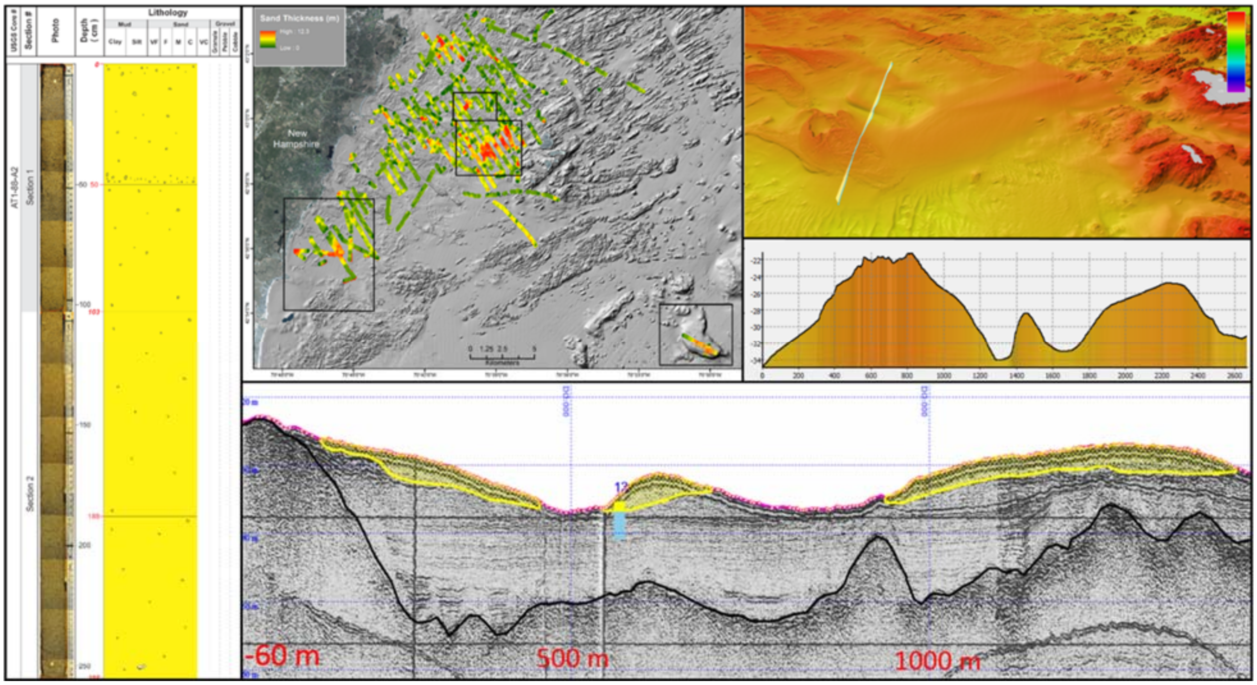
BOEM/New Hampshire Cooperative Agreement (Contract M14ACOOO10) Technical Report

New Hampshire and Vicinity Continental Shelf: Sand and Gravel Resources

By Ward, L.G., McAvoy, Z.S. and Vallee-Anziani, M.

University of New Hampshire Center for Coastal and Ocean Mapping/Joint Hydrographic Center



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New Hampshire and Vicinity Continental Shelf: Sand and Gravel Resources

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University of New Hampshire Center for Coastal and Ocean Mapping/Joint Hydrographic Center

Abstract

Based on the synthesis of relatively recent high-resolution bathymetry, new surficial sediment and geoform maps, and an extensive data archives that includes over ~1280 km of seismic profiles, ~1200 grain size analyses, and 23 vibracores, the distribution of sand and fine gravel was evaluated for the New Hampshire and vicinity continental shelf. This work heavily utilized the results of previous research on sand and gravel resources on the New Hampshire shelf by Birch (1984) and others. Unfortunately, much of the archived data was collected before the Global Navigation Satellite System (GNSS) was used routinely for navigation on research vessels. Consequently, much of the critical data from the archives has large uncertainty associated with the positioning. Furthermore, the seismics are of variable quality. Nevertheless, the data archives coupled with the recent high-resolution bathymetry and surficial sediment mapping provides the bases to develop an initial or 1st order evaluation of the sand and gravel resources and identify areas where follow-up field campaigns are warranted.

To date, five potential sites where sand and fine gravel deposits may be located in quantities suitable for extraction for beach nourishment have been identified. This report focuses on four of these sites due to the availability of seismics and vibracores. The most promising sites are referred to in this study as the Northern Sand Body (NSB) and the Southern Sand Deposits (SSD). Estimates of the volume of sand and fine gravel potentially available in the NSB and the SSD are on the order of 17.3 million m^3 and 16.4 million m^3, respectively. However, these values represent the total volume in area defined by subbottom seismics and include very fine sand and mud. Therefore, the volume of material that may be available for beach nourishment is likely considerably less. Both of these areas, as well as other potential sites identified, need to have high-resolution seismic surveys and vibracoring to fully evaluate the potential of the New Hampshire and vicinity continental shelf sand and fine gravel resources.

The New Hampshire continental shelf has extensive marine modified glacial deposits and associated marine formed shoals. The marine formed features, as well as some of the offshore eroded drumlins, are hypothesized as possible targets for marine mineral resources and will be examined in greater detail in future studies. Some of these deposits may represent significant sand and gravel deposits on the New Hampshire and vicinity continental shelf that have potential for future use for beach nourishment and other efforts to build coastal resiliency.

Introduction

One of the primary goals of the Cooperative Agreement between the Bureau of Ocean Energy Management (BOEM), the University of New Hampshire Center for Coastal and Ocean Mapping/Joint Hydrographic Center (CCOM/JHC), and the New Hampshire Geological Survey (NHGS) is to delineate and map potential sand and gravel deposits on the New Hampshire (NH) and vicinity continental shelf for the primary purpose of beach nourishment to enhance coastal resiliency. Assessment of sand and gravel resources on any continental shelf requires a knowledge of the seafloor bathymetry, morphology, surficial and shallow subsurface sediments, and subsurface seismic stratigraphy. Fortunately, a significant amount of research has been done regarding the sedimentology and seismic stratigraphy of the NH and vicinity inner continental shelf over the last several decades. However, this information has not been systematically synthesized and merged with the high-resolution bathymetry now available and presented in a spatial framework. Therefore, the relevant research on the NH continental shelf and vicinity has been synthesized, databases recovered or built, and the syntheses brought into geospatial or GIS platforms and made readily assessable.

The work conducted by the NH-BOEM Cooperative Agreement on the surficial geology and potential sand and gravel deposits on the NH and vicinity continental shelf is presented in the following reports and products:

1. a synthesis of all available high-resolution multibeam echo sounder (MBES) bathymetry for the western Gulf of Maine (WGOM) and associated backscatter for the NH shelf (Ward, L.G., Johnson, P., Nagel, E., McAvoy, Z.S., and Vallee-Anziani, M., in review, Western Gulf of Maine bathymetry and backscatter synthesis: BOEM/New Hampshire Cooperative Agreement (Contract M14ACOOO10) Technical Report, BOEM Marine Minerals Branch, 381 Elden Street, Herndon, VA, 20170, 18 pp.);
2. new high-resolution surficial geology maps featuring major geoforms (physiographic features) and surficial sediment classifications based on the Coastal and Marine Ecological Classification Standards (CMECS) (Ward, L.G., Vallee-Anziani, M., and McAvoy, Z.S., in review, New Hampshire and vicinity continental shelf: Morphologic features and surficial sediments: BOEM/New Hampshire Cooperative Agreement (Contract M14ACOOO10) Technical Report, BOEM Marine Minerals Branch, 381 Elden Street, Herndon, VA, 20170, 24 pp.); and
3. this report which synthesizes the most relevant subbottom seismics, vibracores, and surficial sediment grain size information with the high-resolution bathymetry, surficial geology maps, and published literature to produce a summary of our present understanding of sand and gravel resources on the NH shelf and vicinity.

Presented here are sand and gravel resource maps, our present understanding of the sedimentological characteristics of these deposits, and potential new sites to explore in the future for the NH shelf and vicinity extending from the coast seaward ~50 km to Jeffreys Ledge and bound by the Massachusetts continental shelf to the south and the Maine shelf to the north (Figure 1). In total, the study area encompasses ~3250 km^2.

Methods

In order to assess the location, characteristics, and volume of sand and fine gravel deposits on the NH and vicinity continental shelf based on previously collected data and publications, the available high-resolution bathymetry and backscatter of the study area was synthesized, all known surficial sediment grain size data was obtained, evaluated, and updated, surficial sediment maps and geoform maps were constructed, and major seismic surveys from the early to mid-1980s were recovered and re-analyzed. All of this information, along with 23 previously collected and described vibracores was used to identify and describe the shelf sand deposits. The high-resolution bathymetry, surficial sediment databases, and surficial geology maps were described elsewhere (identified in the previous section). Here we describe the processing and evaluation of the subbottom seismics and the vibracores and the evaluation of the sand and fine gravel deposits.

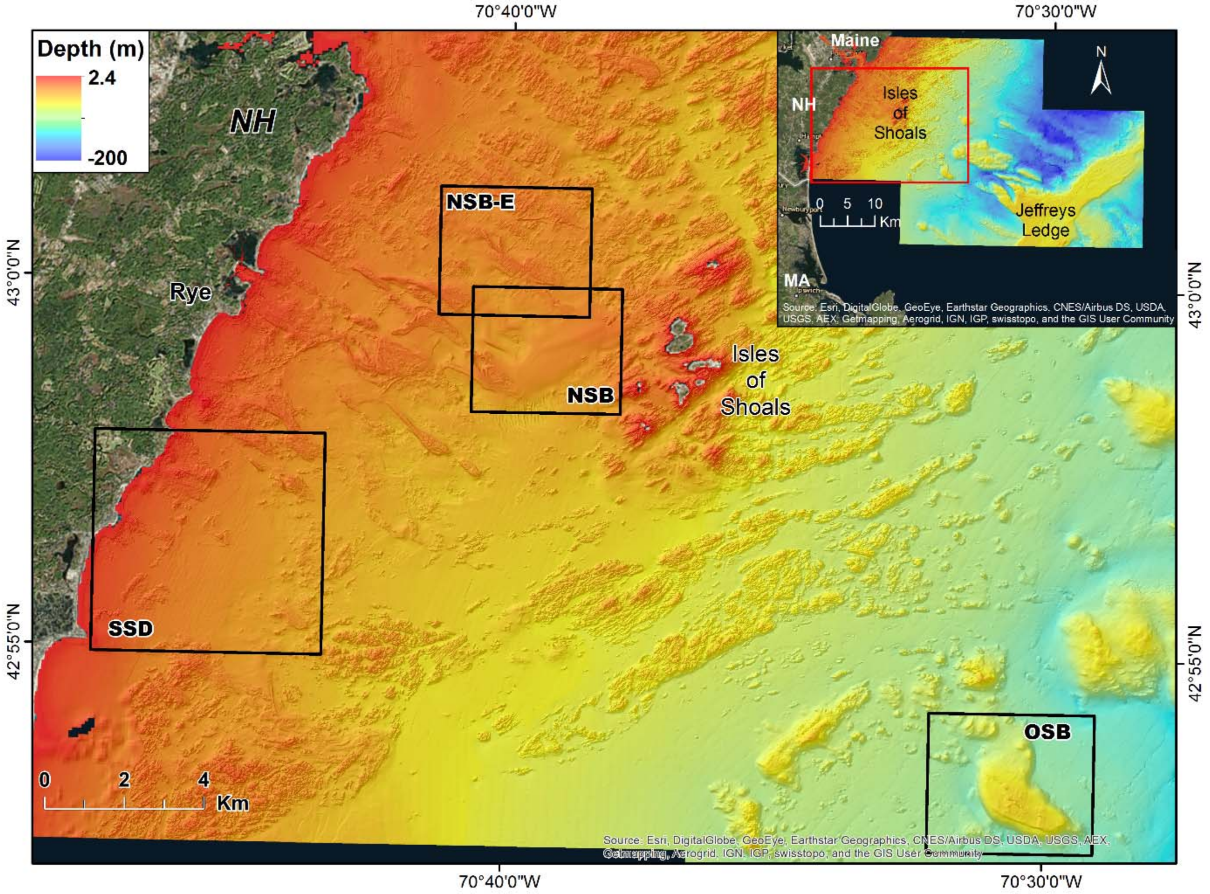

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Figure 1. Location map of the focus areas (outlined in black) where sand and gravel deposits on the New Hampshire continental shelf are described in detail. The inset shows the entire region included in the overall study of the New Hampshire and vicinity continental shelf. SSD is the Southern Sand Deposits; NSB is the Northern Sand Body; NSB-E is the Northern Sand Body Extension; and OSB is the Offshore Sand Body.

Subbottom Seismics

The subbottom seismic surveys used in the evaluation of the sand and gravel deposits on the New Hampshire and vicinity continental shelf were conducted from June 19 – 30, 1981, July 7 – 19, 1982, and July 15 – 17, 1985 by the University of New Hampshire and the United States Geological Survey (Figure 2) (see Birch, 1984, 1986a). The 1981 and 1982 surveys were funded by the National Science Foundation and the 1985 survey was funded by the Minerals Management Service (now the Bureau of Ocean Energy Management or BOEM). The original analog records of all three seismic surveys are stored at the United States Geological Survey Woods Hole Coastal and Marine Science Center Data Archives (1981-018-FA; 1982-021-FA; and 1985-023-FA).

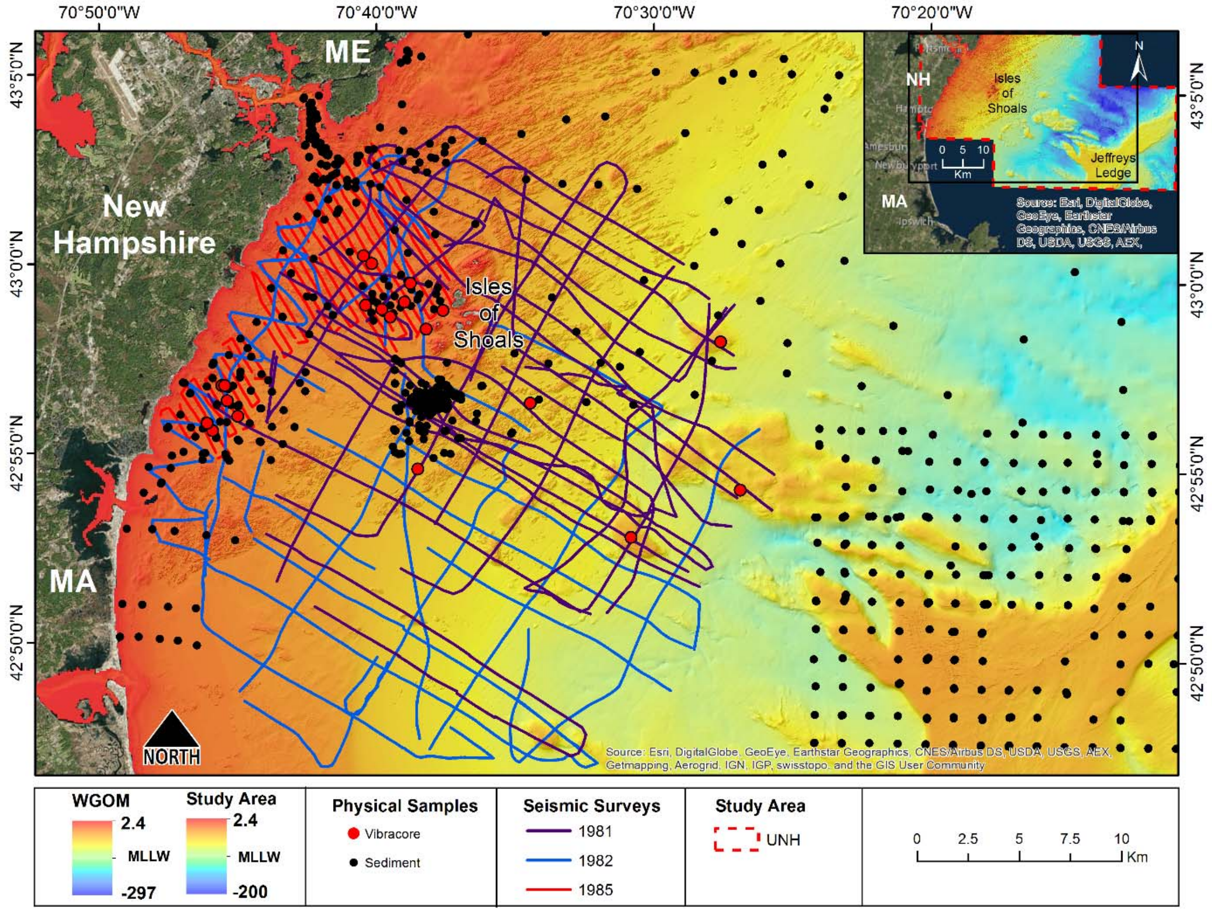


Figure 2. Location map of previous subbottom seismic surveys, vibracores, and surficial sediment samples used in this study from the New Hampshire and vicinity continental shelf.

The 1981 and 1982 surveys were conducted using the United States Geological Survey Research Vessel *Neecho*, an 11.6 m aluminum boat developed for shallow water geophysical surveys. The 1985 survey used the University of New Hampshire Research Vessel *Jere Chase*, a ~13.6 m wooden boat modified as a research platform. The principal subbottom seismic unit for all of the surveys was a 300 joule E.G.&G., model 234 Uniboom system operated at a repetition rate of 0.5 sec. Return echoes were collected with a towed array of hydrophones (20 Aquadyne AQ-1 hydrophones with a 15.2 cm spacing). The signals were amplified (Teledyne Exploration model 300), bandpass filtered (Krohn-Hite model 3700 or 3550 R or Innerspace Technology model 202) and recorded on a dry paper facsimile recorder (EPA model 4100) at a 0.25 sec sweep rate. Positions were determined with a Northstar model 6000 Loran C system and were recorded by hand, typically every 5 to 10 minutes while the surveys were underway. A total of ~1280 km of uniboom tracks were collected (~480 km in 1981, ~600 km in 1982, and ~200 km in 1985).

Processing of the Seismics

Processing of the subbottom seismic records was a labor intensive effort involving transforming the original analog records to digital, analyzing in SonarWiz, and ultimately displaying interpretations of the sand and fine gravel deposits in a GIS platform. The entire workflow for processing of the subbottom seismic records is outlined in Figure 3 and explained in more detail in the subsequent sections.

Analog to Digital Conversion. The analog subbottom seismic surveys were originally scanned and converted to TIFF and/or JPG files during an earlier Cooperative Agreement between New Hampshire and the Mineral Management Service (Ward, 2007). The scanning was done with a Contex MAGNUM XL 54+ (1394) scanner made for oversized or long documents using WIDEimage software. The analog subbottom seismic records were scanned in grayscale at 300 dpi resolution. Subsequently, the TIFF or JPG files were brought into ImageToSEGY software (Chesapeake Technology), where navigation was added and the files converted to SEG-Y format. However, working with the database in SonarWiz (discussed below) revealed that the 1981 and 1982 analog records used in this project were frequently of very low quality (as a result of actually working with scans of scans of the originals). Since the original analog records were stored at the USGS Woods Hole Coastal and Marine Science Center Data Archives, the entire 1981 and 1982 original analog records were re-scanned using greyscale and converted to digital files (TIFF) at the Woods Hole, Massachusetts facility. The original analog seismic records were scanned at 8-bit grayscale TIFF format with 300 dpi horizontal and vertical resolution with a Contex HD4230 Plus scanner using Nextimage software. The new scans are of a much higher quality and reveal far more detail in the subbottom seismic records. However, since the earlier versions were completely processed, only a subset of the newer, higher quality digital files have been analyzed to date in SonarWiz on a as needed bases. The quality of the original scans of the 1985 Birch survey were acceptable and did not require re-scanning.

Processing the Digital Subbottom Seismic Profiles. The SEG-Y files were imported into SonarWiz 6 v.6.01 (Chesapeake Technology) software to enhance the profiles and subsequently analyze the records. Enhancements included modifications of the seismics on screen such as scale corrections, adjusting the vertical exaggeration, or improving the clarity or contrast of the images. Analysis included bottom tracking, identifying and drawing critical reflectors, and computing seismic unit thickness. The SEG-Y files were imported as subbottom profiles (Import SBP Tool) into SonarWiz and converted to CSF (common sonar format) files. Subsequently, all processing was applied to the CSF files. Initial processing included: splitting the subbottom seismic profile files into smaller segments based on orientation and location using the "Split CSF by Time or Ping " function; tracking the seafloor using "Bottom Tracker Tools"; converting the bottom tracks into a seafloor reflector using the "Make Reflector Tool"; and manually drawing other reflectors as needed using the "Acoustic Reflectors Tool". Images from the processed CSF files were exported with the enhancements and interpretations as image cross-sections with all of the features as BMP, JPEG, or TIFF formats. Subsequently, the cross-section images were viewed in SonarWiz 3D, converted to shapefiles (shows shiptracks) and cross-section images to view in ArcGIS or QPS Fledermaus. It should be noted that in cases where seafloor elevations of cross lines of the profiles did not match, the "Datum Align SBP to Bathy Grid" tool was used to adjust the vertical offset of the profile bottom tracks to match a gridded surface. Sediment thickness values were calculated using the "Compute Thickness Tool" which simply determines the vertical distance between the seafloor reflector and sand base reflector.

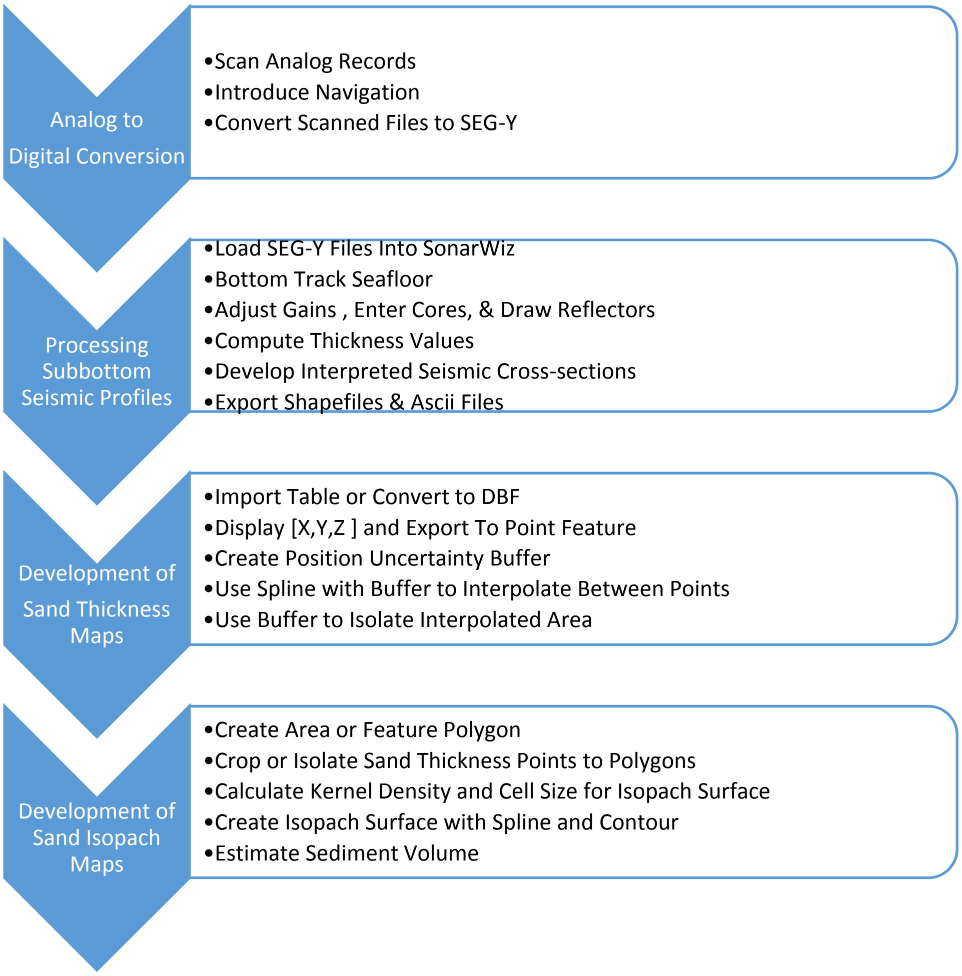


Figure 3. Workflow for processing subbottom seismic profiles.

Computed thickness values were then exported using one of the many feature export tools such as "Ascii CSV", "Ascii Detailed CSV", or "Ascii Simple Thickness, XYZ Text". If a core was located along a subbottom seismic profile, the core position and core log was added to the image using the "Core Tool". Additional formatting of exported files to bring into ArcGIS was done using MATLAB or Excel.

Development of Sand and Fine Gravel Thickness Maps, Isopach Maps, and Estimating Sediment Volume

To develop sand and fine gravel deposit thickness maps, the computed thickness of sand layers developed in SonarWIZ were brought into ERSI ArcGIS 10.3 and converted from a XYZ format to point feature shapefiles. Since navigation for the seismic surveys was based on Loran C with an accuracy estimated to be between ~185 to ~463 m (explained below in section on "Positioning Uncertainty of Seismics and Vibracores"), buffers were drawn around each point with a 125 m radius to allow some estimation of the positioning error. A surface interpolation using "Spline with Barriers" from the Spatial Analyst toolbox in ArcGIS was applied to the thickness points using the 125 m radial buffer as a constraining geometry. The elongated surfaces are displayed as sand thickness maps.

To create an isopach map from sand thickness values exported from SonarWIZ, a bounding area polygon was developed in ArcGIS on a map surface to isolate the area where the point thickness values were going to be interpolated. Boundary geometry was designed to prevent interpolation of sand areas across bedrock outcrops or features likely composed of non-sandy materials. Points outside the bounding area were removed with "Erase Point" from the Editing Tools toolbox. The kernel density estimated by the "Kernel Density Tool" in the Spatial Analyst toolbox in ArcGIS was used to determine an appropriate cell size for each isopach surface by calculating the square root of one over the mean kernel density (cell size formula) of the points inside the area polygons. Similar to the sand thickness surfaces, isopach surfaces were created using a spline interpolation of the isolated points for each area using "Spline with Barriers" from the Spatial Analyst toolbox in ArcGIS.

The sediment volume within the bounding area was computed using the Surface Volume tool in the 3D Analyst toolbox of ArcGIS.

Synthesis of Vibracore Data and Development of Vibracore Logs

A total of twenty-three vibracores were taken on the NH shelf in 1984 and 1988 (12 vibracores from 11 sites in 1984 and 11 vibracores from eight sites in 1988). Both sets of cores were funded through a Minerals Management Service (MMS) - Coastal States Cooperative Agreements (14-12-0001-30115 in 1984 and 14-12-0001-30316 in 1988). All of the vibracores were collected aboard the R/V *Atlantic Twin* (a twin-hull vessel run by Alpine Geophysical Associates, Inc.) using a pneumatic, vibrating hammer-driven coring system. The vibrator is attached to the top of a core pipe (standard 10.1 cm or 4 inch steel pipe) fitted with a ~9 cm (3.5 inch) diameter plastic core liner tube. The recovered tubes were cut in 1 to 1.5 m lengths on board the R/V *Atlantic Twin* to facilitate transportation to the United States Geological Survey facility at Woods Hole, Massachusetts. There the cores in their liners were split lengthwise; half for archiving and a working half for sampling, photography, and description.

The cores were originally described during the periods they were collected by the investigators directing the projects. The cores collected in 1984 were sectioned and photographed (in black and white) at the Woods Hole Coastal and Marine Science Center Samples Repository. Subsequently, the working half was transported to the University of New Hampshire where the cores were described and sampled for grain size analysis (Birch, 1986b). The vibracores collected in 1988 were also sectioned at the United States Geological Survey facility, but were apparently not photographed. The vibracores were then transported to University of New Hampshire for description and analysis (Ward, 1989). A consequence of the cores being taken and analyzed by different investigators at different time periods is that the core descriptions used different criteria and logging methods. This problem was partially addressed with MMS funding in 2007 during which the working halves of both the 1984 and 1988 vibracores taken on the New Hampshire shelf were described using the same methodologies (Ward, 2007).

During the present program all of the original descriptions, data, and photographs (where available) were obtained, synthesized, and presented in uniform core logs create in CorelDraw 7x (64 bit). In addition, the archived halves of six selected cores were reviewed at the USGS facility in Woods Hole, Massachusetts. The core descriptions were verified or modified and the cores photographed at a higher resolution and in color. The photography is important for all the cores as the 1984 cores were originally photographed in black and white and not at a high-resolution and the 1988 vibracores have no associated photographs.

The archived halves of the vibracores are archived at the USGS Woods Hole Coastal and Marine Science Center Samples Repository (http://woodshole.er.usgs.gov/operations/ia/samprepo/). Metadata for the 1984 cores can be found at http://cmgds.marine.usgs.gov/fan_info.php?fa=1984-016-FA .

Positioning Uncertainty of Seismics and Vibracores

Loran C was the navigation system used for the 1981, 1982, and 1985 subbottom seismics surveys (Birch, 1984, 1986a), which form the bases for the subbottom seismic evaluation of sand and gravel deposits on the NH continental shelf. The Loran C coordinates and the time annotations marked on the analog seismics records were recorded by hand typically at 5 to 10 minute intervals. Similarly, the positioning for the vibracores taken on the NH shelf in 1985 (Birch, 1986b) and 1988 (Ward, 1989) was also determined by Loran C. Even without the error in positioning introduced by having location information recorded by hand at a minimum of 5 minute intervals and subsequently matched to hand written time annotations on the analog records (which did not always match), Loran C has a signification error in absolute position that is between ~185 m (0.1 nautical miles) and 463 m (0.25 nautical miles). For reference see U.S. Department of Homeland Security, United States Coast Guard, Navigation Center web site and report:

http://www.navcen.uscg.gov/; and
http://www.navcen.uscg.gov/pdf/loran/handbook/CHAPTER3.pdf; downloaded March 15, 2016.

Therefore, a significant absolute positioning uncertainty exists in the older analog seismic data and the positions of the 1985 and 1988 vibracores. However, Loran C precision was much better than the absolute accuracy (~18 to ~91 m or 60 to 300 ft). To account for this uncertainty, buffers that extended 250 m were placed along the shiptracks and around the vibracore locations to provide a sense of the uncertainty. The worst case scenario was not used, nor the minimum. Instead 250 m was chosen as a likely near minimum, realizing that the uncertainty could be larger. However, comparison of the seismics lines and interpretations with the high-resolution bathymetry allows insights into the likelihood and magnitude or positioning errors.

Surficial Geology of the New Hampshire and Vicinity Continental Shelf

The New Hampshire and vicinity continental shelf is very complex and is composed of extensive bedrock outcrops (in some areas draped with sediments), sand and gravel deposits, and muddy plains and basins. Many of the depositional features are directly or indirectly glacial in origin and have been significantly modified by marine processes as sea level fluctuated since the end of the Wisconsin glaciation. For example, apparent drumlins were eroded, leaving very coarse lag deposits, while supplying sand and fine gravel to develop shoals and sheet sands. It also appears fine grained glacial marine deposits (sandy muds) were winnowed contributing to the sand features as sea level fluctuated (Birch, 1984). Due to the complexity of the seafloor, it was necessary to develop new, high-resolution bathymetry and geologic maps to depict the morphology and sediment composing the seafloor. The production of these maps are explained in other reports cited in the Introduction. The maps are presented here to aid in the description of the surficial geology of the study area and to define the primary physiographic features and locations containing sand and fine gravel deposits.

Utilizing the Coastal and Marine Ecological Standards (CMECS) (FGDC, 2012), the study area was mapped as bedrock or unconsolidated mineral substrate. The unconsolidated substrate was further divided into course unconsolidated sediment (gravel, gravel mixes, and gravelly sediments), which encompasses the Wentworth (1922) size classes from boulder gravels to gravelly sand or gravelly mud) and fine unconsolidated sediment (slightly gravelly sand to mud) (Table 1; Figure 4). The surficial sediments of the study area were also mapped in more detail, although with somewhat greater uncertainty, using the CMECS substrate group classification. This classification is closely aligned with the Wentworth scale and has the advantage of simplifying the classes by combining similar ranges (Table 1; Figures 5 and 6). Finally, based on the high-resolution bathymetry and the surficial sediment maps developed for this study, the major morphologic features or geoforms were identified and mapped (Figure 7). The geoforms depict features that are defined by physiography and composition, but also imply mode of formation.

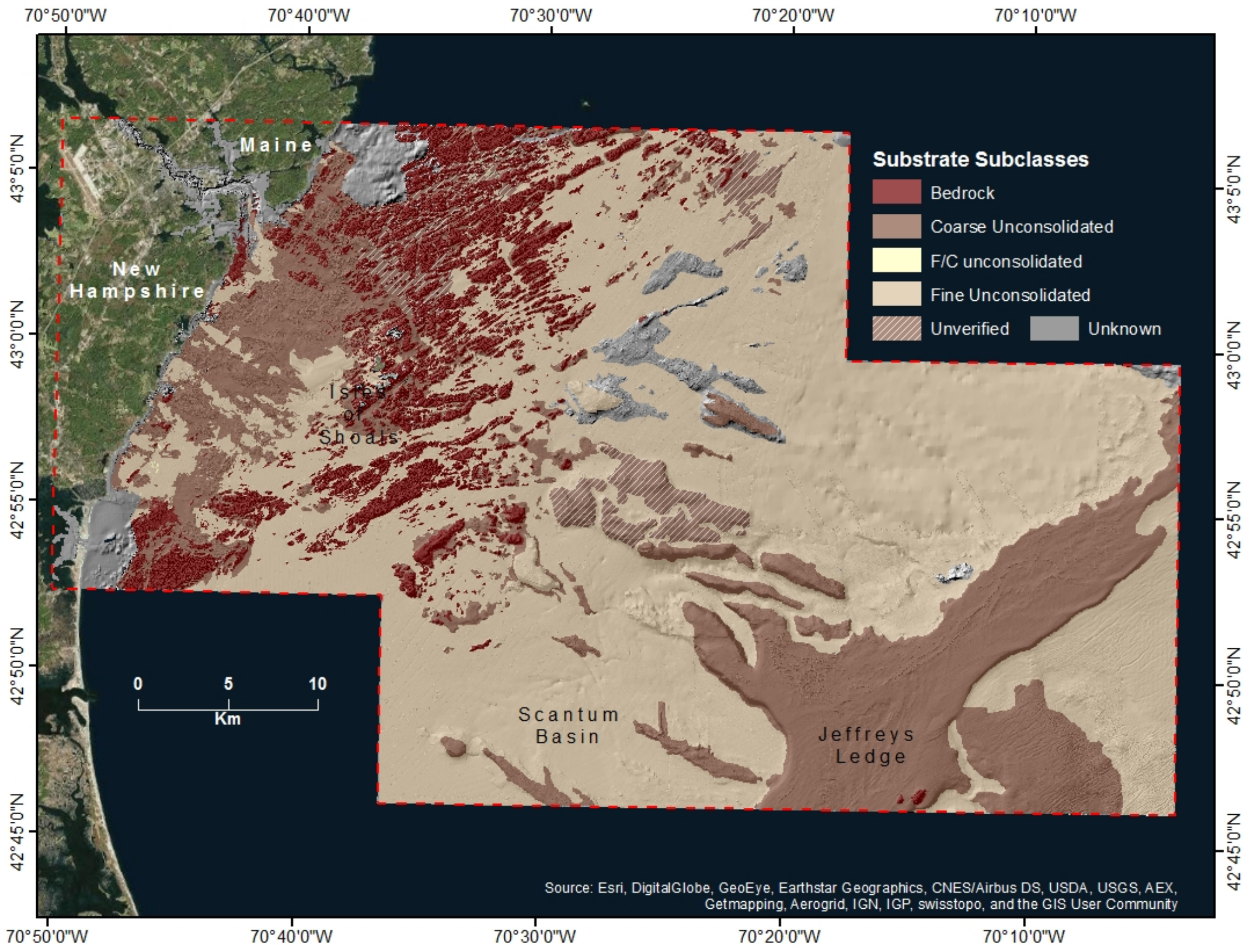
Where possible, the nomenclature for the geoforms was adapted from the CMECS. However, a number of the features on the NH and vicinity continental shelf, and likely many paraglacial shelfs, are not well defined by the geoforms described in CMECS. Therefore, some of the existing terminology was modified from the original definitions and new terms for geoforms added. All of the geoforms used for the NH and vicinity shelf are described in Ward, L.G., Vallee-Anziani, M., and McAvoy, Z.S., in review, New Hampshire and vicinity continental shelf: Morphologic features and surficial sediments: BOEM/New Hampshire Cooperative Agreement (Contract M14ACOOO10) Technical Report, BOEM Marine Minerals Branch, 381 Elden Street, Herndon, VA, 20170, 24 pp. We offer these terms for similar paraglacial continental shelfs.

Surficial Sediments

The New Hampshire continental shelf is dominated by fine unconsolidated substrates seaward of the Isles of Shoals with the exception of marine modified glacial deposits (Figures 4 and 7). The marine modified glacial deposits tend to be composed of coarse unconsolidated sediments ranging from poorly sorted muds, sands, or gravels with boulders (Figure 5). Jeffreys Ledge is composed of gravel and gravel mixes (i.e., sandy gravel). The fine unconsolidated sediments are typically muddy to sandy muds, but can be coarse depending on proximity to glacial features or bedrock. At least one large sand body occurs in the offshore area. Note that a number of the marine modified glacial features (Figure 7) are not mapped (shown as grey hillshade), as their composition is unknown presently. Away from the glacial features the seafloor is mostly muddy transitioning into a sandy mud in a landward direction.

Table 1. CMECS substrate classification. Modified from FGDC (2012).

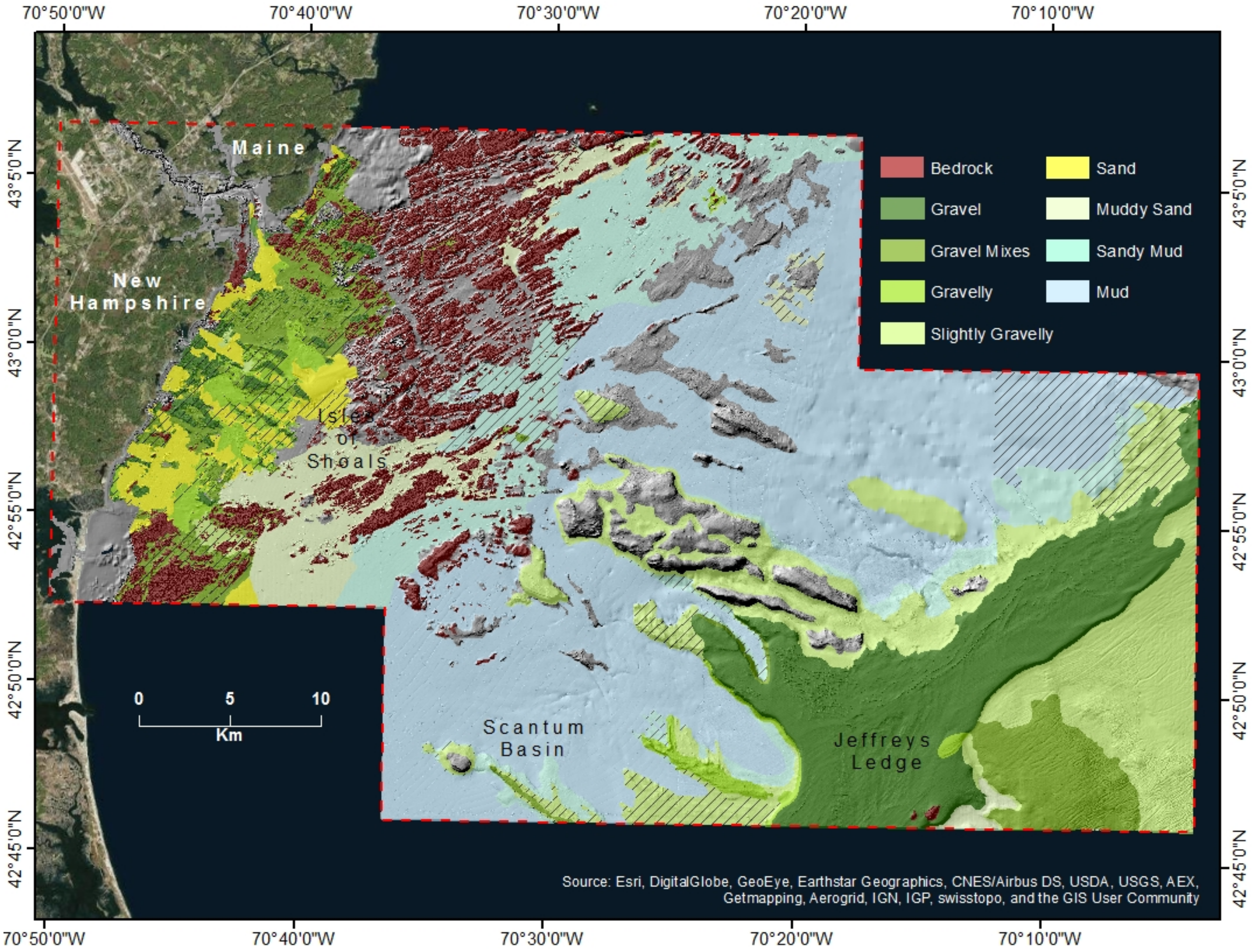
Substrate Origin	Substrate Class	Substrate Subclass	Substrate Group	Substrate Subgroup
Geologic Substrate	Rock Substrate	Bedrock		
	Unconsolidated Mineral Substrate	Coarse Unconsolidated Substrate	Gravel	Boulder
				Cobble
				Pebble
				Granule
			Gravel Mixes	Sandy Gravel
				Muddy Sandy Gravel
				Muddy Gravel
			Gravelly	Gravelly Sand
				Gravelly Muddy Sand
				Gravelly Mud
		Fine Unconsolidated Substrate	Slightly Gravelly	Slightly Gravelly Sand
				Slightly Gravelly Muddy Sand
				Slightly Gravelly Sandy Mud
				Slightly Gravelly Mud
			Sand	Very Coarse Sand
				Coarse Sand
				Medium Sand
				Fine Sand
				Very Fine Sand
			Muddy Sand	Silty Sand
				Silty-Clayey Sand
				Clayey Sand
			Sandy Mud	Sandy Silt
				Sandy Silt-Clay
				Sandy Clay
			Mud	Silt
				Silt-Clay
				Clay



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 4. Surficial sediment map of the New Hampshire and vicinity continental shelf based on the CMECS classification for Geologic Substrates Subclasses (FGDC, 2012).

Landward of the Isles of Shoals the seafloor is extremely heterogeneous due to the mixture of bedrock, marine modified glacial features, and marine formed shoals (Figures 6 and 7). Here, the seafloor is dominated by outcropping bedrock in some areas that tend to have coarse sediment between the ridges. The unconsolidated sediment is composed of sandy sediments to gravel mixes interspersed with gravel areas. The gravel areas are presumably associated with eroded glacial features such as drumlins. Close by are gravelly mixes to gravelly sediments which are frequently gravelly sands. The exposed bedrock likely has gravel mixes to gravelly sediments in the troughs or swales between the bedrock outcrops. The nearshore region has relatively large areas of sand which are found close to shore on nearshore ramps and further offshore associated with eroded glacial features. The largest of these features, referred in this study as the Northern Sand Body, is a potential source of sand for beach nourishment.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 5. Surficial sediment map of the New Hampshire and vicinity continental shelf based on the CMECS classification for Geologic Substrate Groups (FGDC, 2012).

Geoforms

The geoforms identified and classified on the NH shelf show very clear trends (Figure 7). From several kilometers seaward of the Isles of Shoals to Jeffreys Ledge, the geoforms are very large and dominated by marine modified glacial features. During the last sea-level lowstand approximately 11-12 thousands of years before present sea level was between 40 m to 55 m below present (Oldale, 1983; Belknap et al., 1987; Kelley et al., 1992; Barnhardt et al., 1995, Belknap et al., 2002; Barnhardt et al., 2007). During this lowstand the surface of Jeffreys Ledge and the nearby drumlins were at or very close to sea level. Marine processes modified the surface of Jeffreys Ledge and eroded the tops of the drumlins. In addition, the eroded material, which may have included sand and fine gravel, was deposited as aprons around the glacial features.

The inner NH continental shelf within 15 km of the coast contains extensive bedrock outcrops, often separated by troughs with sediment and surrounded by aprons of coarse sediment (Figure 7). The general trend of the outcropping bedrock is northeast-southwest. The bedrock that

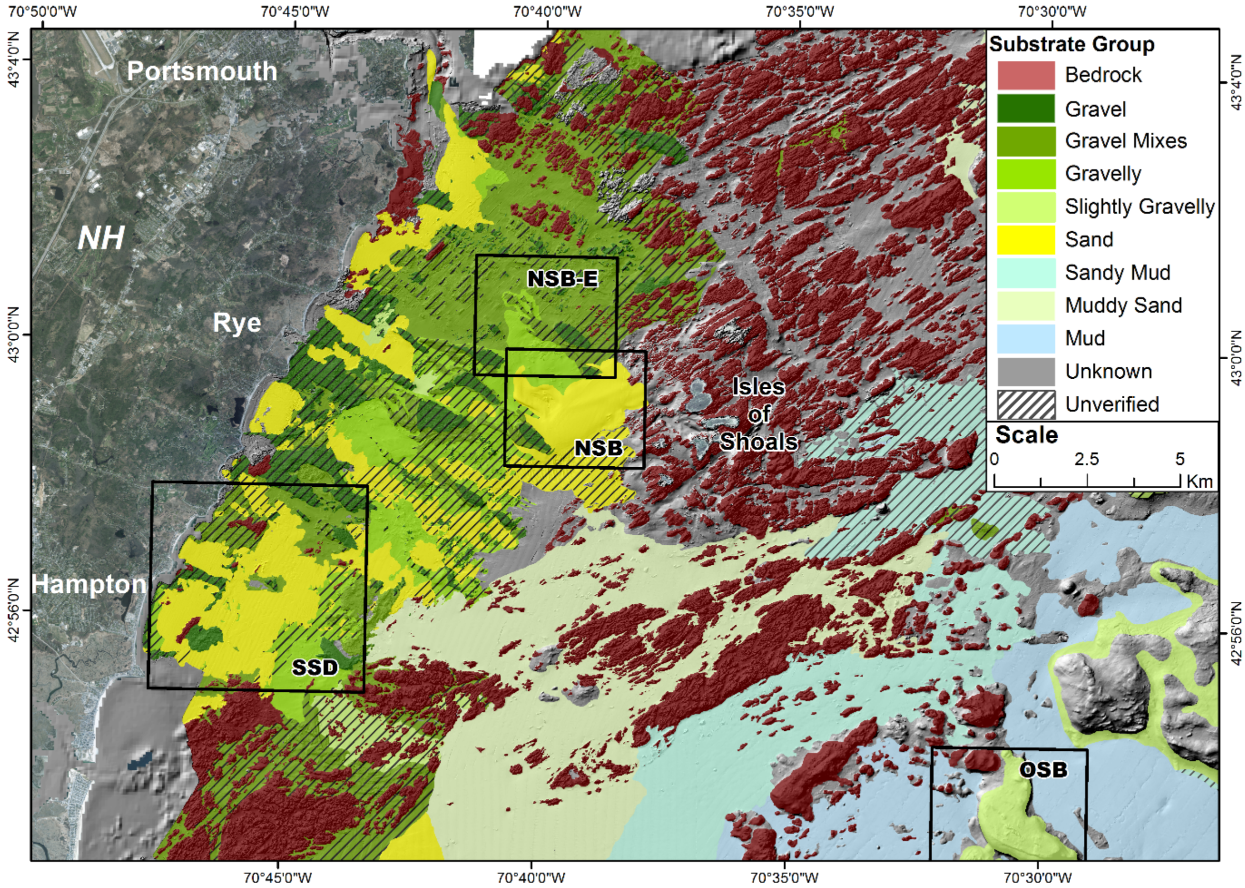


Figure 6. Surficial sediment map of the New Hampshire continental shelf based on the CMECS classification for Geologic Substrate Groups (FGDC, 2012). This map is an enlargement of Figure 5. The focus areas for the sand and gravel studies are outlined in black. SSD is the Southern Sand Deposits; NSB is the Northern Sand Body; NSB-E is the Northern Sand Body Extension; and OSB is the Offshore Sand Body.

dominates the seafloor north of the entrance to Portsmouth Harbor transitions into sediment draped bedrock as the sediment cover becomes more prevalent to the south. The sediment draped bedrock tends to have modified glacial features intermixed in some of the inner shelf areas.

