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A GEOLOGIC OVERVIEW OF CAPE COD: A FIELD TRIP GUIDE

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INTRODUCTION

This overview presents a generalized account of the geology of Cape Cod, demonstrated by scenic overlooks from the Cape Cod Canal to the Provincelands dunes. This generalized approach is necessary because I have not done field work on the Cape since about 1972 and much of my work here was completed by 1967, more than 20 years ago. The outcrops studied in the distant past have no doubt changed greatly or disappeared completely, the result of shore erosion and development. However, the general aspects of the geology, stratigraphy, and geologic history remain relatively unchanged, and can best be demonstrated from broad vistas. I will leave the details of the geology, archaeology, and paleoecology to my co-leaders.

The geology and, in part, the shape of Cape Cod was established by lobation of the Laurentide ice sheet during its retreat. The lobes, from west to east, were the Buzzards Bay lobe, the Cape Cod Bay lobe, and the South Channel lobe, that occupied the western Gulf of Maine east of Cape Cod. Retreat of the lobes was not syncronous; the Buzzards Bay lobe retreated first and the South Channel lobe, last. As a result, the glacial deposits on Cape Cod, in general, become younger towards the east and the youngest deposits occur on the outer cape.

U. S. Geological Survey map I-1736 (Oldale and Barlow, 1986), a geologic map of Cape Cod and the islands, will be the major reference for this part of the field trip.

Among the earliest visitors to Cape Cod were Gosnold, in 1602, Champlain in 1605 and 1606, Hudson in 1609, and John Smith in 1614. There is no evidence that the Vikings were the first to visit, but they could have been. Many of these early visits ended in violence between the Indians and Europeans, including killing and kidnaping. The Pilgrims, in 1620, first landed at the tip of the cape. They explored as far south as Eastham where their first contact with the Indians, a fight, occurred. During the expedition they stole whatever Indian posessions they wanted. This unhappy situation between the Indians and Europeans has a modern counterpart when the natives exploit, or are exploited by, the summer invaders from offcape.

ROUTE 6 CANAL OVERVIEW

The first stop of the field trip is on the east end of the Sandwich moraine and is an overlook of the Cape Cod Canal. The Sandwich moraine and

Buzzards Bay moraine form the so-called back bone of Cape Cod. The Buzzards Bay moraine, not visable from this point, parallels the Buzzards Bay shore and forms the Elizabeth Islands chain southwest of Woods Hole. A short distance south of the canal, the Sandwich moraine deposits overlie the Buzzards Bay moraine deposits (Mather et al., 1940, 1942).

The canal is located in a through valley that was originally occupied by two streams, the Scussett River that flowed northeast into Cape Cod Bay and the Monument or Manomet River that flowed southwest into Buzzards Bay. The divide between the two streams was at an altitude of about 29 feet (9 m) (Farson, 1977). The through valley is thought to have formed as water from a glacial lake in Cape Cod Bay escaped to the Buzzards Bay valley. The outlet may have had an initial altitude of about 80 feet (24 m), about the surface altitude of the earliest deltas associated with the lake. Erosion lowered this threshold and consequently the level of the lake. The outlet was abandoned when lower outflow routes developed as the ice retreated from Cape Cod Bay. The through valley and the two rivers provided an easy portage between Cape Cod and Buzzards Bay. By 1627, colonists had established a trading post in the valley for trade between the English settlers of New England and the Dutch settlers of New Amsterdam. Miles Standish of Alden and Mullens fame proposed a canal between Cape Cod Bay and Buzzards Bay to avoid the dangerous shoals southeast of the cape (Farson, 1977). More than a century later, a canal was proposed by George Washington, among others, as a way to avoid sea blockades such as those imposed by the British during the Revolutionary War and the War of 1812. After numerous false starts, by various companies who were licensed by Massachusetts to dig the canal, the canal was completed in 1914 by a company headed by August Belmont--a feat commemorated by the glacial boulder at this site. Following World War I, the canal was bought by the United States and improved by the U. S. Army Corps of Engineers to what you now see. It is the widest canal in the world.

