MAP GQ-786

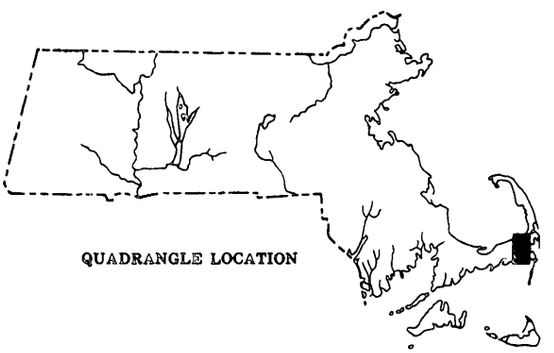
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
COMMONWEALTH OF MASSACHUSETTS
DEPARTMENT OF PUBLIC WORKS

GEOLOGIC QUADRANGLE MAPS OF THE UNITED STATES

GEOLOGIC MAP OF THE HARWICH QUADRANGLE BARNSTABLE COUNTY, CAPE COD MASSACHUSETTS

By
Robert N. Oldale



PUBLISHED BY THE U. S. GEOLOGICAL SURVEY
WASHINGTON, D. C.
1969

MAP GQ-786

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

TO ACCOMPANY MAP GQ-786

GEOLOGY OF THE HARWICH QUADRANGLE, BARNSTABLE COUNTY, CAPE COD, MASSACHUSETTS

By

Robert N. Oldale

INTRODUCTION

The Harwich quadrangle is at the east end of inner Cape Cod, a narrow peninsula trending easterly and bounded by Cape Cod Bay to the north and Nantucket Sound to the south (fig. 1). Inner Cape Cod is composed chiefly of glacial deposits derived from a lobe of a glacier that occupied Cape Cod Bay. In the Harwich quadrangle deposits are mostly gravelly sand and have been mapped as the Sandwich moraine deposits, the Harwich outwash plain deposits, glacial lake, and glacial lake bottom deposits. Sandwich moraine deposits have a ridge-like form and maximum altitudes somewhat above the surrounding outwash deposits. The surface of the Harwich outwash plain deposits slopes gently south toward Nantucket Sound from a steep ice-contact slope facing Cape Cod Bay. Glacial lake and lake bottom deposits occur north of the Sandwich moraine and Harwich outwash plain deposits, and are the youngest glacial deposits in the quadrangle.

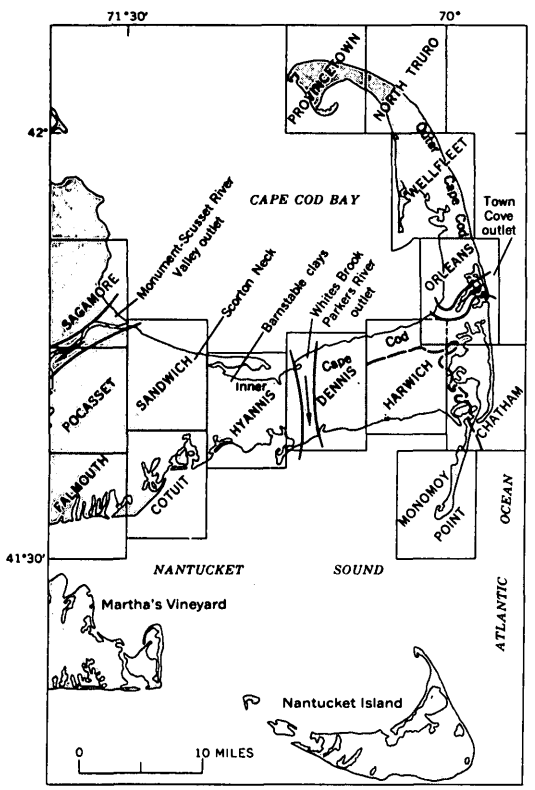


FIGURE 1.—Index map showing possible outlets for the lake in Cape Cod Bay. Dashed line shows southern and western limit of till and boulders in the Harwich, Orleans, and Chatham quadrangles.

Borehole data from the quadrangle (Koteff and Cotton, 1962) show that the mapped deposits are at least 160 feet thick and overlie a coarse to clayey silt 153 feet thick that in turn is underlain by compact till 116 feet thick that rests on crystalline basement. There are no major till layers at the base of the mapped deposits or interbedded with the silt, therefore the silt and overlying sandy deposits are believed to have been laid down during a single glaciation. Multiple drifts on Martha's Vineyard (Kaye, 1964, p. C134) indicate more than one glaciation on Cape Cod and till from these earlier glaciations may make up a part of the till that rests upon the basement.

