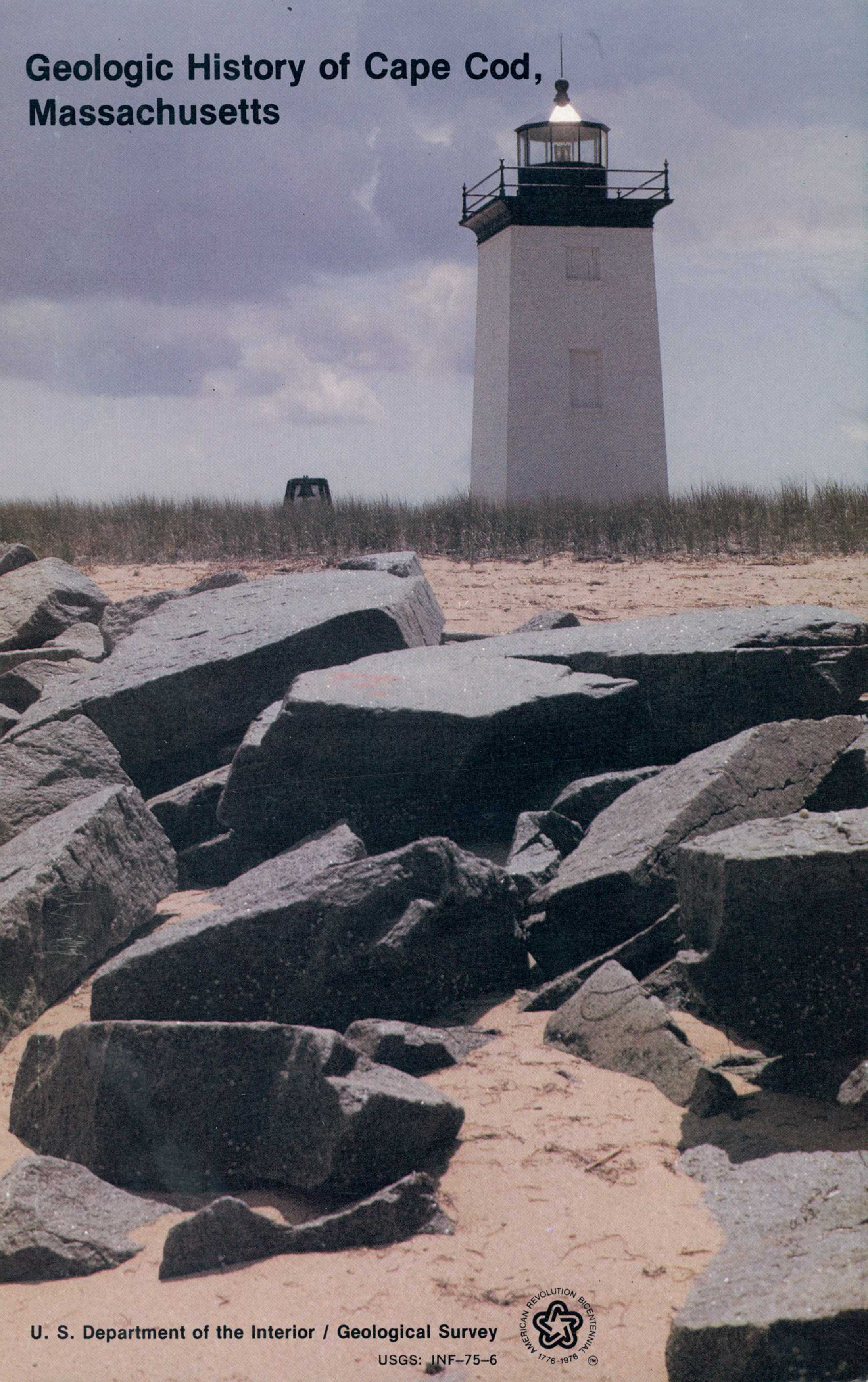
Geologic History of Cape Cod, Massachusetts



U. S. Department of the Interior / Geological Survey

USGS: INF-75-6

"East and ahead of the coast of North America . . . there stands in the open Atlantic the last fragment of an ancient and vanished land."

From an aerial infrared photograph of Cape Cod.

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Introduction

Cape Cod, a sandy peninsula built mostly during the Ice Age, juts into the Atlantic Ocean like a crooked arm. Because of its exposed location, Cape Cod was visited by many early explorers. Although clear-cut evidence is lacking, the Vikings may have sighted this land about 1,000 years ago. It was visited by Samuel de Champlain in 1605, and his detailed descriptions and charts have helped present-day scientists to determine the rate of growth of Nauset Beach marsh and Nauset spit. Bartholomew Gosnold, a lesser known explorer, settled for a short time on the Elizabeth Islands to the southwest and gave Cape Cod its name in 1602.

The Pilgrims first landed in America on the tip of Lower Cape Cod after they

Figure 1. Index map of southeastern Massachusetts.

were turned back from their more southerly destination by shoals between Cape Cod and Nantucket Island. On Cape Cod they found potable water and food and had their first fight with the natives. The Pilgrims, however, decided that this land was too isolated, too exposed, and too sandy to support them, and they sailed across Cape Cod Bay to establish Plymouth. These features remain today. Small villages are separated by large areas of forest, dune, beach, and marsh. This unspoiled natural beauty makes Cape Cod one of the most favored vacation areas for the people living in the thickly settled Northeastern States.

Cape Cod is of particular interest to geologists because it was formed by glaciers very recently in terms of geologic time. During the Great Ice Age, (the Pleistocene Epoch which began 2

Figure 2. During the southward advance of the ice, New England may have looked like the present day Greenland icecap—a barren landscape of snow and ice.

to 3 million years ago), glaciers advanced from the north into the temperate regions of the Earth. Glacial ice covered the land at least four times. Each advance was accompanied by a worldwide lowering of sea level because the source of the ice was water from the seas. When the glaciers melted, the climate and sea level were probably much like they are today. In fact, some scientists believe that the Earth is presently between glacial episodes and that ice once again will advance across the land.

