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What is that sticking out of the sand?

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Cape Cod is subject to erosion when wind, waves, and currents erode the sand along the shoreline. Coastal storms (e.g., Hurricane Sandy in October 2012, followed by several large, slow moving extra-tropical storms locally referred to as nor'easters) dramatically intensified erosion in many areas on Cape Cod, lowering beach

Figure 1. Locations of some of the preserved ancient landscapes that are now exposed on Cape Cod.

elevation and eroding coastal banks and dunes. During just one of these winter storms, referred to as the Blizzard of 2013 (2/8-9/2013), some locations along the Cape experienced more than 20 feet of erosion leaving beach stairs dangling in the air, and damaging some dwellings.

Cape Cod residents and tourists who frequently visit the shore should understand that the shape of the beach changes from day to day as well as seasonally. This summer beachgoers may find that the beach offers new discoveries they may not have encountered before (Figure 1). At many locations, the scouring effects of ocean waves revealed a scene from the ancient past – the exposure of stumps "growing" out of the beach and a black smelly peat layer poking out through the beach sand and dunes. Some of these features were exposed previously after a series of nor'easters in March 2010, only to have been lost from sight during the intervening years. The recent storms revealed these ancient landscapes to a degree rarely seen.

Why is it visible now?

On Cape Cod most of our beaches are "transgressive," which is defined as a beach migrating landward and upward (in the long term) and covering the lagoon or salt marsh that lies behind it (Figure 2). In turn, the salt marsh also moves landward and upward invading upland forests and other fresh water environments. This process has been occurring on Cape Cod for thousands of years. The means by which a beach migrates landwards are predominantly overwash (the transport of sediments over the beach and dune system by storm waves which deposits a fan of sediments on the landward side), and wind-blown sands. The driving mechanism behind this process is sea level rise and episodic storm events. Sea level has been rising globally since the end of the last ice age when glaciers started melting more than 20,000 years ago. (Fairbanks, 1989). After the area became ice free, large portions of the inner continental shelf remained exposed allowing for the development and then flooding of many land-based

