

3. SEABED FEATURES

GEOMORPHOLOGY

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The general configuration of the Massachusetts coast shoreline and inner shelf is controlled by the structure and composition of the regional bedrock framework. Bedrock in the region consists of complexly deformed metamorphic and intrusive rocks produced by multiple orogenic (mountain-building) events that have occurred since the Precambrian Era (> 540 million years ago) and the opening of the modern Atlantic Ocean (~250 million years ago) (Zen 1983; Robinson *et al.* 1998).

Surficial geologic features throughout Massachusetts were largely shaped during the Laurentide glaciation, which reached its most southern advance around 21,000 years ago, and during post-glacial fluctuations in relative sea level. Three glacial ice lobes occupied the present sites of Buzzard's Bay, Cape Cod Bay, and the Great South Channel to the east of Cape Cod. The southern limit of glaciation is marked by moraines on Martha's Vineyard and Nantucket (Schlee and Pratt 1970; Oldale 2001; Uchupi *et al.* 1996; Poppe *et al.* 2007). Cape Cod was formed by glacial outwash plains as the glaciers receded. During the glacial retreat, large lakes were formed in Nantucket Sound and Cape Cod Bay (Poppe *et al.* 2007; Oldale 2001). Tundra-like conditions existed at the ice edge as evidenced by peat deposits.

Following deglaciation, the Holocene marine transgression (sea level rise) is thought to have started around 10-12,000 years ago and has been the most important process shaping the Massachusetts coastal region and the large banks in the Gulf of Maine. When Paleo-indians first arrived in Massachusetts between 11,000 and 8,000 years ago, sea level was lower than present and the shoreline was located seaward from where it is today (Oldale 2001). Therefore, submerged archeological sites can be found in the Massachusetts ocean planning area. Since then, the ongoing sea level rise has caused the shoreline to migrate landward. Energetic waves and currents have reworked the older glacial deposits along the coast, leaving behind coarse-grained sediment and bedrock in many areas of shallow seafloor, and depositing finer-grained muddy sediment in deeper basins offshore.

There are seven regions with distinct geomorphology within the planning area: 1) north of Cape Ann, 2) Massachusetts Bay, 3) Stellwagen Basin, 4) Cape Cod Bay, 5) the backside of the Cape, 6) Nantucket and Vineyard Sounds, and 7) Buzzards Bay. North of Cape Ann is dominated by the influence of the Merrimack River. Sandy seafloor with interspersed areas of hard bottom and dynamic sand wave fields are characteristic. Within Massachusetts Bay, distinctive elongate ridges composed of glacial till (drumlins) define the seafloor. Stellwagen Basin is a deep, depositional basin with finer grained silts and clays, including hard clay nodules. Cape Cod Bay is a relatively featureless

35 seafloor with large regions of sand and mud in the central portion. The backside of the Cape is
36 defined by the strong currents that rapidly winnow soft sediment, leaving a seafloor dominated by
37 coarse unstratified glacial till. Nantucket and Vineyard Sounds, south of the Cape, are dominated by
38 large shoals and sand wave fields. Buzzards Bay is an estuarine system that is dominated by sand and
39 mud with rocky outcrops. The major sediment composition for the planning area is available in
40 [Figure 3.1](#) (DMF 2008 [still needs a couple of datasets to be finished](#)). Throughout these areas, softer
41 sediment has a characteristically higher organic content than coarser sediment.

42 While the foregoing text gives a basic description of the major seafloor regimes within the planning
43 area, it is important to note that the complicated underlying geology has led to high variability in
44 seafloor composition. Massachusetts is in the process of collecting sediment samples and acoustic
45 imagery of the seafloor throughout the state to better define the seafloor composition and geology.
46 This high resolution information is the backbone of any concerted seafloor mapping, habitat
47 mapping, or management exercise.

48 **SEDIMENT TRANSPORT**

49 Sediment transport is a highly complex engineering topic since the four key components for
50 calculating sediment transport, water flow, seafloor roughness, sediment grain density, and sediment
51 grain shape (morphology), are highly variable. Over 100 years of research has examined sediment
52 transport because it is important in relation to shoreline protection and the establishment of offshore
53 mining sites, as well as several engineering topics including erosion around structures, backfilling of
54 dredged channels and nearshore morphological change (Zhou 2001).

55 The major depositional basins in the planning area are Stellwagen Basin, Cape Cod Bay, and
56 Buzzards Bay. Modeling and long-term monitoring have confirmed that sediment transport in the
57 planning area north of Cape Cod occurs primarily during storms (Bothner and Butman 2007).
58 Typically, waves during storms with winds from the northeast resuspend sediments, which are
59 transported by shallow currents from western Massachusetts Bay toward Cape Cod Bay and by
60 deeper currents to Stellwagen Basin. Tidal currents, wind-driven currents, and currents associated
61 with spring runoff are insufficient to resuspend sediments (Werme and Hunt 2007).

