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FILE REPORT

PRELIMINARY STUDY OF BEACH EROSION OF THE SHORELINE BETWEEN NANTASKET BEACH AND DUXBURY BEACH, MASSACHUSETTS

by

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by

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Introduction

This report summarizes the results of a preliminary examination of the shoreline between Nantasket Beach and Duxbury Beach, which was made in preparation for a projected detailed study of the shoreline erosion. The survey was made during the week of September 16, 1946.

Geology

The costal area exposed to wave erosion consists of glacial deposits, bedrock, and post-glacial marsh, dune, and beach deposits. No bedrock is exposed on Nantasket Beach, but outcrops are abundant along the shoreline east from the south end of Nantasket Beach to the north end of North Scituate Beach. Southeast from North Scituate Beach no bedrock is exposed along the shoreline as far as Brant Rock, a distance of about 12½ miles. Between Brant Rock and the mouth of Green Harbor outcrops of bedrock are numerous. No bedrock is exposed along the northern part of Duxbury Beach, and it is probable that there are no exposures in the southern part, but this segment has not yet been examined.

Most of the Coastal area under consideration is composed of glacial and post-glacial deposits. The Nantasket Beach area consists of prograded beach deposits and drumlins. In the Scituate quadrangle ground moraine forms the coastline between Shore Acres and Cedar Point, and First, Second, Third and Fourth cliffs are drumlins. In the Duxbury quadrangle till underlies the beach at Beadles Rocks and forms the sea cliffs from Ocean Bluff to the mouth of Green Harbor River. On Duxbury beach glacial sand and gravel compose the small hill 1200 feet north of the auto park, and either gravel or till composes the small ridge diagonal to the beach 1500 feet farther north.

Some of the beaches are separated from the mainland by marshes, bays, ponds, or rivers. The beach at Scituate Neck northwest of North Scituate Beach borders marsh as does the southern part of North Scituate Beach, and the beaches between the drumlins from First cliff south to the mouth of North River. The beach south of Fourth cliff borders South River. Duxbury Beach borders marsh in places at its north end and Back River and Duxbury Bay in its central and southern parts.

Configuration of the Shoreline

Submergence made the shoreline very irregular by forming numerous coves, bays, and estuaries. The shape of the shoreline has been determined by this initial irregularity plus changes brought about by subsequent wave action. In general waves tend to straighten a shoreline, but the rapidity with which it is straightened is dependent in part upon the kinds of materials present. Along this shoreline the bedrock has been eroded very little, and till has resisted erosion more than have the marsh, sand and gravel deposits.

The shoreline between the south end of Nantasket Beach and the north end of North Scituate Beach is very irregular owing to the abundance of Bedrock exposures which form the headlands and retard erosion. This section of the shoreline is still in the youthful stage of wave erosion. South from North Scituate Beach the shoreline is more regular, although it is interrupted by Scituate Harbor, North River, and Green Harbor River, and has headlands at Shore Acres, Cedar Point, First Cliff, Second Cliff, Third Cliff, Fourth Cliff, and Brant Rock. The headlands are drumlins or ground moraine areas that have been eroded more slowly than the low marsh or sand and gravel areas between.

In places the beaches have small seaward projections or "nodes." Such a projection at the south end of North Scituate Beach (Cohasset quadrangle) is directly inshore from Cowan Rocks and probably is due to local protection given that part of the beach by the Rocks, which act as a breakwater. The outward bulge in Sand Hills Beach (Scituate quadrangle) is apparently due to a shoal area several hundred feet offshore that is indicated by the presence of large boulders exposed at low tide. The outward bulge in the beach at Beadles Rocks (Duxbury quadrangle) at the north end of Rexhame Beach, is due to the presence of a boulder platform, exposed at low tide on the lower part of the beach.

Sources of Beach Materials

Glacial and post-glacial deposits constitute the principle sources of beach material. Rivers probably contribute some sand and fine gravel to the beaches, but this is believed to be a very minor source. The exposures of bedrock in the zone of wave action show only very slight effects of wave erosi n, so that very little of the beach material has been derived from the bedrock. That the beach materials are derived mainly from glacial deposits is shown by the fact that the shingle on the beaches is composed of the same types of rock found in the till and gravel that are exposed in the sea cliffs.