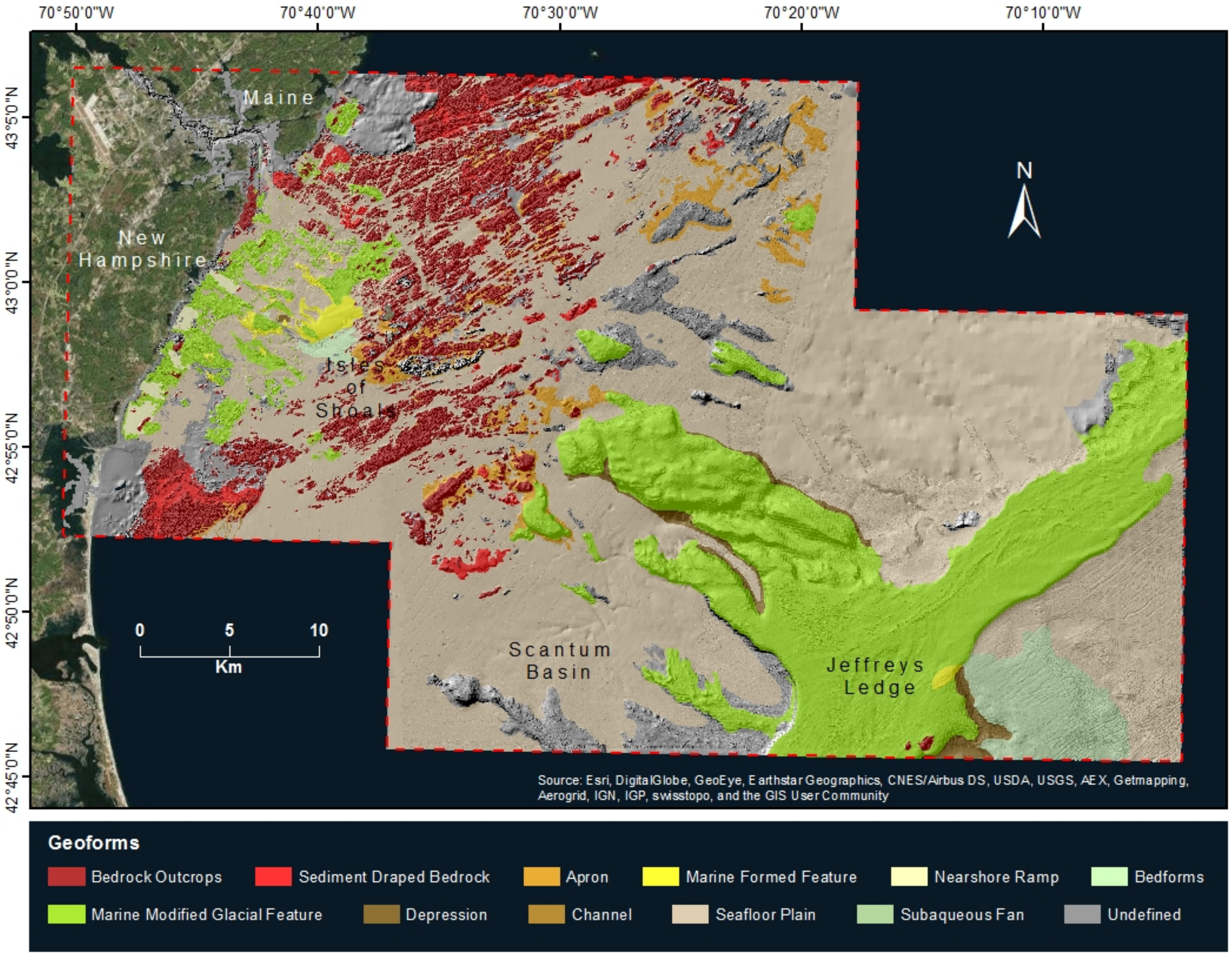
Extensive marine modified (eroded) glacial features are found landward of the Isles of Shoals and south of Portsmouth Harbor. Features that appear to be the roots of eroded drumlin deposits and eskers are common. Associated with these eroded glacial features are marine formed shoals. It is hypothesized that many of these shoals are formed from sediments eroded from glacial features (after Carter and Orford, 1988). The largest sandy shoal in the study area is located just landward the Isles of Shoals (the Northern Sand Body) and lies between two eroded drumlins.

Description of Sand and Gravel Deposits (Focus Areas)

A first order understanding of the distribution of sand and fine gravel deposits on the NH and vicinity continental shelf is based on the following:

1. the development and review of the high-resolution bathymetry, surficial sediments and geoform maps;
2. a systematic review and verification of the earlier interpretations of the seismic stratigraphy and depositional units on the NH shelf by Birch (1984, 1986a) based on surveys conducted in 1981, 1982, and 1985; and
3. the synthesis and additional analyses of vibracores taken on the NH shelf originally described in Birch (1986b) and Ward (1989).

One of the major products of this effort is the development of maps that depict the interpolated thickness of sand and fine gravel deposits largely based on subbottom seismic profiles (Figure 8). The sand thickness surfaces are restricted to a 250 m buffer along the shiptracks with no merging across lines. This is done because at a large scale the seafloor is extremely heterogeneous with extensive bedrock outcrops, cobble, and boulder deposits. Therefore, contouring between lines can be misleading. A 250 m buffer was chosen because the navigation for the seismic surveys was based on Loran C which can have an error in absolute position of between 185 to ~463 m (as discussed above in Positioning Uncertainty of Seismics and Vibracores). Therefore, a 250 m buffer provides the boundaries where the seismic data is likely valid.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 7. Major physiographic features (geoforms) of the New Hampshire and vicinity continental shelf.

Examination of the sand thickness map indicates five areas where the sand and fine gravel likely exceeds several meters and represent potentially significant deposits (shown by warmer colors in Figure 8). In this study, four of the areas are reviewed where additional information including vibracores are available (outlined in black in Figure 8). The focus areas are referred to by their relative positions and associated features and include: the Southern Sand Deposits, the Northern Sand Body, the Northern Sand Body Extension, and the Offshore Sand Body. The use of the term "body" here implies positive relief of the feature above the surrounding seafloor and formation or modification by marine processes, while "deposit" implies a sand sequence below the surrounding seafloor with little or no surficial expression. The database for each of the focus areas is described below. Another potential site near the entrance to Portsmouth Harbor will be evaluated in future studies.

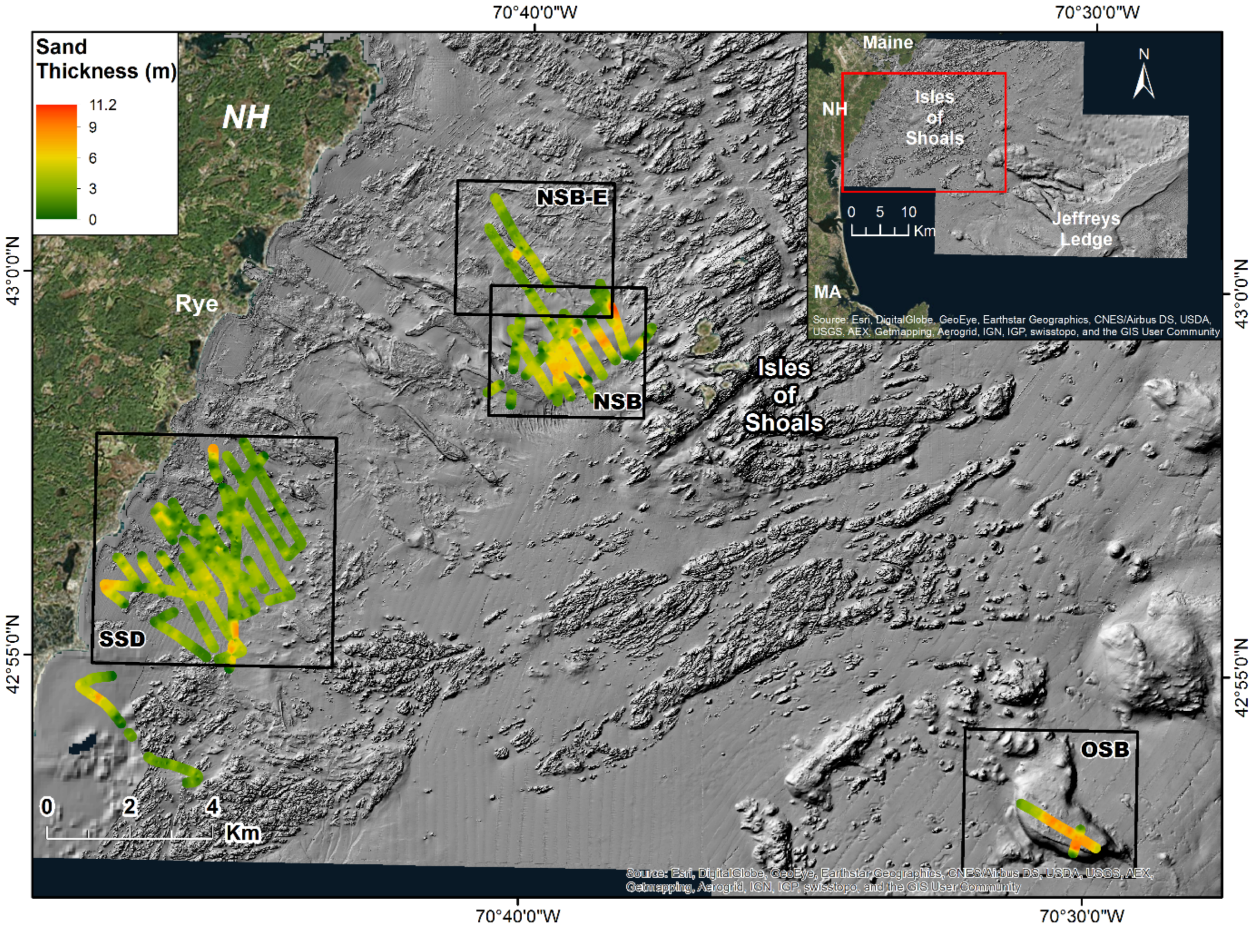
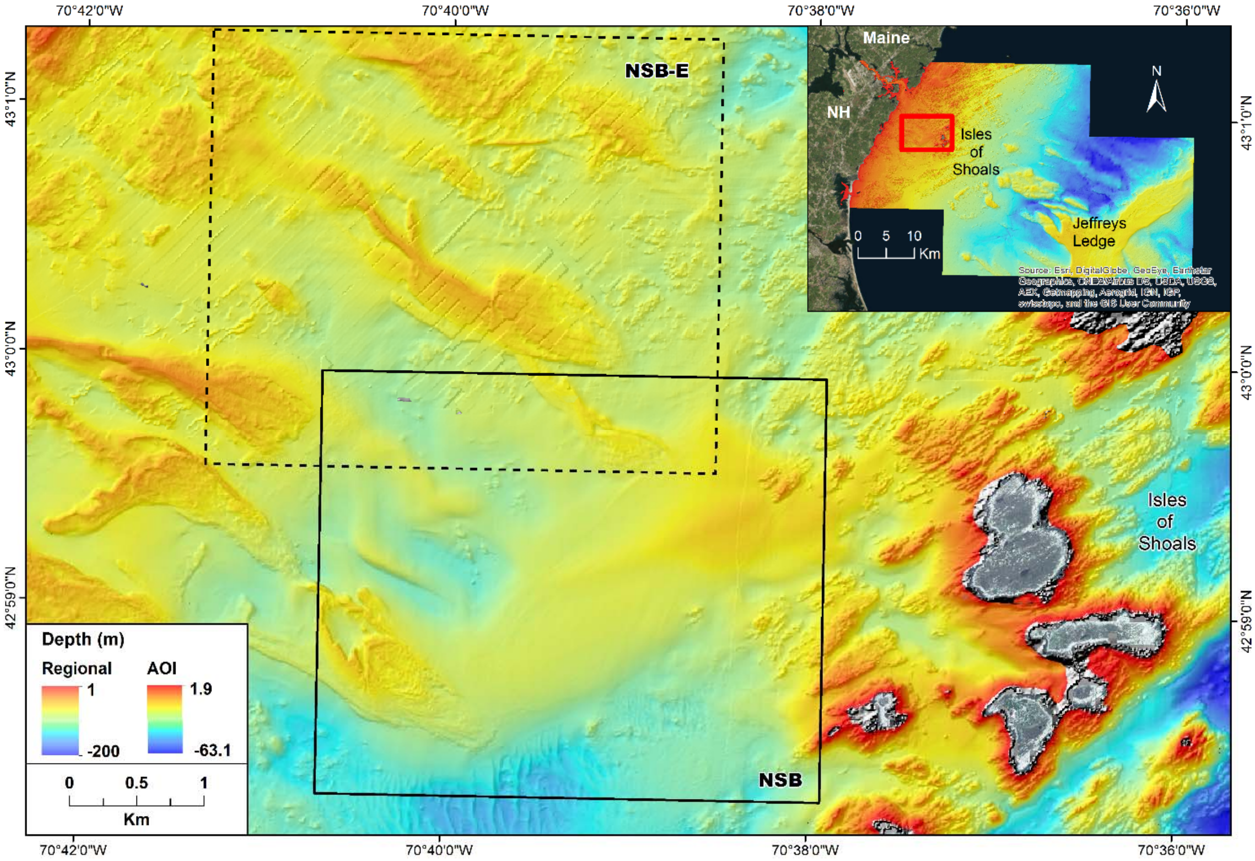


Figure 8. Sand and gravel thickness map for the New Hampshire and vicinity continental shelf. The sand thickness is given in meters and is for a 250 m wide buffer along the shiptracks. Because of the extreme variability of the seafloor (e.g., sand deposits, rocky outcrops, eroded drumlins composed of course gravel and boulders), the sand thicknesses do not extend between shiptracks. The surface interpolated along the shiptracks was generated from the point thickness values using a radial buffer (250 m) to constrain the distance. The focus areas for the sand and gravel studies are outlined in black. SSD is the Southern Sand Deposits; NSB is the Northern Sand Body; NSB-E is the Northern Sand Body Extension; and OSB is the Offshore Sand Body.

Northern Sand Body

The Northern Sand Body (NSB) is located ~10 km offshore, just landward of the Isles of Shoals. The feature is relatively large extending ~3.2 km in length, ~1.3 km in width, and has a maximum relief of ~7 m (in comparison to the surrounding seafloor) (Figure 9). The NSB has an elongated shape and a relatively smooth, but slightly rounded surface as demonstrated in the bathymetry. Interestingly, the NSB extends between what appears to be the roots of two eroded drumlins. In addition, the southeastern border of the NSB is very steep with a sand wave field located adjacent to the feature indicating active sediment transport. Conversely, the northwestern border has a much gentler slope and extends into what appear to be sandy shoals. All of these features are potential sand and gravel resources.

The origin of the NSB is not clear. Birch (1984) proposed that many of these sand deposits resulted from erosion and winnowing of the glacial marine sediments deposited during the last sea level highstand as the Wisconsin ice sheet waned, leaving a sandy lag at the surface. Subsequently, marine processes (waves) developed shoals during the following regression and subsequent transgression. Many of the depositional features found landward of the Isles of Shoals and south of Portsmouth Harbor appear to be glacial in origin which have been significantly modified by marine processes as sea level fluctuated since the end of the last major glaciation. As stated above, it appears that the NSB extends between two eroded drumlins. It is



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 9. Location and bathymetry of Northern Sand Body (NSB; outlined in solid black lines) on the New Hampshire shelf (insert). AOI in legend is the depth scale for the body of the figure.

hypothesized that the NSB may have formed from sediments eroded from glacial features as described by Carter and Orford (1988) in similar paraglacial environments in Canada. It is easy to visualize that both of these processes could be at play in the formation of the sandy shoal systems.

Surficial Sediments. The surface of the NSB is composed of sand to gravelly sand (based on gravel/sand/mud ratios, after Folk, 1954; 1980). The sands range mostly from poorly to moderately well sorted medium sand to coarse sand, although some very poorly sorted very coarse sand to poorly sorted fine sands occur on the flanks (based on mean phi size, after Wentworth, 1922) (Figure 10). There appears to be a slight fining in mean grain size from the northeast to the southwest across the NSB suggesting a possible transport direction or a reduction in wave energy. The surrounding surficial sediments are gravelly to gravel mixes and coarse gravels associated with the remnants of glacial deposits (e.g., eroded drumlin).

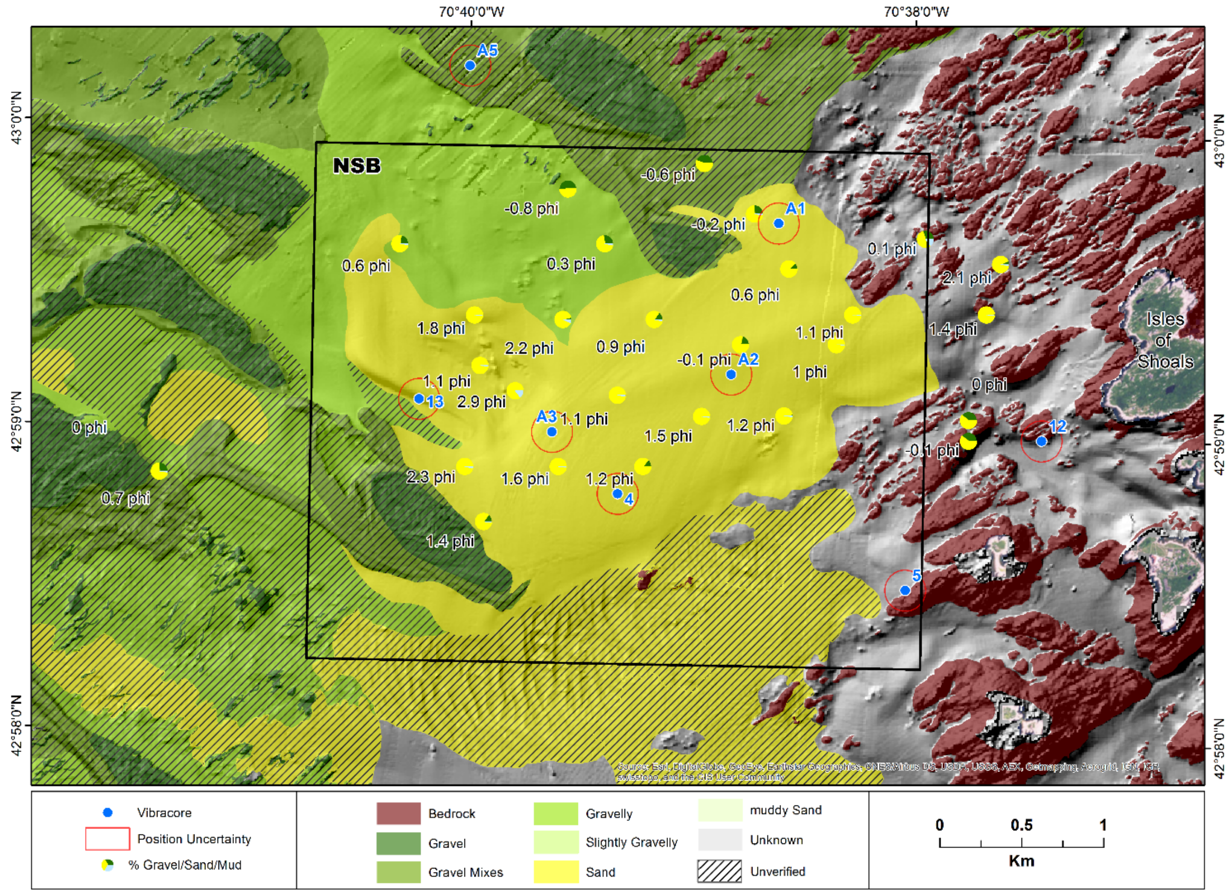


Figure 10. Surficial sediment map, grain size data, and locations of vibracores for the Northern Sand Body. Surficial sediment map based on the CMECS classification for Geologic Substrate Groups. Pie charts show distribution of gravel, sand, and mud. The mean grain size is given as phi units.

Vibracores. The subsurface sand layer on the NSB is characterized by 4 vibracores (Figure 10), ranging in length from ~3.5 to ~7.1 m (Figures 11 – 14, Appendix 1). The upper portions of each of these vibracores are Holocene sands.

Vibracore A2 located near the center axis of the NSB is relatively typical of the vibracores taken on the NSB (Figure 11). The upper ~3.1 m of the sediment column is composed of primarily medium to coarse sand with some very coarse sand, shell fragments, and scattered pebbles. Three sediment samples from this section are >96% sand with 1 to 3% gravel. Mean size of the sand fraction is 1.2 to 1.4 phi or moderately well to well sorted medium sands. Below ~3.1 m to ~5.6 m the core is fine to very fine sand with shell fragments. Below ~5.6 m to the base of the core at ~7.1 m, the sediments become finer and the mud content increases. The sand fraction decreases from 92% at 3.1 m to 35% at ~7.0 m, while the mud content increase from 8% to 62%. Unfortunately, the mean grain size is only available for the sand fraction. However, the sand fraction mean size decreases to 3.0 phi, indicating the end of the sand sequence is near.

Vibracore UNH 4, located on the southeastern side of the NSB is ~6.5 m in length and penetrates the Holocene sand deposit and terminates in the underlying glacial marine muds (Figure 12). The upper ~0.14 m of the vibracore represents a surface lag that likely has been winnowed and as a result is coarser than the underlying sands. The surface sediment is medium to coarse sand with rock fragments and has a sharp contact with the underlying fine sand that extends from ~0.14 m to ~3.5 m. The sand content of a sample taken at ~1.15 m is ~93% and the mud content is 7%. In general the sediment fines downward to fine to very fine sand with increasing mud content to ~5.0 m. The mud content of a sample taken at ~4.0 m is 40%. From ~5.0 to ~5.7 m the sand continues to become finer (very fine sand) and the mud content increases. At ~5.7 m a relatively sharp contact occurs with the underlying mud, presumably glacial marine sediments. A sample taken at ~6.2 m is ~16% sand and ~84% mud or a sandy mud which is characteristic of the glacial marine sediments deposited during the sea-level highstand following the last major glaciation.

Vibracore A1, located on the northern end of the NSB (Figure 10), is relatively short (~4.4 m) and is composed of medium to coarse sand over its upper ~3.5 m (Figure 13). The sand contents of sediment samples taken at 0.05, 0.7, ad 2.0 m are composed of >97% sand with a mean phi size from 1.0 to 1.3 (moderately to well sorted medium sand). The sediments coarsen slightly at 3.1 m with the gravel content increasing to 6% with 93% sand. The bottom of the core from ~3.6 m to the base continues to fine downward, terminating in fine to very fine sand.

In contrast, vibracore A3, located closer to the southwestern end of the axis of the NSB (Figure 10), is a relatively long core penetrating ~5.8 m and is largely a fine to very fine sand over the entire length (Figure 14). The upper 0.3 m is a poorly sorted fine sand. However, a sediment sample from 0.05 m depth is 98% sand with a mean phi size of 1.7 (moderately sorted medium sand). This sample, which appears to be slightly coarser than the rest of the core, is probably a lag deposit covering the surface. From ~0.3 to ~4.3 m very fine to fine sand dominates. Sediment samples from 1.2 and 2.25 m are 97-98% sand with a mean grain size of 2.4 and 2.5 phi (sand fraction only). However, the mud content increases to 15% at 3.7 m depth. A sample taken near the base of the core (5.7 m) has a mud content of 49%. Again, it appears at depth the sediments are transitioning to a sandy mud.

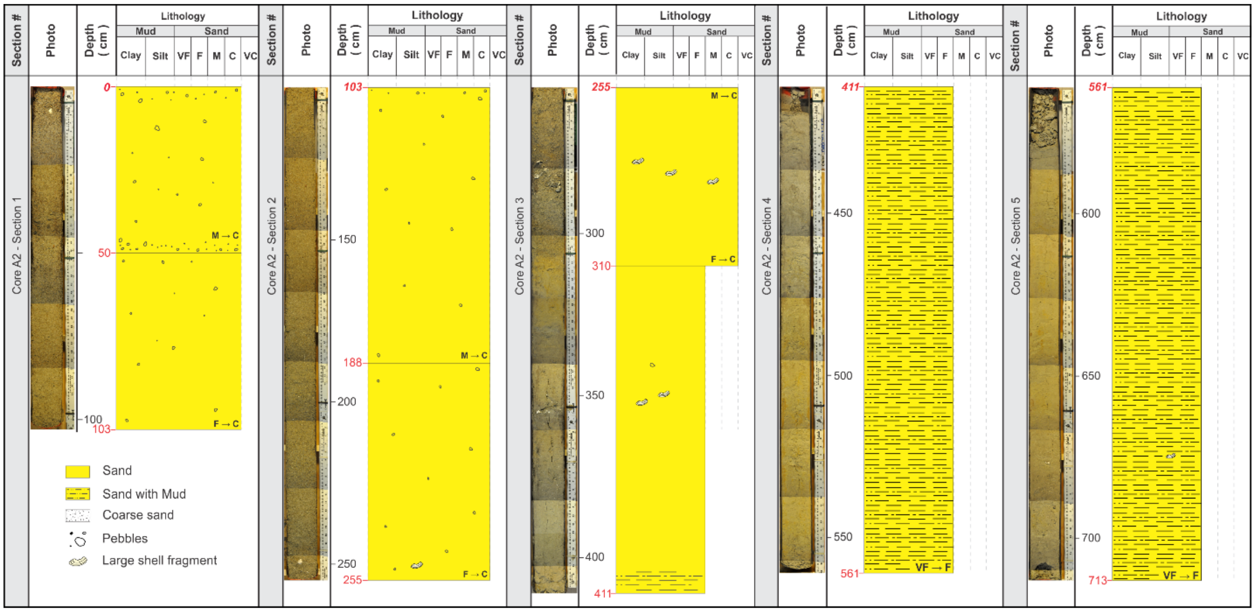


Figure 11. Log for vibracore A2. The location of the core is given in Figure 10. A full description of the core is given Appendix 1.

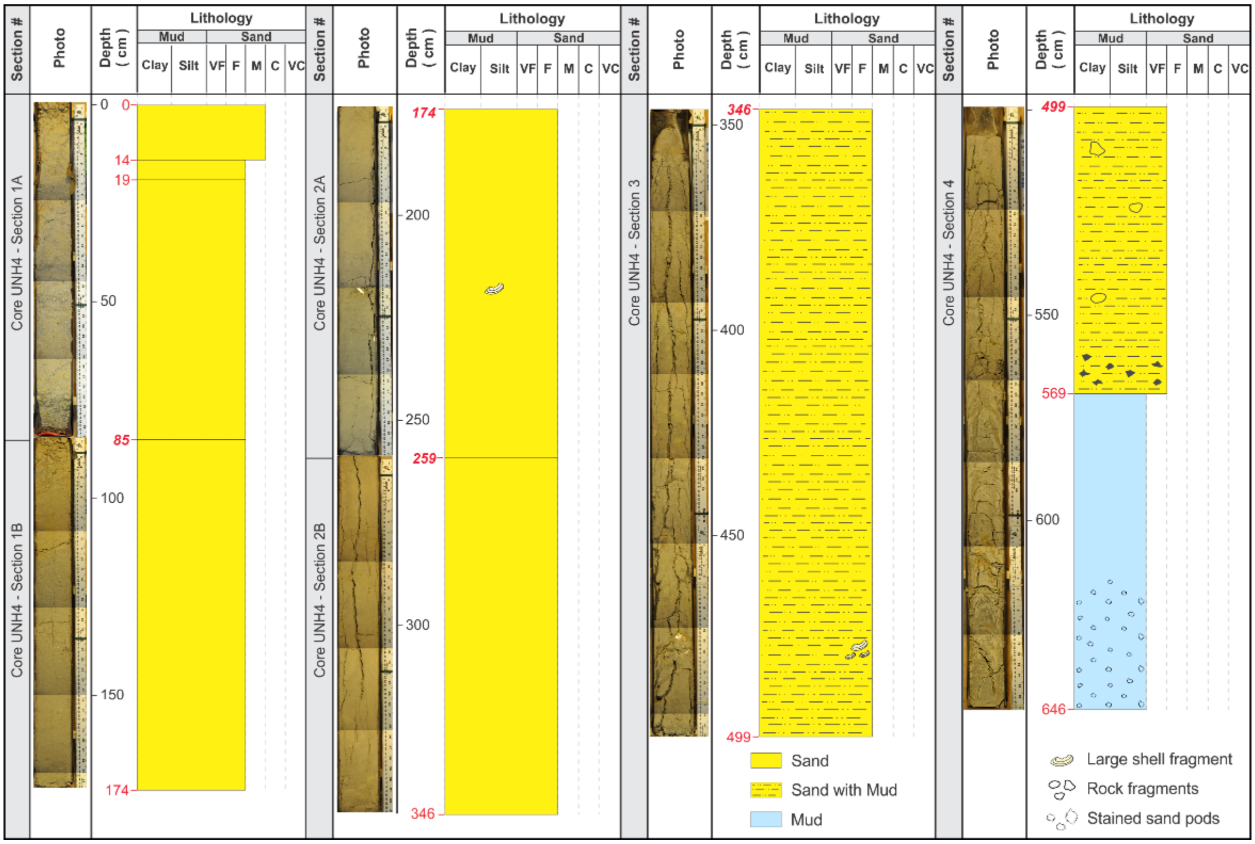


Figure 12. Log for vibracore UNH 4. The location of the core is given in Figure 10. A full description of the core is given Appendix 1.

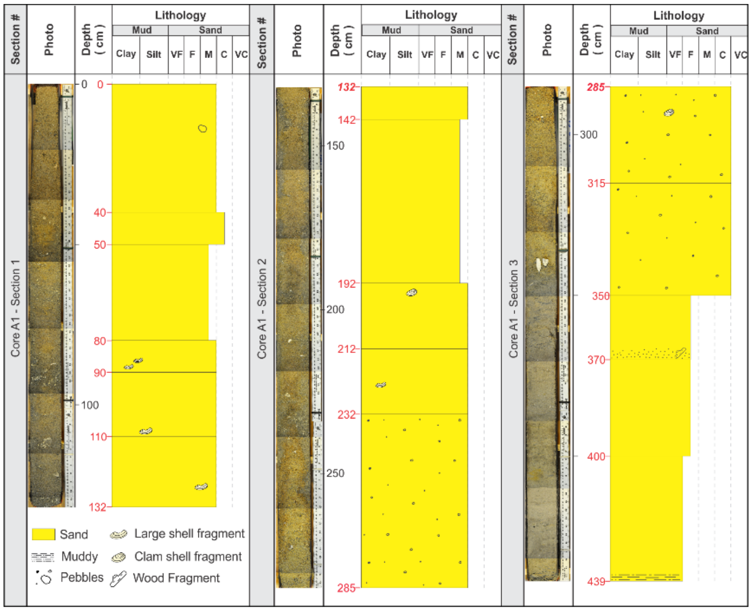


Figure 13. Log for vibracore A1. The location of the core is given in Figure 10. A full description of the core is given Appendix 1.

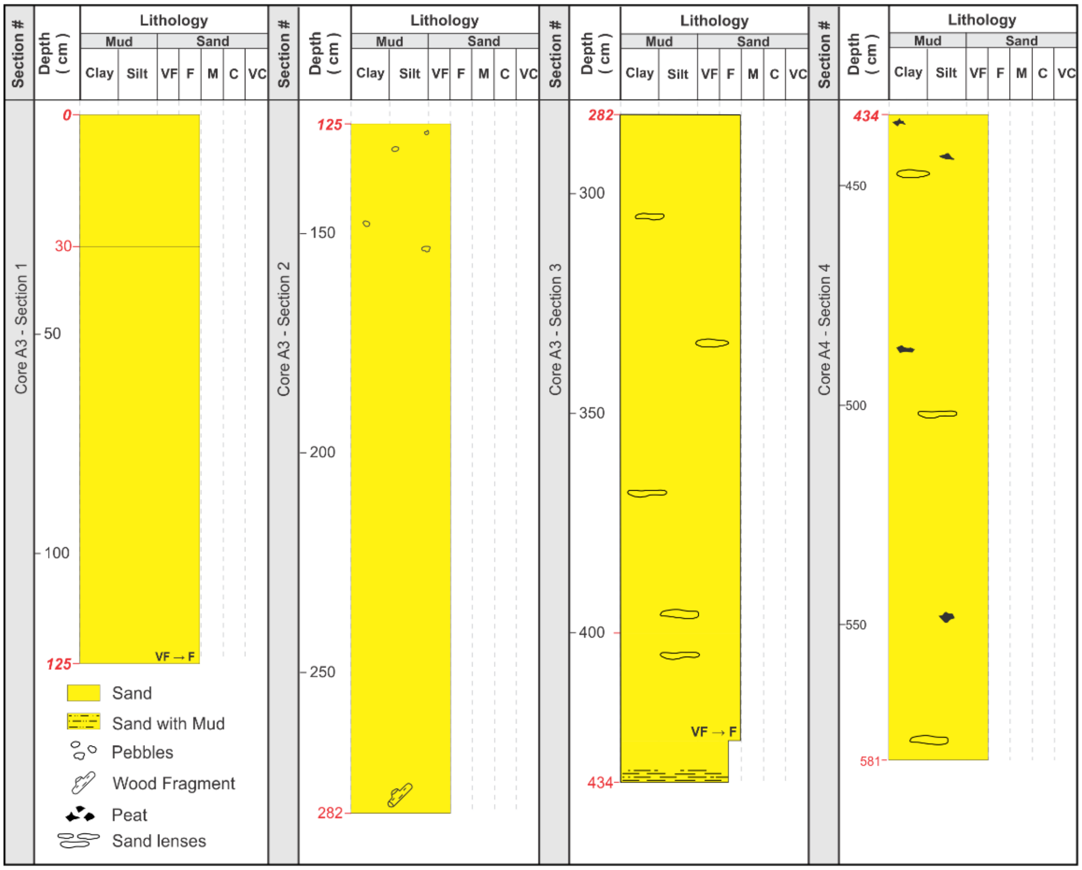


Figure 14. Log for vibracore A3. The location of the core is given in Figure 10. A full description of the core is given Appendix 1.

Subbottom Seismics. The subbottom seismic profiles for the NSB (Figure 15) display moderate to intense, parallel to subparallel top reflectors with a mounding geometry (Figures 16 – 21). The overall feature appears to extend between two eroded drumlins. The base of the sand and fine gravel unit is defined by a hard reflector that is interpreted as an unconformity eroded into mud rich sediments. At the ends of the NSB are very dark reflectors likely composed of coarse gravels and are interpreted as the base of eroded drumlins (see cross-section A – A' on Figure 15 and Figure 21).

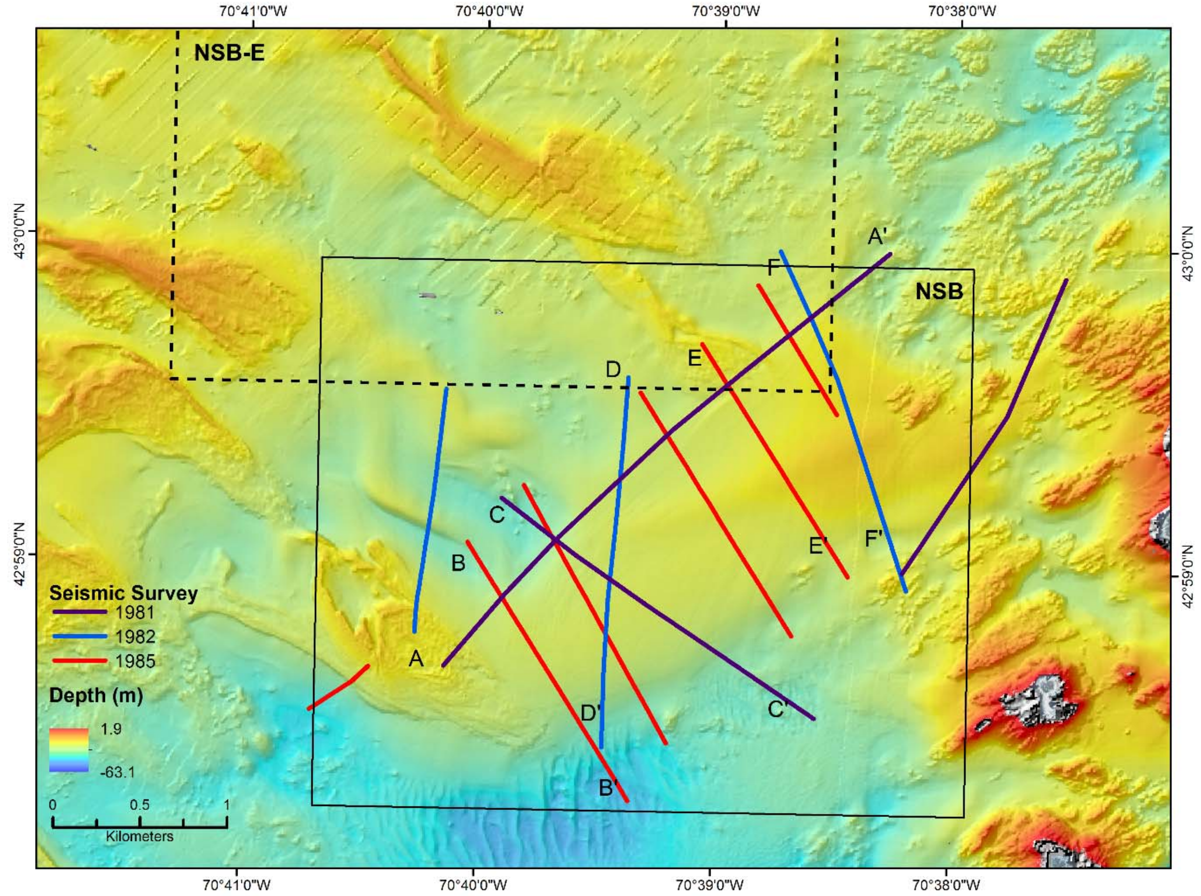


Figure 15. Location of shiptracks on the NSB for subbottom seismics profiles. Labelled shiptracks correspond to seismic profiles discussed in the text show in Figures 16 to 21).

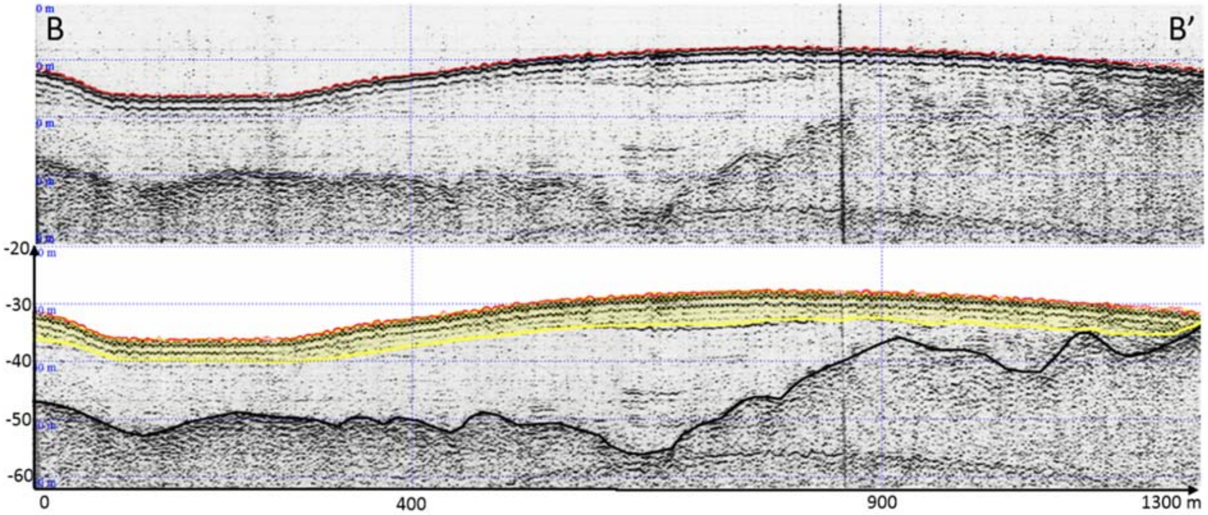


Figure 16. Subbottom seismic profile for line B – B'. See Figure 15 for the location. Vertical exaggeration is 20x. Depth is meters below sea level. Yellow outlines interpreted sand deposit. Blackline is top of bedrock.

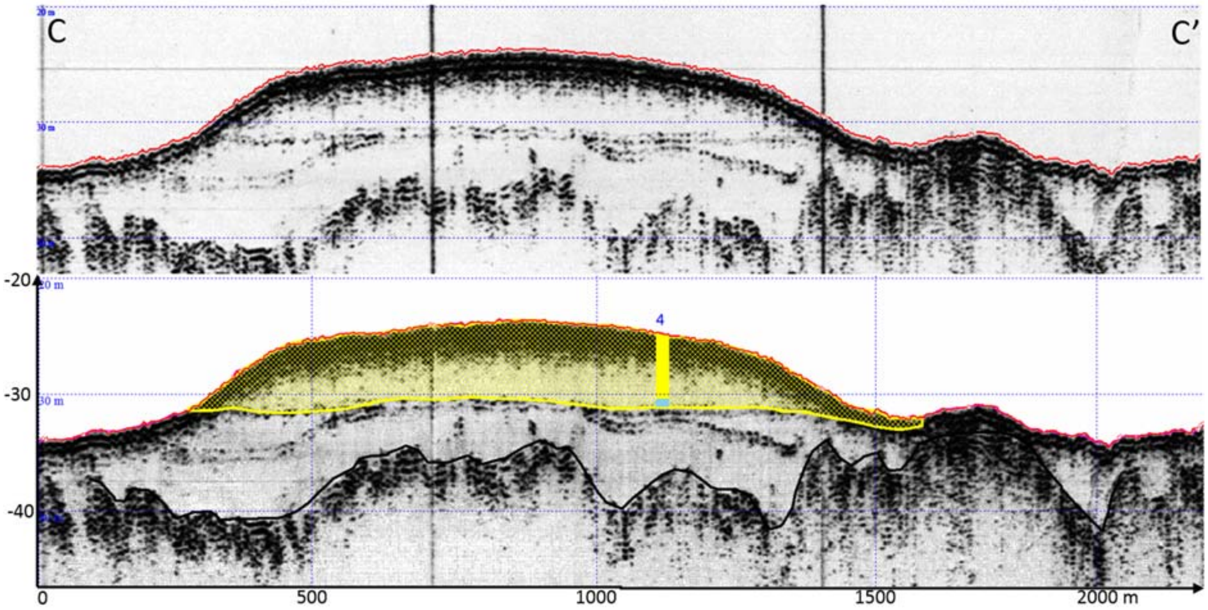


Figure 17. Subbottom seismic profile for line C – C'. See Figure 15 for the location. Vertical exaggeration is 20x. Depth is meters below sea level. Yellow outlines interpreted sand deposit. Blackline is top of bedrock. Note location of vibracore UNH 4 near the middle of the lower profile which penetrates the entire sand sequence and the underlying muddy sediments (glacial marine sediments).

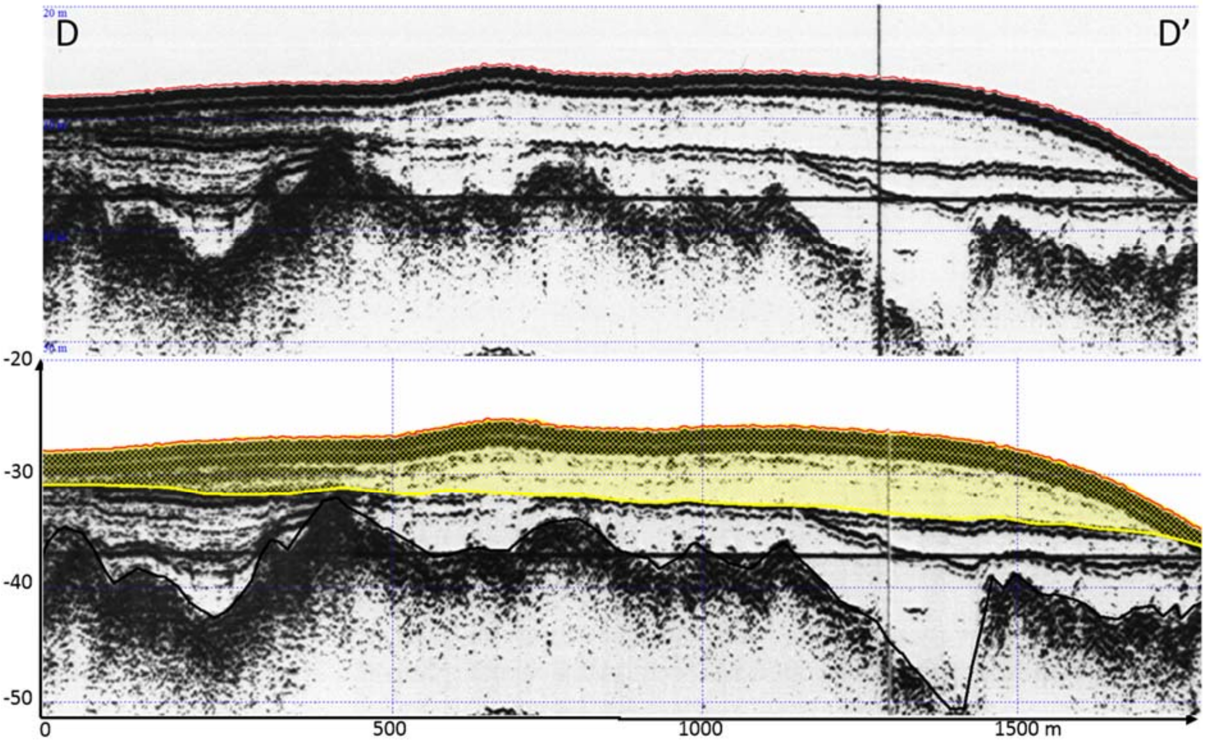


Figure 18. Subbottom seismic profile for line D – D'. See Figure 15 for the location. Vertical exaggeration is 20x. Depth is meters below sea level. Yellow outlines interpreted sand deposit

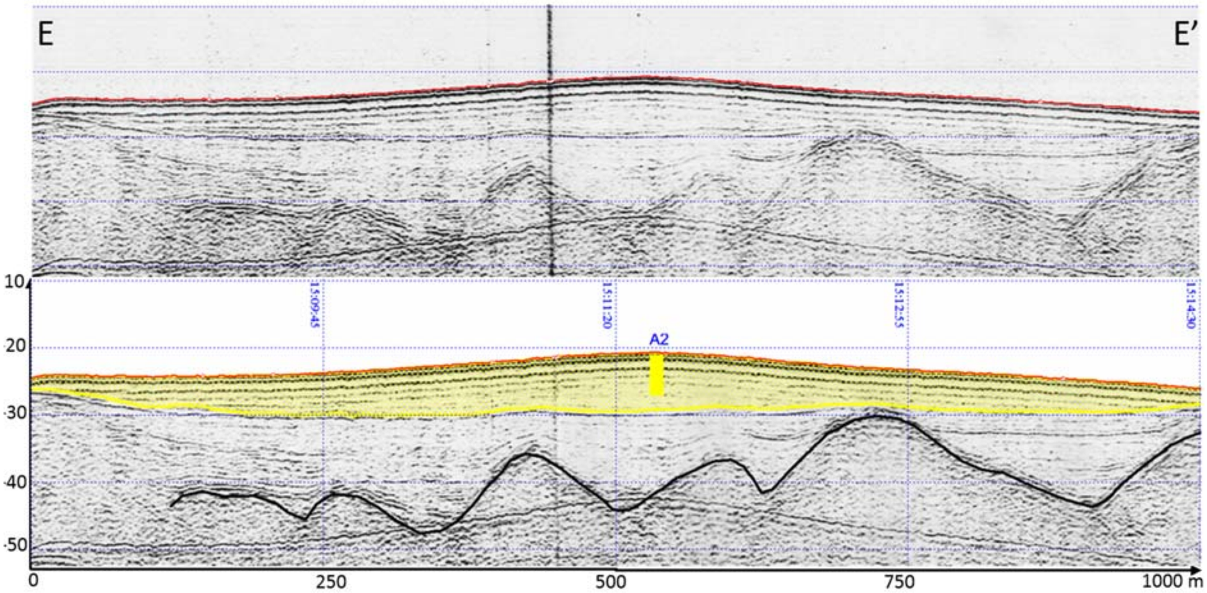


Figure 19. Subbottom seismic profile for line E – E'. See Figure 15 for the location. Vertical exaggeration is 20x. Depth is meters below sea level. Yellow outlines interpreted sand deposit. Blackline is top of bedrock. Note vibracore A2 near center of lower profile which is confined to the upper sand body.

