

## Glacial Geology -- Notes<sup>1</sup>

**Oldale and O'Hara 1984** Get figures 12 and 13

End moraines on Cape Islands - glaciotectionic - analogy Thompson Glacier end moraine in Canadian Arctic Archipelago - glacier is overriding its outwash plain displacing outwash deposits forward and upward. New sheets added to base of moraine and till is deposited on moraine as ice overrides it. Formed during readvances of late Wisconsinan ice over preglacial, interglacial and glacial deposits. Moraines formed as ice advanced upward and over the coastal plain cuesta or ice-contact margins of outwash plains, shearing off sheets of material and transporting them forward and upward beyond ice front. Thrusting facilitated by clay and silt beds; permafrost could have strengthened loose gravel and sand.

Coastal end moraines = till over stratified drift and layers of basal till indicate fluctuations. Episodes of stagnation zone retreat when outwash plains formed alternated with episodes of ice-front readvance when end moraines formed. By as much as 25 km readvance. Similar to L Michigan up to 12 end moraine building readvances. Up to 460 km/1000 yrs.

Ice SE Mass retreated 150 km from outermost end moraine to N of Boston in 2500 yrs - during this time many opportunities for readvances.

Recession = alternating episodes of ice-front retreat when outwash formed and ice-front advance when moraines built. May be similar to L Michigan where >12 moraine-building episodes caused by readvancing ice during overall retreat.

Not stillstands in which advance balanced by ablation. As ice margin advanced detachable sheets of drift and preglacial strata up to 1x0.5x30m displaced beneath and beyond ice margin to form moraine. Outwash plains on Cape deposited atop and beyond downwasting stagnant ice.

End moraine structure from exposures and gravel pits.

Preglacial Cape - broad lowland underlain by consolidated PreCambrian to Mesozoic age. About Elizabeth Islands and S Shore Cape - cuesta underlain by unconsolidated Cretaceous to Pleistocene age. N face scarp of cuesta - narrow, steep-walled N-sloping valleys.

ACK moraine include deformed Sangamon an age beds; MV includes deformed Montauk tills of early Wisconsinan formations. Can relate Buzz Bay and Sandwich Moraines to marine beds N of Boston.

Overall drift 20-30,000 yrs BP. C.A. Kaye - willow leaves 15000 BP also peat 12,700 BP

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<sup>1</sup> Additional handwritten notes, notecards, and source material are in the Harvard Forest Archive

**Woodworth and Wigglesworth** – recognize ice-thrust nature of moraines with Gay Head thrusting and folding of Tertiary and Cretaceous strata within moraine.

**Kaye** 1964 a,b proposed two Illinoian age moraines and third of early Wisconsinan age. Thrust folding and faulting of old drift, pre-Pleistocene strata and interglacial deposits. Proposed imbrications of permafrost slabs 30 m thick.

O + O – glaciotectionic end moraines. Formed as advancing ice thrust sheets of drift and preglacial strata beneath and beyond ice front. Contrary to general belief that Mass end moraines are primarily sedimentary and formed by stationary glacier terminus when advance balanced by ablation.

Compared with characteristics in literature on thrust moraines. “Ice thrust” “Ice-push Moraines” “Ice-thrust –ridge” etc. Flint – excluded ice-thrust from his discussions of end moraines – restricted to small ridges.

O+O thrust ridge=single ridge; thrust moraine=larger feature comprised of many ridges. Both characterized by:

- Largely stratified drift or preglacial strata veneered in places by till.
- Dislocation of strata
- Repetition of stratigraphic units
- Interlayering of glacial drift and preglacial strata
- Deformed strata underlain by undisturbed strata. Large-scale deformation
- Tilted strata with dip direction opposite or different from regional or original dip
- Large deformation structures – thrust faults displaced 1 km+; thrust sheets 100m x 1 km; folds of 10s to 100s of meters
- Morphology – positive relief relative to adjacent drift; morphologic grain roughly parallel to ice front; topographic low adjacent to proximal side of moraine; surface slope towards ice; valley slope towards ice as in valleys cut towards escarpment.

Dominant characteristic of the coastal end moraine – composed largely of stratified deposits veneered in many places by till. E.g., older stratified material capped by till. Much of ACK moraine capped by gravelly sand.

MV – exposures show moraine composed of essentially Cretaceous and Tertiary Strata including pre-late Wisconsinan till and sorted.

Elizabeths and Cape – moraines composed largely of glaciofluvial and glaciolacustrine deposits veneered by till.

Stratified drift difficult to recognize as glaciotectonic – but thick accumulations of boulder-free, well-sorted material glaciofluvial and glaciolacustrine unlikely to be deposited against or beneath ice.

