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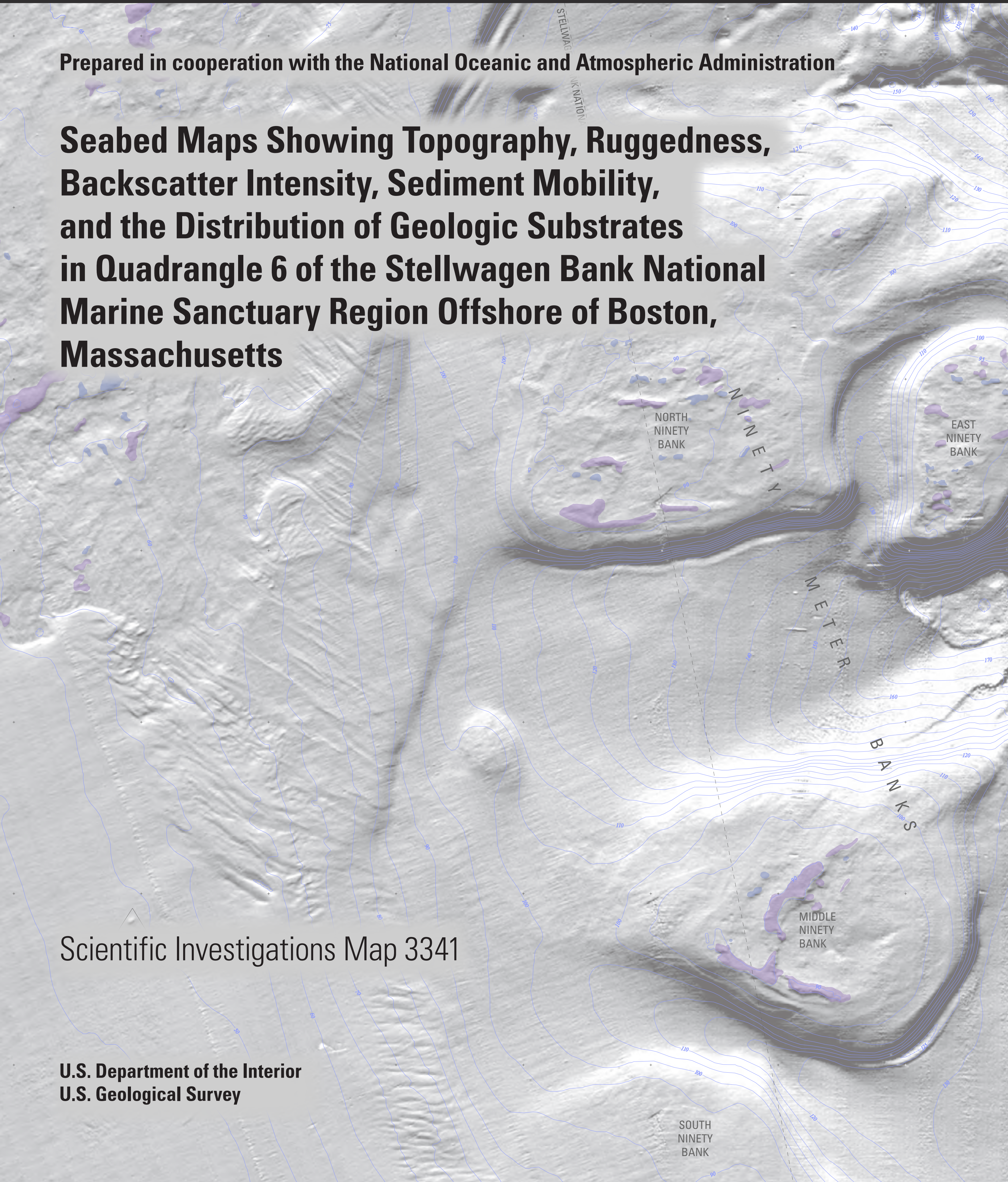
Seabed Maps Showing Topography, Ruggedness, Backscatter Intensity, Sediment Mobility, and the Distribution of Geologic Substrates in Quadrangle 6 of the Stellwagen Bank National Marine Sanctuary Region Offshore of Boston, Massachusetts



Scientific Investigations Map 3341

U.S. Department of the Interior
U.S. Geological Survey

Cover. Sun-illuminated topographic imagery and boulder ridges shown on Map A of this report.

Seabed Maps Showing Topography, Ruggedness, Backscatter Intensity, Sediment Mobility, and the Distribution of Geologic Substrates in Quadrangle 6 of the Stellwagen Bank National Marine Sanctuary Region Offshore of Boston, Massachusetts

By Page C. Valentine and Leslie B. Gallea

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SALLY JEWELL, Secretary

U.S. Geological Survey
Suzette M. Kimball, Acting Director

U.S. Geological Survey, Reston, Virginia: 2015

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Suggested citation:
Valentine, P.C., and Gallea, L.B., 2015, Seabed maps showing topography, ruggedness, backscatter intensity, sediment mobility, and the distribution of geologic substrates in quadrangle 6 of the Stellwagen Bank National Marine Sanctuary region offshore of Boston, Massachusetts: U.S. Geological Survey Scientific Investigations Map 3341, 10 sheets, scale 1:25,000, and 21-p. pamphlet, http://dx.doi.org/10.3133/sim3341.

ISSN 2329-132X (online)

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[Available for download at http://dx.doi.org/10.3133/sim3341]

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Conversion Factors

Multiply	By	To obtain
	Length	
millimeter (mm)	0.03937	inch (in.)
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
meter (m)	1.094	yard (yd)
kilometer (km)	0.5400	mile, nautical (nmi)
	Area	
square meter (m^2)	10.76	square foot (ft^2)
square kilometer (km^2)	0.2916	square nautical mile (nmi^2)
square kilometer (km^2)	0.3861	square mile (mi^2)

Map Projection Information

Mercator; Geodetic Reference System 1980; horizontal datum: North American Datum of 1983

Longitude of central meridian 70°19' W.; latitude of true scale 41°39' N.

False easting 0 m; false northing 0 m ; vertical datum: Mean Lower Low Water

Digital Image Resolution

The resolution of pixels in spatial datasets follows the conventions used in the spatial data and modeling communities. The format is "*n*-meter resolution," where *n* is a numerical value for the length. The usage translates into a pixel with a length of n on all sides that covers an area of *n* meters × *n* meters.

Grain-Size Classification

Grade[1]	Grain size	
	Range[1] (millimeter)	Scale[2] (phi)
Gravel, boulder	256 to <4,096	−8 to −11
Gravel, cobble	64 to <256	−6 to −7
Gravel, very coarse pebble	32 to <64	−5
Gravel, coarse pebble	16 to <32	−4
Gravel, medium pebble	8 to <16	−3
Gravel, fine pebble	4 to <8	−2
Gravel, granule	2 to <4	−1
Sand, very coarse	1 to <2	0
Sand, coarse	0.5 to <1	1
Sand, medium	0.25 to <0.5	2
Sand, fine	0.125 to <0.25	3
Sand, very fine	0.062 to <0.125	4
Silt	0.004 to <0.062	5 to 8
Clay	<0.004	9, 10, 11, …
Mud (silt+clay)	<0.062	5 and higher

[1]Udden, 1914; Wentworth, 1922; Folk, 1954; Blair and McPherson, 1999.

[2]Krumbein, 1936.

To convert particle diameter (D) in millimeter (mm) to phi units (φ): $\varphi = -\log_2 D = -3.3219 \log_{10} D$

To convert particle diameter (D) in phi units (φ) to mm: $D = 2^{-\varphi}$

Composite Grain-Size Classification Used in This Study

Composite grade	Grain size	
	Range (millimeter)	Scale (phi)
$Gravel_2$ (G_2)	8 to <64	−3, −4, and −5
$Gravel_1$ (G_1)	2 to <8	−1 and −2
Coarse-grained sand (cgS)	0.25 to <2	2, 1 and 0
Fine-grained sand (fgS)	0.062 to <0.25	4 and 3

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By Page C. Valentine and Leslie B. Gallea

Abstract

The U.S. Geological Survey (USGS), in cooperation with the National Oceanic and Atmospheric Administration's National Marine Sanctuary Program, has conducted seabed mapping and related research in the Stellwagen Bank National Marine Sanctuary (SBNMS) region since 1993. The area is approximately 3,700 square kilometers (km^2) and is subdivided into 18 quadrangles. Seven maps, at a scale of 1:25,000, of quadrangle 6 (211 km^2) depict seabed topography, backscatter, ruggedness, geology, substrate mobility, mud content, and areas dominated by fine-grained or coarse-grained sand. Interpretations of bathymetric and seabed backscatter imagery, photographs, video, and grain-size analyses were used to create the geology-based maps. In all, data from 420 stations were analyzed, including sediment samples from 325 locations. The seabed geology map shows the distribution of 10 substrate types ranging from boulder ridges to immobile, muddy sand to mobile, rippled sand. Mapped substrate types are defined on the basis of sediment grain-size composition, surface morphology, sediment layering, the mobility or immobility of substrate surfaces, and water depth range. This map series is intended to portray the major geological elements (substrates, topographic features, processes) of environments within quadrangle 6. Additionally, these maps will be the basis for the study of the ecological requirements of invertebrate and vertebrate species that use these substrates and guide seabed management in the region.

Introduction

The Stellwagen Bank National Marine Sanctuary region lies offshore of Boston, Massachusetts, extending from Stellwagen Bank in the south to the southern part of Jeffreys Ledge in the north (fig. 1). The region includes the SBNMS and is subdivided into 18 quadrangles with a combined area of approximately 3,700 square kilometers (km^2). This publication presents maps at a scale of 1:25,000 that portray the physical characteristics of the seabed in quadrangle 6 (211 km^2). Interpretations of seabed substrates, topographic features, and processes are based on multibeam bathymetric and backscatter imagery that show seabed topography and the relative reflectivity (representing hardness and softness) of seabed substrates; and on sediment grain-size analyses and video and photographic imagery that provided data used to interpret the features and patterns observed in the sonar imagery.

Three maps in this series focus on regional physical characteristics of the seabed such as topography (Map A), ruggedness (Map B), and backscatter (Map C). Interpretive maps show the distribution of 10 substrates, which range from boulder ridges to immobile, muddy fine-grained sand to mobile, rippled, coarse-grained sand (Map D, sheets 1–4), and also provide overviews of substrate mobility (Map E), the distribution of substrates dominated by fine- or coarse-grained sand (Map F), and the distribution of substrate mud content (Map G).

A substrate is characterized not just by sediment type (mud, sand, gravel), but also by surficial features (for example, ripples), sediment layering (for example, finer sediment partly covering coarser sediment), and sediment movement. The methodology employed to delineate seabed substrates is discussed in the Mapping Methods section of this report.