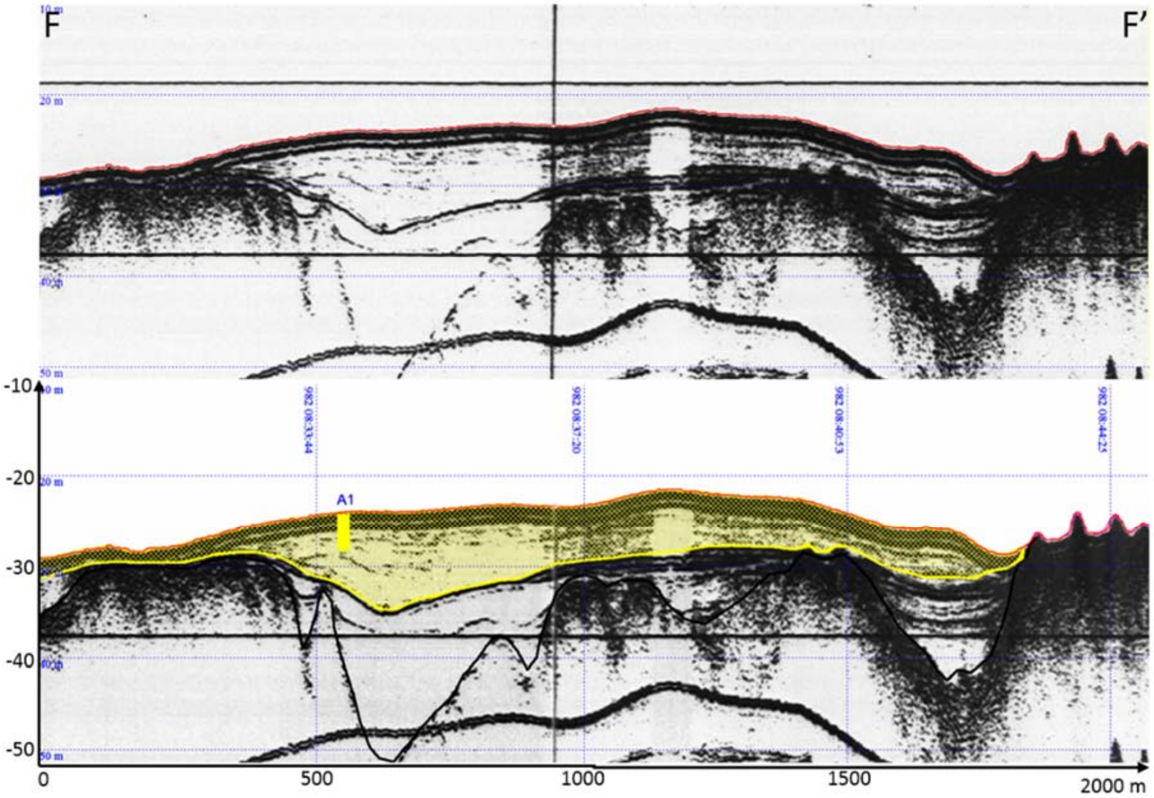


Figure 20. Subbottom seismic profile for line F– F'. See Figure 15 for location. Vertical exaggeration is 20x. Depth is meters below sea level. Yellow outlines interpreted sand deposit. Note vibracore A1 on lower profile is confined to the upper sand body. The vibracore is described in Figure 13 and Appendix 1.

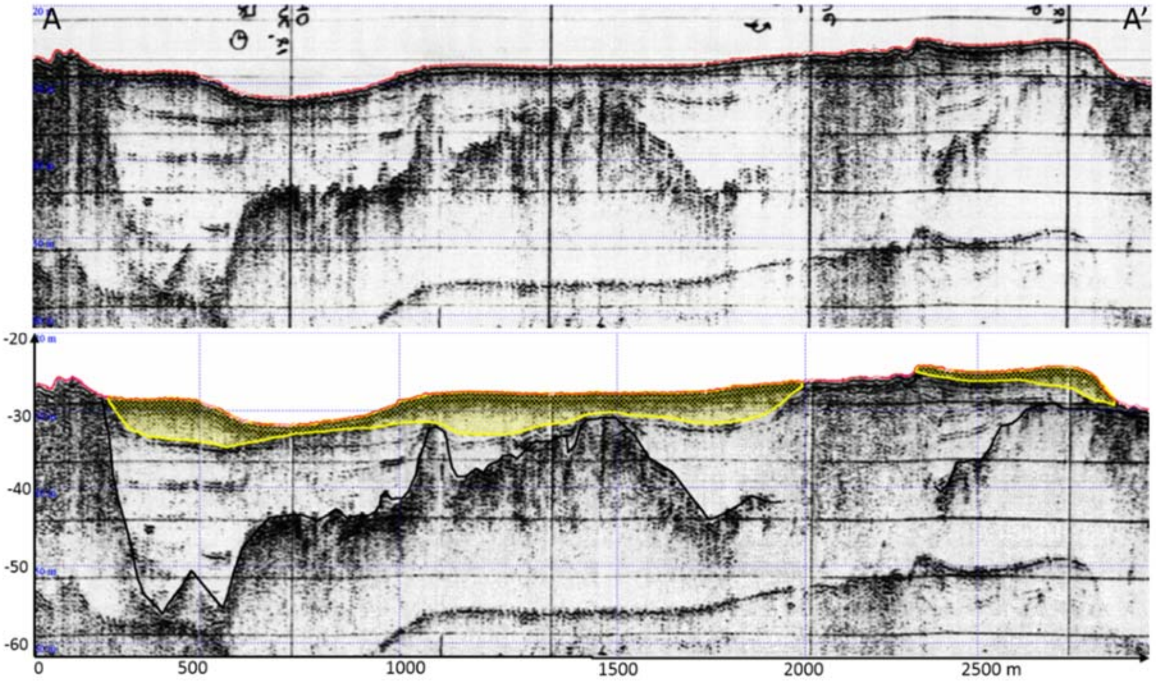


Figure 21. Subbottom seismic profile for line A - A'. See Figure 15 for the location. Vertical exaggeration is 20x. Depth is meters below sea level. Yellow outlines interpreted sand deposit.

Potential Sand and Gravel Thickness and Isopach Maps. The sand and gravel thickness and the isopach maps for the NSB shows the thickest deposits occur at the northeastern end and along the axis of the feature (Figure 22 and 23). The lines showing the sediment thickness (Figure 22) correspond to the interpolated thickness values along each subbottom seismic profile line. The thickness values are restricted to a 250 m buffer with no merging across lines.

In order to develop an isopach map of the NSB, an artificial boundary was placed around the feature near where the sand lense pinches out as identified by the seismics profiles and the development of the sand and fine gravel thickness map. The sand and gravel isopach map uses a spline interpolation between sand and fine gravel thickness values within a defined boundary and develops a gridded surface (Figure 23). The procedure is explained in more detail in the section titled "Development of Sand and Fine Gravel Thickness Maps, Isopach Maps, and Estimating Sediment Volume".

Calculation of Potential Volume of Sand and Gravel Deposits in the NSB. The volume of sediment in the NSB that was interpreted as sand and fine gravel was computed using the isopach map and the Surface Volume tool in the 3D Analyst toolbox in ArcGIS (explained previously in "Development of Sand and Fine Gravel Thickness Maps, Isopach Maps, and Estimating Sediment Volume "). Using this methodology, the volume of sediment was estimated to be on the order of 17.3 million m^3. This value agrees reasonable well with Birch (1984) who estimated the volume of sediment in this area (his boundaries are not clear) to be on the order of 25 million m^3. However, Birch was very vague about the actual value and the area that was included in this estimate.

It is important to note that in the estimate provided here simply represents the area above the seismic reflector interpreted as the base of a sand and gravel deposit. The gravity cores taken in the NSB show the sediments fine downward and increase in mud content with depth. In addition, the data on the composition is somewhat vague. Therefore, the volume is an estimate of area, not composition. Nevertheless, the results show that this site has potential as a significant sand and gravel deposit and warrants further seismic studies and vibracoring.

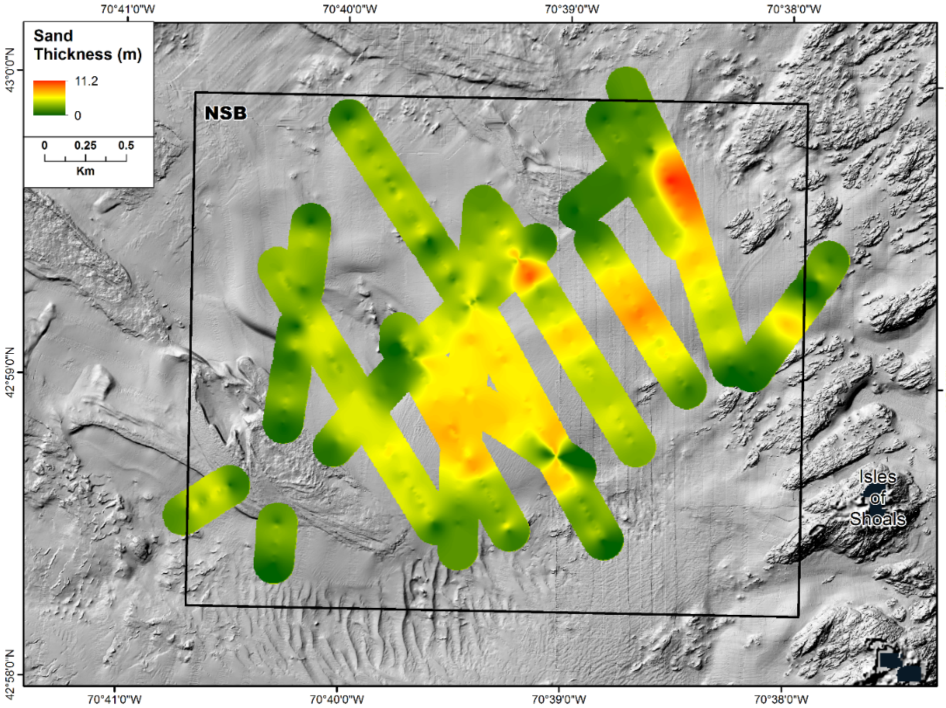


Figure 22. Sand thickness map of the Northern Sand Body. The interpolated surface was generated from the point thickness values using a radial buffer (250 m) to constrain the distance contoured.

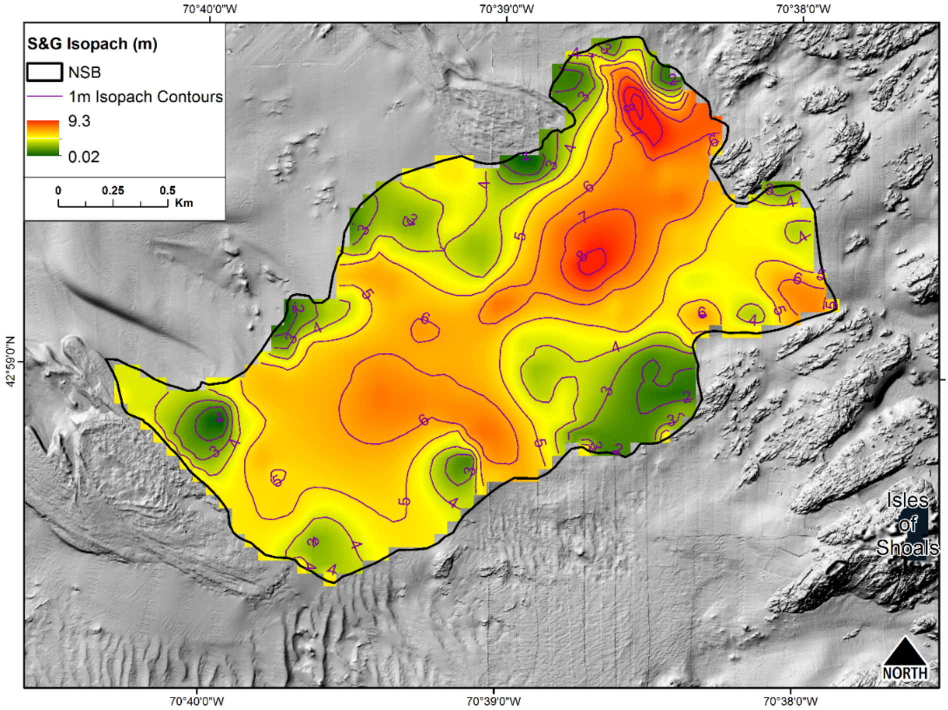


Figure 23. Isopach map of sand and fine gravel thickness for the Northern Sand Body. The contours are in 1 m increments. The interpolated surface was generated from point thickness values constrained to the geometry of a polygon feature.

Northern Sand Body Extension

Adjacent to the NSB are a number of sand and gravel deposits that are interpreted as marine modified glacial features and marine formed features or shoals. The geoform focused on in this study as being representative of these features extends ~4 km in length, ~0.5 km in width, and has ~10 m of positive relief above the surrounding seafloor at its highest point (Figure 24). The marine modified glacial features and associated marine formed features or shoals likely formed from the erosion of glacial geoforms such as drumlins or eskers and subsequent transport and deposition by marine process (after Carter and Orford, 1988). The glacial features, which are common on the NH shelf, were deposited during the last glacial maximum as ice advanced across the Gulf of Maine. After the retreat of the ice front as the glaciation ended, isostatic rebound caused a sea-level lowstand between 40 m to 55 m below present sea level (Belknap et al., 2002; Barnhardt et al., 2007) that was followed by a transgression. During the lowstand when the inner shelf was exposed and during the ensuing transgression, the glacial features were eroded leaving the coarsest sediments (coarse gravel) and distributing the finer sediments (mud to fine-gravels). The mud was transported offshore and deposited in deeper water or basins. The sand and fine gravel was deposited more locally to the glacial features and were shaped by marine processes (waves and currents). In addition, the glacial marine sediments (frequently sandy muds) deposited during the highstand that blanketed large areas of the NH shelf were exposed to marine processes during the lowstand and transgression and were likely eroded and winnowed. Again, the finer sediments moved offshore into deeper water and the sandier sediments were reworked into sand shoals by marine processes (Birch, 1984). Likely, a combination of both of these processes occurred resulting in coarse gravel deposits and sand and fine-gravel shoals and plains.

The marine modified glacial features and associated marine formed shoals are common in the NH and vicinity continental shelf. Therefore, future studies are needed fully evaluate their potential as sources of sand and gravel deposits.

Surficial Sediments. Based on CMECS, the sediments in the Northern Sand Body Extension and nearby geoforms are largely gravelly (likely gravelly sand) to gravel mixes (likely sandy gravel), with the exception of the roots or bases of eroded glacial features which are likely coarse gravel (Figure 25; Table 1). The surficial sediment samples taken in this area range from 0.3 to -1.8 phi or coarse sands to very coarse sand, with one granule gravel (8 total samples). Almost all of the samples are very poorly sorted. However, the coarser sediments would be harder to sample and are likely underrepresented.

Vibracores. Vibracores A4 and A5 (Figures 26 and 27; Appendix 1) are located on a marine formed shoal or feature (hypothesis) (Figure 25). Core A4 is ~5.75 m in length, but does not completely penetrate the sand sequence. The core is primarily composed of very coarse sand to gravelly sediments in the upper ~2.8 m, then slightly fines downward to medium and coarse sand at ~4.3 m. A sediment sample from ~0.3 m is 28% gravel and 70% sand. The gravel content decreases to 6% with 91% sand at ~2.2 m. At ~3.5 m the gravel and sand are 2% and 96%, respectively. A sandy mud lense occurs from ~4.3 to ~4.8 m. A sample from the mud lense at 4.7 m is 17% sand and 83% mud. Below the mud lense more sand is found that coarsens downward to a coarse to very coarse sand at the base of the core.

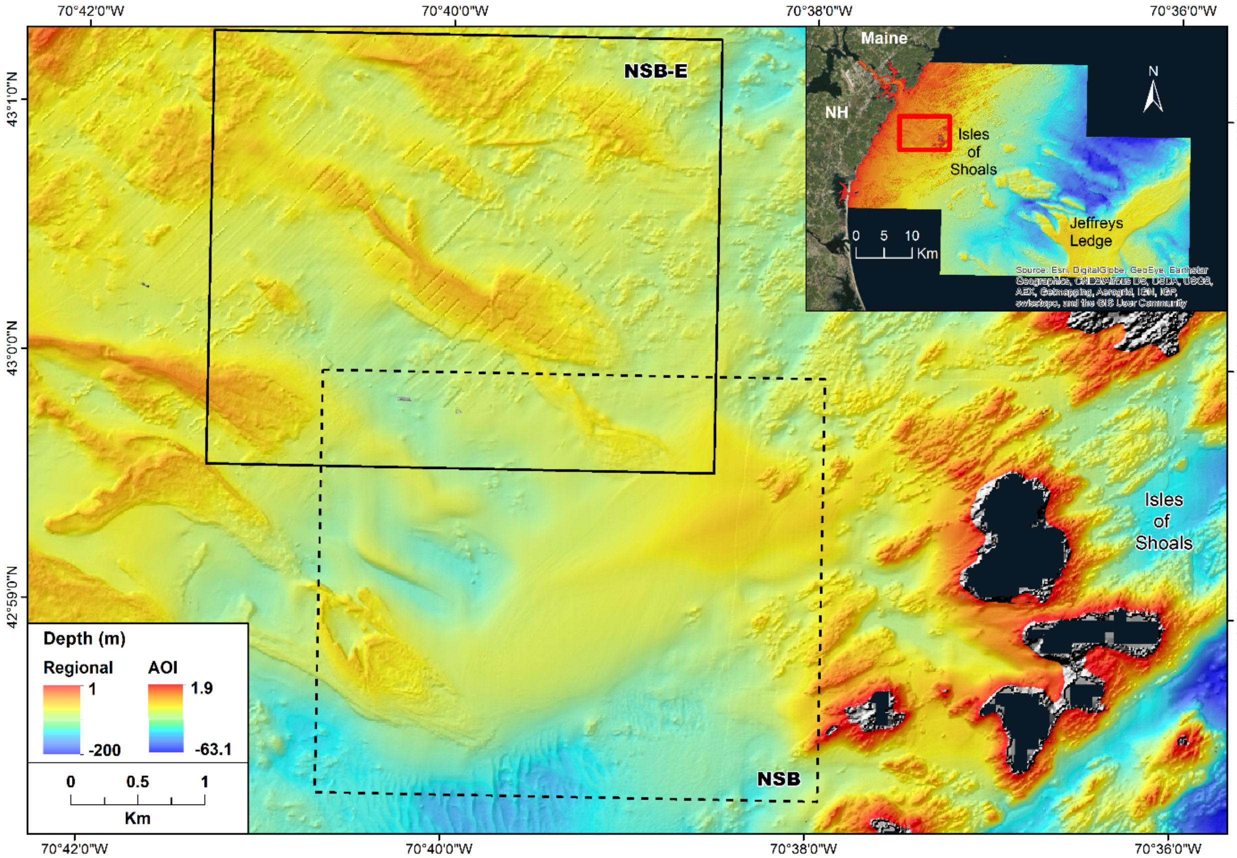


Figure 24. Location and bathymetry of Northern Sand Body Extension (NSB-E; outlined in solid black) on New Hampshire shelf (insert). AOI in legend is the depth scale for the body of the figure.

Core A5 is short (~3.4 m) and only samples the upper portion of the sand and gravel deposit. The upper 1.6 m is coarse to very coarse sand or granule with pebbles and cobbles. A sediment sample from ~0.5 m depth is 39% gravel with 56% sand. A sandy mud layer occurs from ~1.6 to 2.3 m. A sediment sample from 2.0 m is 33% sand and 67% mud. Below ~2.1 m, the sediments coarsen downward terminating in a fine to coarse sand. At ~3.0 m the gravel and sand contents are 2% and 90%, respectively.

Interestingly, both vibracores have a sandy mud lens in the middle of the core, although the layer is much deeper in A4 (~4.3 to 4.7 m) than in A5 (~1.6 to 2.1 m), separating coarser deposits. The origin of the sandy mud lense is not clear, but its characteristics are not unlike the glacial marine sandy muds associated with the highstand. However, its position within coarse sands and gravels complicate this interpretation.

Subbottom Seismics. The marine modified glacial feature is crossed by three subbottom seismic lines, one running perpendicular to the feature and two crossing obliquely (Figure 28). The cross-section profile confirms the sand and fine gravel body is relatively narrow (~0.5 km), but has over 10 m of positive relief (Figure 29). Most of the feature that is above the surrounding seafloor is composed of sand and fine gravel. The subbottom seismics profiles running obliquely along the

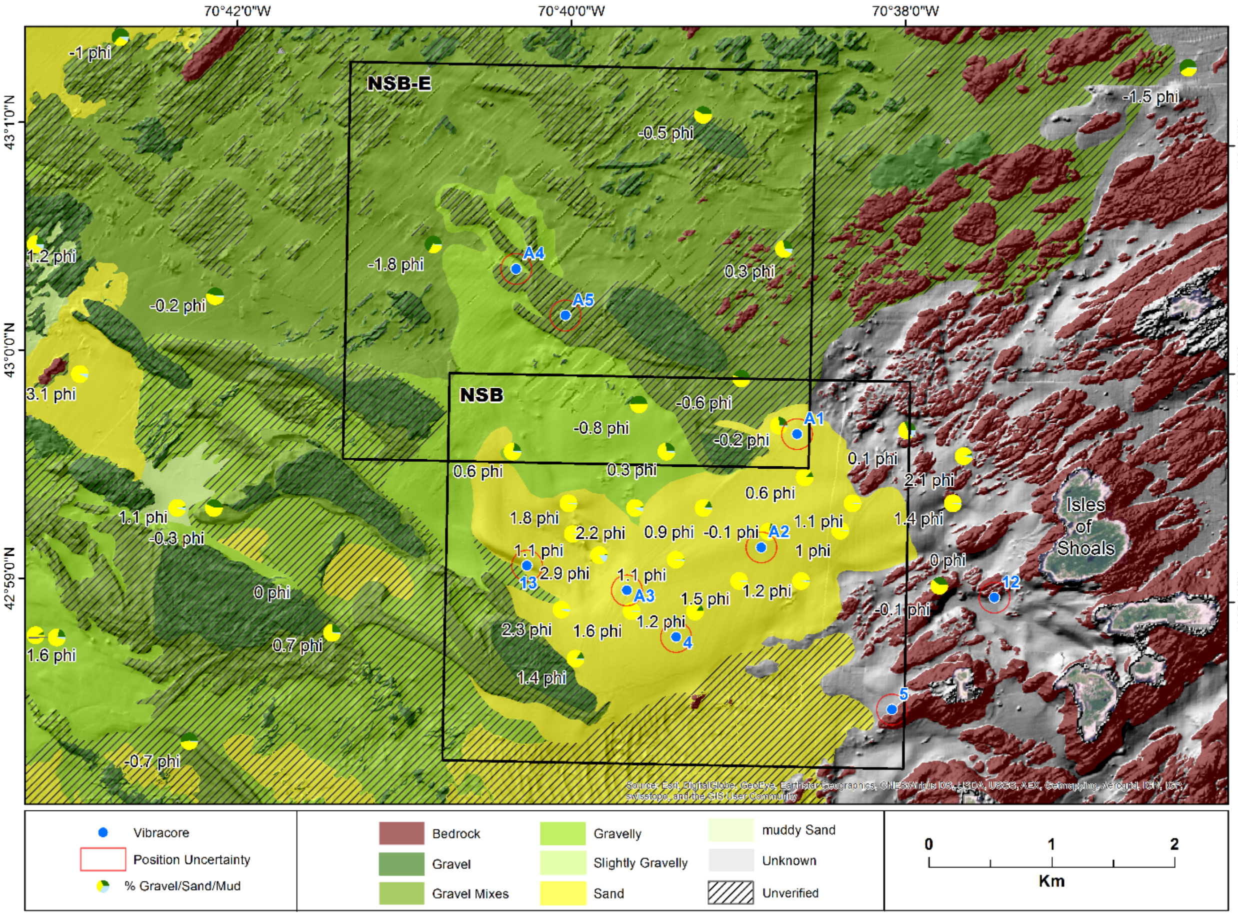


Figure 25. Surficial sediment map (CMECS), grain size data, and locations of vibracores for the Northern Sand Body Extension (upper black box). Pie charts show distribution of gravel, sand, and mud. Mean grain size given as phi units. The dark green, elongated features are likely the remnants of eroded glacial features and likely are composed of coarse gravels.

feature have less relief, but show the sand and fine gravel extend over the entire length, thickening at the axis (Figures 30 to 32).

Potential Sand and Fine Gravel Thickness Map. At present only three seismic lines cross the sand body which limits the potential for developing a fully integrated isopach map or a volume estimation (Figure 33). In addition, the sand thickness surfaces are restricted to a 250 m buffer along the shiptracks with no merging across lines. However, the existing seismic lines, along with the two vibracores, indicate the marine modified glacial features and associated marine formed shoals may contain significant sand and fine gravel deposits. The thickest deposit along the ridge of the feature is on the order of 8 m of sand and gravel. However, the rest of the sand thickness surfaces are much thinner. Thus, these features warrant further investigation, especially since there are a number of them on the NH and vicinity continental shelf.

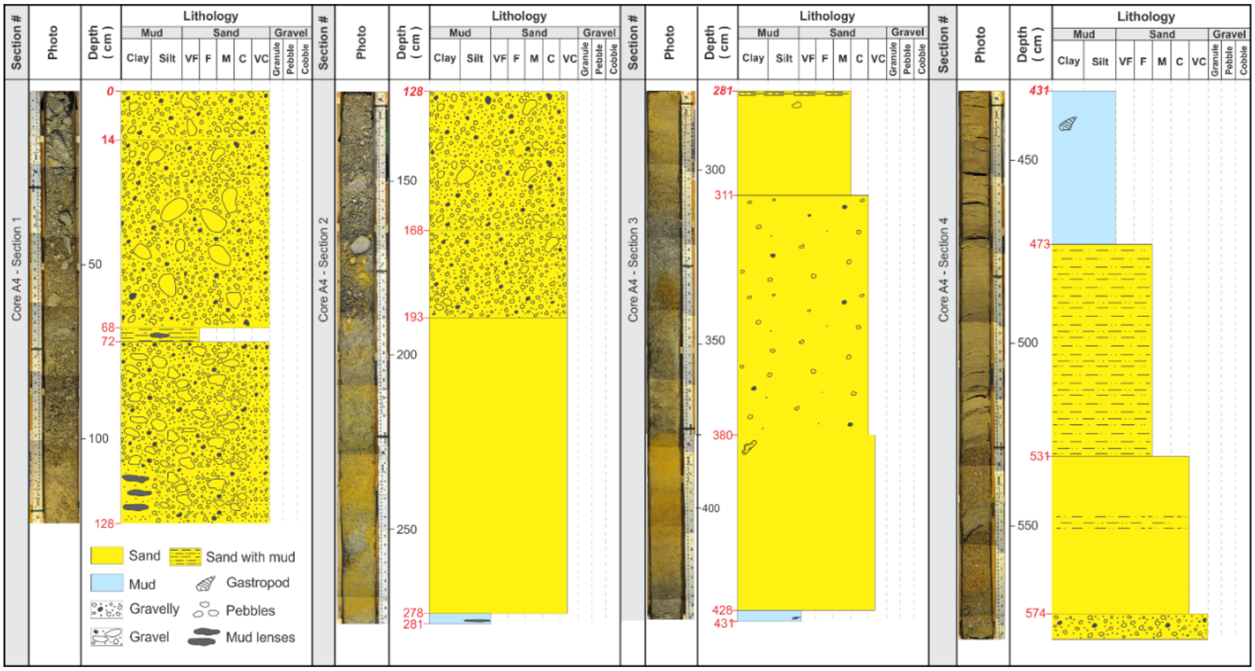


Figure 26. Log for vibracore A4. The location of the core is given in Figure 25. A full description of the core is given Appendix 1.

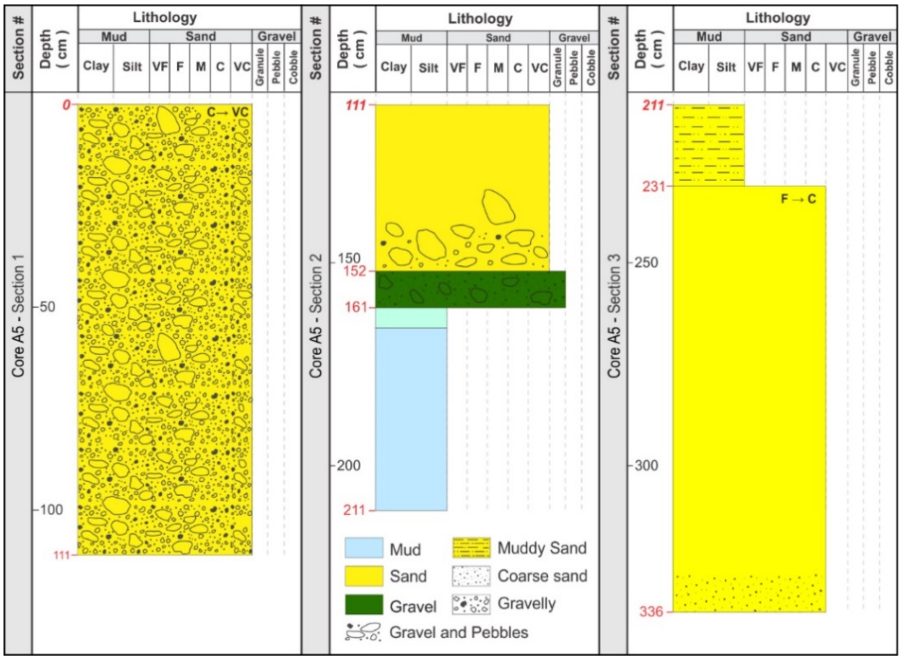


Figure 27. Log for vibracore A5. The location of the core is given in Figure 25. A full description of the core is given Appendix 1.

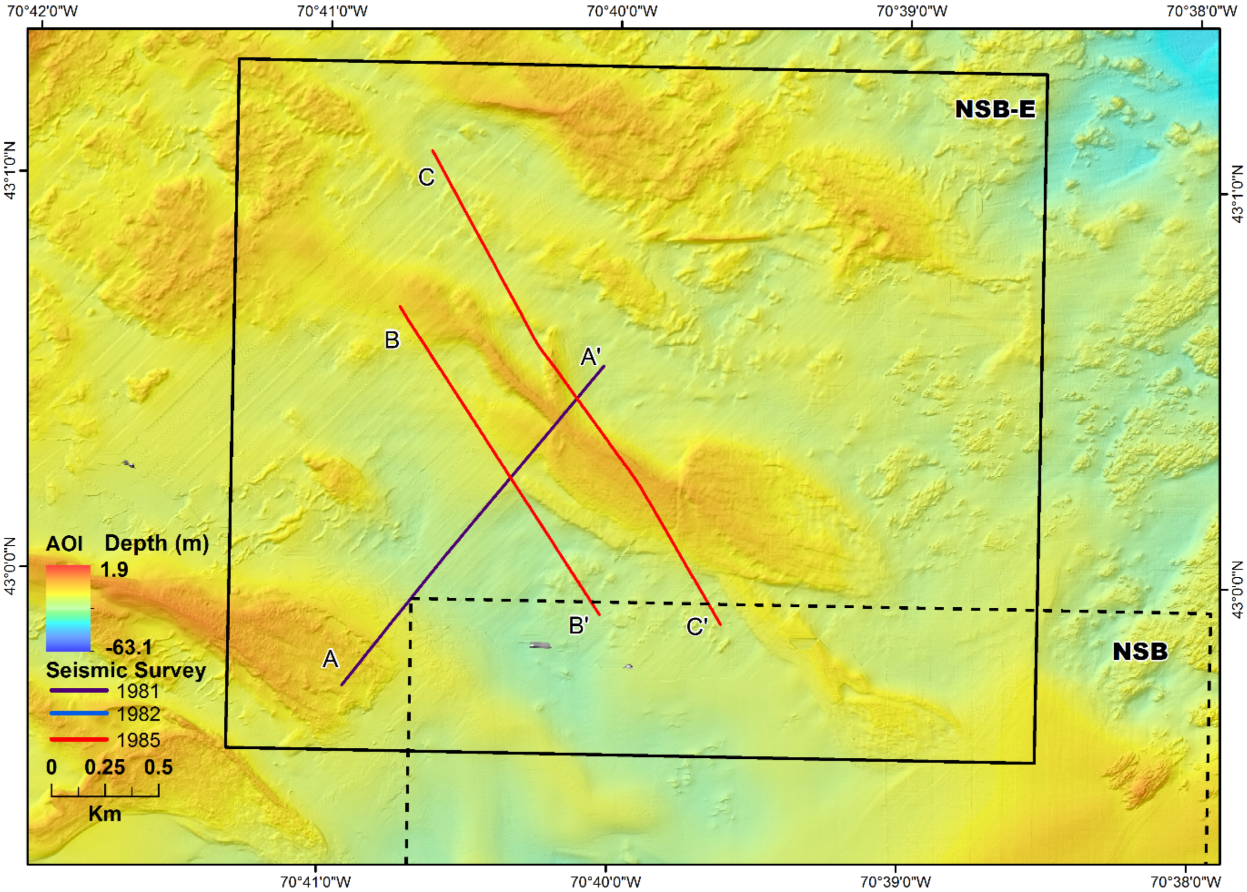


Figure 28 Location of shiptracks for the subbottom seismic profiles on the NSB-E shown in this report. AOI in legend is the depth scale for the body of the figure.

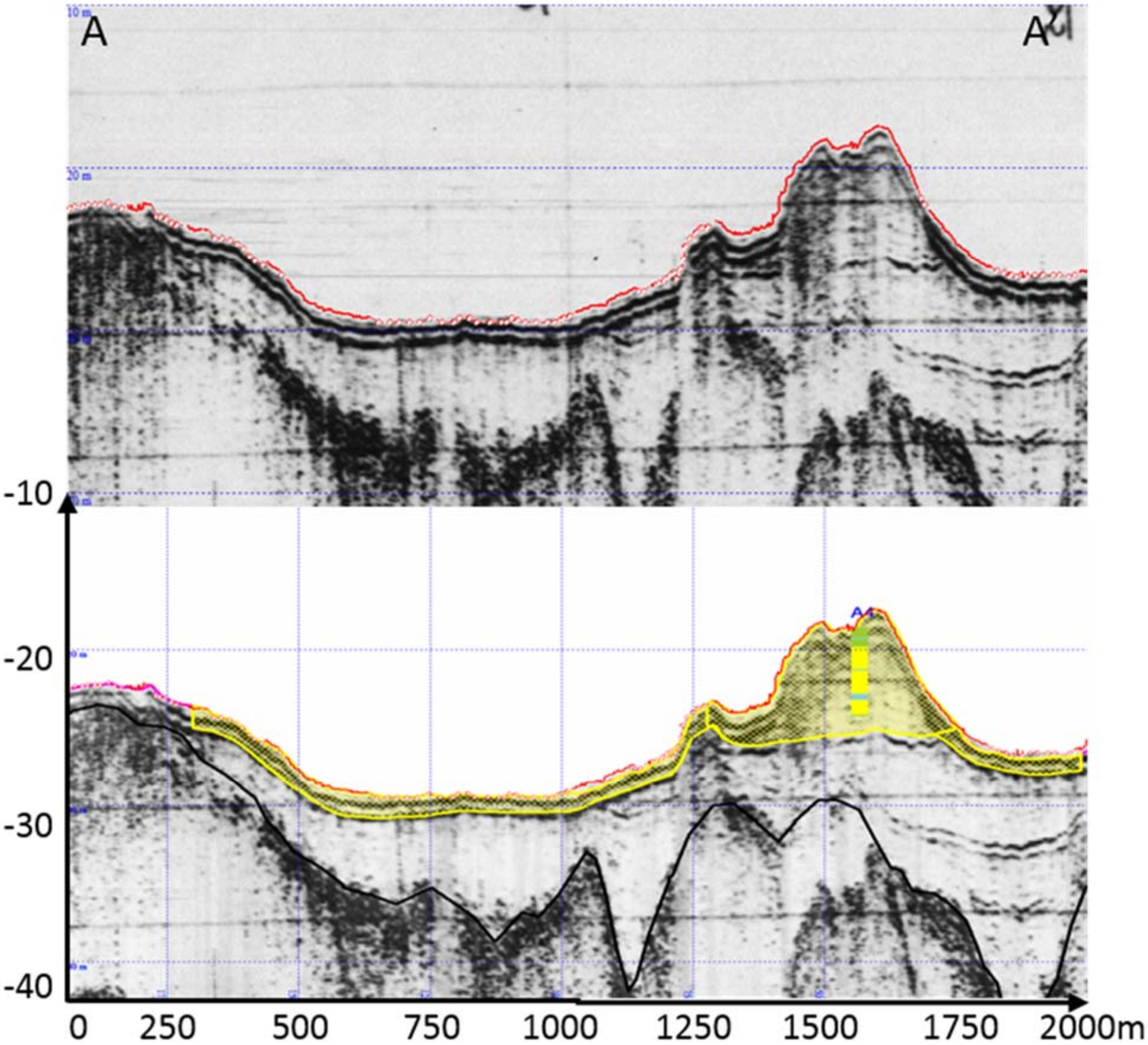


Figure 29. Subbottom seismic profile for line A– A'. See Figure 28 for location. Vertical exaggeration is 20x. Depth is meters below sea level. Yellow outlines interpreted sand deposit. Blackline is top of bedrock. Note vibracore A4 on lower profile. The vibracore is described in Figure 26 and Appendix 1.

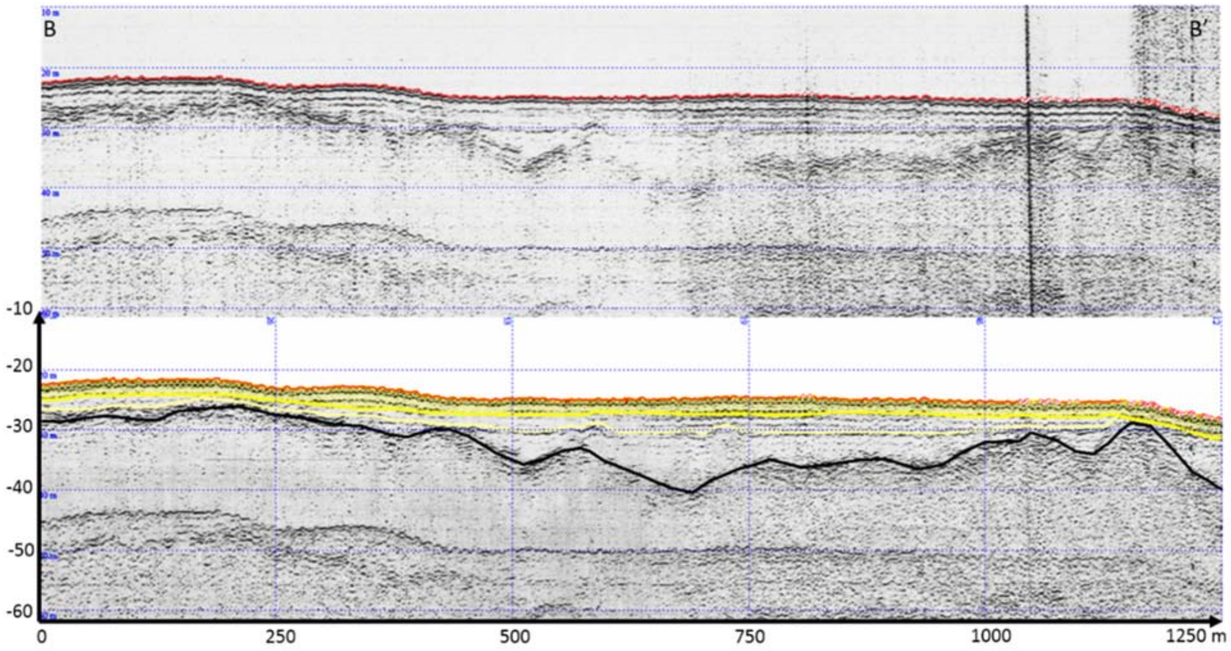


Figure 30. Subbottom seismic profile for line B – B'. See Figure 28 for location. Vertical exaggeration is 20x. Depth is meters below sea level. Yellow outlines interpreted sand deposit. Blackline is top of bedrock.

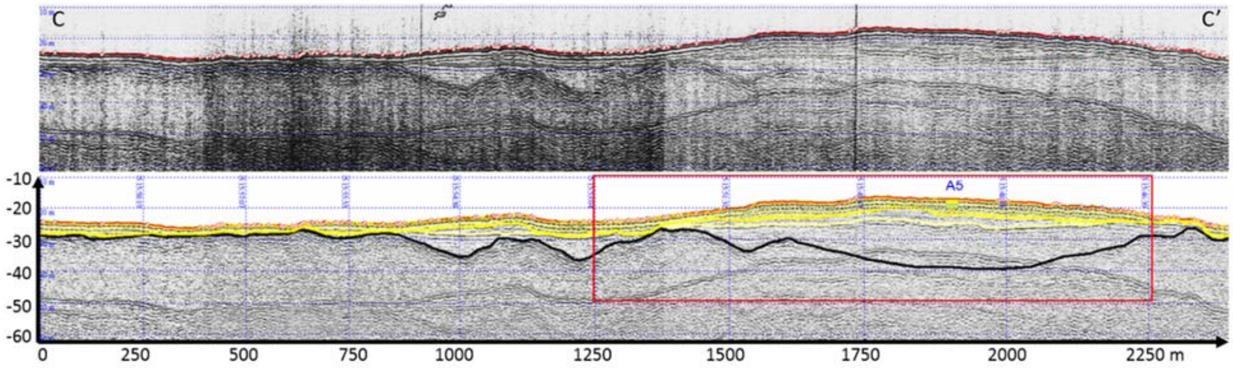


Figure 31. Subbottom seismic profile for line C – C'. See Figure 28 for location. Vertical exaggeration is 20x. Depth is meters below sea level. Yellow outlines interpreted sand deposit. Blackline is top of bedrock. Note vibracore A5 in lower figure. This area is enlarged in Figure 32.

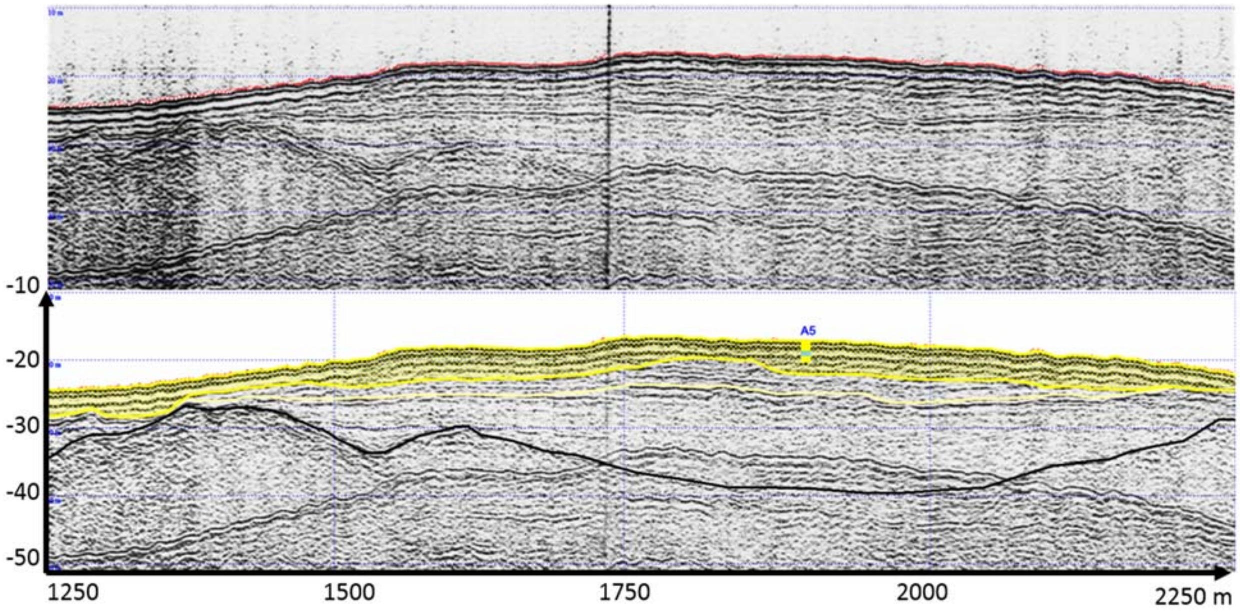


Figure 32. Enlargement of part of subbottom seismic profile C – C’ shown in Figure 31. Vertical exaggeration is 20x. Depth is meters below sea level. Yellow outlines interpreted sand deposit. Blackline is top of bedrock. Note vibracore A5 in lower figure (described in Figure 27 and Appendix 1).