SHOOTFLYING HILL

Route 6 runs along the crest of the Sandwich moraine with Cape Cod Bay to the north and Vineyard and Nantucket Sounds to the south. The moraine consists of a veneer of till and boulders underlain by stratified drift, including sand and gravel and rhythmically bedded silt and clay. Both the Sandwich moraine and the Buzzards Bay moraine have been interpreted to be glaciotectonic features (Oldale and O'Hara, 1984) formed as the lobes readvanced and thrust previously deposited drift. This stop is located on the crest of the moraine and, to the south, overlooks the inner Cape outwash plains. To the north, it overlooks the proximal side of the moraine, deposits of the Cape Cod Bay lake, and marsh and spit deposits of Holocene age. The inner-cape outwash plains were deposited by meltwater from the Cape Cod Bay lobe. The plain immediately below the overlook was mapped as the Barnstable outwash plain. The Mashpee pitted plain, mapped and named by Mather, Goldthwait, and Theismeyer (1940, 1942) is to the west and the Harwich outwash plain is to the east.

If the weather is clear, several major stratigraphic units can be seen at

this stop. The oldest unit forms a number of isolated kames, hills that rise above the level of the outwash plains, along the Nantucket Sound and Vineyard Sound shore. Several kames can be seen to the south from this overlook. The kames were probably formed when the front of the Cape Cod Bay lobe was located north of the offshore islands and the present south shore of the inner cape.

The Mashpee pitted plain and the Barnstable outwash plain formed next, probably when the ice front of the Cape Cod Bay lobe was located somewhat north of the Sandwich moraine and the Buzzards Bay ice front was located somewhat west of the Buzzards Bay moraine. A readvance of these lobes, the Buzzards Bay lobe first, formed the Buzzards Bay and Sandwich moraines. Retreat of the Cape Cod Bay lobe followed, and the Harwich outwash plain formed behind and in front of the Sandwich moraine.

SCARGO HILL TOWER

Scargo Hill tower is located on one of two kames that rise slightly above the Harwich outwash plain. Glacial deposits located between the kames, the Harwich outwash plain, and the Sandwich moraine and the shore are interpreted to be ice-contact deltas and shallow water sediments of the Cape Cod Bay glacial lake. The deltas along this part of the shore generally have altitudes of about 60 feet (18 m) while to the west, older deltas have altitudes closer to 80 feet (24 m). The latter may have formed during the earliest high stage of the Cape Cod Bay lake. Initially, the lake was very narrow as the ice pulled away from the inner cape, but it became a significant body of water when the large outwash deltas developed on outer Cape Cod and along the west shore from Plymouth to Duxbury.

Postglacial deposits including spits, beaches, marshes, and dunes formed as the Holocene rise in sea level drowned the glacial cape. Sandy Neck and the Barnstable marshes can be seen to the west. Both features began to develop about 4,000 years ago, when sea level was about 25 feet (7.5 m) below the present level (Redfield, 1965; Redfield and Rubin, 1962). Provincelands spit, seen at the outer end of the cape if it is very clear, started to form about 6,000 years ago (Zeigler et al, 1965).

CHATHAM LIGHT

On the way to Chatham Light the route crosses the much collapsed Harwich outwash plain. Large and small kettle holes and shallow valleys interrupt the outwash plain. Many of the large kettle lakes have bottoms well below present sea level and represent ice blocks as much as 200 feet (60 m) thick. Valleys occur on all of the cape outwash plains. They are relict because many are dry. They cross kettle holes and were thus cut early, before the ice blocks buried by outwash melted. These valleys were probably cut not by glacial meltwater because they do not start at the ice-contact head, but by rain water and water from melting snow before the outwash plains became vegetated. Permafrost could have prevented the surface water from percolating into the

sandy outwash plain deposits. However, there is no evidence of permafrost and the outwash deposits themselves provide evidence for abundant meltwater and a temperate climate during deglaciation. Robert Thorson (oral commun., 1987) has suggested that an unvegetated or poorly vegetated outwash plain surface may have been sufficient to favor runoff over percolation. Runoff may have been encouraged by the ubiquitous layer of wind deposited silty sand that caps the coarser, more permeable, outwash sand and gravel. Spring sapping has also been suggested as an origin for the valleys.

