

Geologic Resource Evaluation Scoping Summary

Boston Harbor Islands National Recreation Area

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U.S. Department of the Interior



The Geologic Resource Evaluation (GRE) Program provides each of 270 identified natural area National Park Service (NPS) units with a geologic scoping meeting, a digital geologic map, and a geologic resource evaluation report. Geologic scoping meetings generate an evaluation of the adequacy of existing geologic maps for resource management, provide an opportunity for discussion of park-specific geologic management issues and, if possible, include a site visit with local geologic experts. The purpose of these meetings is to identify geologic mapping coverage and needs, distinctive geologic processes and features, resource management issues, and potential monitoring and research needs. Outcomes of this scoping process are a scoping summary (this report), a digital geologic map, and a geologic resource evaluation report.

The National Park Service held a GRE scoping meeting for Boston Harbor Islands National Recreation Area (BOHA) on July 12, 2007 at the National Park Service Regional Support Office in Boston, Massachusetts followed by a site visit in the afternoon. Tim Connors (NPS-GRD) facilitated the discussion of map coverage and Bruce Heise (NPS-GRD) led the discussion regarding geologic processes and features at the national recreation area. Participants at the meeting included NPS staff from the park, Northeastern Region, and Geologic Resources Division, geologists from Northeastern University, Boston College, the Massachusetts Coastal Zone Management office, Woodhouse Geosciences, University of Massachusetts, Amherst, and Office of the Massachusetts State Geologist as well as cooperators from Colorado State University (see table 1). This scoping summary highlights the GRE scoping meeting for Boston Harbor including the geologic setting, the plan for providing a digital geologic map, a prioritized list of geologic resource management issues, a description of significant geologic features and processes, lists of recommendations and action items, and a record of meeting participants.

Park and Geologic Setting

Boston Harbor Islands National Recreation Area is a partnership park. Eight different landowners manage the land as the Boston Harbor Islands Partnership. The National Park Service helps facilitate resource management and provide guidance for the park. The national recreation area, authorized on November 12, 1996, covers 1,482 acres on 34 islands or former islands. The boundary is at mean low tidal stage. These islands spread from Thompson Island in Boston Harbor, south towards Quincy Bay and Hingham Bay and east towards the greater Massachusetts Bay and the open Atlantic Ocean. The Graves is the easternmost point in the national recreation area. The outer islands are more rocky and windswept. The inner islands are generally larger, sandy with recovering forest areas. The harbor is part of the Boston Basin, a topographic lowland. Boston Harbor Islands National Recreation Area sits within six 7.5'-quadrangles of interest east of Boston, Massachusetts.

The Boston Harbor Islands are part of the accreted Avalon Terrane. An accreted terrane is a crustal block or fragment that exhibits distinctive geology, which attached onto the margin of a continent as a result of tectonic processes. A terrane is demonstrably different from surrounding rocks and is usually fault-bounded. The Avalon Terrane tangentially collided with North America during the

Acadian orogenic event some 390 million years ago (Ma). Rocks of this terrane include weakly metamorphosed shelf and shallow marine sediments of the Boston Bay Group, arc volcanics, gabbroic intrusions, and granites. Bedrock outcrops on several of the islands in Boston Harbor including Slate Island, Calf Island, Little Calf Island, Rainsford Island, Worlds End, The Brewster Islands, and Moon Island. The dominant bedrock unit, deposited in a fault-bounded basin, is the Cambridge Formation (argillite), which dates to approximately 580 Ma. Mafic dikes and sills intruded this unit as seen on Calf Island. Dominant geologic structures include patterned joints, fault traces, and tension gashes.

Pleistocene glaciers covered eastern Massachusetts and glacial to post-glacial surficial features from at least two separate glaciations dominate the landscape at the national recreation area. Glaciers left mantles of glacial till across the area. Most of the Boston Harbor islands are part of a drowned drumlin cluster. Drumlins are low, smooth, rounded, elongate hills typically composed of glacial deposits such as till, but may also form from bedrock. They form beneath the margin of the glacier. Glacial flow controls drumlin morphology, which tends to have a blunt nose pointing in the direction from which the ice approached, and a gentler tail slope. There are more than 200 drumlins in the Boston Basin, 30 of which are part of the Boston Harbor Islands. Peddocks Island has five separate drumlins. Boston Harbor is a sediment-starved system and coastal processes continue to carve and erode the shorelines of all the islands.

