and the white circles indicate the locations of the present 2015 investigation.

Finkl & Andrews (2007)

Finkl and Andrews (2007) described geologic units and potential sand resources along the northeast Florida coastline from Volusia to Nassau Counties from the shoreline to an approximate depth of 150 ft. No new data was collected for that study. Using the same bathymetric and geotechnical data presented herein, sediment resources were estimated based on "morphological units" -- broader geologic formations such as ebb-tidal deltas, shoals, sand waves, and ridge fields, among others.

Phelps et al., (2007)

Phelps et al. conducted a four-year study from 2002 through 2005 as a follow up to the Meisburger and Field (1975) study along the NE Florida Atlantic coast. The study made use of updated bathymetric data not available to Meisburger and Field and included field work components of shallow seabed sonar sub-bottom profiling data and limited Vibracore collection (yellow squares in **Figure 2.2**). Phelps et al. focused their investigation principally on the development of a geologic understanding of the paleochannel morphology of the nearshore area, that pattern of the rivers, streams and shoals that existed at lower stands of sea level across the inner shelf (as described by Henry, 1971, above). Utilizing the sub-bottom profile data and a very small number of Vibracore samples, the investigators developed a model map of these channels (**Figure 2.2**).

It is noted that the Vibracores utilized in the development of that geologic model did not sample areas on the shoulders of the hypothesized channels, only areas within the channels predicted from the sonar sub-bottom. Consistent with their hypothesis, these samples revealed very fine sediments[2], consistent with channel infilling processes. **Figure 2.3** depicts photographs of the Vibracore collected in the large paleochannel identified south of the B5 shoal in **Figure 2.2**.

Phelps et al. further opined that the channels and their adjacent shoals, some of which are the 'B' shoals identified by Meisburger and Field, would be genetically linked, formed in tandem via the littoral processes that existed at the time of those lower stands of sea level, similar to the finding of Henry, 1971. Phelps et al. did not, however, carry the Vibracore sampling to that stage. In later discussion, Zarillo et al. (2009, see below) hypothesized that such areas adjacent to the infilled channels may contain coarser, re-worked beach sediments. Generally, these features lie in Federal waters just outside the 3-mile State/Federal boundary. The 2015 Vibracores discussed herein were collected to test and/or support these hypotheses through analysis of the adjacent shoals.

<u>Zarillo et al (2009)</u>

As part of an ongoing BOEM effort, Zarillo et al. conducted biological and numerical (wave effect) analyses on numerous borrow areas in Federal waters, most of which were associated with 'A' shoals identified in the M&F 1975 study. This work was performed principally in support of BOEM's development of borrow areas for Federal shore protection projects. Zarillo's work did not extend to Nassau County, although the work performed for the Duval County areas provides insight into what could be expected for shoal areas to the north. Subsequent direct communications with the principal investigator, Dr. Gary Zarillo, confirmed this link and provided additional information specific to Nassau County features.

[2] It should be noted that the logging, sampling, and degree of analysis of some of these fine-sediment layers in the older Vibracores is not as detailed as the sampling analysis conducted for the present study.

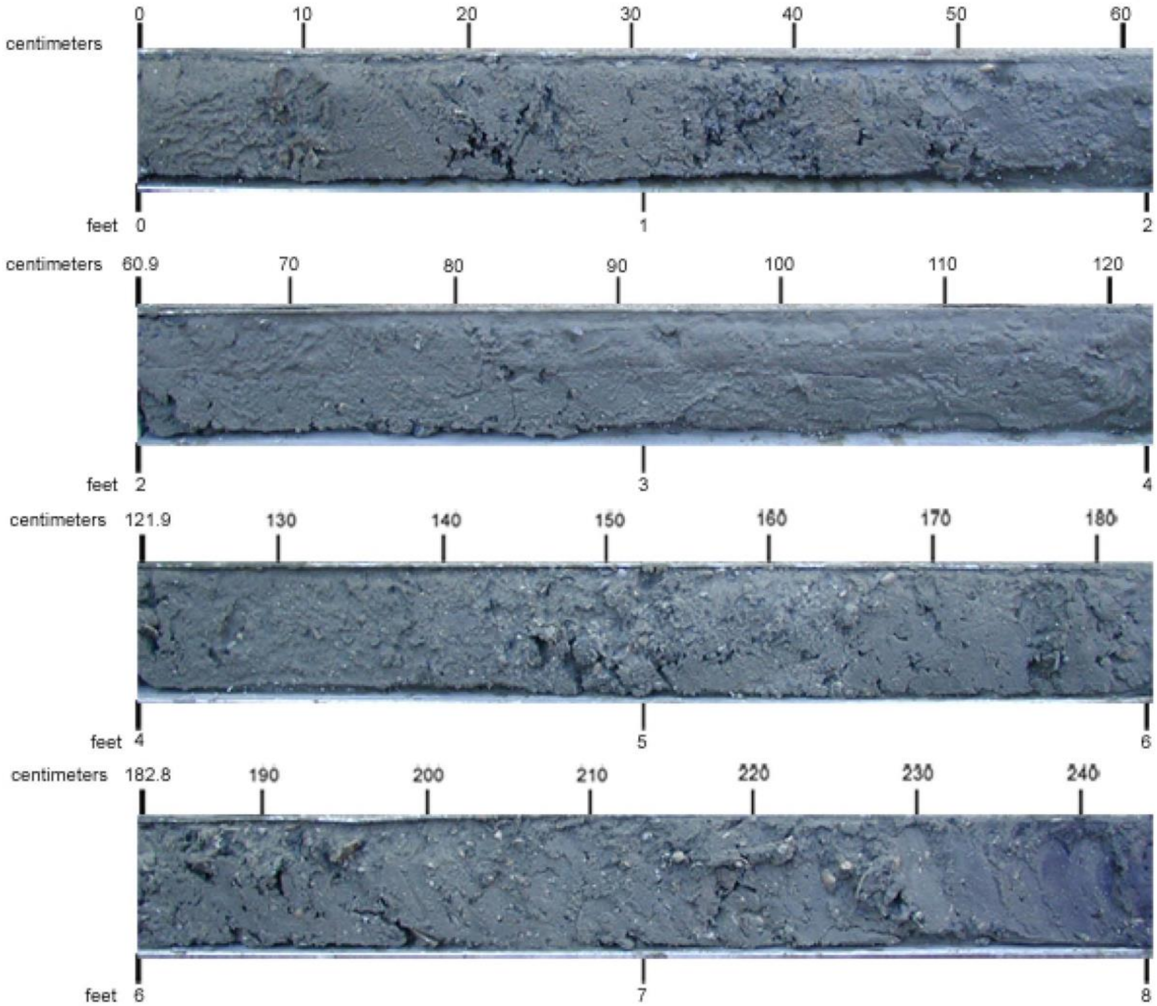

Figure 2.3 Photolog of the upper 8 feet of Vibracore VNA-01, collected in 2004 by Phelps et al. (2007) in the center of the large paleochannel identified south of the B5 Shoal (see **Figure 2.2**). Note the dark gray color and the appearance of silts/fines throughout and the transition to clay roughly 7.5 ft downcore. Comparing the Vibracore location to the bathymetry in **Figure 2.2**, the sample was collected at an elevation of -44 ft NAVD88 (approx.), which would indicate the clay layer beginning at -51.5 ft NAVD88.