Cape Cod is a dynamic environment and ever changing. The dominant factor in the changing landscape is the sea. Where the cape is unprotected from wave attack, sea cliffs have formed in the glacial deposits. In places, barrier beaches protect the glacial deposits from erosion. However, the protection is temporary as the barriers can change form or wash away, mostly during major storms. The breach in this barrier was first developed during a northeast storm in January 1987. The continuing impact of the still widening breach includes increased tidal range and flow within the lagoon, shoaling of the harbor as flood-tidal deltas develop, and erosion along the mainland shore. Changes in the barrier system protecting the mainland from wave attack appear cyclic, as does erosion of the mainland when changes in the barrier system occur. Evidence of a breakdown in the barrier system and erosion of the mainland that occurred in 1851 is shown by the inactive sea cliff below Chatham Light. During the time the Chatham shore was exposed to wave attack, roads and houses were destroyed and as much as 100 feet (30 m) of cliff retreat occurred (Leatherman, 1988). The erosion following the latest breach has already claimed one house and, unless hard protective measures are taken, will probably claim more. A laissez faire attitude prevailed for a short time after the recent break, but as expensive land and houses began to go, that changed. The willingness to live with nature gave way to screams for engineering structures to protect the mainland shore from wave attack or to close the breach in the barrier.

FORT HILL

The glacial features seen from this stop on were deposited by the South Channel lobe. From Chatham Light the route crossed the deeply embayed eastern flank of the Harwich outwash plain. The large embayments, Pleasant Bay and Little Pleasant Bay, represent sublobes of South Channel ice, against which the Cape Cod Bay lobe outwash was deposited.

Fort Hill overlooks Nauset Harbor, an embayment formed by a sublobe of South Channel ice. The Nauset sublobe is thought to have been larger initially and to have occupied the site of the Eastham plain. Fort Hill is part of the Eastham plain and across the harbor, to the southeast, are the Nauset Heights ice-contact deposits. The Nauset Heights deposits may be contemporaneous with, or somewhat younger than, the Harwich outwash plain deposits and are the oldest of the South Channel lobe units. The Eastham plain deposits are considered to be the youngest South Channel lobe outwash unit.

Nauset Harbor is bordered on three sides by sea cliffs cut into the

glacial drift. The cliff erosion may have occurred before the barrier spit formed or when the embayment was much larger and the mudflats and marshes had not yet developed. The embayment is the result of the Nauset sublobe and was here when the sea transgressed; the cliffs may originally have been ice-contact slopes that were later modified by wave erosion. The opening in the barrier is presently migrating northward and the southern spit is about 1/2 mile (.8 km) longer than it was in 1962. Nauset Harbor spit changed greatly in the 1978 February storm. Previous to the storm, dunes up to 40 feet (12 m) high occupied the spit north of the inlet.

Samuel de Champlain visited Nauset Harbor and made the first map of the region in 1605. The map shows the headlands and barrier spits up to a mile seaward of their present position. The distribution of the marsh and sand flats on the map is remarkably similar to the present distribution.

MARCONI SITE

This is the site from which the first transatlantic wireless transmission between the United States and Europe was made in 1903. Offshore is the site of the pirate ship Whydah, wrecked in a storm in 1717 and now being excavated. The ship's bell, cannon, gold, silver, and other artifacts have been found. The presence of the Whydah probably explains the gold coins occasionally found in the beach deposits along this shore.

Geologically the Marconi site is located at the southern end of the Wellfleet outwash plain deposits, the largest and next to oldest of the South Channel lobe drift units. Its southern flank was deposited against the Nauset sublobe. Following the retreat of the sublobe, the Eastham outwash plain was deposited against the ice-contact slope of the Wellfleet plain. The difference in elevation between the plains and the general westerly slope of the outwash plain surfaces can be clearly seen. The latter unequivocally establishes the presence of ice to the east and is the primary evidence for ice in the Gulf of Maine during late Wisconsinan time, a point that advocates of the late Wisconsinan minimal ice sheet model need to be reminded of periodically.

The great cliff along the "back side" of "lower" Cape Cod, local terms that mean "out back" and "northeast" (as in downwind to Maine), demonstrates dramatically the erosion that will eventually reduce the cape to a series of low islands and broad sand shoals. Erosion along this shore, although sporatic and local in nature, averages about 3 feet/year (1 m/year). The eroded material is transported, by longshore drift, southward to nourish the barriers from Eastham to Chatham and northward to build the Provincelands spit. Major erosion along the east shore of the cape and the southwest and west shore of Cape Cod Bay occurs mostly during severe winter northeast storms. In contrast, major erosion along the south shore and the Buzzards Bay shore occurs during summer and fall hurricanes.