Geologic Mapping for Boston Harbor Islands National Recreation Area

During the scoping meeting Tim Connors (NPS-GRD) showed some of the main features of the GRE Program's digital geologic maps, which reproduce all aspects of paper maps, including notes, legend, and cross sections, with the added benefit of GIS compatibility. The NPS GRE Geology-GIS Geodatabase Data Model incorporates the standards of digital map creation set for the GRE Program. Staff members digitize maps or convert digital data to the GRE digital geologic map model using ESRI ArcMap software. Final digital geologic map products include data in geodatabase, shapefile, and coverage format, layer files, FGDC-compliant metadata, and a Windows HelpFile that captures ancillary map data. Completed digital maps are available from the NPS Data Store at <http://science.nature.nps.gov/nrdata/>.

When possible, the GRE program provides large-scale (1:24,000) digital geologic map coverage for each park's area of interest, usually composed of the 7.5-minute quadrangles that contain park lands (figure 1). Maps of this scale (and larger) are useful to resource management because they capture most geologic features of interest and are positionally accurate within 40 feet. The process of selecting maps for park management begins with the identification of existing geologic maps and mapping needs in vicinity of the park. Scoping session participants then select appropriate source maps for the digital geologic data to be derived by GRE staff as well as determine areas in need of further mapping or refinement. Table 2 (at the end of this document) lists the source maps chosen for Boston Harbor Islands National Recreation Area as well as any further action required to make these maps appropriate for inclusion in the final geologic map for the site. Most of the BOHA islands are contained on the Hull, Massachusetts 7.5' quadrangle.

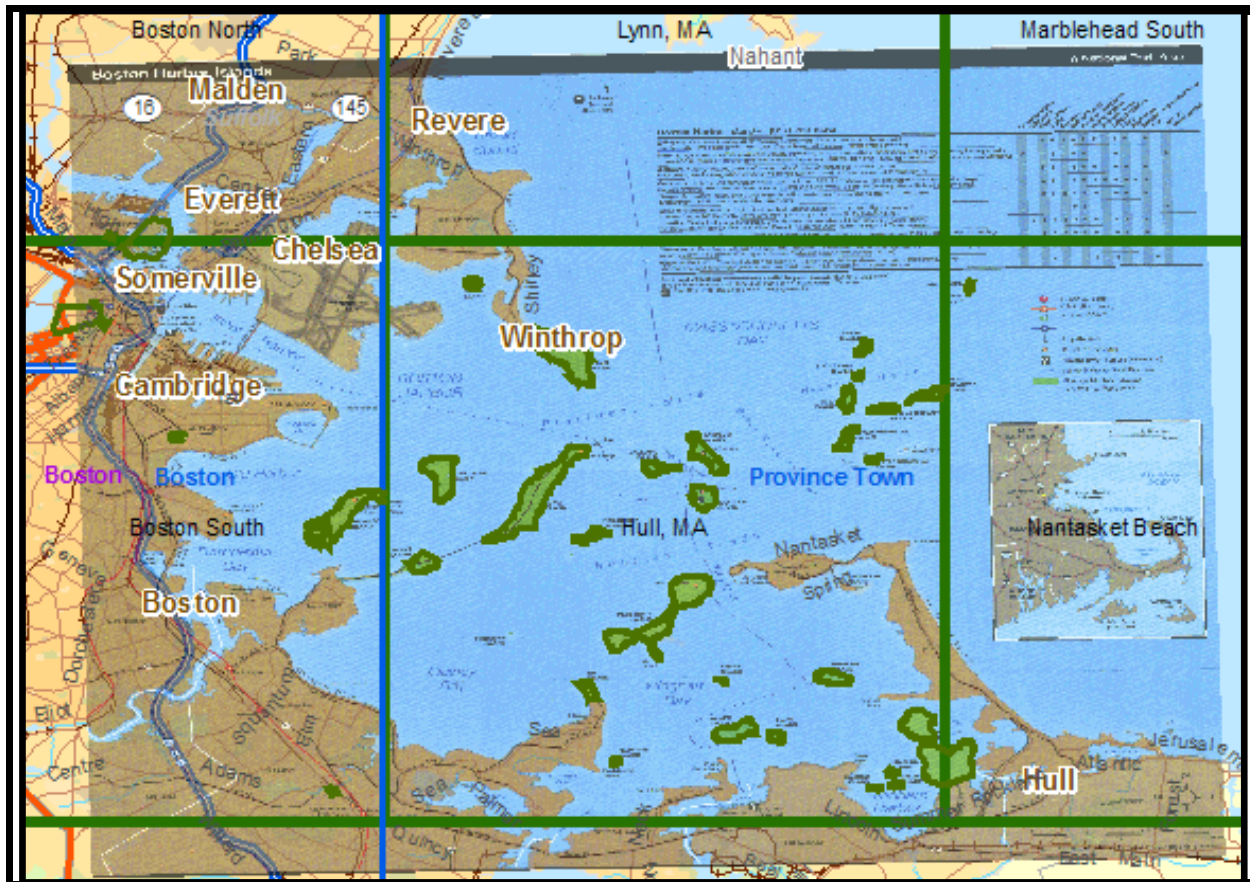


Figure 1. BOHA islands and relation to 7.5' USGS quadrangles

Joe Kopera (Office of Massachusetts State Geologist) assembled an excellent summary document on the status of geologic mapping in NPS areas in Massachusetts that should also be consulted with the material below. It is entitled “Selected available geologic information for: Minuteman National Historical Park, Saugus Iron Works, Boston Harbor Islands National Recreation area”.

