Geomorphological Development of Western Buzzard's Bay Coast through Onshore Reworking of Glaciofluvial Deposits

Matt Giess, Duncan FitzGerald, Zoe Hughes, Alice Staro

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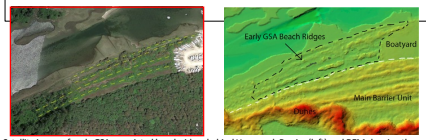
Abstract

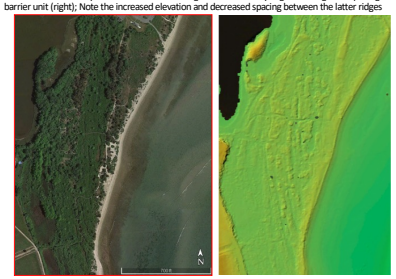
Deglaciation of southern New England produced drainage through ridge and valleys that characterize the northwestern Buzzards Bay (MA) coast. As the ice retreated, meltwater streams deposited vast quantities of sand and gravel along the valleys and in the offshore region to a lower stand of sea level. As sea level rose, storm waves and tidal currents reworked sediment onshore within drowned valleys bordered by till-covered bedrock peninsulas. This landward movement of sediment was especially integral in shaping: 1. Horseneck Beach barrier, 2. spit systems fronting Allen's Pond, 3. dune system east toward Barney Joys Point, and 4. Beach-ridges within Slocum River Embayment. This onshore movement of an estimated 20 million m3 of sand, here labeled the "Great Sand Event," occurred relatively rapidly during a period from 4,000 to 3,000 years ago. It is noteworthy that much of the sand comprising Horseneck Beach is a highly mature sand (90% quartz and very well sorted) indicating considerable reworking. Analysis of photographs, ground-penetrating radar transects, and marsh cores reveal paleo-tidal inlets, prograding beach ridges, and spit systems, which have been used to identify and chronicle evolution of the paleo-entrance of Westport River Estuary and broad sand platform upon which the surface geomorphology developed. Variability in elevation and width between drowned backbarrier beach ridges and ridges comprising the main Horseneck Barrier system delineate differences in age and abundance in sand. The most landward beach ridges are low and widely spaced indicating a sparse supply of sediment characterizing the early period of the Great Sand Event (GSE). This contrasts with the continuous thick beach ridge units marking the progradation and formation of Horseneck Beach. Following the end of the GSE, extensive backbarrier infilling and decreased the tidal prism in the Westport River Estuary allowed spit accretion and western extension of the Horseneck Barrier. This study has unraveled a complex geomorphologic and sedimentologic history of an isolated sand-rich region of Buzzards Bay, capturing a massive onshore movement of sand.

C/D Great Sand Event

Large quantities of sand reworked onshore (~ 3 ka) causing the Great Sand Event. Beach ridges began forming on the eastern and western ends of the Westport River Estuary, and in front of Allen's Pond, coincident with strandplain development in western Slocum River Embayment. As the major Horseneck barrier developed, early beach ridges were partially drowned.



Satellite image of early GSA-associated beach ridges behind Horseneck Barrier (left) and DEM showing the contrast between early GSA-associated beach ridges and the heavily vegetated ridges comprising the main barrier unit (right); Note the increased elevation and decreased spacing between the latter ridges



Satellite image and DEM of the strandplain along west shore of Slocum River Embayment ~ 2.5 – 3.0 ka

Methods

More than 11 kilometers of Ground Penetrating Radar (GPR) transects were collected during the summer of 2022 to delineate the barrier lithosome, its facies architecture, and basement contacts. Using a frequency of 400 MHz, GPR records typically extended to depths of more than 7 m. An open-source R Software RGPR was used to process the GPR records. Additionally, 45 Dutch-auger cores were taken in the backbarrier marsh to determine the extent and timing of emplacement of the sand platform upon which the marsh and rear drowned ridges were formed.

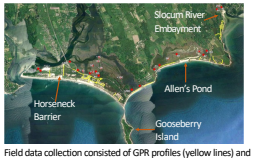
Ground-penetrating radar unit used to image subsurface

Study Area

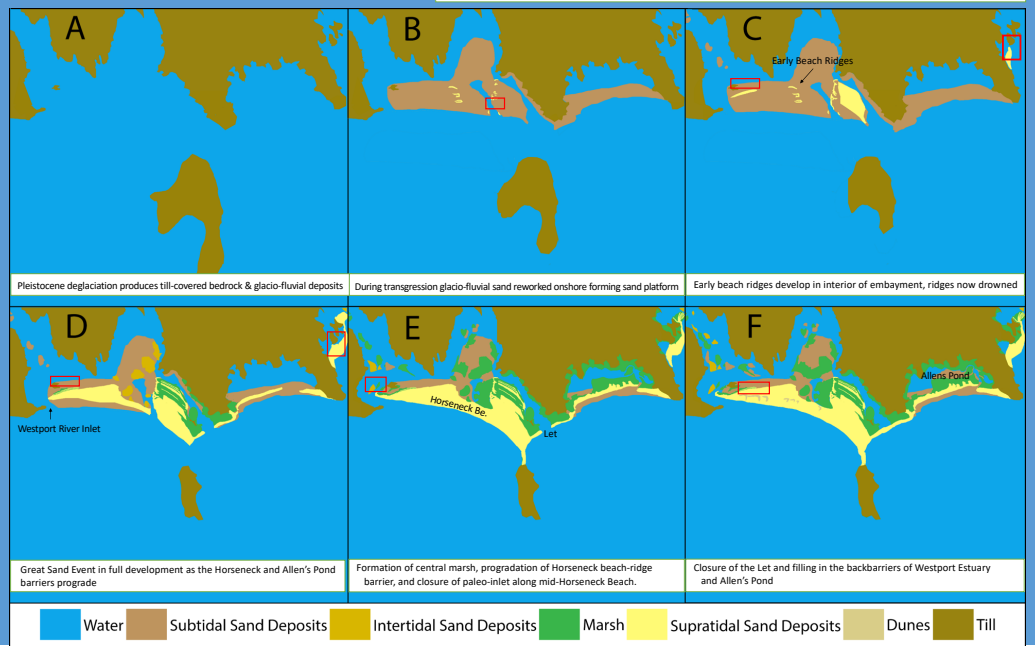
Study area extends along the indented coastline of northwestern Buzzards Bay in southern Massachusetts spanning from Horseneck Beach eastward to Slocum River Embayment. The sandy barriers in the study area are characterized by:

1: Mixed-energy setting, abundant sand related to offshore glacio-fluvial deposits
2: Horseneck Barrier is a product of the Great Sand Even, massive sand coming ashore ~ 3000 yrs BP
3: Dominant longshore transport east to west at Allen's Pond and Horseneck Beach & north into Slocum R. Embayment.
4: Gooseberry Island and Causeway produce littoral cells and isolate longshore transport.
5: Gooseberry Island once contributed sand and cobble to landward shorelines.

Study area located in western Buzzards Bay, MA



Field data collection consisted of GPR profiles (yellow lines) and basal peat depth samples (red dots)

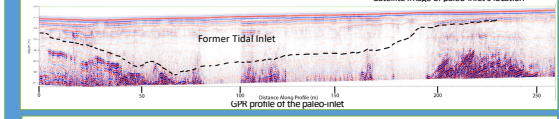


A De-glaciation left till covered bedrock & glacio-fluvial sediment in valleys

B Initial Inlet Formation

Following deglaciation, offshore glacio-fluvial sediment was moved onshore forming a sand platform and incipient beach ridge development in far backbarrier region in Westport River Estuary. At this time, tidal exchange occurred through two tidal inlets, one at the present location and one in the middle of the barrier shown in aerial at left by yellow line.

Satellite image of paleo-inlet's location



GPR profile of the paleo-inlet

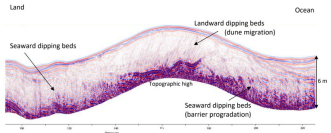
E Inlet Migration and Spit Accretion During the Late GSE

The Great Sand Event formed Horseneck barrier and deposited large amounts of sand within the Westport River Estuary, significantly decreasing the tidal prism. This resulted in closure of the mid-barrier inlets. The extensive deposition of sand built a broad sand platform within the estuary that was colonized by a widespread saltmarsh Additionally, decreasing tidal prism caused recurved spit construction at westwardend of the barrier narrowing Westport River Inlet.

Satellite image of present (red line) and past (yellow lines) recurves of the accreted spit

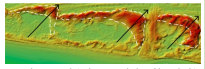
F Recent Developments

Recent dune migration and human alterations obscure the area's early sedimentological history. For example, landward dune migration has overprinted former beach progradation. Also, sometime in the past 200 years, the Let closed allowing for additional marsh development.



Landward dipping dune reflectors overlying seaward dipping prograding barrier reflectors.

Satellite image of dunes. Yellow line shows GPR line



DEM shows trends in dune morphology (dotted white lines) and direction of dune migration (black arrows)

Conclusions

1: Reworking of offshore glacio-fluvial sediment during Holocene transgression produced the Great Sand Event accounting for massive volume of Horseneck barrier, Allens Pond spits, and Slocum Embayment strandplain.
2: During early stages of the Great Sand Event, two inlets existed in the current center of Horseneck Barrier, each around 250 m wide and 5m deep. These inlets closed as backbarrier infilling decreased tidal prism.
3: Initial sand movement onshore coupled with continued influx through inlets, built sand platform leading to extensive marsh development in the East and West Branches of Westport River Estuary.
4: During late stages of the Great Sand Event, spit accretion at western end of Horseneck Barrier deflected Westport River and narrowed Westport River Inlet.

Acknowledgments: Project funded by Buzzards Bay Coalition through Rathmann Family Foundation grant.

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Image of GPR units used for this project

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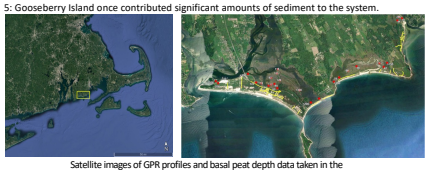
1: Mixed-energy setting in which both waves and tides are active

2: Punctuated progradation.

3: Dominant longshore transport (LST), mostly east to west along the Allen's Pond and Horseneck Beach regions and northward into Slocum River Embayment.

4: A major obstruction in the longshore transport system consisting of Gooseberry Island and the associated causeway.

5: Gooseberry Island once contributed significant amounts of sediment to the system.



Satellite images of GPR profiles and basal peat depth data taken in the study area (left) and study area location along the coastline (right)

B Initial Inlet Formation

Following deglaciation, offshore glacio-fluvial sediment was moved onshore forming a sand platform. Incipient beach ridge developed in the far backbarrier region within the Westport River Estuary. At this time, tidal exchange occurred through two tidal inlets, one at the present location and one in the middle of the barrier.

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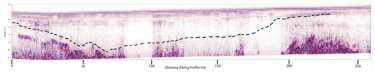

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