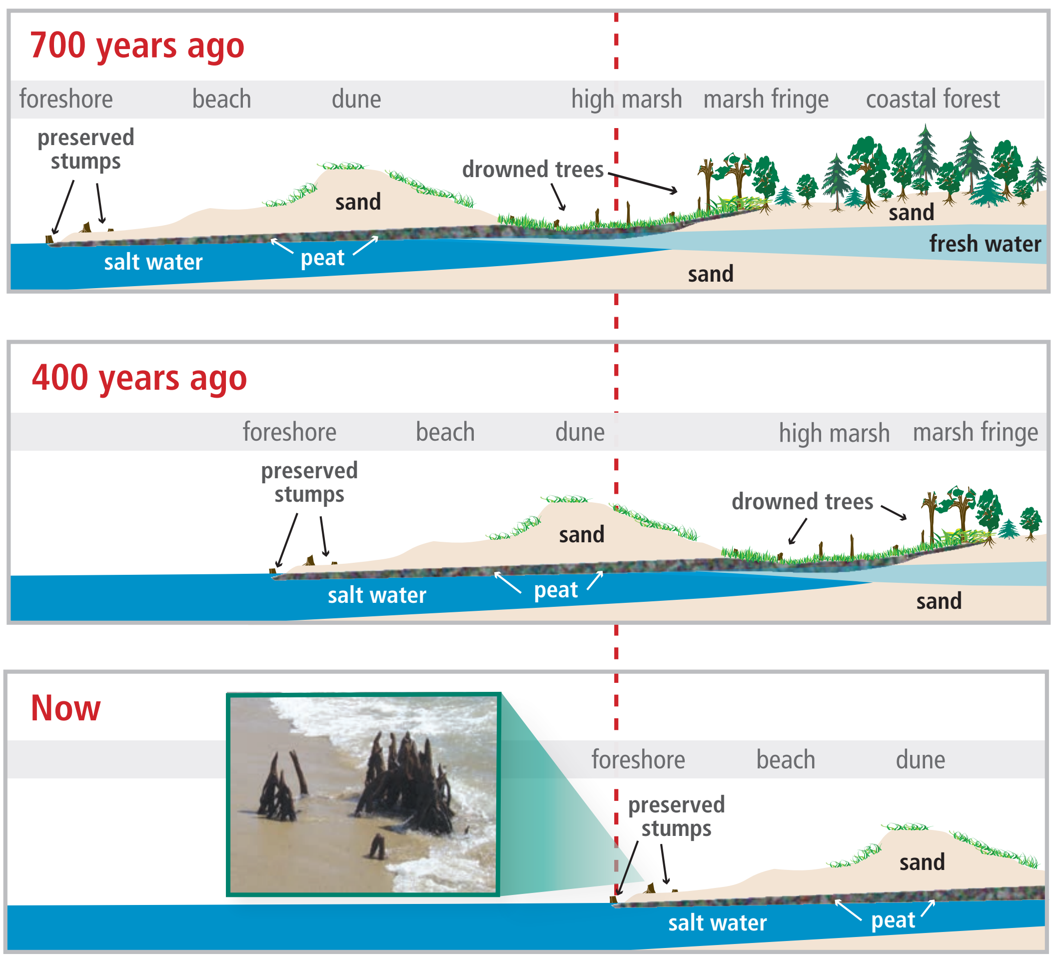

Figure 2. Series of images explaining marine transgression.

ecosystems including shorelines, deltas, lakes, coastal forests, and salt marshes (Belknap, Gontz, and Kelley, 2005). As the glacial ice continued to melt, sea levels rose rapidly causing shorelines to retreat along the continental shelf and flooding fresh water environments.

Deposits of mud, organic rich peat, and tree stumps do not form along the high energy beaches, where they are now exposed, but represent the remnants of ancient environments drowned by flooding ocean waters and then covered by coastal sands and peat (Figure 2). Ancient coastal forests on Cape Cod were often outcompeted by salt marsh flora as soils transitioned from fresh to salt water. Now these preserved ancient landscapes have become exposed by the retreat of the shoreline due to accelerated rates of sea level rise coupled with occasional storm events which can rapidly scour away the overlying beach sand. Coastal forests can be drowned in response to both long-term passive (e.g., sea level rise) and active mechanisms. Passive coastal change resulting from global sea level rise occurs over hundreds to thousands of years while active mechanisms can occur at time scales as little as hours, such as during episodic storm events.

Generally, steeper high-energy waves during the winter months cause sediment to move seaward and the milder late spring through fall wave causes sand to return to the beach. This winter the many coastal storms experienced on Cape Cod provided more and stronger waves than usual, therefore many beach elevations are lower than normal and eroded coastal banks and dunes still have steep slopes. The sand that is missing from the dry beach is moved during storms and stored in shallow water areas offshore, typically forming a nearshore sandbar. These bars cause some wave energy to be expended offshore of the beach, protecting the beach and dune banks from some of the brunt of the erosion caused by future storms. During the summer months the more gentle wind and waves bring sand back onto the dry beach from the offshore bars. The growth of coastal vegetation during the summer months allows more sand to become stabilized along the steep scarps of eroded coastal landforms.

The exposed features (e.g., clay, peat, and stumps explained in more detail on the following pages) are common environments on our coastline, but not typical to a sandy beach. In some locations they will likely be buried over the course of this summer, only to be exposed yet again during another intense winter storm season. At many sites along the New England coastline, newly revealed coastal forests are often destroyed by the destructive forces of storm waves (Clark, 1986). For example, recent erosion at the South Cape Beach drowned forest has led to significant removal of outcropping peat and stumps. This has left many of these remnants of the ancient environment in pieces, along the wrack line of the modern beach.

What is it?

The stratigraphic record (aka the layer cake of different types of soil, that you would encounter by digging a hole, with each layer correlating to a distinct ancient environment) of Cape Cod changes dramatically depending on the exact area in which you are looking at it. In general, there are layers of till and outwash deposits characterized by a mix of sand, gravel, and large boulders, and/or glacial lacustrine clay (ancient lake deposits) form the basement of many coastal landforms on Cape Cod. These earlier deposits have been reworked by waves and wind and often capped by salt marsh peats and sandy beach/dune material. During the regression when sea levels were about 400 feet (130 meters) below present levels, forest soils and freshwater marshes, were deposited over the ancient lake clays. As sea level began to rise, large areas of Cape Cod's ancient landscapes were removed from the geologic record by erosion and reworking of sediment. The record left by a migrating beach illustrates the transition between fresh and saltwater systems. In this case, areas once containing coastal forests transitioned to salt marsh or beach environments. Evidence of these former landscapes can be seen in the recently exposed outcrops on Cape Cod beaches.