Boston Harbor Islands National Recreation Area expressed interest in obtaining detailed geologic map coverage for all islands and former islands within park boundaries. There are six 7.5' quadrangles of interest: Marblehead South, Lynn, Boston North, Nantasket Beach, Hull, and Boston South (figure 2). Boston Harbor Islands have approximately 90% surficial geologic cover and 10% bedrock exposure. At present, there is adequate published, non-digital bedrock geologic map coverage, completed by the U.S. Geological Survey (MF 1241) for two of the quadrangles of interest (Boston North and Boston South). Bedrock geologic map coverage needs persist in the Marblehead South, Lynn, Nantasket Beach, and Hull quadrangles. Unpublished, detailed bedrock maps exist for all of the south harbor islands by Meg Thompson and Richard Bailey from Wellesley College and Northeastern University, respectively. At this point in time, these maps are not ready for GRE use.

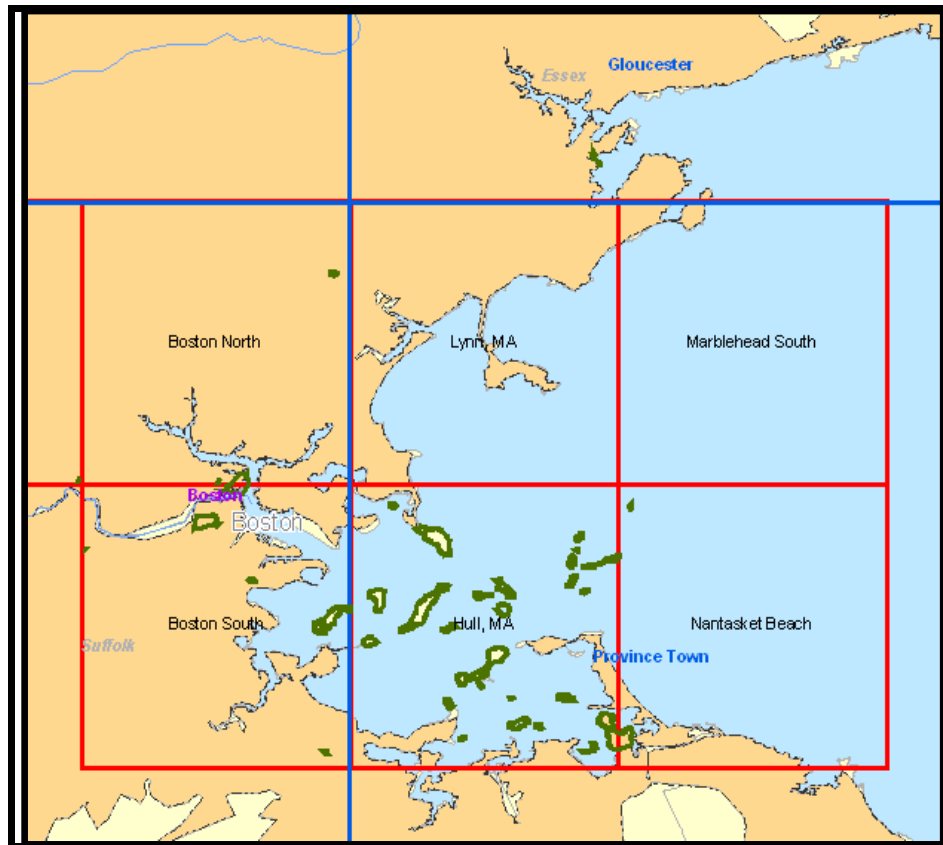


Figure 2. Quadrangles of interest for Boston Harbor Islands National Recreation Area. The figure shows USGS 7.5' quadrangles (red outline), 30' × 60' sheet (blue outline, blue font labels), and 1° × 2° sheets (purple outline, purple font labels). The green outlines represent park boundaries.