Several of the maps in this series (A, B, and C) have been published previously at a scale of 1:60,000 (Valentine, 2005); they are presented here at higher resolution (1:25,000). Map A was published previously at 1:25,000 (Valentine and others, 1999, 2010), but did not show the distribution of boulder ridges. Maps D (sheets 1–4), E, F, and G are new interpretations of geological substrate composition, surficial features, and mobility.

The purpose of the map series is to provide a range of information about the distribution of physical attributes of the seabed in quadrangle 6 at a scale (1:25,000) that is justified by the density of data. High resolution information will serve as a foundation for further study of seabed processes such as sediment transport, for ecological studies of vertebrate and invertebrate species that use these substrates as habitat, and for planning and managing usage of the seabed.

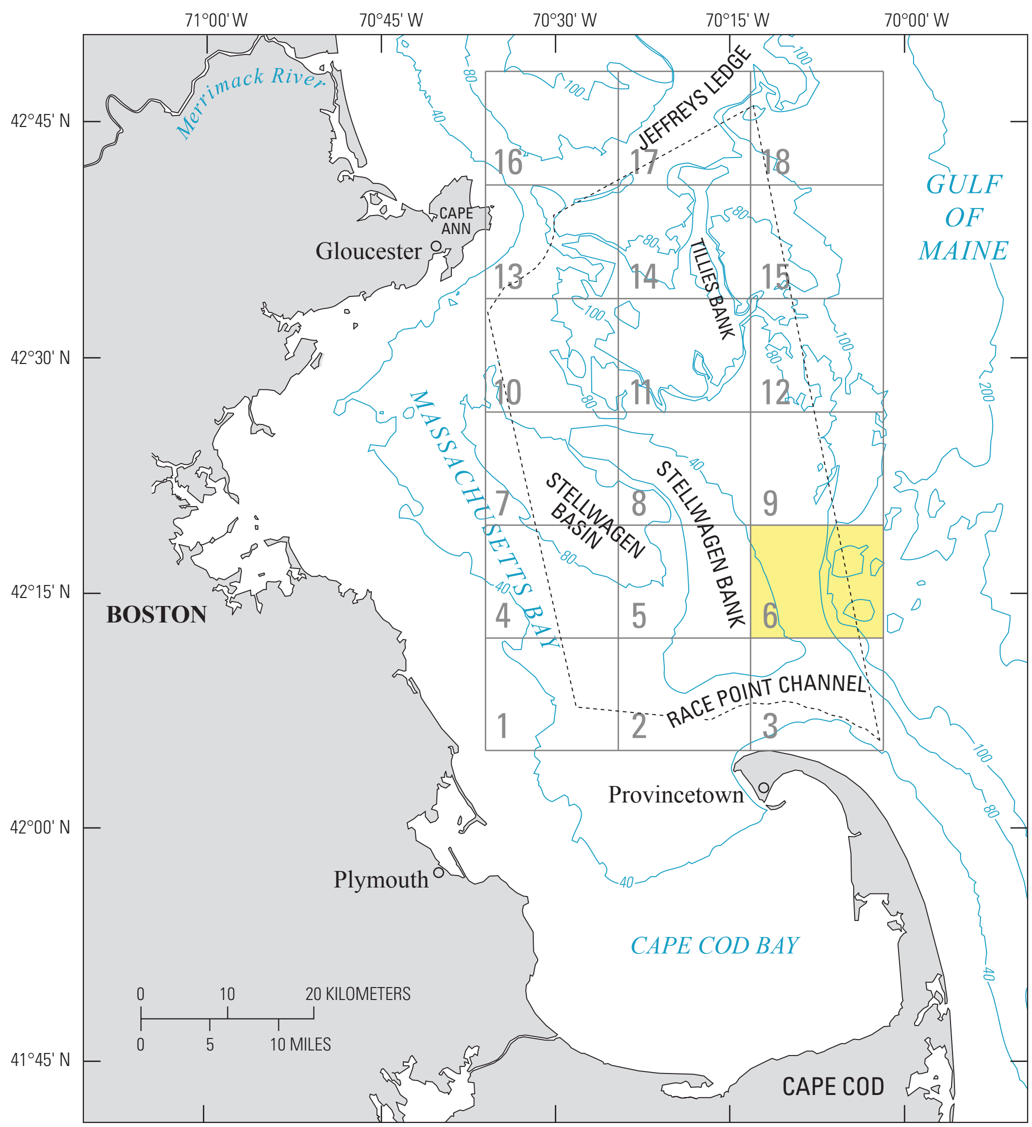


Figure 1. Shows location of quadrangle 6 (highlighted in yellow). Stellwagen Bank National Marine Sanctuary boundary is shown as a dashed line. Bathymetric contours are labeled in meters.

Map A. Sun-Illuminated Topography and Boulder Ridges

Map A (see figure 2) shows seabed topographic imagery derived from multibeam sonar bathymetric data contoured at a 5-meter (m) interval. Water depths range from 35 m on Stellwagen Bank in the west to 180 m in the valleys in the east that separate the Ninety Meter Banks. Boulder ridges <1 m and ≥1 m in height are shown as semi-transparent polygons overlying topography. They represent an area of 3.0 km^2 in quadrangle 6 (table 1).

The seabed represents a glaciated terrain modified by postglacial sediment transport processes. For a description of seabed features in this quadrangle, see a map showing sun-illuminated topography (Valentine and others, 1999, 2010). To view maps and descriptions of seabed topography and the distribution of boulder ridges and bedrock outcrops in the entire Stellwagen Bank National Marine Sanctuary region, see Maps A, B, and F of Valentine (2005).

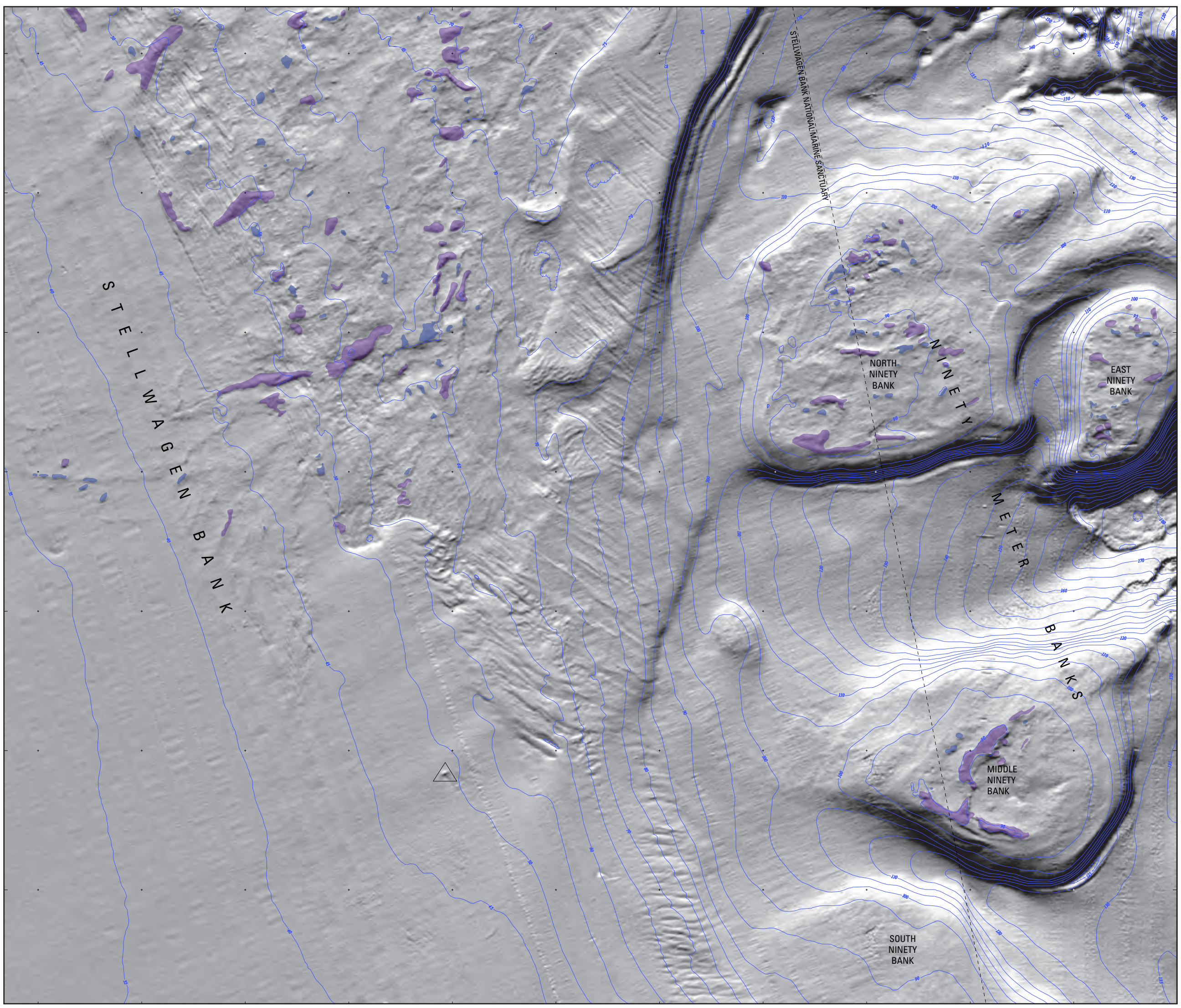


Figure 2. Sun-illuminated topographic imagery and boulder ridges shown on Map A.

In quadrangle 6, 5-m and 1-m topographic contours were generated from bathymetric data collected by the Simrad EM1000 multibeam sonar echo sounder used in the mapping survey. On Map A, only 5-m contours are shown. They accurately represent the morphology of seabed features such as large and small banks and valleys and some of the boulder ridges. However, as 5-m contours do not adequately show the characteristic hummocky relief of the seabed in areas dominated by gravel deposits and small boulder ridges, they are supplemented by 1-m contours on maps B and D–G in areas of relatively rough seabed. See the Mapping Methods section of this report for further explanation of the use of 1-m contours.

Several geographic features were named during the mapping project (table 2). A possible shipwreck site is noted on the map.

Table 1. Areas of the seabed represented by boulder ridges.

[Boulder ridges are segregated into two height categories, <1 meter (m) and ≥1 m. Areas of the seabed represented by boulder ridges and bedrock outcrops in all 18 quadrangles in the Stellwagen Bank National Marine Sanctuary (SBNMS) region are listed in table 1 of Map F of Valentine (2005). Abbreviation used: km^2, square kilometer]

Region	Area of imaged seabed (km^2)	Area of boulder ridges in quadrangle 6 and its SBNMS portion (km^2)		Area of boulder ridges in quadrangle 6 and its SBNMS portion (percent)	
		<1 m	≥1 m	<1 m	≥1 m
Quadrangle 6	211	0.5	2.5	0.2	1.2
SBNMS portion of quadrangle 6	157	0.4	1.9	0.2	1.2

Table 2. Geographic names for quadrangle 6.