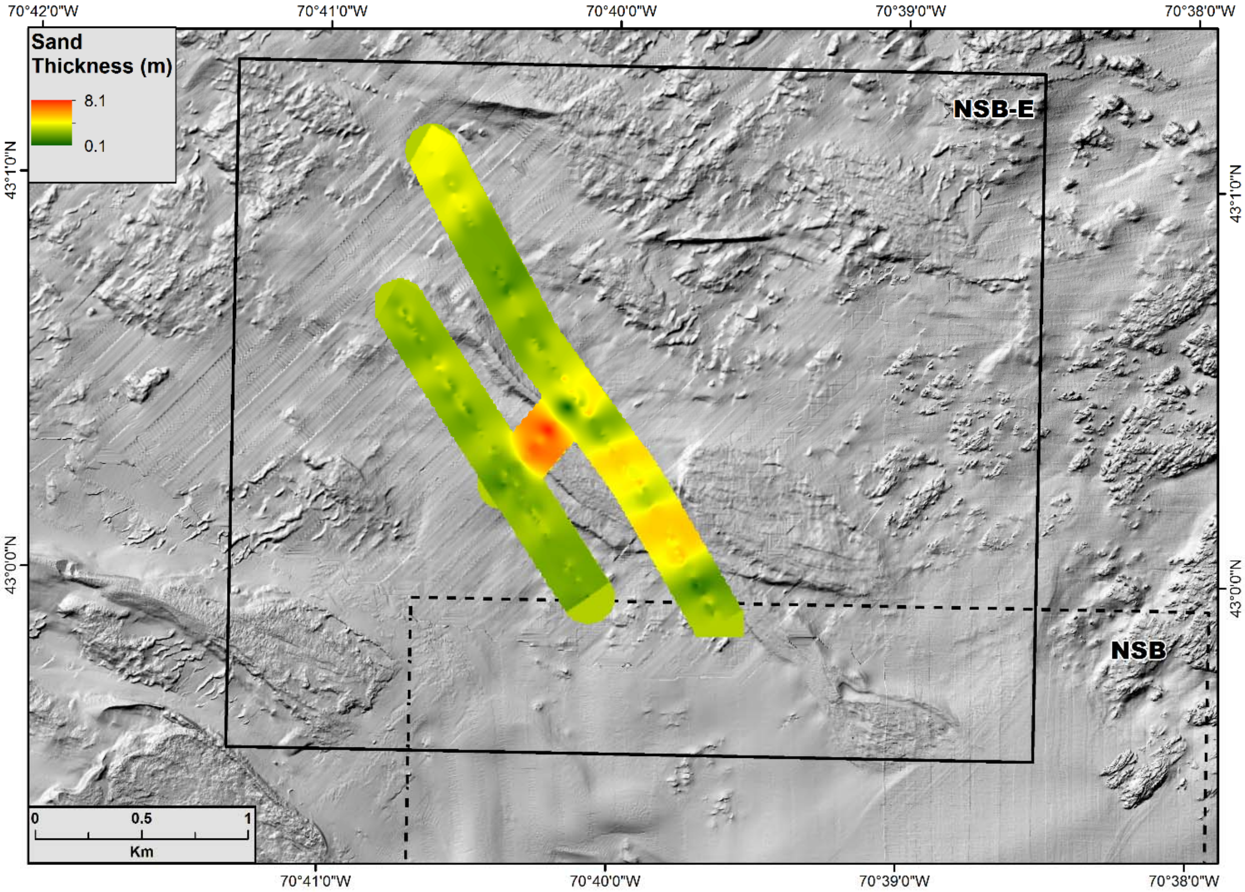
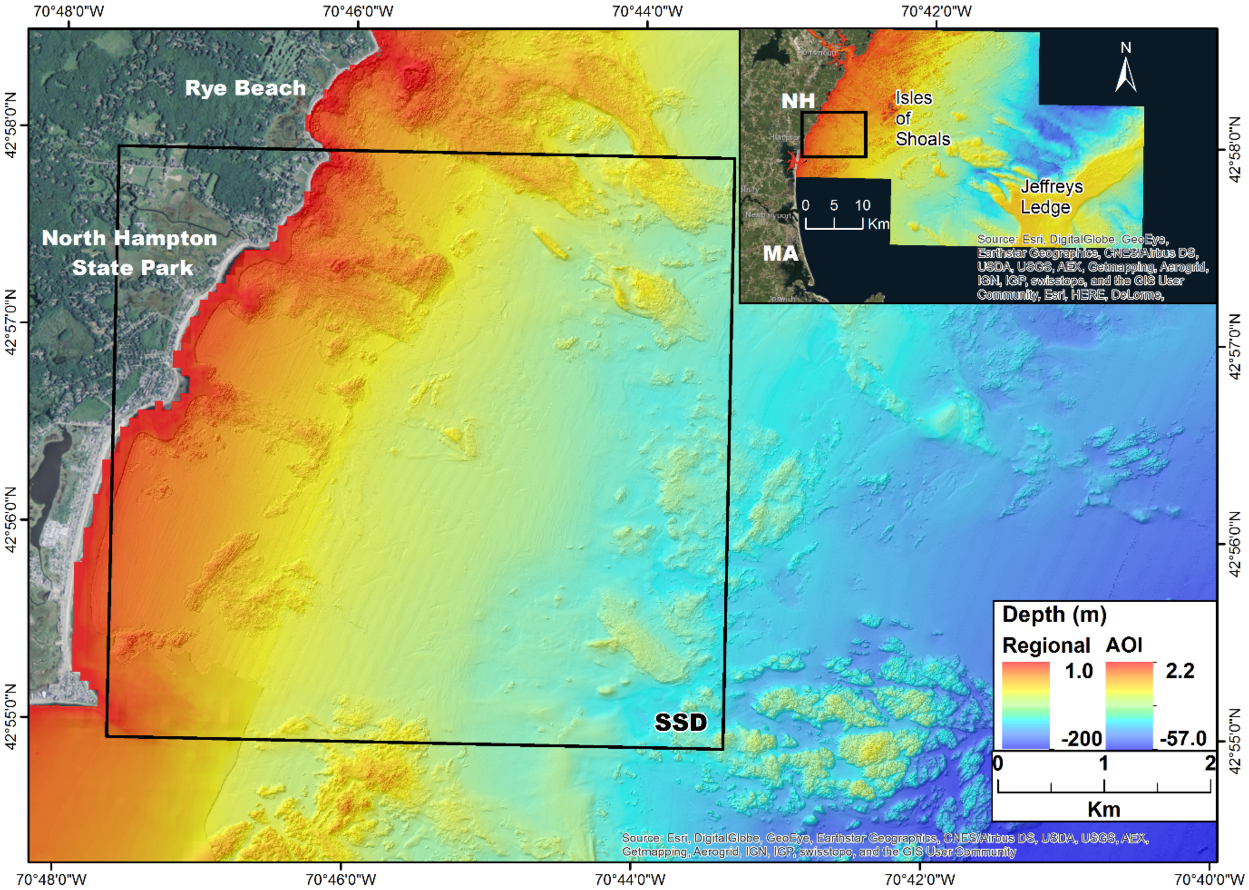


Figure 33. Sand thickness map of the Northern Sand Body Extension. The interpolated surface was generated from the point thickness values using a radial buffer (250 m) to constrain the distance.

Southern Sand Deposits

Much of the NH continental shelf is composed of outcropping bedrock and marine modified glacial deposits. However, along the southern portion of the New Hampshire inner shelf (Figures 1, 34 and 35), the seafloor is somewhat flatter and has relatively thick sediment deposits. Birch (1984; 1986b) mapped relatively thick sand and gravel deposits in this region (referred to as the Southern Sand Deposits or SSD in this report). Some of the sand deposits are related to the nearshore ramp of the nearby beaches. However, some of the sand and gravel deposits appear to be sheet sands or in shallow basins. The origin of these sand and fine gravel deposits needs to be addressed in future studies.

Surficial Sediments. The surficial sediment map using CMECS indicate the seafloor at the SSD is highly variable and includes some bedrock outcrops, gravel (likely eroded glacial deposits), gravel mixes (likely sandy gravel), gravelly (likely gravelly sand), slightly gravelly (slightly gravelly sand), and sand (Figure 35). The sand ranges from 2.2 to 3.0 phi, which is fine to very fine sand (Wentworth, 1922), with the sand closest to shore on the nearshore ramp the finest. There are fine to medium gravel around some of the eroded glacial features or bedrock.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community, Esri, HERE, DeLorme,

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 34. Location and bathymetry of Southern Sand Deposits (SSD; outlined in black line) on the New Hampshire shelf (insert). AOI in legend is the depth scale for the body of the figure.

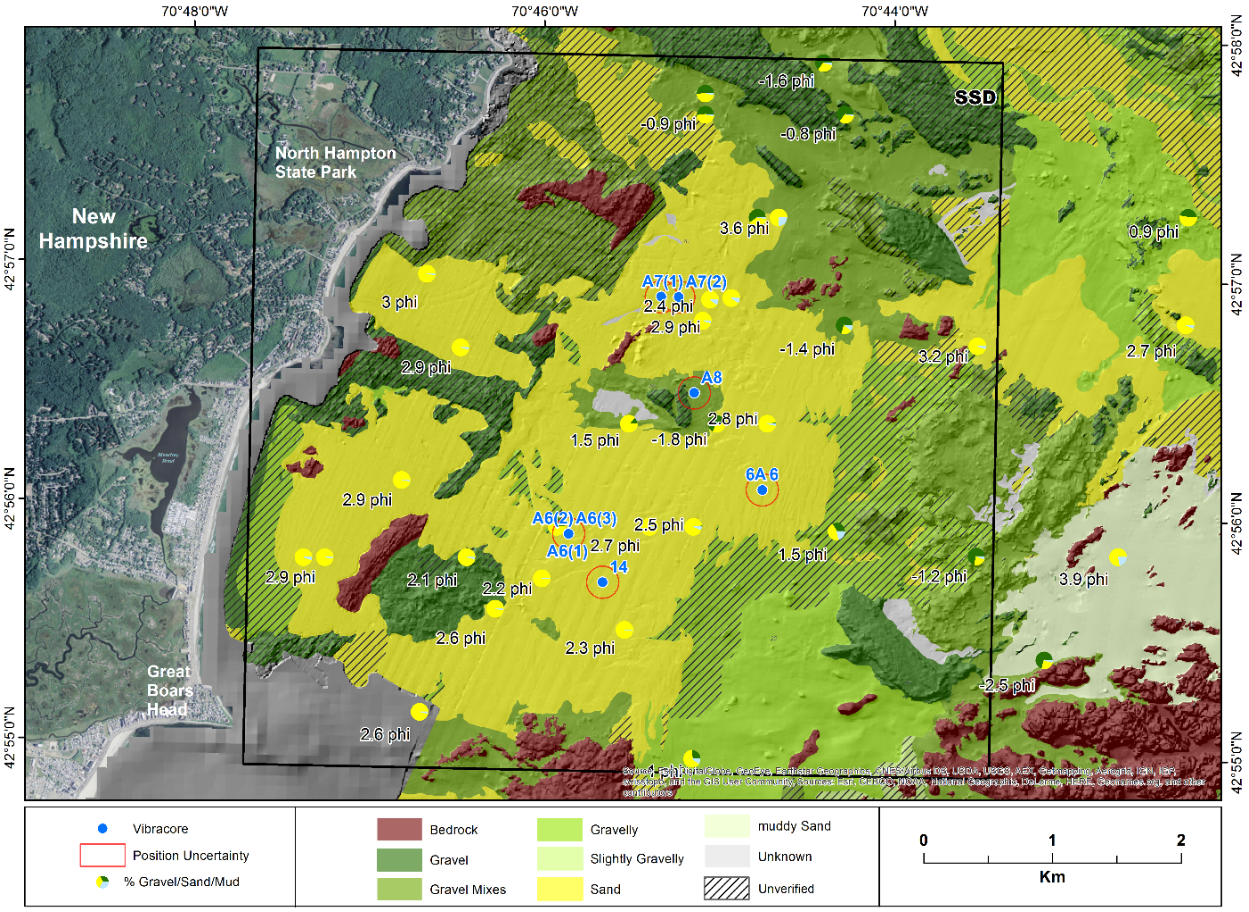


Figure 35. Surficial sediment map, grain size data, and locations of vibracores for the Southern Sand Deposits. Surficial sediment map based on the CMECS classification for Geologic Substrate Groups (FGDC, 2012). Pie charts show distribution of gravel, sand, and mud. The mean grain size is given as phi units.

Vibracores. Nine vibracores from 5 different locations (3 sites were cored multiple times) were collected in the SSD (Figure 35). The northern most vibracores from the SSD are relatively short, with A7(1) penetrating ~1.2 m and A7(2) penetrating ~2.0 m. Both are largely coarse to very coarse sand with a gravel lense and contain pebbles and some cobbles, which would explain the lack of penetration (Figure 36; Appendix 1). A sediment sample taken near the surface of A7(2) is 2% gravel, 93% sand, and 5% mud. A sample from ~0.9 m depth is 27% gravel and 71% sand. However, at the bottom of the core the gravel content is reduced to 16%, sand 72%, but the mud content has increased to 12%.

Vibracore A8, located about ~1 km south of the cores at A7, was taken adjacent to what is believed to be a marine modified glacial deposit. Similar to A7, the upper ~0.55 m is coarse to very coarse course sand with pebbles and a cobble (Figure 37; Appendix 1). A sediment sample from ~0.3 m was 16% gravel, 72% sand and 12% mud. Below ~0.55 m to the base of the core at ~4.0 m the sediments are mostly gravelly muddy sands with a high mud content, with the exception of a coarse sand layer with pebbles and cobbles from 0.95 to 1.05 m. A sediment sample taken at 0.6 m is 6% gravel, 49% sand, and 45% mud. Two samples taken much deeper in the core were similar. For example at 1.75 m the sample is 14% gravel, 45% sand, and 41% mud and at 3.95 m the sample is 8% gravel, 46% sand, and 46% mud. Also, the muddy sediment in the lower section has pebbles and some cobbles. The sequence strongly suggests a glacial origin or at least a significant contribution of sediment from a glacial deposit.

Vibracore UNH 6 and UNH 6A are located about ~2.2 km southeast of site A7 and in slightly deeper water (Figures 38 and 39; Appendix 1). Both UNH 6 am 6A are significantly longer than the previous cores (A7 and A8 sites) and each penetrate ~8.5 m. However, only the upper ~1.5 m in UNH 6 (Figure 38) and ~3.0 m in UNH 6A is sand (very fine to fine sand). And both have appreciable mud content. Samples taken at ~1.4 m and 2.4 m in core 6A are 94% sand and 6% mud and 93% sand and 7% mud, respectively. Below this depth, the sediments are muddy to the bottom of the cores. For example, a sample from 5.55 m depth in core 6A is 2% sand and 98% mud. Thus, the sand is confined to the surface, while the deeper depths are likely the fine-grained glacial marine sediments deposited during the highstand (Birch, 1984).

Vibracores at sites A6(1), A6(2), and A6(3) are located in the southern extent of the SSD and in slightly shallower water than site UNH 6 (Figure 35). Cores A6(1) and A6(2) are short, ~2.3 m and ~1.6 m, respectively, and are composed of fine to medium sand. The sand content from eight sediment samples taken from A6(1) and A6(2) exceed 93% and four are ~98%. Core A6(3) is longer (5.9 m) than A6(1) and A6(2), but only the upper ~3.9 m is sand (four sediment samples are ~99 % sand) (Figure 40: Appendix 1). Below 3.9 m the sediments are muddy with the mud content of two samples being 96% and 98%.

Vibracore UNH14, located close by site A6 (~0.6 km seaward and to the southeast), penetrated ~7.9 m (Figure 41). The upper ~0.6 m of the core is a fine sand which grades into more silty sediments from ~0.6 to ~1.4 m. The sediments transition back into very fine to fine sand from ~1.4 m to ~2.4 m. A sediment sample from 0.3 m (upper sand) is 93% sand and 7% mud. A sediment sample from the lower sand lense at 1.55 m is ~87% sand and 13% mud. Thus, the entire upper section is a silty to very fine muddy sand. Muddy sediments occur below ~2.4 m to the base the core. The mud contents of samples taken at 4.1 m, 5.3 m, and 7.3 m are ~97%, ~98%, 94%. Again, most likely the deposit is associated with the fine-grained glacial marine sediments associated with the highstand with the surface slightly winnowed.

Subbottom Seismics. There is a relatively large amount of subbottom seismics for the SSD that has varying degrees of quality. The figures presented in this report represent a subset of the seismics that show trends or were chosen because there were vibracores taken in the vicinity of the seismic profiles. As discussed in previous sections, the navigation for the seismics and the vibracore locations was based on Loran C, which has a large uncertainty in absolute position. As an estimate of the uncertainty, a 250 m buffer is placed around the shiptracks or station locations to indicate the potential uncertainty. Therefore, the placement of vibracores on subbottom seismic profiles are only estimates because of the uncertainty.

Seismic profile A – A’ extends in a north-south direction (Figure 42), starting with a rocky outcrop and ending in a hard bottom (Figure 43). Between the outcrop and the hard bottom, the upper 3 – 4 m of the seismic profile is interpreted as sand and/or fine gravel. This is confirmed by vibracores. The section has three vibracores, A7(1), A7(2), and A8. The vibracores at site A7 are

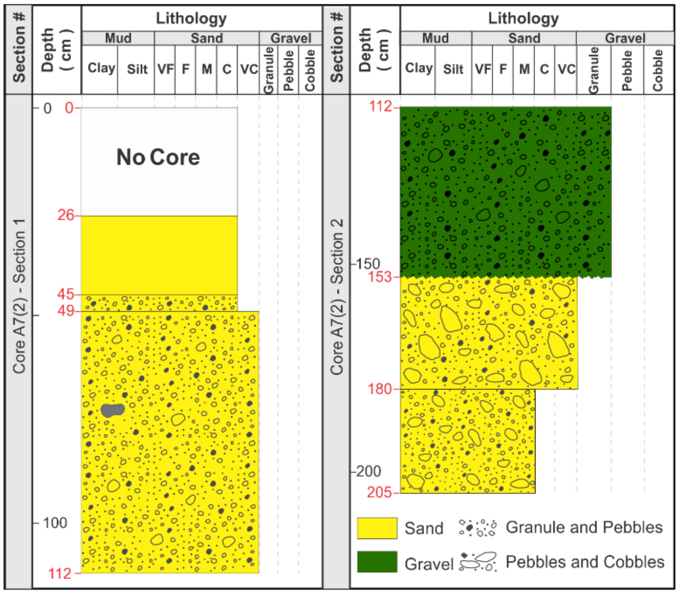


Figure 36. Log for vibracore A7(2). The location of the core is given in Figure 35. A full description of the core is given Appendix 1.

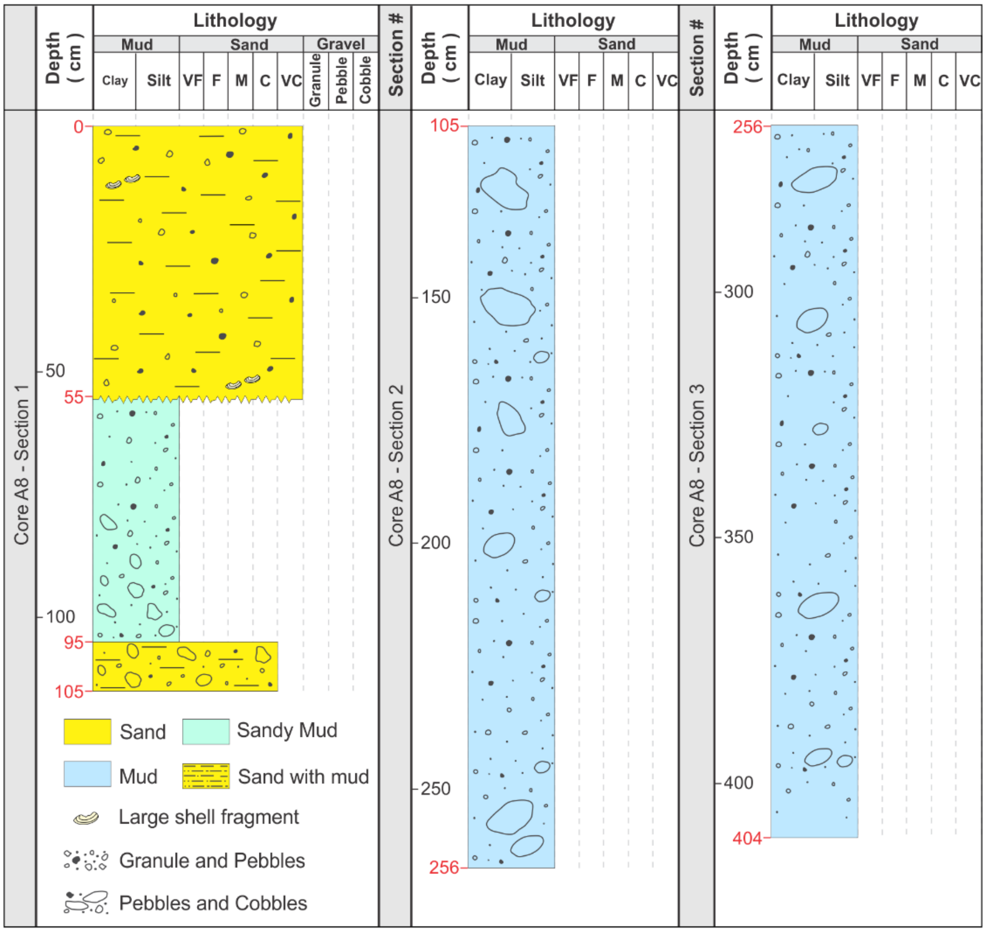


Figure 37. Log for vibracore A8. The location of the core is given in Figure 35. A full description of the core is given Appendix 1.

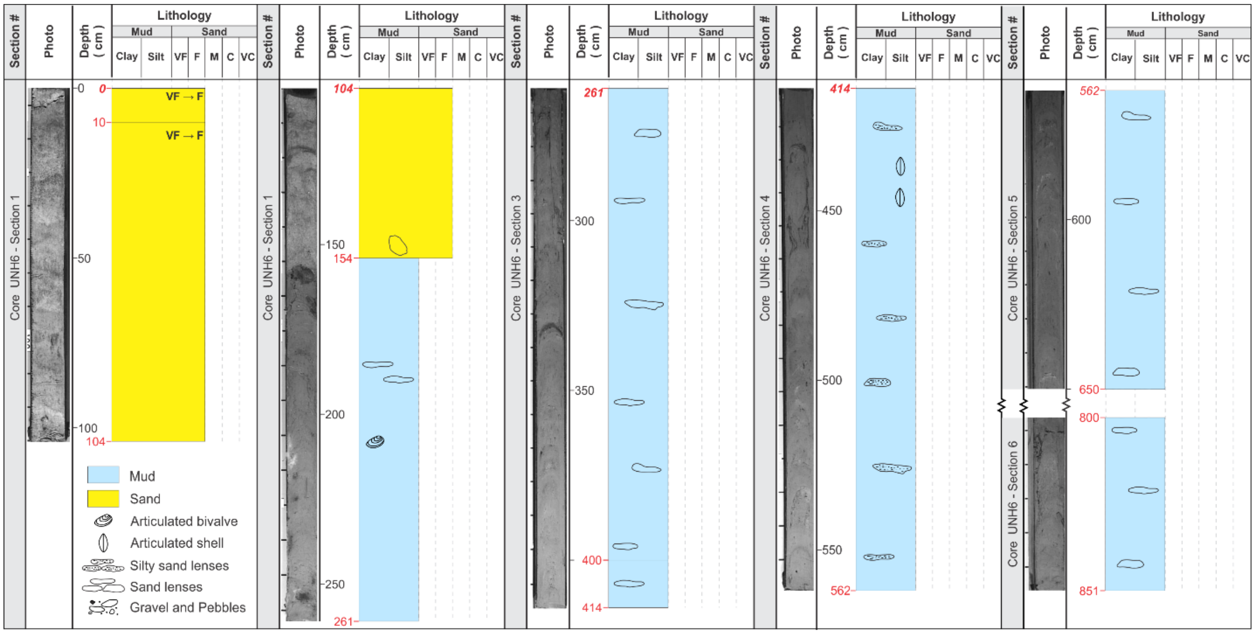


Figure 38. Log for vibracore UNH6. The location of the core is given in Figure 35. A full description of the core is given Appendix 1.

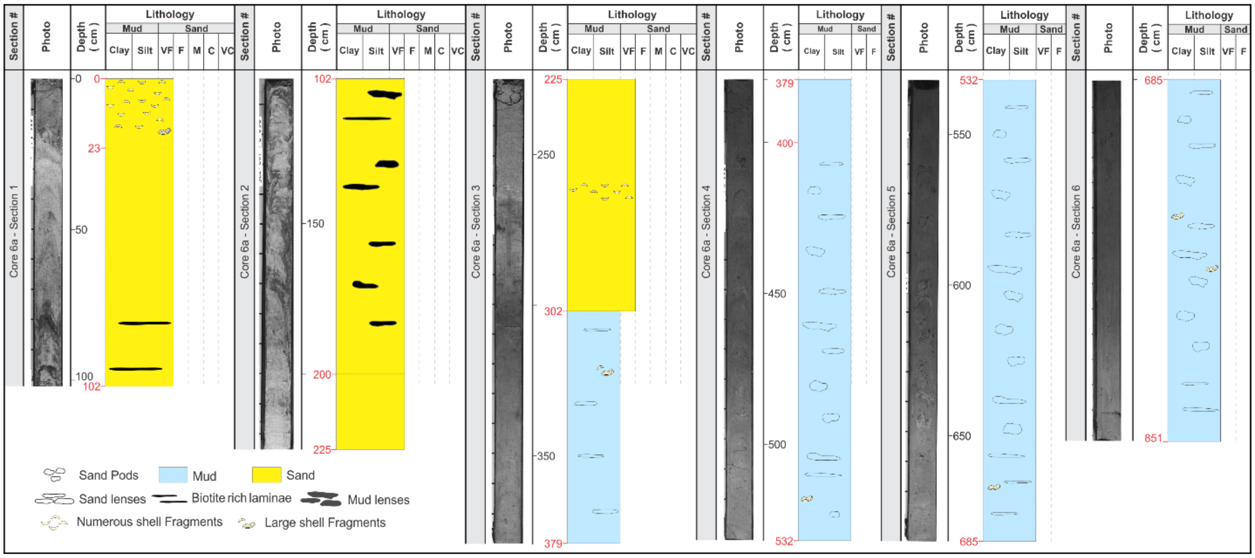


Figure 39. Log for vibracore UNH6A. The location of the core is given in Figure 35. A full description of the core is given Appendix 1.

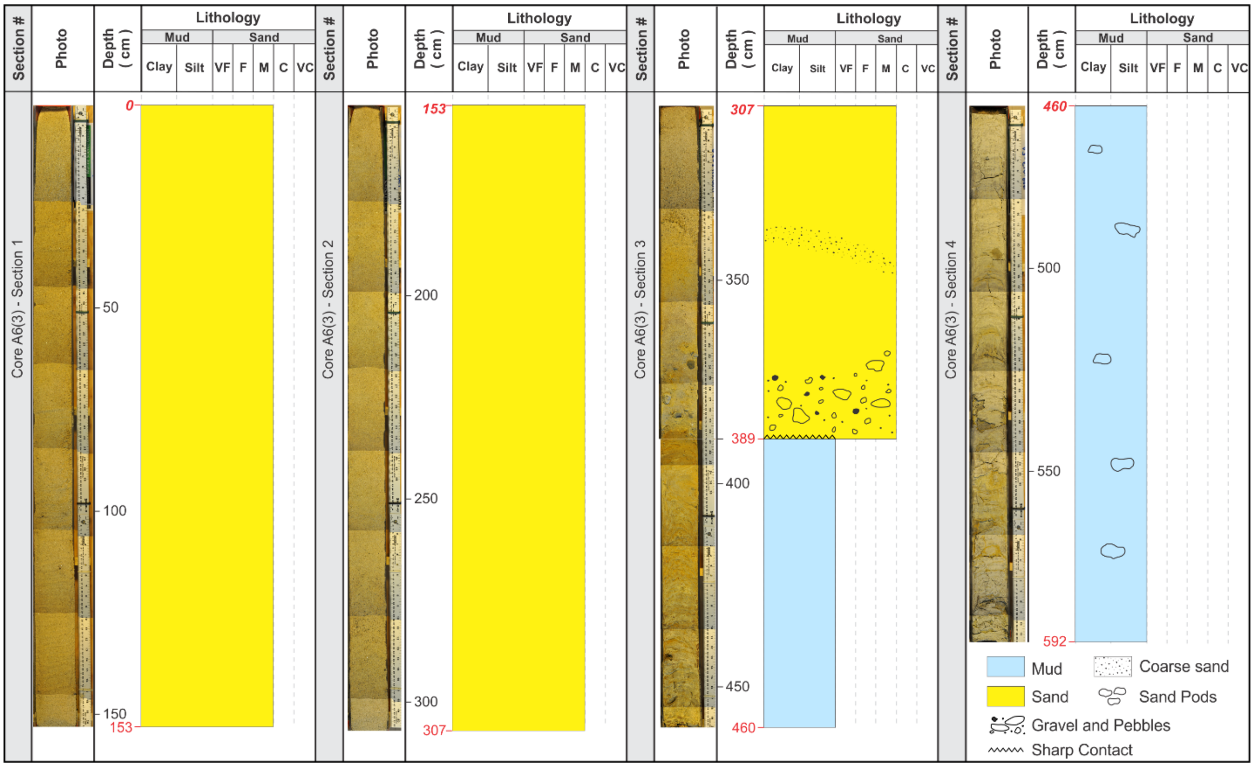


Figure 40. Log for vibracore A6(3). The location of the core is given in Figure 35. A full description of the core is given Appendix 1.

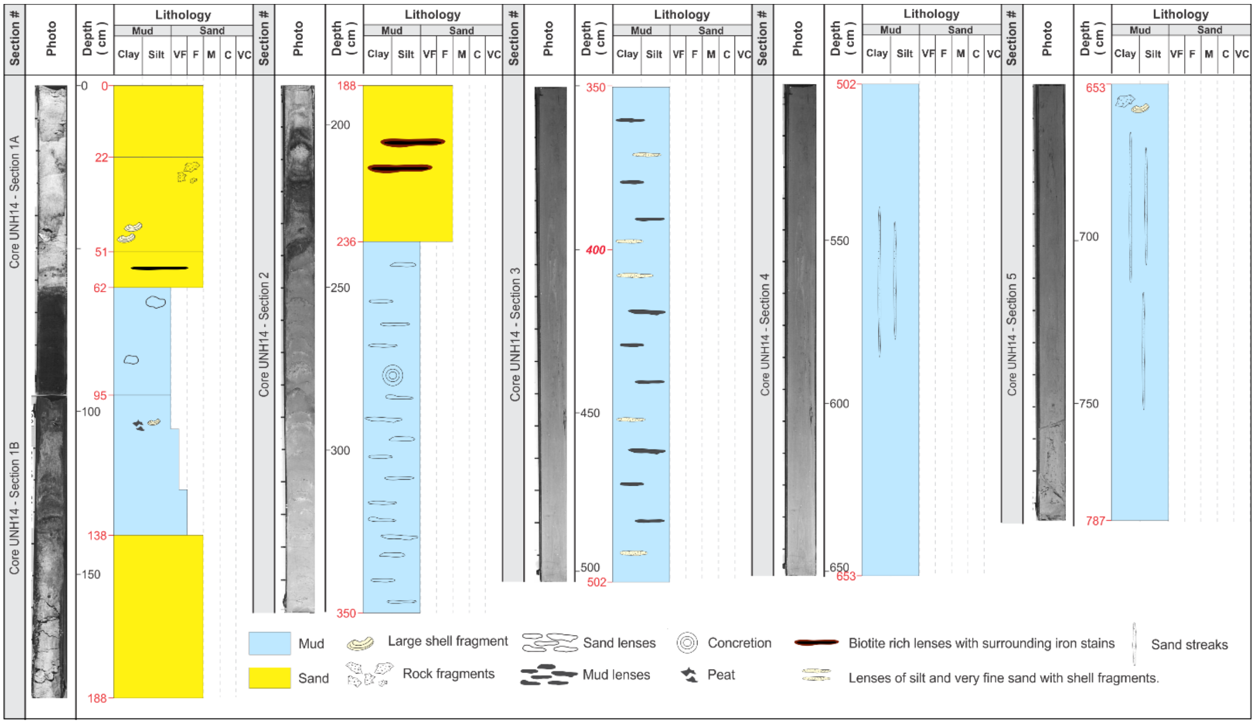


Figure 41. Log for vibracore UNH14. The location of the core is given in Figure 35. A full description of the core is given Appendix 1.

essentially at the same location, but were separated on the seismic profile for display purposes. Both are composed of medium to very coarse sand with gravel including pebbles and some cobbles. But both are very short and penetrate only ~2 m or less. Vibracore A8 is longer, but only the upper ~0.5 m is coarse to very coarse sand with gravel including pebbles and some cobbles. Below this the sediments are muddy to very fine sands. However, the mud contains pebbles and cobbles. It appears the sands and fine gravels are confined to the upper few meters. However, it also appears that about half the sediments below the surface lag deposit are sand. Based on the location of vibracore A8 adjacent to what is interpreted as a marine modified glacial feature and the composition of the core, it appears that the sediments in the area of the geoform are at least partially glacially derived.

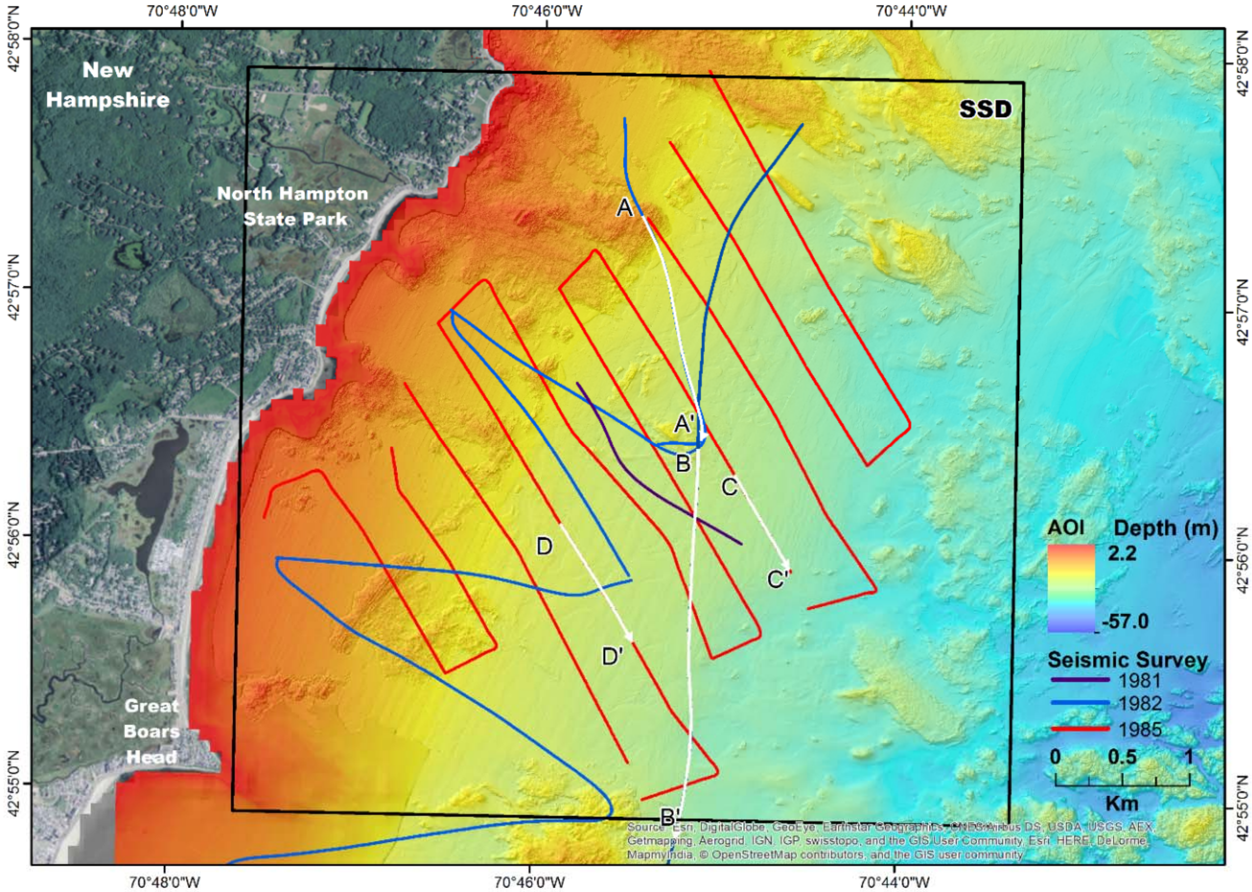
Seismic profile B – B' is essentially an extension of line A-A' (Figure 42). There are no vibracores on line B - B'. The seismic sequence looks similar to A – A' with the upper few meters being composed of sand and fine-gravel and underlain by glacial-marine sediments (Figure 44). Seismic profile C – C' is located seaward of A – A' and B – B' and extends southeastward towards deeper water (Figure 42). The subbottom profile has two vibracores located along its track (UNH 6 and UNH 6a) (Figure 45). Vibracore UNH 6A agrees reasonably well with the seismic interpretation for the sand thickness considering the positioning uncertainty. The vibracore indicates the upper ~3.1 m is very fine to fine sand and is underlain by muddier deposits. This is fairly consistent with the seismic profile. However, core UNH 6 shows less sand than the interpreted seismic line.

Seismic profile D – D' is oriented southeastward and is positioned in the lower portion of the SSD (Figure 42). There are 4 vibracores along this seismic line including three at site A6 (1, 2, and 3) and UNH 14. Cores A6(1) and A6(2) are short and are medium sand or a fine to medium sand. Core A6(3) has greater penetration with ~3.9 m of medium sand underlain by mud. These cores agree with the seismic interpretations of the sand layer (Figure 46). Core UNH 14 is ~7.9 m in length, with the upper ~2.4 m composed of very fine to fine sand; below ~2.4 m the sediments are muddy. The seismic interpretation indicates the sand lense is thicker, but does overlie muddy sediments. This discrepancy could be a function of positioning uncertainty.

Potential Sand and Gravel Thickness and Isopach Maps. The sand and fine gravel thickness map in the SSD reflect several patterns. Some of the thicker sand deposits are found landward in the SSD and are related to the nearshore ramps for the nearby beaches (Figure 47). Sand deposits on the order of 8 m are found in this region (maximum). The sand thickness map also shows relatively thick deposits of sand near the southern end and near the center of the SSD.

In order to develop isopach maps for the SSD, two areas were defined by artificial boundaries that were assumed to be dominantly sand (Figure 48). This was done to prevent the isopachs from crossing or including areas that were not sand and gravel that were between seismic lines (e.g., bedrock outcrops or glacial features). Also, the nearshore ramps were omitted due to lack of high-resolution seismic lines and the probability that this area would not be used as a source of sand and fine gravel for beach nourishment. Subsequently, the sand and gravel isopach maps were developed by a spline interpolation between sand and fine gravel thickness values within the defined boundaries and presented as a gridded surface (Figure 48). Overall, the isopach maps indicate the potential sand and fine gravel deposits are relatively thin, typically < 5 m, but with a few slightly deeper areas. However, the overall areal extent is reasonably large.

Calculation of Potential Volume of Sand and Gravel Deposits in the SSD. The volume of sediment in the SSD that was interpreted as sand and fine gravel was computed as before using the isopach map and the Surface Volume tool in the 3D Analyst toolbox in ArcGIS (explained previously in "Development of Sand and Fine Gravel Thickness Maps, Isopach Maps, and Estimating Sediment Volume "). Using this methodology, the volume of sediment was estimated to be on the order of 5.9 million m^3 in the northern area and approximately 10.5 million m^3 in the southern area (Figure 48). The sum of these estimates (16.4 million m^3) agrees reasonable well with Birch (1984) who estimated the volume of sediment in this whole area (although his boundaries are not clear) to be on the order of 25 million m^3. However, Birch was very vague about the actual value and the area that was included in this estimate. Also, the present estimates are for a more confined area. Again, it is important to note in the estimate provided here simply represents the area above the seismic reflector interpreted as the base of a sand and gravel deposit for the two isolated areas. The gravity cores taken in the SSD show the sediments fine downward and increase in mud content with depth. In addition, the data on the composition is somewhat vague. Therefore, the volume is an estimate of area, not composition. Nevertheless, the results indicates this site has potential as a significant sand and gravel deposit and warrants further seismic studies and vibracoring.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community, Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

Figure 42. Location of shiptracks on the SSD for subbottom seismic profiles. Highlighted sections show location of profiles in Figures 43 to 46. AOI in legend is the depth scale for the body of the figure.

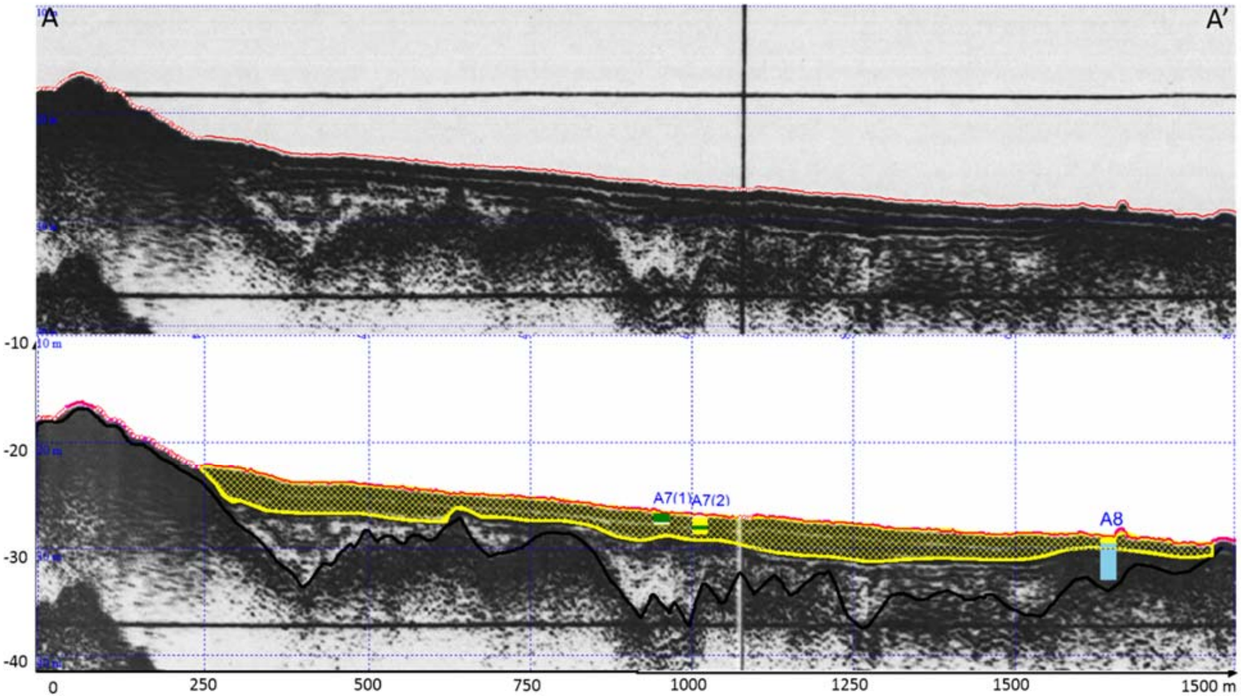


Figure 43. Subbottom seismic profile for line A – A'. See Figure 42 for location. Vertical exaggeration is 20x. Depth is meters below sea level. Yellow outlines interpreted sand deposit. Note vibracores A7(1), A7(2), and A8 in the lower figure. The description of the vibracores are given in Appendix 1.

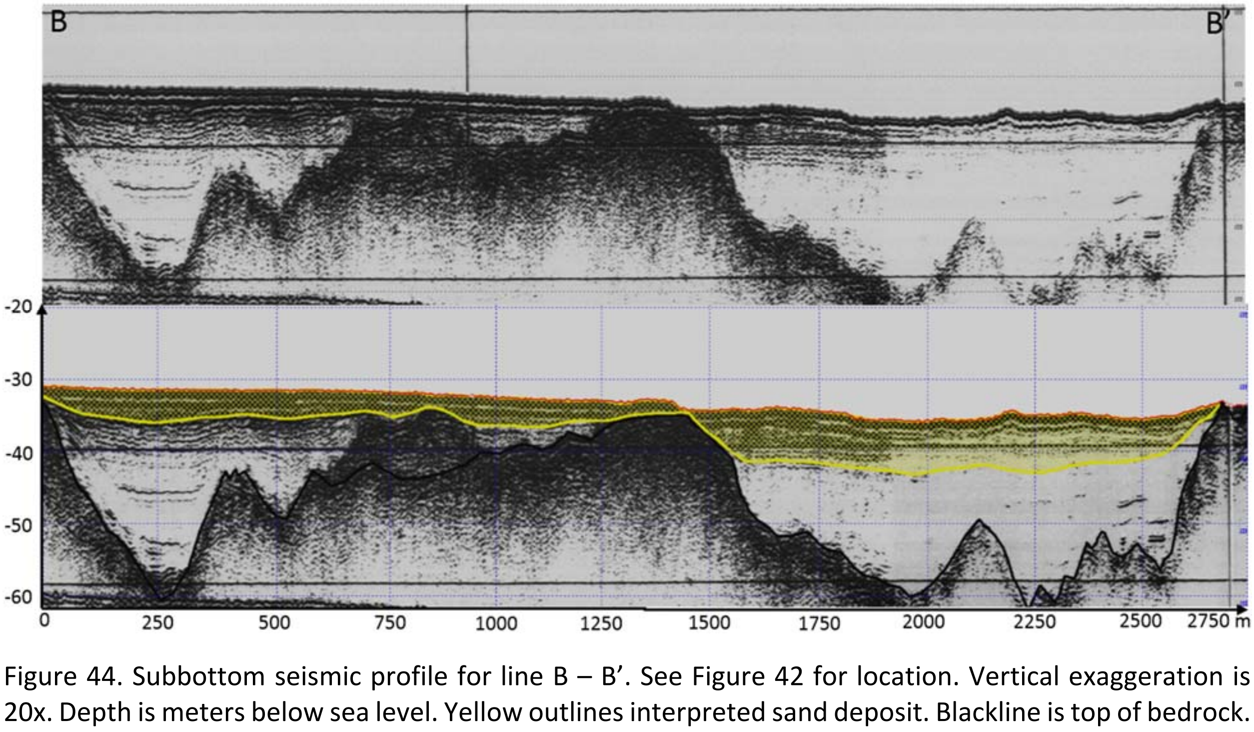


Figure 44. Subbottom seismic profile for line B – B'. See Figure 42 for location. Vertical exaggeration is 20x. Depth is meters below sea level. Yellow outlines interpreted sand deposit. Blackline is top of bedrock.

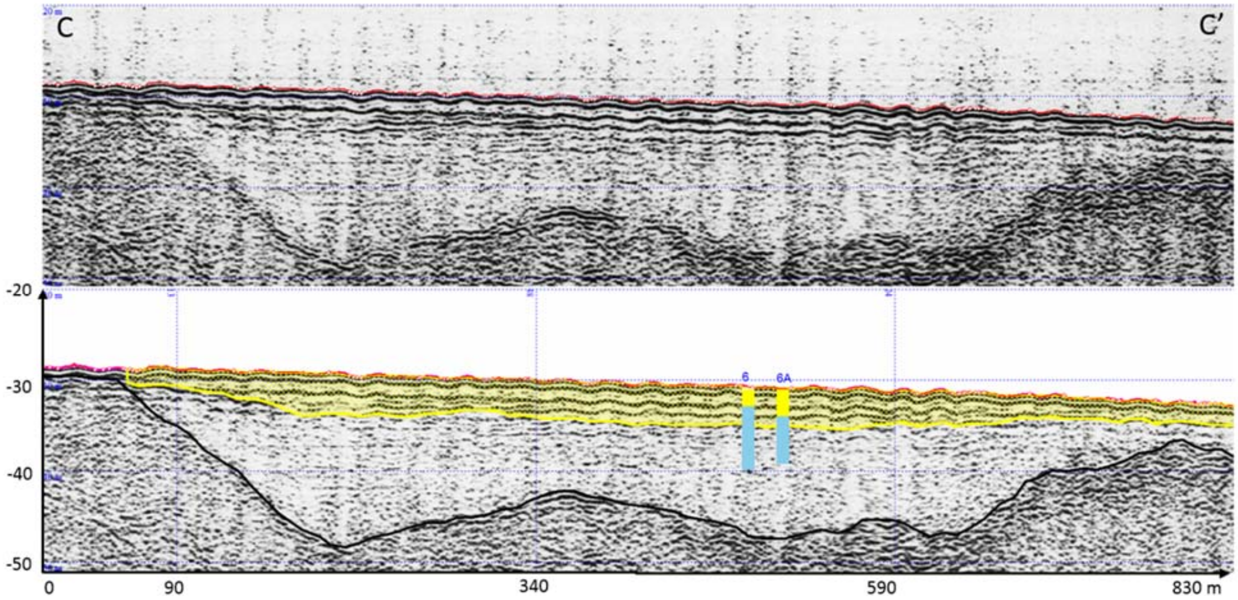


Figure 45. Subbottom seismic profile for line C – C'. See Figure 42 for location. Vertical exaggeration is 20x. Depth is meters below sea level. Yellow outlines interpreted sand deposit. Blackline is top of bedrock. Note vibracores UNH 6 and 6A in the lower figure. The vibracore log for UNH 6 is given in Figure 38. The description of the vibracores are given in Appendix 1.