The Glacial Cape Cod

The geologic history of Cape Cod mostly involves the last advance and retreat of the ice in southern New England and the rise in sea level that followed the melting of the ice. These events occurred within the last 25,000

Figure 3. The glacier advanced across Cape Cod between 18,000 and 25,000 years ago. Its maximum southward position is marked today by gravel deposits on the continental shelf. South of the ice sheet the shelf was exposed. Bulges in the ice front are called lobes.

years, and many events can be dated by using radioactive carbon techniques. Sometime between 18,000 and 25,000 years ago the glacier reached its maximum advance, a position marked approximately by the islands of Nantucket and Martha's Vineyard. About 15,500 years ago the ice started to recede rapidly northward by progressive melting; within roughly 1,000 years the glacier front had retreated to a point north of Boston. The retreat of the ice from the islands to a position north of Cape Cod may have taken only a few hundred years.

The rock debris deposited by the glaciers, called *drift,* overlies a surface of much older rock similar to the bedrock exposed throughout the rest of New England. On Cape Cod this older rock is buried by drift ranging from 200 to more than 600 feet thick. Because the geologic history of this older rock is

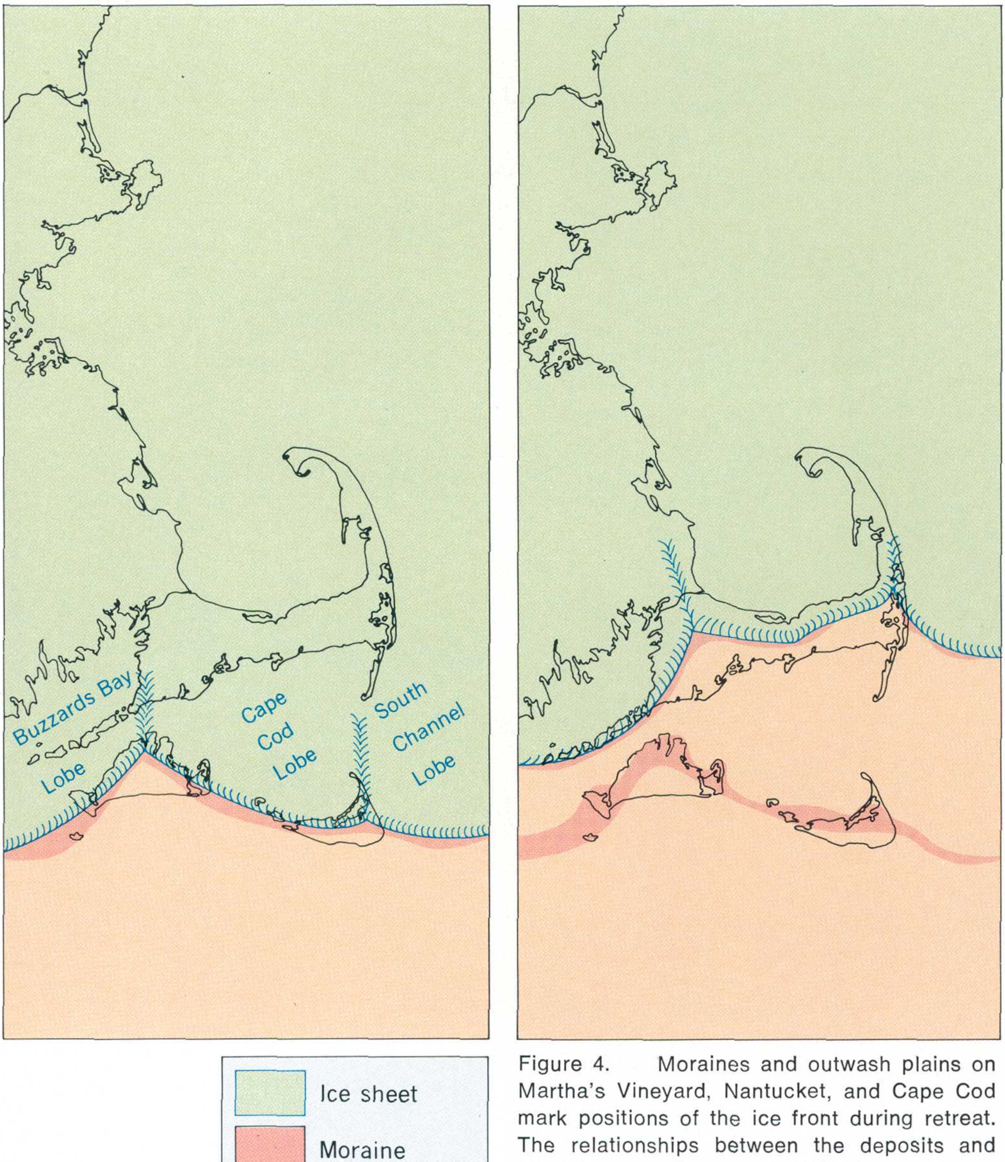


Figure 4. Moraines and outwash plains on Martha's Vineyard, Nantucket, and Cape Cod mark positions of the ice front during retreat. The relationships between the deposits and the lobes can be seen in this figure.

complex and only incidental to the glacial and postglacial history of Cape Cod, it will not be described here.

Drift consists of very fine to very coarse rock debris. If unstratified, it is called *till.* Till is deposited directly by ice. Because it is not sorted and stratified by water, till is a mixture of all sizes of rock debris ranging from clay-sized fragments to boulders. Stratified drift, on the other hand, is deposited after the rock debris has been transported and sorted by water. The clay and silt-sized rock fragments are carried into quiet water and deposited as a glacial lake or glacial marine sediments. The result of glacial action on Cape Cod is shown on a generalized geologic map (plate 1, page 20) that depicts the distribution of various kinds of glacial deposits.