[Named geographic features that lie within quadrangle 6 of the Stellwagen Bank National Marine Sanctuary region are listed below. Most features were named during the mapping project, and a link to the official description is provided. Some feature names are historical; no official description is available for them. To view the location and description of all of the named geographic features in the Stellwagen Bank National Marine Sanctuary region, see Valentine (2005)]

Geographic name	Description
East Ninety Bank	http://woodshole.er.usgs.gov/project-pages/stellwagen/html/geonames.html#eastninetybank
Middle Ninety Bank	http://woodshole.er.usgs.gov/project-pages/stellwagen/html/geonames.html#middleninetybank
Ninety Meter Banks	http://woodshole.er.usgs.gov/project-pages/stellwagen/html/geonames.html#ninetymeterbanks
North Ninety Bank	http://woodshole.er.usgs.gov/project-pages/stellwagen/html/geonames.html#northninetybank
South Ninety Bank	http://woodshole.er.usgs.gov/project-pages/stellwagen/html/geonames.html#sninetybank
Stellwagen Bank	First mapped by Henry S. Stellwagen in 1854–1855; and named for him in 1854 by Alexander Bache, Superintendent of the U.S. Coast Survey. http://stellwagen.noaa.gov/about/discovery.html

Map B. Seabed Ruggedness

Map B (see figure 3) shows the results of an analysis of multibeam sonar bathymetric data to calculate seabed ruggedness, a measure of changes in elevation (water depth) over small areas. It is based on a terrain ruggedness index (TRI) developed by Riley and others (1999) to quantify topographic heterogeneity on land. The TRI of Riley and others measures the *sum change* in elevation between a central grid cell (pixel) and its eight neighboring grid cells, found by squaring the eight differences in elevation, summing the squared differences, and taking the square root of the sum. Here, a seabed TRI is used to measure ruggedness more directly by calculating the *average change* in elevation between a central pixel and its eight neighbors, found by averaging the absolute values of the eight differences in elevation (see Map D of Valentine, 2005). Comparing the two methods, a central pixel (representing a positive feature) with an elevation (water depth) value of 10 m and eight neighboring pixels with values of 15 m would have a TRI value of 14.1 m using the method of Riley and others (1999) and a seabed TRI value of 5.0 m using the method employed here.

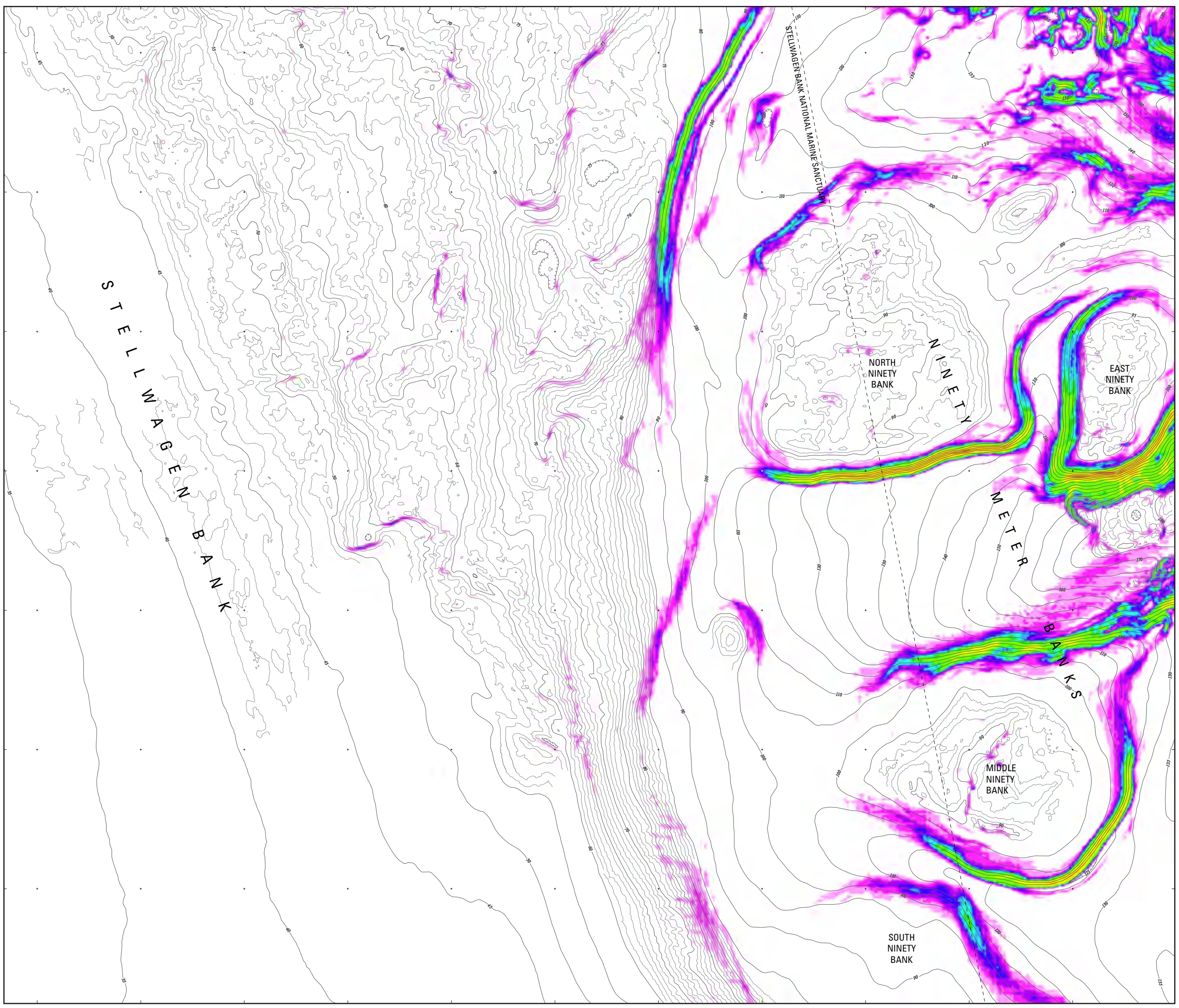


Figure 3. Seabed ruggedness imagery shown on Map B.

For Map B, seabed TRI values were calculated to determine the average change in water depth between a central 13-m pixel and the eight pixels that surround it, an area measuring 39×39 m. Subsequently, a smoothing filter was applied to the ruggedness index image. The filter calculated the mean of the seabed TRI value of each pixel and its eight neighboring pixels. Map colors represent the average change in elevation, in centimeters (cm), which is shown in 10-cm increments in the 30 to 100 cm range, in 50-cm increments in the >100 to 200 cm range, and in 100-cm increments in the >200 to 600 cm range. Average changes in elevation less than 30 cm are not shown in color. For example, on the map, blue represents central pixels having an average elevation change of >70 to 80 cm with respect to their surrounding eight-pixel areas.

Seabed ruggedness ranges from a low of 0 to 30 cm in much of quadrangle 6 to a high of 200 to 400 cm on the steep flanks of the Ninety Meter Banks (substrate F of Map D) in the eastern part of the quadrangle. Ruggedness values in the 0 to 30 cm range represent an area of approximately 188 km^2, whereas values in the >200 to 400 cm range represent only 0.4 km^2 (table 3). To view maps and a description of seabed ruggedness and slope of the entire Stellwagen Bank National Marine Sanctuary region see Maps D and E, respectively, of Valentine (2005).

Table 3. Areas of the seabed represented by ruggedness intervals.

[Areas of seabed are represented by four ruggedness intervals of 0 to 30 centimeters (cm), >30 to 100 cm, >100 to 200 cm, and >200 to 400 cm. Data in columns 3 and 4 are rounded to one decimal place. Areas of seabed represented by ruggedness intervals in all 18 quadrangles of the Stellwagen Bank National Marine Sanctuary (SBNMS) region are listed in table 1 of Map D of Valentine (2005). Abbreviation used: km^2, square kilometer]

Region	Area (km^2)	Area of seabed within four ruggedness intervals (km^2)				Area of seabed within four ruggedness intervals (percent)			
		0–30 cm	>30–100 cm	>100–200 cm	>200–400 cm	0–30 cm	>30–100 cm	>100–200 cm	>200–400 cm
Quadrangle 6	211	187.7	20.2	2.4	0.4	89.1	9.6	1.2	0.2
SBNMS portion of quadrangle 6	157	150.4	6.4	0.4	0	95.7	4.1	0.2	0

Map C. Backscatter Intensity and Sun-Illuminated Topography

Map C (see figure 4) shows imagery of seabed backscatter intensity derived from multibeam sonar data. Backscatter intensity values (1–8) are a measure of the strength of sound waves reflected from the seabed. When color-coded and mapped, they reveal patterns that are a useful guide for delineating the geographic extent of substrate types. Backscatter values of yellow to red (6–8) represent relatively hard substrates and those of blue to blue-green (1–3) relatively soft substrates. Highest values (7, 8) are found on a portion of Stellwagen Bank (substrates C and D1 of Map D) and on the tops of the Ninety Meter Banks (substrates C and D2) and represent boulder ridges and pebble, cobble, boulder gravel partially veneered by coarse-grained sand. Lowest values (1, 2) are found in the deepest parts of the valleys that separate the Ninety Meter Banks (substrates G1, G2) and represent muddy, fine-grained sand. Intermediate values (3–6) represent both fine- and coarse-grained sand that constitute much of the seabed in the quadrangle. Interpretations of backscatter intensity patterns in quadrangle 6 are based on sediment grain-size analyses and video and photographic imagery of the seabed. It is not possible to recognize the substrate types mapped in this report using backscatter intensity alone.