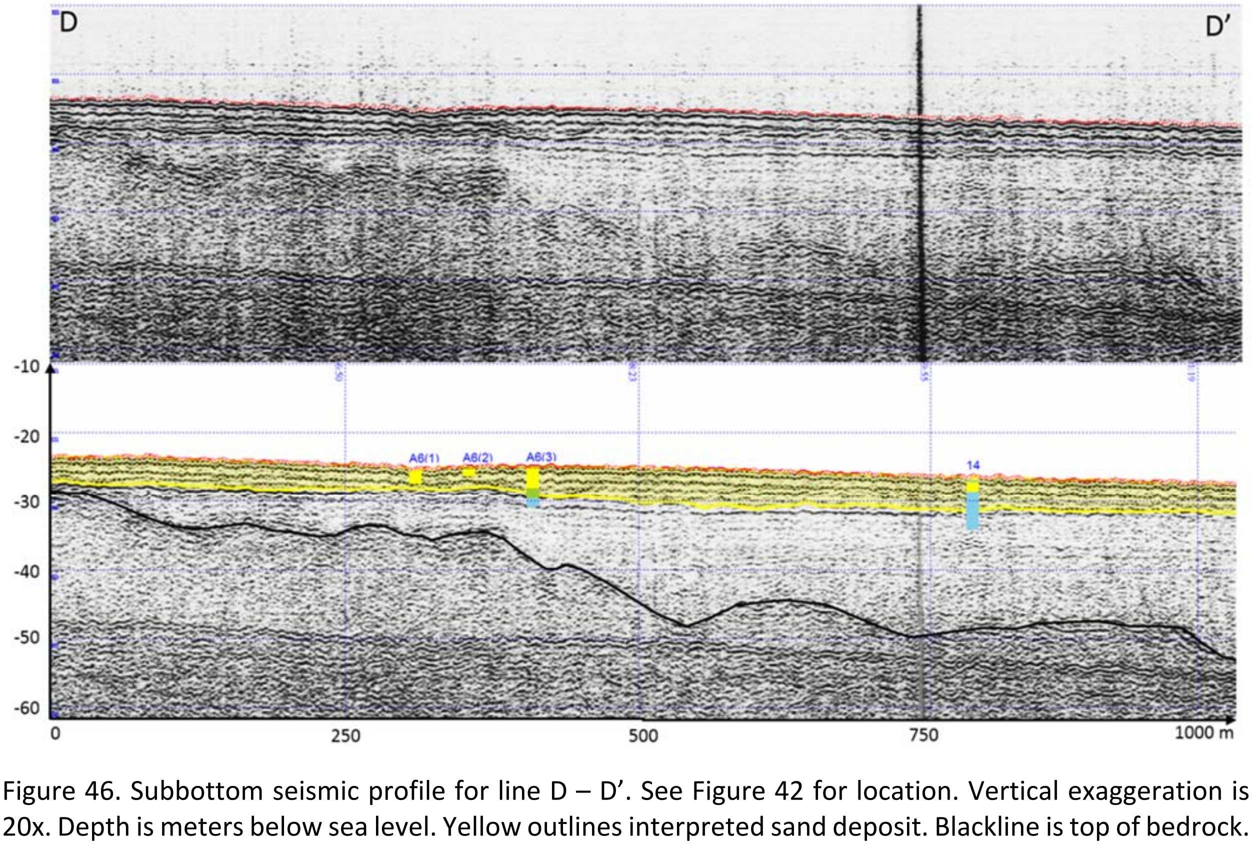
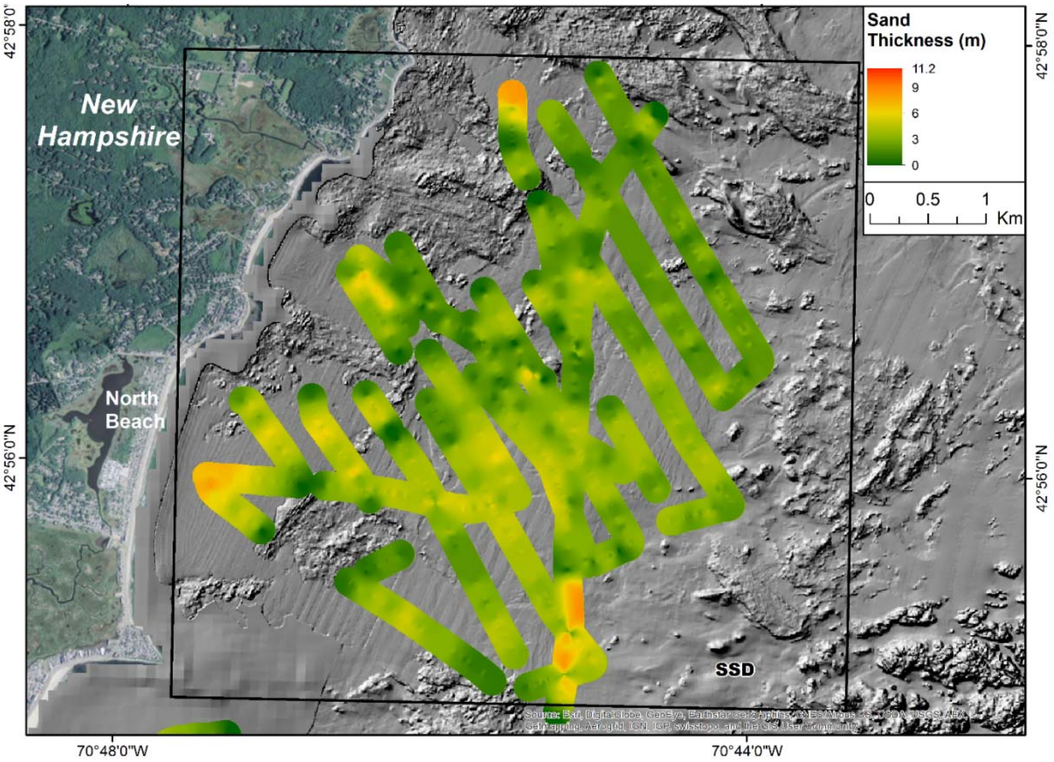
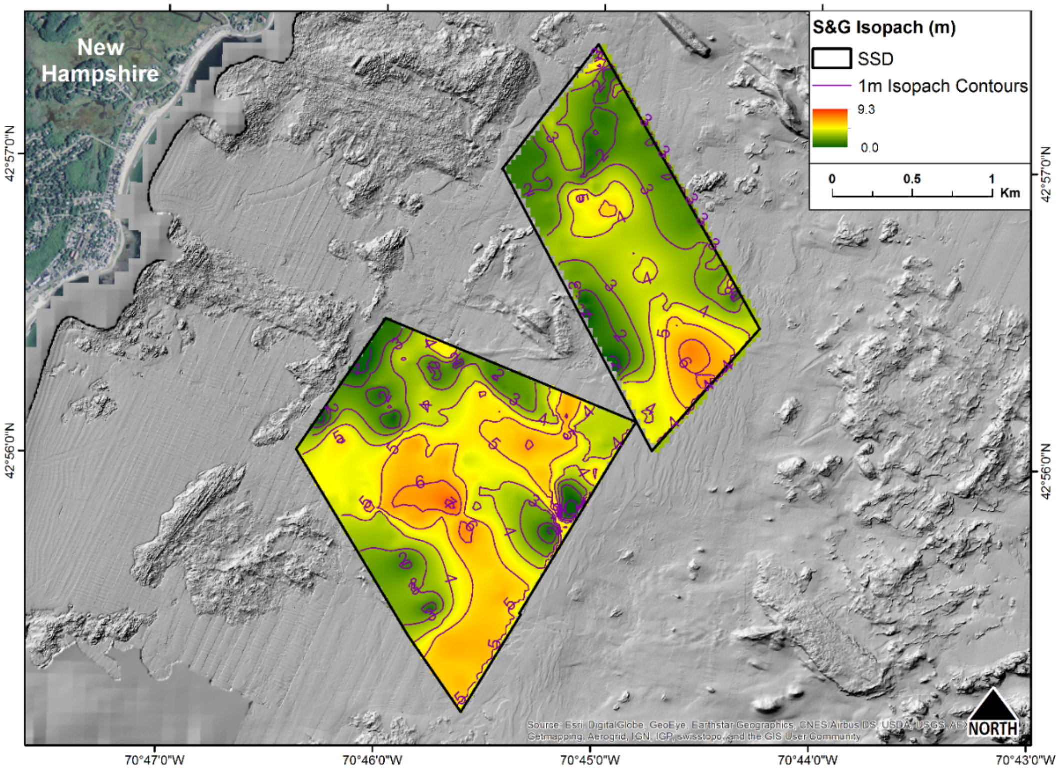


Figure 46. Subbottom seismic profile for line D – D'. See Figure 42 for location. Vertical exaggeration is 20x. Depth is meters below sea level. Yellow outlines interpreted sand deposit. Blackline is top of bedrock. Note vibracores A6(1), A6(2), A6(3) and UNH 14 in the lower figure. The vibracore log for A6(3) is given in Figure 40. The description of the vibracores are given in Appendix 1.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 47. Sand thickness map of the Southern Sand Deposits. The interpolated surface was generated from the point thickness values using a radial buffer (250 m) constrain the distance.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 48. Sand and fine gravel isopach map for the two areas within the Southern Sand Deposits. Interpolated surface was generated from point thickness values constrained by the polygon.

Offshore Sand Body

The Offshore Sand Body (OSB) is located ~32 km offshore and about half way between the Isles of Shoals and Jeffreys Ledge (Figure 1). The feature is ~4 km in length, ~1.5 km in width, and has a surface area of ~8 km^2 (Figure 49). The surface of the OSB slopes to the north where it ultimately merges with the seafloor. At its shallowest point, the OSB has a depth of ~45 m. The bathymetry shows the feature has steep flanks and rises up to ~50 m off the surrounding seafloor. The depth of the surface would have exposed the OSB to shallow water wave processes, perhaps even the intertidal zone, during the last sea level low stand. It is very likely the relatively thick sand deposits result from erosion of fines and concentration of sandy sediments on a marine modified glacial feature.

Surficial Sediments. At present there is no surficial sediment grain size data for the OSB with the exception of the top of vibracore UNH 3. As a result the surficial sediment mapping is largely dependent on MBES backscatter. It appears that the surficial sediments of OSB are composed of fine unconsolidated sediments, most likely slightly gravelly sand (Figure 50). However, the actual sediments may show more variability and ground truth is needed to resolve the sediment types including sandy muds and muds. The seafloor surrounding the OSB is mapped as fine unconsolidated sediments.

Vibracore. In general, vibracore UNH 3, which penetrated to a depth below the surface of ~7.1 m, shows the upper ~ 6.1 m is composed of medium to coarse sand fining downward to very fine sand where it unconformably overlies muddy deposits (Figure 51). The upper ~1.9 m of the core is medium to coarse sand with shell fragments and pebbles. From ~1.9 m to ~2.8 m the core is fine to medium sand with lenses of coarse sand and gravel with pebbles. From ~2.8 m to ~3.1 m, fine sands dominate ending in sandy mud. The sediments coarsen again from ~3.1 m to 4.2 m ending with medium to coarse sand. Below ~4.2 m the sediments continue to fine and become siltier until a sharp unconformity at 6.1 m, where the sediment abruptly change to mud to sandy mud extending to the base at ~7.1 m. Grain size analysis of selected samples show that at 0.6 m the sediment is composed of 6% gravel, 90% sand and 4% mud. A sample from 2.0 m below the surface is 16% gravel, 75% sand and 9% mud. At ~4.4 m the sediment is <1%gravel, 81% sand and ~19% mud. The mud content increases downward from 4% at 0.6 cm, 10% at 2.0 m, and 19% at 4.4 m indicating the OSB was winnowed by shallow water processes forming a lag deposit in the upper sediment column.

As stated above, the upper portion of the vibracore likely was exposed to marine processes during the last lowstand (Birch, 1984), which probably reached a low of ~40 to 55 m below present sea level at ~11-12 thousands of years before present (Oldale, 1983; Kelley et al., 1992; Barnhardt et al., 2007). The underlying muddy deposits are likely glacial marine sediments deposited during the last highstand (equivalent to the Presumpscot Formation described by Bloom, 1960). The source of the sand may be erosion of the underlying glacial marine sediments.

Subbottom Seismics. The subbottom seismic profiles, along with vibracore UNH 3, indicate that there is a ~6 m sand and fine gravel layer on the surface of the OSB (Figures 49 to 52). Here, only line A to A', which includes the vibracore, is shown. This is partially a result of the poor quality of the other seismic lines in this area. Placement of the vibracore on the seismic record indicates a strong reflector occurs close to the depth where the sand abruptly changes from sand to mud at

~6 m. However, actual position of the core on the seismic profile is only estimated due to the uncertainty of the navigation based on Loran C. The base of the seismic profile appears to be bedrock which may be overlain by till on the OSB. Birch (1984) hypothesized based in the same seismic lines that the lower portion of the seismic profile may be remnant coastal plain sediments. However, present interpretation favors bedrock with underlying till deposits.

Sand and Fine Gravel Thickness Map. As indicated above, mapping of this potential significant sand and fine gravel feature is hindered by lack of high-resolution subbottom seismics and ground truth (e.g., vibracores). However, the existing seismic lines and single vibracore indicate the sand and fine gravel thickness may be on the order of 10 m (Figure 53). Although the potential volume and characteristics of sand deposits cannot be determined, this feature is considered an important target for future field campaigns.

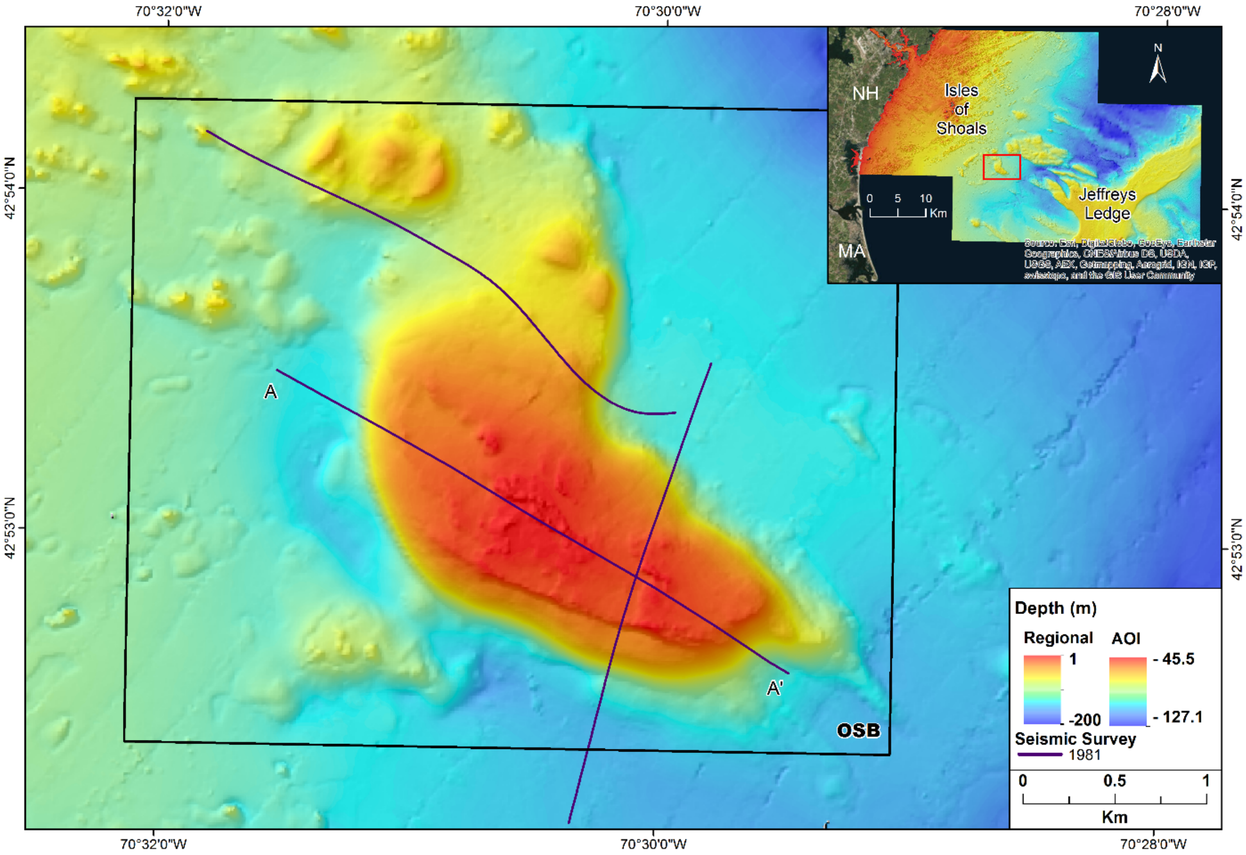


Figure 49. Location and bathymetry of Offshore Sand Body (OSB; outlined in dashed black line) on New Hampshire shelf (insert). Location of shiptracks on the OSB for subbottom seismic profiles. AOI in legend is the depth scale for the body of the figure.

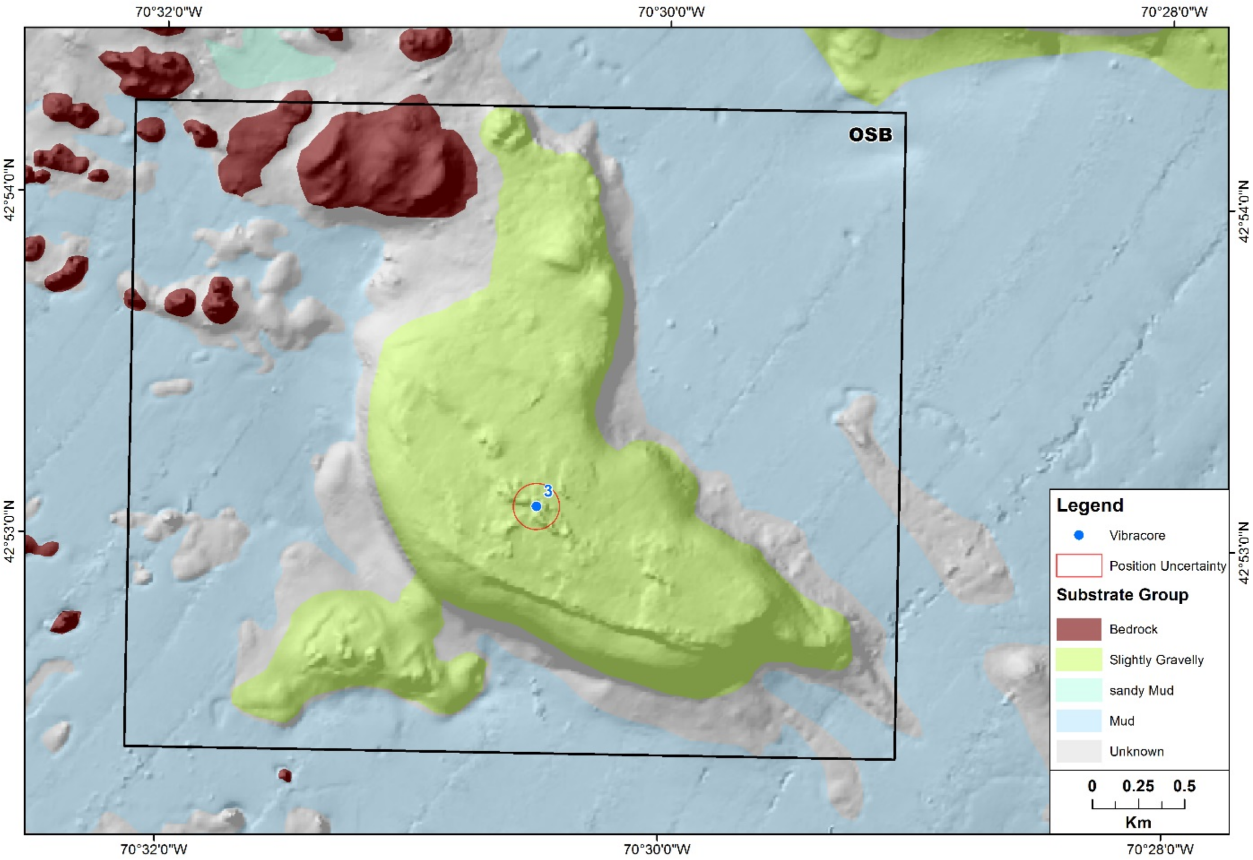


Figure 50. Surficial sediment map and locations of vibracore (UNH 3) for the Offshore Sand Body. Surficial sediment map based on the CMECS classification for Geologic Substrate Groups (FGDC, 2012).

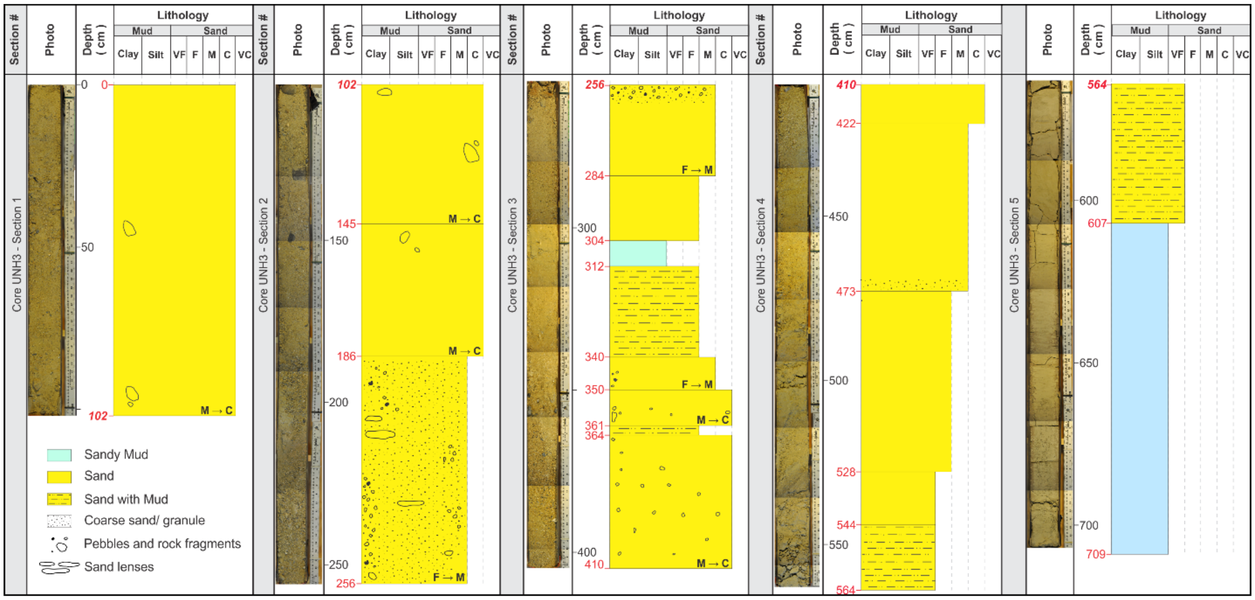


Figure 51. Vibracore log from site UNH 3 taken in 1984 on the Offshore Sandy Body (OSB). The location of the vibracore is shown in Figure 50. The full core log with greater detail is given in Appendix 1.

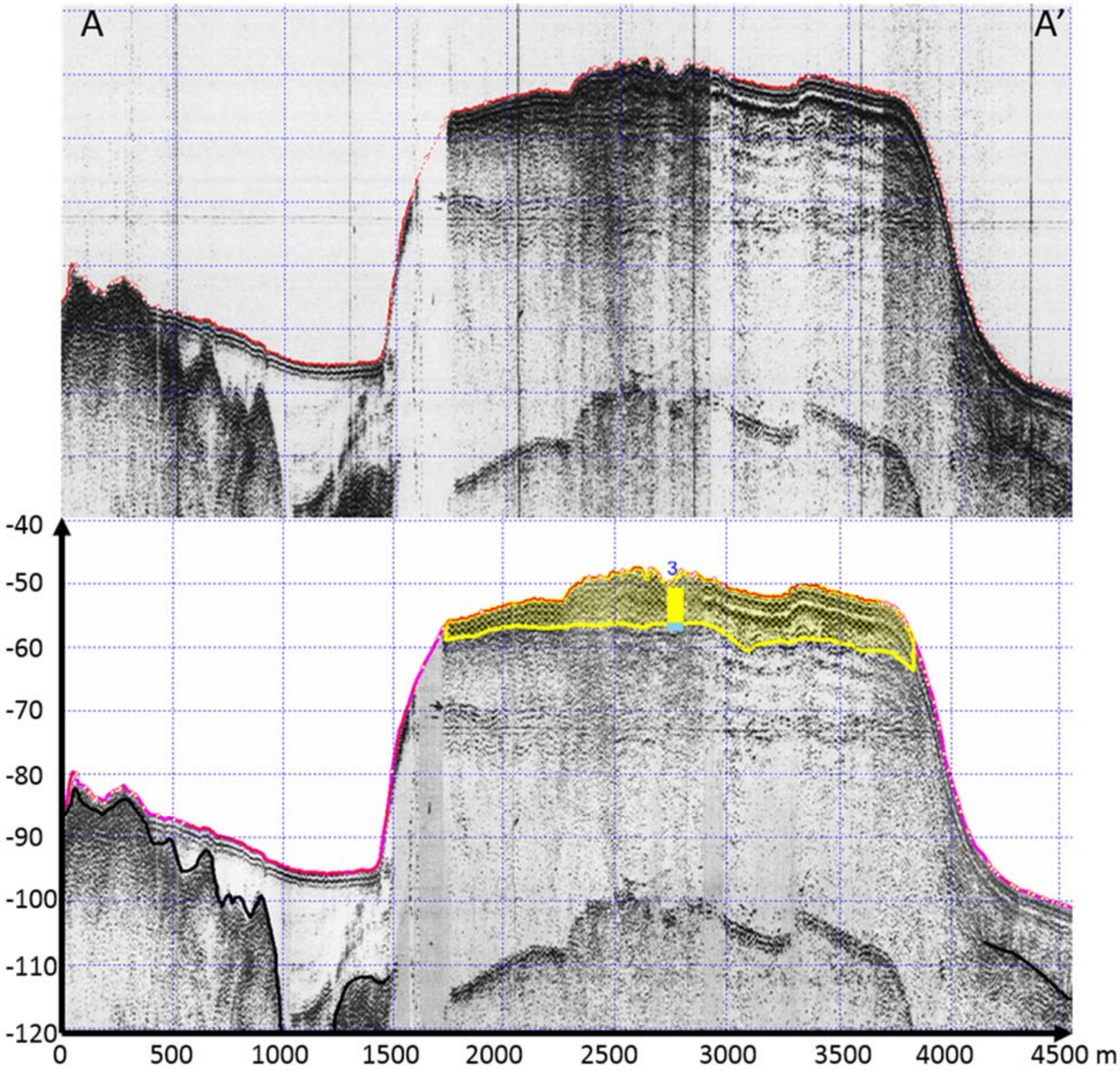


Figure 52. Subbottom seismic profile for line A – A’. See Figure 49 for location. Vertical exaggeration is 20x. Depth is meters below sea level. Yellow outlines interpreted sand deposit. Note vibracore UNH 3 shown in the lower figure. The log of the vibracore is given in Figure 51 and the full description is given in Appendix 1.

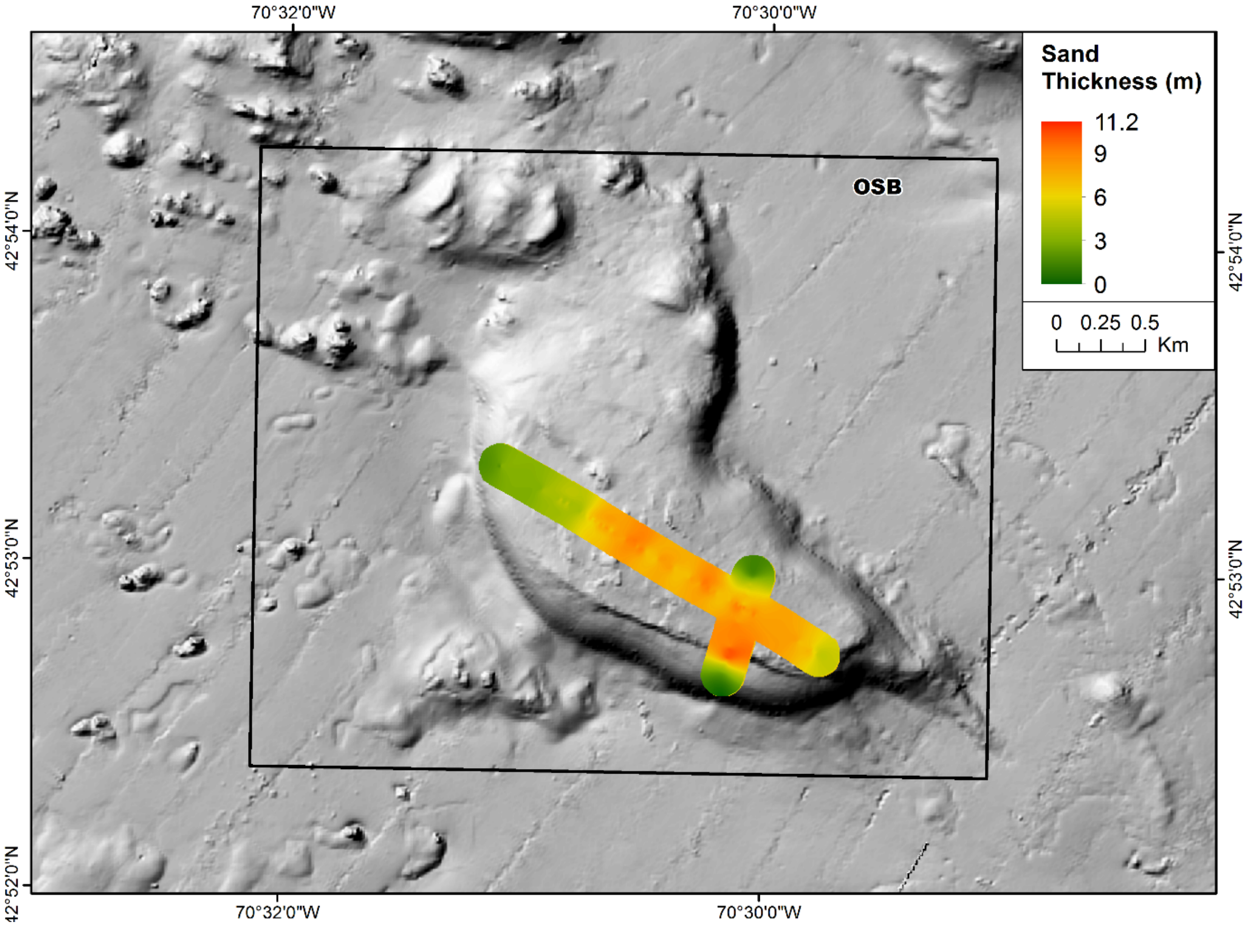


Figure 53. Sand thickness map for the Offshore Sand Body. The interpolated surface was generated from the point thickness values using a radial buffer (250 m) constrain the distance.

Summary

The geology, shallow stratigraphy, and surficial sediments of the New Hampshire and vicinity continental shelf have been studied extensively in the past. However, this work has not been systematically reviewed, evaluated, and placed in geospatial databases. This study addresses these issues. Based on previous work and an extensive archived database including over ~1280 km of seismic profiles, ~1200 grain size analyses, and 24 vibracores, the potential distribution of sand and fine gravel deposits on the NH shelf that is suitable for beach was assessed and potential sites for further study identified.

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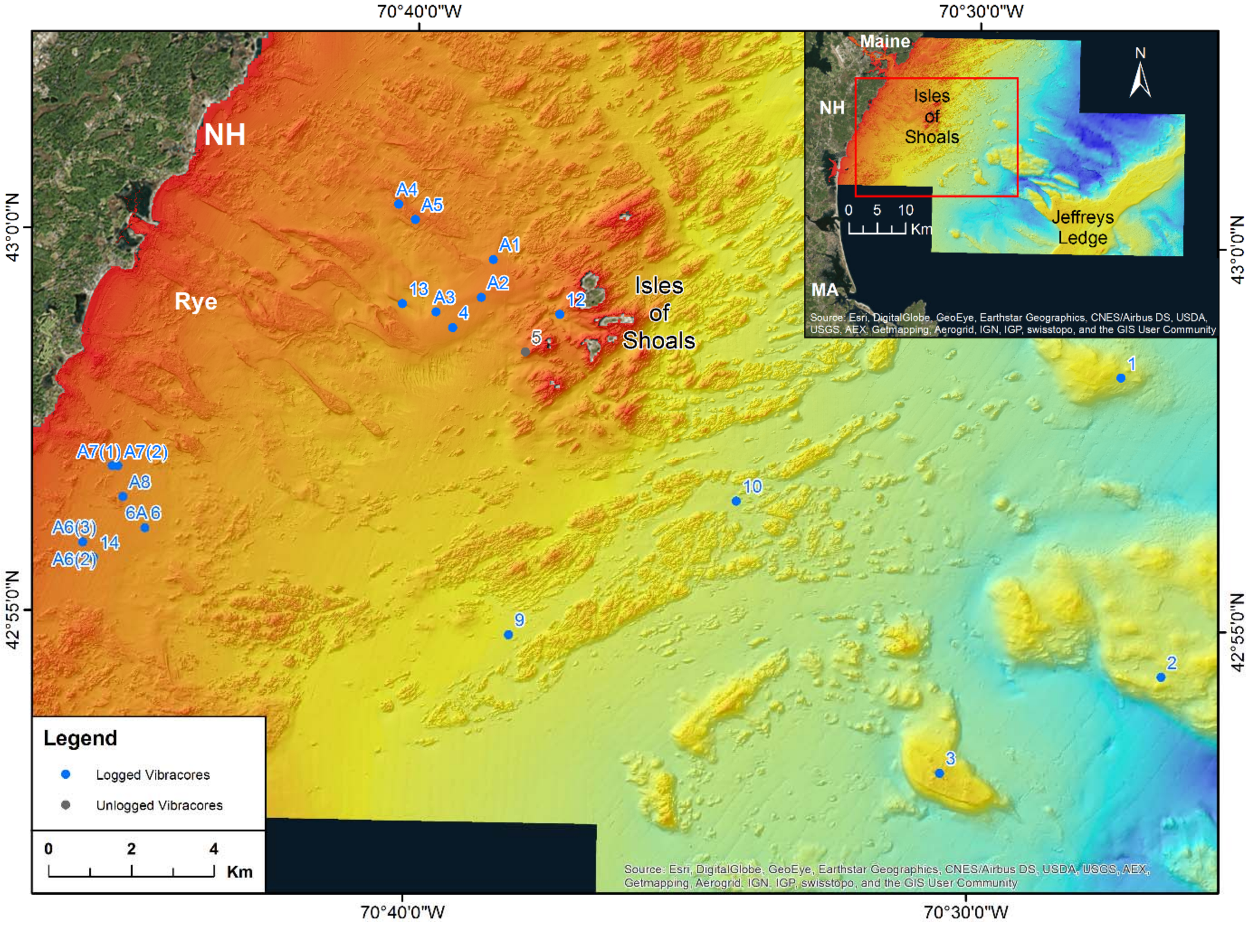
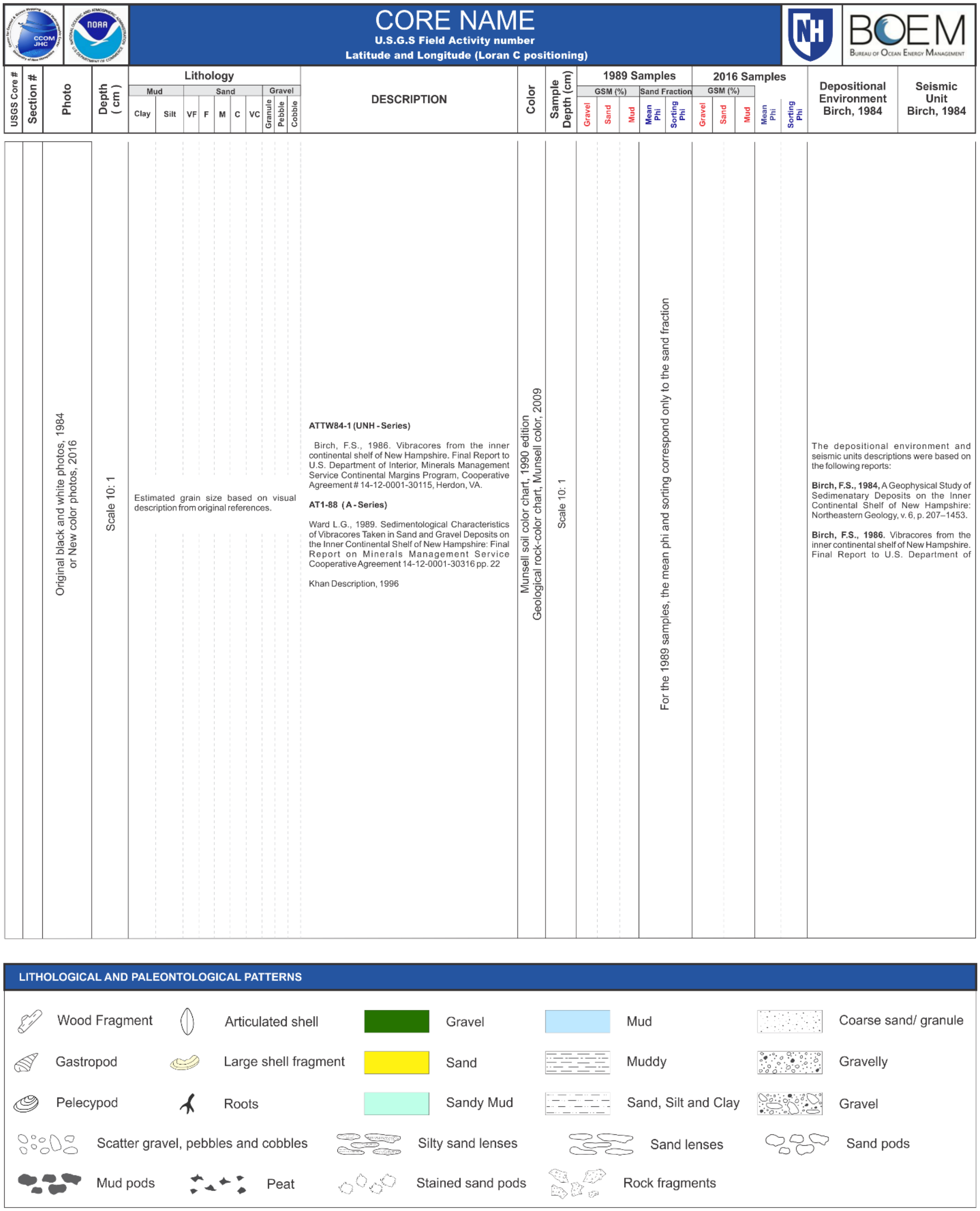
Appendix 1. Vibracore Logs

The synthesis of the descriptions and anlayses of the vibracores taken on the New Hampshire continental shelf are presented in this Appendix. The locations of all of the vibracores are shown in the following figure. Also, the format of the core logs is shown below.



Vibracore locations map displaying the unlogged (in black) and logged (in blue) vibracores from the 1984 and 1988 series vibracores.

Example of template used for the vibracore logs.



CORE NAME

U.S.G.S Field Activity number

Latitude and Longitude (Loran C positioning)

USGS Core #	Section #	Photo	Depth (cm)	Lithology											DESCRIPTION	Color	Sample Depth (cm)	1989 Samples					2016 Samples					Depositional Environment Birch, 1984	Seismic Unit Birch, 1984
				Mud		Sand					Gravel							GSM (%)			Sand Fraction		GSM (%)						
				Clay	Silt	VF	F	M	C	VC	Granule	Pebble	Cobble					Gravel	Sand	Mud	Mean Phi	Sorting Phi	Gravel	Sand	Mud	Mean Phi	Sorting Phi		

Original black and white photos, 1984 or New color photos, 2016

Scale 10: 1

Estimated grain size based on visual description from original references.

ATTW84-1 (UNH - Series)

Birch, F.S., 1986. Vibracores from the inner continental shelf of New Hampshire. Final Report to U.S. Department of Interior, Minerals Management Service Continental Margins Program, Cooperative Agreement # 14-12-0001-30115, Herdon, VA.

AT1-88 (A - Series)

Ward L.G., 1989. Sedimentological Characteristics of Vibracores Taken in Sand and Gravel Deposits on the Inner Continental Shelf of New Hampshire: Final Report on Minerals Management Service Cooperative Agreement 14-12-0001-30316 pp. 22

Khan Description, 1996

Munsell soil color chart, 1990 edition

Geological rock-color chart, Munsell color, 2009

Scale 10: 1

For the 1989 samples, the mean phi and sorting correspond only to the sand fraction

The depositional environment and seismic units descriptions were based on the following reports:

Birch, F.S., 1984, A Geophysical Study of Sedimenatary Deposits on the Inner Continental Shelf of New Hampshire: Northeastern Geology, v. 6, p. 207–1453.

Birch, F.S., 1986. Vibracores from the inner continental shelf of New Hampshire. Final Report to U.S. Department of

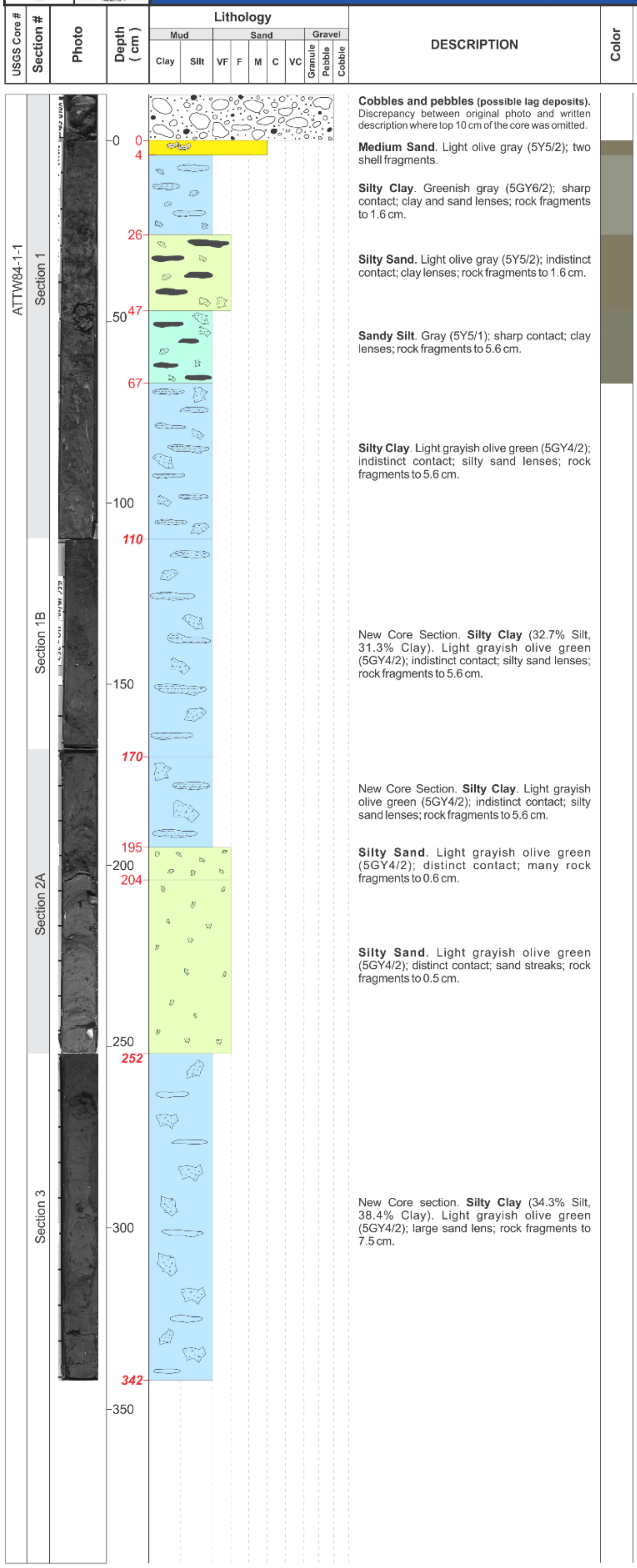
LITHOLOGICAL AND PALEONTOLOGICAL PATTERNS

- Wood Fragment
- Articulated shell
- Gravel
- Mud
- Coarse sand/ granule
- Gastropod
- Large shell fragment
- Sand
- Muddy
- Gravelly
- Pelecypod
- Roots
- Sandy Mud
- Sand, Silt and Clay
- Gravel
- Scatter gravel, pebbles and cobbles
- Silty sand lenses
- Sand lenses
- Sand pods
- Mud pods
- Peat
- Stained sand pods
- Rock fragments

UNH-1

U.S.G.S Field Activity #: 1984-016-FA

Latitude: 42.97167 Longitude: 70.45667



DESCRIPTION

Cobbles and pebbles (possible lag deposits). Discrepancy between original photo and written description where top 10 cm of the core was omitted.

Medium Sand. Light olive gray (5Y5/2); two shell fragments.

Silty Clay. Greenish gray (5GY6/2); sharp contact; clay and sand lenses; rock fragments to 1.6 cm.

Silty Sand. Light olive gray (5Y5/2); indistinct contact; clay lenses; rock fragments to 1.6 cm.

Sandy Silt. Gray (5Y5/1); sharp contact; clay lenses; rock fragments to 5.6 cm.

Silty Clay. Light grayish olive green (5GY4/2); indistinct contact; silty sand lenses; rock fragments to 5.6 cm.

New Core Section. **Silty Clay** (32.7% Silt, 31.3% Clay). Light grayish olive green (5GY4/2); indistinct contact; silty sand lenses; rock fragments to 5.6 cm.

New Core Section. **Silty Clay**. Light grayish olive green (5GY4/2); indistinct contact; silty sand lenses; rock fragments to 5.6 cm.

Silty Sand. Light grayish olive green (5GY4/2); distinct contact; many rock fragments to 0.6 cm.

Silty Sand. Light grayish olive green (5GY4/2); distinct contact; sand streaks; rock fragments to 0.5 cm.

New Core section. **Silty Clay** (34.3% Silt, 38.4% Clay). Light grayish olive green (5GY4/2); large sand lens; rock fragments to 7.5 cm.

Sample Depth (cm)	1989 Samples GSM (%) Gravel	1989 Samples GSM (%) Sand	1989 Samples GSM (%) Mud	1989 Samples Sand Fraction Mean Phi	1989 Samples Sand Fraction Sorting Phi	2016 Samples GSM (%) Gravel	2016 Samples GSM (%) Sand	2016 Samples GSM (%) Mud	2016 Samples Mean Phi	2016 Samples Sorting Phi
150	1.9	34.4	64.0							
302	1.7	25.9	72.7							

Depositional Environment Birch, 1984	Seismic Unit Birch, 1984
Lodgment till; prior 13.800 YBP while glaciers still covered the region.	**Unit 1.** Diamicton.