Most of the drift on Cape Cod has been fashioned into either *moraines* or

Figure 5. A moraine and outwash plain of the Malaspina Glacier, Alaska, illustrate conditions envisioned for Cape Cod. Note the contrast between unsorted and unstratified till of the moraine and the well-sorted and stratified drift. Holes in the outwash, called kettles, form over melting blocks of buried ice.

outwash plains. Both features mark positions of the ice front. Moraines are ridges of rock debris formed by moving ice. At times the front of the ice may remain more or less in the same place because the advance of the ice is balanced by melting. The rock fragments carried by the ice are piled up along the ice front in much the same manner as a conveyor belt carries along material and dumps it at the end of the belt. Minor advances of the ice front may rearrange the debris to form a larger and higher moraine. Moraines may also form when the ice front advances and bulldozes the sand and gravel of an outwash plain into a ridge. The moraine on Cape Cod was formed by a combination of these processes.

Outwash plains make up most of the landscape of Cape Cod. They were built by meltwater streams that changed

Figure 6. Aerial view of the outwash plain in Schuchert Valley, Alaska. The outwash plain sediments are deposited beyond the ice front by streams of meltwater. The braided pattern is characteristic of meltwater streams because sediment loads are high and water volume varies with the rate of melting.

course from time to time and deposited sand and gravel to form a broad flat plain sloping away from the ice front.

Drift deposits also occur in the form of highly irregular and unorganized kame and kettle terrain in some places. A *kame* is a knoll or hill of rock debris that originally filled a hole in the ice. A *kettle* is almost exactly the opposite of a kame. It is a hole in glacial debris originally filled by a large piece of ice. The upstream parts of outwash plains may also have kame and kettle terrain that results from the deposition of debris over and around a thin, uneven and stagnant wedge of ice. As the buried wedge of ice melts, collapse zones form in the outwash deposits. At the present time, however, only the outwash plain on the eastern half of upper Cape Cod has a collapse zone. The collapse zones of outwash plains to the west have been

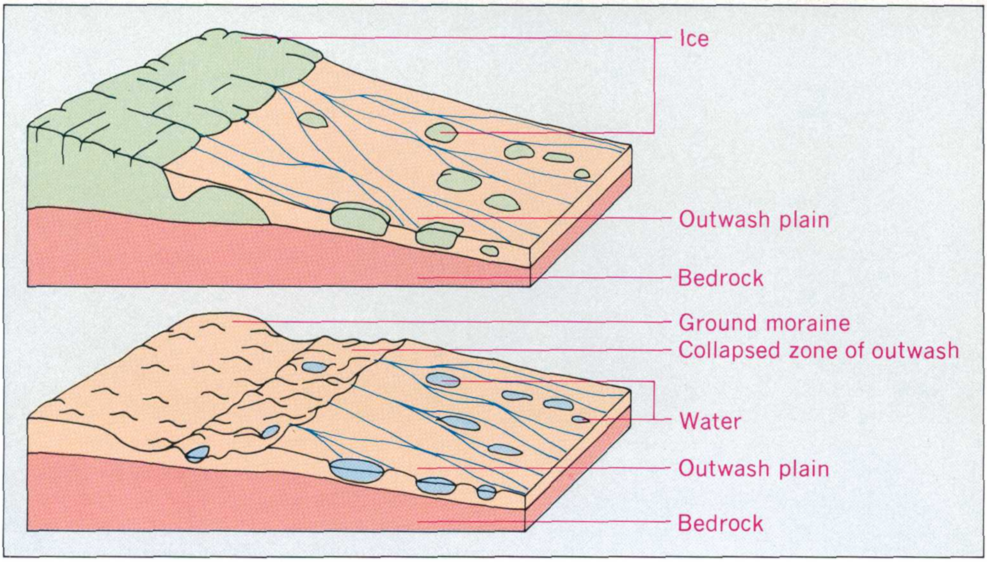


Figure 7. Photograph and drawing showing the relationship of buried ice to a collapsed zone of an outwash plain and kettles.

incorporated into the moraine, and those on lower Cape Cod have been removed by marine erosion.

The glacial materials that make up kame and kettle terrain are called *ice-contact deposits* because they reflect the closeness of glacial ice. These deposits are highly variable in composition and include till, well-sorted sand and gravel, and laminated silt and clay. Boulders commonly occur in these deposits. The distribution of ice-contact deposits, except for those included in the outwash plain, is shown on the geologic map (plate 1, page 20).

Lake deposits along the north shore of Cape Cod were deposited in a glacial lake that formed between the ice front and Cape Cod during the northward retreat of the ice front from Cape Cod Bay. In places, these deposits formed deltas as meltwater streams discharged sand

Figure 8. Ice-contact deposits of the Malaspina Glacier, Alaska. Till, boulders, and sand and gravel are underlain by the irregular surface of melting ice. Silt and clay (glacial rock flour) are being deposited in ponds that occupy depressions in the ice surface.

and gravel into the lake along the ice front. Some distance from the deltas (or ice front), the glacial sediments are composed of silt and clay. These finer sediments were deposited in the deeper parts of the lake. The silt and clay from these deposits were once used to make bricks at Barnstable.

A major outlet for the glacial lake was cut through the tip of the moraine near the southwest shore of the Bay. The escaping water eroded the moraine leaving a natural lowland that was later to become the site of the Cape Cod Canal.

Many other features of the Cape Cod landscape owe their existence, at least in part, to glaciation. The numerous lakes and ponds occur in kettle holes whose bottoms are below the ground-water table. Where the lakes and ponds are shallow or have a gently shelv-

Figure 9. Cape Cod Canal. Except for bridges, roads, and buildings, the region probably looked much the same 14,000 years ago.

ing shore, they are very susceptible to a lowering of the water table either by drought or heavy use of ground water. Many Cape Codders remember the drought of the early 1960's when some ponds dried up and many were greatly reduced in size. Presently we can do little about drought, but we can use our ground water wisely.

