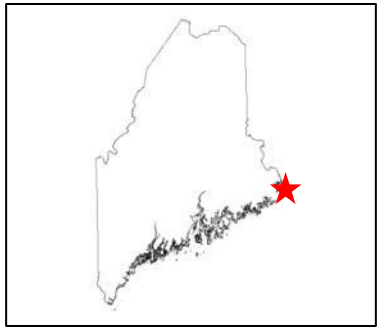
Maine Geologic Facts and Localities

August, 1998

Active Coastal Processes in the Lubec Embayment



44° 49‘ 50.51“ N, 66° 59‘ 34.16“ W

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Introduction

Between West Quoddy Head and the town of Lubec, Maine are some of the most interesting beaches and coastal features in the region (Figure 1).

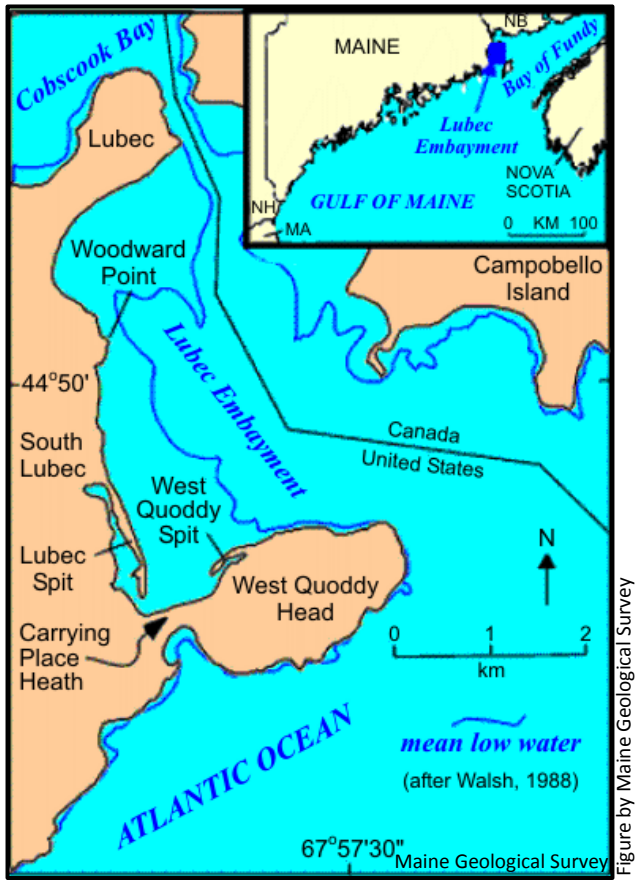

Figure by Maine Geological Survey

Figure 1. Location map of Lubec Embayment.

Coastal Setting

The tides in the Lubec Embayment exceed 6 meters on full and new moons (spring tides), providing the greatest tidal range on the East Coast of the United States. Water rushes in and out past West Quoddy Head State Park twice a day at up to 1.96 meters per second (4 knots) and alternately covers and exposes the extensive tidal flats of the Lubec Embayment. Waves are kept to a minimum by the sheltering effects of land masses on all sides. This is called fetch restriction, and waves cannot become larger than about 0.7 meters high because there is not sufficient water area for the wind to blow across (Walsh, 1988). Thus, geologists call the Lubec Embayment a "tide-dominated" beach system in reference to the kind of energy available to move sand and gravel on beaches.

Geologic History

The bedrock of the area includes the Quoddy Formation, consisting of dark-colored shale and argillite, and abundant gabbro and diabase intrusions (Bastin and Williams, 1914; Gates, 1977; Osberg and others, 1985). The rocks date back to the Silurian Period, approximately 415 to 440 million years ago. Glacial sediment rests on the bedrock and was deposited by melting ice around 14,000 years ago (Thompson and Borns, 1985). Till, in the form of a moraine, makes up Lubec Neck and is well exposed at the town gravel pit on Route 189 (Kelley and others, 1991). Till is a glacial deposit composed of a mixture of boulders, cobbles, sand and mud. Glaciomarine muddy sediment, containing fossils from 14,000 to 12,000 years old, covers the till in most places indicating the flooding of coastal Maine by the sea as the glacier retreated. This glaciomarine mud is now widely exposed along the coast in the faces of eroding bluffs. In a very few places, a layered sand and gravel deposit overlies the glacial-marine sediment.

Geologic History

This material is thought to represent a coastal beach or nearshore deposit formed when sea level fell across the present shoreline between about 11,000 and 10,000 years ago. Where the marine sand and gravel is absent, a peat deposit often covers the glaciomarine mud as at Carrying Place Heath (Figure 1 and Figure 2).