Much of the geotechnical portion of Zarillo's work in NE Florida supports the findings described above, where the sediments lying atop the bathymetric highs (shoals or ridge crests) are found to have coarser sediments, while the sediment in the bathymetric lows consists of finer sediments with higher percentages of muds, fines, and organics. Ridge and shoal crest features in the shallower waters (from the shoreline to depths of 35-40 ft, perhaps slightly deeper) will experience increased reworking by storm-generated bottom currents. Such processes remove finer sediments and leave coarser sediments, thereby improving the sediment quality of the upper layers of the seabed, and limiting both the growth of benthic organisms and the development of biologically active seabottoms in those same layers.

Zarillo et al. (2009) and personal communications with Zarillo also suggest that the shoal features identified by M&F 1975 and further described by Phelps et al. (2007) would be more likely to contain coarser sands due to their linkage to the channel and shoal morphology indicated by Phelps. That is, some of these shoal features may likely be the adjacent ebb shoal highs associated with ebb shoal/river delta systems that existed at lower stands of sea level.

Simplistically, Phelps et al. (2007) and Zarillo et al. (2009) predicted a linked morphology of shoals and channels offshore of Nassau County, but neither investigation directly sampled the shoals in this area. Previous investigators have taken cores either in the bathymetric lows adjacent to the "B" shoals (e.g. the ICONS cores), or in areas of suspected in-filled channels (the FGS/Phelps cores closer to shore). These 'B' shoal features near the present-day shoreline have never been directly sampled prior to the current investigation.

3.0 VIBRACORE COLLECTION

To further investigate the hypotheses of Phelps et al. (2007) and Zarillo et al. (2009) and explore the nature of the sediments of the 'B' shoal features identified in by Meisburger and Field (1975), thirteen sediment Vibracores were acquired by Athena Technologies, Inc., in October 2015 at the locations depicted in **Figure 3.1**. The Vibracores collected in 2015 follow the naming convention NCVB-15-"XX"; the identifier is shortened to "XX" in **Figure 3.1**. The four primary sampling locations are the B4 shoal, the B5 shoal, east of the B5 shoal (offshore), and south of the B5 shoal.

The Vibracores consisted of three-inch galvanized steel tubes, vibrated into the seabed for approximately 20 feet (or to refusal) to extract the sample sediments in the upper seabed. The cores were acquired from a 35-ft open-deck pontoon boat. The sampling rig does not include a rig set upon the bottom, thus the seabed impact of the rig is limited to the three-inch diameter core tube and the three small anchors (1.3x2.0 ft, 40-lb each, approx.) used to hold the vessel on station. Geotechnical analyses, sampling, logging, and Vibracore photography and laboratory testing procedures are discussed in detail in **Appendix B**.

Figure 3.2 depicts an example set of photographs from NCVB-15-01, collected along the western edge of the B5 shoal shown in **Figure 2.2,** illustrating the sandy or shelly sediments in the upper 10 feet, transitioning to solid stiff clay in the lower 8+ feet of the Vibracore. The photographs likewise illustrate the change in color (and likely change in sediment characteristics) of the sediments beginning at 4 to 5 feet below the seabed. Also seen in **Figure 3.2** is a shelly layer, perhaps deposited during a storm, around 10.5 to 11.0 ft below the seabed in this location.

Figure 3.3 provides an example of a Vibracore log prepared by a professional geologist at Athena Technologies, Inc. This log corresponds to the photos of **Figure 3.2** for Vibracore NCVB-15-01. The log provides a detailed geologic description of the Vibracore, including its horizontal and vertical coordinates and the vertical distribution of sediment types and colors along the length of the core. In the present case, the upper 6.5 ft of the seabed in this area is characterized as fine sand, SP material in the Unified Soils Classification System (USCS). The material is noted as having traces of shell fragments. The sediments were assigned a color grading on the Munsell color scale of 10 Y 7/1 transitioning to a 10 Y 5/1. This is a fine sand that is light gray (Value = 7) with very low color intensity (Chroma = 1) to a fine sand that is gray (Value = 5) with very low color intensity (Chroma = 1). The 10Y designation describes the hue of the sands (Y- yellow, versus reds, blues, greens or pinks for example). In **Figure 3.3**, the sample transitions to an SP-SM material below 6.5 ft, which includes noticeable silty fine sediments and a darker color grade (a Value of only 4). At the bottom of the Vibracore, the material is a dark green highly plastic clay (CH material) with a color Value of only 3.

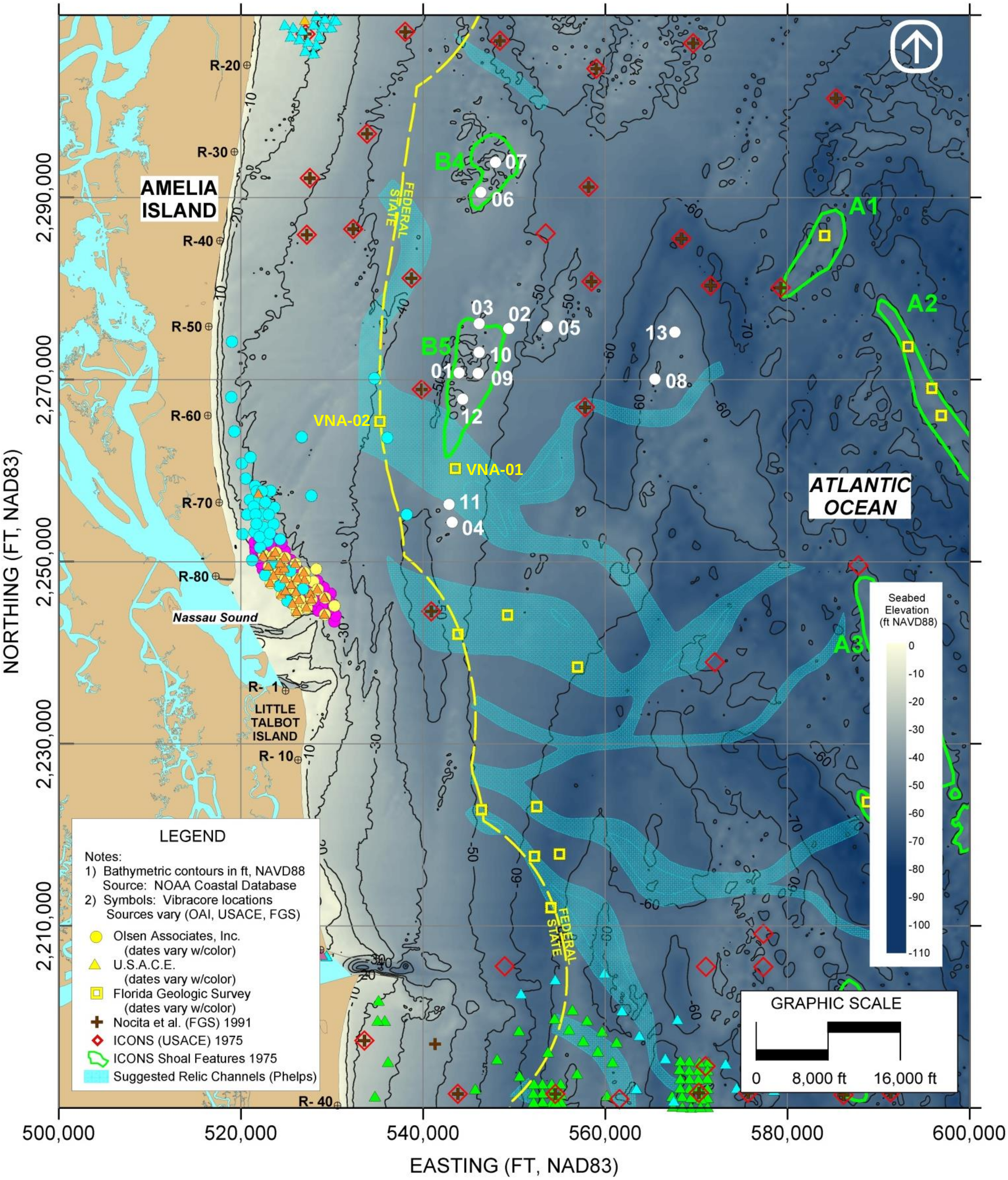

Figure 3.1 The locations of the thirteen Vibracores collected in October 2015 in relation to previous geotechnical investigations, the general location of ‘A’ and ‘B’ shoals (Meisburger and Field 1975), and the hypothesized paleochannel locations (Phelps et al., 2007). Note the two yellow square symbols south and west of the B5 shoal, denoting Vibracores from Phelps.