Outwash plains on Cape Cod are cut by numerous stream valleys that are customarily dry or occupied only by tidal creeks. Streams are lacking because the outwash deposits are highly permeable and rain and snow meltwater quickly percolate into the ground. The valleys were cut after the outwash plains were formed but before all the buried ice blocks had melted. Although the process is not completely understood, the valleys were probably cut by rainwater and spring snow meltwater when

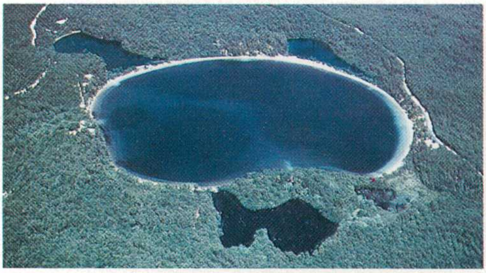


Figure 10. Great Pond, east of Wellfleet, is a kettle. It marks the site of a large block of ice left behind by the retreating glacier and buried by outwash deposits. Smaller ponds have been separated from the main pond by beach deposits formed in much the same way as spits form along the ocean shore.

Figure 11. The Pamet River Valley in Truro. This is the largest of the numerous valleys cut into the outwash plains of Cape Cod. The lower parts of these valleys are drowned indicating that they were cut before the postglacial rise of the sea.

glacial and near-glacial temperature maintained an impermeable layer of frozen ground in the upper part of the outwash deposits. Later, parts of many valleys became inundated by the post-glacial rise in sea level.

At the end of glaciation and before the landscape was well covered by vegetation, winds winnowed silt and sand from the exposed glacial sediments and deposited this material as a thin, but almost continuous blanket on the drift surface. Stones on the drift surface were cut, faceted, and polished by sandblasting. These stones, called *ventifacts,* can now be found within the windblown layer. They are distinctively shaped and some have been mistaken for tools of Indian origin.

Large boulders, many feet across, are common on Cape Cod. Too large to have been transported by streams,

Figure 12. A ventifact from the soil zone of Cape Cod, carved and polished by the wind.

they were deposited directly by the ice and are most abundant in moraine and ice-contact deposits. Those found far out on outwash plains, like Enos Rock, were deposited from partly buried ice blocks stranded behind the retreating ice front. Some rock fragments in the glacial deposits can be recognized as having come from distant outcrops. Small black stones of fossilized wood, for example, may have come from an outcrop near Middleboro. Gray to white quartzite stones containing fossil shells may have come from an area southwest of Middleboro.

Although most of the stones in the glacial deposits are rock types common to the bedrock of southeastern New England, a careful search will sometimes produce rare stones that give evidence of less known episodes in the geologic history of the Cape Cod region.

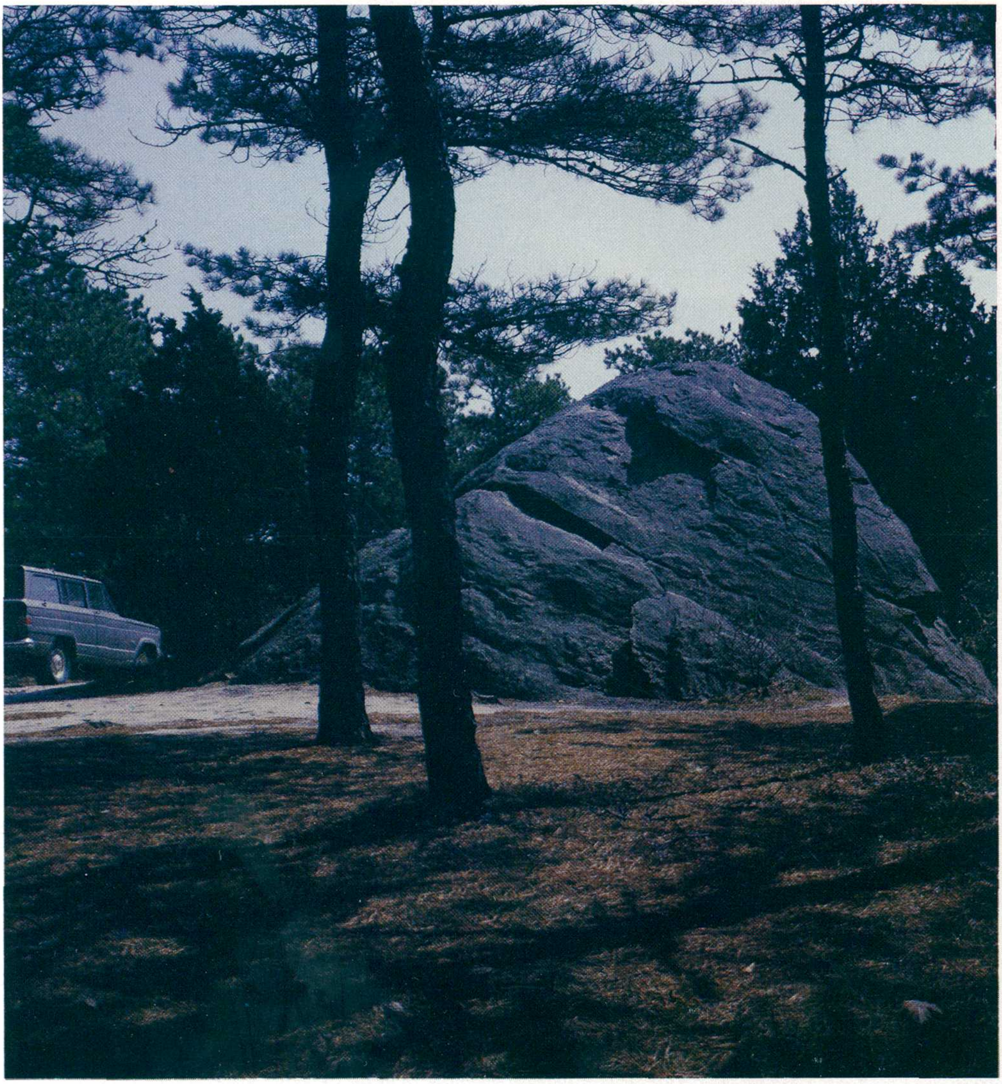


Figure 13. Enos Rock in Eastham, the largest glacial boulder on Cape Cod. Pits dug at the base showed as much rock below the surface as above it. A boulder this big could have been deposited only by a large block of ice.