Involutions and congeliturbate in the upper part of the glacial deposits and late-glacial eolian deposits attest to periglacial conditions during the retreat of the ice from Cape Cod Bay. Permafrost may have reduced the permeability of the sandy deposits allowing stream erosion to cut the valleys in the Harwich outwash plain when sea level was lower than present. Later the post-glacial rise in sea level partly submerged the glacial deposits and marine processes formed sea cliffs, beaches, and marshes. Onshore winds deposited the dunes.

PLEISTOCENE GEOLOGY

Sandwich moraine deposits.—The Sandwich moraine deposits make up the Sandwich moraine, the east trending part of the Falmouth moraine mapped by Woodworth and Wigglesworth (1934, p. 61). The Sandwich moraine was mapped by Mather, Goldthwait, and Theismeyer (1942, p. 1132) in the Sandwich, Pocasset, and Sagamore quadrangles. Recently the author has mapped the Sandwich moraine in the Hyannis, Dennis, and Harwich quadrangles (fig. 1). In the Hyannis quadrangle it is similar to the moraine to the west and forms an unbroken high standing ridge north of the outwash plain. In the Dennis quadrangle it forms a discontinuous ridge separated by ice-contact heads of the Harwich outwash plain. The moraine is limited to a small area north of Upper and Lower Millpond in the Harwich quadrangle. Two exposures in the Dennis quadrangle show Harwich outwash plain deposits overlying Sandwich moraine deposits. Borehole data east of the moraine in the Harwich quadrangle also show a similar stratigraphic relationship (Carl Koteff, 1967, oral communication). Maximum altitudes on the moraine are higher than those on the outwash plain and glacial lake deposits.

Sandwich moraine deposits are mostly medium to very coarse sand and pebble to cobble gravel. Till occurs throughout the deposit, but most commonly at or near the surface. Boulders up to several tens of feet in diameter occur scattered throughout the deposit and on the surface. Lithologies of stones most commonly found in the deposit are granites, felsic volcanics, and quartzites.

Harwich outwash plain deposits.—The upper surface of the Harwich outwash plain deposits slopes gently toward Nantucket Sound with gradients that range from eight to fourteen feet per mile. The upstream end of the outwash plain is an ice-contact slope inclined steeply toward Cape Cod Bay. Maximum altitudes of about

140 feet occur northeast of Cliff Pond in Brewster. The surface is interrupted in many places by kettle holes that mark the site of ice blocks buried by the drift. The largest kettle holes intercept the water table and contain marsh deposits or ponds such as Cliff, Long, Seymour, and Upper Mill Ponds. The bottoms of these larger kettle holes are some distance below sea level. Numerous valleys are eroded into the southern part of the outwash plain. They trend south to southwest and have southerly gradients. The bottoms of the valleys in many places are interrupted by kettle holes. The lower part of most are drowned and occupied by tidal rivers and salt marsh deposits. Similar valleys, called furrows, occur in the Mashpee pitted plain to the west in the Cotuit and Falmouth quadrangles (fig. 1) (Mather and others, 1942, p. 1160).

The Harwich outwash plain deposits are mostly sand and gravel that generally decrease in coarseness from north to south. Clayey silt occurs in some places in both the north and south parts of the outwash plain deposits. Till bodies and boulders up to several tens of feet in diameter occur within and overlying the sand and gravel north and east of the heavy dashed line on the map and the dashed line on figure 1.

The lithologies of stones most commonly represented in the deposit (fig. 2) include granites 52.5 percent, felsic volcanic rocks 15 percent, and quartzites 9.5 percent.

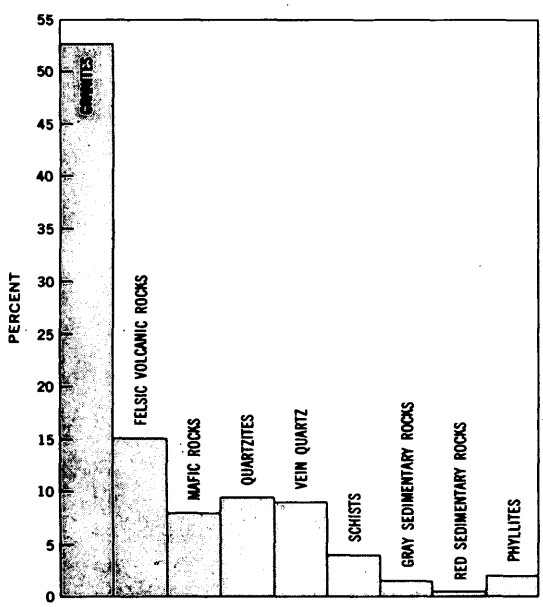


FIGURE 2.—Histogram showing the averages of lithologies of stones found in the Harwich outwash plain deposits. Based on twenty-five stone counts of 100 stones each.