Dislocations – MV Cretaceous strata are 80 m and Tertiary are 30 m above undisturbed positions beneath central outwash plain. Similar phenomena on Elizabeths and ACK. Cape – find glaciolacustrine deposits at moraine front where couldn't have been a lake.

MV – intercalation of Cretaceous and Tertiary age strata. Also interlayering of preglacial and drift materials.

Deformation is superficial – underlain by undeformed strata. No tectonic activity in NE since Paleozoic.

Tilted beds in all of the end moraines. MV – Cretaceous and Tertiary beds tilt steeply N whereas intact beds slight tilt to S.

Large folds and faults seen at Gay Head. Many small features at Nashawena and Cuttyhunk.

End moraines generally stand well above adjacent stratified drift. Grain = individual ranks of ridges trending approximately parallel to ice front. Esp in Sandwich moraine. Ridges approx. rectangular in plan. E.g., very small ridges south of larger ridges. Each ridge in moraine may represent a single thrust.

Canada – ridges often bordered up-ice by a low where the material came from. True in general of moraines on Cape and islands – bordered to N by major topo lows. Partly due to removal of material by ice thrust.

Cuesta escarpment pre-glacial sloped towards ice. To advance to MV ice moved up valleys deeply incised in cuesta of Cretaceous and Tertiary age. Same in ACK and Elizabeths.

If thrust need moraine-outwash contact that dips beneath the moraine. No sites show moraine below outwash so contact dips Nward beneath moraine.

Sandwich moraine can see outwash deposits in moraine – thrust up by advance.

Hypothesis need fluctuating ice front. Direct evidence in moraines and till that veneers moraines in many places. Readvance by up to 25 km. So, formed during over-all retreat as ice front fluctuated. During stagnation-zone retreat outwash plain and ice-contact deposits formed. Alternated with ice advance when end moraines formed.

Where did thrusting take place? Subglacially right behind ice-front; englacially near front; or beyond ice front. O+O favor first and last because most of ACK moraine not overridden

by ice. Force was result of forward glacier movement and load of glacier on drift. Easiest relief to this force was towards ice front – in form of thrust faults and shear zones, arcuate in profile that originated beneath ice and terminated beyond it.

So outwash laid down as ice stagnates and melts; ice then readvances thrusting it up in folds; ice can override the ridges and lay down thin till; stagnates and lays down new outwash to N.

Permafrost may play a role in the formation of thrust moraines – hydrologically and structurally. Or intercalated clay and silt as provide zones with high pore pressures that facilitate shearing. Lots of clay and silt. Permafrost evidence equivocal.

O+O do favor permafrost as mechanism to consolidate sand and gravel and means of freezing glacier to sediments below and transmitting shear forces.