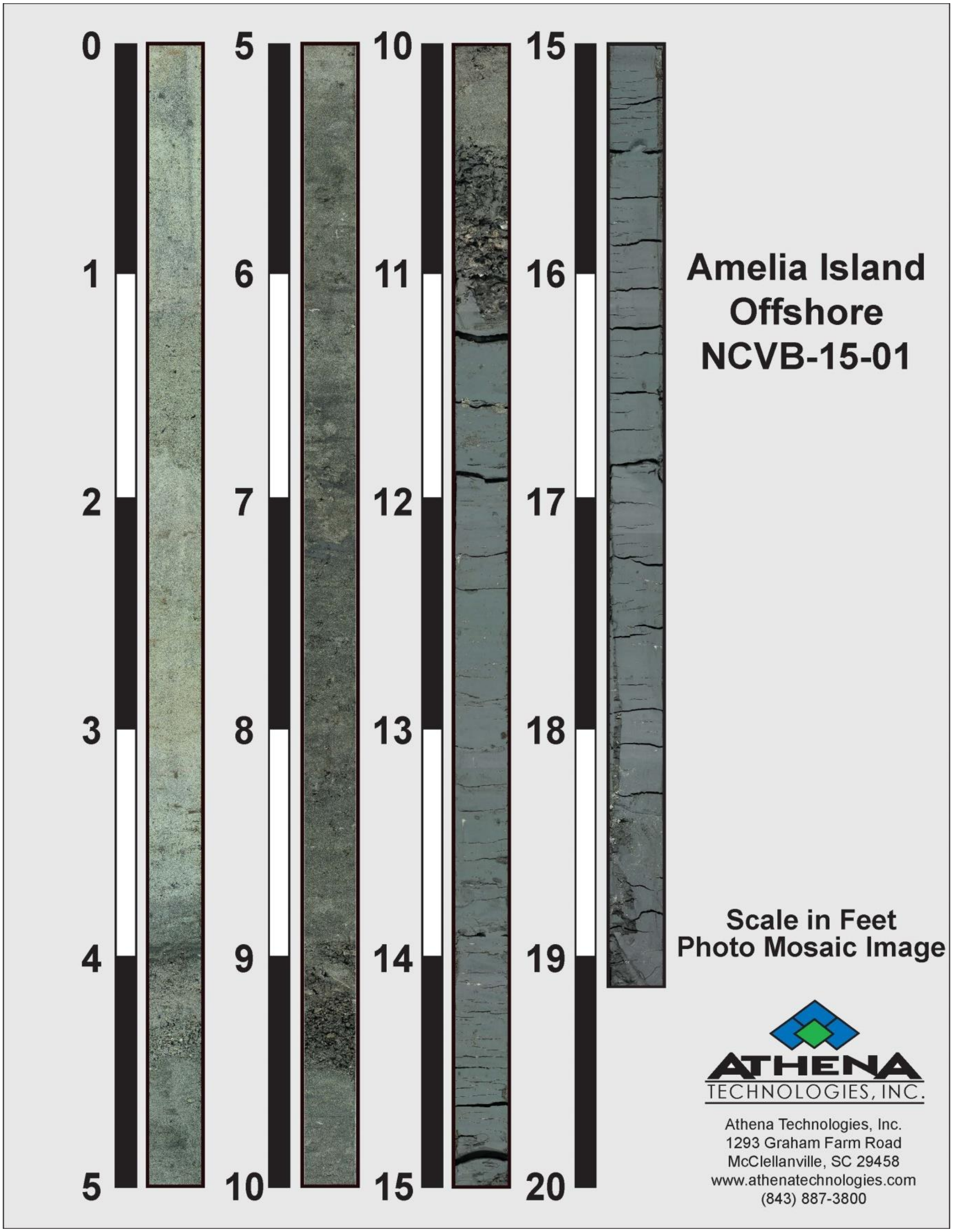

Figure 3.2 Vibracore photographs of core NCVB-15-01, collected offshore Amelia Island in October 2015. Divisions are feet from the seabed to over 19 ft below the seabed. Note the transition from sandy or shelly sediments around 11 ft to stiff gray clay below.