Stones similar to the red sandstones, conglomerates, and shales of the Connecticut Valley are scattered throughout the glacial deposits. They may indicate that 200 million years ago Cape Cod was part of a region of large lakes and swamps where dinosaurs roamed. Fossil wood of evergreen trees, shelly marl, and sharks' teeth suggest that before the Ice Age the Cape Cod region may have been a low flatland supporting pines and bordered by lagoons and estuaries. Such a landscape would resemble the present Atlantic Coastal Plain south of Cape Cod.

Cape Cod and the Sea

During the glaciation and for some time after the retreat of the ice from the vicinity of Cape Cod, the sea level was about 400 feet lower than it is today. Much of the continental shelf south of

Figure 14. For some time after the retreat of the ice, the sea remained several hundreds of feet below its present level. The land shown in brown was exposed by the lowered sea level shortly after the retreat of the ice from southeastern Massachusetts. As the ice melted, the sea rose gradually. Only the area shown in yellow is above sea level today.

Nantucket and Martha's Vineyard was exposed. Mastodon, mammoth, and other extinct mammals of the Ice Age, and possibly early man, roamed the forest and meadow beyond the ice. As more and more of the glacial ice melted, the sea level rose and the shelf area became progressively inundated. At first the sea rose quickly, about 1 foot every 100 years. But about 2,000 years ago, the rate decreased to about a third of a foot per 100 years. These rates of rising sea were determined from the levels and ages of salt-marsh peat from the continental shelf and from beneath the Great Marshes at Barnstable.

About 6,000 years ago the rising sea reached the glacial cape; since then, ocean waves have eroded the fragile land. The sea, however, does not simply destroy the land. Much of the eroded material is reworked, transported, and

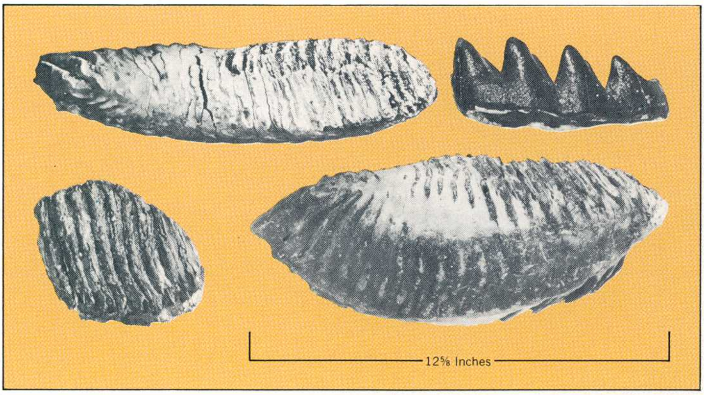


Figure 15. Teeth of extinct mastodon and mammoth dredged from the continental shelf south and east of Cape Cod.

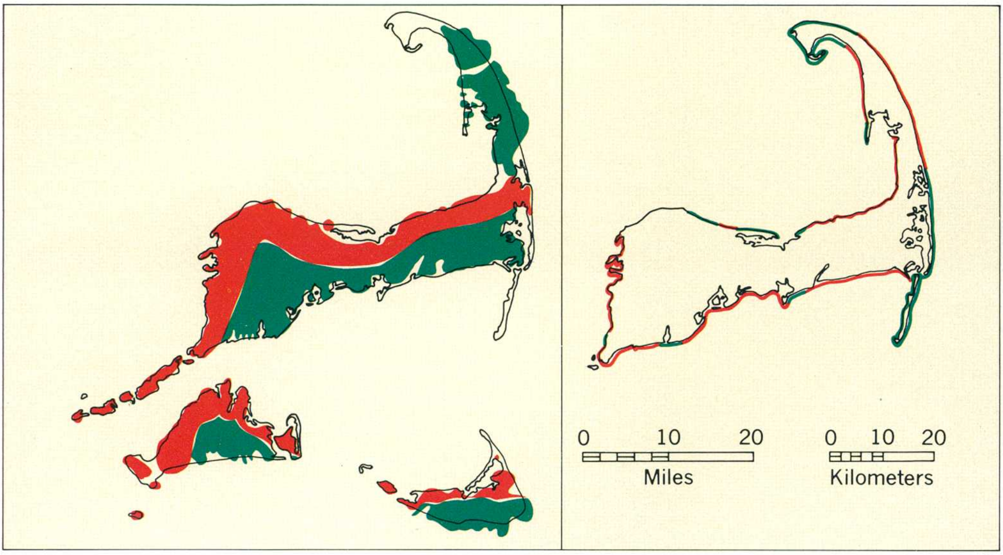


Figure 16. About 6,000 years ago, before extensive wave erosion of the glacial deposits had occurred, the glacial Cape Cod probably resembled the map on the left. The present major pattern of erosion and deposition is shown on the map at the right. Red shows shoreline undergoing erosion; green shows shoreline undergoing deposition.

redeposited by waves and longshore currents to form new land. Most new land is composed of beach deposits in the form of spits and marsh. The largest spits on Cape Cod are the Provincetown, Nauset Beach, Monomoy Island, and Sandy Neck. Numerous smaller spits occur in many places along the Cape Cod shore. The spits grow by the deposition of material at their outer end, and currents may cause the ends to curve, forming a recurved spit typified by the hook at Provincetown and the southern tips of the Nauset Beach and Monomoy Island. Other spits, called *tombolos,* connect once-isolated islands to the mainland.

Many spits shelter a quiet body of water called a lagoon. Associated with the lagoon are marshes and sand or mud flats. The growth and development of these features, as well as the lagoon,

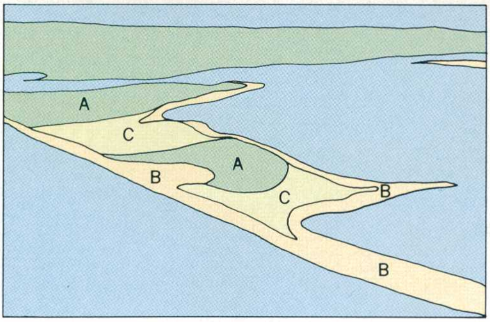


Figure 17. Wellfleet Harbor is protected on the seaward side by a number of islands composed of outwash deposits (A). The islands are tied together and to the mainland by spits called tombolos (B). Behind the spits the lagoons are filled by marsh (C).

are closely related to the growth of the protecting spit. For example, Sandy Neck at Barnstable has grown during the past 3,000 years from a spit a little over 1 mile long protecting a small lagoon and a few patches of marsh to a spit 6 miles long protecting a large lagoon and a marsh of several square miles.