Glacial lake deposits.—Deposits north of the ice-contact head of the Harwich outwash plain and Sandwich moraine composed of gravelly sand, pebble to cobble gravel, with minor amounts of till, clayey silt, and numerous scattered large boulders have been mapped as glacial lake deposits (Ql). These deposits have maximum altitudes of 50 to 60 feet along a line roughly parallel with the shore of Cape Cod Bay. Depositional gradients for these deposits cannot be determined, but they were probably south toward the head of the Harwich outwash plain and Sandwich moraine. These deposits are believed to be similar to those that make up Scorton Neck (fig. 1), a proglacial delta.

Glacial lake bottom deposits.—Deposits north of the moraine and outwash plain composed of interbedded gravelly sand, sand, and clayey silt have been mapped as glacial lake bottom deposits (Qlb). Maximum altitudes are about 30 feet and the lake bottom deposits are separated from the lake deposits by a distinct scarp in most places.

Sand and gravel, undifferentiated.—Undifferentiated gravelly sand and pebble to cobble gravel is mapped in the bottom of the valleys or furrows in the Harwich outwash plain. The age of this unit is not certain and is probably in part Pleistocene and in part Holocene.

Late-glacial eolian deposits.—A thin, but widespread mantle of wind-deposited sand and silt overlies the glacial deposits and is not mapped. The windblown materials have been mixed with the underlying glacial sand and gravel to form a congeliturbate identified as till by some workers (Sayles and Knox, 1943, p. 1574) and caused Woodworth and Wigglesworth to propose the Vineyard interglacial stage (1934, p. 261). Its origin however can be determined by the many wind-cut stones included in the deposit. The late-glacial eolian deposit is of Pleistocene age and can be distinguished from Holocene dune sand by its yellow-brown color and the presence of a well-developed soil profile. This can best be seen in the sea cliffs where a dark-gray to black A horizon separates yellow-brown wind-deposited sediments of Pleistocene age from nearly white dune sand of Holocene age.

POST-PLEISTOCENE GEOLOGY

Beach deposits.—The beach is generally composed of sand and pebble to cobble gravel eroded from the drift and transported laterally along the shore by waves and currents. In some places numerous boulders up to several tens of feet in diameter occur on the beach. These boulders have been eroded from till or clayey silt deposits exposed in the cliff directly above the beach. Large boulders offshore mark earlier positions of the sea cliffs. Beach deposits occur along the shores of many of the ponds. These deposits, derived from the drift, are composed of sand and gravel.

Swamp and marsh deposits.—Salt marsh deposits occur adjacent to the coast behind spits and in the drowned portion of furrows and breached kettle holes. They are composed of decaying marine grasses and reeds mixed with varying proportions of marine sand, silt, and clay. They are capped by live marine or, in some places, fresh-water grasses and reeds. Thickness of the marsh deposits is unknown, but in the drowned furrows and breached kettle holes they may be several tens of feet thick.

Fresh water swamp deposits occur in many kettle holes and in the upstream parts of furrows. Many swamps have been converted to cranberry bogs. Swamp deposits are generally only a few feet thick, but thicker deposits may occur in kettle ponds.

Dune deposits.—Dunes occur in many places near the coast. They are composed of sand and granule gravel derived from the beaches and carried inland by onshore winds. They are in most places only a few feet thick, but in some places may be as much as ten feet thick. Thin, discontinuous dune deposits occur on fresh-water beach deposits in some places. Dune deposits have little or no soil profile.

PLEISTOCENE HISTORY

The stratified deposits that make up Cape Cod were laid down during the retreat of the last glacier in southeastern Massachusetts as it is only locally overlain by till deposited either by minor readvances of the ice front or as flow tills. Therefore, with the possible exception of a part of the basal till identified in the boreholes in the Harwich quadrangle, the glacial deposits are younger than those to the south on Nantucket and Martha's Vineyard (fig. 1) and older than the late-glacial deposits to the north of Boston. The advance of the last ice into southeastern Massachusetts occurred about 20,000 to 26,000 years ago.