For example, the stones in the till exposed in the sea cliff of the Allerton Hill drumlin at the north end of Nantasket Beach are composed chiefly of Cambridge slate. The cobbles and pebbles of the shingle that constitute the beach south of the drumlin also are composed chiefly of Cambridge slate, but include other types of rock found in the drumlin.

As the shoreline recedes material is eroded from the headlands, the beach ridges, the sea cliffs between headlands, the wave cut benches under the beaches, and the offshore sea bottom.

The headlands which are composed of glacial materials constitute one of the most important sources of beach materials. Allerton drumlin at the north end of Nantasket Beach, and First, Second, Third, and Fourth Cliffs in Scituate are good examples of drumlins that form headlands.

The importance of these headlands as sources of beach material in this area is shown by the fact that shingle extends along shore from them and constitutes a large part of the beaches near the headlands. This shingle is progressively finer and less angular, and diminishes in quanity away from the headlands. As sand is an important constituent of glacial deposits it is reasonable to conclude that much of the sand on the beaches also came from the headlands.

On Nantasket Beach, shingle extends for a little more than a mile south from Allerton drumlin. This shingle contains some small boulders ($2\frac{1}{2}$ to 3 feet in length) and numerous cobbles at the south side of the drumlin, but the shingle becomes finer southward so that near the southern end of the deposit it is composed chiefly of pebbles.

Another but smaller deposit of shingle extends as a low beach ridge, just above the high tide line, from Atlantic Hill at the south end of the beach northwestward for about three-fourths of a mile. This shingle probably came from till deposits eroded from the vicinity of Atlantic Hill, as a boulder platform is exposed there at low tide indicating the former presence of a till hill. The drumlins at First, Second, Third, and Fourth cliffs each have shingle deposits extending from them in such a manner as to show that most of the material was derived by erosion of the drumlins. A large shingle beach ridge extends southeast from Fourth Cliff. It gradually diminishes in size southeasterly and ends about two miles southeast of Fourth Cliff, beyond which the beach is composed almost entirely of sand. Some of this shingle may have come from Third Cliff before the present mouth of the river was cut through the beach during the storm of 1898.

Some cobbles on many of the beaches are encrusted with shell material (possibly bryozoa colonies). This material accumulates on the cobbles when they are on the bottom offshore and the presence of the encrusted cobbles indicates that some of the beach material has come from offshore during heavy storms. Several large cobbles partly crusted with the shell material were seen on the crest of the shingle beach ridge at the north end of Cedar Point, north of Scituate Harbor. These cobbles appear to be part of the shingle thrown onto the beach by the severe storm in November 1945. Several of these encrusted cobbles were seen on the beach attached to seaweed showing that some have been dragged inshore by the seaweed.

An excellent example of the shoreward migration of stones small enough to be moved by wave action is afforded by the coal which was driven to the beach from barges sunk in the winter of 1944-45 off Fieldston in the town of Marshfield. Much coal was picked up from the beach in the summers of 1945 and 1946 at Rexhame and Fieldston. One man reported that he had picked up about a half ton of coal from the beach at Rexhame and a woman reported that she had picked up considerable coal at Fieldston a half mile to the south.