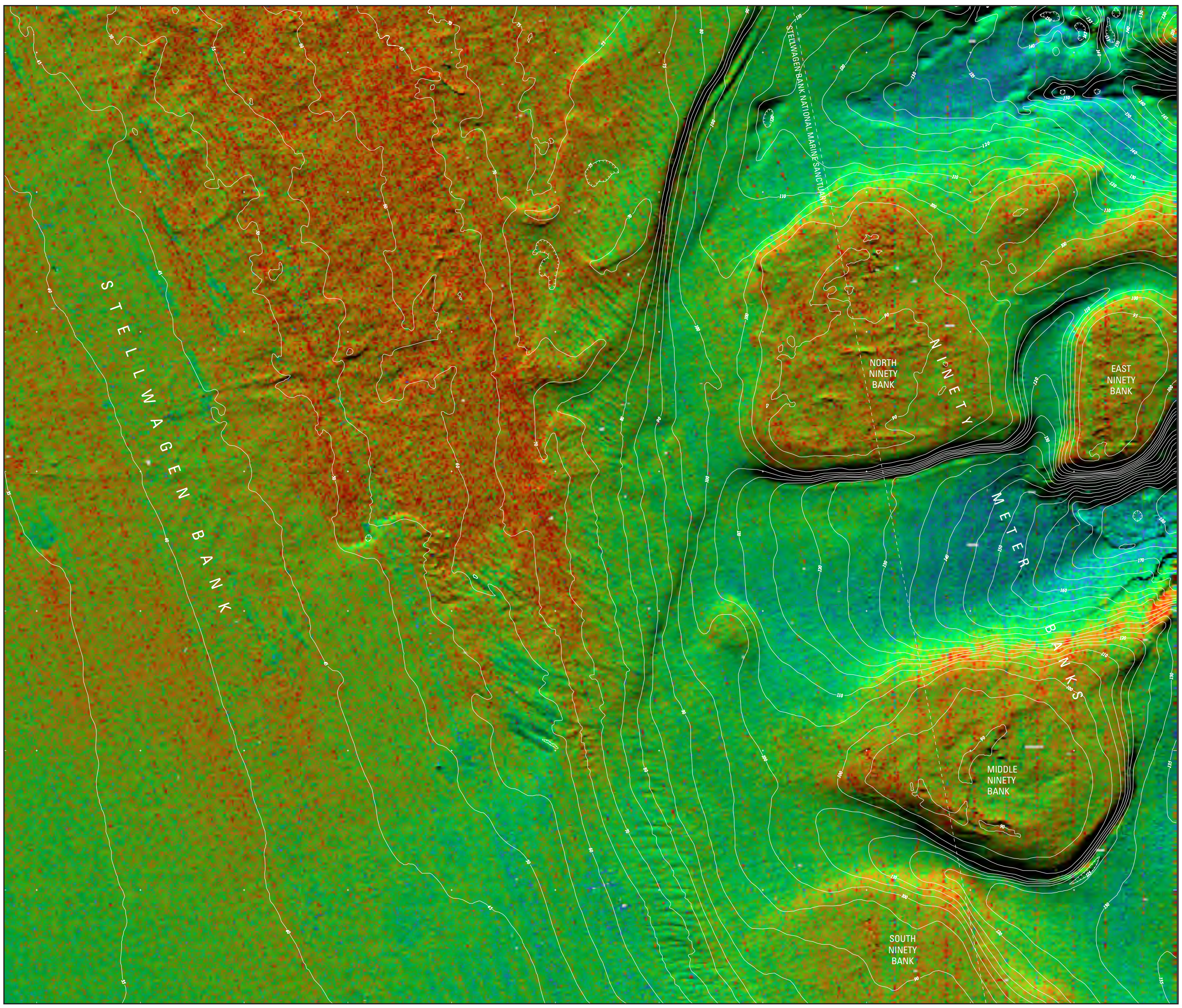


Figure 4. Backscatter intensity and sun-illuminated topographic imagery shown on Map C.

Map D. Distribution of Geologic Substrates

The geologic substrates of quadrangle 6 were formed by glacial processes of erosion and deposition, were subsequently modified by the effects of rising postglacial sea-level, and presently are affected by storm and tidal currents. A discussion of the morphology of seabed features in this quadrangle and their origin can be found in Valentine and others (1999, 2010). Map D (see figure 5) shows the distribution of 10 substrates characterized by grain-size composition, surface morphology, sediment layering, the mobility or immobility of their surfaces, and water depth range. For layered substrates, grain-size analysis was performed on samples collected from the upper layer of sand that partially covers pebble, cobble, or boulder gravel. Substrates range widely in character from ridges of piled boulders to smooth, muddy, fine-grained sand. The shallow surfaces of banks are characterized by relatively coarse sediments, including coarse-grained sand, complex substrates of sand partially covering gravel, and boulder ridges in some parts. The deep valleys are floored by relatively fine sediments which increase in mud content with water depth. The flanks of banks are transition zones where substrates grade from shallower coarse sediment to deeper fine sediment. For further explanation of substrate analysis, see the Mapping Methods section of this report (table 4).

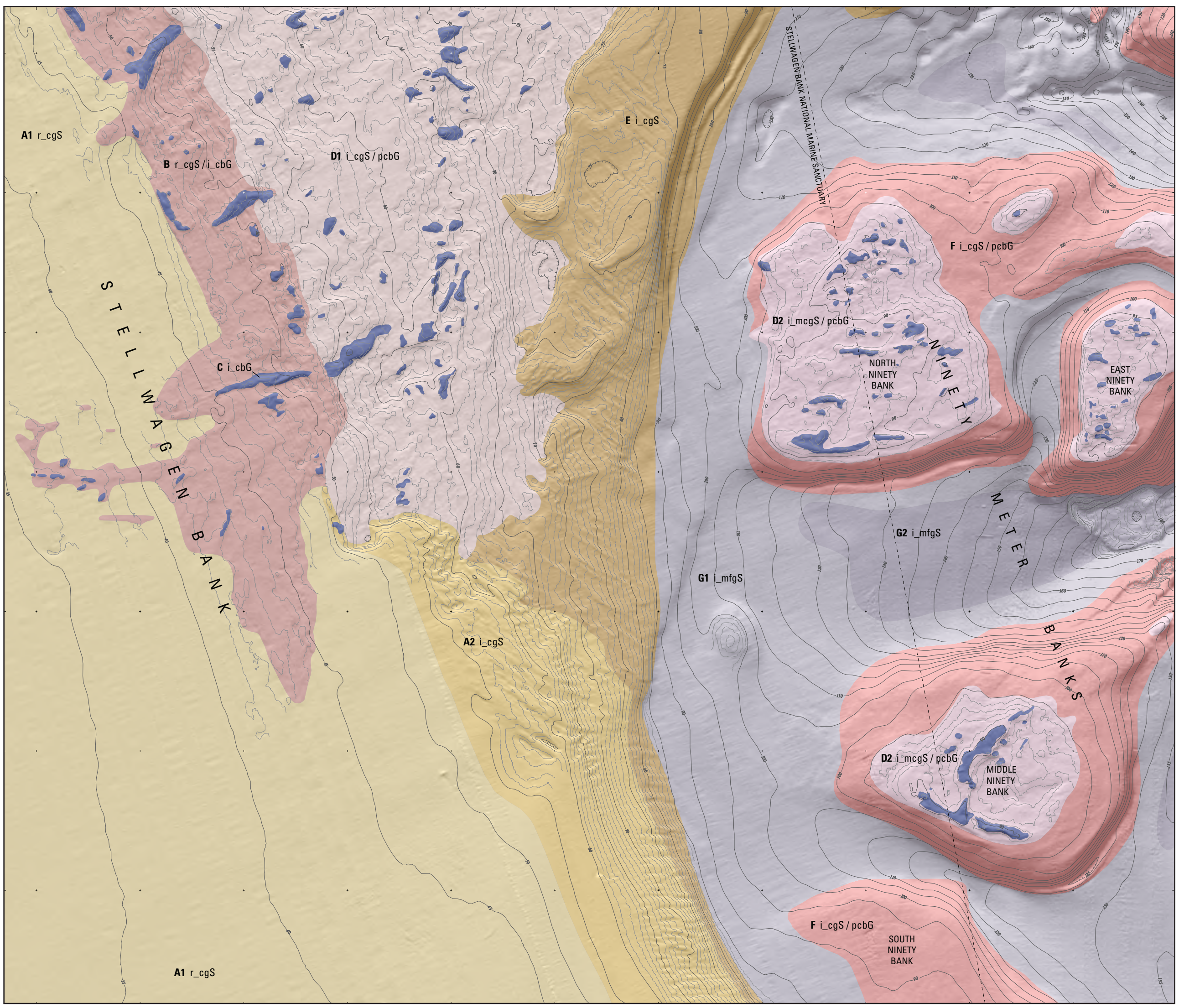


Figure 5. Geologic substrates and sun-illuminated topographic imagery shown on Map D, sheet 4.

Sheet 1. Seabed geology.—Map D, sheet 1 shows the distribution of 10 geologic substrates.

Sheet 2. Seabed geology and stations.—Map D, sheet 2 shows the distribution of 10 geologic substrates and locations of sampling stations and video drift tracks.

Sheet 3. Seabed geology and station data types.—Map D, sheet 3 shows the distribution of 10 geologic substrates and locations of stations and data types (grain-size analyses, photo and video imagery) used to recognize substrates.

Sheet 4. Seabed geology and sun-illuminated topography.—Map D, sheet 4 (see figure 5) shows the distribution of 10 geologic substrates overlaid on sun-illuminated topography to show the relationship between substrate types and seabed features.

Description of Map Units (Also Printed on Map D Sheets)

[Grain-size composition of each map unit is given as mean weight percent for each grain-size category (table 5). Weight percent values may not add to 100 due to rounding. Textural characteristics for substrates B, D1, D2, and F represent the partial sediment veneer overlying gravel. Substrate unit names (tables 6, 7) describe sediment grain-size composition, surficial morphology, sediment layering, and the mobility or immobility of their surfaces. See Conversion Factors for a grain-size classification of sediment grades (Wentworth, 1922) and composite sediment grades of this study. Sand is divided into two composite grades: fine-grained sand (fgS; 0.062 to <0.25 mm) and coarse-grained sand (cgS; 0.25 to <2 mm). Gravel is also divided into two composite grades: Gravel$_1$ (G_1; 2 to <8 mm) and Gravel$_2$ (G_2; 8 to <64 mm). Abbreviations: r, rippled; i, immobile; m, muddy (≥10 weight percent mud); fgS, fine-grained sand; cgS, coarse-grained sand; G_1, Gravel$_1$; G_2, Gravel$_2$; p, pebble; c, cobble; b, boulder. The notation "i_cgS / pcbG" means "immobile, coarse-grained sand; partial veneer on pebble, cobble, boulder gravel." See Mapping Methods for further explanation]

A1 r_cgS—Rippled, coarse-grained sand.—Substrate A1 is a mobile sand deposit on the upper flank of Stellwagen Bank. Depth range is 30 to 56 m. Mean weight percents per grain-size category: mud, <1; sand, 90 (fgS, 3; cgS, 88); gravel, 9 (G_1, 8; G_2, 1). Substrate A1 is equivalent to the mobile portion of adjacent substrate B; and it is similar to adjacent immobile substrate A2 which lies at deeper depths (53–77 m) on the lower flank of Stellwagen Bank and contains more fine-grained sand (11 weight percent).