Once formed, spits do not remain unchanged for long. Sand grains are winnowed from the beach deposits by wind and carried inland where they form dunes. On the small spits, the dunes are only a few tens of feet high, but on Sandy Neck, Monomoy Island, and the Provincetown spits, dunes reach heights of 40 to 100 feet above sea level. In places the dunes are stable and covered with vegetation. Older stabilized dunes may have a forest cover growing on a well-developed soil. In the past, these soils have been buried by younger

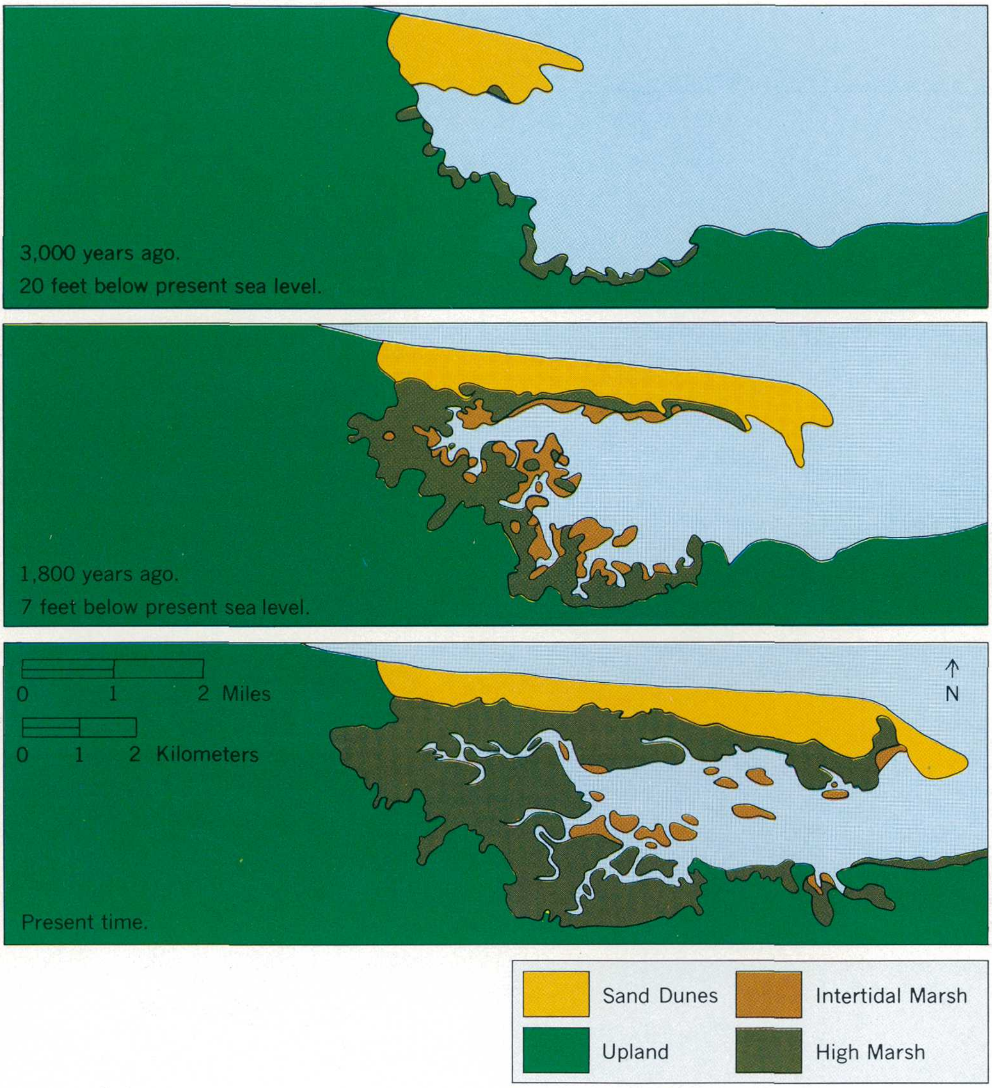


Figure 18. Stages in the growth of Sandy Neck spit and the Great Marshes west of Barnstable from 3,000 years ago to present time. The marsh grew upward in response to the rising sea and laterally in response to the growth of the spit.

dunes. On Sandy Neck, flint chips, animal bones, and hearth stones from Indian encampments are associated with some of these older soils.

Geologic Map of Cape Cod

The geologic map has been compiled from U.S. Geological Survey 7½-minute geologic quadrangle maps of Cape Cod. An understanding of the geologic relationships of the Cape Cod region contributes to the fund of information about the geologic history, natural environment, and mineral-resource potential of the United States continental margin. On a more local framework, geological and geophysical studies as well as water resource surveys provide data enabling one to identify and locate the natural resources of Cape Cod and to recommend how best to use them. Today, the most valuable resources of