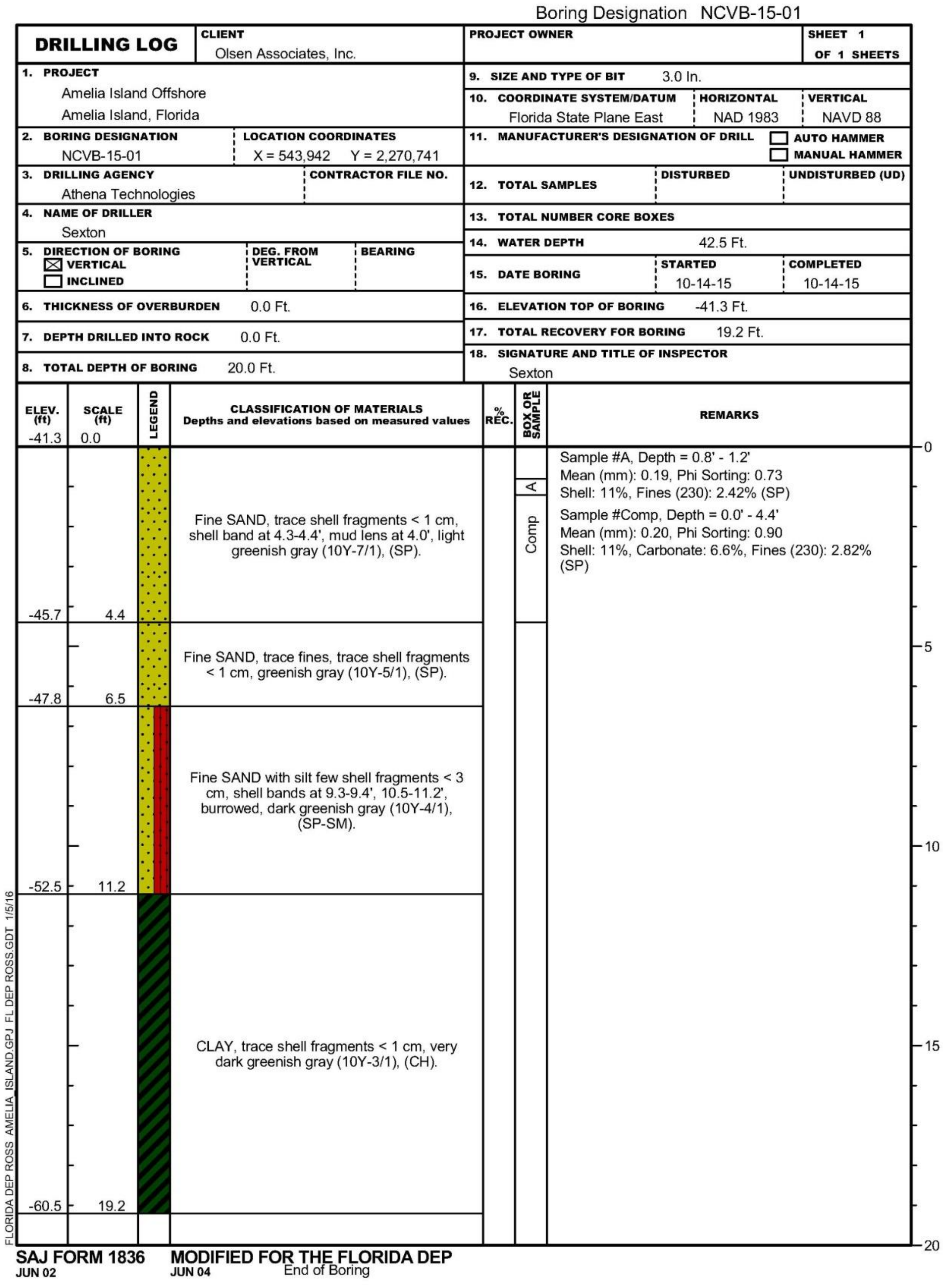

Figure 3.3 Vibracore log corresponding to the photographs in **Figure 3.2** for core NCVB-15-01, collected offshore Amelia Island in October 2015.

4.0 MULTIBEAM BATHYMETRIC DATA COLLECTION

In addition to the physical Vibracore samples, high-resolution multibeam bathymetric data were collected in weather-restricted segments between December 2015 to March 2016 in the vicinity of the B4 and B5 shoals to establish the seabed elevations where several of the Vibracores were collected and to assess the consistency of the seabed elevation and sand isopachs in those areas. The bathymetry presented in **Figures 1.1** to **3.1** is composed of older NOAA bathymetric data. More specifically, the data in the vicinity of the 2015 Vibracores dates to the 1970's, and is of relatively coarse resolution as compared to the new multibeam survey data (line spacings of 100 to 200 ft in 1970, versus data points less than 3 ft apart over the whole survey area in 2015). These multibeam data were collected by Arc Surveying and Mapping, Inc., of Jacksonville, FL. The surveyor's report is attached as **Appendix C**, and the processed XYZ data can be found on the accompanying CD-ROM disc.

As described in the surveyor's report, an area of approximately 1.0 square miles was surveyed at the B4 shoal, encompassing the October 2015 Vibracores #06 and #07. At the B5 shoal, an area of approximately 2.0 square miles was surveyed around Vibracores #02, #03, #09, #10, and #12. Shaded perspective maps of the B4 shoal and B5 shoal bathymetries relative to the Vibracore locations are depicted in **Figures 4.1** and **4.2**, respectively. These data indicate the smaller-scale irregular ridge features that appear to lie atop the much larger-scale shore-parallel ridge seen in **Figures 2.2** and **3.1**. The features appear in somewhat broken and scattered fashion in a slightly SW-NE trending alignment relative to the more N-S trending large scale ridge. The overall appearance of the surface features indicates some sub-aqueous working or weathering, furthering the scattered and broken condition.

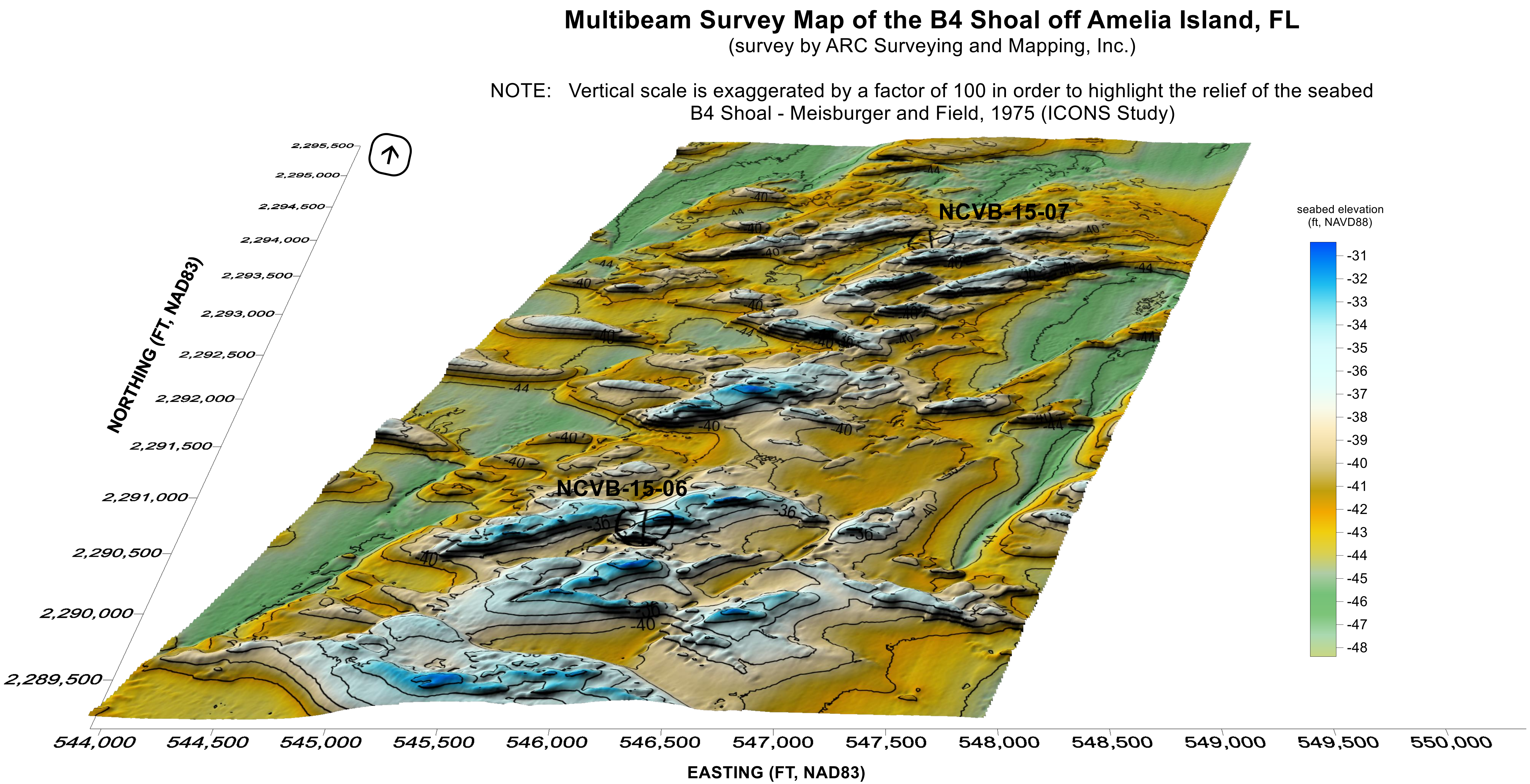

Figure 4.1 2015-2016 Multibeam survey map of the B4 shoal identified by Meisburger and Field (1975). Locations of the two October 2015 Vibracores collected in the shoal, NCVB-15-06 AND NCVB-15-07 are denoted in black.