A2 i_cgS—Immobile, coarse-grained sand.—Substrate A2 is an immobile sand deposit on the lower flank of Stellwagen Bank. Depth range is 53 to 77 m. Mean weight percents per grain-size category: mud, 1; sand, 83 (fgS, 11; cgS, 72); gravel, 16 (G_1, 11; G_2, 5). Substrate A2 is similar to adjacent mobile substrate A1 which lies at shallower depths (30–56 m) and contains less fine-grained sand (3 weight percent). It contains less mud and fine-grained sand than substrate E.

B r_cgS / i_cbG.—Rippled, coarse-grained sand; partial veneer on immobile, cobble, boulder gravel—Substrate B is a layered substrate of mobile sand overlying immobile gravel on the shallow flank of Stellwagen Bank. Depth range is 36 to 58 m. Mean weight percents per grain-size category: mud, <1; sand, 92 (fgS, 5; cgS, 86); gravel, 8 (G_1, 7; G_2, 1). Cobbles and boulders are identified on the basis of video and photographic imagery. Boulder ridges (substrate C) are present. The mobile sand layer of substrate B is equivalent to adjacent mobile substrate A1.

C i_cbG—Immobile, cobble, boulder gravel.—Substrate C is immobile gravel that forms topographic ridges where cobbles and boulders are piled upon one another and are separated by voids. It is identified on the basis of video and photographic images of mapped topographic ridges. It is present on the flank of Stellwagen Bank where it is associated with substrate B (36–58 m) and Substrate D1 (50–83 m), and on the tops of North, East, and Middle Ninety Banks where it is associated with substrate D2 (87–105 m). It is equivalent to boulder ridges <1 m and ≥1 m on Maps A, E, F, and G.

Description of Map Units (Also Printed on Map D Sheets)—Continued

D1 i_cgS / pcbG.—Immobile, coarse-grained sand; partial veneer on pebble, cobble, boulder gravel—Substrate D1 is a layered substrate of immobile sand overlying immobile gravel on the flank of Stellwagen Bank. Depth range is 50 to 83 m. Mean weight percents per grain-size category: mud, 4; sand, 50 (fgS, 16; cgS, 34); gravel, 45 (G_1, 11; G_2, 34). Pebbles, cobbles, and boulders are identified on the basis of video and photographic imagery. Boulder ridges (substrate C) are present. Substrate D1 is similar to substrate D2 which lies at deeper depths (87–105 m) on the tops of North, East, and Middle Ninety Banks and has higher mud content (12 weight percent).

D2 i_mcgS / pcbG.—Immobile, muddy, coarse-grained sand; partial veneer on pebble, cobble, boulder gravel—Substrate D2 is a layered substrate of immobile sand overlying immobile gravel on the tops of North, East, and Middle Ninety Banks. Depth range is 87 to 105 m. Mean weight percents per grain-size category: mud, 12; sand, 76 (fgS, 22; cgS, 55); gravel, 12 (G_1, 8; G_2, 4). Pebbles, cobbles, and boulders are identified on the basis of video and photographic imagery. Boulder ridges (substrate C) are present. Substrate D2 is similar to substrate D1 which lies at shallower depths (50–83 m) on the flank of Stellwagen Bank and has lower mud content (4 weight percent).

E i_cgS.—Immobile, coarse-grained sand—Substrate E is an immobile sand deposit on the lower flank of Stellwagen Bank. Depth range is 66 to 122 m. Mean weight percents per grain-size category: mud, 4; sand, 82 (fgS, 18; cgS, 64); gravel, 14 (G_1, 9; G_2, 5). Boulder ridges are absent. Substrate E is similar in mud content to substrate D1 and contains more mud and fine-grained sand than substrate A2.

F i_cgS / pcbG.—Immobile, coarse-grained sand; partial veneer on pebble, cobble, boulder gravel—Substrate F is a layered substrate of immobile sand overlying immobile gravel on the flanks of the Ninety Meter Banks. Depth range is 90 to 148 m. Mean weight percents per grain-size category: mud, 9; sand, 69 (fgS, 25; cgS, 44); gravel, 22 (G_1, 13; G_2, 9). Pebbles, cobbles, and boulders are identified on the basis of video and photographic imagery. Boulder ridges are absent. Substrate F is similar to substrates D1 and D2, except that F lies at deeper depths, and the partial veneer of coarse grained sand on the gravel is more extensive.

G1 i_mfgS.—Immobile, muddy, fine-grained sand—Substrate G1 is an immobile muddy sand deposit in valleys between Stellwagen Bank and the Ninety Meter Banks. Depth range is 85 to 171 m. Mean weight percents per grain-size category: mud, 10; sand, 88 (fgS, 78; cgS, 10); gravel, 1 (G_1, 1; G_2, 1). Substrate G1 is similar to substrate G2 which lies at deeper depths (125–185 m) and has higher 4 phi sand (58 weight percent) and higher mud content (23 weight percent).

G2 i_mfgS.—Immobile, muddy, fine-grained sand—Substrate G2 is an immobile muddy sand deposit in the deep parts of valleys lying between the Ninety Meter Banks. Depth range is 125 to 185 m. Mean weight percents per grain-size category: mud, 23; sand, 77 (fgS, 77; cgS, 1); gravel, 0. Substrate G2 has the highest mud content of all substrates in quadrangle 6.

Map E. Sediment Mobility

Map E (see figure 6) shows the 10 geologic substrates of Map D classified as four substrate types on the basis of the mobility of their surfaces as determined by the presence or absence of sand ripples and gravel features observed in video and photographic imagery. Mobile, rippled sand represents substrate A1. A combination of mobile, rippled sand and immobile gravel features that the sand partially covers represents substrate B. Boulder ridges (two mapped units based on height above the seabed), which are large, immobile features of gravel substrate, represent substrate C. Immobile sediment is represented by all other substrates based on the absence of sediment ripples.

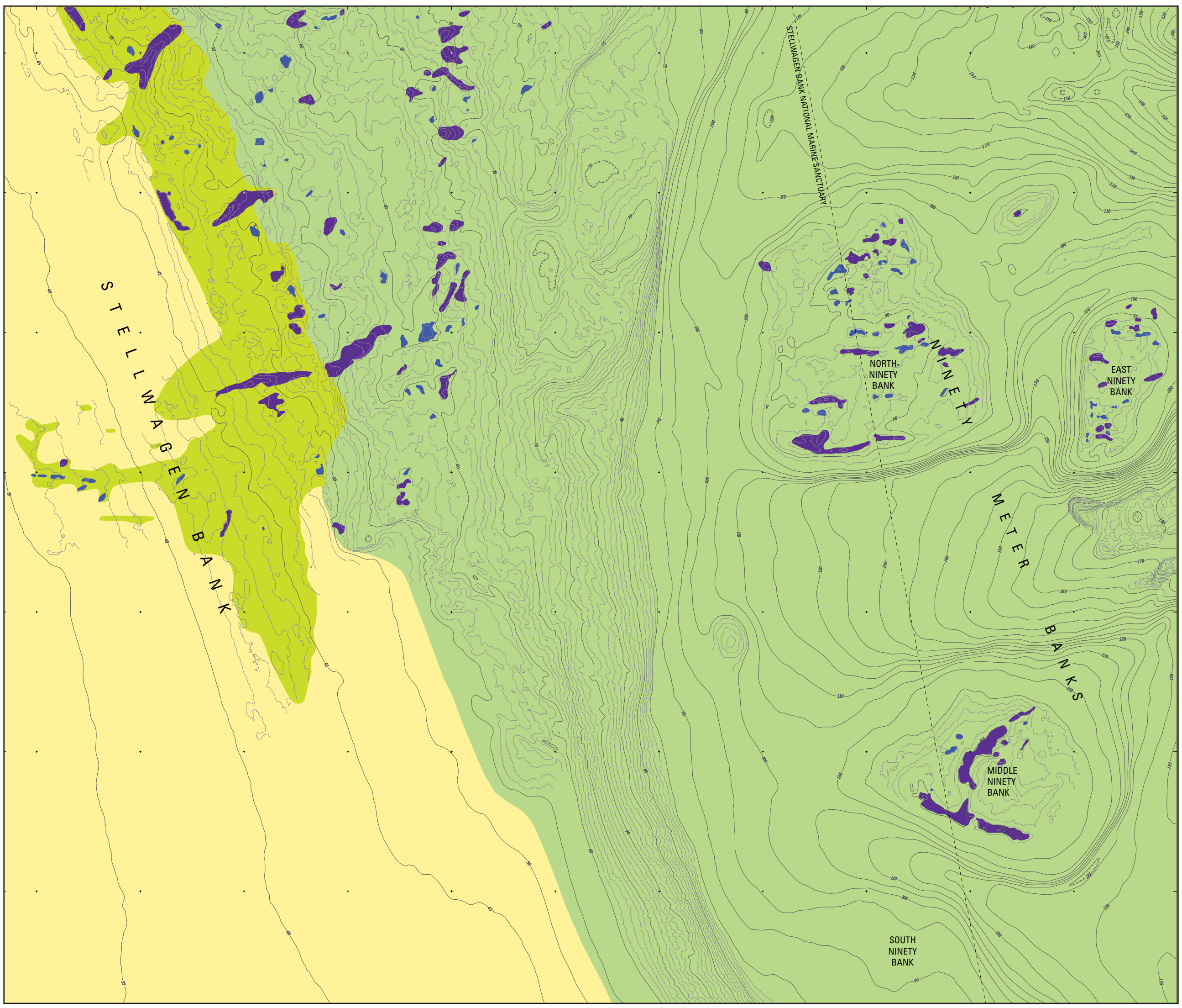


Figure 6. Distribution of mobile and immobile substrates shown on Map E.

Map F. Distribution of Fine- and Coarse-Grained Sand

Map F (see figure 7) shows nine geologic substrates of Map D (excluding substrate C, boulder ridges) classified as two substrate types on the basis of grain-size analysis (table 5). Both the unlayered substrates (A1, A2, E, G1, G2) and the upper parts of layered substrates (B, D1, D2, F) have higher weight percentages of sand than of gravel or mud. Substrates included in the coarse-grained sand composite (A1, A2, B, D1, D2, E, F) contain ≥50 mean weight percent sand, of which the largest portion is coarse-grained sand (2+1+0 phi). Substrates in the fine-grained sand composite (G1, G2) also contain ≥50 mean weight percent sand, but the largest portion is fine-grained sand (3+4 phi), and it has a higher mud content than the coarse-grained sand substrate.