Character of the Beaches

The beaches between Nantasket Beach and Duxbury Beach are composed in part of shingle and in part of sand. The modern Nantasket Beach is composed of shingle at its north end and part shingle and part sand at its south end. The middle section of the modern beach between Strawberry Hill and Sagamore Head is composed of sand with only a very few scattered stones. The pocket beaches between the south end of Nantasket Beach and North Scituate Beach have much shingle, and the sand concentrations are mainly at the east ends of the beaches. This relationship is to be seen particularly at the beach in Cohasset, on the north side of Atlantic Ave., east of Nichols Road. The southeast end of this beach is composed entirely of sand, and the northwest end entirely of shingle. Sand predominates at the north end of the North Scituate Beach and shingle at the south end. Also the beaches between First and Second cliffs and Second and Third cliffs Scituate are chiefly sand at their north ends and shingle at their south ends. The distribution of sand and shingle on a beach is determined largely by the shape and orientation of the shoreline, and the location of the source of the beach materials. In most places the sources of shingle are drumlins and ground moraine areas exposed to wave action. The sand migrates along a beach faster and farther than the shingle and, therefore, the sandy section of a beach is to be found more remote from the source than the shingle section. Nantasket Beach has shingle at both ends and sand in the middle. The shingle derived from Allerton drumlin at the north end of the beach has migrated a little more than a mile south, where it largely disappears. The shingle derived from former till deposits at the south end of the beach has migrated north about three-fourths of a mile to where it also practically disappears. The middle section of the beach, about a mile and a quarter long, is nearly all sand and has very little shingle.

Some beaches, however, have the shingle concentrated largely or entirely at one end. Although beach materials are constantly shifted by wave action, such shifting may not be strong enough to disturb the asymmetry of such beaches. That restriction of shingle to one end of the beach has persisted for a long time is indicated by the fact that both the older (higher) and younger (lower) parts of the beach segment are composed of shingle. Moreover, the shingle segments have no associated sand dunes; had the beaches been very sandy for an appreciable time, dunes would have been formed. It is common for the very sandy beaches to be backed by a dune belt, although the dunes may not be very conspicuous topographic features.

A concentration of shingle at one end of a beach indicates that end as the source of the shingle. The sandy end of such beaches is protected from major storms by a rocky headland, or islands, both. Such protecting features prevent marked reversals of the prevailing shore drift, so that the sand tends to remain at the sandy end of the beach until it is blown inland to form sand dunes, or is carried off-shore to deep water.

The composition of a beach deposit is an important factor in planning control of shoreline erosion. Beaches composed of coarse shingle have relatively steep profiles between high and low tide levels, whereas sand beaches have much flatter profiles and consequently are much wider than shingle beaches.

The upper parts of coarse shingle beaches are so steep that the swift backwash on them prevents deposition of sand. These parts, therefore, are composed of small boulders, cobbles, and large pebbles without any sand. Sections of beaches which have both coarse shingle and sand in the same locality have the coarse shingle usually near the high tide shoreline at the top of the beach and the sand on the lower part of the beach. The shingle has a relatively steep profile, whereas the sand has a much flatter profile, and at the junction of the two the beach profile has an abrupt bend. This is well shown at the south end of Nantasket Beach.

Waves of different sizes develop different profiles of equilibrium on the beach deposits. Much of the shifting of beach material is due to the reshaping of the profile by storms of different intensities. An unusually severe storm usually erodes the beach deposits considerably and carries the eroded material offshore or onto the lower part of the beach. Where a ridge forms the top of the beach, however, the beach material, particularly shingle, may be thrown onto and back of the ridge. At the time this study was made three beach ridges could be seen on the shingle beaches. As would be expected, the largest ridge, which has been in existence for a long time and which is modified by only the most severe storms, is also the highest and the farthest landward. The other two beach ridges are of recent origin, formed probably since the storm of November 1945. The smallest beach ridge is farthest seaward, and like the middle ridge it is composed of finer shingle than the main ridge. These smaller ridges will probably be destroyed by the next severe storm.

Transportation of Beach Materials

More study must be made before the direction and magnitude of the prevailing shore drift are known fully, but the following five general facts are apparent:

1. As storms of greatest intensity on this coast are northeast storms, they should be most effective in causing wave erosion and transportation of debris because they have a comparatively unlimited fetch from the open ocean. The prevailing shore drift under these circumstances should be southward on sections of the coast trending north-south, and westward on sections of the coast trending east-west. Accordingly the prevailing shore drift on Nantasket Beach and the beaches from North Scituate Beach to Duxbury Beach should be southward, whereas the prevailing drift on the pocket beaches between the south end of Nantasket Beach and Cohasset Harbor should be westward. The prevailing direction of drift is reversed, however, in the lee of prominent headlands or islands.