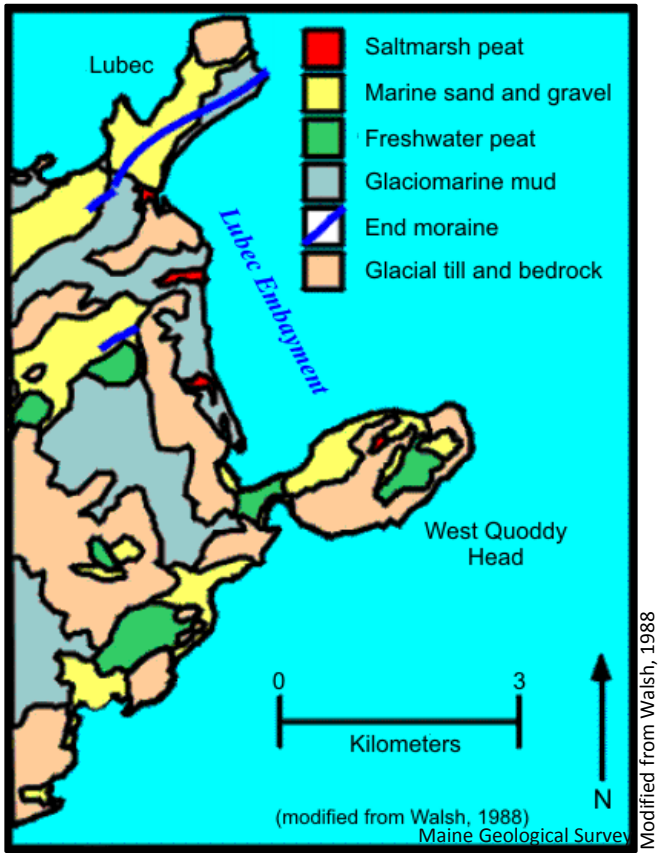

Figure 2. Geologic map of Lubec Embayment area.

Geologic History

The youngest features in the area are the beaches, salt marshes and tidal flats. They are Holocene in age, or less than 10,000 years old.

Sea level has risen all along the coast of Maine for the past 10,000 years (Kelley and others, 1991). The rate of sea-level rise has varied in the past, but the rate recorded by the Eastport tide gauge since 1930 has averaged 2.7 millimeters per year (Lyles and others, 1988). In response to rising sea level, coastal bluffs of glacial sediment erode and beaches and marshes move landward. The exact mechanisms by which these environments shift location can be complex, and we shall focus below on the beaches.

Historic Shoreline Changes in the Lubec Embayment

The earliest maps of Lubec Embayment were prepared by the British and depict a shoreline very different in appearance from that of today. In 1785 a long spit extended to the north from the Carrying Place Heath (Figure 3). By 1805 the large spit had changed into a smaller spit connected to the mainland on the north and a barrier island beach (Figure 3). In the 1830 map these two beaches are reconnected in a more landward position and a salt marsh had formed in the sheltered area behind the beach (Figure 3). "Marston's Dike" refers to an embankment built on the marsh for agricultural purposes, and the "Basin" was a natural harbor.