An example of a recently exposed outcrops. The color and sediment type (sand/mud/clay) changes indicate different depositional environments.

Clay

Clay that was deposited by glacial activity, often within large lakes formed by meltwater, can often be found under the peat. These stratigraphic layers are periodically exposed during storms and then are reburied as the beach and dune systems are reshaped by wind and waves. In southeastern Massachusetts, the materials deposited at the terminal end of the glacier, impounded large bodies of fresh water during the initial glacial melting period. This turned the landscape of what is now Cape Cod Bay into a glacial lake; the blue clay relates to deposits formed in this fresh water environment.

An example of clay exposed, as one of the layers comprising the coastal bank.

An example of clay exposed at the surface of a beach.

Peat

Peat is a soft organic material consisting of partly decayed plant matter that accumulated in a water-saturated environment and in the absence of oxygen. Peat can take hundreds to thousands of years to form and is quite fragile. It can be quickly eroded by waves or human activities. In order to preserve this coastal resource some towns on Cape Cod have prohibited the removal of peat for the purposes of harvesting shellfish (information usually available in shellfish regulations on your town website). The peat on Cape Cod is derived from both fresh and saltwater marshes and can often contain preserved remnants of past terrestrial environments including stumps secured in growth position (explained in more detail on next page). Peat deposits can provide a wealth of information about past environments, including whether it was fresh, or salt water and at what elevation they were formed.

A log located within a peat deposit.

A layer of peat exposed in the inter-tidal zone of the beach.

A close-up of a peat deposit showing the roots, sticks, and twigs that are intertwined throughout the peat matrix.

Stumps

Stumps protruding from the peat on Cape Cod are often Atlantic White Cedar (*Chamaecyparis thyoides*) or Eastern Red Cedar (*Juniperus Virginiana*), which are associated with coastal environments along the U.S. Atlantic Coast. Cedar wood has natural properties that allow for its preservation in harsh coastal environments. Their position along exposed coastlines greatly increases their vulnerability to coastal change especially during storms. Despite their proximity to the coast even low levels of salinity can negatively impact the trees, with mortality from higher levels of saltwater poisoning; either from permanent inundation (aka sea level rise) or storm surge pooling in low lying areas.

Eastern red cedars have been observed growing in close proximity to salt marshes along coastal barrier systems. These Red Cedar trees are capable of living within 1.5 feet vertically of mean high water when on exposed barrier systems and lower when in close proximity to sheltered salt marsh and back barrier environments (Gontz, Maio, and Rueda, In Press). Tree stumps are typically poor indicators of sea level for scientists; however certain species can provide an upper limit on sea level positions as they cannot survive with their roots submerged in salt water. Assuming the trees died from salt water submergence and not some other factor such as fire, their position and age of death provides an approximate marker in space and time for the transition between fresh and salt water environments.

A series of nor'easters in the spring of 2010 swept the New England coastline resulting in significant erosion along South Cape Beach, a barrier system located in Mashpee. The erosion revealed 111 stumps and a preserved peat outcrop. It is likely that the stumps represent an ancient Eastern Red Cedar, (*Juniperus virginiana*), stand growing in a back-barrier environment, and drowned by episodic storm events, and moderate rates of sea-level rise. The site has provided ample research and education opportunities.

Example of a modern day Red Cedar forest located near a coastal system.

A stump sticking out of a layer of peat at Coast Guard Beach in Eastham. Based on two samples from within the vicinity of the stump it is likely more than 8,000 years old.

Erosion along a 200-meter section of South Cape Beach State Park (Mashpee) revealed the presence of 111 preserved stumps in growth position in intertidal and subtidal areas within an intermittent peat deposit.

What can it tell us?