2. The distribution of shingle both to the north and south of the drumlins and other till hills undergoing erosion south of North Scituate Beach shows that there has been considerable northward as well as southward drift. It also shows that shingle has not migrated

from its source much more than a mile along the beach in the direction of the prevailing drift. Two miles appears to be approximately the maximum distance of migration for the shingle under the most favorable conditions, such as exist at Humarock Beach.

3. Because sand migrates much faster and farther than shingle, it is more difficult to determine its source and hence the distance it has traveled. It is significant that at no place along this section of the coast does much accretion of sand appear to be taking place. The long groin at Brant Rock in the town of Marshfield has trapped very little sand. The shoreline appears to be slowly receding along its entire length except where bedrock is exposed. The general absence of accretion along this coastline indicates, therefore, that only rather small amounts of sand and shingle are being transported by the prevailing shore drift.

Sand that is eroded from the sea cliffs migrates quite rapidly along the segments of the beach composed of shingle, where the slope of the beach is too steep for the deposition of sand. On the sandy portions of the beach, where the slope of the beach is low, sand migrates less rapidly and may be deposited during considerable periods.

4. Boulders up to $2\frac{1}{2}$ to 3 feet in diameter have been moved appreciable distances by wave action, but larger boulders seem to have remained within a very few feet of their original position on the wave-cut platform. Thus, boulder-strewn platforms on which large boulders are numerous, are localized, and exposed at low tide, in front of the till cliff, the finer constituents of the till having been transported along the beach. Boulder pavements, therefore, mark the sites of drumlins that have been partly or completely eroded away. It is

noteworthy that coatings of barnacles and algae are found commonly on boulders larger than $2\frac{1}{2}$ to 3 feet in diameter; such growths could not form or persist on boulders subject to much movement.

A remarkable concentration of boulders moved by the waves may be seen south from Third Cliff to the mouth of North River in Scituate, where boulders 2 to $2\frac{1}{2}$ feet in diameter are spread out as a layer 200 to 300 wide on the flat surface of a bed of peat. The boulders are remarkably well sized and they are crowded together in a single layer. These boulders have undoubtedly been eroded from the till of Third Cliff and transported to their present position by the waves.

5. The available evidence indicates that beach material does not migrate to any appreciable extent from one beach to another around prominent headlands. Instead, the shore drift appears normally to divide at the outer end of headland and to carry the eroded debris toward the beaches on either side. This phenomenon needs more study, but the evidence acquired so far indicates that many of the beaches can be treated as separate units when considering the source, migration, and disposal of their beach materials. For example, Nantasket Beach acts as a unit from Allerton Hill at the north end to Atlantic Hill at the south end. Similarly, each of the pocket beaches between Nantasket Beach and North Scituate Beach are apparently independent of each other so far as the sources and disposal of their beach materials are concerned. Also, the beaches between North Scituate Beach and Duxbury Beach, which are separated by estuaries or prominent headlands, are to a considerable extent independent of each other.

Rate of Beach Erosion

The rate of beach erosion is difficult to determine except by comparison of the present day conditions with old maps and records. This has not yet been investigated. The evidence acquired so far indicates that the shoreline is slowly receding. Efforts have been made to retard the erosion by the construction of sea walls in places. Fresh erosion scars on the unprotected sea cliffs show that the sea cliffs are being cut back by storm waves.

There are indications that the sand beaches are being eroded faster than they are being replenished. Beaches in front of sea walls are replenished only by shore drift and by material brought to the beach from offshore. As erosion progresses, sand is removed first and the shingle, if any, is concentrated on the beach.

Control of Erosion

The coastline is being eroded not only by the waves but also by rain wash and wind. Rain wash is most important on the high cliffs of the drumlins where recent wave erosion has exposed bare slopes. If wave erosion is stopped by the construction of sea walls to protect the bases of the till slopes and the slopes are covered with grass, rain wash can be largely prevented. This would, of course, remove a source of natural replenishment of sand for the beaches.