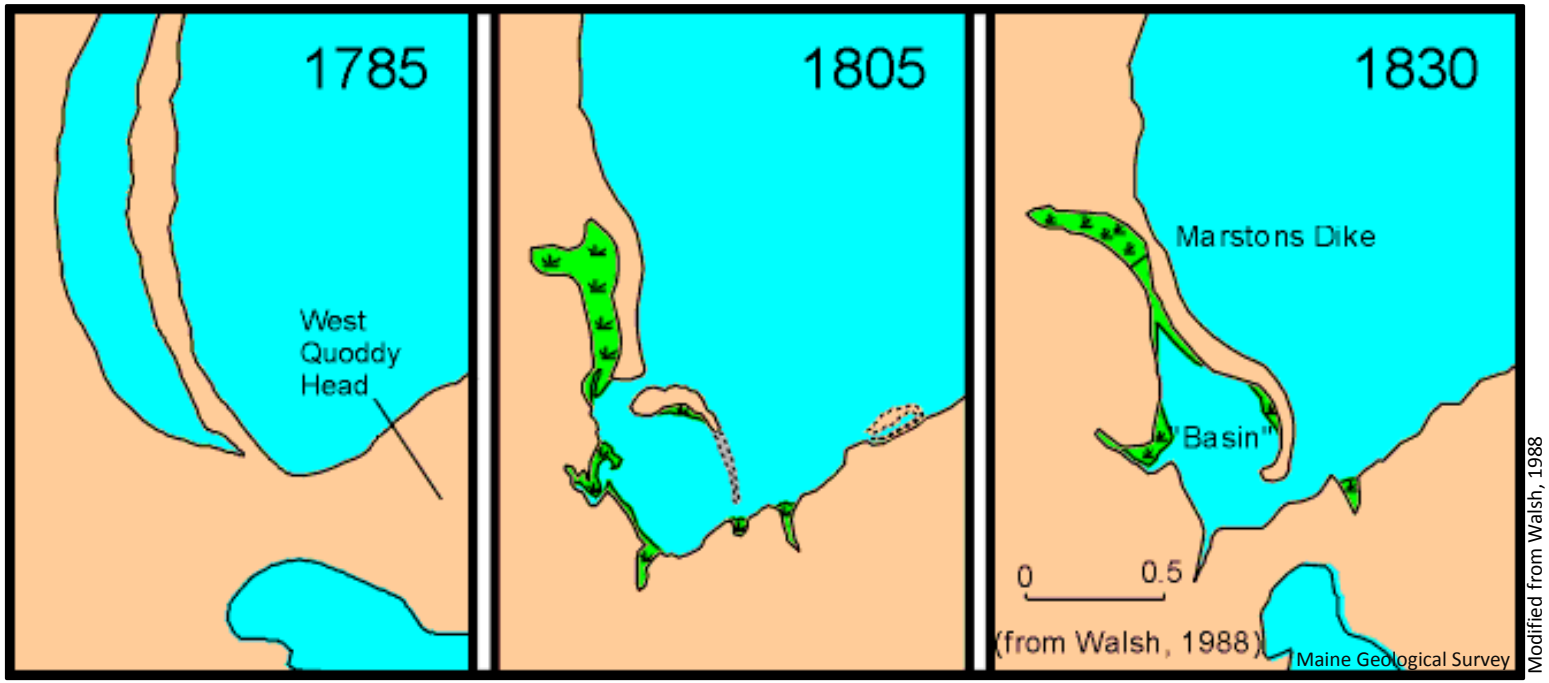

Figure 3. Maps showing changes between 1785 and 1830.

Historic Shoreline Changes in the Lubec Embayment

By 1840 the spit had again divided into a small south-trending spit and a barrier island (Figure 4). The whole system had also moved moved landward, and only a small salt marsh remained. The barrier island disappeared by 1862, and the present spit began to grow toward the south (Figure 4). Also, a new spit began to form on West Quoddy Head, possibly the same one depicted as intertidal in 1805 (Figure 4). The 1919 map shows that the southward growth had paused and a pronounced curve developed at the south end of the spit (Figure 4). The pause in growth and protection afforded by the beach allowed an extensive salt marsh to fill in the area behind most of the beach. On the 1919 map buildings, roads and piers are shown near the northern end of the beach.