This spring, scientists from the Woods Hole Oceanographic Institution's Coastal Systems Group and NOSAMS* sought to document the Coast Guard Beach site. Based on the concept that the past is the key to the future they hope to elucidate how ancient coastal environments responded to climate change. This information provides context to current changes and enhances societies' ability to anticipate and effectively react to future change

Radiocarbon (14C) is a naturally occurring unstable (i.e. radioactive) isotope of carbon that decays at a constant, known rate. While alive, through photosynthesis and up the food chain, all carbon in biomass, from plants to higher animals, contain atmospheric levels of 14C. However, once a plant or organism dies, there is no mechanism to replace 14C and its abundance begins to decline. Therefore, as soon as any carbon drops out of the cycle of biological processes (e.g., through burial in mud or soil) the abundance of 14C begins to decline. After 5,730 years only half remains. After 11,460 years only a quarter of the original amount remains. This process, which continues until no detectable 14C remains, is the basis of carbon dating. The age of two dated samples from Coast Guard Beach (Figure 1) date to around 10,000 years old.

A team of coastal geologists and radioisotope scientists worked together to stratigraphically map the outcropping remnants of ancient landscapes at Coast Guard Beach. They collected dozens of organic samples for radiocarbon dating. The research will help to decipher the evolution of the Cape Cod shoreline during the past 10,000 years. Preserved ancient landscapes provide valuable insights into how ancient Native Americans responded to past fluctuations in climate and can help identify locations containing cultural resources. (Gontz, Maio and Rueda, In Press). The once exposed seafloor surrounding Cape Cod undoubtedly held early human settlements making use of the once abundant coastal resources (Bell, 2009). Artifacts found at numerous locations along the once exposed continental shelf document that estuarine environments were favorable for prehistoric human habitation (Bailey et al., 2007; Bailey and Flemming, 2008; Straight, 1990). Evidence of submerged ancient landscapes associated with Native American habitation in the waters surrounding Cape Cod has included drowned forests, peat deposits and artifacts dredged by fisherman. When these cultural resources are found with preserved environments they provide valuable context to current and future change.

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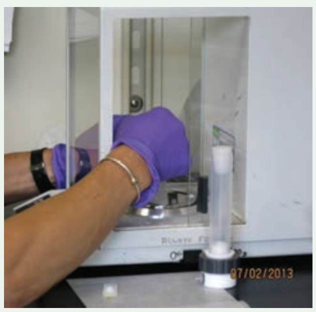
Summary

Ancient landscapes revealed along transgressing coastlines provide a time sensitive opportunity to research the environmental and human response to past climate change. Research and education opportunities afforded by recently revealed ancient landscapes are time sensitive, because once they are revealed in coastal settings they are often destroyed due to the

* The National Ocean Sciences Accelerator Mass Spectrometry (NOSAMS) Facility is a National Science Foundation facility dedicated to providing the ocean science community with radiocarbon data.

One of NOSAMS' two accelerator mass spectrometers. In these instruments, the atoms of 14C in a sample are counted and compared to those in a standard. This information can be used to determine the age of samples younger than about 50,000 years.



Samples, such as wood or peat, are weighed into individual reactors (above) for pretreatment in an automated reaction system (left). Pretreatment removes extraneous carbon, such as carbonate and soluble humic material, and ensures that the carbon being dated is from the selected macrofossil.

continued landward march of the shoreline. With accelerated rates of sea level rise (SLR) and increased storm activity predicted for the future, paleolandscapes revealed along coastlines will be increasingly common and short lived. This fact makes it important that coastal scientists are prepared to research these sites and utilize their educational value before they are lost to the rising seas.

The wood, peat, and fossil assemblages found within these areas allow for a reconstruction of past coastal changes providing context to current and future changes. Preserved ancient landscapes also provide a "teaching moment," serving as a powerful visualization for the landward migration of coastal systems in response to continued marine transgression. Public understanding of how the coastal environment responded to climate fluctuations in the past is crucial for the effective development and implementation of appropriate mitigation and adaptation strategies for the future. Without a clear understanding of past changes there is little hope for anticipating future changes and effectively confronting the challenges posed by accelerated rates of sea level rise and increased storm activity associated with climate change. Failure to anticipate future changes, due to a lack of understanding about past changes, leaves society vulnerable to coastal hazards.

Due to the vast stores of knowledge contained in these preserved ancient landscapes and their associated cultural resources it is imperative that they are studied and protected from human activity. Disturbance of these ancient deposits and associated cultural resources could lead to an irretrievable loss of information regarding past cultures and their response to coastal change.

The exposed features are typically short-lived on our shoreline. The natural processes that govern the beach have replenished over 5' of sand from March to May (as shown in the pictures above) at Coast Guard Beach in Eastham.

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