There is published non-digital surficial mapping that covers the entire park area completed by the U.S. Geological Survey, but the scale (1:100,000) may be too coarse for resource management (GMAP 74763; Kaye, C.A., 1978, Surficial geologic map of the Boston area, Massachusetts, , Open-File Report OF-78-111, 1:100000 scale). It was mentioned that more detailed surficial maps may be available in the very near future for the entire Boston area from newer USGS compilations. Dr. Byron Stone is the USGS geologists compiling these maps. In July, 2008, Dr. Stone indicated his new compilations would capture many of the surficial and glacial features requested by the park. Upon the completion of this map, the park will need to review it to determine if the mapping is of adequate scale for their management needs. If not, the park has an agreement with both Boston University and Northeastern University for shoreline and surficial mapping. This could provide the opportunity to generate larger scale maps if funding can be found.

Additionally, the Office of the Massachusetts State Geologist (OMSG) is trying to create a Quaternary geologic map for Massachusetts and connect it with similar products of Rhode Island and Connecticut. Peter Rosen and colleagues from Northeastern University are doing shoreline mapping for the park. Existing subaqueous data may be useful to add to the forthcoming USGS surficial mapping. Table 2 lists the source maps chosen for Boston Harbor Islands National Recreation Area and mapping needs in certain quadrangles, in addition to a unique “GMAP ID”

number assigned to each map by GRE staff for data management purposes, map scale, and action items.

At the present time, GRE staff need to formulate plans on how to best synthesize and acquire digital files of both the bedrock and surficial geology for the BOHA area. This will likely be a lengthy, iterative process that will require additional follow-up.

For the time being, and with the understanding that better, larger-scale mapping is forthcoming, the following maps could serve as interim products (scanned georeferenced images and USGS digital GIS data) for a cursory overview of area geology:

- (74763) Kaye, C.A., 1978, Surficial geologic map of the Boston area, Massachusetts, U.S. Geological Survey, Open-File Report OF-78-111, 1:100000 scale
- (2436) Kaye, C.A., 1980, Bedrock geologic maps of the Boston North, Boston South, and Newton quadrangles, Massachusetts (sheet 1 / 2), U.S. Geological Survey, Miscellaneous Field Studies Map MF-1241, sheet 1 / 2, 1:24000 scale
- (74765) Kaye, C.A., 1980, Bedrock geologic maps of the Boston North, Boston South, and Newton quadrangles, Massachusetts (sheet 2 / 2), U.S. Geological Survey, Miscellaneous Field Studies Map MF-1241, sheet 2 / 2, 1:24000 scale
- (71108) Butman, Bradford, Valentine, P.C., Danforth, W.W., Hayes, Laura, Serrett, L.A., and Middleton, T.J., 2004, Shaded relief, sea floor topography and backscatter intensity of Massachusetts Bay and the Stellwagen Bank region offshore of Boston, Massachusetts, , Geophysical Investigations Map I-2734, 1:125000 scale
- (74984) Ackerman, Seth D.; Butman, Bradford; Barnhardt, Walter A.; Danforth, William W.; Crocker, James M., 2006, High-Resolution Geologic Mapping of the Inner Continental Shelf: Boston Harbor and Approaches, Massachusetts, , Open-File report OF-2006-1008, 1:125000 scale

Additional items of interest pertaining to geologic mapping from the scoping

The national recreation area has some interest in landform maps, shoreline maps, seafloor topography and benthic habitat maps. U.S. Geological Survey Open-File Report 2006-1008 will be useful for submerged resource studies. The U.S. Geological Survey recently completed sea floor topographic mapping in the Boston area: (71108) Butman, Bradford, Valentine, P.C., Danforth, W.W., Hayes, Laura, Serrett, L.A., and Middleton, T.J., 2004, Shaded relief, sea floor topography and backscatter intensity of Massachusetts Bay and the Stellwagen Bank region offshore of Boston, Massachusetts, USGS, Geophysical Investigations Map I-2734, 1:125000 scale

Geologic Resource Management Issues

The scoping session for Boston Harbor Islands National Recreation Area provided the opportunity to develop a list of geologic features and processes, which will be further discussed in the final GRE report. During the meeting, participants prioritized the most significant geologic issues as follows:

- (1) Coastal Issues
- (2) Mass wasting
- (3) Disturbed lands and mineral extraction
- (4) Seismicity
- (5) Paleontological resources
- (6) Lacustrine maintenance

Coastal Issues

The coastlines of Boston Harbor Islands National Recreation Area vary from sandy and pebbly beaches, to eroded bluffs, to rocky boulder fields. When the Pilgrims first explored Boston Harbor, they counted over 50 distinct islands. Since then, erosion has reduced that number to approximately 35. Sheep Island was 25 acres in colonial time and now is barely exposed above the sea and is only a few acres in size. Princes Head is nearly submerged. Variations in sea level cause shoreline erosion. Sea level has risen approximately 1 m (3 ft) since colonial times or 0.2 m (0.8 ft) in the last 100 years. Coastal processes active at Boston Harbor Islands include rainwash, tombolo formation, migrating landforms, gullying, bluff and retreat terrace formation, and slumping. Recent studies indicate slumping along the coasts of several islands creates a series of intermittent slumps and retreat platforms separated by gullied slopes.