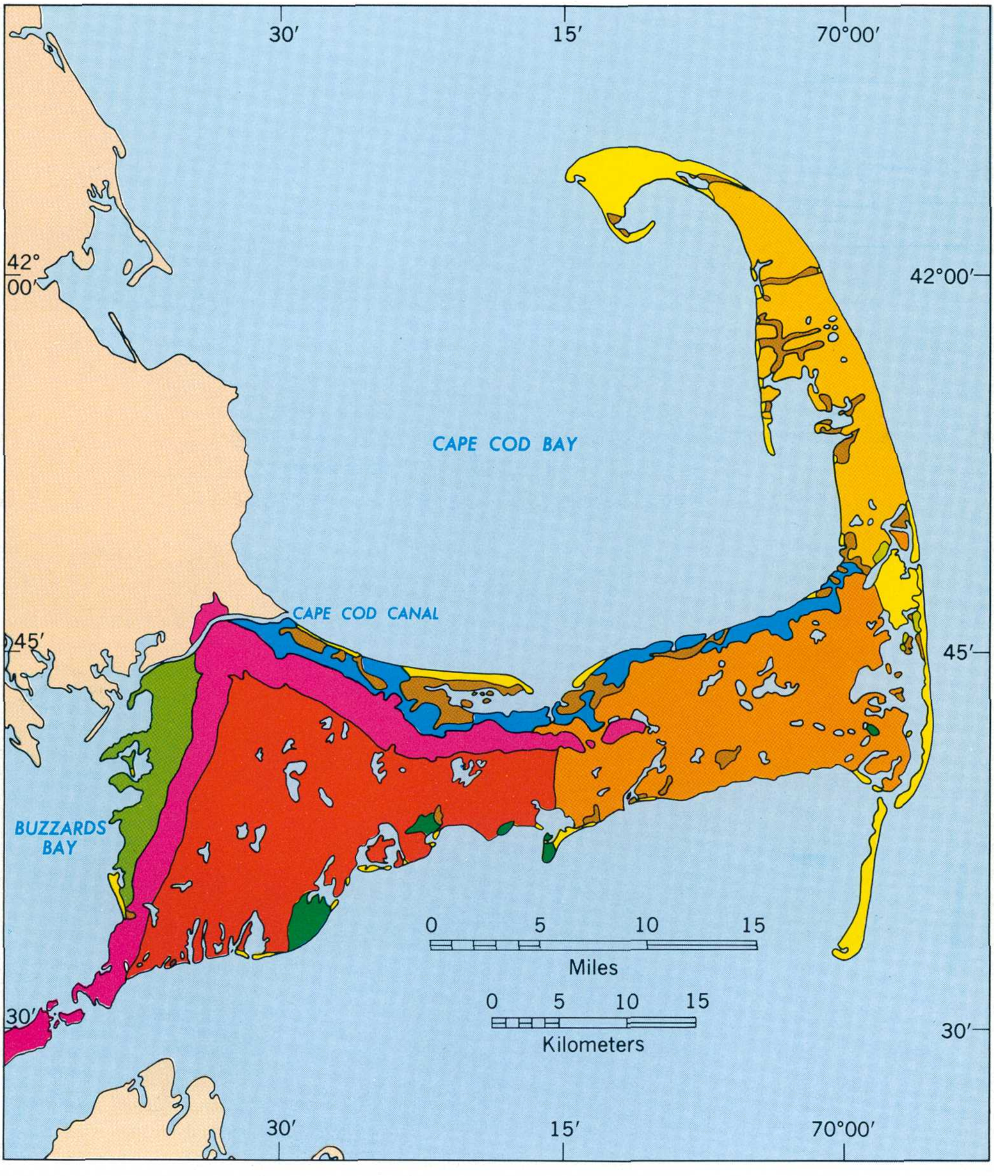
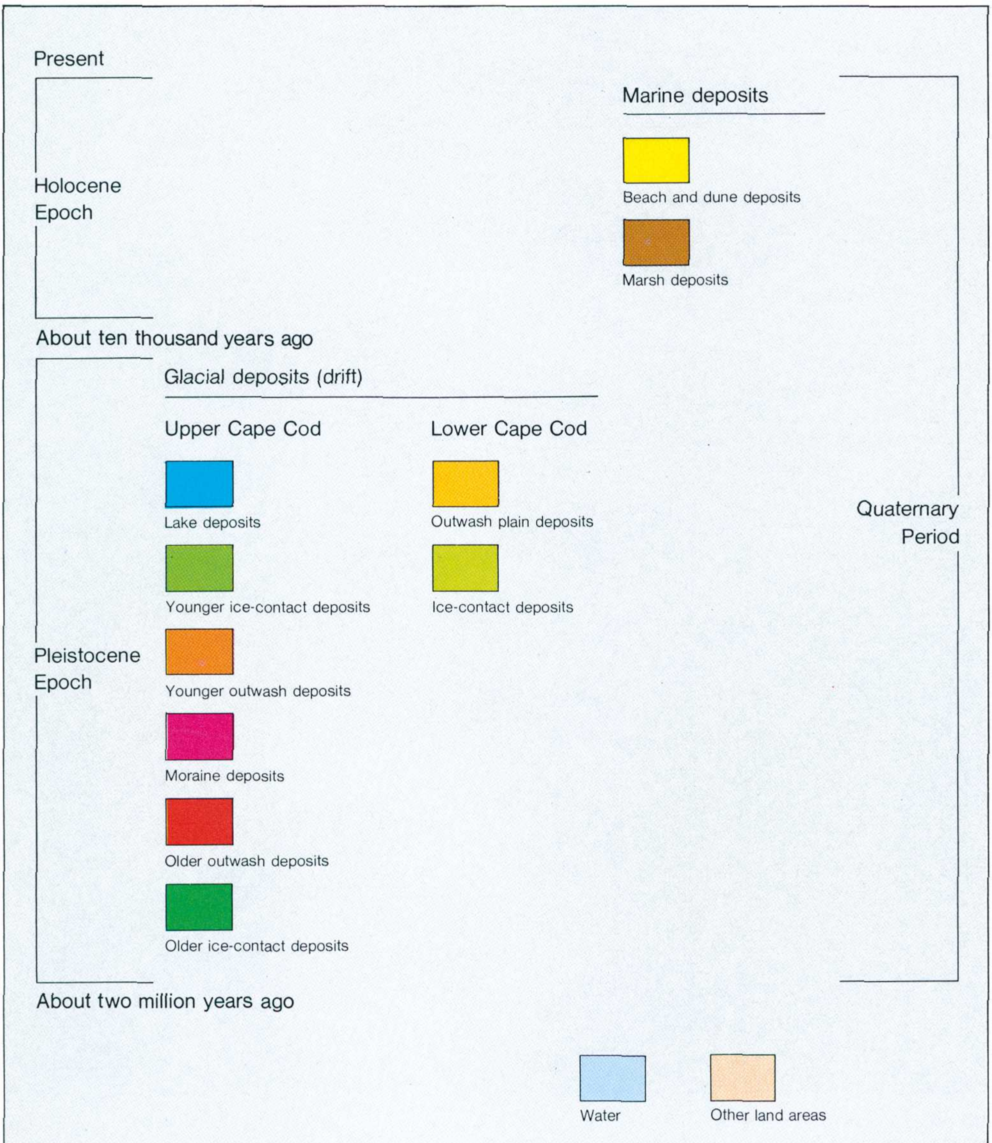


Plate 1. Geologic map of Cape Cod.

the Cape appear to be recreation and a large, although limited, reservoir of pure fresh ground water. However, additional studies, care, and good planning are required if both are to be utilized fully and at the same time be preserved for the future.