Radiocarbon dates on reworked shell and wood fragments from drift on outer Cape Cod give dates of 20,700 + 2000 years (Zeigler and others, 1964, p. 710) and 26,000 + 1000 years (W-1585 Washington Laboratory, U.S. Geological Survey). A radiocarbon date from Zach's Cliff, Martha's Vineyard, on leaves in a clay stratigraphically below ablation till and outwash (Kaye, 1964, p. C138) suggest that ice still occupied the site of Cape Cod about 15,000 years ago. Radiocarbon dates on barnacles from late-glacial marine clay near Boston indicate that the ice had retreated from Cape Cod Bay by about 14,000 years ago (Kaye and Barghorn, 1964, p. 75). Therefore the drift on Cape Cod is believed to be about 14,000 to 15,000 years old. The oldest deposits in the quadrangle are the till and silt identified in the boreholes and seismic surveys (Koteff and Cotton, 1962; Oldale and Tuttle, 1965). The till is believed to be a basal till deposited by the last ice. The silt is believed to be a glacial lake sediment deposited during the retreat of the ice across Nantucket Sound, possibly in a proglacial lake in Nantucket Sound dammed to the south by drift.

The ice retreated to a position approximated by the south shore of Cape Cod Bay where the Sandwich moraine and Harwich outwash plain indicate a major stillstand. The inline position of the moraine and ice-contact head of the outwash plain suggests that the two features are about the same age, and although Harwich outwash plain deposits overlie the Sandwich moraine deposits in two exposures in the Dennis quadrangle, they may actually interfinger. The moraine and outwash plain represent different conditions of deposition that probably occurred simultaneously along the ice front.

The Sandwich moraine is believed to have been deposited mostly as ice-contact alluvial fans in places where the relative elevation of the ice surface and the surface of the outwash caused abrupt changes in the gradient of melt-water streams along the ice-contact zone. Ice push ridges on the moraine in the Hyannis quadrangle (fig. 1) indicate that the moraine was built in part by minor readvances of the ice. Till found in the fluvial deposits may have been deposited during these advances, or as flow tills from partly buried ice blocks. The silty clay, silt, and fine to very fine sand that occur in the moraine were deposited in small ponds caused by melting of buried ice blocks or by the damming of streams by earth flows.

The Harwich outwash plain is believed to have been deposited where the altitude of the ice surface was lower and where melt-water streams crossed the ice-contact zone with little change in gradient. Maximum altitudes on the outwash plain of about 140 feet northeast of Cliff Pond suggest that the major source of the Harwich outwash plain deposits in the Harwich quadrangle may have been in this area. Numerous ice blocks left behind by the retreating glacier were buried by the outwash deposits. Many, in the northern part of the outwash plain, were only partly buried and contributed till and boulders to the fluvial deposits. Silty clay in the fluvial deposits was laid down in small ponds caused by the partial melting of buried ice blocks. The thick silt layer identified in the borehole in Harwich (Koteff and Cotton, 1962) suggests that the Harwich outwash plain may be a proglacial delta deposited in a lake that occupied Nantucket Sound. If so, the outwash exposed above sea level would be delta topset beds graded to the level of the lake.

Retreat of the ice away from the Sandwich moraine and the ice-contact head of the Harwich outwash plain ended the development of these features. A proglacial lake, that eventually occupied most of Cape Cod Bay, is believed to have formed between the retreating ice front and the glacial deposits to the east, south, and west. Evidence for the lake includes the clay, silt, and fine to very fine sand deposits north of the moraine and outwash plain in the Harwich and Dennis quadrangles, the Barnstable clay, and Scorton Neck, a proglacial delta in the Sandwich quadrangle (fig. 1), the proglacial deltas along the west side of Cape Cod Bay at Duxbury (Chute, 1965), and the delta foreset beds in the Wellfleet quadrangle (Oldale, 1968). In addition the deposit in Cape Cod Bay, inferred by Hoskins and Knott (1961, p. 339) to be glacial till, in large part may be a glacial lake bottom deposit. The generally flat upper surface and homogeneity of this deposit as compared to glacial till or ice-contact deposits suggests lake bottom sediments. Boulders, by which Hoskins and Knott identified the deposit as till may have been dropped into the sediments by icebergs. The earliest outlets for the lake are thought to have been Whites Brook and Parkers River valleys and Monument River and Scusset River valley, now the site of the Cape Cod Canal (fig. 1). Both outlets had an altitude of about 30 feet above sea level. Initially the divides may have been higher as the glacial deposits are easily eroded. Later stages of the lake are thought to have drained through Town Cove (fig. 1). Complete drainage of the lake occurred when the ice retreated from Cape Cod Bay and streams drained eastward into Great South Channel.

A minor stillstand of the ice a short distance north of the south shore of Cape Cod Bay is indicated by the deposits north of the Sandwich moraine and Harwich outwash plain. These deposits are composed of sediments inferred to have been laid down in the proglacial lake. In the Harwich quadrangle the coarser grained deposits with maximum altitudes of about 60 feet are believed to be proglacial deltas similar to the Scorton Neck delta. The lower level deposits composed of interbedded gravelly sand, silt and silty clay are thought to be lake bottom or bottomset deposits.