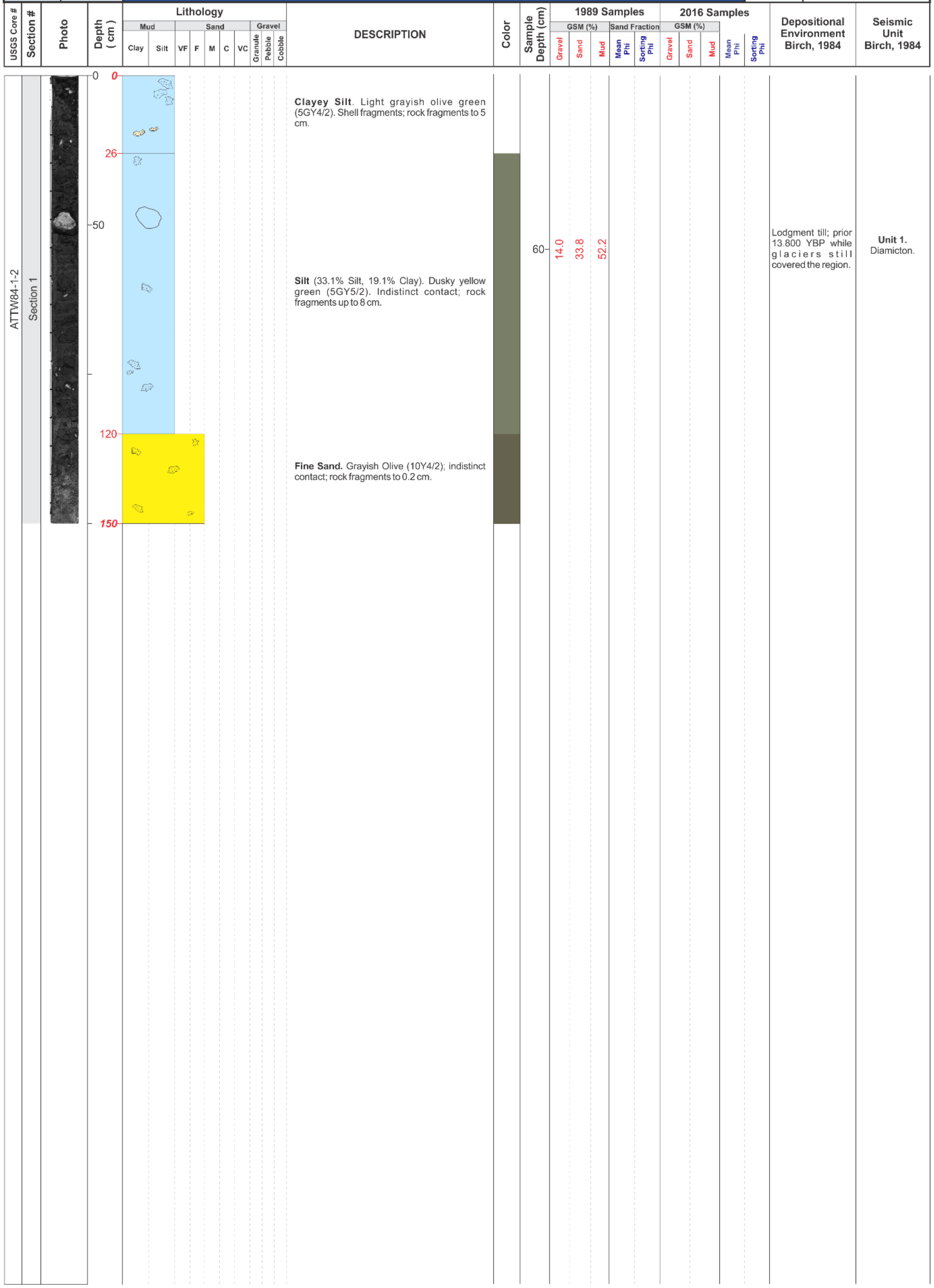
Original Reference: Birch, F.S. 1986b. Vibracores from the inner continental shelf of New Hampshire. Final Report to U.S. Department of Interior, Minerals Management Service Continental Margins Program, Cooperative Agreement # 14-12-0001-30115, Herdon, VA.

Page 1 of 1

UNH-2

U.S.G.S Field Activity #: 1984-016-FA

Latitude: 42.90667 Longitude: 70.44333



Clayey Silt. Light grayish olive green (5GY4/2). Shell fragments; rock fragments to 5 cm.

Silt (33.1% Silt, 19.1% Clay). Dusky yellow green (5GY5/2). Indistinct contact; rock fragments up to 8 cm.

Fine Sand. Grayish Olive (10Y4/2); indistinct contact; rock fragments to 0.2 cm.

Lodgment till; prior 13.800 YBP while glaciers still covered the region.

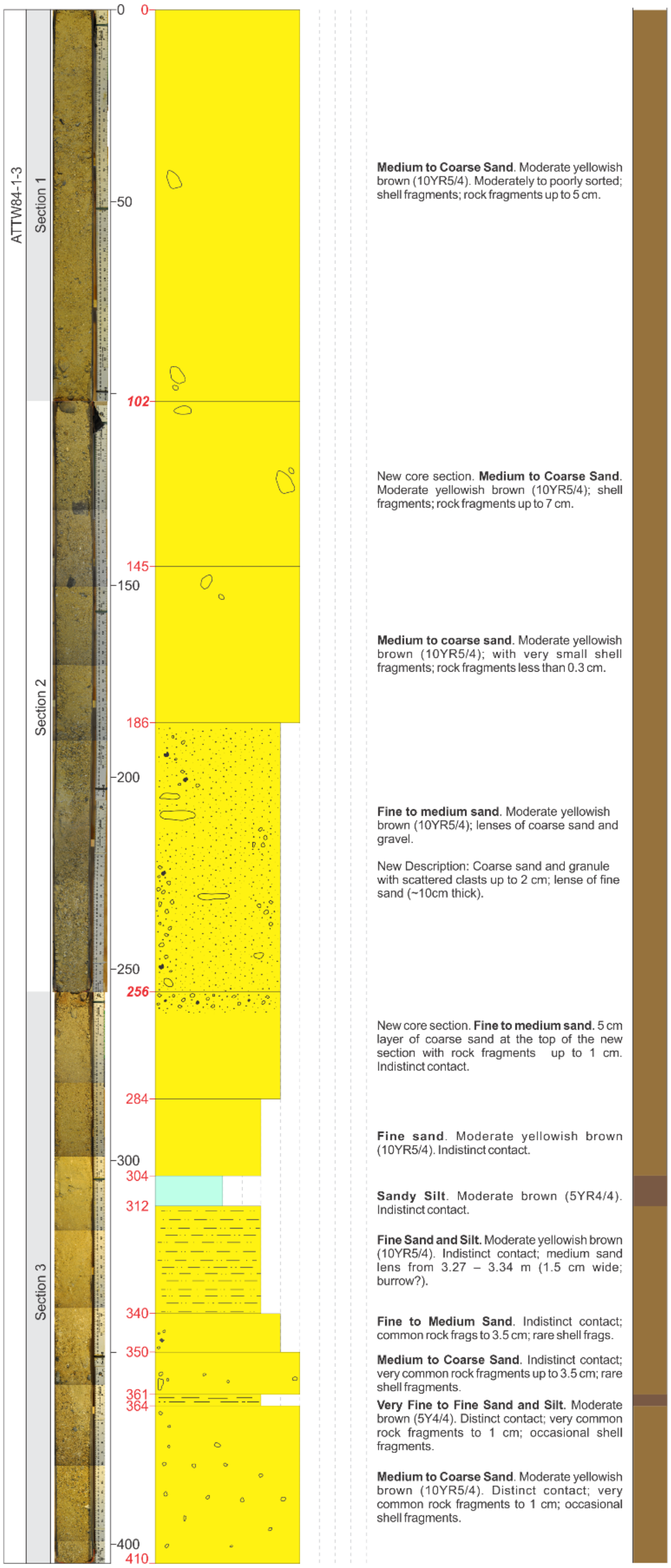
Unit 1.
Diamicton.

Original Reference: Birch, F.S. 1986b. Vibracores from the inner continental shelf of New Hampshire. Final Report to U.S. Department of Interior, Minerals Management Service Continental Margins Program, Cooperative Agreement # 14-12-0001-30115, Herdon, VA.

UNH-3

U.S.G.S Field Activity #: 1984-016-FA
Latitude: 42.88500 Longitude: 70.50833

USGS Core #	Section #	Photo	Depth (cm)	Lithology	DESCRIPTION	Color	Sample Depth (cm)	1989 Samples GSM (%) Gravel	Sand	Mud	1989 Sand Fraction Mean Phi	Sorting Phi	2016 Samples GSM (%) Gravel	Sand	Mud	Mean Phi	Sorting Phi	Depositional Environment Birch, 1984	Seismic Unit Birch, 1984
ATTW84-1-3	Section 1		0–102				60	6.2	90.1	3.8								Sand mounds since the last post-glacial lowstand.	**Unit 4.** Holocene sand sheets and mounds. From top of the core up to 607 cm.
	Section 2		102–256				202	15.8	75.2	9.3									
	Section 3		256–410																



Medium to Coarse Sand. Moderate yellowish brown (10YR5/4). Moderately to poorly sorted; shell fragments; rock fragments up to 5 cm.

New core section. **Medium to Coarse Sand**. Moderate yellowish brown (10YR5/4); shell fragments; rock fragments up to 7 cm.

Medium to coarse sand. Moderate yellowish brown (10YR5/4); with very small shell fragments; rock fragments less than 0.3 cm.

Fine to medium sand. Moderate yellowish brown (10YR5/4); lenses of coarse sand and gravel.

New Description: Coarse sand and granule with scattered clasts up to 2 cm; lense of fine sand (~10cm thick).

New core section. **Fine to medium sand.** 5 cm layer of coarse sand at the top of the new section with rock fragments up to 1 cm. Indistinct contact.

Fine sand. Moderate yellowish brown (10YR5/4). Indistinct contact.

Sandy Silt. Moderate brown (5YR4/4). Indistinct contact.

Fine Sand and Silt. Moderate yellowish brown (10YR5/4). Indistinct contact; medium sand lens from 3.27 – 3.34 m (1.5 cm wide; burrow?).

Fine to Medium Sand. Indistinct contact; common rock frags to 3.5 cm; rare shell frags.

Medium to Coarse Sand. Indistinct contact; very common rock fragments up to 3.5 cm; rare shell fragments.

Very Fine to Fine Sand and Silt. Moderate brown (5Y4/4). Distinct contact; very common rock fragments to 1 cm; occasional shell fragments.

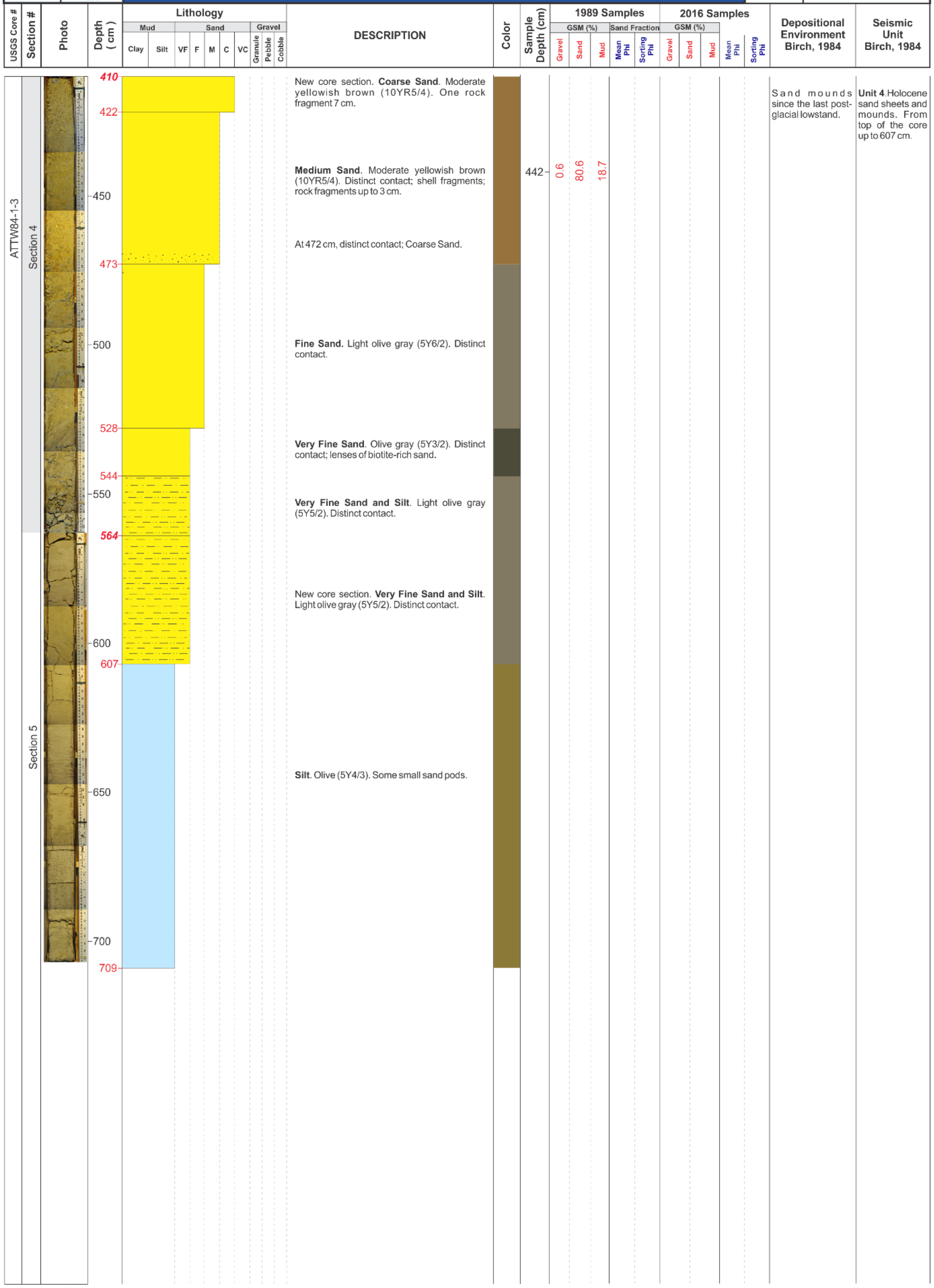
Medium to Coarse Sand. Moderate yellowish brown (10YR5/4). Distinct contact; very common rock fragments to 1 cm; occasional shell fragments.

Original Reference: Birch, F.S. 1986b. Vibracores from the inner continental shelf of New Hampshire. Final Report to U.S. Department of Interior, Minerals Management Service Continental Margins Program, Cooperative Agreement # 14-12-0001-30115, Herdon, VA.

UNH-3

U.S.G.S Field Activity #: 1984-016-FA

Latitude: 42.88500 Longitude: 70.50833



New core section. **Coarse Sand**. Moderate yellowish brown (10YR5/4). One rock fragment 7 cm.

Medium Sand. Moderate yellowish brown (10YR5/4). Distinct contact; shell fragments; rock fragments up to 3 cm.

At 472 cm, distinct contact; Coarse Sand.

Fine Sand. Light olive gray (5Y6/2). Distinct contact.

Very Fine Sand. Olive gray (5Y3/2). Distinct contact; lenses of biotite-rich sand.

Very Fine Sand and Silt. Light olive gray (5Y5/2). Distinct contact.

New core section. **Very Fine Sand and Silt**. Light olive gray (5Y5/2). Distinct contact.

Silt. Olive (5Y4/3). Some small sand pods.

Sand mounds since the last post-glacial lowstand.

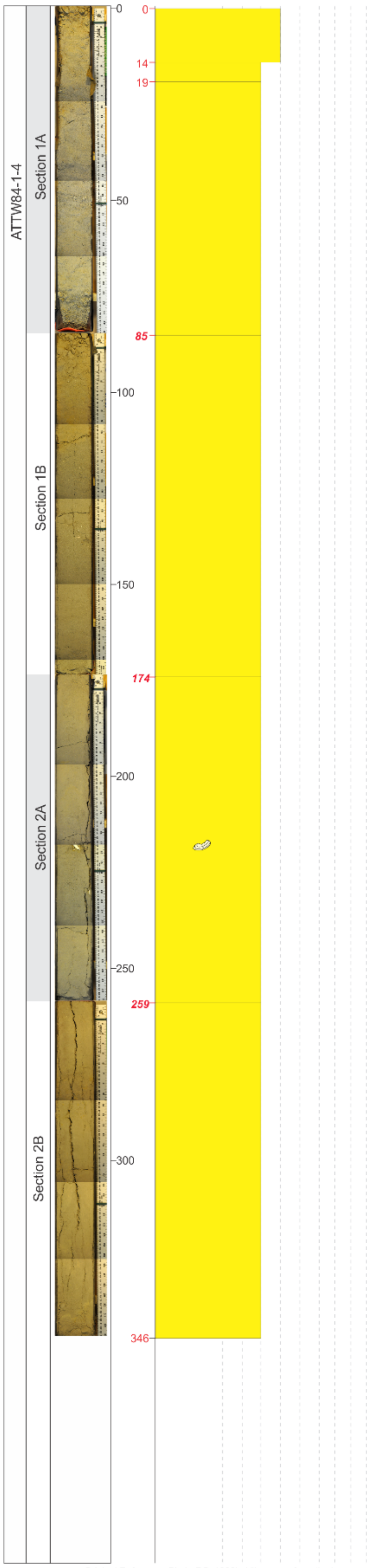
Unit 4.Holocene sand sheets and mounds. From top of the core up to 607 cm.

Original Reference: Birch, F.S. 1986b. Vibracores from the inner continental shelf of New Hampshire. Final Report to U.S. Department of Interior, Minerals Management Service Continental Margins Program, Cooperative Agreement # 14-12-0001-30115, Herdon, VA.

UNH-4

U.S.G.S Field Activity #: 1984-016-FA
Latitude: 42.98000 Longitude: -70.65500

USGS Core # | Section # | Photo | Depth (cm) | Lithology (Mud: Clay, Silt; Sand: VF, F, M, C, VC; Gravel: Granule, Pebble, Cobble) | DESCRIPTION | Color | Sample Depth (cm) | 1989 Samples (GSM (%): Gravel, Sand, Mud; Sand Fraction: Mean Phi, Sorting Phi) | 2016 Samples (GSM (%): Gravel, Sand, Mud; Mean Phi, Sorting Phi) | Depositional Environment Birch, 1984 | Seismic Unit Birch, 1984



Medium Sand. Moderate Yellowish Brown (10YR5/4). Shell fragments; rock fragments to 0.5 cm.
Khan Description: **Coarse Sand**. Moderately to poorly sorted; sharp lower contact.

Fine Sand. Yellowish Gray (5Y7/2). Distinct contact.

Fine Sand. Light Gray (N7). Shell fragments; stained patches; dusky yellow (5Y6/4).

Khan Description: **Medium Sand**. Moderately sorted; very small shell fragments; grain size generally fines towards base.

New core section. **Fine Sand**. Olive Gray (5Y4/2). Shell fragments.

Khan Description: **Fine Sand**. Moderately to well sorted, very fine grains towards bottom; mica flakes.

New core section. **Fine Sand**. Olive Gray (5Y4/2); shell fragments.

Khan Description: **Very Fine Sand**.Generally grain size fines toward base with increasing mud content; mica flakes and fossil shells; lower contact with mud seems to be gradational.

New core section. **Fine Sand**. Olive Gray (5Y4/2); small patches of peat near base.

Khan Description: **Very Fine Sand**. Generally grain size fines toward base with increasing mud content; mica flakes and fossil shells; lower contact with mud seems to be gradational.

Sample Depth (cm)	Gravel	Sand	Mud
115	0.4	93.0	6.7

Sand mounds since the last post-glacial lowstand.

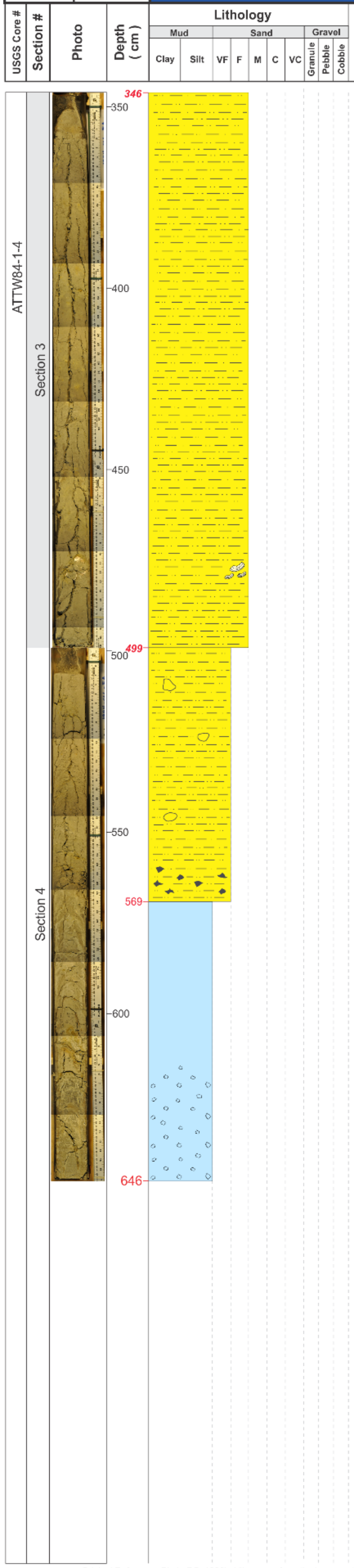
Unit 4.Holocene sand sheets and mounds. From the top of the core up to 569 cm.

Original Reference: Birch, F.S. 1986b. Vibracores from the inner continental shelf of New Hampshire. Final Report to U.S. Department of Interior, Minerals Management Service Continental Margins Program, Cooperative Agreement # 14-12-0001-30115, Herdon, VA.

UNH-4

U.S.G.S Field Activity #: 1984-016-FA

Latitude: 42.98000 Longitude: -70.65500



DESCRIPTION

New core section. **Fine Sand and Silt** (31.2 % Silt, 8.9 % Clay). Olive Gray (5Y4/2). Shell fragments; peat pods to 0.5 cm; mica rich.

Khan Description: **Very Fine Sand**. Generally grain size fines toward base with increasing mud content; mica flakes and fossil shells; lower contact with mud seems to be gradational.

New core section. **Very Fine Sand and Silt**. Dark Gray (5Y4/1). Shell fragments; rock fragments up to 3 cm; abundant peat pods near base.

Khan Description: **Very Fine Sand**. Generally grain size fines toward base with increasing mud content; mica flakes and fossil shells; lower contact with mud seems to be gradational.

Silty Clay (39.8 % Silt, 44.7 % Clay). Dark Gray (5Y4.5/1). Shell fragments; distinct contact; stained sand pods (5YR).

Khan Description: **Mud**. Hard, compact, no lamination, blocky.

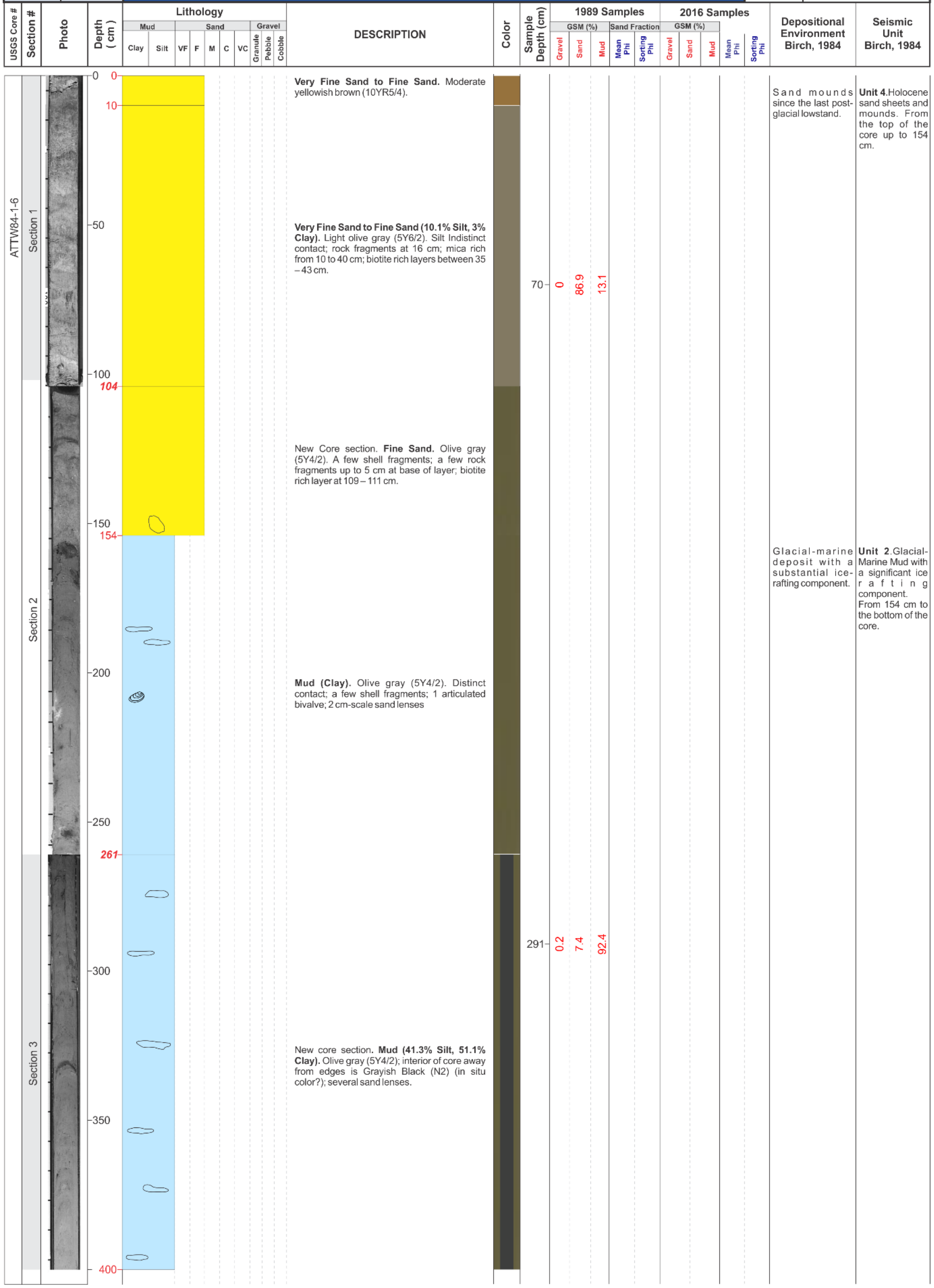
Sample Depth (cm)	1989 Samples GSM (%) Gravel	Sand	Mud	Sand Fraction Mean Phi	Sorting Phi	2016 Samples GSM (%) Gravel	Sand	Mud	Mean Phi	Sorting Phi
396	0	59.9	40.1							
619	0.9	15.6	84.5							

Depositional Environment Birch, 1984	Seismic Unit Birch, 1984
Sand mounds since the last post-glacial lowstand.	**Unit 4**.Holocene sand sheets and mounds. From the top of the core up to 569 cm.
Glacial-marine deposit with a substantial ice-rafting component.	**Unit 2**.Glacial-Marine Mud with a significant ice rafting component. From 569 cm to the bottom of the core.

Original Reference: Birch, F.S. 1986b. Vibracores from the inner continental shelf of New Hampshire. Final Report to U.S. Department of Interior, Minerals Management Service Continental Margins Program, Cooperative Agreement # 14-12-0001-30115, Herdon, VA.

UNH-6

U.S.G.S Field Activity #: 1984-016-FA
Latitude: 42.93500 Longitude: -70.74500



Very Fine Sand to Fine Sand. Moderate yellowish brown (10YR5/4).

Very Fine Sand to Fine Sand (10.1% Silt, 3% Clay). Light olive gray (5Y6/2). Silt Indistinct contact; rock fragments at 16 cm; mica rich from 10 to 40 cm; biotite rich layers between 35 – 43 cm.

New Core section. **Fine Sand.** Olive gray (5Y4/2). A few shell fragments; a few rock fragments up to 5 cm at base of layer; biotite rich layer at 109 – 111 cm.

Mud (Clay). Olive gray (5Y4/2). Distinct contact; a few shell fragments; 1 articulated bivalve; 2 cm-scale sand lenses

New core section. **Mud (41.3% Silt, 51.1% Clay).** Olive gray (5Y4/2); interior of core away from edges is Grayish Black (N2) (in situ color?); several sand lenses.

Sand mounds since the last post-glacial lowstand.

Unit 4. Holocene sand sheets and mounds. From the top of the core up to 154 cm.

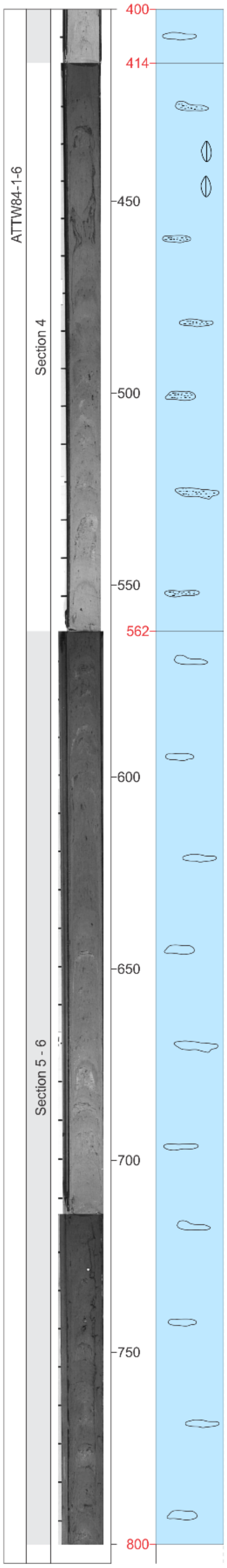
Glacial-marine deposit with a substantial ice-rafting component.

Unit 2. Glacial-Marine Mud with a significant ice rafting component. From 154 cm to the bottom of the core.

Original Reference: Birch, F.S. 1986. Vibracores from the inner continental shelf of New Hampshire. Final Report to U.S. Department of Interior, Minerals Management Service Continental Margins Program, Cooperative Agreement # 14-12-0001-30115, Herdon, VA.

UNH-6

U.S.G.S Field Activity #: 1984-016-FA
Latitude: 42.93500 Longitude: -70.74500



DESCRIPTION

Continuation section 3. **Mud (41.3% Silt, 51.1% Clay).** Olive gray (5Y4/2); interior of core away from edges is Grayish Black (N2) (in situ color?); several sand lenses.

New core section. **Mud (42.7% Silt, 53.8% Clay).** Gray (5Y5/1); a few shell fragments; articulated shells in vertical sand streaks (life position and burrow fill?); silty sand lenses throughout.

New core section. **Mud.** Gray (5Y5/1); a few shell fragments; numerous cm-scale sand lenses or pods.

Sample Depth (cm)	1989 Samples GSM (%) Gravel	1989 Samples GSM (%) Sand	1989 Samples GSM (%) Mud	1989 Samples Sand Fraction Mean Phi	1989 Samples Sand Fraction Sorting Phi	2016 Samples GSM (%) Gravel	2016 Samples GSM (%) Sand	2016 Samples GSM (%) Mud	2016 Samples Mean Phi	2016 Samples Sorting Phi
474	0	3.6	96.5							

Depositional Environment Birch, 1984

Glacial-marine deposit with a substantial ice-rafting component.

Seismic Unit Birch, 1984

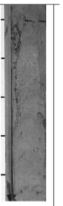
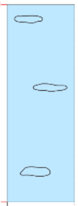
Unit 2. Glacial-Marine Mud with a significant ice rafting component. From 154 cm to the bottom of the core.

Original Reference: Birch, F.S. 1986. Vibracores from the inner continental shelf of New Hampshire. Final Report to U.S. Department of Interior, Minerals Management Service Continental Margins Program, Cooperative Agreement # 14-12-0001-30115, Herdon, VA.

UNH-6

U.S.G.S Field Activity #: 1984-016-FA

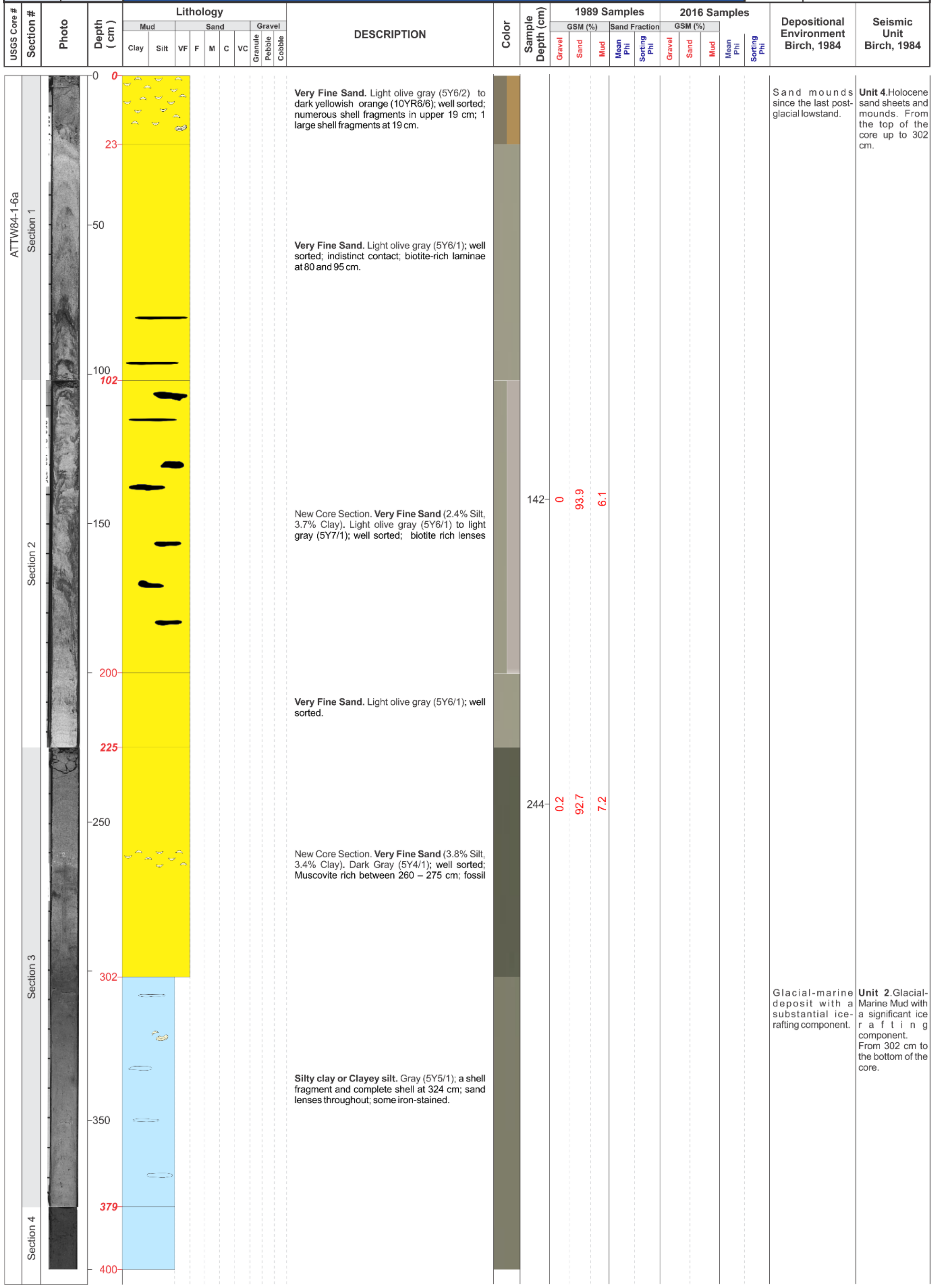
Latitude: 42.93500 Longitude: -70.74500

USGS Core #	Section #	Photo	Depth (cm)	Lithology: Mud (Clay, Silt); Sand (VF, F, M, C, VC); Gravel (Granule, Pebble, Cobble)	DESCRIPTION	Color	Sample Depth (cm)	1989 Samples GSM (%) Gravel	1989 Samples GSM (%) Sand	1989 Samples GSM (%) Mud	1989 Samples Sand Fraction Mean Phi	1989 Samples Sand Fraction Sorting Phi	2016 Samples GSM (%) Gravel	2016 Samples GSM (%) Sand	2016 Samples GSM (%) Mud	2016 Samples Mean Phi	2016 Samples Sorting Phi	Depositional Environment Birch, 1984	Seismic Unit Birch, 1984
ATTW84-1-6	Section 6		800 851		Continuation of section 6. **Mud.** Gray (5Y5/1); a few shell fragments; numerous cm-scale sand lenses or pods.													Glacial-marine deposit with a substantial ice-rafting component.	**Unit 2**.Glacial-Marine Mud with a significant ice rafting component. From 154 cm to the bottom of the core.

Original Reference: Birch, F.S. 1986. Vibracores from the inner continental shelf of New Hampshire. Final Report to U.S. Department of Interior, Minerals Management Service Continental Margins Program, Cooperative Agreement # 14-12-0001-30115, Herdon, VA.

UNH-6a

U.S.G.S Field Activity #: 1984-016-FA
Latitude: 42.93500 Longitude: -70.74500



Very Fine Sand. Light olive gray (5Y6/2) to dark yellowish orange (10YR6/6); well sorted; numerous shell fragments in upper 19 cm; 1 large shell fragments at 19 cm.

Very Fine Sand. Light olive gray (5Y6/1); well sorted; indistinct contact; biotite-rich laminae at 80 and 95 cm.

New Core Section. **Very Fine Sand** (2.4% Silt, 3.7% Clay)**.** Light olive gray (5Y6/1) to light gray (5Y7/1); well sorted; biotite rich lenses

Very Fine Sand. Light olive gray (5Y6/1); well sorted.

New Core Section. **Very Fine Sand** (3.8% Silt, 3.4% Clay)**.** Dark Gray (5Y4/1); well sorted; Muscovite rich between 260 – 275 cm; fossil

Silty clay or Clayey silt. Gray (5Y5/1); a shell fragment and complete shell at 324 cm; sand lenses throughout; some iron-stained.

Sand mounds since the last post-glacial lowstand.

Unit 4. Holocene sand sheets and mounds. From the top of the core up to 302 cm.

Glacial-marine deposit with a substantial ice-rafting component.

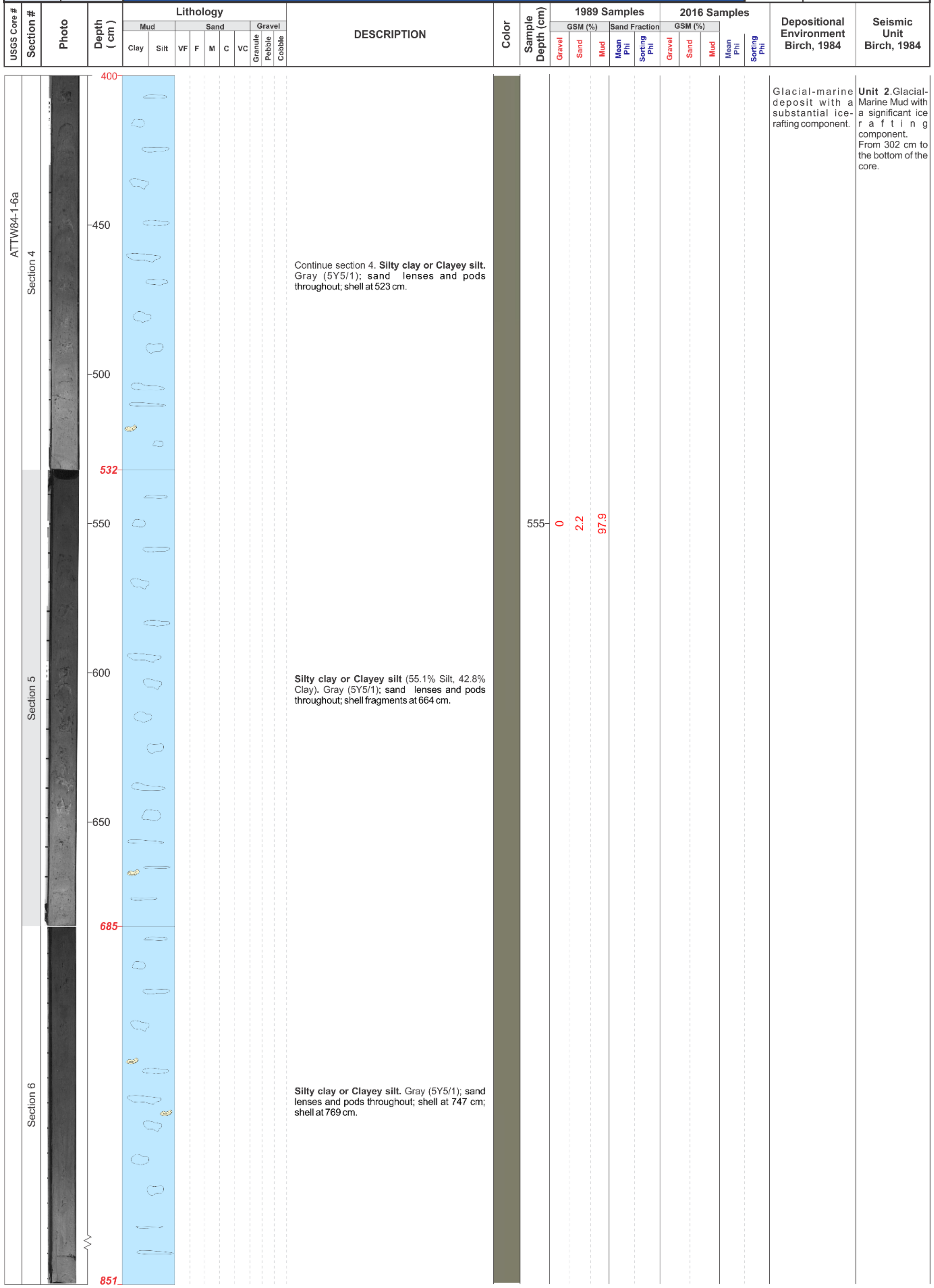
Unit 2. Glacial-Marine Mud with a significant ice rafting component. From 302 cm to the bottom of the core.

Original Reference: Birch, F.S. 1986. Vibracores from the inner continental shelf of New Hampshire. Final Report to U.S. Department of Interior, Minerals Management Service Continental Margins Program, Cooperative Agreement # 14-12-0001-30115, Herdon, VA.

UNH-6a

U.S.G.S Field Activity #: 1984-016-FA

Latitude: 42.93500 Longitude: -70.74500



Continue section 4. **Silty clay or Clayey silt.** Gray (5Y5/1); sand lenses and pods throughout; shell at 523 cm.

Silty clay or Clayey silt (55.1% Silt, 42.8% Clay). Gray (5Y5/1); sand lenses and pods throughout; shell fragments at 664 cm.

Silty clay or Clayey silt. Gray (5Y5/1); sand lenses and pods throughout; shell at 747 cm; shell at 769 cm.

Glacial-marine deposit with a substantial ice-rafting component.

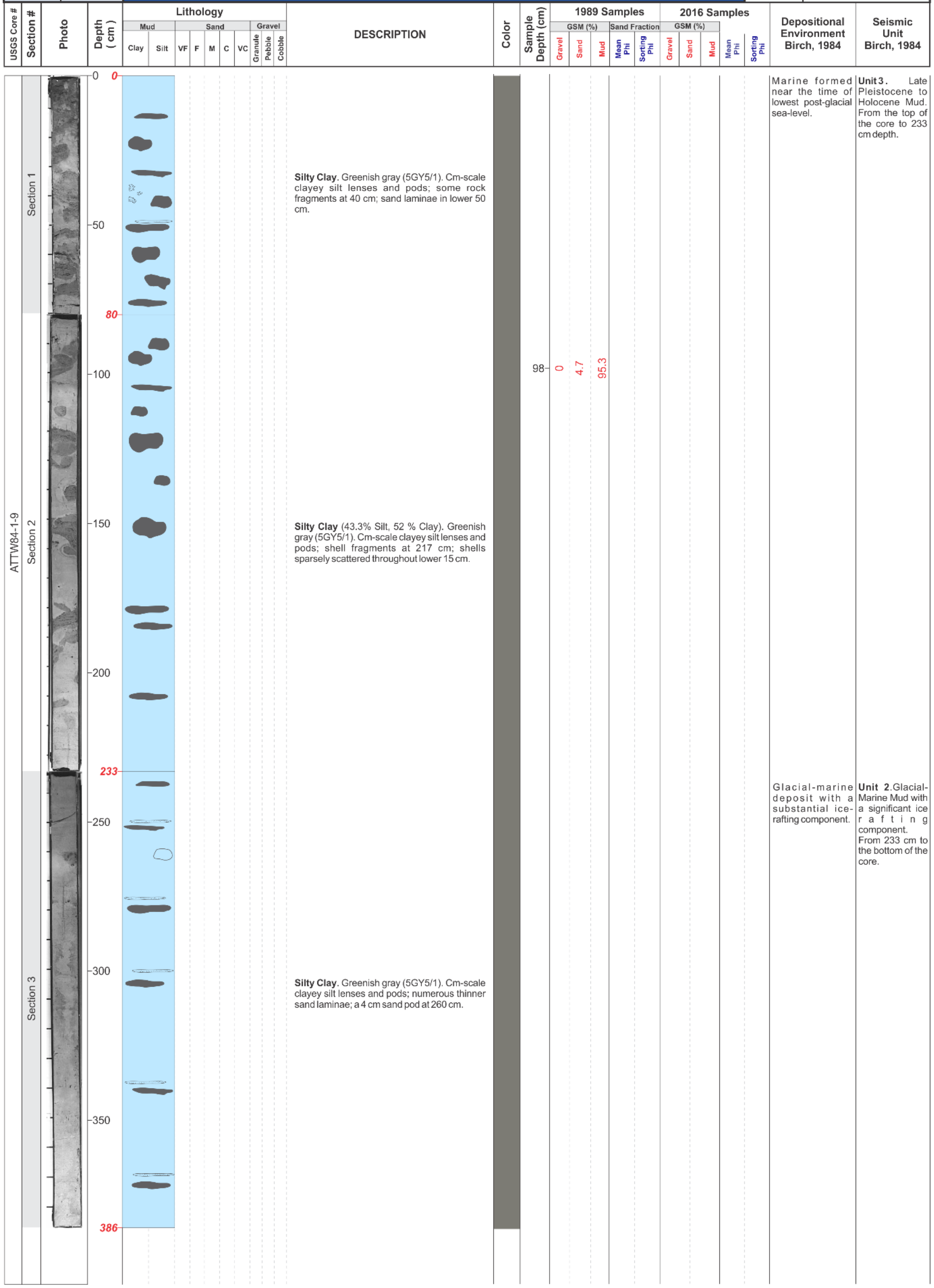
Unit 2. Glacial-Marine Mud with a significant ice rafting component. From 302 cm to the bottom of the core.

Original Reference: Birch, F.S. 1986. Vibracores from the inner continental shelf of New Hampshire. Final Report to U.S. Department of Interior, Minerals Management Service Continental Margins Program, Cooperative Agreement # 14-12-0001-30115, Herdon, VA.

Page 1 of 2

UNH-9

U.S.G.S Field Activity #: 1984-016-FA
Latitude: 42.91333 Longitude: -70.63667



Silty Clay. Greenish gray (5GY5/1). Cm-scale clayey silt lenses and pods; some rock fragments at 40 cm; sand laminae in lower 50 cm.

Silty Clay (43.3% Silt, 52 % Clay). Greenish gray (5GY5/1). Cm-scale clayey silt lenses and pods; shell fragments at 217 cm; shells sparsely scattered throughout lower 15 cm.

Silty Clay. Greenish gray (5GY5/1). Cm-scale clayey silt lenses and pods; numerous thinner sand laminae; a 4 cm sand pod at 260 cm.

Marine formed near the time of lowest post-glacial sea-level.

Unit 3. Late Pleistocene to Holocene Mud. From the top of the core to 233 cm depth.

Glacial-marine deposit with a substantial ice-rafting component.

Unit 2. Glacial-Marine Mud with a significant ice rafting component. From 233 cm to the bottom of the core.

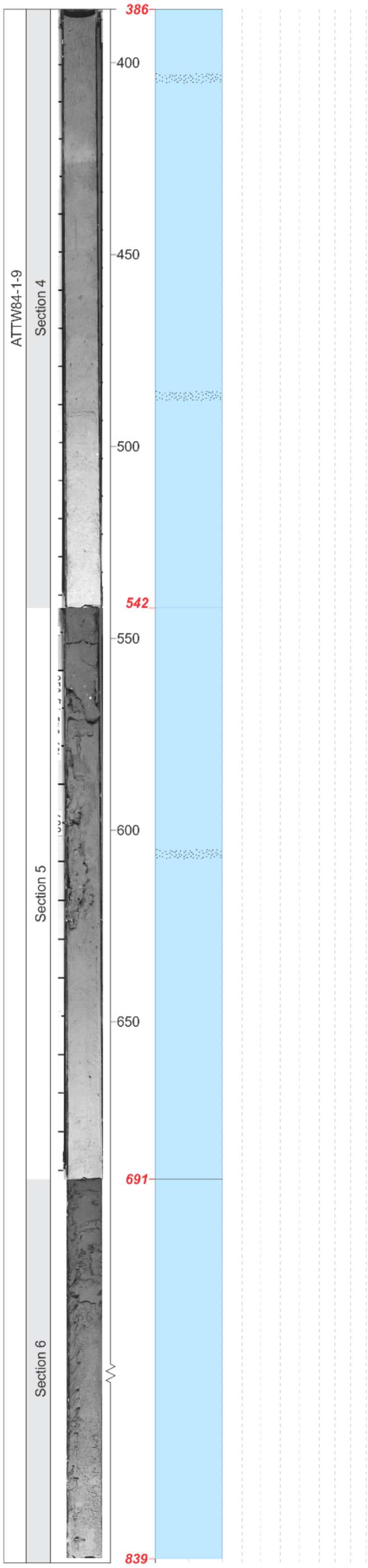
Original Reference: Birch, F.S. 1986b. Vibracores from the inner continental shelf of New Hampshire. Final Report to U.S. Department of Interior, Minerals Management Service Continental Margins Program, Cooperative Agreement # 14-12-0001-30115, Herdon, VA.