Wind erodes the sandy beaches and sand dunes, but, of course, is ineffective on the shingle beaches. Much sand is blown up and down the beaches and some is blown inland to form sand dunes. Unless it is blown back again, the sand that is blown inland is lost to the beach. In places, as at Rexhame Beach at the north edge of the Duxbury quadrangle, considerable sand has been removed from the beach and deposited in dunes.

Sea walls prevent sand from being blown landward from the beach until the sand is built up to or nearly to the tops of the walls. Groins also trap sand that moves along the beach, until the groins become buried. Wind-blown sand tends to lodge against sea walls and to raise the levels of the beaches at the walls. This is advantageous because it tends to retard wave erosion at the bases of the walls.

The dune ridges at the inner edges of beaches are often higher than the shingle beach ridges and hence afford effective protection against unusually high storm tides and wave damage. Dune ridges should be protected from blowouts by cultivating the grass cover. At Rexhame Beach large holes have been cut through the main dune ridge by the wind where the grass cover was destroyed. Storm waves at high tide have gone several hundred feet inland through these holes, and have carried rocks 12 inches in diameter for 100 feet from the former position of the wave cut cliff on the seaward side of the dune ridge. Some property damage has been caused in this way.

Although most of the shoreline between Nantasket Beach and Duxbury Beach consists of unconsolidated glacial and post-glacial deposits the shoreline does not appear to be receding as rapidly as the east shoreline of Cape Cod, which has an average retreat about 3 feet per year and which is also cut into glacial deposits. Wave erosion is naturally retarded between Nantasket Beach and Duxbury Beach by headlands of bedrock and hard till which help to hold the intervening beaches. The till headlands such as First, Second, Third, and Fourth cliffs in Scituate are being cut back, but more slowly than deposits of sand and gravel would be. Each of these headlands is bordered by a boulder pavement which at low tide has an exposed width of 200 to 300 feet. These boulder pavements mark the sites of the portions of the till hills that have been eroded by the waves. The boulders that could not be moved by the waves and so have become concentrated on the wave cut bench are so numerous that they act to protect the wave cut bench under them from further erosion. They also help to protect the sea cliffs behind them, as the water is shallower over the boulder pavements than in adjacent sections of the beach, and the force of the waves is considerably diminished in moving across them. Boulders also cover the upper part of the beach at the foot of the sea cliffs composed of till and help to retard erosion of the upper part of the wave cut bench.

It is significant that little or no sand and shingle is being shifted across the boulder platforms below mid-tide level. Proof of this is afforded by the fact that the boulders show no modern abrasion; instead, they are covered by barnacles and seaweed, and many show weathered surfaces that would not endure abrasion. In contrast with this the boulders on the upper parts of the beaches between the bases of the wave cut cliffs and approximately mid-tide level show much evidence of recent abra ion; this is caused by shingle which is washed up and down this part of the beach by waves when the tide is high.

Sea walls for protecting property are most effective on sand beaches and least effective on shingle beaches. Well constructed sea walls at the north end of Duxbury Beach, at Fieldston Beach, and at the north end of North Scituate Beach, where the beaches are composed mostly of sand, have protected the property behind them from any appreciable damage; where the beaches are composed of shingle, the sea walls have been less effective. The beach from 500 to 1000 feet east of Gun Rock, about seven-tenths of a mile east of the south end of Nantasket Beach, is a shingle beach. The severe storm in November 1945 threw a large quantity of shingle over the sea wall and caused considerable damage to houses and property. The same storm threw shingle over the sea wall at Hatherly Beach in the northern part of the Scituate quadrangle and damaged houses and other property.

Sea-walls built along shingle beaches need to be higher and stronger than those built along sandy beaches. Owing to the fact that the shingle beaches have steeper profiles than the sand beaches, the waves at high tide come much closer to the high tide shoreline before they break on a shingle beach than on a sand beach, and, therefore, strike a sea wall on a shingle beach with greater force than one on a sand beach. Many sea walls are built on the seaward sides of the crests of shingle beaches, and are accordingly exposed to severe pounding by storm waves. The walls increase the upward thrust of waves breaking against them and cause the waves to hurl shingle over the walls higher than if the walls were absent. To prevent the shingle from going over the walls they need to be built as high as possible and as far back of the high tide line as is practicable.