The route to Highland Light crosses the Pamet Valley, the largest of the outwash plain valleys. If not blocked by a barrier beach on the Atlantic end,

the Pamet River would be a seaway, completely separating the lower cape into two parts and making the northern part an island. The valleys in the Wellfleet outwash plain, called hollows, are probably the large end member of all the outwash plain valleys. Within the Wellfleet plain, they represent significant fluvial erosion, shortly after the plain was built. Where the hollows interrupt the great cliff, they provide access to the beach. They were a vital means of escape for sailors stranded on the beach and also made it easier for wreckers to save lives and then scavange the wrecks.

HIGHLAND LIGHT

One of the early classic Quaternary sections in New England is exposed in the cliffs below the lighthouse. The section consists of rhythmically laminated clay that is underlain by gravel and overlain by fine sand. The beds were correlated to the pre-Wisconsinan stratigraphy of Long Island and Martha's Vineyard by Fuller (1914) and Woodworth and Wigglesworth (1934). Zeigler considered the Highland plain deposits to be early Wisconsinan in age (Zeigler et al., 1964). These age assignments and regional correlations are no longer considered valid because the units exposed in the cliff are quite restricted and overlie the Wellfleet plain deposits. The deposits are now inferred to be glaciolacustrine in origin, laid down in a glacial lake, unrelated to the Cape Cod Bay lake, that developed between the Cape Cod Bay and South Channel lobes and the ice-contact flank of the Wellfleet plain.

Three late Wisconsinan outwash plains can be seen from this overlook. We are standing on the surface of the lake deposits that form the Highland plain. The ice-contact slope of the higher Wellfleet plain can be seen to the south marked by the granite tower, a memorial to Jenny Lind, a famous Gay Nineties song bird. To the north is the lower Truro plain. The Wellfleet and Truro plains were formed as deltas, graded to different levels of the Cape Cod Bay glacial lake. The Wellfleet plain is the oldest and the Truro plain is next to the youngest feature related to the lake. The Eastham plain, to the south of the Wellfleet plain, is considered to be the youngest because, above sea level, its deposits are entirely fluvial and the plain was graded to a lower and, most likely, younger level of the lake.

Highland Light is the most powerful light on the New England coast and can be seen from more than 20 miles (32 km) at sea. The light is threatened by the retreat of the cliff which, in the last 10 years, has averaged about five feet (1.5 m) per year (Leatherman, 1988). The retreat is facilitated by landslides in the lake clay and overlying sand.

PROVINCELANDS VISITOR CENTER

The route from Highland Light to the final overview leaves the glacial cape at High Head. The scarp just to the east of Pilgrim Lake is a sea cliff that was eroded in the glacial drift before the Provincelands spit was formed.

Just beyond Pilgrim Lake, a lagoon now artificially closed from the sea, the dune sand is burying trees and encroaching on the road. The sand must be removed to keep the road open. Dark layers within the dune sand are old soil horizons. The beach and dune deposits of the Provincelands rest on late Wisconsinan strata deposited in the sea during the final retreat of the ice. The marine deposits are in part equivalent to the glaciomarine mud that crops out above sea level along the New England coast from Boston northward. They indicate that during the final stages of ice retreat from the vicinity of Cape Cod, the crust was isostatically depressed below the late Wisconsinan low sea level (Oldale, in press). As a result, the sea level history of outer Cape Cod is complex and includes a transgression followed by regression during latest Wisconsinan time. The Holocene transgression may not have started until after about 11.0 ka. The Provincelands spit began to form about 6,000 years ago as the sea transgressed the glacial cape. The longshore current carried sand eroded from the glacial deposits northward and westward into deep water off the tip of the glacial cape to form a recurved spit. As sea level rose, new spits were developed along the Atlantic shore, each one recurving toward Cape Cod Bay (Zeigler et al., 1965). The oldest beach deposits occur along the Cape Cod Bay shore and they become progressively younger toward the Atlantic Ocean. As the barrier beach grew toward the Atlantic Ocean, erosion along the Cape Cod Bay side has removed, at least in part, the oldest spits. Wind erosion and deposition continue to move and modify the dunes and, except for the foredune along the Atlantic shore, the dunes may be unrelated in age to the beach deposits beneath them.