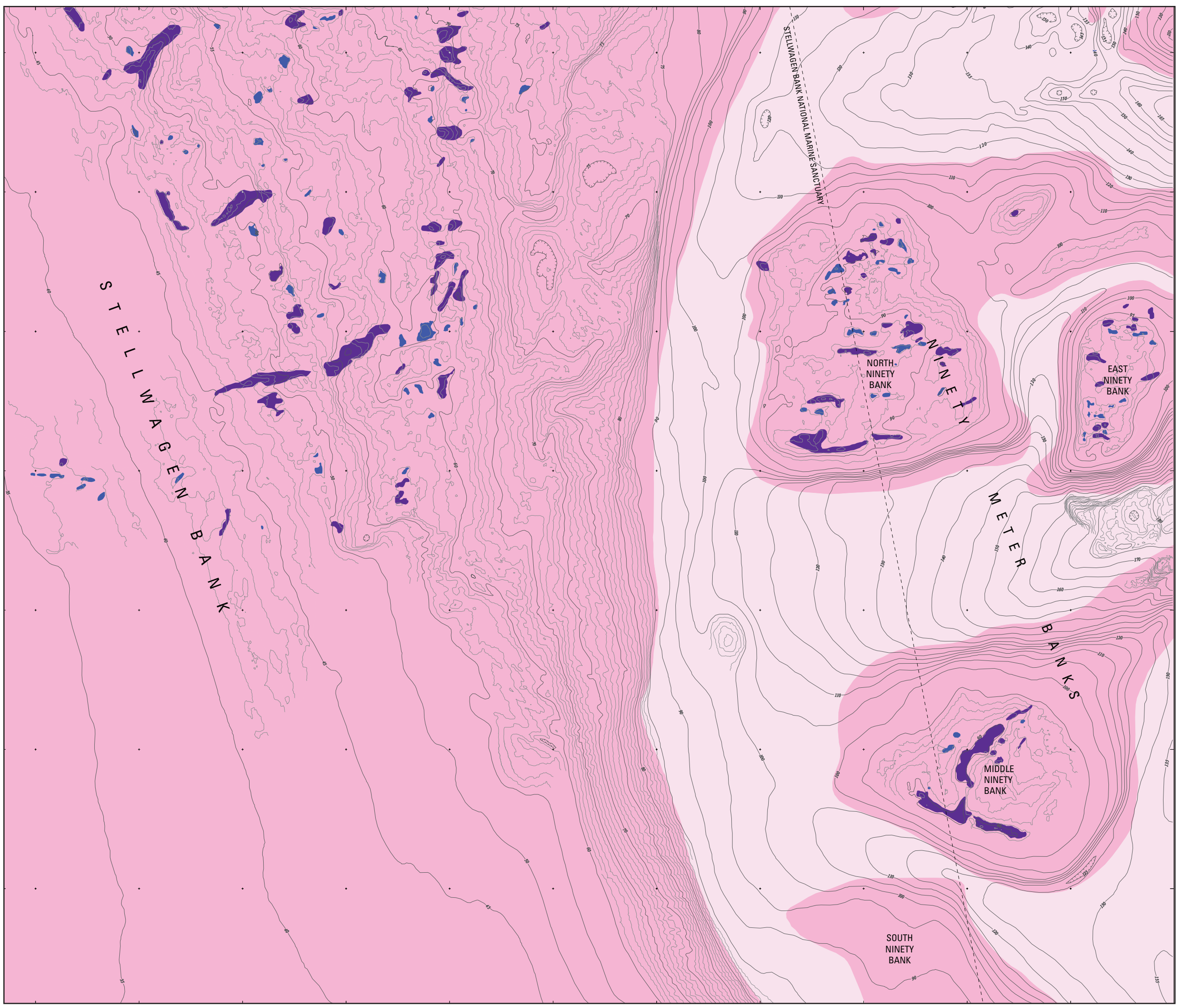


Figure 7. Distribution of fine- and coarse-grained sand substrates and immobile boulder ridges shown on Map F.

Map G. Distribution of Substrate Mud Content

Map G (see figure 8) shows nine geologic substrates of Map D (excluding substrate C, boulder ridges) classified as five substrate types on the basis of mean mud weight percent (table 5). Mud content generally increases with water depth. Substrates containing ≤1 weight percent mud occupy the shallow flank (A1, B) and part of the steep southern flank (A2) of Stellwagen Bank. Substrates containing >1 to 5 weight percent mud occupy the northern flank of the bank (D1 and E). Substrates containing >5 to 10 weight percent mud occupy the flanks of the Ninety Meter Banks (F) and the shallow parts of the valleys between those banks and Stellwagen Bank (G1). A substrate containing >10 to 20 weight percent mud lies on the tops of North, East, and Middle Ninety Meter Bank (D2). A substrate containing >20 to <50 weight percent mud, the highest of all substrates in this quadrangle, occupies the deep parts of the valleys that separate the Ninety Meter Banks (G2).

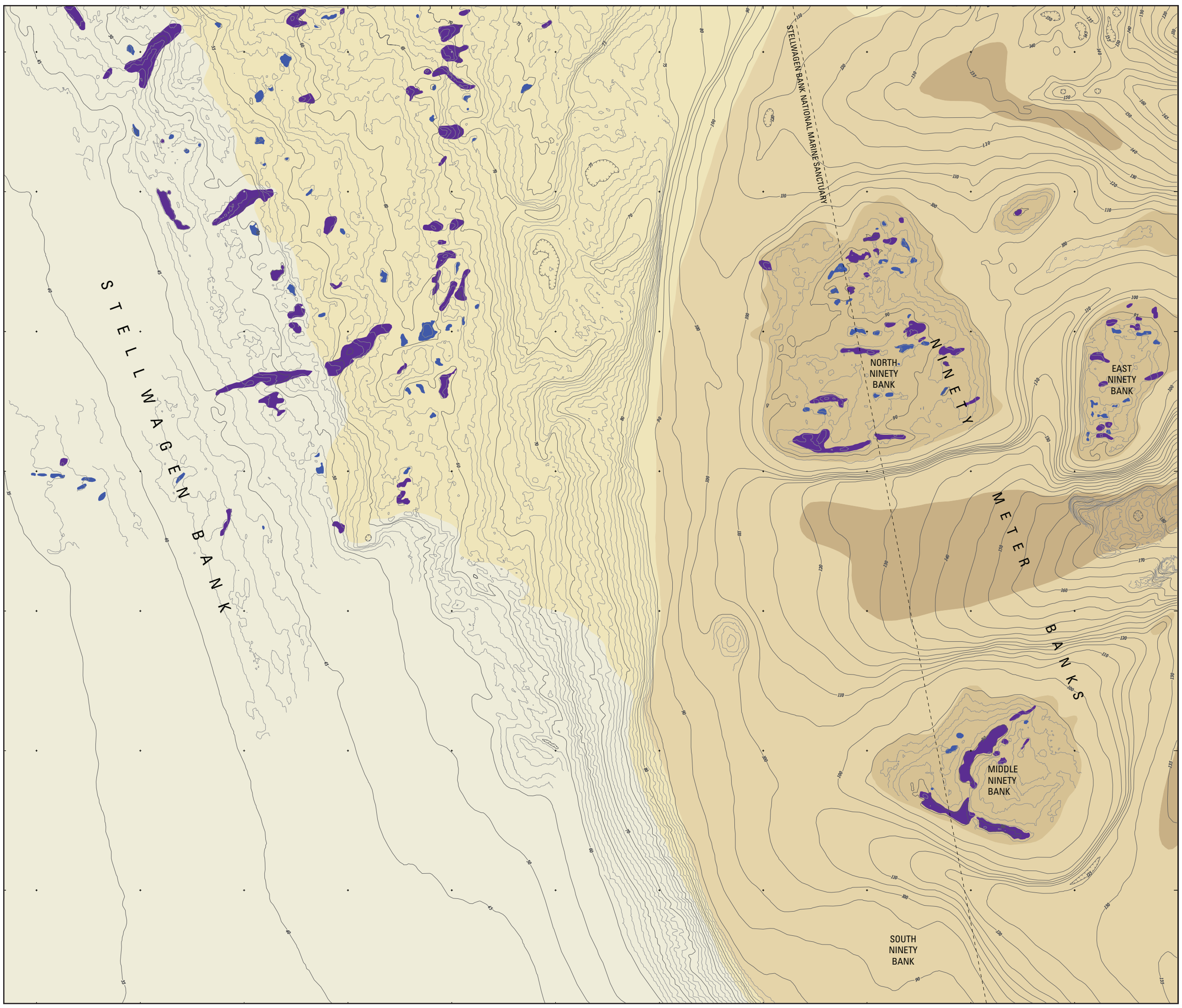


Figure 8. Distribution of substrate mud content and immobile boulder ridges shown on Map G.

Mapping Methods

Topographic features are accurately represented by 5-m bathymetric contours where the seabed is relatively smooth. However, 5-m contours, especially where they are widely spaced, do not adequately show the characteristic hummocky relief of the seabed in areas dominated by gravel deposits and small boulder ridges. In such areas on Maps B and D–G, the 5-m contours are supplemented by 1-m contours to display complex, low-relief topographic features. In areas of relatively smooth seabed where gravel features are absent, the 1-m contours are not shown. In these areas, changes in water depths recorded by the sonar are not resolvable to the extent that they can be contoured at a 1-m interval and produce usable information. Such contours produce incoherent patterns of lines that misrepresent topographic complexity. Bathymetric data are used for seabed ruggedness analysis, which delineates topographic features by measuring changes in elevation over small areas. For a description of the use of bathymetric data to compute seabed ruggedness, see the Map B section of this report.

Geologic substrates of the seabed are characterized by their physical properties. Multibeam topographic and backscatter imagery, video and photographic imagery, and sediment grain-size analyses were used to recognize 10 substrates (Map D, sheets 1–4). Backscatter imagery revealed patterns on the seabed characterized by soft to hard (muddy to sandy to gravelly) substrates and their relationship to seabed topography. Video and photographic imagery showed gravel and piled boulder ridge substrates (which are difficult to sample), seabed structures related to sediment mobility (sand ripples), and partial layering of finer over coarser sediments.

Grain-size analyses of seabed samples provided information on mud, sand, and gravel content (table 4). For layered substrates (for example, sand partially covering gravel), only the top layer was collected and analyzed for sediment texture. Individual samples were compared on the basis of their textural composition, with special emphasis placed on the following:

1. weight percent of phi (φ) grain sizes;
2. significant phi grain sizes (≥10 weight percent of the sample);
3. mud, sand, and gravel weight percents;
4. sand fraction subdivided into fine-grained sand, fgS (3 and 4 phi), and coarse-grained sand, cgS (0, 1, and 2 phi), in weight percents;
5. gravel fraction (granules and pebbles only) subdivided into G_1 (–1 and –2 phi), and G_2 (–3, –4, and –5 phi), in weight percents;

Table 4. Grain-size analyses of sediment samples and assignment of stations to geologic substrates.