Page 2 of 2

UNH-9

U.S.G.S Field Activity #: 1984-016-FA
Latitude: 42.91333 Longitude: -70.63667

USGS Core #	Section #	Photo	Depth (cm)	Lithology	DESCRIPTION	Color	Sample Depth (cm)	1989 Samples GSM (%) Gravel	Sand	Mud	Sand Fraction Mean Phi	Sorting Phi	2016 Samples GSM (%) Gravel	Sand	Mud	Mean Phi	Sorting Phi	Depositional Environment Birch, 1984	Seismic Unit Birch, 1984
ATTW84-1-9	Section 4		386–542		**Silty Clay** (41% Silt, 57.2%Clay). Greenish gray (5GY5/1). Clayey silt or very fine sand layers at 401 - 402 and 487-489 cm; shells scattered sparsely throughout.		424	0.9	1.8	98.2								Glacial-marine deposit with a substantial ice-rafting component.	**Unit 2**.Glacial-Marine Mud with a significant ice rafting component. From 233 cm to the bottom of the core.
	Section 5		542–691		**Silty Clay**. Greenish gray (5GY5/1). Sand layers at 607 - 609; shells scattered sparsely throughout.														
	Section 6		691–839		**Silty Clay**. Greenish gray (5GY5/1). Shell at 742 cm.														

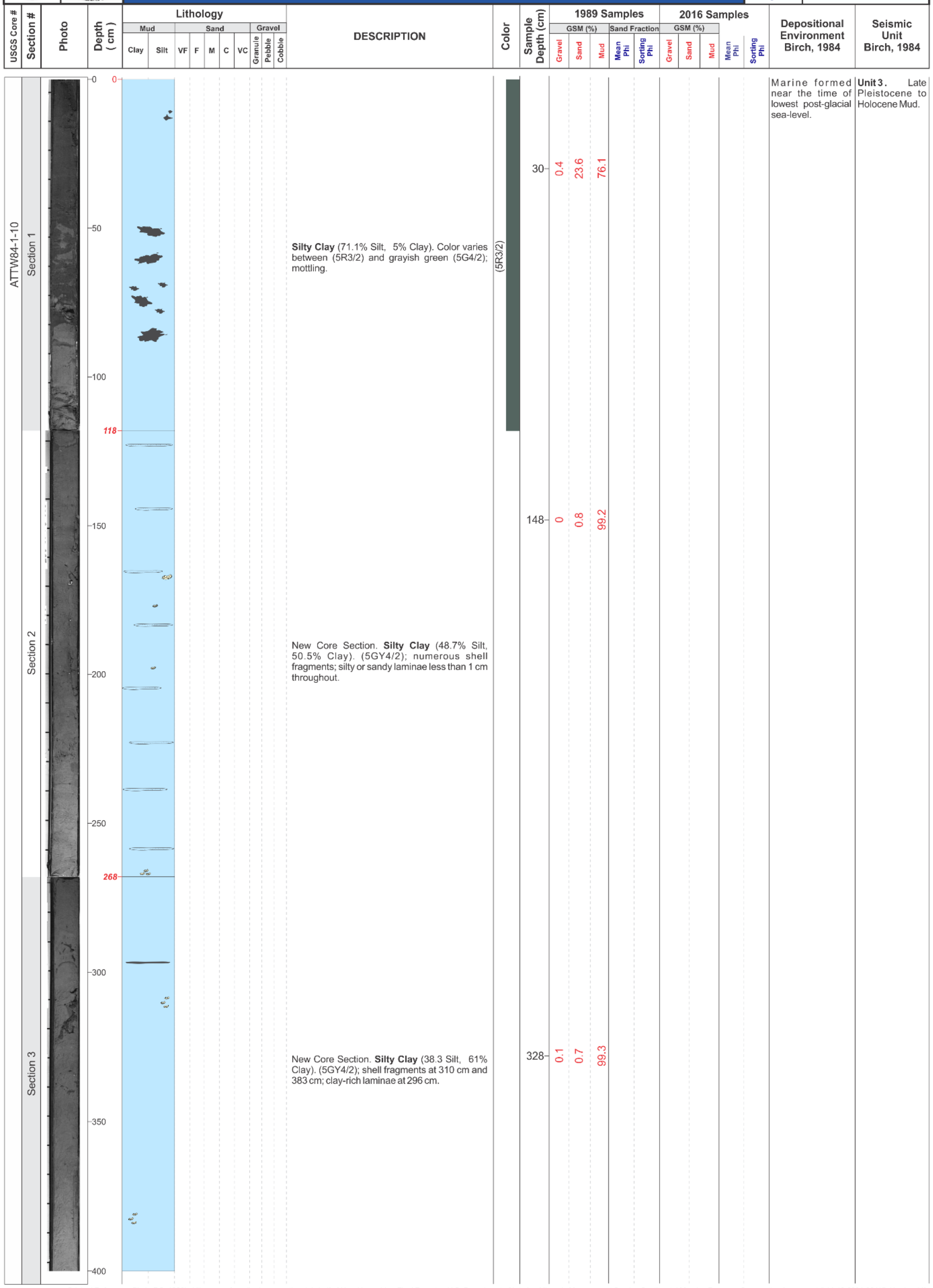


Original Reference: Birch, F.S. 1986b. Vibracores from the inner continental shelf of New Hampshire. Final Report to U.S. Department of Interior, Minerals Management Service Continental Margins Program, Cooperative Agreement # 14-12-0001-30115, Herdon, VA.

UNH-10

U.S.G.S Field Activity #: 1984-016-FA

Latitude: 42.94333 Longitude: -70.57000



Sample Depth (cm)	Gravel	Sand	Mud
30	0.4	23.6	76.1
148	0	0.8	99.2
328	0.1	0.7	99.3

Silty Clay (71.1% Silt, 5% Clay). Color varies between (5R3/2) and grayish green (5G4/2); mottling.

New Core Section. **Silty Clay** (48.7% Silt, 50.5% Clay). (5GY4/2); numerous shell fragments; silty or sandy laminae less than 1 cm throughout.

New Core Section. **Silty Clay** (38.3 Silt, 61% Clay). (5GY4/2); shell fragments at 310 cm and 383 cm; clay-rich laminae at 296 cm.

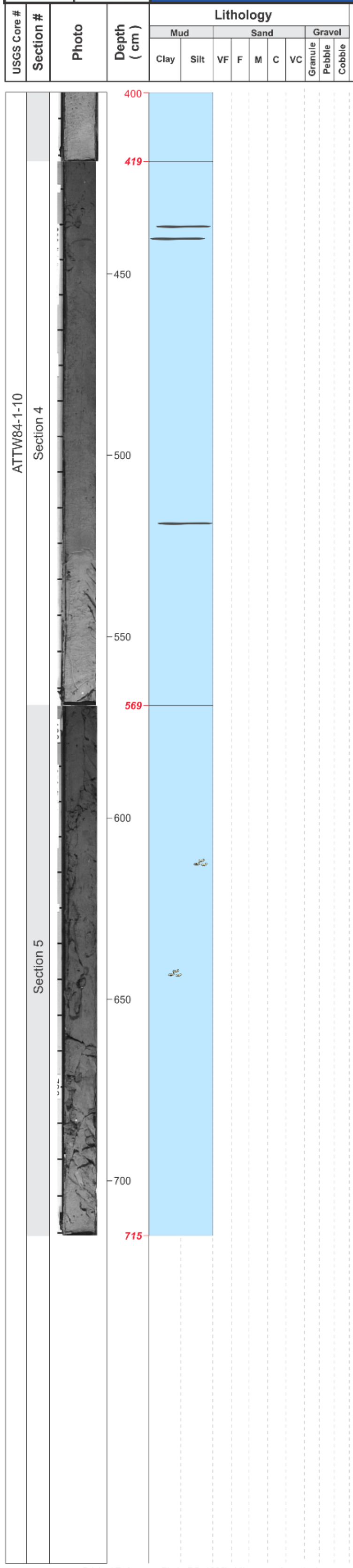
Depositional Environment: Marine formed near the time of lowest post-glacial sea-level.

Seismic Unit: **Unit 3.** Late Pleistocene to Holocene Mud.

Original Reference: Birch, F.S. 1986b. Vibracores from the inner continental shelf of New Hampshire. Final Report to U.S. Department of Interior, Minerals Management Service Continental Margins Program, Cooperative Agreement # 14-12-0001-30115, Herdon, VA.

UNH-10

U.S.G.S Field Activity #: 1984-016-FA
Latitude: 42.94333 Longitude: -70.57000



DESCRIPTION

Continue from Section 3. **Silty Clay** (38.3 Silt, 61% Clay). (5GY4/2).

New Core Section. **Silty Clay** (39.4% Silt, 59% Clay).(5GY4/2); clay-rich laminae at 437 cm, 442 cm and 518 cm.

New Core Section. **Silty Clay** (42.8% Silt, 56.5% Clay).(5GY4/2); shell fragments at 612 cm and 642 cm.

Color	Sample Depth (cm)	1989 Samples GSM (%) Gravel	Sand	Mud	Sand Fraction Mean Phi	Sorting Phi	2016 Samples GSM (%) Gravel	Sand	Mud	Mean Phi	Sorting Phi
	449	0.3	1.2	98.4							
	589	0	0.7	99.3							

Depositional Environment Birch, 1984

Marine formed near the time of lowest post-glacial sea-level.

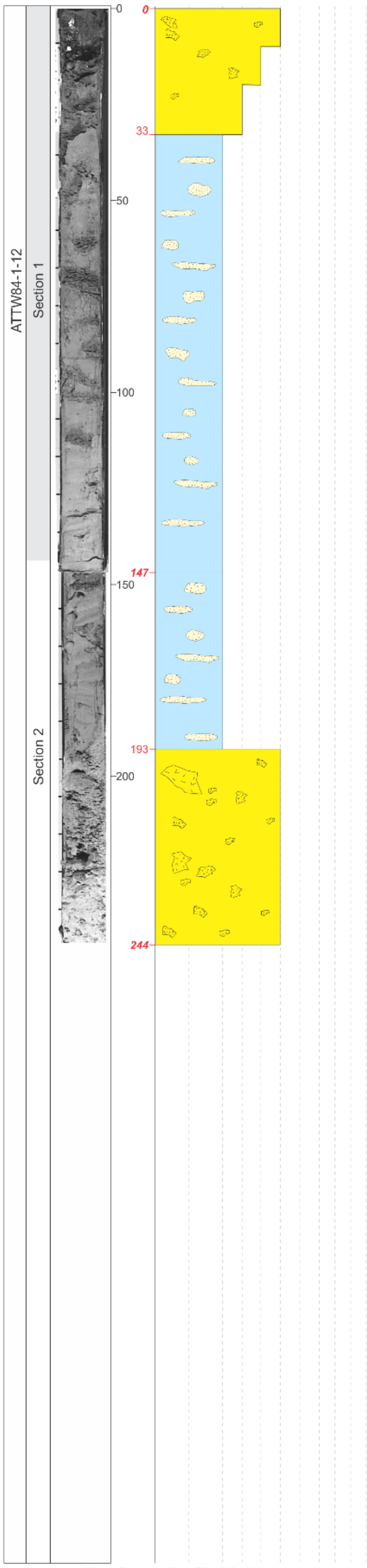
Seismic Unit Birch, 1984

Unit 3. Late Pleistocene to Holocene Mud.

Original Reference: Birch, F.S. 1986b. Vibracores from the inner continental shelf of New Hampshire. Final Report to U.S. Department of Interior, Minerals Management Service Continental Margins Program, Cooperative Agreement # 14-12-0001-30115, Herdon, VA.

UNH-12

U.S.G.S Field Activity #: 1984-016-FA
Latitude: 42.98333 Longitude: -70.62333



Depth (cm)	DESCRIPTION	Sample Depth (cm)	1989 Samples					2016 Samples					Depositional Environment Birch, 1984	Seismic Unit Birch, 1984
			GSM (%)			Sand Fraction		GSM (%)						
			Gravel	Sand	Mud	Mean Phi	Sorting Phi	Gravel	Sand	Mud	Mean Phi	Sorting Phi		
0–33	**Fine to Medium Sand**. Light olive gray (5Y5/2) to medium dark gray (N4). Fining downward to very fine sand; occasional rock fragments; shell fragments common to 13 cm; shell fragments fine downwards.												Sand mounds since the last post-glacial lowstand.	Redefined as: **Unit 4.** Holocene sand sheets and mounds. From top of the core to 33 cm depth.
33–147	**Clayey Silt**. Dusky yellow green (5GY5/2). Numerous sand lenses and pods containing shell hash.													Redefined as: **Unit 2.** Glacial-Marine Mud with a significant ice rafting component. From 33 cm to 193 cm depth.
147–193	**Clayey Silt** (43% Silt, 39.3% Clay). Light olive gray (5Y5/2). With pods and lenses of fine to medium sand with many shell fragments.	157	1.4	16.5	82.3								Glacial-marine deposit with a substantial ice-rafting component.	
193–244	**Fine to Medium Sand**. Olive gray (5Y4/2). Numerous rock fragments up to 10 cm.	197	40.5	34.0	25.6								Lodgment till; prior 13.800 YBP while glaciers still covered the region.	Redefined as: **Unit 1.** Diamicton. From 193 cm to the bottom of

NOTE: Based on recent reassessment, BOEM Project 2016, seismic units were redefined for this core, as shown in the core description.

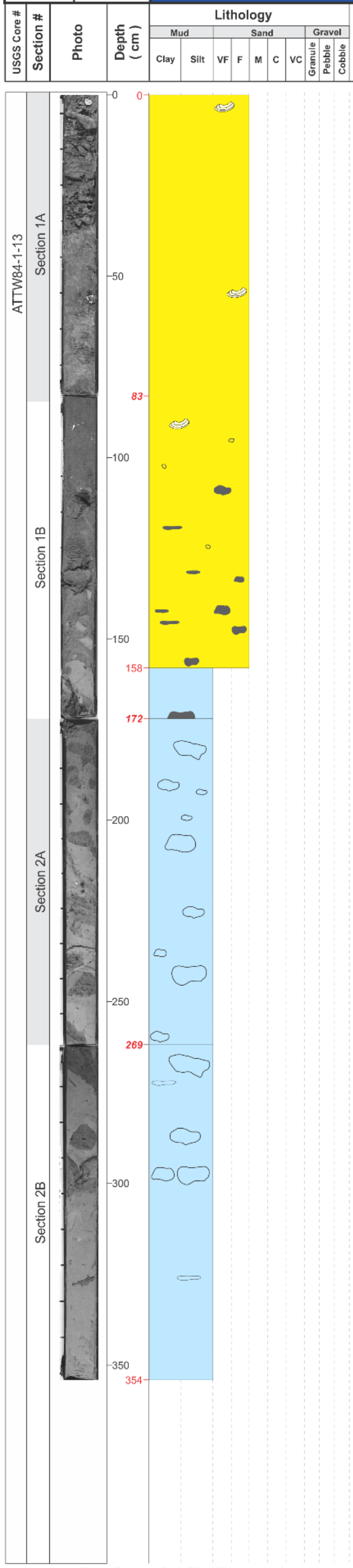
Birch, 1986 Interpreted the depositional environment as:	Birch, 1986 Interpreted the entire core as:
	Unit 4
Sand mounds since the last post-glacial lowstand.	Holocene sand sheets and mounds.

Original Reference: Birch, F.S. 1986b. Vibracores from the inner continental shelf of New Hampshire. Final Report to U.S. Department of Interior, Minerals Management Service Continental Margins Program, Cooperative Agreement # 14-12-0001-30115, Herdon, VA.

UNH-13

U.S.G.S Field Activity #: 1984-016-FA

Latitude: 42.98500 Longitude: -70.67000



DESCRIPTION

Fine Sand. Dusky yellow green (5GY4/2). ~90% Quartz, sub-angular, massive with faint mottling through out; large shell fragments.

Khan Description: **Medium Sand**. Light gray (N7), moderately sorted, zone of fossil shell fragments up to 20 cm thick at top and at 1 m.

New core section. **Fine Sand**. Dusky yellow green (5GY4/2). Numerous shell fragments; cm-scale clay lenses and compacted pods; rock fragments up to 3 cm.

Khan Description: **Medium Sand**. Light gray (N7), moderately sorted, zone of fossil shell fragments up to 20 cm thick at top and at 1 m.

Clayey Silt or Silty Clay . Dusky yellow green (5GY4/2). Distinct contact; very compact 10-cm clay or silt pod at base with iron staining.

New Core Section. **Clayey Silt or Silty Clay.** Dusky yellow green (5GY4/2). Very compact zone at 208 cm; Fine sand pods or lenses irregularly spaced throughout core; decreasing in occurrence towards base of section; iron staining in compact zones.

New Core Section. **Clayey Silt or Silty Clay.** Dusky yellow green (5GY4/2). Fine sand lenses and pods at top and 284 cm.

Sample Depth (cm)	1989 Samples GSM (%) Gravel	Sand	Mud	Sand Fraction Mean Phi	Sorting Phi	2016 Samples GSM (%) Gravel	Sand	Mud	Mean Phi	Sorting Phi
20	0.2	90.1	9.7							
250	0	21.7	78.2							

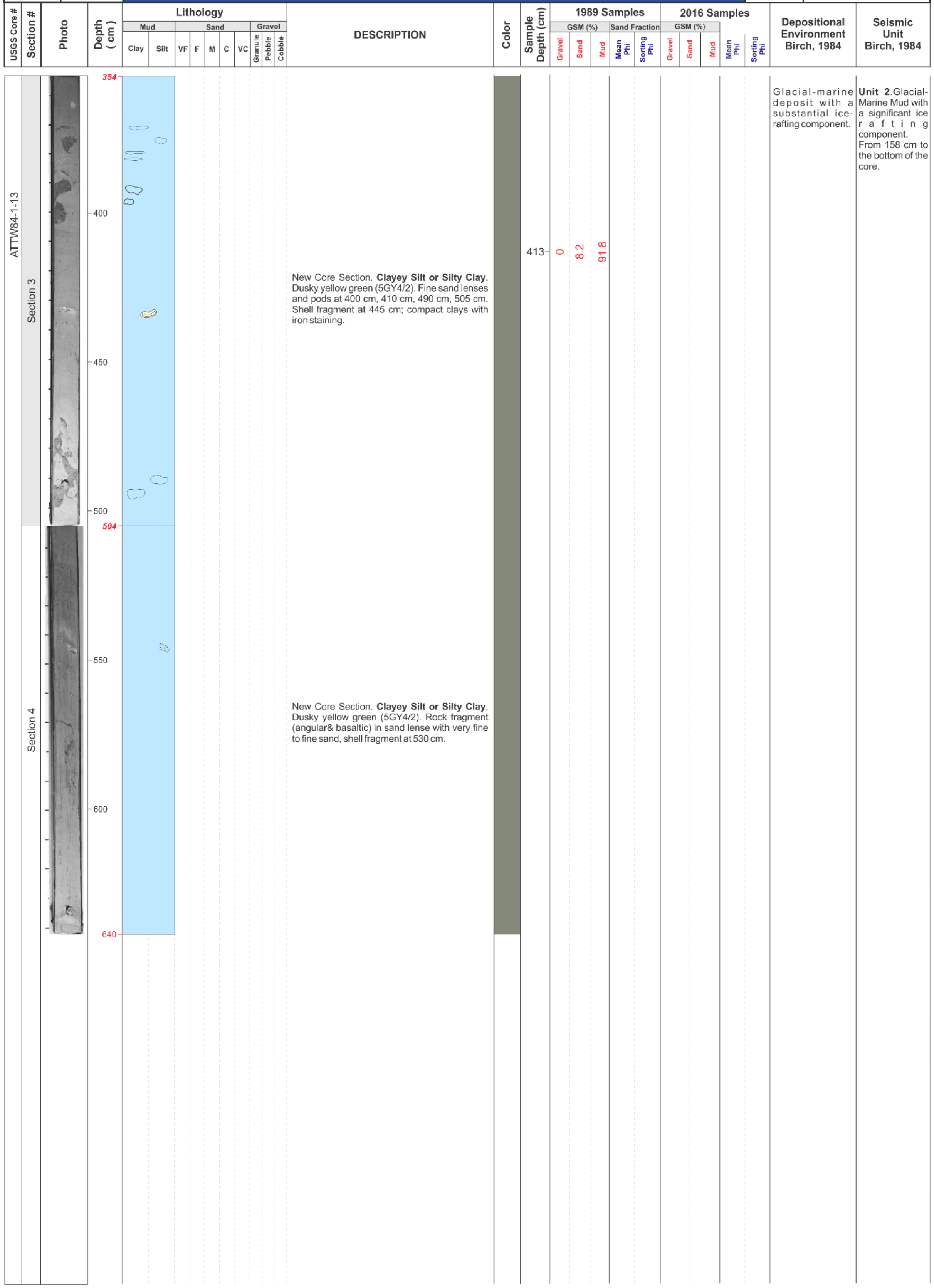
Depositional Environment Birch, 1984	Seismic Unit Birch, 1984
Sand mounds since the last post-glacial lowstand.	**Unit 4.** Holocene sand sheets and mounds. From the top of the core up to 158 cm.
Glacial-marine deposit with a substantial ice-rafting component.	**Unit 2.** Glacial-Marine Mud with a significant ice rafting component. From 158 cm to the bottom of the core.

Original Reference: Birch, F.S. 1986b. Vibracores from the inner continental shelf of New Hampshire. Final Report to U.S. Department of Interior, Minerals Management Service Continental Margins Program, Cooperative Agreement # 14-12-0001-30115, Herdon, VA.

UNH-13

U.S.G.S Field Activity #: 1984-016-FA

Latitude: 42.98500 Longitude: -70.67000



New Core Section. **Clayey Silt or Silty Clay.** Dusky yellow green (5GY4/2). Fine sand lenses and pods at 400 cm, 410 cm, 490 cm, 505 cm. Shell fragment at 445 cm; compact clays with iron staining.

New Core Section. **Clayey Silt or Silty Clay.** Dusky yellow green (5GY4/2). Rock fragment (angular& basaltic) in sand lense with very fine to fine sand, shell fragment at 530 cm.

Sample Depth (cm)	Gravel	Sand	Mud
413	0	8.2	91.8

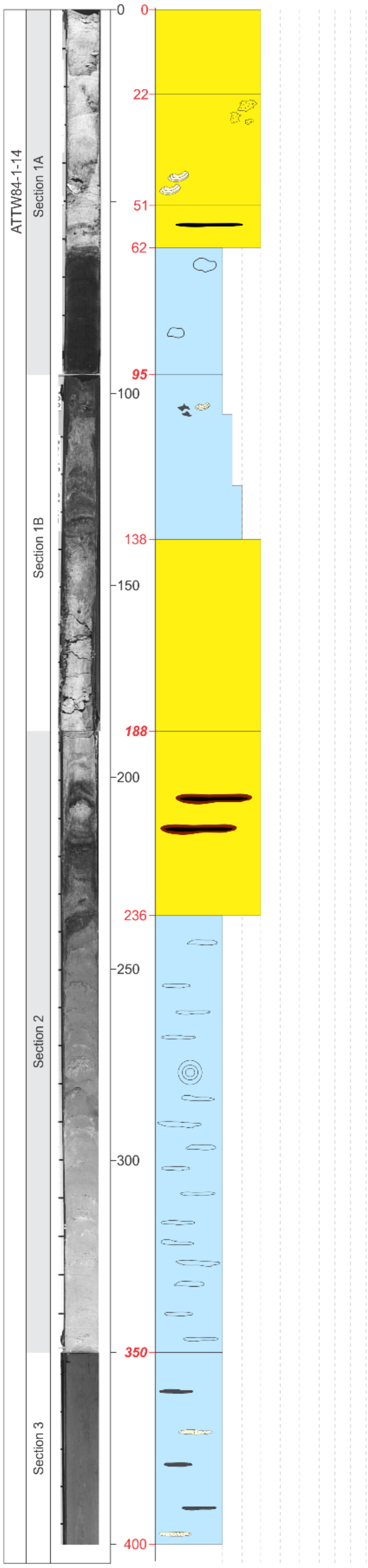
Depositional Environment Birch, 1984: Glacial-marine deposit with a substantial ice-rafting component.

Seismic Unit Birch, 1984: **Unit 2.** Glacial-Marine Mud with a significant ice rafting component. From 158 cm to the bottom of the core.

Original Reference: Birch, F.S. 1986b. Vibracores from the inner continental shelf of New Hampshire. Final Report to U.S. Department of Interior, Minerals Management Service Continental Margins Program, Cooperative Agreement # 14-12-0001-30115, Herdon, VA.

UNH-14

U.S.G.S Field Activity #: 1984-016-FA
Latitude: 42.92833 Longitude: -70.76000



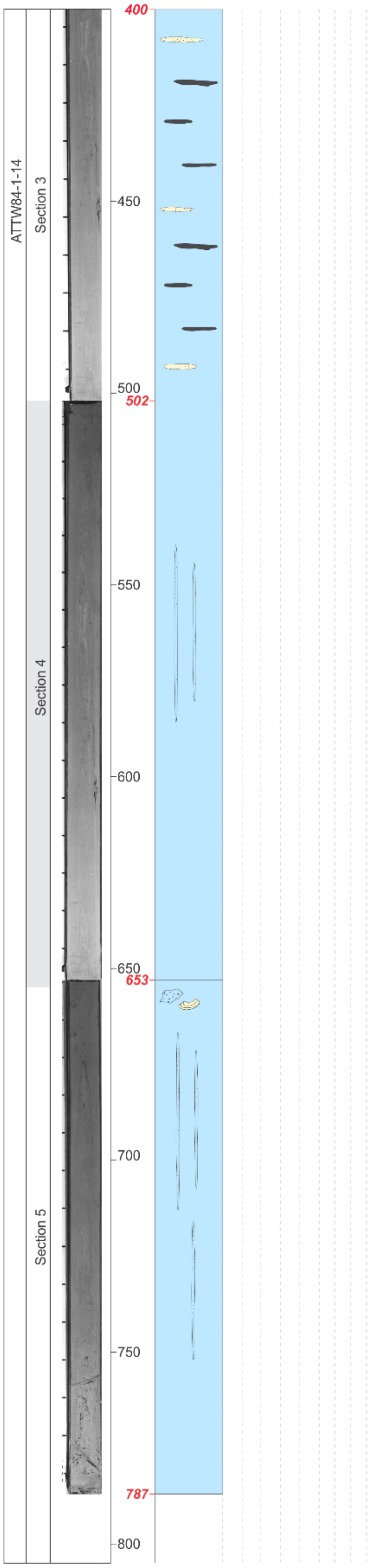
USGS Core #	Section #	Depth (cm)	DESCRIPTION	Sample Depth (cm)	1989 Samples GSM (%) Gravel	Sand	Mud	Depositional Environment Birch, 1984	Seismic Unit Birch, 1984
ATTW84-1-14	Section 1A	0–22	**Fine Sand**. Light yellowish brown (10YR6/4). Shell fragments at 14 cm.						
		22–51	**Fine Sand**. Yellowish gray (5Y7/2). Distinct contact; shell fragments at the base of layer; rock fragments up to 6.4 cm at 23 cm depth. 3.6% Silt and 3.4% Clay.	30	0.1	92.9	7.0	Sand mounds since the last post-glacial lowstand.	**Unit 4**.Holocene sand sheets and mounds.
		51–62	**Fine Sand**. Yellowish gray (5Y7/2). Distinct contact; one biotite-rich lens.						
		62–95	**Silt**. Dusky Yellowish Brown (10YR2/2). Organic rich; two pods of very fine sand with iron stain .						
	Section 1B	95–138	New core section. **Silt**. Dusky Yellowish Brown (10YR2/2). grading down to very fine to fine sand; shell fragments and peat at 103 cm.						
		138–188	**Very Fine Sand to Fine Sand**. Dusky Light olive gray (5Y5/2). 11.1% Silt and 2.3% Clay.	155	0	86.7	13.4	Sand mounds since the last post-glacial lowstand.	**Unit 4**.Holocene sand sheets and mounds.
	Section 2	188–236	New core section. **Very Fine Sand to Fine Sand**. Dusky Light olive gray (5Y5/2); two biotite rich lenses with surrounding iron stains.						
		236–350	**Silty Clay or Clayey Silt**. (5GY4/2). Numerous sand lenses, thinner than 1 cm; 5 cm concretion at 280 cm.					Glacial-marine deposit with a substantial ice-rafting component.	**Unit 2**.Glacial-Marine Mud with a significant ice rafting component. From 236 cm to the bottom of the core.
	Section 3	350–400	New core section. **Silty Clay or Clayey Silt** (48.1% Silt, 48.7% clay). (5GY4/2). A few pods of silt and very fine sand; some contains shell						

Original Reference: Birch, F.S. 1986b. Vibracores from the inner continental shelf of New Hampshire. Final Report to U.S. Department of Interior, Minerals Management Service Continental Margins Program, Cooperative Agreement # 14-12-0001-30115, Herdon, VA.

UNH-14

U.S.G.S Field Activity #: 1984-016-FA
Latitude: 42.92833 Longitude: -70.76000

USGS Core # | Section # | Photo | Depth (cm) | Lithology: Mud (Clay, Silt); Sand (VF, F, M, C, VC); Gravel (Granule, Pebble, Cobble) | DESCRIPTION | Color | Sample Depth (cm) | 1989 Samples: GSM (%) (Gravel, Sand, Mud); Sand Fraction (Mean Phi, Sorting Phi) | 2016 Samples: GSM (%) (Gravel, Sand, Mud); Mean Phi; Sorting Phi | Depositional Environment Birch, 1984 | Seismic Unit Birch, 1984



Continue from section 3. **Silty Clay or Clayey Silt** (48.1% Silt, 48.7% clay). (5GY4/2). A few pods of silt and very fine sand; some contains shell fragments.

New Core Section. **Silty Clay or Clayey Silt** (45.4% Silt, 52.9% clay). (5GY4/2). Vertical streak of very fine sand from 555 cm to 592 cm.

New Core Section. **Silty Clay or Clayey Silt** (39.3% Silt, 54.9% clay). (5GY4/2). Shell fragments at 660 cm; rock fragment at 660 cm (1.5 cm); few vertical sand streaks.

Sample Depth (cm)	Gravel	Sand	Mud
410	0	3.2	96.8
531	0	1.7	98.3
733	0	5.7	94.2

Depositional Environment Birch, 1984: Glacial-marine deposit with a substantial ice-rafting component.

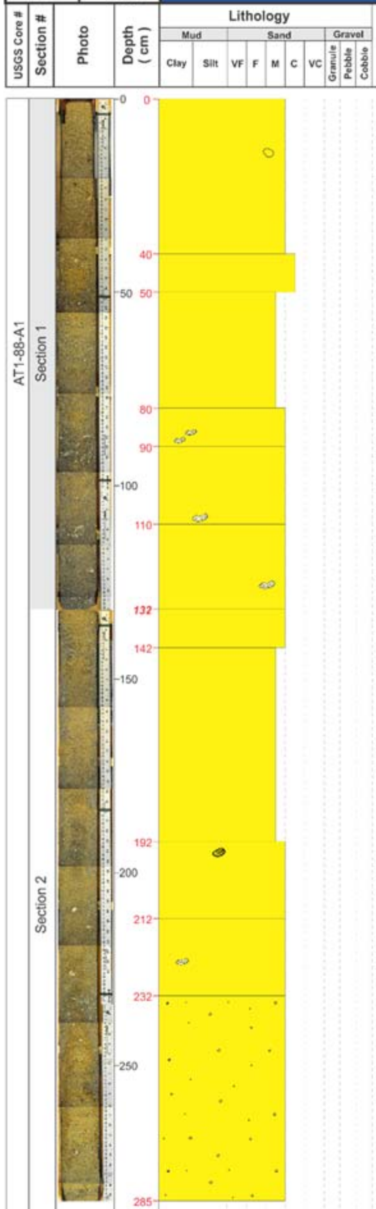
Seismic Unit Birch, 1984: **Unit 2**. Glacial-Marine Mud with a significant ice rafting component. From 236 cm to the bottom of the core.

Original Reference: Birch, F.S. 1986b. Vibracores from the inner continental shelf of New Hampshire. Final Report to U.S. Department of Interior, Minerals Management Service Continental Margins Program, Cooperative Agreement # 14-12-0001-30115, Herdon, VA.

A1

U.S.G.S Field Activity #: 1988-017-FA

Latitude: 42.9950 Longitude: -70.6433



DESCRIPTION

Medium to Coarse Sand. Moderate brown (5YR4/4) to moderate yellow brown color; coarse sand (0.5-1 mm) in top 10 cm; poorly sorted; occasional shell fragments; 1 rock fragment, pebble (2.5 cm) at ~15 cm; coarsening upward; mainly quartz.

Medium to Very Coarse Sand. Darker color than layer above; poorly sorted; shell fragments.

Medium Sand. Light olive gray (5Y5/2); small amount of coarse sand; moderately poorly to poorly sorted; mainly quartz.

Medium to Coarse Sand. Light olive gray (5Y5/2); grain sizes range from 0.25 to 1.00 mm; shell fragments in upper part; mainly quartz.

Medium to Coarse Sand. Light olive gray (5Y5/2); grain sizes range from 0.25 to 1 mm; sand dollar fragments at ~90 cm; mainly quartz.

Medium to Coarse Sand. Light olive gray to olive gray (5Y5/2 to 5Y3/2); moderately to poorly sorted in upper part; poorly sorted lower part; shell fragments in upper part; sand dollar fragment at ~130 cm; mainly quartz.

New core section. **Medium to Coarse Sand.** Light olive gray to olive gray (5Y5/2 to 5Y3/2); shell fragments at base; sand dollar fragments mainly quartz with dark mineral grains; small amount of coarse sand.

Medium Sand. Olive gray (5Y3/2); shell fragments common throughout; grains range from 0.25-0.5 mm; small amount of coarse sand (0.5 to1.0 mm).

Medium to Coarse Sand. Olive gray (5Y3/2); poorly sorted quartz sand; shell fragments common; large clam shell at ~195 cm.

Medium to Coarse Sand. Olive gray (5Y3/2); poorly sorted; shell fragments common; spiral shell fragments; sand dollar fragments.

Medium to Coarse Sand. Light olive gray (5Y5/2) to grayish olive (10Y4/2); poorly sorted; shell fragments common, few pebbles.

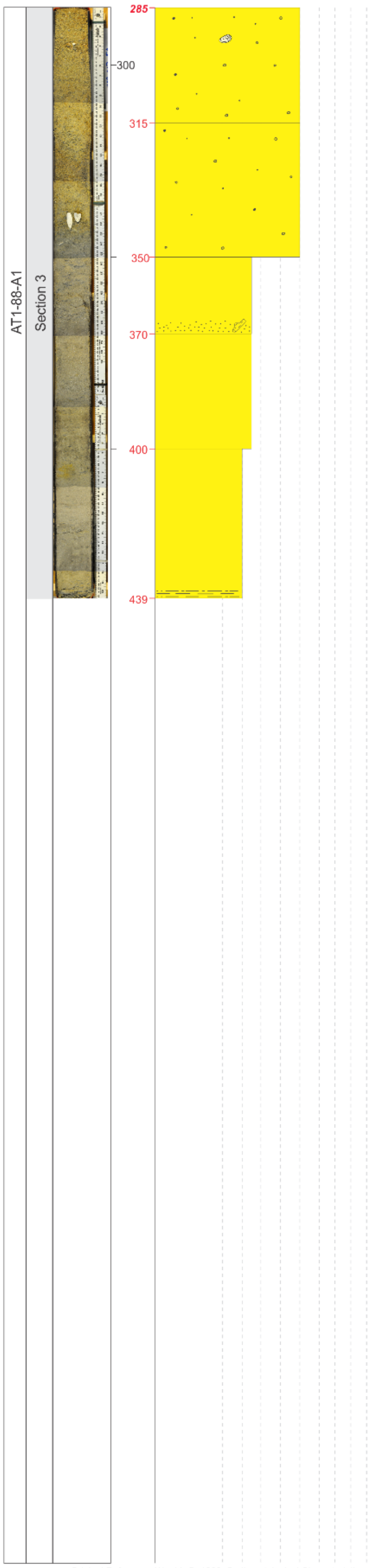
Sample Depth (cm)	1989 Samples					2016 Samples				
	GSM (%)			Sand Fraction		GSM (%)				
	Gravel	Sand	Mud	Mean Phi	Sorting Phi	Gravel	Sand	Mud	Mean Phi	Sorting Phi
5	3.0	97.0	1.0	1.0	0.54					
70	< 1.0	98.0	< 1.0	1.3	0.47					
200	1.0	98.0	1.0	1.1	0.5					

Depositional Environment Birch, 1984	Seismic Unit Birch, 1984
Sand mounds since the last post-glacial lowstand.	**Unit 4**.Holocene sand sheets and mounds. From the top of the core to the bottom.

Original Reference: Ward L.G. 1989. Sedimentological Characteristics of Vibracores Taken in Sand and Gravel Deposits on the Inner Continental Shelf of New Hampshire: Final Report on Minerals Management Service Cooperative Agreement 14-12-0001-30316 pp. 22

A1

U.S.G.S Field Activity #: 1988-017-FA
Latitude: 42.9950 Longitude: -70.6433



DESCRIPTION

New core section. **Medium to Very Coarse Sand.** Light olive gray to olive gray (5Y5/2 to 5Y3/2); very poorly sorted, grains range from 0.25-1 mm; few pebbles up to 5 mm in size; occasional shell fragments in lower half; clam shell fragments.

Fine to Very Coarse Sand. Slightly darker olive gray than layer above (5Y3/2); occasional pebbles up to 9 mm; shell fragments in lower part.

Fine Sand. Light olive gray (5Y6/1); some coarse grains 1- 2 mm, poorly sorted; mica flakes up to 4 mm; coarse sand layer near bottom; contains woody stems.

Fine Sand. Medium light gray to olive gray (N6 to 5Y4/2); moderate sorted towards top and moderate to well-sorted towards bottom, fine quartz sand ranging from 0.12-0.25 mm; mica content very high in places, some thin light and dark layers in basal part, mottled at base.

Fine to Very Fine Sand. Medium gray to dark gray (5Y4/1 to N5); moderate sorted; thin dark layers between 415 to 420 cm; coarse to very coarse mica rich olive gray layer; at 420 cm; mottled below the mica layer; lower 10 cm shows some mud content; mud ball at base.

Sample Depth (cm)	1989 Samples					2016 Samples				
	GSM (%)			Sand Fraction		GSM (%)				
	Gravel	Sand	Mud	Mean Phi	Sorting Phi	Gravel	Sand	Mud	Mean Phi	Sorting Phi
310	6.0	93.0	1.0	0.9	0.77					
390	0	95.0	5.0	2.2	0.52					

Depositional Environment Birch, 1984

Sand mounds since the last post-glacial low-stand.

Seismic Unit Birch, 1984

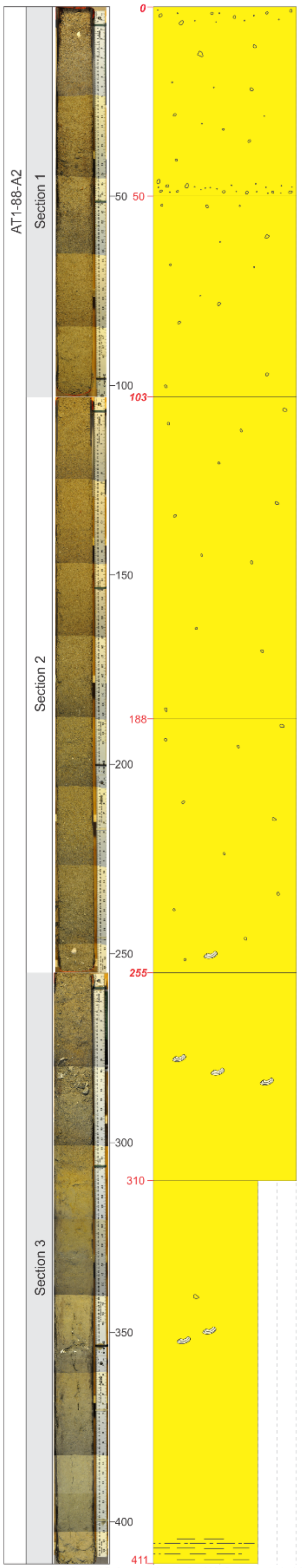
Unit 4. Holocene sand sheets and mounds. From the top of the core to the bottom.

Original Reference: Ward L.G. 1989. Sedimentological Characteristics of Vibracores Taken in Sand and Gravel Deposits on the Inner Continental Shelf of New Hampshire: Final Report on Minerals Management Service Cooperative Agreement 14-12-0001-30316 pp. 22

A2

U.S.G.S Field Activity #: 1988-017-FA

Latitude: 42.9867 Longitude: -70.6467



DESCRIPTION

Medium to Coarse Sand. Grayish orange (10YR7/4), moderate yellow brown to dark yellowish brown (10YR4/2) towards base; poorly sorted medium to coarse quartz sand with occasional pebbles (4-8 mm); some fine and very coarse sand also present.

Fine to Coarse Sand. Dark yellowish brown (10YR4/2); poorly sorted quartz sand, some very coarse sand; occasional pebbles (2-5 mm), occasional mica flecks; few shell fragments.

New core section**. Medium to Coarse Sand.** Light olive gray (5Y5/2) to olive gray (5Y3/2); poorly sorted; occasional pebbles (~ 2 to 7 mm), very small shell fragments; mica flecks at 180 cm; some fine sand.

Fine to Coarse Sand. Light olive gray (5Y5/2) to grayish olive (10Y4/2) in upper part and olive gray (5Y3/2) to dark gray (N3) in lower part; poorly sorted quartz sand; scattered mica flecks decreasing downward; occasional pebbles to 5 mm; occasional shell fragments.

New core section. **Fine to Coarse Sand.** Olive gray (5Y4/1) to dark gray in upper part, olive gray to olive black (5Y2/1) in lower part; medium to coarse grained towards top and fine to coarse grained towards base; poorly sorted quartz sand; shell fragments common; mica flecks up to 3 mm common throughout.

Very Fine to Fine Sand. Olive gray (5Y4/1) to olive black (5Y2/1); moderate to well sorted; organic matter with shell debris common, scattered mica flecks and biotite grains; fine grained towards base with some mud, one pebble at 340 cm.

Color

Sample Depth (cm)	1989 Samples					2016 Samples				
	GSM (%)			Sand Fraction		GSM (%)				
	Gravel	Sand	Mud	Mean Phi	Sorting Phi	Gravel	Sand	Mud	Mean Phi	Sorting Phi
5	1.0	98.0	1.0	1.4	0.48					
50	3.0	96.0	1.0	1.2	0.53					
170	1.0	98.0	1.0	1.3	0.53					
310	0	92.0	8.0	2.6	0.61					
390	0	89.0	11.0	3.0	0.36					

Depositional Environment Birch, 1984

Sand mounds since the last post-glacial lowstand.

Seismic Unit Birch, 1984

Unit 4. Holocene sand sheets and mounds. From top of the bottom.

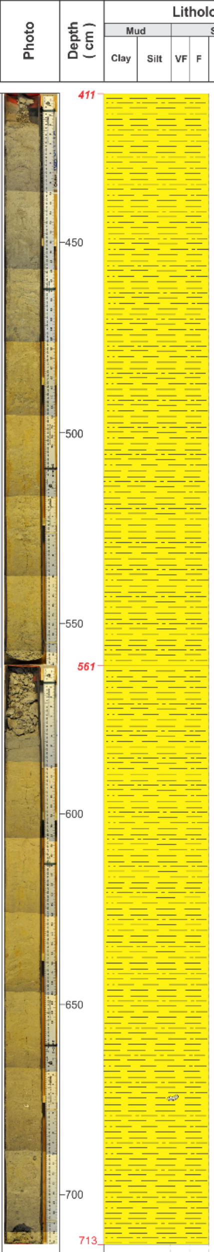
Original Reference: Ward L.G. 1989. Sedimentological Characteristics of Vibracores Taken in Sand and Gravel Deposits on the Inner Continental Shelf of New Hampshire: Final Report on Minerals Management Service Cooperative Agreement 14-12-0001-30316 pp. 22

A2

U.S.G.S Field Activity #: 1988-017-FA
Latitude: 42.9867 Longitude: -70.6467

USGS Core #: AT1-88-A2

Section 4 (411–561 cm); Section 5 (561–713 cm)



DESCRIPTION

New core section. **Very Fine to Fine Sand, with Mud.** Light olive gray (5Y6/1) to olive gray (5Y4/1); moderately well sorted, dark patches in upper 40 cm , moderately stained, dark thin line may be mud or peat at ~520 cm, shell fragments common.

New core section. Very Fine to Fine Sand, with Mud. Olive gray (5Y4/1) to olive black (5Y2/1) in lower part; moderately well sorted; shell fragments, mica flecks with few biotite flecks common throughout.

Sample Depth (cm)	1989 Samples GSM (%) Gravel	Sand	Mud	Sand Fraction Mean Phi	Sorting Phi	2016 Samples GSM (%) Gravel	Sand	Mud	Mean Phi	Sorting Phi
500	0	76.0	24.0	3.2	0.34					
700	3.0	35.0	62.0	3.0	0.78					

Depositional Environment Birch, 1984

Sand mounds since the last post-glacial lowstand.

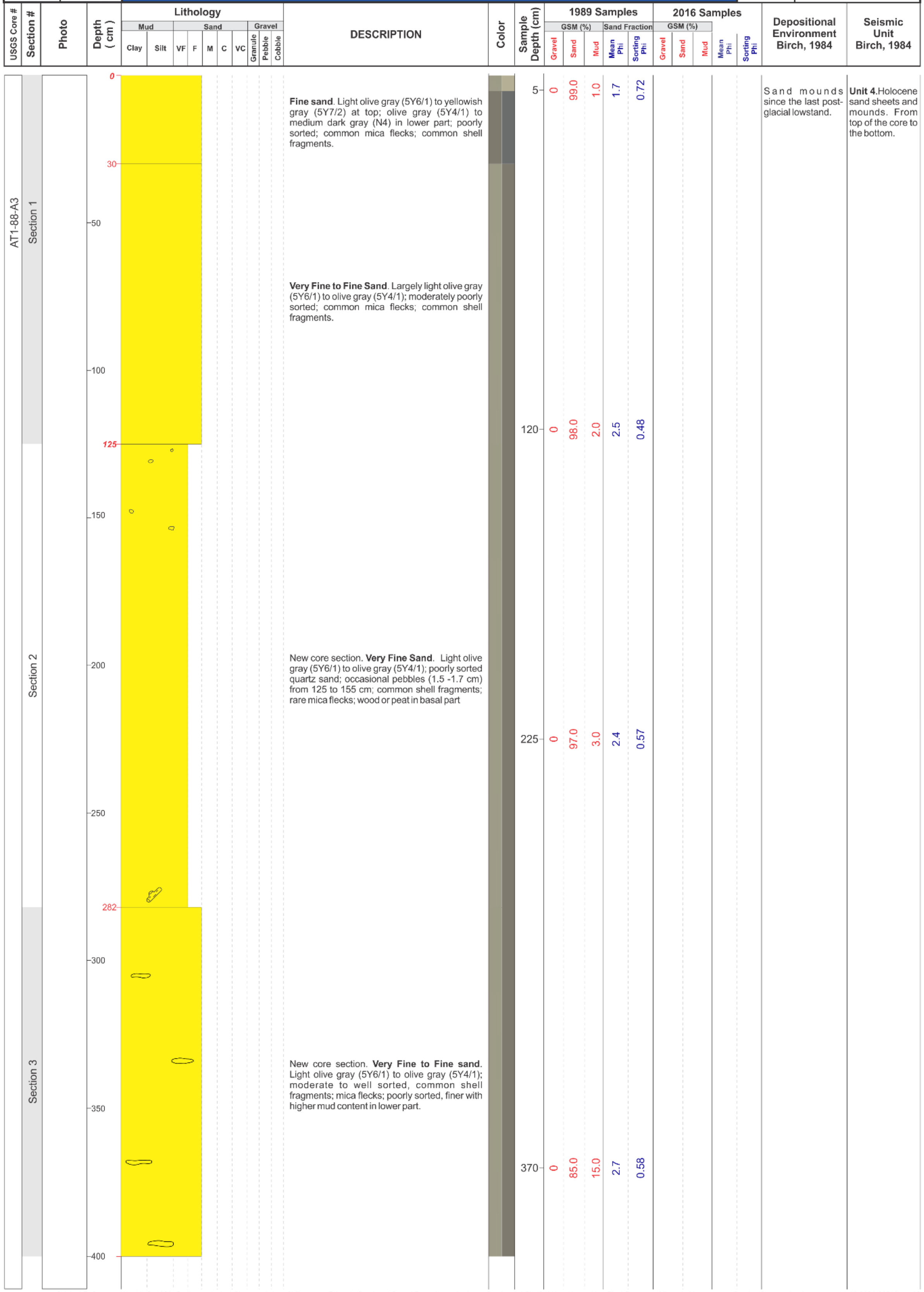
Seismic Unit Birch, 1984

Unit 4. Holocene sand sheets and mounds. From top of the bottom.