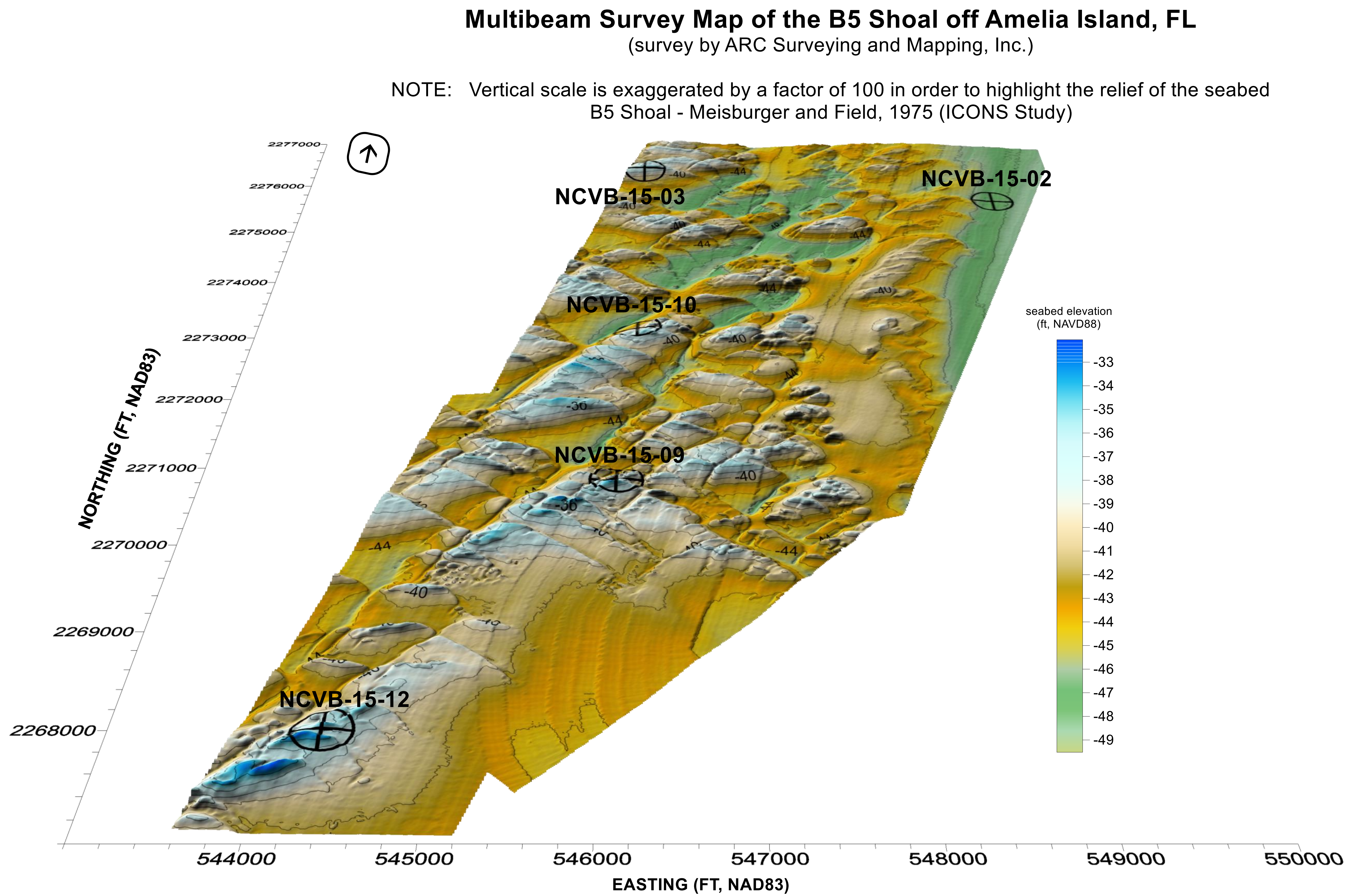

Figure 4.2 2015-2016Multibeam survey map of the B5 shoal identified by Meisburger and Field (1975).
The October 2015 Vibracores collected in the vicinity of the shoal are denoted in black.

5.0 RESULTS & DISCUSSION

The boring logs of all thirteen Vibracores shown in **Figure 3.1** are provided in the geologist report in **Appendix B**. From each Vibracore, a composite sample was prepared of the upper sand lens (USCS SP classification[3], generally), which varies in thickness from sample to sample. A summary of the grain size distribution, mean and median grain sizes, percent carbonate content, visual percent shell, and Munsell color of the composite samples is provided in **Table 5.1**. The corresponding grain size distribution curves for the thirteen composite samples are plotted in **Figure 5.1**. The percent fines (percent passing the #230 standard sieve) of each composite sample can likewise be determined from **Table 5.1** and **Figure 5.1**.

Generally, the Vibracores collected on the B4 and B5 shoals contain a lens of muddy sands (5 to 15% fines) typically beginning at an elevation of -45 to -47 ft NAVD88 (approx.) and extending down-core. At deeper depths, a clay layer was found in most Vibracores at an elevation of -51 to -53 ft NAVD88 and deeper.

5.1 B4 Shoal

Two Vibracores, NCVB-15-06 and NCVB-15-07 were collected within the B4 shoal identified in the ICONS study. The shoal identified by Meisburger and Field (1975) lies roughly 4 to 5 miles south of the St. Marys River entrance and 4.5 to 5.0 miles offshore of Amelia Island. The B4 shoal appears to lie between two small paleochannels proposed by Phelps et al. (2007). As depicted in **Figure 3.1** and **Figure 4.1**, the irregular sand features atop the shoal rise from the shore-parallel ridge to crest elevations of -30 ft NAVD88 (approx.). At the western toe of the ridge, the seabed dips to elevations deeper than -50 ft NAVD88. Vibracores #06 and #07 were collected at seabed elevations of approximately -34 ft and -40 ft NAVD88, respectively (see **Appendix B**).

Accordingly, composite samples of the upper SP lens of Vibracores #06 and #07 were developed from the upper 10.3 ft and upper 6.9 ft of the Vibracores, respectively. Both Vibracores indicate a transition to siltier SP-SM materials at depths of -44.5 ft and -46.9 ft NAVD88. Vibracore #07 transitions to clay materials at -52.6 ft, and Vibracore #06 found no clay material to the bottom of the sample at -48.2 ft NAVD88.

[3] SP – material classified as poorly graded sands, gravelly sands, little or no silt/fines (<5%). Poorly graded indicates a narrow range of grain sizes. SP-SM indicates poorly graded sands with silt/fines (>5%).

Table 5.1 Summary of the grain size distributions, mean, median, sorting, percent carbonate, and color of the composite samples from the thirteen supplemental Vibracores collected off the coast of Amelia Island, FL in October 2015.