Overall, the system is sediment-starved. Eroding drumlins provide some sediment for beach nourishment. The enclosures of the harbor - Winthrop Beach to the north and Nantasket Beach to the south - contain drumlin sediments. Nantasket Beach is a retrograding barrier beach system anchored to drumlins and nourished locally by a remnant deltaic sand body offshore. Such sand sources are very isolated and scarce. Coastal features at Boston Harbor Islands include tombolos, salients, beaches, retrograding barrier beach areas anchored to drumlins, retreat platforms, raised sea level terraces (bedrock on Squaw Rock and a raised spit on Thompson Island), embayed salt marshes, perched salt marshes, fringing salt marshes, gravel barrier beaches, and intertidal substrates and assemblages. Intertidal areas and salt marshes provide habitat and breeding areas for coastal water birds. Rocky deposits at the base of bluffs and retreat terraces provide lobster habitat. There are many remaining questions coastal processes and controls at Boston Harbor Islands. Coastal geologists and geomorphologists are not sure why tombolos are forming and if till platforms support tombolo formation. Natural salients (local areas of sediment accumulation on shorelines) such as those on Thompson Island may be forming because of longshore sediment saturation and local wave convergence. Coastal geologists are unsure what effect boat wake is having on coastal retreat. Park resource management needs to understand how sediment moves within the entire system at Boston Harbor Islands. Delineated sediment sources and sinks are needed data sets for resource management.

Submerged areas offshore have Boston Blue Clay and overlying marine sediments as flat surfaces, eroding retreat terraces around the islands, and reworked sediment areas. Major channels are natural drowned drainages separated by flat terraces. Flat terraces seem to support tombolo formation.

Benthic habitats are constantly changing as coastal retreat proceeds and sediment transport patterns change. Powerful storms can have significant impacts on park resources, especially in shoreline areas. Storm vulnerability assessments and recovery plans are ongoing for Boston Harbor Islands National Recreation Area (contact: Mark Borrelli NPS-GRD).

Mass Wasting

The unconsolidated surficial geologic units and artificial fill on Boston Harbor Islands are prone to mass wasting processes such as creep and slumping when exposed on a slope. Gravity, frost heave, root wedging, undercutting, and erosion, are primary causes of natural slope instability. Certain clay-rich lenses within some glacial drumlins on the islands may provide local slip surfaces for larger slumps. Human activities such as landscaping, trail construction, and facilities development may accelerate mass wasting. The national recreation area is in the midst of redeveloping historic resources on Peddocks Island and the high slopes there are prone to mass wasting. For future development planning, slope vulnerability assessments on the island would be a useful data set.

Disturbed Lands and Mineral Extraction

Boston Harbor Islands have been exposed to anthropogenic disturbances for hundreds of years starting with Native American quarries on islands such as Slate Island. Outer Brewster Island has the Austine quarry once used for argillite for building stones. The last known quarry activity was in 1980. Some of this quarried stone is visible on Charlestown building exteriors. Historic land use was not always conducive to ecological health. For this reason, the park is restoring and relocating some historic dumps and cemeteries on Rainsford Island and Long Island, respectively.

Boston Harbor Islands' strategic location was of interest to the military and many forts including Fort Andrews, Fort Standish, Fort Warren, and Fort Strong remain on Peddocks Island, Lovells Island, Georges Island, and Long Island, respectively. Future park planning may include restoring old sea walls and revetments on several islands. Some of these piers and sea walls are more than 150 years old and include concrete. They stand as examples of early applications of coastal engineering in the United States.

Artificial fill comprises much of the Boston area's substrate. Spectacle Island was a dumping site for tunnel construction debris. Material from the "Big Dig" raised the island 24 to 30 m (80-100 ft). Some of this debris may contain hazardous material such as asbestos. Gallops Island also has fill and is now closed because of asbestos debris littering the beach. Long Island also has significant fill material. Deer Island has a large wastewater treatment facility that dominates the viewshed of the island. An offshore sewage tunnel extends nearly 13 km (8 miles) into the harbor. Surrounding development threatens natural resources at the recreation area including water quality, air quality, sediment supply, and viewshed.

Because of its status as a recreation area and part of the Boston Harbor Islands Partnership, visitor safety and access to the islands is a management priority. Shoreline access features may interfere with natural coastal processes such as longshore drift. The access dock for Spectacle Island experienced problems by increasing erosion of the adjacent marina and beach. Shoreline erosion below the supports for the bridge between Moon Island and Long Island prompted the introduction of stabilizing engineering structures. Local populations want shoreline engineering structures such as revetments, rip rap, and jetties in place to armor coastal areas near homes. Once shoreline-

engineering structures are in place, erosion accelerates elsewhere prompting the need for more structures. This would dramatically change shoreline dynamics.