62 [Sediment transport models in Buzzards Bay, Nantucket and Vineyard Sounds, and the Backside
63 of Cape Cod ... still need references and general sed transport Figure of general sed transport for
64 state?](#)

65 Another important consideration is the sediment transport and shoreline retreat along the coast.
66 Although the Massachusetts shoreline is technically outside of the planning area, the planning area
67 will likely see increased pressure on its mineral resources for shoreline armoring. Without repeated
68 profile measurements, it is hard to predict long-shore and cross-shore sediment transport. There are
69 engineering formulas and models designed to do this, but the variability of the nearshore is such that
70 the formulas and models are approximations. Additionally, the impact of storm events can be a

71 primary sediment transport mechanism on the coast. Although there is no statewide, high-resolution
72 modeling, there are localized shoreline evolution studies and transport models (Miselis *et al.* 2008).
73 The major long-shore and cross-shore currents are identified in [Figure 3.2](#). The need for regional
74 sediment management planning is well-known. For example, the Army Corps of Engineers and the
75 Department of Conservation and Recreation are planning on a regional transport study from the NH
76 border to the tip of Cape Ann.

77 **SEDIMENT QUALITY**

78 *Major contributors: Matt Leibman and Michael Bothner*

79 Regional studies of Massachusetts coastal waters have documented the spatial distribution of several
80 classes of contaminants, including trace metals, chlorinated pesticides, polychlorinated biphenyls
81 (PCBs), and polycyclic aromatic hydrocarbons (PAHs) in sediment and biota (NRC 1995; McDowell
82 1997; Hunt *et al.* 2006; NCCOS 2006; EPA 2007; Bothner and Butman 2007; Buchholtz ten Brink *et*
83 *al.* 2002). These contaminants preferentially bind to sediments that are fine grained and contain high
84 organic carbon and as a result, the distribution of contaminants is strongly controlled by the
85 distribution of fine grained sediments. While there are generally decreasing contaminant
86 concentrations in sediments with distance from land-based contaminant sources, the variable and
87 generally coarse sediment texture in Massachusetts Bay and coastal Cape Cod Bay complicates the
88 trend. For example, in central Cape Cod Bay, where finer sediments are found, concentrations of
89 contaminants derived from Boston are elevated compared to their levels in coarse sediments closer
90 to the source (Ravizza and Bothner 1996).

91 The area anticipated to have the highest levels of contamination in an offshore location is the
92 Massachusetts Industrial Waste Site (IWS), which was used for the disposal of radiological wastes
93 through 1959 and chemical wastes through 1977. Contaminants at the IWS and the adjacent
94 Massachusetts Bay Disposal Site are typically found at concentrations below sediment quality
95 guidelines for moderate likelihood of adverse effects to marine organisms (NOS 1996; Liebman and
96 Brochi 2008). Both disposal sites are outside of the planning area. Within the planning area, sediment
97 quality has been addressed in two published time-series studies in the vicinity of the Massachusetts
98 Bay Outfall for greater Boston's treated sewage effluent (Dahlen *et al.* 2006; Bothner and Butman
99 2007). These studies describe an environmentally insignificant increase in silver and the bacterium
100 spore *Clostridium perfringens* (a benign indicator of sewage particles) in surface sediments at stations
101 closest to the outfall. Other areas off eastern Massachusetts were found to have contaminant
102 concentrations below sediment quality guidelines (Long *et al.* 1995).

103 The only other contaminant and toxicological studies available in the planning area have been done
104 for dredging and construction activities. The data is contained within reports generated for permits
105 so can be hard to extract, but it is part of the public record. Based on the results from research done
106 for the outfall and for the disposal sites, it is assumed that contaminants within sediments throughout
107 the planning area are generally at levels that are not expected to cause adverse effects to marine

108 organisms, or to bioaccumulate through the food chain. All disposal sites within the planning area are
109 only used for clean material.

110 The planning area does encompass two smaller bays where chemical contaminants, bacteria, and low
111 oxygen conditions may be significant factors governing the health of the seafloor community:
112 Wellfleet Harbor and outer New Bedford Harbor. However, for the majority of the planning area
113 sediment quality is not likely to be impaired.

114 **BIOLOGICAL FEATURES**

115 Seabed features of biological origin can play a unique and significant role in the ecosystem of an area.
116 Some remarkable examples of such features include coral reefs and deep-sea vent communities.
117 Within Massachusetts, the only surveyed biological feature is eelgrass. Eelgrass (*Zostera marina*) is a
118 key structure-forming species and is well-known as an important refuge for many fish ([refs](#)). Eelgrass
119 coverage has declined sharply from estimated historical coverage, and the decline is thought to be
120 linked to impaired water quality. While once abundant throughout shallow coastal waters, the major
121 beds are now found around Cape Cod and in Buzzards Bay. Buzzards Bay eelgrass has declined by
122 more than half since 1988 (Costa 2003s).

123 Kelp (*Laminaria*) is an algae and does not have roots as eelgrass does, but it is a structure-forming
124 species found usually in deeper waters. Kelp is known to occur in large beds based on observational
125 data, but the distribution of kelp has not been mapped. Shellfish also form large seafloor features.
126 This includes large populations of infaunal species such as quahogs as well as large piles of encrusting
127 shellfish such as blue mussels (while these features have not been surveyed, habitat suitability maps
128 have been produced for shellfish). Also of potential importance are regions with large concentrations
129 of sulfur sponge. There are other features such as clay nodules and clay “pipes” that could be of
130 bacterial origin, and as such would be considered important biological features of the seafloor. Due
131 to the difficulty of mapping such features, there is little known about the extent and importance of
132 such features. *Marine Fisheries* is currently working on an effort to catalog the occurrence of sulfur
133 sponge. [Figure 3-3 \(could do a map of eelgrass + kelp + shellfish + sulfur sponge.\)](#)

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