Composite			B4 Shoal		B5 Shoal							East of B5		South of B5	
Sample No. (NCVB-15-)			-06	-07	-01	-02	-03	-09	-10	-12	-05	-08	-13	-04	-11
Seabed Surface Elevation (ft, NAVD88)			-34.2	-40.0	-41.3	-46.8	-36.1	-37.3	-39.8	-35.8	-40.9	-47.4	-53.1	-41.9	-43.1
Length of Upper SP Lens (ft)			10.3	6.9	6.5	0.0	9.2	8.3	5.8	8.3	10.5	9.5	9.0	3.0	2.0
Sieve			Percent Passing (Finer Than)												
	Phi	mm													
3/4"	-4.25	19.03	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
5/8"	-4.00	16.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
3.5	-2.50	5.66	99.76	99.57	99.88	99.79	100.00	99.27	99.66	99.82	100.00	99.76	99.75	99.64	99.12
4	-2.25	4.76	99.76	99.40	99.53	99.46	99.95	99.22	99.53	99.82	100.00	99.57	99.72	99.44	98.55
5	-2.00	4.00	99.55	98.84	99.32	99.32	99.91	98.72	99.39	99.65	99.85	99.46	99.67	99.16	98.20
7	-1.50	2.83	98.99	97.91	99.09	98.77	99.78	97.60	99.10	99.41	99.62	98.96	99.30	98.66	97.45
10	-1.00	2.00	97.57	96.97	98.72	98.16	99.53	96.62	98.73	99.07	99.14	98.30	99.03	97.97	96.67
14	-0.50	1.41	96.45	95.55	98.07	97.51	99.17	95.23	98.10	98.52	98.52	97.22	98.57	97.10	95.94
18	0.00	1.00	95.24	94.10	97.17	96.88	98.54	93.57	96.97	97.98	97.80	95.52	97.78	96.24	95.33
25	0.50	0.71	94.08	92.51	95.32	96.28	97.37	90.25	94.44	97.29	96.88	93.15	96.08	95.48	94.76
35	1.00	0.50	92.37	90.12	91.96	95.52	95.68	82.65	89.83	95.41	95.54	89.27	92.57	94.57	93.79
45	1.50	0.35	89.65	86.67	88.24	94.61	93.21	75.41	84.85	92.42	92.95	82.72	88.04	92.78	92.00
60	2.00	0.25	85.01	81.12	82.46	93.03	87.87	70.34	80.03	87.36	83.90	64.93	78.14	88.14	87.29
80	2.50	0.18	58.83	55.67	57.74	85.21	58.53	59.52	66.18	67.59	45.97	25.08	54.60	66.18	65.60
120	3.00	0.13	7.07	8.40	15.94	39.63	9.34	15.96	14.94	15.84	9.39	6.50	26.16	11.37	14.41
170	3.50	0.09	1.97	2.63	4.29	11.47	2.43	3.10	3.07	3.59	2.52	1.58	5.41	3.73	2.79
200	3.75	0.07	1.42	2.02	3.22	8.46	1.74	2.14	2.10	2.72	1.86	1.23	3.45	3.03	2.02
230	4.00	0.06	1.20	1.79	2.82	7.53	1.37	1.79	1.71	2.40	1.65	1.13	3.06	2.72	1.72
Mean (mm)			0.20	0.21	0.20	0.15	0.18	0.23	0.20	0.18	0.20	0.25	0.19	0.19	0.19
Median (mm)			0.15	0.15	0.15	0.12	0.15	0.15	0.18	0.14	0.17	0.21	0.15	0.14	0.14
Sorting (phi)			0.94	1.06	0.90	0.91	0.67	1.23	0.96	0.77	0.72	0.92	0.91	0.90	1.06
Percent Carbonate			8.80	10.90	6.60	-	4.70	12.40	15.53	7.00	7.90	11.50	7.40	9.00	-
Percent Shell, Visual			12.11	15.17	10.66	12.34	4.63	20.32	7.90	8.91	12.05	12.86	9.61	13.78	19.98
Munsell Color Value			7	7	7	4	7	6-7	6-7	5-6	7	7	5, 7	7	5

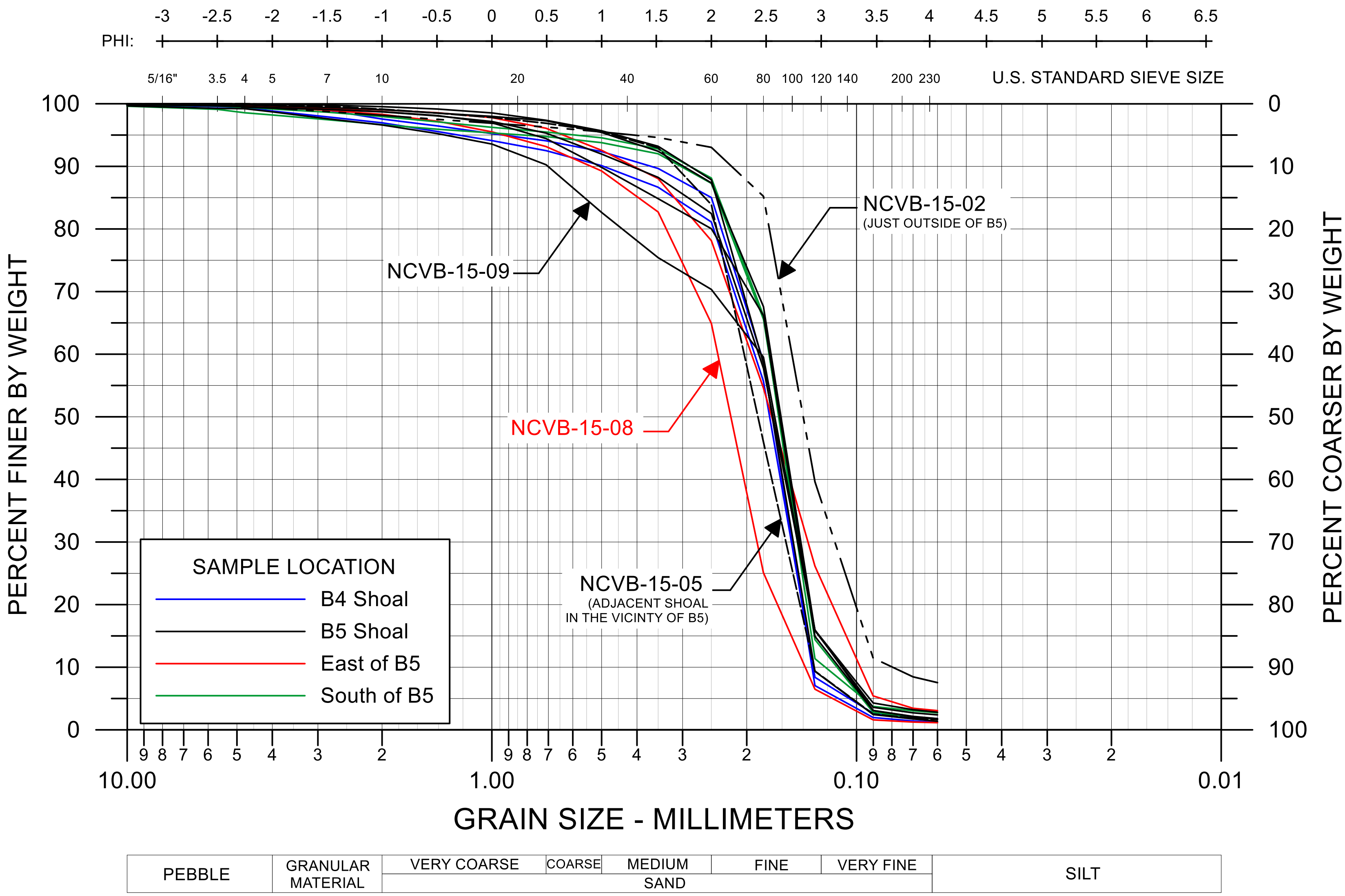

Figure 5.1 Grain size distribution curves of the composite samples representing the thirteen Vibracores collected offshore of Amelia Island, FL in October 2015.