Seismicity

Earthquakes are not widely associated with the Boston Harbor area, but small earthquake events are occurring along local faults. In 1755, a large earthquake near Cape Anne was strong enough to ring bells, topple chimneys and weather vanes, and damage stone walls from Portland Maine to Hartford, Connecticut. Its magnitude is estimated at 6.4 on the Richter scale. If such an event were to occur today, the damage estimates are in the billions of dollars. Large seismic events may trigger mass wasting and damage park infrastructure. Several of the islands and much of the city of Boston also have significant fill material, which may become very unstable during an earthquake. The nearest seismic station is at the Weston Observatory (<http://www.bc.edu/research/westonobservatory/>). The U.S. Geological Survey monitors seismic activity throughout the region. Recent activity is available at the following earthquake-monitoring website: <http://earthquake.usgs.gov/eqcenter/recenteqsus/>.

Paleontological Resources

The fossil resources at Boston Harbor Islands National Recreation Area have yet to be comprehensively studied or inventoried. The pre-Cambrian bedrock units of turbidites with slump folds (soft sediment deformation?) throughout the region contain significant fossils recording early marine life. Grape Island has some excellent exposures. Fossils concentrate on the bedding planes and display ring-like structures. There is some concern regarding fossil theft in the recreation area. Fossils include ostracodes and foraminifera. Pleistocene marine fossil remains are within the glacial till exposures on many islands. A field inventory would be a helpful data set for resource management.

Lacustrine Maintenance

Most of the pond features on the Boston Harbor Islands are natural ponds formed as glacial retreat left remnant ice chunks that melted to form kettle ponds. Other ponds are man made. A brackish pond on Thompson Island is being restored to a natural salt marsh by the removal of a 50 acre impoundment. There is a “skating pond” on Thompson Island adjacent to the marsh. Because of rising sea level, subsequent salt-water incursion creates salt marshes. However, the Ice Pond on Worlds End contains freshwater.

Features and Processes

Aeolian Dunes

As described below, glacial ice covered the Boston Basin during the Pleistocene Epoch. Once the glacial ice melted and retreated northward, the stark landscape was devoid of any stabilizing vegetation. The prevailing winds picked up the sand and silt from glacial deposits, transporting them on currents to create dunes and loess deposits. At Boston Harbor Islands National Recreation Area, paleodunes formed after the latest glacial retreat are comprised of sand and silt as remnants of an aeolian dune field that blanketed the entire area. Dunes are eroding away on some islands. The few dune features that remain on the landscape are significant because the sediment supply is extremely limited. Aeolian features outcrop at Nantasket Beach, Lovells Island, and the south end of Thompson Island (downwind of the classic Gilbert delta deposit). The dune sand at Lovells Island is immature and the source remains unknown.

Glacial Features

During the Pleistocene Epoch, more than 10,000 years ago, glacial ice sheets descended from the north over eastern Massachusetts, covering the landscape. Glaciers are effective agents of erosion, beveling hills and other topographic highs while transporting vast amounts of sediments picked up en route. When the glacial ice melts and retreats, these sediments remain and may cover the underlying landscape. If glacial retreat is rapid, the sediments once entrained in the glacial ice are relatively unsorted and contain fragments of various sizes ranging from the smallest clay to boulders. Collectively, these deposits are called glacial till. In Boston Harbor, two distinct till deposits record two glacial advances. The ice was approximately 150 to 300 m (500-1,000 ft) thick here. Outwash streams typically accompany glacial melting by draining downslope away from the melting ice front. These sediment choked streams leave sorted channel, delta, and floodplain deposits. Thin glacial deltaic and outwash deposits mantle the bedrock. Deltaic deposits formed by water flowing from melting glaciers and outwash streams into glacial lakes. These deltas have characteristic assemblages. The most glacial-distal set are called bottom set beds. Angled foreset beds cover the bottom sets and top sets cover the entire sequence. As glacial ice pulls further back, the delta collapses and the whole sequence repeats itself. Locally, deltaic deposits on Thompson Island provide classic examples of delta formation.

Within the boundaries and surrounding areas of Boston Harbor Islands National Recreation Area, glaciers left chunks of remnant ice that melted to form kettle ponds. Other glacial features in the park include drumlins, thick till deposits, glacial erratics, retreat terraces (boulder terraces), moraines (longshore spits), eskers, and striated bedrock exposures. Striations indicate predominantly north-south ice motion. Moraine deposits may be present. The islands are part of the only submerged drumlin field in the United States. Other examples are in Nova Scotia, Ireland, and Germany. Over 200 drumlins are part of the entire field in the Boston Basin.