[Table 4 in Excel format is available at http://dx.doi.org/10.3133/sim3341. Grain-size analyses of sediment samples for this quadrangle and the other 17 quadrangles of the Stellwagen Bank National Marine Sanctuary region have been published in USGS Data Series 469 (Valentine and others, 2010)]

Combining the traditional five sand grades into two composite grades (fine- and coarse-grained sand) was a key factor in delineating substrate types. See the Conversion Factors section of this report for a grain-size classification of sediment grades and composite sediment grades of this study (fgS, cgS, G_1, G_2) in millimeters (mm) and equivalent phi units. Gravel particles larger than 6.4 cm (–5 phi) were not collected in this study, although cobbles and boulders were observed in seabed imagery.

The geologic substrates shown on Map D are described on the basis of grain-size composition, significant phi grain sizes present, sediment layering, sediment mobility, surface morphology, and water depth range (tables 5–7). Each geologic substrate is *identified* by a unique *symbol* that uses letters and numbers such as A1, A2, B, and so forth. A substrate is *identified and briefly described* by a *two-part name* that combines the unique symbol with a non-unique combination of characters (table 7) that describe the major physical attributes of the substrate. For example, the two-part substrate name "B r_cgS / i_cbG" means "substrate B—rippled, coarse-grained sand; partial veneer on immobile cobble, boulder gravel." In the present approach to substrate classification, the need to construct two-part names that are both informative and brief can produce names for two (or more) substrates in which substrate symbols are unique but the descriptive parts of the names are identical. This is the case for substrates A2 and E (i_cgS), D1 and F (i_cgS / pcbG), and G1 and G2 (i_mfgS). Differences between substrates that have identical physical attributes listed in their names are documented in the Description of Map Units section and tables 5 and 6 of this report.

Table 5. Sediment textural characteristics of mapped geologic substrates.

[Textural characteristics for unlayered substrates (A1, A2, E, G1, G2) are based on grain-size analysis. For layered substrates (B, D1, D2, F), textural characteristics are based on grain-size analysis of the upper layer of sand that partially veneers pebble, cobble, or boulder gravel. The underlying gravel is identified based on video imagery. Substrate C is not listed as it consists of boulder ridges identified by seabed topography and visual inspection using video and photographic imagery. Weight percent values may not add to 100 due to rounding; <1 means ≤0.5 weight percent. A sand (4, 3, 2, 1, 0 phi), mud (>4 phi), or gravel (G_1, G_2) grain size is termed "significant" in a substrate if its mean weight percent for all samples of a substrate type is ≥10. Abbreviations used: fgS, fine-grained sand (3 and 4 phi combined); cgS, coarse-grained sand (0, 1, and 2 phi combined); G_1, $Gravel_1$ (–1 and –2 phi combined); G_2, $Gravel_2$ (–3, –4, and –5 phi combined); m, meter]

Geologic substrate symbol	Number of samples	Sample water depth range; mean (m)	Mean weight percent of significant grain sizes, phi (φ) units	Weight percent							
				Samples	Mud	fgS	cgS	Sand	G_1	G_2	Gravel
A1	128	30–56	2φ (14), 1φ (45), 0φ (28)	Range	0–1	<1–15	50–98	52–99	<1–26	0–21	<1–47
		41		Mean	<1	3	88	90	8	1	9
A2	26	53–77	3φ (10), 2φ (19), 1φ (35), 0φ (19)	Range	<1–1	2–37	32–93	44–98	1–36	0–35	1–55
		62		Mean	1	11	72	83	11	5	16
B	22	36–58	2φ (19), 1φ (40), 0φ (27)	Range	0–1	2–21	65–97	78–99	<1–20	0–8	<1–22
		48		Mean	<1	5	86	92	7	1	8
D1	28	50–83	3φ (14), 2φ (15), 1φ (11), G_1 (11), G_2 (34)	Range	1–9	3–46	7–64	15–92	2–31	3–75	5–81
		61		Mean	4	16	34	50	11	34	45
D2	15	87–105	>4φ (12), 3φ (15), 2φ (21), 1φ (23), 0φ (10)	Range	8–22	11–42	34–65	55–89	1–14	0–25	3–34
		94		Mean	12	22	55	76	8	4	12
E	31	66–122	3φ (16), 2φ (26), 1φ (28), 0φ (10)	Range	2–10	3–48	24–87	38–98	0–28	0–26	0–53
		80		Mean	4	18	64	82	9	5	14
F	21	90–148	3φ (17), 2φ (16), 1φ (17), 0φ (11)	Range	5–14	8–54	20–65	39–91	0–27	0–32	0–54
		111		Mean	9	25	44	69	13	9	22
G1	39	85–171	>4φ (10), 4φ (29), 3φ (49)	Range	2–18	44–94	0–39	80–97	<1–5	1–7	0–8
		113		Mean	10	78	10	88	1	1	1
G2	9	125–185	>4φ (23), 4φ (58), 3φ (19)	Range	19–29	70–80	0–2	71–81	0–0	0–0	0–0
		145		Mean	23	77	1	77	0	0	0

Table 6. Geologic substrate symbols, names, and brief descriptions.

[Textural characteristics for substrates B, D1, D2, and F represent the partial sediment veneer overlying pebble, cobble, or boulder gravel. See table 5 for textural characteristics of individual substrates; see table 7 for explanation of characters used in the substrate name to describe the physical attributes of substrates. Abbreviations used: m, meter; wt pct, weight percent]

Geologic substrate symbol	Substrate name	Substrate name translation	Brief description and comparison to other substrates
A1	A1 r_cgS	A1—Rippled, coarse-grained sand	Substrate A1 is equivalent to the mobile portion of adjacent substrate B; and it is similar to adjacent immobile substrate A2 which lies at deeper depths (53–77 m) on the lower flank of Stellwagen Bank and contains more fine-grained sand (11 wt pct).
A2	A2 i_cgS	A2—Immobile, coarse-grained sand	Substrate A2 is similar to adjacent mobile substrate A1 which lies at shallower depths (30–56 m) and contains less fine-grained sand (3 wt pct). It contains less mud and fine-grained sand than substrate E.
B	B r_cgS/i_cbG	B—Rippled, coarse-grained sand; partial veneer on immobile cobble, boulder gravel	Boulder ridges (substrate C) are present. The mobile sand layer of substrate B is equivalent to adjacent mobile substrate A1.
C	C i_cbG	C—Immobile, cobble, boulder gravel	It is present as boulder ridges on the flank of Stellwagen Bank where it is associated with substrate B (36–58 m) and substrate D1 (50–83 m), and on the tops of North, East, and Middle Ninety Banks where it is associated with substrate D2 (87–105 m).
D1	D1 i_cgS/pcbG	D1—Immobile, coarse-grained sand; partial veneer on pebble, cobble, boulder gravel	Substrate D1 is similar to substrate D2 which lies at deeper depths (87–105 m) on the tops of North, East, and Middle Ninety Banks and has higher mud content (12 wt pct). It is also similar to substrate F which lies at deeper depths on the flanks of the Ninety Meter Banks. Boulder ridges (substrate C) are present.
D2	D2 i_mcgS/pcbG	D2—Immobile, muddy, coarse-grained sand; partial veneer on pebble, cobble, boulder gravel	Substrate D2 is similar to substrate D1 which lies at shallower depths (50–83 m) on the flank of Stellwagen Bank and has lower mud content (4 wt pct). Boulder ridges (substrate C) are present.
E	E i_cgS	E—Immobile, coarse-grained sand	Substrate E is similar in mud content to substrate D1 and contains more mud and fine-grained sand than substrate A2.
F	F i_cgS/pcbG	F—Immobile, coarse-grained sand; partial veneer on pebble, cobble, boulder gravel	Substrate F is similar to substrates D1 and D2, except that F lies at deeper depths on the flanks of the Ninety Meter Banks, and the partial veneer of coarse grained sand on the gravel is more extensive.
G1	G1 i_mfgS	G1—Immobile, muddy, fine-grained sand	Substrate G1 is similar to substrate G2 which lies at deeper depths (125–185 m) and has higher 4 phi sand (58 wt pct) and higher mud content (23 wt pct).
G2	G2 i_mfgS	G2—Immobile, muddy, fine-grained sand	Substrate G2 has the highest mud content (23 wt pct) of all substrates in quadrangle 6. See description for substrate G1.

Table 7. Characters used in substrate names to describe the physical attributes of substrates.

[Sand substrates (≥50 weight percent sand) are classified as fine-grained sand (fgS) or coarse-grained sand (cgS) depending on which represents the largest weight percent in the sand fraction. Abbreviation used: mm, millimeter]

Attribute characters of substrate name	Substrate attribute character description, grain size (phi [φ] units)
b	Boulder; diameter ≥256 mm (–8 φ and larger particles)
c	Cobble; diameter 64 to <256 mm (–6 and –7 φ)
cgS	Coarse-grained sand; diameter 0.25 to <2 mm (2, 1, and 0 φ)
fgS	Fine-grained sand; diameter 0.062 to <0.25 mm (4 and 3 φ)
G	Gravel, ≥50 weight percent; diameter ≥2 mm (–1 φ and larger particles)
i	Immobile
m	Muddy; ≥10 to <50 weight percent mud (clay+silt); diameter <0.062 mm (>4 φ)
p	Pebble; diameter 4 to <64 mm (–2, –3, –4, and –5 φ)
r	Rippled
S	Sand, ≥50 weight percent; diameter 0.062 to <2 mm (4, 3, 2, 1, and 0 φ)
/	"Partial veneer on." For example, "i_cgS/pcbG" means "immobile, coarse-grained sand; partial veneer on pebble, cobble, boulder gravel"

Seabed Sediment Collection, Processing, and Analysis

As a part of the process of mapping the sea floor, the USGS developed the SEABed Observation and Sampling System (SEABOSS) to collect samples and video and photographic images of the seabed to aid in the interpretation of seabed sonar imagery. A modified Van Veen sediment grab sampler is mounted in the center of the SEABOSS frame, which ensures the sampler is properly oriented on the seabed when a sample is collected. Before deployment, the sampler bucket's jaws are opened by collapsing the extended arms to a near-horizontal position and locking them in place with two catches. The sampler operates passively to sample the seabed; it is not spring loaded.

To collect a sediment sample, the SEABOSS frame was lowered gently onto the seabed, reducing tension on the cable, which caused the two locking catches to be automatically released by gravity. As the cable was retrieved, the grab sampler's arms were pulled upward, closing the bucket around the sediment, and the SEABOSS was lifted off the seabed.

The SEABOSS was retrieved and set upon a wooden platform that kept the sampler bucket and camera systems above the deck. The sampler's arms were held in the upright position manually or by tension on the cable, the two doors on the upper side of the bucket were opened, and the sediment was removed. For this project, the upper 2 cm of sediment, representing the surface of the seabed, were removed with a rectangular shovel 2-cm deep and stored in a plastic bag for grain-size analysis. The remaining sediment was dumped into a tray on the deck below the sampler and discarded, after which the sampler was washed in preparation for sampling at the next site. Further information on the SEABOSS can be found in Valentine and others (2000).