The composite samples of Vibracores #06 and #07 are nearly identical in sediment characteristics. Each exhibit a mean grain diameter (or characteristic size) of 0.20 to 0.21 mm, with a median grain size of 0.15 mm and roughly 1.2% to 1.8% fines (silts, #230 sieve). The typically larger shell fragments within these samples cause the average (mean) sediment diameter to be larger than the median diameter, which is heavily influenced by the large quantity of fine sand in the sample. Very few of the sediment particles (quartz or carbonate) are larger in size than the #4 sieve (4.76 mm) The samples contain 8.8% to 10.9% carbonate material (supported by visual shell estimates of 12.1 to 15.2%). Both SP lenses were color graded to have Munsell color Values of 7 (light gray), with low Chroma values of 1 on a 10Y hue. **Figure 5.2** depicts the photolog of Vibracore #06.

COMMENTS: Clearly from **Figure 4.1**, these composite samples from #06 and #07 represent the sand ridges and sub-shoals atop the B4 shoal. The sediments in the lower portions of the Vibracores (below the SP lens) suggest that the areas away from and off the small bathymetric highs will contain increasing levels of fine sediments, and ultimately clay at lower elevations. Inspection of the seabed surface of the B4 shoals indicates the potential for a very irregular distribution of sediments across the shoal, and that perhaps the sediments in the -06 and -07 Vibracores might represent the coarsest materials in the shoal. Compared to the paleochannel Vibracore samples described by Phelps, these higher-elevation samples are noticeably coarser, have much whiter/lighter colored sediment and have a much lower fines content (as judged from generalized log descriptions and photography, comparable grain size metrics unavailable).

5.2 B5 Shoal

Six Vibracores, NCVB-15-01, NCVB-15-02, NCVB-15-03, NCVB-15-09, NCVB-15-10, and NCVB-15-12, were collected within the B5 shoal identified in the ICONS study. The shoal identified by Meisburger and Field (1975) lies roughly 8 miles south of the St. Marys River entrance (4 miles north of Nassau Sound), and approximately 4.5 miles offshore of Amelia Island. As shown in **Figure 3.1**, the B5 shoal lies just north of one of the largest apparent paleochannels proposed by Phelps et al. (2007).

As depicted in **Figure 3.1** and **Figure 4.2**, the irregular sand features atop the shoal rise from the shore-parallel ridge to crest elevations of -33 ft NAVD88 or shallower (approx.). Similar to the B4 shoal, at the western toe of the ridge, the seabed dips to elevations deeper than -50 ft NAVD88. The six Vibracores in this area were collected from seabed elevations ranging from -36.1 ft to -46.8 ft NAVD88. As depicted in **Figure 4.2**, the majority of the Vibracores are sited on the higher ridges and sub-shoals, but some are off (and below) these features (i.e. Vibracore #02 at -46.8 ft) (see **Appendix B**). Similar to the Vibracores of the B4 shoal, the B5 Vibracores indicate a transition to siltier SP-SM materials at depths of -45 ft to 47 ft NAVD88 and indicate the presence of clay around -51 to -53 ft NAVD88.

Figure 5.2 Photo log of Vibracore #NCVB-15-06, collected in October 2015 on the B4 Shoal off Nassau County, FL (Meisburger and Field, 1975). The geotechnical log can be found in Appendix B.

As before, composite samples of the upper SP lens of these Vibracores were developed and analyzed. In the case of Vibracore #02, no SP lens was identified. The silty upper SP-SM lens from -46.8 ft to -53.0 ft, just above the clay layer, was sampled and found to contain 7.5% fines and a Munsell color Value of 4 (dark gray). As plotted in **Figure 5.1**, this sample has a very fine median grain size of 0.12 mm. Inspection of **Figure 4.2** indicates that this Vibracore was not sited upon any ridge or sub-shoal bathymetric high at the B5 shoal location.

For the other five Vibracores located upon the B5 shoal, the upper SP sand lens ranged in thickness from 5.8 ft to 9.2 ft. Median grain sizes ranged from 0.14 mm to 0.18 mm with mean grain sizes of 0.18 to 0.23 mm. The higher mean sediment diameters were generated by higher percentages of carbonate (shell) material, although none of the shell/carbonate particles were very large in size, as indicated by the very small percentages of material retained on the #4 sieve. In terms of fines content, the SP composite samples on B5 were found to have between 1.37 and 2.82% fine material passing the #230 sieve. Carbonate content ranged from 4.7% to over 15.5%, with visual estimates of shell reaching as high as 20 for sample -10. Color grades for Value (brightness) ranged from 5 to 7, indicate gray to light gray sediments that are perhaps slightly darker than the material found in the B4 shoal.

Inspection of **Figure 3.1** indicates a small ridge offshoot from the B5 shoal off to the Northeast. One Vibracore was collected in this area, NCVB-15-05. This sample, collected in slightly deeper waters at -40.9 ft NAVD88, revealed a 9.6 ft lens of fine sand with median and mean grain sizes of 0.17 mm and 0.2 mm, respectively. The composite lens was graded for color with a Munsell Value of 7. The sample had a fines content of 1.65% (#230 sieve) and a carbonate content of 7.9%

<u>COMMENTS:</u> As depicted in **Figure 4.2**, the composite samples from #01, #03, #09, #10, and #12 represent at least portions of the sand ridges and sub-shoals atop the B5 shoal. Consistent with the overall findings, the sediments below the SP lens in these Vibracores suggest that the areas away from and off the small bathymetric highs will contain increasing levels of fine sediments, and ultimately clay at lower elevations. This is directly evidenced by the sediments found in Vibracore #02, which had no upper SP lens. Inspection of the seabed surface of the B5 shoals indicates the potential for a very irregular distribution of sediments across the shoal, and that perhaps the sediments in Vibracores #09 and #10 might represent the coarsest materials in the shoal (see distributions plotted in **Figure 5.1**). Overall the sediments are relatively fine, and the coarsest of materials are those with increased shell/carbonate content. Similar to the B4 shoal, the samples in the B5 shoal, when compared to the paleochannel Vibracore samples described by Phelps, are noticeable coarser, have much whiter/lighter colored sediment and have a much lower fines content (as judged from generalized log descriptions and photography, comparable grain size metrics unavailable).

5.3 East of the B5 Shoal

Vibracores NCVB-15-08 and NCVB-15-13 were collected upon a large chevron-shaped ridge roughly 9 miles offshore between the B5 and A2 shoals, approximately. This ridge feature was not bathymetrically surveyed in 2015. It lies in deeper waters and the two Vibracores were collected at elevations of -47 ft and -53 ft, respectively. These two samples are located north of one of the paleochannels suggested by Phelps et al. (2007, **Figure 3.1**). Meisburger and Field (1975) characterized this as an area of no further interest (seemingly based on sampling just off the actual feature itself). Its relatively high local elevation and broad extent made it a location of interest in the present study. It is noted again that the prior researchers did not have the benefit of the higher-resolution bathymetry shown in **Figure 3.1**. Vibracore NCVB-15-08, collected at a seabed elevation of -47.4 ft NAVD88, produced a 9.5 ft upper lens of fine sand (SP), lying atop a silty SP-SM lens beginning at -57 ft NAVD88.. The shelly SP lens, containing 11.5% carbonate material, produced a median grain size of 0.21 mm and a mean grain size of 0.25 mm, with only 1.13% fines (#230 sieve). This is the coarsest of the composite samples collected in the study. The SP lens of #08 was graded as a Munsell Value of 6 to 7 (closer to 7, light gray).