As erosion of the beaches in front of the sea-walls progresses the beaches slowly disappear and ultimately the walls are destroyed. How long this will take in a given locality, however, is difficult to estimate.

Suggestions for Further Work

The following geologic studies are proposed for a detailed study of the shoreline between Nantasket and Duxbury Beaches:

1) Map the geology of the Coastal area.

2) Map the wave-cut cliffs now exposed to wave erosion.

3) Map the shingle and the sand beaches.

4) Make profiles of the beaches at significant places to show the profiles of the different types of beaches in different localities.

5) Study the migration of shingle and sand.

6) Study the shape and coarseness of the shingle and sand in relation to shore drift.

7) Check all the evidence relating to the directions of prevailing shore drifts.

8) Examine sea walls as to their effectiveness and behavior.

9) Study the rivers in the area to see if they bring much material to the beaches.

10) Study the topography of the sea bottom adjacent to the beaches as shown on charts and air photos.

11) Study shoreline changes and the rates of shoreline recession by references to old maps and reports, and by consulting local residents.

12) Look up wind directions and tidal currents for this section of the coast.

13) Determine the distribution of peat on the beaches.

14) Study the beach cusps to see if they affect shore drift and the movements of material along the beaches.

15) Examine the shoreline at low tide for evidence of bars and troughs parallel to the shoreline.

(To accompany report by N. E. Chute "Beach erosion of the shoreline between Nantasket Beach and Duxbury Beach, Massachusetts").

EXPLANATION

Qbs

Beach deposits and sand dunes

Qs

Swamp and salt marsh deposits
(Chiefly sand, silt, clay and peat, some gravel)

Qal

Alluvium
(Chiefly post-glacial stream deposits of gravel, sand and silt)

Ql

Lake deposits
(Chiefly bottom deposits of fine gravel, sand, silt and clay)

Qo

Outwash plain
(Sand and gravel plains deposited by streams of glacial meltwater and variously pitted by kettle holes)

Qkt

Kame terrace
(Terrace deposits of sand and gravel deposited by streams of glacial meltwater on one or both sides of a valley between the valley walls and residual masses of glacial ice in the valley)

Qc

Crevasse filling
(Sand and gravel deposited in crevasses in the ice)

Qid

Ice-hole delta
(Sand and gravel deposited as a delta in hole in the ice and bounded completely or nearly completely by ice-contact slopes)

Qdp

Delta plain
(Pitted sand and gravel plain chiefly of deltal origin)

Qk

Kame and kame field
(Sand and gravel deposited as individual knobs (kames) or groups of knobs (kame fields). Deltas, kame terraces, and outwash plains, so thoroughly pitted with ice-block holes (kettle holes) that their specific origin is not recognizable are mapped as kame fields

Qe

Esker
(Ridge of sand and gravel, mostly segmented and with uneven crestlines)

Qgm

Ground moraine
(Chiefly till. Most of the till areas are underlain by sand and gravel)

Qd

Drumlin
(Oval-shaped hill composed in large part of till)

Bedrock outcrops
(lg, fine-grained leucogranite; bg, porphyritic biotite fine-grained granite; rh, porphyritic rhyolite; dg, Dedham granodiorite; qt, quartzite)

af

Artificial fill

cb

Cranberry bog

Contact
(Dashed where approximately located)

Direction of ice movement
(Indicated by glacial striae, chatter marks, and grooves on outcrops)

Pit

Operating or recently operated pit

Abandoned pit

(Most of the pits are in sand and gravel deposits, a few are in till and clay deposits. Letter symbols indicate the composition of the deposits. The symbols are arranged in order of abundance of materials present, with the most abundant material first: cl, clay; si, silt; s, sand; p, pebble gravel; c, cobble gravel; and b, boulders)

Quarry

O 90'-b60'

Well

(First number is the depth of well in feet; the second number prefixed by b is depth to bedrock in feet. The latter number is omitted on wells that did not reach bedrock)