Grain-size analyses of the sediment samples were performed at the USGS Woods Hole Coastal and Marine Science Center in Woods Hole, Massachusetts, by using a standard suite of analytical methods (Poppe and others, 2005). This laboratory has been in operation since 1963 and has analyzed many thousands of sediment samples collected by the USGS in New England.

Seabed Photographs

Photograph collection methods

In addition to collecting sediment samples, the SEABOSS is equipped to record video and photographic imagery of the seabed.

The SEABOSS is not a towed system. It incorporates a modified Van Veen sediment grab sampler, a still camera, two color video cameras, and an array of lasers into a frame that is lowered to the seabed from a stationary vessel which is then allowed to drift. A navigation receiver is placed on the ship at the location from where the SEABOSS is launched. The navigation system uses global positioning system (GPS) techniques, so locations of photographs are accurate to within 10 m. During deployment, the camera system hangs directly below the side of the ship, and the recorded navigation data closely approximate the position of the camera system near the seabed.

The ship was oriented so that wind and waves would not cause it to drift over the conducting cable attached to the SEABOSS. The winch operator used a video feed from the system to maintain the cameras at the proper height above the seabed; the scientist used the video feed to decide when to trigger the still camera and record the time the photo was taken. The height of the camera above the seabed (76 cm; 30 inches [in.]) and the size of objects in the images were determined by viewing a pattern of laser beams on the seabed.

All photographic images were acquired with a Photosea underwater-camera system.

[Abbreviations used: m, meter; ft, foot; s, second]

Camera	Photosea model no. 1000A; rated to 305 m (1,000 ft)
Strobe	Photosea model no. 1500S; rated to 457 m (1,500 ft); flash 1/750 s
Lens	Nikkor underwater 28-mm lens with a +1-diopter lens attachment; aperture set between f11 and f16; focus set at 0.8 m (2.5 ft)
Film	Kodak Portra 400 NC color film; bulk roll 10-m (33-ft) long with 250 exposures; exposure time 1/150 s

Photograph processing methods

Exposed film was developed in bulk 250-exposure rolls by a commercial film-processing company. The bulk rolls of negatives were then sent for scanning to a commercial digitizing company where the negatives were scanned by using Kodak Photo CD software (into PCD format images). A PCD image file of each negative was generated and archived on CD–ROM. PCD images can be used to generate images at resolutions ranging from 96×64 pixels to 3072×2048 pixels. The PCD images were converted to Joint Photographic Experts Group (JPEG) format (Valentine and others, 2010; available for downloading in two resolutions: medium [1536×1024 pixels], and high [3072×2048 pixels]).

Image information and accessibility

Each photographic image was taken at a height of approximately 76 cm (30 in.) above the seabed and represents an area of 0.39 m^2 (4.17 ft^2) that measures 76 cm (30 in.) wide and 51 cm (20 in.) long. The data tag on the right-hand margin of the image displays information in the following format: NNNYYHHMM, where NNN is the image number on the film roll, YY is the last 2 digits of the year, and HH and MM are time in hours and minutes, respectively.

Seabed photographs have been modified to an Exchangeable Image File Format (EXIF) so that important image metadata and data can be displayed in the comment EXIF tag of the JPEG images. For access to seabed images, see Valentine and others (2010).

Data Catalog

This report contains geographic information system (GIS) data in both vector and raster format. The vector data are provided in shapefile format compatible with Esri ArcView and ArcGIS software. These data are in the Geographic North American Datum of 1983 (NAD 83) coordinate system. The raster data are provided in Esri binary grid format in a custom Mercator projection with the following parameters: longitude of central meridian 70°19' W., latitude of true scale 41°39' N., false easting 0 m, false northing 0 m, datum NAD 83. Data layers archived here should not require additional processing to be used in Esri software.

Each GIS data layer from this publication is cataloged below for easy access. The descriptions of the individual data layers are included below the filename. A separate column contains a browse graphic showing the data layer extent and coverage. Clicking on this graphic will open a larger version of the image in a new browser window.

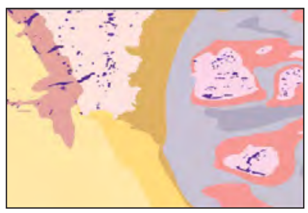
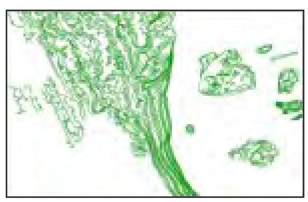
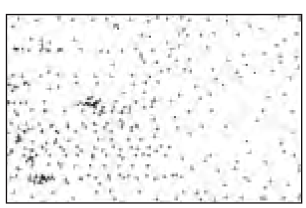
The files necessary to load each dataset into a compatible GIS have been compressed into a single zipped file along with Federal Geographic Data Committee (FGDC)-compliant metadata (HTML, text, and XML formats). A second XML metadata format file, generated and viewable by ArcCatalog, is also included in the zipped file. For convenience, the FGDC-compliant HTML, text, and XML versions of the metadata for each dataset have links provided below. The geologic interpretation zipped file also contains the symbology layer files necessary to replicate the seven individual interpretive maps (A–G) presented in this publication.

Data layers generated for this report are supplemented by a linked list of previously published data layers from the Stellwagen Bank National Marine Sanctuary region that are relevant to quadrangle 6. Included in these data layers are the photograph locations and sediment sample analyses used in the geologic substrate interpretations.

To download the data from the table below, right mouse click on the link in the 'Download' column. Select 'Save Target As...' to save a compressed zipped file to the local hard drive. The download file size is indicated under the file name. Uncompress the zipped files using an extraction utility.

Data Layers and Data for Quadrangle 6

[Abbreviations used: NAD 83, North American Datum of 1983; MB, megabyte; m, meter]

Data-layer name and description	View	Metadata	Download
SIM3341_geologic_interp—Polygon shapefile of the geologic substrate interpretation of the seabed in quadrangle 6. Attribute fields can be used to symbolically illustrate the seven individual interpretive maps presented in this publication. The layer files representing this symbology are included in the zipped file. (Geographic, NAD 83)		HTML Text XML	SIM3341_geologic_interp.zip File size: 0.6 MB
SIM3341_1m_contours—Polyline shapefile of the 1-m contours in quadrangle 6. These particular contours are used in some areas to reveal small features not shown by 5-m contours. (Geographic, NAD 83)		HTML Text XML	SIM3341_1m_contours.zip File size: 0.6 MB
SIM3341_13mbathy—Esri binary grid of the 13-m×13-m cell-size bathymetry of quadrangle 6 used as the basis for the generation of the 1-m contours and the terrain ruggedness analyses. (Custom Mercator projection, NAD 83)		HTML Text XML	SIM3341_13mbathy.zip File size: 2.5 MB
SIM3341_stations_geology—Point shapefile of station locations and Excel file of sediment grain-size analyses and assignment of stations to substrate types. (Geographic, NAD 83)		HTML Text XML	SIM3341_stations_geology.zip File size: 0.3 MB

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Appendix 1. Supplementary, Previously Published Data Layers From the Stellwagen Bank National Marine Sanctuary Region Relevant to Quadrangle 6

Data layer	Location of data and associated metadata	Source
	Seabed raster data	
Sun-illuminated sea-floor topography; and TIFF world file	http://pubs.usgs.gov/sim/2005/2840/DATA/sunillum/sunillum.zip	Valentine, 2005
Backscatter intensity and sun-illuminated sea-floor topography; and TIFF world file	http://pubs.usgs.gov/sim/2005/2840/DATA/backscatter/bcksctter.zip	Valentine, 2005
Sea-floor ruggedness; and TIFF world file	http://pubs.usgs.gov/sim/2005/2840/DATA/rugged/ruggedimage/ruggedimage.zip	Valentine, 2005
Esri binary grid used as the basis for the terrain rugged analyses (custom Mercator projection, NAD 83)	http://pubs.usgs.gov/sim/2005/2840/DATA/rugged/rugged.zip	Valentine, 2005
Sea-floor slope; and TIFF world file	http://pubs.usgs.gov/sim/2005/2840/DATA/slope/slopeimage/slopeimage.zip	Valentine, 2005
	Esri-formatted GIS files of features and surfaces; and seabed photographs	
Stellwagen Bank National Marine Sanctuary boundary	http://pubs.usgs.gov/sim/2005/2840/DATA/SBNMS_boundary/sbnmsbnd.zip	Valentine, 2005
Quadrangle boundaries	http://pubs.usgs.gov/sim/2005/2840/DATA/quadbnd/quadbnd.zip	Valentine, 2005
Bathymetric contours	http://pubs.usgs.gov/sim/2005/2840/DATA/bathy/bathy.zip	Valentine, 2005
Boulder ridges <1 meter in height	http://pubs.usgs.gov/sim/2005/2840/DATA/ridges/ridges0.zip	Valentine, 2005
Boulder ridges ≥ 1 meter in height	http://pubs.usgs.gov/sim/2005/2840/DATA/ridges/ridges1.zip	Valentine, 2005
Bedrock outcrops	http://pubs.usgs.gov/sim/2005/2840/DATA/bedrock/bedrock.zip	Valentine, 2005
Sea-floor ruggedness	http://pubs.usgs.gov/sim/2005/2840/DATA/rugged/rugged.zip	Valentine, 2005
Sea-floor slope	http://pubs.usgs.gov/sim/2005/2840/DATA/slope/slope.zip	Valentine, 2005
Seabed observation stations—Video drift track locations	http://pubs.usgs.gov/sim/2005/2840/DATA/videotrack/sbnmsallvid.zip	Valentine, 2005
Seabed observation stations—Sediment sample locations and Excel file of grain-size analyses	http://pubs.usgs.gov/ds/469/DataCatalog/sb_sedsamples.zip	Valentine and others, 2010
Photographic images of the seabed—Locations of individual photographs	http://pubs.usgs.gov/ds/469/DataCatalog/sb_photolocs.zip	Valentine and others, 2010
JPEG images of the seabed from quadrangles 1–18 in medium and high resolution	http://pubs.usgs.gov/ds/469/html/DataCatalog.html	Valentine and others, 2010

Prepared by the USGS Science Publishing Network
Edited by Natalie Juda, Reston PSC
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Valentine and Gallea—**Seabed Maps of Quadrangle 6 in the Stellwagen Bank National Marine Sanctuary Region Offshore of Boston, Mass.**—Scientific Investigations Map 3341

ISSN 2329-132X (online)
http://dx.doi.org/10.3133/sim3341