The second Vibracore, #13, produced a 9-ft lens of fine sand (SP), lying above an SP-SM layer starting at -62 ft NAVD88, and ultimately a clay layer starting at -65.2 ft. The SP lens of Vibracore #13 produced a median grain size of only 0.15 mm and mean grain size of 0.19 mm, with a fines content of 3.06% (#230 sieve). The upper SP lens also consisted of 7.4% carbonate materials.

COMMENTS: While the shape of this feature is different than the B4 and B5 shoals, and lies in deeper waters, it does appear as a bathymetric high and accordingly does appear to have sandy sediments lying atop finer siltier sediments and clay. The feature is much broader than the B4 and B5 shoals, thus its origins are likely different, perhaps more of a former broad ebb shoal feature versus a more shore-parallel former shoreline or reworked nearshore feature.

5.4 South of the B5 Shoal

South of the B5 shoal, and south of the large paleochannel identified by Phelps et al. 2007), two Vibracores were collected to determine if sandy coarser sediments similar to the B5 shoal could be identified. Vibracores NCVB-15-04 and NCVB-15-11 were collected approximately 4.0 mi offshore of Amelia Island's southern terminus (**Figure 3.1**). Water depths in this area are deeper than those found atop the B5 shoals. The seabed elevation for Vibracore #04 was -41.9 ft NAVD88, and the elevation for #11 was -43.1 ft NAVD88.

Generally consistent with the pattern of SP and SP-SM lenses found on the B5 shoal, the upper SP lenses for Vibracores #04 and #11 were found to be 3.0 ft and 2.0 ft in thickness, respectively. The sediments lying below the SP lenses contained high levels of silt, classified as SP-SM in #11 but as SM in Vibracore #04. SM materials have even higher levels of silts and fines versus SP-SM materials, and are referred to as 'silty sands' versus 'sand with silt' in the USCS general description scheme. In both Vibracores, the sediments transition to dark gray clays at approximately -51 ft NAVD88.

Analysis of the upper SP lens of both Vibracores reveals fine quartz sands with median grain sizes of 0.14 mm. The mean grain size of these upper sediments is 0.19 mm, indicating at least some higher percentage of larger sand particles in the coarser half of the grain size distribution (see **Figure 5.1**). The sediments in these samples have fines percentages of 1.7 to 2.7% (passing the #230 sieve). The samples were graded for color with Munsell Values of 5 to 7.

<u>COMMENTS:</u> Sediments lying along the same shore-parallel ridge feature containing the B4 and B5 shoals, but well south of B5 and B4 and south of a large identified paleochannel generally exhibit the same characteristics as the sediments found in the B4 and B5 shoals, *for the same corresponding elevations*. South of the large paleochannel identified by Phelps, the seabed elevations do not rise to those found in the B5 and B4 shoals. Correspondingly there are only thin SP lenses of fine sand atop the large ridge feature before the sediments transition down-core to SP-SM and SM materials. The silty SP-SM and SM lenses correspond in elevation to similar lenses at similar elevations in the B5 shoal Vibracores. Likewise, the clay layer seen in #04 and #11 begins at approximately the same elevations as the clay layer in the B5 shoal.

6.0 CONCLUSIONS

This report describes the collection and analyses of thirteen shallow seabed sediment Vibracores and supporting high-resolution multibeam hydrographic survey data acquired to describe limited areas of the seabed in Federal waters off Amelia Island, Nassau County, FL (**Figure 1.1**). The data described herein were collected to supplement existing marine geotechnical data in the region, dating back to the late 1960's and 1970's, and to contribute to the understanding of both the spatial characteristics of the existing seabed sediments in the area and the underlying paleochannel morphology of the seabed. The data describe areas not previously sampled and add to the marine geologic model proposed by Phelps et al. (2007). This model, further described by Zarillo et al. (2009), theorizes that the nearshore seabed consists of infilled river channels and adjacent higher-elevation shoals, both created during lower sea levels. The higher elevation shoals are hypothesized by these researchers to be comprised of coarser reworked sediments, versus finer, siltier sediments that have infilled the paleochannels.

The present data collection focuses on these higher elevation shoal areas, those previously unsampled but identified by Meisburger and Field (1975) from the earliest marine geotechnical field work in the area. In particular, the current work focused on a long, nearly shore-parallel ridge lying four to miles offshore of the Amelia Island shoreline in Federal Waters. This ridge contains the B4 and B5 shoals identified, but not sampled, by Meisburger and Field.

From the collection of Vibracores along the shore-parallel ridge and on the B4 and B5 shoals, some general observations can be offered. A lens of muddy sands (5 to 15% fines, SP-SM or SM material in the USCS classification scheme) is found across most of the area sampled by the Vibracores. This lens is typically found at an elevation of -45 to -47 ft NAVD88 (approx.) and extends down-core. At deeper depths, a clay layer (CH or CL material) was found in many Vibracores, beginning at elevations of -51 to -53 ft NAVD88.

Above the silty SP-SM layer, up to -30 ft NAVD88 in limited areas, the higher elevation shoals do contain coarser sand (SP) sediments with varying levels of carbonate (shell) material and much lower levels of silts and fines (less than 2% passing the #230 sieve). The color of these sediments is likewise much lighter, typically average a Munsell Value of 6 or 7. These coarser sediments, however, are still comprised of relatively fine quartz sand, with typical median grain diameters of 0.14 to 0.18 mm and mean diameters of 0.18 to 0.23 mm. The increased mean values are the result of the presence of varying levels of carbonate (shell) material that exists in broken, hash-like form in the quartz sand. There is very little evidence of any medium or coarse quartz sand in the samples collected.

The high-resolution multibeam bathymetric data collected at the B4 and B5 shoals reveals that the shallower features, above the clay and silty sand levels, exist in irregular, broken small ridges and smaller sub-shoal features that sit atop the larger shore-parallel ridge. These features appear to be oriented in a slightly oblique angle to the ridge and the shoreline, lying more in a NE-SW orientation, but in scattered fashion. Comparison of the Vibracore locations to the high-resolution bathymetry confirms that the sand material lies in these higher elevation ridges, mounds, and sub-shoals.

Discussion of Geologic Model Applicability The thirteen Vibracore samples collected in October 2015 for this study supplement the existing dataset and potentially support the geological model proposed by Phelps et al. (2007) and further discussed by Zarillo et al. (2009), although the support is somewhat subjective and limited by the small number of data points. These limited results do indicate areas of coarser and cleaner sand deposits in the higher elevation areas adjacent to some of the identified paleochannel locations. The new Vibracores do not, however, completely differentiate the sediments collected within identified paleochannel areas from the sediments collected at the same absolute elevations in the adjacent areas of higher elevation shoals.

All the Vibracores, in a paleochannel or upon a shoal, seem to indicate a silty SP-SM or SM layer beginning at approximately -45 ft to -47 ft NAVD88 and extending down-core to -51 to -53 ft NAVD88, where the sediments transition to clay in nearly every core investigated. The specific sample characteristics of the silty sediment layers in either dataset are not readily available for comparison, but inspection of the photographs of the two Vibracore sets does suggest that perhaps the paleochannel sediments are finer/siltier/muddier, and darker, than the corresponding samples collected adjacent to the channels. This would support the paleochannel model, albeit only from a subjective, visual standpoint. Again, the Vibracores do indicate that above a certain elevation, roughly -45 ft NAVD88, sediments exist that are principally sandy in content. A more detailed sub-bottom sonar survey, collected at high resolution along the length of the ridge (N-S) and with a focus on only the upper 20 to 30 feet of the seabed might better identify the existence of these paleochannels.

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