During a major ice age, global sea level lowers because glacial ice sheets entrain vast quantities of water. Along the east coast, major rivers carved canyons towards the Atlantic Ocean. Today, with higher sea level, local river channels such as the Charles, Mystic, and Neponset rivers are now drowned estuaries. Paleoriver channel deposits exist on some islands in the harbor.

Bluff Erosion

Rising sea level and restricted sediment supply are causing increased bluff erosion on many of the Boston Harbor Islands. As a wave undercuts and oversteepens a shoreline bluff, slumping temporarily protects the remaining higher bluffs from wave action and a retreat terrace surface forms. Eventually rainwash creates rills and gullies on the bluff and retreat terraces. This continually lowers the highlands on the islands. The overall height of the bluff controls the rate of the slumping process. Lower bluffs erode faster because the volume necessary to develop a protective series of retreat terraces does not exist. Bluffs higher than 10 m (32 ft) have more protective slough volume. Rills eventually form gullies which erode quickly and move more material down to stabilize the lower surfaces even more.

Geology and History Connections

Established to preserve historical and cultural resources, Boston Harbor Islands National Recreation Area has connections to the earliest events in American history. During the early 1600's, Pilgrims

fleeing religious persecution in England were the first Europeans to see the harbor dotted with protective, buffering islands and settled the area. Native Americans had a presence in the area much earlier than that. Islands such as Deer Island have a darker past as Native Americans, interned there, starved to death in the 1600s. Long Island provided a quarantine area for people suffering from yellow fever. Historic graffiti and engraving in bedrock on several islands attests to early human presence.

Boston Harbor Islands have always been a strategic lookout to the Atlantic Ocean and many islands have lighthouses and still contain remnants of historic forts and weapon outposts for defense of Boston Harbor. Boston Light on Little Brewster Island is the oldest lighthouse in the United States. Fort Warren on Georges Island, now a manicured area, was once an American Civil War era prisoner of war camp. Nut Island was once a munitions plant. Nearby Princes Head provided a testing ground for munitions developed at the plant.

The scenic beauty of Boston Harbor Islands inspired Frederick Law Olmsted to design a landscape on Worlds End. The success of Boston Harbor now provides a model for other restoration and resurgence efforts elsewhere.

The history of Boston Harbor Islands is heavily influenced by the underlying geology. The history of the islands are also inseparable with that of Boston itself. John Winthrop sailed from England to the east coast of America with his Puritan followers to found a “city upon a hill” – Boston, once called Trimountain. The geologic setting for this city, specifically the Trimountain area (Copp’s, Beacon, and Fort hills) at Boston Harbor Islands National Recreation Area headquarters, was a key factor in fulfilling the Puritan dream. The Boston area provided: 1) a safe harbor created by erosion of the soft bedrock units, 2) drumlin islands in the harbor that buffered the sea and offered places for strategic fortifications, 3) the glacial processes created the three hills that offered safety to the Puritans, and 4) artesian spring and well water on the Trimountain (Dave Woodhouse, written communication, 2007).

History of Geologic Science

Boston Harbor Islands has links to significant advances in geologic study. The first use of the term drumlin in the United States is recorded here. Classic examples of shoreline processes including beach formation provided early research targets for geologists such as D.W. Johnson in the early 20th century. In the 1960s, Kaye and Barghoorn assembled what is regarded as the first sea level curve in Boston Harbor. Using carbon dating of salt marshes, geologists developed theories on glacial rebound and the effects of glaciations on global sea level. Glibert defined the stratigraphy of a delta, which remained the universal model until the 1950’s, based on exposures on Thompson Island. This remains a type locality for lake deltas.

Type Sections and Unique Features

Type sections refer to the originally described sequence of rock that constitute a geologic unit. It serves as an objective standard for comparison with spatially separated parts of that same unit. Preferably, a type section describes an exposure in an area of maximum unit thickness and completeness. Though not formal type sections, there are excellent quality exposures of Proterozoic and Pleistocene geologic units in the national recreation area. There is a well documented unconformity between the base of the Proterozoic Boston Bay Group sediments and older granite

exposed on Rocky Neck and Worlds End. There is published paleomagnetic data and age dates for rocks on Worlds End (contact: Meg Thompson at Wellesley College). The Cambridge Formation (argillite) and intruded diabase are exposed at Slate Island and at Boston Light on Little Brewster Island. Two glacial tills from two distinct glacial advances crop out on Long Island and Great Brewster Island (compound drumlins). The upper brown till from the Late Wisconsin advance overlies a lower, older gray till from the Late Illinoian advance. A weathered surface separates the two tills. This is an unusual preservation because successive glacial events in the same area tend to erase evidence of previous glaciations.