The Ultimate Cape Cod

The forces of marine erosion will continue to attack Cape Cod and the land will eventually be worn away. New lands built by waves, currents, and winds will not balance the loss of land to the sea. We can guess the rate of loss based on a few things we know. For example, we know that the cliffed ocean side of lower Cape Cod loses about 5 acres a year to marine erosion. New land constructed from this eroded material averages about 2 acres per year. Thus for each acre lost, less than half



Explanation.

an acre is gained. Estimates for other parts of the Cape probably vary greatly from this figure. But at some distant time—not for many generations, however—Cape Cod will be nothing more than a few low sandy islands surrounded by shoals. Nothing will be left to supply a group of hungry tourists with drink, food, or even an opportunity to fight with the "natives."

(from material provided by Robert N. Oldale)

Credits

Frontispiece and figure 9 ....
Benjamin Harrison, Buzzards Bay, Massachusetts.

Figures 5, 6, and 8 ....
J. H. Hartshorn, University of Massachusetts at Amherst.

Cover, figures 10, 16, 18, and 19 ....
U.S. National Park Service.

Figure 19. U-shaped dunes of the Provincetown spit. Sand from the beach at upper right is picked up and carried inland by strong northwest winds.

Plate 1 . . . .
Generalized from detailed mapping by K. F. Mather, R. P. Goldthwait, L. R. Theismeyer, J. H. Hartshorn, Carl Koteff, and R. N. Oldale.

Selected Additional Reading

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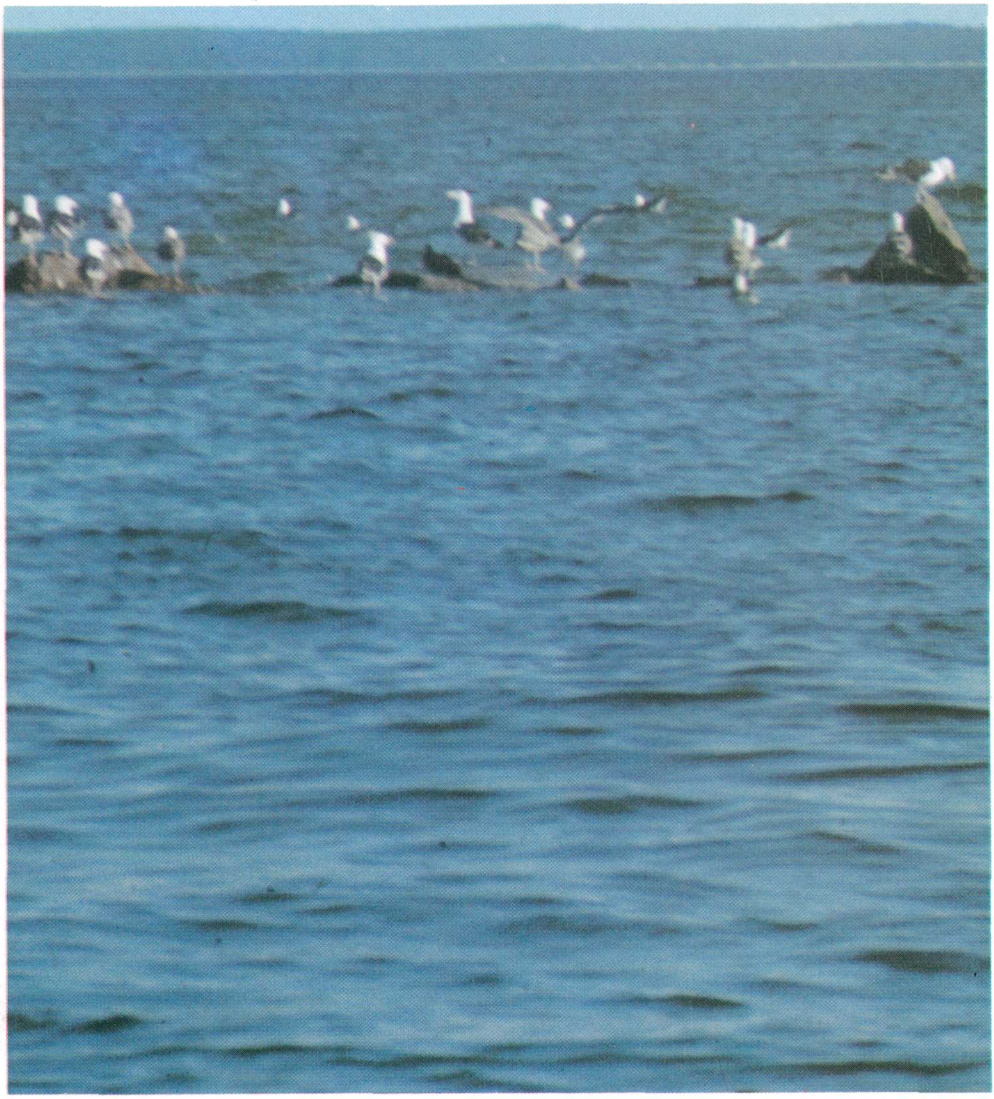

Figure 20. All of Cape Cod may eventually look like Billingsgate Island. Now only a shoal, this island was once large enough for a small community of several houses and a lighthouse.

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. administration.

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V. E. McKelvey, Director
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