A late-glacial eolian mantle was deposited under periglacial conditions following the retreat of the ice. Much of the material may have come from lake deposits exposed in Cape Cod Bay after the proglacial lake drained. Permafrost indicated by congeliturbate and involutions occurred for some time after the retreat of the ice. The valleys, called furrows (Mather and others, 1942, p. 1160), are not completely understood. They were cut during late-glacial time before ice blocks buried in the outwash plain were completely

melted, and when permafrost reduced the permeability of the glacial deposits, presently too great to support streams capable of cutting such valleys. They were not eroded by melt-water streams as they do not completely cross the outwash plain. The subparallel arrangement and poorly developed tributary pattern suggest some sort of subsurface control. However, the truncated beds at the sides of the furrows clearly show them to be erosional (Mather and others, 1942, p. 1160), probably cut by streams draining into Nantucket Sound when sea level was considerably lower than at present. Finally complete melting of the ice blocks produced the kettle holes.

POST-PLEISTOCENE HISTORY

Near the end of glaciation in southeast Massachusetts sea level was at least 300 feet below its present level (Emery, 1967, p. 685). After glaciation sea level rose to partly submerge the glacial deposits on Cape Cod. Marine processes are believed to have begun operating on the glacial deposits by about 6000 years ago (Zeigler and others, 1965, p. 305), and sea level reached approximately its present position by about 3500 years ago (Redfield, 1965, p. 52). Wave erosion has formed the sea cliffs. The eroded glacial deposits have been transported and redeposited by waves and currents to form beaches and sand flats. Marshes have formed in areas sheltered by glacial deposits or barrier beaches. Onshore winds have transported and redeposited the beach sand to form dunes.

REFERENCES

Chute, N. E., 1965, Geologic map of the Duxbury quadrangle, Plymouth County, Massachusetts: U.S. Geol. Survey Geol. Quad. Map GQ-466.

Emery, K. O., 1967, Sea levels 7,000 to 20,000 years ago: Science, v. 157, p. 684-687.

Hoskins, Hartley, and Knott, S. T., 1961, Geophysical investigation of Cap Cod Bay, Massachusetts, using the continuous seismic profiler: Jour. Geology, v. 69, p. 330-340.

Kaye, C. A., 1964, Outline of Pleistocene geology of Martha's Vineyard, Massachusetts: U.S. Geol. Survey Prof. Paper 501-C, p. C134-C139.

Kaye, C. A., and Barghorn, E. S., 1964, Late Quaternary sea-level change and crustal rise at Boston, Massachusetts, with notes on the autocompaction of peat: Geol. Soc. America Bull., v. 75, p. 63-80.

Koteff, Carl, and Cotton, J. E., 1962, Preliminary results of recent deep drilling on Cape Cod, Massachusetts: Science, v. 137, p. 34.

Mather, K. F., Goldthwait, R. P., and Theismeyer, L. R., 1942, Pleistocene geology of western Cape Cod, Massachusetts: Geol. Soc. America Bull., v. 53, p. 1127-1174.

Oldale, R. N., 1968, Geologic map of the Wellfleet quadrangle, Barnstable County, Cape Cod, Massachusetts: U.S. Geol. Survey Geol. Quad. Map GQ-750.

Oldale, R. N., and Tuttle, C. R., 1965, Seismic investigations in the Harwich and Dennis quadrangles, Cape Cod, Massachusetts: U.S. Geol. Survey Prof. Paper 525-D, p. D101-D105.

Redfield, A. C., 1965, Ontogeny of a salt marsh estuary: Science, v. 147, p. 50-55.

Sayles, R. W., and Knox, A. S., 1943, Fossiliferous tills and intertill beds of Cape Cod, Massachusetts: Geol. Soc. America Bull., v. 54, p. 1569-1612.

Woodworth, J. B., and Wigglesworth, Edward, 1934, Geography and geology of the region including Cape Cod, the Elizabeth Islands, Nantucket, Martha's Vineyard, No Man's Land, and Block Island: Harvard Coll. Mus. Comp. Zoology Mem., v. 52, 322 p.

Zeigler, J. M., Tuttle, S. D., Tasha, H. J., and Giese, G. S., 1964, Pleistocene geology of outer Cape Cod, Massachusetts: Geol. Soc. America Bull., v. 75, p. 705-714.

_____1965, The age and development of the Provincelands Hook, outer Cape Cod, Massachusetts: Limnology and Oceanography, v. 10, p. 298-311.