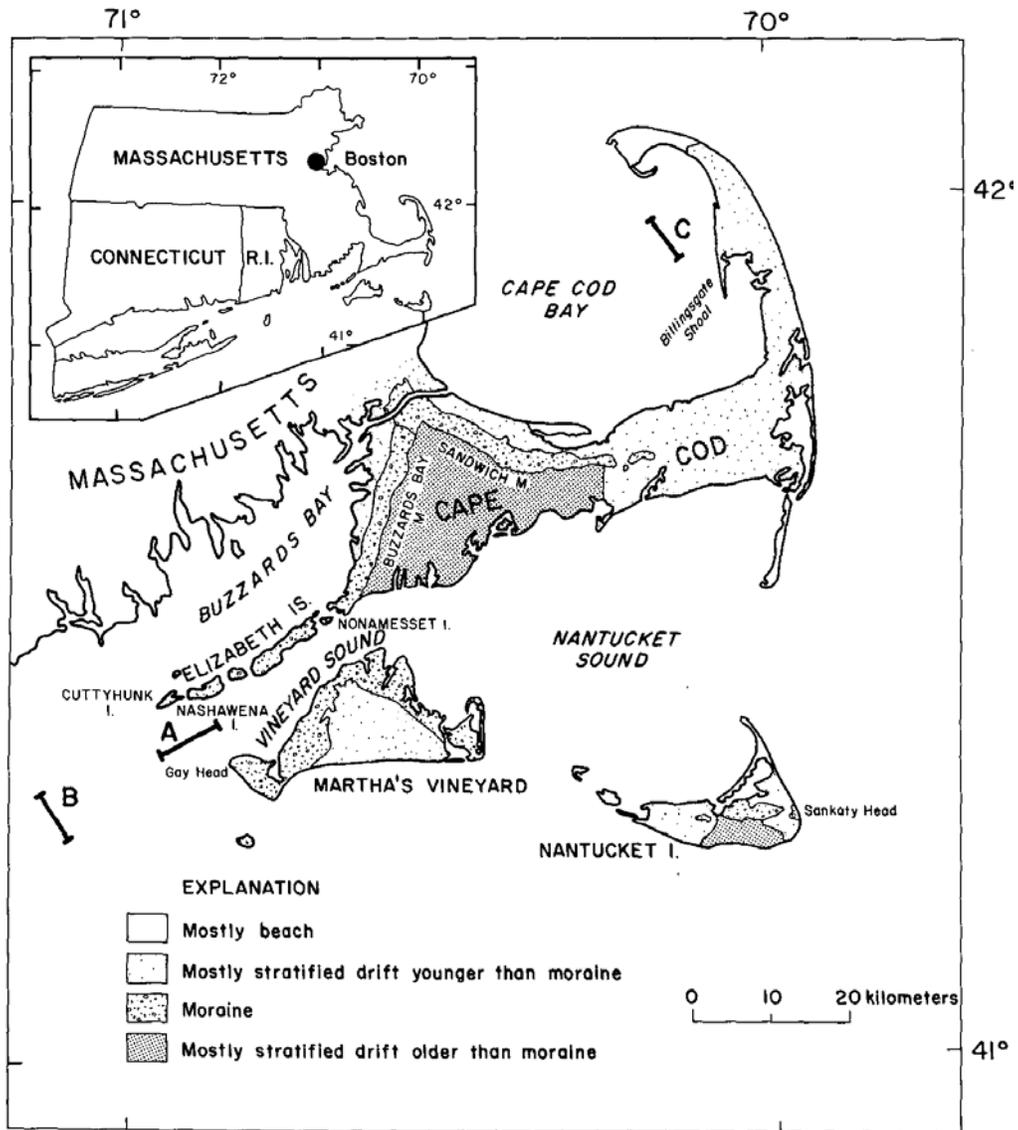
As moraines formed – younger thrust sheets added to base of moraine. Small ridges formed in outwash beyond main moraine front – represent first stage in deformation. Older ridges overridden by ice. Some erosion of ridges and deposition of basal till – obscured some thrust morphology, as did ablation till, flowtill and outwash. In most places except ACK overriding was extensive and covered most of moraine.

**Mills and Wells 1974** – similar explanation for western Long Island. Thrust Cretaceous sediments as much as 1.6 km up and beyond ice front. Then ice overran emplaced thrust sheets.

Similar elsewhere in LI and Block Island. So, most major end moraines in northeastern US have glaciotectionic origin.

Thompson Glacier NWT – Axel Heiberg Glacier:

- Active thrust sheets in distal part of moraine; inactive thrust sheets in middle become increasing obscured by erosion and deposition of stratified drift; inactive in proximity to ice become obscured by drift deposited directly in front of ice
- Moraine being overridden by glacier; saw near complete overriding nearby
- Youngest part of moraine furthest from the ice front; moraine constructed by adding thrust sheets to base
- - youngest thrust sheet = 1 yr, small ridge in outwash at front of moraine. Analogous to small ridges out in front of Sandwich moraine.