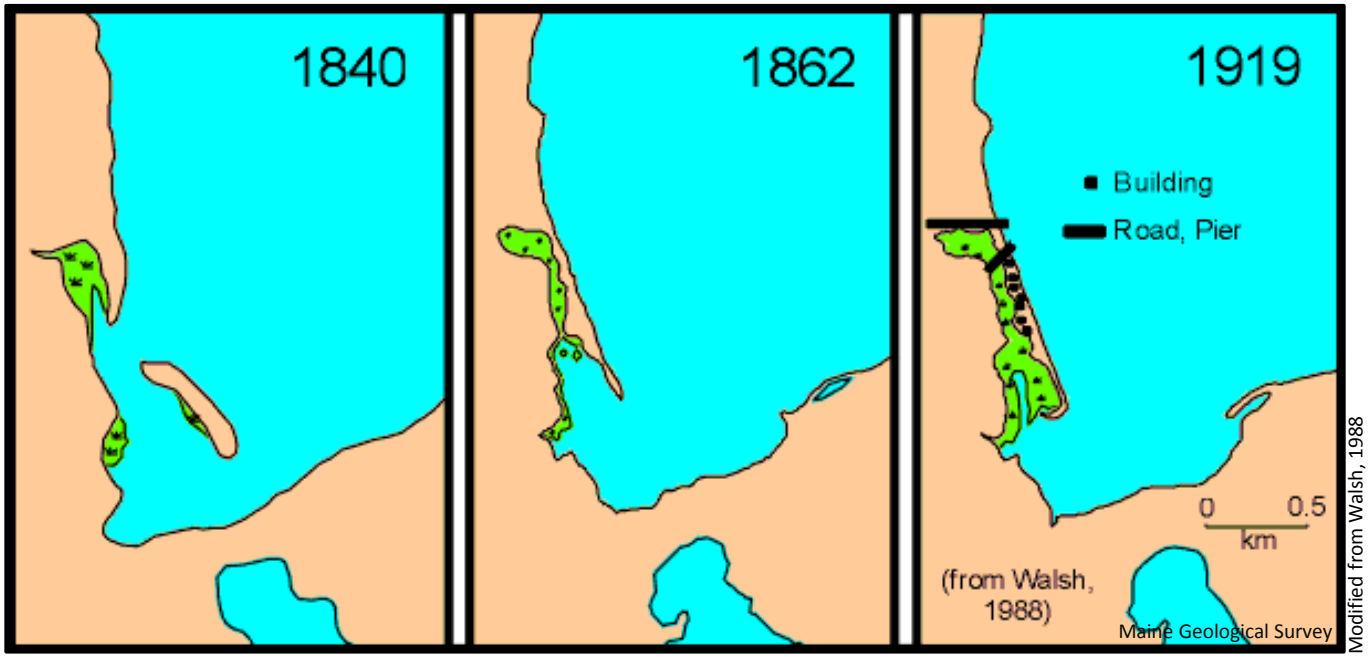

Figure 4. Maps showing changes between 1840 and 1919.

Historic Shoreline Changes in the Lubec Embayment

The spit has grown several hundred meters south since 1919 (Figure 4 and Figure 5) and retreated landward so that only some supporting posts remain from the buildings that had existed earlier. So rapid has been the recent growth of the beach, that salt marsh has not yet developed south of the 1919 spit terminus. As the spit continues to grow to the south, its tip is forcing the tidal creek to adjust to a new position (Figure 5). In addition, growth of the beach to the south will eventually project it into the Carrying Place Heath, which is already eroding at a rate greater than 0.5 m/yr (Walsh, 1988).

Figure 5. Aerial photo of Lubec Embayment.

Modern Coastal Processes

In an embayment where waves are very small, and in a tidal regime where waves only reach the beach for a brief period every day, what processes occur that have led to the profound rearrangement of this system over the past two centuries? The most important process today is tidal movement, and if "the present is the key to the past" (the motto of geology), tides must have been important in earlier years.

Close examination of the actively growing tip of the spit reveals a large accumulation of seaweed. Each plant has a "holdfast" or large stone that it attaches to when it begins to grow. Seaweed has air pockets along its length (bladders) that allow it to remain erect when it is underwater. These bladders also provide buoyancy to the plant and stone. When strong currents rush over the stone with attached seaweed, the buoyancy of the plant allows the current to drag the stone with the current. On flooding tides, the water rushes towards the beach and especially to the end of the spit, and stones and seaweed accumulate. After a short while the seaweed dies and breaks off, leaving behind a stone and some sand newly added to the beach.

Modern Coastal Processes

Evidence for this process can be found in the many drag marks left by the stones and seaweed over the tidal flat (Figure 6).

Photo by Maine Geological Survey

Figure 6. Drag marks on the tidal flat.

Modern Coastal Processes

In the winter, ice freezes to the tidal flat at low tide. Some sand and gravel is frozen into the bottom of ice blocks. As the tide rises, the ice floats and carries sand and gravel off the flat. Ice blocks are generally carried by the tides into the salt marsh area where they are stranded on the marsh and back side of the beach. In springtime, the ice melts and large quantities of mud, sand and gravel are left on the beach and marsh (Figure 7).

Figure 7. Tidal flat in winter.

The Future of the Beach

The history of the Lubec Embayment is recorded in vintage maps as well as in many deposits on the modern tidal flat. A shipwreck exists in the "Basin" location of the 1830 map, and Marstons Dike is still visible on the salt marsh. The bottom of an earlier beach that moved landward is also recognized as a low ridge in the central part of the tidal flat (Walsh, 1988). Peat deposits crop out on the beach, testifying to the formerly greater extent of the heath.

The future will probably bring still more changes to this beach system. The growth of the spit to the south may lead it into the Carrying Place Heath and accelerate erosion of that peat deposit. Alternatively, the narrow part of the spit may become breached, as occurred twice in the history of this system. Then two beaches would possibly migrate to a more landward location. Finally, the beach attached to West Quoddy Head (Figure 4) may continue to grow to the west and link up with the other spit.

References and Additional Information

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