Although Cape Cod is a fragile land, its ability to adjust to sea-level rise is well shown by the developing spits and shoals. If sea level continues to rise, Cape Cod may persist in some form long after the rock-bound coast of New England and its port cities are drowned.

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ROAD LOG

Cape Cod can be approched in several ways. From Amherst, the Massachusetts turnpike connects with I-495 south which ends at Route 6, the basic route for the trip. From the Boston area, there are two ways to the cape. Route 128, the circumferential highway around Boston, connects with Route 24 which connects with I-495. Route 128 also connects with Route 3 which connects with Route 6 at the Cape Cod Canal Sagamore Bridge. From Providence Route I-195 connects with Route I-495. Route 6 travels along the north side of the Cape Cod Canal. STOP 1, is a canal overview from Route 6. The overview is east of Route I-495, about 2.0 miles, and west of Route 3, about 1.7 miles. From Route I-495 it is the third pulloff on the right and from Route 3 it is the second pulloff on the left.

Leaving stop 1 turn east on Route 6. At the rotory Route 6 turns right and crosses the Sagamore Bridge. Continue east on Route 6 to the Shoot Flying Hill overview (STOP 2). The parking area is on the left side of the east bound barrel. Climb the stairs to the top of the hill. Leaving the parking area is difficult as you need to pull out into the high speed lane of Route 6. It is best to leave from the west end of the parking area, where ths line of sight is longest. Please be very careful.

Continue east on Route 6 to Union Street, exit 8. Turn north on Union Street to Route 6A in Yarmouth. Turn east on Route 6A. At the cementary in Dennis turn right onto Scargo Hill Road. Shortly after the turn Scargo Hill Road bears left at the fork with Old Bass River road. Continue on Scargo Hill Road to a left turn that goes to Scargo Hill tower (STOP 3). Climb the tower for this overview.

Return to Scargo Hill Road and turn left on Route 6A. Continue east on Route 6A to Brewster. In Brewster, turn right onto Route 137. At Route 28, turn left and continue on to Chatham. At the rotory, take Main Street to where it takes a sharp left. Turn right to Chatham Light (STOP 4).

Go north on Shore Road and Route 28 to Orleans, where Route 28 joins Route 6A. Continue northward to the Eastham rotory. Take Route 6 north to Governor Prence Road, a left fork. Turn right onto Fort Hill Road to Fort Hill overview (STOP 5).

Return to Route 6 and turn right. Continue on the the entrance road for the Cape Cod National Seashore headquarters. Turn right and carefully follow signs for the Marconi site (STOP 6).

Return to Route 6 and continue north. The road drops down into the Pamet River Valley (See p. 10 of the field trip guide).

Turn right onto South Highland Road to the Highland Light Road and Highland Light (STOP 7).

Return to Route 6 by taking a right onto South Highland Road and a left onto Highland Road. Turn north on Route 6. At High Head, the road crosses from glacial deposits to the deposits of the Provincelands spit. Continue northward to Point Road. Turn right to the Provincelands Visitor Center (STOP 8). To leave Cape Cod, return to Route 6 and turn south.

DISTANCES BETWEEN MAJOR POINTS

	miles
Canal overview to Shootflying Hill	15.0
Shootflying Hill to Union Streeet	7.3
Union Street to Rte. 6A	1.4
Rte. 6A to Scargo Hill Rd.	3.5
Rte. 6A/Scargo Hill Rd. int. to Scargo Hill Tower.	1.0
Scargo Hill Rd./Rte. 6A int. to Rte. 137.	4.6
Rte. 137 to Rte. 28.	7.2
Rte. 28 to Main St., Chatham.	3.3
Shore Rd, Chatham/Rte. 28 int. to Eastham Rotory.	9.2
Eastham Rotory to Governor Prence Rd.	1.4
Governor Prence Rd. to Park Headquarters Rd.	6.5
Park Headquarters Rd./Rte 6 int. to Pamet Bridge.	7.6
Pamet Bridge to South Highland Rd.	2.5
Highland Rd./Rte. 6 int. to High Head.	1.9
High Head to Point Rd.	4.5