Other unique features in the national recreation area include bedrock drumlins, the Gilbert delta on Thompson Island, and an esker overlapping into a kettle pond on Thompson Island. Peddocks Island has a series of five different drumlins connected by tombolos.

Recommendations

- (1) In a GIS, layer vegetation maps, invasive species data, and insect taxa information with digital geologic maps to determine correlations and connections between biology and underlying geologic units.
- (2) Promote detailed geologic bedrock mapping of outer islands. Don Wise (UMass, Amherst) expressed interest in field mapping.
- (3) Perform a comprehensive paleontological inventory of the national recreation area.
- (4) Contract a geologist to perform landform mapping for the Boston Harbor Islands.
- (5) Consult the Massachusetts Department of Conservation and Recreation regarding potential removal of old sea walls.
- (6) Consider installing wind mills for clean, renewable energy for BOHA.
- (7) Obtain any historic aerial photographs (modern aerial photography is difficult due to the proximity of Logan International Airport), which may aid restoration efforts.

Action Items

- (1) GRE will obtain and scan historic maps of Boston area from the U.S. Geological Survey ca. 1900.
- (2) GRE will produce digital bedrock and surficial geologic map for the national recreation area (see above geologic mapping section).
- (3) GRE report author will obtain D.W. Johnson's publications from 1925 and 1910 regarding shoreline classifications in Boston Harbor.
- (4) GRE report author will obtain shoreline publication by Rosen and Fitzgerald (2004).
- (5) GRD will consider a possible paleontological inventory for the national recreation area.
- (6) GRD team will reference Army Corps of Engineers work in Boston Harbor.

References

www.nps.gov/boha (accessed July 31, 2007)

Kaye, C.A.; Barghoorn, E. 1964. Late Quaternary sea-level change and crustal rise at Boston, Massachusetts, with notes on the autocompaction of peat. *GSA Bulletin* v. 75; no. 2; p. 63-80.

Drake, S.A. 1873. Old Landmarks and Historic Personages of Boston. Viewable online at: <http://books.google.com/books?id=SHoWJBoPXgAC&pg=PA1&lpg=PA1&dq=trimountain+bosto>

[n&source=web&ots=vql3gatdQA&sig=0rpwTU1pyDF1C5jM2eP4P0ZgfTA](#) (accessed July 31, 2007).

Table 1. Scoping Meeting Participants

Name	Affiliation	Position	Phone	E-Mail
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Woodhouse, David	Woodhouse Geosciences	Geologist	941-773-8682	davewoodhouse@verizon.net

Table 2. GRE Mapping Plan for Boston Harbor Islands National Recreation Area

Covered Quadrangles	GMAP ¹ ID	Reference	GRE appraisal	GRE Action	Scale
Boston North	74765	Kaye, C.A., 1980, Bedrock geologic maps of the Boston North, Boston South, and Newton quadrangles, Massachusetts (sheet 2 / 2), , Miscellaneous Field Studies Map MF-1241, sheet 2 / 2, 1:24000 scale	2008-0703: for BOHA useful for bedrock geology of 3-7.5' quads; not known to be digital. May be digitized by OMSG or GRE	May digitize	24000
Boston North	2436	Kaye, C.A., 1980, Bedrock geologic maps of the Boston North, Boston South, and Newton quadrangles, Massachusetts (sheet 1 / 2), , Miscellaneous Field Studies Map MF-1241, sheet 1 / 2, 1:24000 scale	2008-0703: for BOHA useful for bedrock geology of 3-7.5' quads; not known to be digital. May be digitized by OMSG or GRE	May digitize	24000
Multiple	74763	Kaye, C.A., 1978, Surficial geologic map of the Boston area, Massachusetts, , Open-File Report OF-78-111, 1:100000 scale	2008-0703: useful for surficial geology; not known to be digital	May digitize but will likely await newer USGS mapping	100000
Multiple	74984	Ackerman, Seth D.; Butman, Bradford; Barnhardt, Walter A.; Danforth, William W.; Crocker, James M., 2006, High-Resolution Geologic Mapping of the Inner Continental Shelf: Boston Harbor and Approaches, Massachusetts, , Open-File report OF-2006-1008, 1:125000 scale	2008-0703: not in NGMDB, but found in pubs	May convert	125000
multiple	71108	Butman, Bradford, Valentine, P.C., Danforth, W.W., Hayes, Laura, Serrett, L.A., and Middleton, T.J., 2004, Shaded relief, sea floor topography and backscatter intensity of Massachusetts Bay and the Stellwagen Bank region offshore of Boston, Massachusetts, , Geophysical Investigations Map I-2734, 1:125000 scale	2008-0703: shows seafloor topography; might be useful	May convert	125000

¹GMAP numbers are unique identification codes used in the GRE database.