Original Reference: Ward L.G. 1989. Sedimentological Characteristics of Vibracores Taken in Sand and Gravel Deposits on the Inner Continental Shelf of New Hampshire: Final Report on Minerals Management Service Cooperative Agreement 14-12-0001-30316 pp. 22

A3

U.S.G.S Field Activity #: 1988-017-FA
Latitude: 42.9833 Longitude: -70.6600



Fine sand. Light olive gray (5Y6/1) to yellowish gray (5Y7/2) at top; olive gray (5Y4/1) to medium dark gray (N4) in lower part; poorly sorted; common mica flecks; common shell fragments.

Very Fine to Fine Sand. Largely light olive gray (5Y6/1) to olive gray (5Y4/1); moderately poorly sorted; common mica flecks; common shell fragments.

New core section. **Very Fine Sand**. Light olive gray (5Y6/1) to olive gray (5Y4/1); poorly sorted quartz sand; occasional pebbles (1.5 -1.7 cm) from 125 to 155 cm; common shell fragments; rare mica flecks; wood or peat in basal part

New core section. **Very Fine to Fine sand**. Light olive gray (5Y6/1) to olive gray (5Y4/1); moderate to well sorted, common shell fragments; mica flecks; poorly sorted, finer with higher mud content in lower part.

Sample Depth (cm)	Gravel	Sand	Mud	Mean Phi	Sorting Phi
5	0	99.0	1.0	1.7	0.72
120	0	98.0	2.0	2.5	0.48
225	0	97.0	3.0	2.4	0.57
370	0	85.0	15.0	2.7	0.58

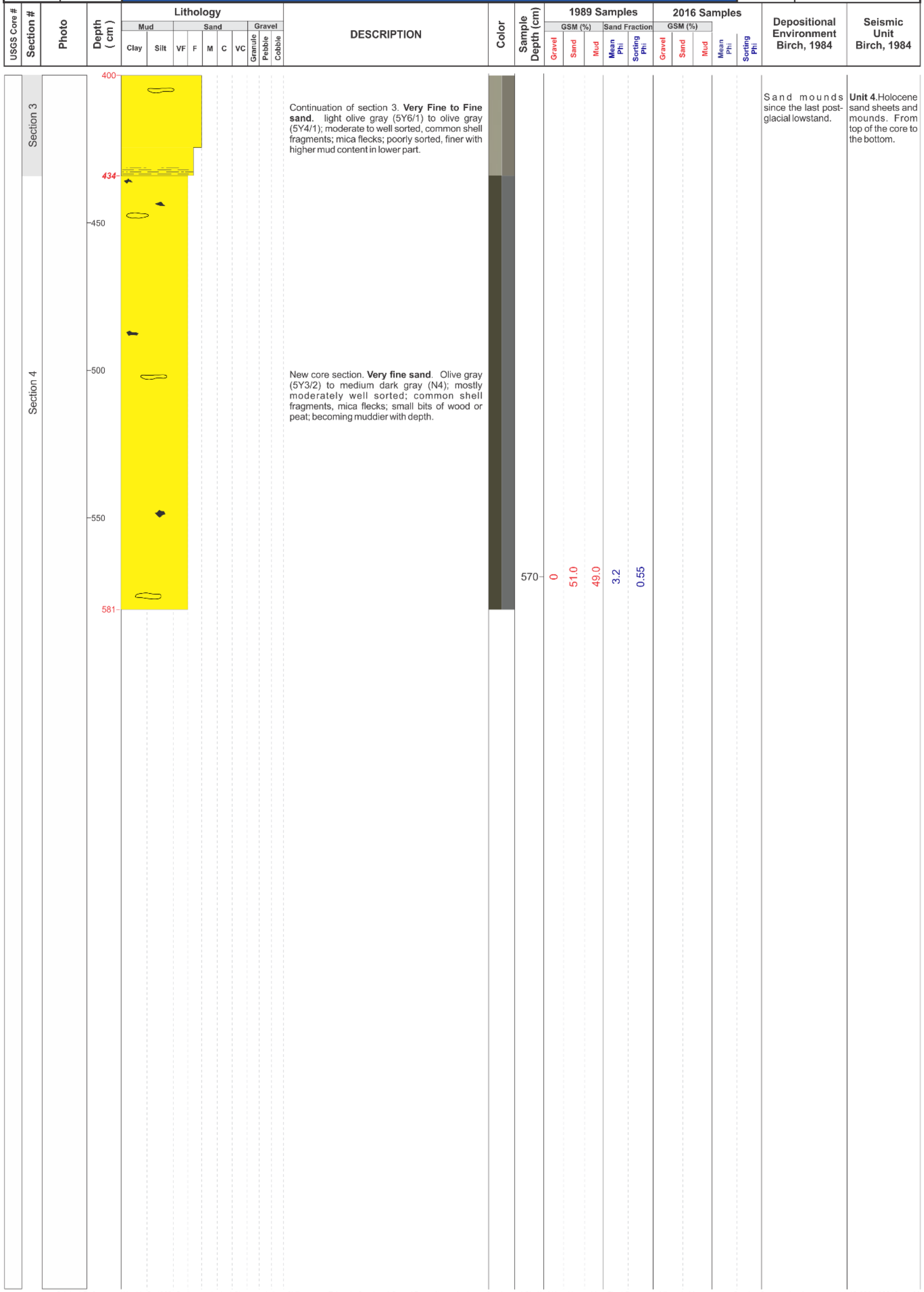
Depositional Environment Birch, 1984: Sand mounds since the last post-glacial lowstand.

Seismic Unit Birch, 1984: **Unit 4.**Holocene sand sheets and mounds. From top of the core to the bottom.

Original Reference: Ward L.G. 1989. Sedimentological Characteristics of Vibracores Taken in Sand and Gravel Deposits on the Inner Continental Shelf of New Hampshire: Final Report on Minerals Management Service Cooperative Agreement 14-12-0001-30316 pp. 22

A3

U.S.G.S Field Activity #: 1988-017-FA
Latitude: 42.9833 Longitude: -70.6600



Sample Depth (cm)	1989 Samples GSM (%) Gravel	Sand	Mud	Sand Fraction Mean Phi	Sorting Phi	2016 Samples GSM (%) Gravel	Sand	Mud	Mean Phi	Sorting Phi
570	0	51.0	49.0	3.2	0.55					

Continuation of section 3. **Very Fine to Fine sand.** light olive gray (5Y6/1) to olive gray (5Y4/1); moderate to well sorted, common shell fragments; mica flecks; poorly sorted, finer with higher mud content in lower part.

New core section. **Very fine sand**. Olive gray (5Y3/2) to medium dark gray (N4); mostly moderately well sorted; common shell fragments, mica flecks; small bits of wood or peat; becoming muddier with depth.

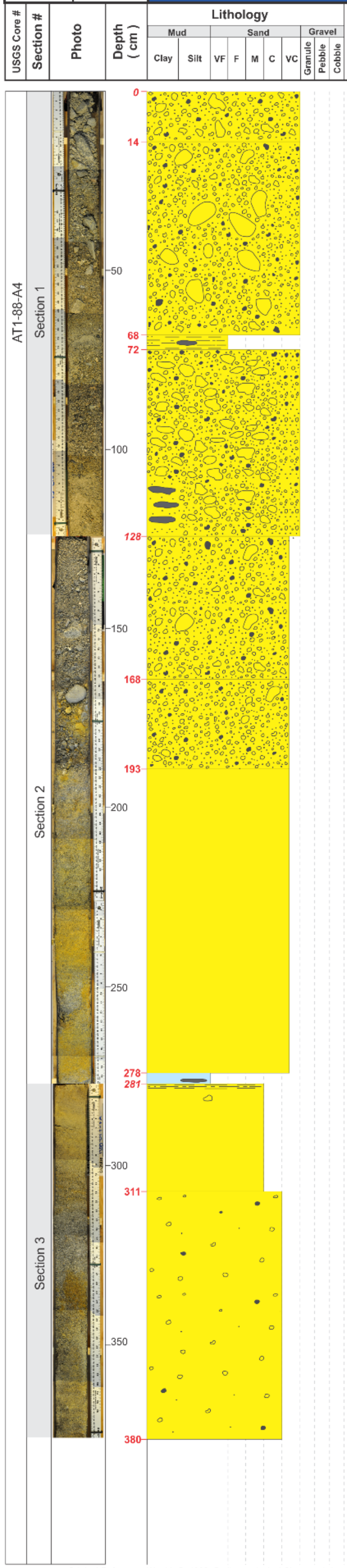
Depositional Environment Birch, 1984	Seismic Unit Birch, 1984
Sand mounds since the last post-glacial lowstand.	**Unit 4.** Holocene sand sheets and mounds. From top of the core to the bottom.

Original Reference: Ward L.G. 1989. Sedimentological Characteristics of Vibracores Taken in Sand and Gravel Deposits on the Inner Continental Shelf of New Hampshire: Final Report on Minerals Management Service Cooperative Agreement 14-12-0001-30316 pp. 22

A4

U.S.G.S Field Activity #: 1988-017-FA

Latitude: 43.0067 Longitude: -70.6717



DESCRIPTION

Fine to Very Coarse Sand - Gravelly. Light olive gray (5Y6/1) to olive black (5Y2/1); poorly sorted; scattered pebbles (up to 1 cm) in upper half; pebbles and cobbles (4.3 cm) in lower half; large cobble at surface (8 cm).

Medium to Very Coarse Sand - Gravelly. Olive gray (5Y4/1) to light olive gray (5Y6/1); very-poorly sorted; pebbles and cobbles (6.5 cm); dropstones (up to 9.5 cm) at 30 - 40 cm, occasional shell fragments.

Very Fine Sand and Mud Olive gray (5Y4/1); mud lense.

Medium to Very Coarse Sand - Gravel. Olive gray (5Y4/1) to light olive gray (5Y6/1); very poorly sorted; coarse to very coarse grains with fine sand matrix along; very common pebbles and cobbles to ~4 cm; shell fragments; mud lense from ~110 to 125 cm.

New core section. **Very Coarse Sand**. Olive gray (5Y4/1) to light olive gray (5Y6/1); very poorly sorted; pebbles and cobbles common (2-8 cm); shell fragments common.

Coarse to Very Coarse Sand - Gravelly. Olive black (5Y2/1) to medium dark gray (N4); very poorly sorted; scattered shell fragments; common pebbles (up to 3.5 cm); some cobbles; mud lense with fine sand at base with sharp contact.

Very Coarse Sand - Gravelly. Olive black (5Y2/1) to medium dark gray (N4); very poorly sorted; scattered shell fragments; common pebbles (up to 3.5 cm); some cobbles; mud lense with fine sand at base with sharp contact.

Mud. Olive gray (5Y4/1); mud lense at the base.

New core section. **Medium Sand**. Olive gray (5Y4/1); top 1cm olive black (5Y2/1); upper 1 cm has muddy sand; poorly sorted; 1 pebble (2 cm).

Coarse Sand. Olive gray (5Y4/1); scattered small pebbles.

Sample Depth (cm)	1989 Samples GSM (%) Gravel	Sand	Mud	Sand Fraction Mean Phi	Sorting Phi	2016 Samples GSM (%) Gravel	Sand	Mud	Mean Phi	Sorting Phi
30	28.0	70.0	2.0	0.7	0.79					
220	6.0	91.0	3.0	1.2	0.97					
350	2.0	96.0	2.0	1.2	0.7					

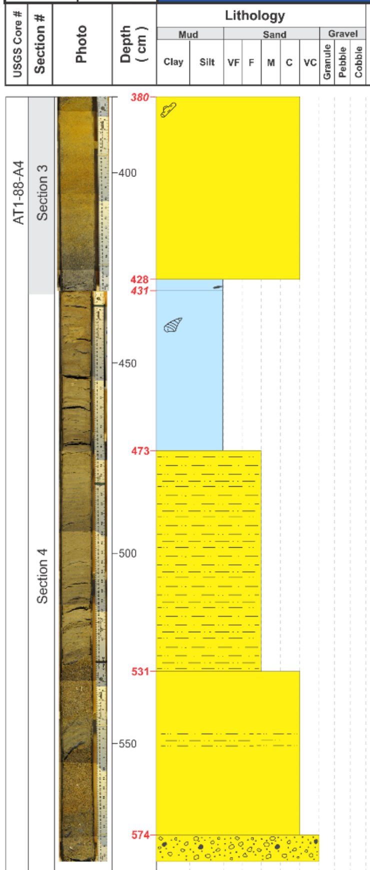
Depositional Environment Birch, 1984	Seismic Unit Birch, 1984
Sand mounds since the last post-glacial lowstand.	**Unit 4**. Holocene sand sheets and mounds. From top of the core to the bottom.

Original Reference: Ward L.G. 1989. Sedimentological Characteristics of Vibracores Taken in Sand and Gravel Deposits on the Inner Continental Shelf of New Hampshire: Final Report on Minerals Management Service Cooperative Agreement 14-12-0001-30316 pp. 22

A4

U.S.G.S Field Activity #: 1988-017-FA

Latitude: 43.0067 Longitude: -70.6717



DESCRIPTION

Continuation of section 3. Medium to Coarse Sand. Olive gray (5Y4/1); one wood fragment; mud lense at ~430 cm (~4 cm thick) to end of section.

Mud. Mud lense with sand pods inside one.

New core section. **Mud**. Olive gray (5Y4/1) to olive black (5Y2/1); shell hash in upper part; occasional organic (dark) spots; gastropod test at~440 cm.

Fine Sand with Mud. Olive gray (5Y4/1); common mica flecks, muddy lense in bottom part; sharp unconformity at base.

Coarse Sand. Medium dark gray (N4) to dark gray (N3); gradational contact with muddy lense (2.5 cm thick) at ~550 cm depth; coarse sand below lense.

Very Coarse Sand - Gravelly. Grayish Black (N2); very coarse to gravelly sand; common

Sample Depth (cm)	1989 Samples GSM (%) Gravel	Sand	Mud	Sand Fraction Mean Phi	Sorting Phi	2016 Samples GSM (%) Gravel	Sand	Mud	Mean Phi	Sorting Phi
470	0	17.0	83.0	3.0	0.76					

Depositional Environment Birch, 1984

Sand mounds since the last post-glacial lowstand.

Seismic Unit Birch, 1984

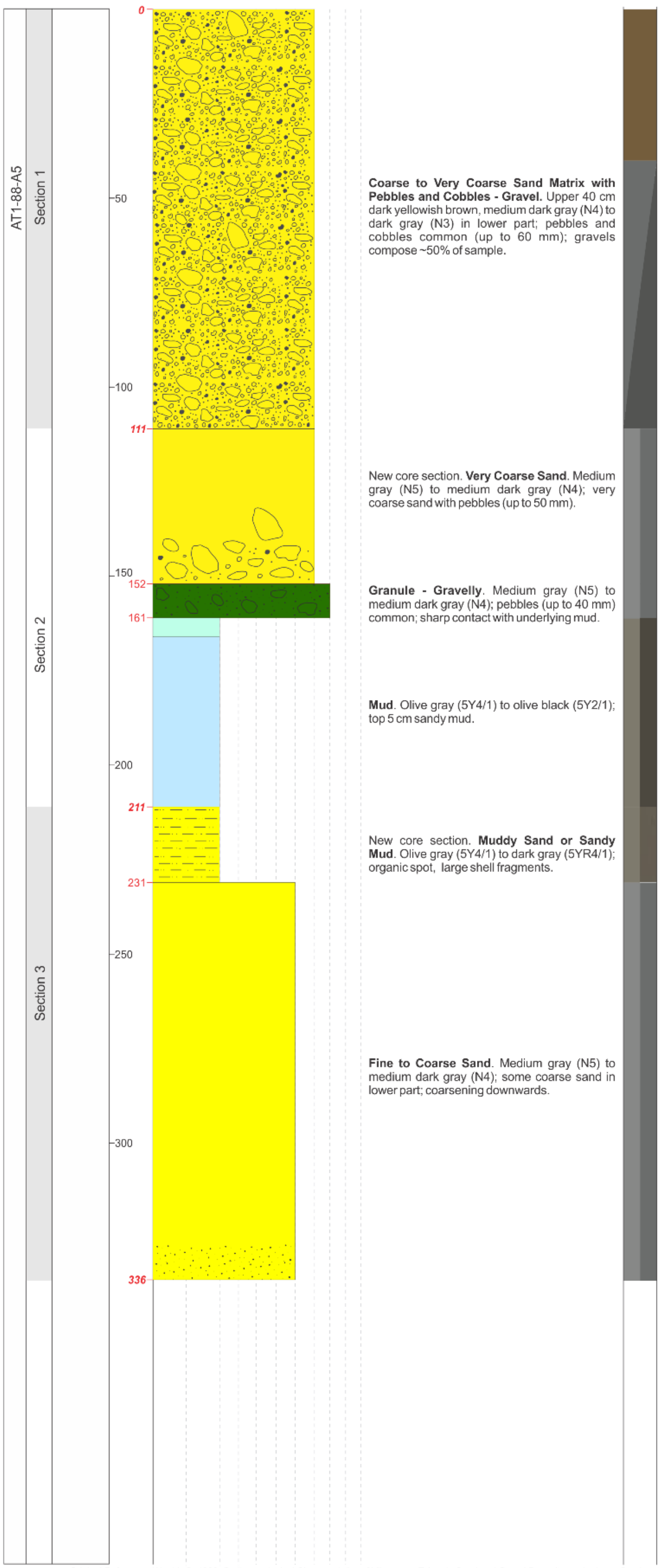
Unit 4.Holocene sand sheets and mounds. From top of the core to the bottom.

Original Reference: Ward L.G. 1989. Sedimentological Characteristics of Vibracores Taken in Sand and Gravel Deposits on the Inner Continental Shelf of New Hampshire: Final Report on Minerals Management Service Cooperative Agreement 14-12-0001-30316 pp. 22

A5

U.S.G.S Field Activity #: 1988-017-FA

Latitude: 43.0033 Longitude: -70.6667



DESCRIPTION

Coarse to Very Coarse Sand Matrix with Pebbles and Cobbles - Gravel. Upper 40 cm dark yellowish brown, medium dark gray (N4) to dark gray (N3) in lower part; pebbles and cobbles common (up to 60 mm); gravels compose ~50% of sample.

New core section. **Very Coarse Sand**. Medium gray (N5) to medium dark gray (N4); very coarse sand with pebbles (up to 50 mm).

Granule - Gravelly. Medium gray (N5) to medium dark gray (N4); pebbles (up to 40 mm) common; sharp contact with underlying mud.

Mud. Olive gray (5Y4/1) to olive black (5Y2/1); top 5 cm sandy mud.

New core section. **Muddy Sand or Sandy Mud**. Olive gray (5Y4/1) to dark gray (5YR4/1); organic spot, large shell fragments.

Fine to Coarse Sand. Medium gray (N5) to medium dark gray (N4); some coarse sand in lower part; coarsening downwards.

Sample Depth (cm)	1989 Samples GSM (%) Gravel	Sand	Mud	Sand Fraction Mean Phi	Sorting Phi	2016 Samples GSM (%) Gravel	Sand	Mud	Mean Phi	Sorting Phi
50	39.0	56.0	5.0	0.6	0.9					
200	0	33.0	67.0	2.9	0.88					
300	2.0	90.0	8.0	1.8	1.03					

Depositional Environment Birch, 1984

Sand mounds since the last post-glacial lowstand.

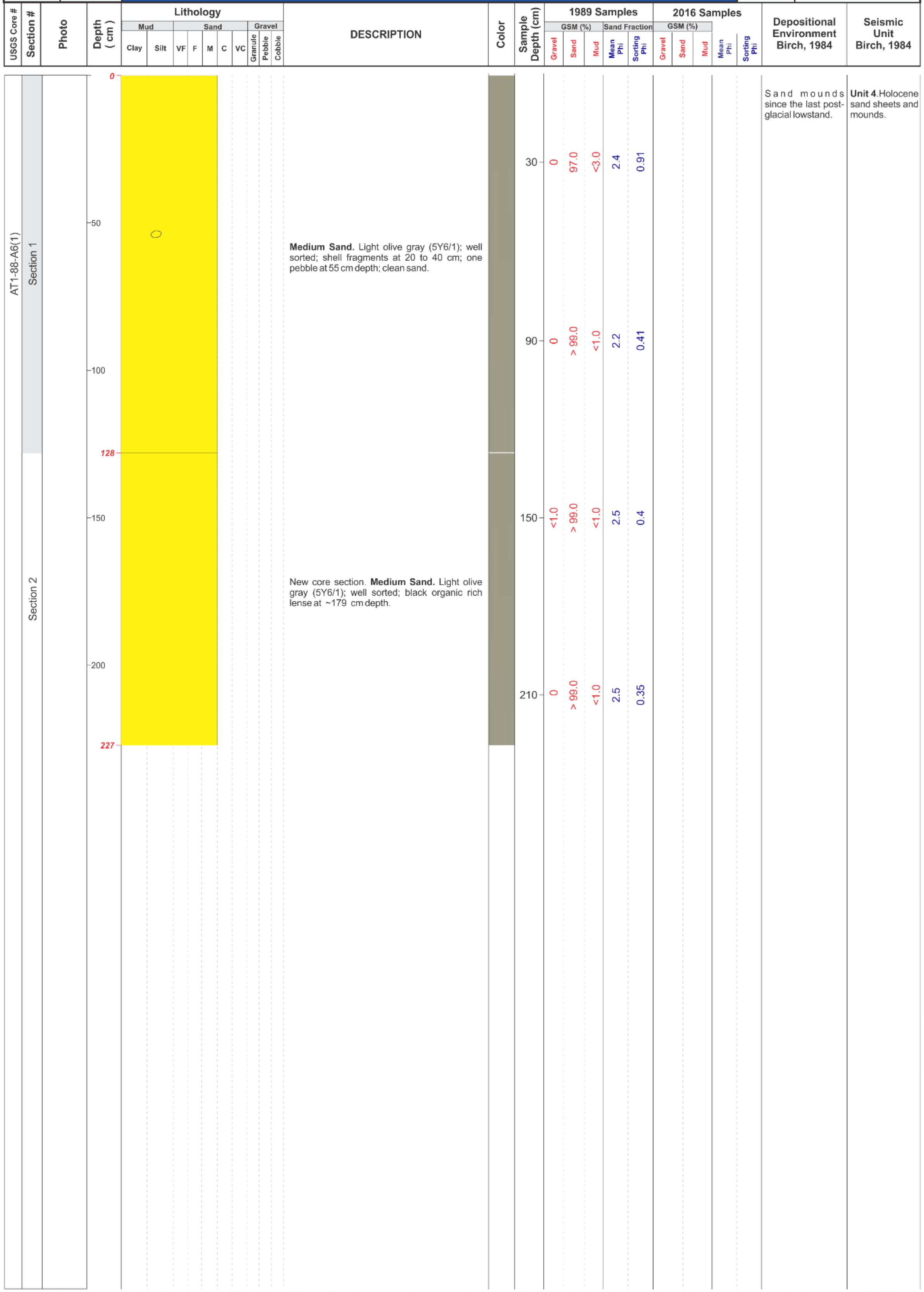
Seismic Unit Birch, 1984

Unit 4.Holocene sand sheets and mounds. From top of the core to the bottom.

Original Reference: Ward L.G. 1989. Sedimentological Characteristics of Vibracores Taken in Sand and Gravel Deposits on the Inner Continental Shelf of New Hampshire: Final Report on Minerals Management Service Cooperative Agreement 14-12-0001-30316 pp. 22

A6(1)

U.S.G.S Field Activity #: 1988-017-FA
Latitude: 42.9317 Longitude: -70.7633



Medium Sand. Light olive gray (5Y6/1); well sorted; shell fragments at 20 to 40 cm; one pebble at 55 cm depth; clean sand.

New core section. **Medium Sand.** Light olive gray (5Y6/1); well sorted; black organic rich lense at ~179 cm depth.

Sample Depth (cm)	1989 Samples GSM (%) Gravel	Sand	Mud	Sand Fraction Mean Phi	Sorting Phi	2016 Samples GSM (%) Gravel	Sand	Mud	Mean Phi	Sorting Phi
30	0	97.0	<3.0	2.4	0.91					
90	0	> 99.0	<1.0	2.2	0.41					
150	<1.0	> 99.0	<1.0	2.5	0.4					
210	0	> 99.0	<1.0	2.5	0.35					

Depositional Environment Birch, 1984	Seismic Unit Birch, 1984
Sand mounds since the last post-glacial lowstand.	**Unit 4.** Holocene sand sheets and mounds.

Original Reference: Ward L.G. 1989. Sedimentological Characteristics of Vibracores Taken in Sand and Gravel Deposits on the Inner Continental Shelf of New Hampshire: Final Report on Minerals Management Service Cooperative Agreement 14-12-0001-30316 pp. 22

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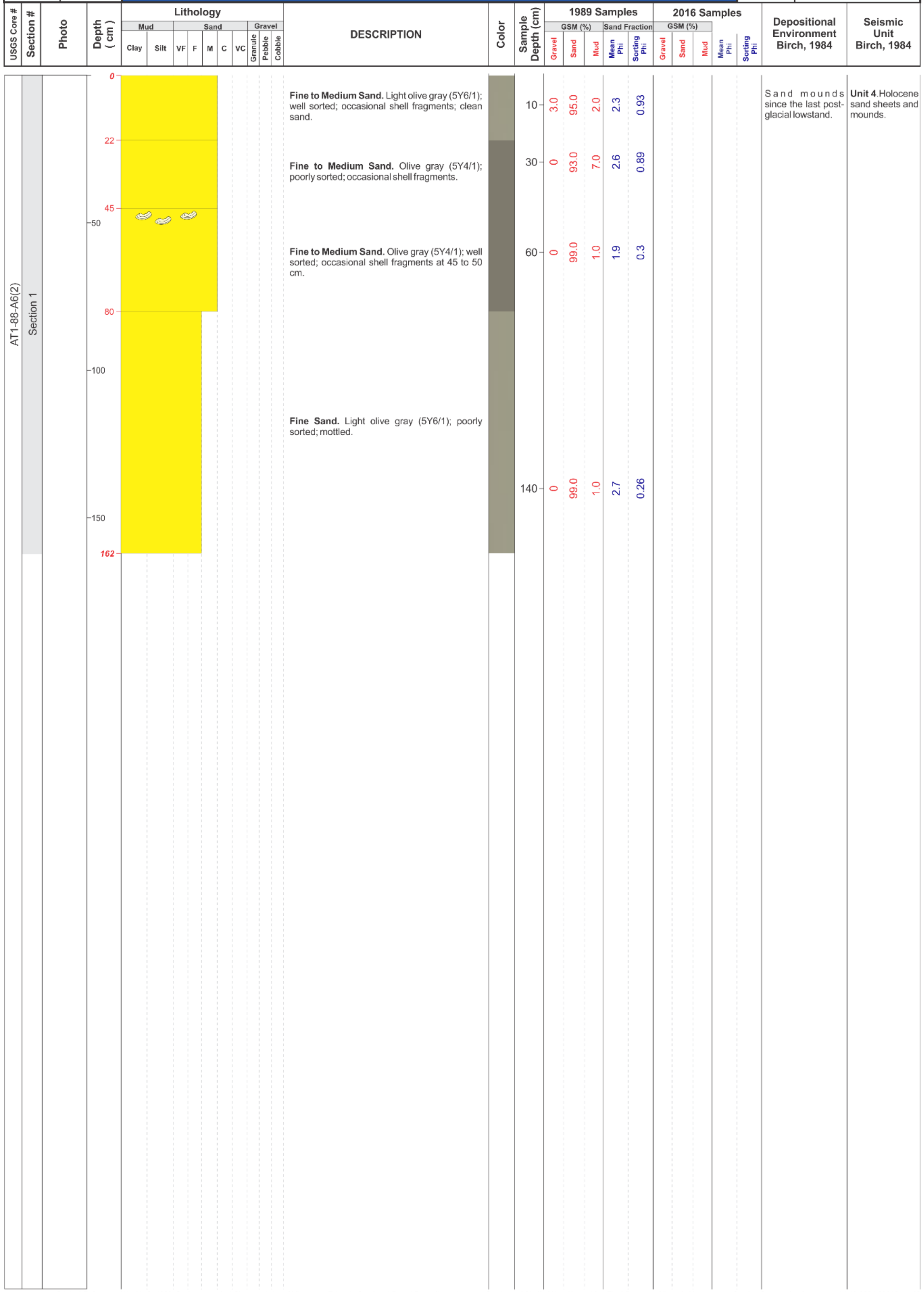
A6(2)

U.S.G.S Field Activity #: 1988-017-FA
Latitude: 42.9317 Longitude: -70.7633



Fine to Medium Sand. Light olive gray (5Y6/1); well sorted; occasional shell fragments; clean sand.

Fine to Medium Sand. Olive gray (5Y4/1); poorly sorted; occasional shell fragments.

Fine to Medium Sand. Olive gray (5Y4/1); well sorted; occasional shell fragments at 45 to 50 cm.

Fine Sand. Light olive gray (5Y6/1); poorly sorted; mottled.

Sample Depth (cm)	Gravel	Sand	Mud	Mean Phi	Sorting Phi
10	3.0	95.0	2.0	2.3	0.93
30	0	93.0	7.0	2.6	0.89
60	0	99.0	1.0	1.9	0.3
140	0	99.0	1.0	2.7	0.26

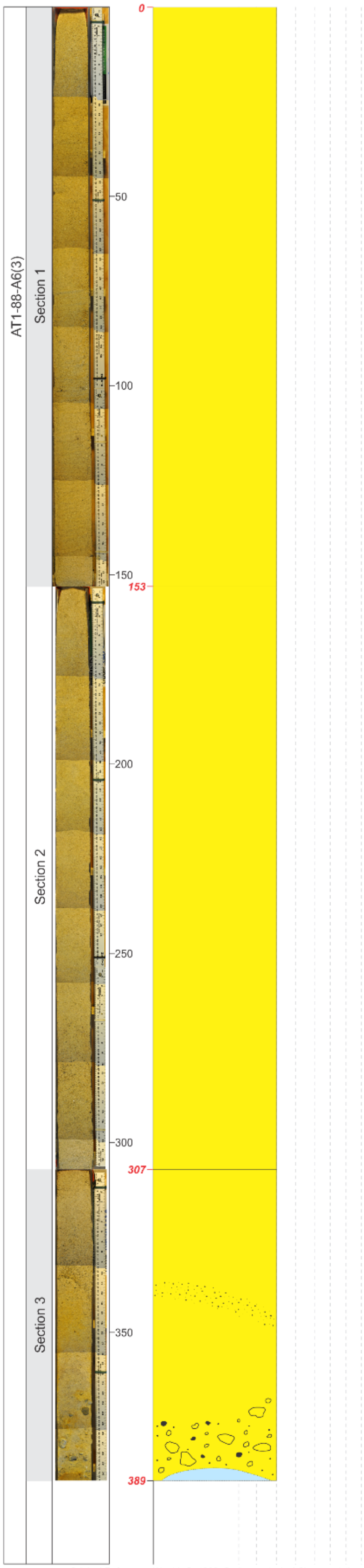
Depositional Environment Birch, 1984: Sand mounds since the last post-glacial lowstand.

Seismic Unit Birch, 1984: **Unit 4**.Holocene sand sheets and mounds.

Original Reference: Ward L.G. 1989. Sedimentological Characteristics of Vibracores Taken in Sand and Gravel Deposits on the Inner Continental Shelf of New Hampshire: Final Report on Minerals Management Service Cooperative Agreement 14-12-0001-30316 pp. 22

A6(3)

U.S.G.S Field Activity #: 1988-017-FA
Latitude: 42.9317 Longitude: -70.7633



DESCRIPTION

Medium Sand. Light yellowish brown (10YR6/4); well sorted; medium with some coarse sand; very homogeneous; organic debris at ~150 cm (speck).

New core section. **Medium Sand.** Light yellowish brown (10YR6/4); almost coarse sand; some bedding between ~260 to 290 cm.

New core section. **Medium Sand.** Light olive gray (5Y6/1); upper 25 cm medium sand; well sorted; coarse sand lense at ~340 cm; pebbles (up to 4 cm) in lower part, sharp lower contact with mud.

Sample Depth (cm)	1989 Samples GSM (%) Gravel	Sand	Mud	Sand Fraction Mean Phi	Sorting Phi	2016 Samples GSM (%) Gravel	Sand	Mud	Mean Phi	Sorting Phi
30	0	> 99.0	< 1.0	1.7	0.39					
120	0	> 99.0	< 1.0	1.8	0.46					
220	0	> 99.0	< 1.0	2.0	0.42					
350	<1.0	> 99.0	<1.0	1.7	0.57					

Depositional Environment Birch, 1984	Seismic Unit Birch, 1984
Sand mounds since the last post-glacial lowstand.	**Unit 4**.Holocene sand sheets and mounds. From top of the core to 389 cm.

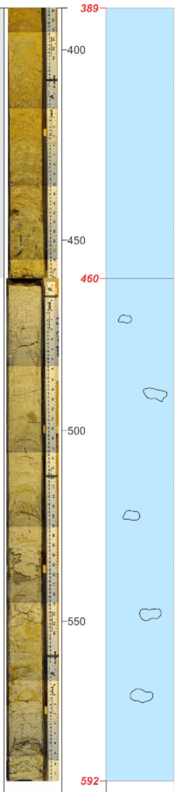
Original Reference: Ward L.G. 1989. Sedimentological Characteristics of Vibracores Taken in Sand and Gravel Deposits on the Inner Continental Shelf of New Hampshire: Final Report on Minerals Management Service Cooperative Agreement 14-12-0001-30316 pp. 22

A6(3)

U.S.G.S Field Activity #: 1988-017-FA
Latitude: 42.9317 Longitude: -70.7633

USGS Core #: AT1-88-A6(3)

Section #: Section 3, Section 4



DESCRIPTION

Continuation of section 3. Mud. Light olive gray (5Y6/1) to olive gray (5Y4/1); light brown (10YR6/4) near top.

Mud. Light olive gray (5Y6/1) to olive gray (5Y4/1); common very fine sand pods; shell fragments at 535 cm.

Sample Depth (cm)	1989 Samples GSM (%) Gravel	Sand	Mud	Sand Fraction Mean Phi	Sorting Phi	2016 Samples GSM (%) Gravel	Sand	Mud	Mean Phi	Sorting Phi
470	0	4.0	96.0							
580	0	2.0	98.0							

Depositional Environment Birch, 1984: Glacial-marine deposit with a substantial ice-rafting component.

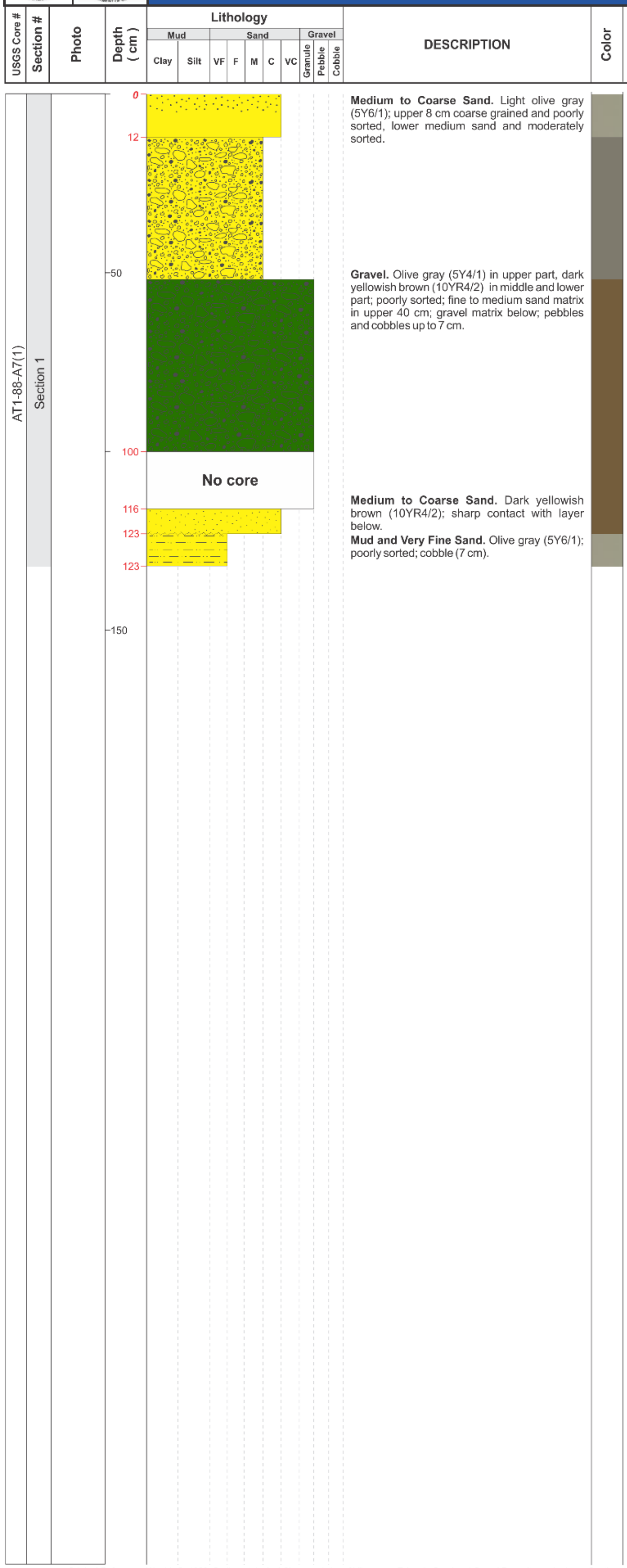
Seismic Unit Birch, 1984: **Unit 2**.Glacial-Marine Mud with a significant ice rafting component. From 389 cm to the bottom of the core.

Original Reference: Ward L.G. 1989. Sedimentological Characteristics of Vibracores Taken in Sand and Gravel Deposits on the Inner Continental Shelf of New Hampshire: Final Report on Minerals Management Service Cooperative Agreement 14-12-0001-30316 pp. 22

A7(1)

U.S.G.S Field Activity #: 1988-017-FA

Latitude: 42.9483 Longitude: -70.7533



DESCRIPTION

Medium to Coarse Sand. Light olive gray (5Y6/1); upper 8 cm coarse grained and poorly sorted, lower medium sand and moderately sorted.

Gravel. Olive gray (5Y4/1) in upper part, dark yellowish brown (10YR4/2) in middle and lower part; poorly sorted; fine to medium sand matrix in upper 40 cm; gravel matrix below; pebbles and cobbles up to 7 cm.

Medium to Coarse Sand. Dark yellowish brown (10YR4/2); sharp contact with layer below.

Mud and Very Fine Sand. Olive gray (5Y6/1); poorly sorted; cobble (7 cm).

Sample Depth (cm)	1989 Samples					2016 Samples					Depositional Environment Birch, 1984	Seismic Unit Birch, 1984
	GSM (%)			Sand Fraction		GSM (%)						
	Gravel	Sand	Mud	Mean Phi	Sorting Phi	Gravel	Sand	Mud	Mean Phi	Sorting Phi		
10	3.0	92.0	5.0	1.7	1.10						Sand mounds since the last post-glacial lowstand.	**Unit 4**.Holocene sand sheets and mounds.
30	9.0	83.0	8.0	1.7	1.05							

Original Reference: Ward L.G. 1989. Sedimentological Characteristics of Vibracores Taken in Sand and Gravel Deposits on the Inner Continental Shelf of New Hampshire: Final Report on Minerals Management Service Cooperative Agreement 14-12-0001-30316 pp. 22

A7(2)

U.S.G.S Field Activity #: 1988-017-FA
Latitude: 42. 9483 Longitude: -70.7533

Depth (cm)	DESCRIPTION
0–26	No Core
26–45	**Medium to Coarse Sand.** Olive black (5Y2/1); poorly sorted.
45–49	**Coarse Sand and Granule.** Light olive gray (5Y6/1); pocket of coarse sediments with pebbles; large shell fragments.
49–112	**Coarse Sand to Very Coarse.** Olive black (5Y2/1) at top to light olive gray (5Y6/1) at base; some granule and pebbles (up to 3.5 cm); mud pod at ~7.5 cm.
112–153	New Core Section. **Gravel.** Olive gray (5Y4/1); poorly sorted; sharp lower contact; coarse sand and gravel; pebbles common; sharp contact with underlying unit.
153–180	**Medium to Coarse Sand.** Light olive gray (5Y6/1) to olive gray (5Y4/1); poorly sorted; pebbles and cobbles common (up to 8 cm).
180–205	**Fine to Medium Sand.** Light olive gray (5Y6/1); poorly sorted; occasional pebbles (up to 5 cm).

Sample Depth (cm)	1989 Samples GSM (%) Gravel	Sand	Mud	Sand Fraction Mean Phi	Sorting Phi	2016 Samples GSM (%) Gravel	Sand	Mud	Mean Phi	Sorting Phi
30	2.0	93.0	5.0	0.9	0.98					
90	27.0	71.0	2.0	0.6	0.95					
195	16.0	72.0	12	2.0	1.18					

Depositional Environment Birch, 1984	Seismic Unit Birch, 1984
Sand mounds since the last post-glacial lowstand.	**Unit 4**.Holocene sand sheets and mounds.

Original Reference: Ward L.G. 1989. Sedimentological Characteristics of Vibracores Taken in Sand and Gravel Deposits on the Inner Continental Shelf of New Hampshire: Final Report on Minerals Management Service Cooperative Agreement 14-12-0001-30316 pp. 22

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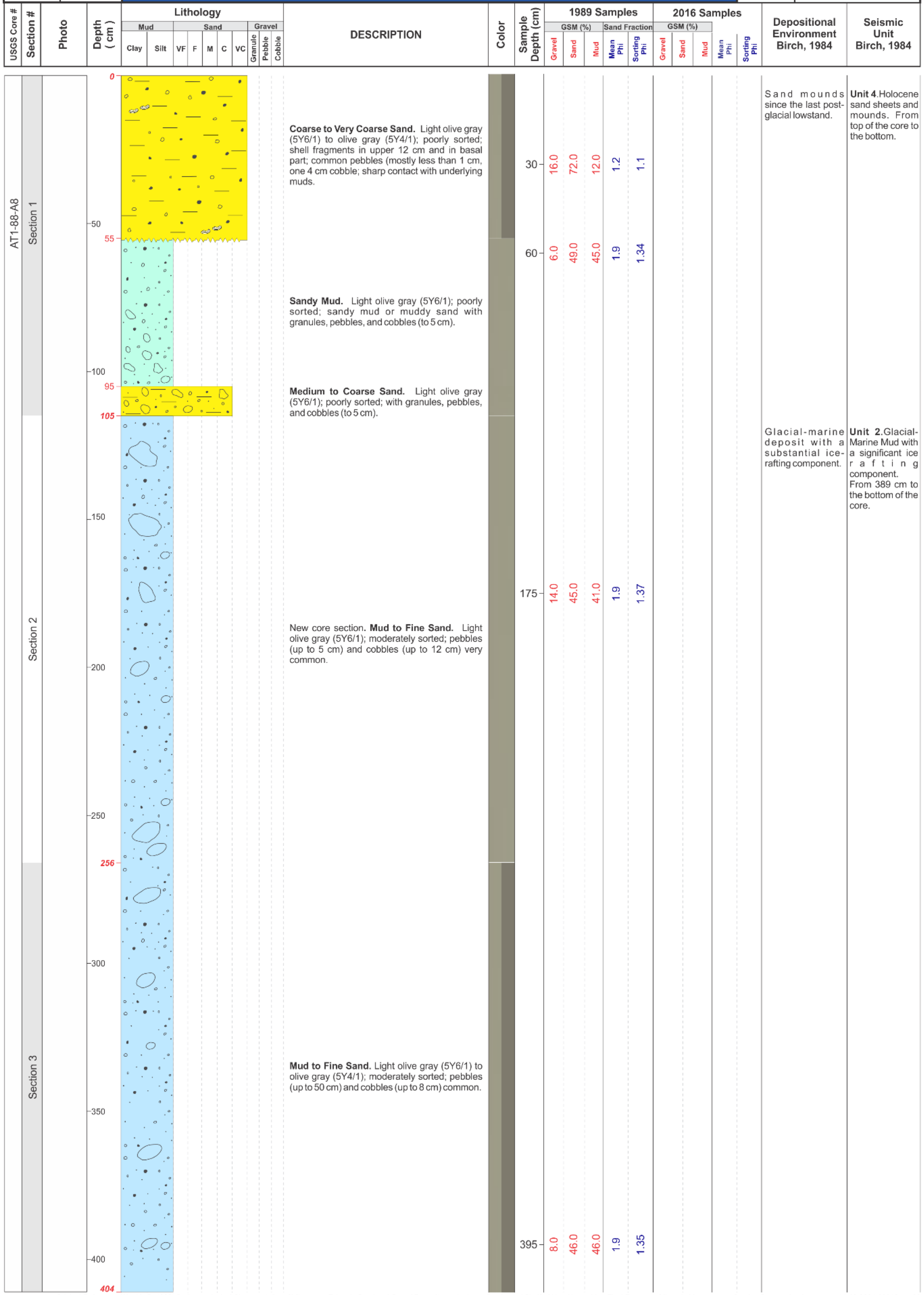
A8

U.S.G.S Field Activity #: 1988-017-FA

Latitude: 42.9417 Longitude: -70.7517



Coarse to Very Coarse Sand. Light olive gray (5Y6/1) to olive gray (5Y4/1); poorly sorted; shell fragments in upper 12 cm and in basal part; common pebbles (mostly less than 1 cm, one 4 cm cobble; sharp contact with underlying muds.

Sandy Mud. Light olive gray (5Y6/1); poorly sorted; sandy mud or muddy sand with granules, pebbles, and cobbles (to 5 cm).

Medium to Coarse Sand. Light olive gray (5Y6/1); poorly sorted; with granules, pebbles, and cobbles (to 5 cm).

New core section. **Mud to Fine Sand.** Light olive gray (5Y6/1); moderately sorted; pebbles (up to 5 cm) and cobbles (up to 12 cm) very common.

Mud to Fine Sand. Light olive gray (5Y6/1) to olive gray (5Y4/1); moderately sorted; pebbles (up to 50 cm) and cobbles (up to 8 cm) common.

Sample Depth (cm)	Gravel	Sand	Mud	Mean Phi	Sorting Phi
30	16.0	72.0	12.0	1.2	1.1
60	6.0	49.0	45.0	1.9	1.34
175	14.0	45.0	41.0	1.9	1.37
395	8.0	46.0	46.0	1.9	1.35

Sand mounds since the last post-glacial lowstand.

Unit 4. Holocene sand sheets and mounds. From top of the core to the bottom.

Glacial-marine deposit with a substantial ice-rafting component.

Unit 2. Glacial-Marine Mud with a significant ice rafting component. From 389 cm to the bottom of the core.

Original Reference: Ward L.G. 1989. Sedimentological Characteristics of Vibracores Taken in Sand and Gravel Deposits on the Inner Continental Shelf of New Hampshire: Final Report on Minerals Management Service Cooperative Agreement 14-12-0001-30316 pp. 22