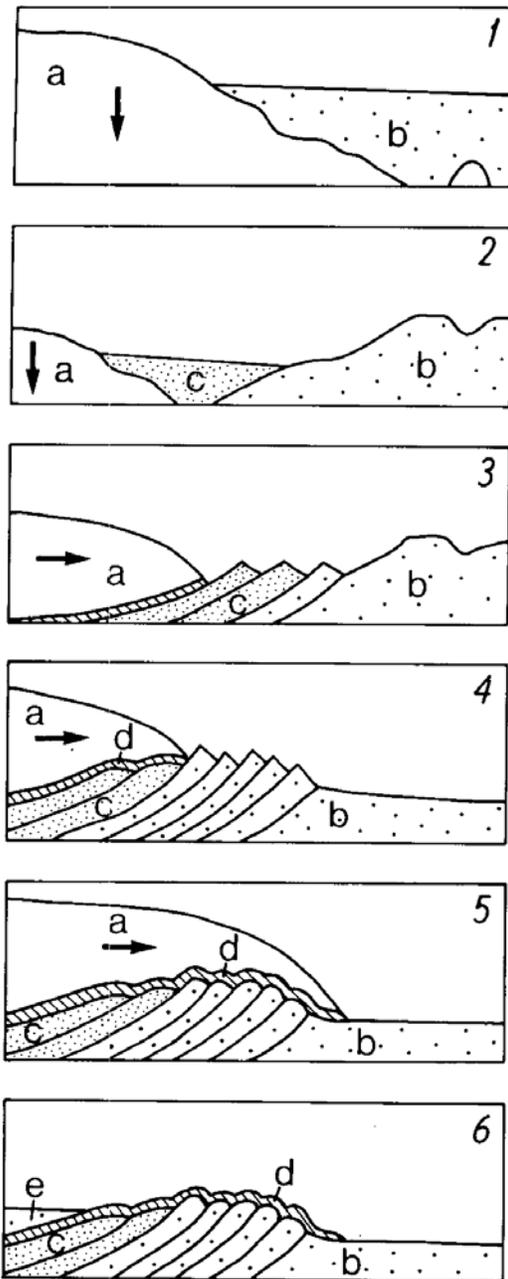
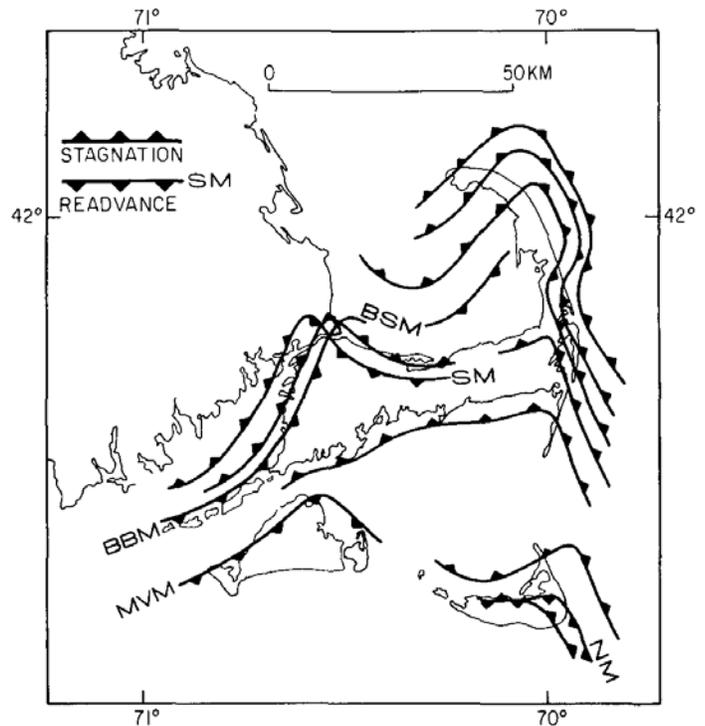


Figure 12. Inferred sequence in the formation of the coastal end moraines. In this example, the moraine is composed largely of stratified drift. Designations are: (a) ice; downward-pointing arrow is downwasting stagnant ice, right-pointing arrow is advancing ice and ice front; (b) older outwash deposited during stagnation-zone retreat; (c) younger outwash deposited during stagnation-zone retreat; (d) basal till (discontinuous in many places) deposited by overriding ice; (e) outwash younger than the moraine deposited during stagnation-zone retreat. Stages 1 and 2, outwash-plain formation beyond stagnant downwasting ice. Stages 3 and 4, formation of the thrust moraine beyond an advancing ice front; thrust sheets increase in age from right to left. Stage 5, complete or partial overriding of the moraine and deposition of a till veneer. Stage 6, retreat of the ice and deposition of younger outwash.

**Figure 13. Major ice-front positions during the retreat of the late Wisconsin ice from Cape Cod and the islands. Stagnation positions represent episodes of out-wash-plain building. Advance positions represent episodes of moraine-building. NM, Nantucket moraine; MVM, Martha's Vineyard moraine; BBM, Buzzards Bay moraine; SM, Sandwich moraine; BSM, Billingsgate Shoal moraine.**



[A late Wisconsin marine incursion into Cape Cod Bay, Massachusetts](#)  
[RN Oldale - Quaternary Research, 1988](#)

**Abstract**

Reinterpretation of seismic-reflection data from Cape Cod Bay has produced a revised late Wisconsin history. Acoustically laminated deposits, originally inferred to be glaciolacustrine, are shown to be glaciomarine by tracing them to glaciomarine mud in Stellwagen Basin, north of Cape Cod Bay. A late Wisconsin marine deposit of nonglacial origin overlies the glaciomarine deposits in Cape Cod Bay. Both deposits indicate that the crust was isostatically depressed below the late Wisconsin eustatic sea level and that deglaciation and marine submergence occurred simultaneously. Valleys cut into the marine deposits, both glacial and nonglacial, indicate that a low sea-level stand, the result of isostatic rebound, occurred shortly after the marine incursion. A transgressive unconformity and marine deposits, both mostly of Holocene age, overlie the late Wisconsin deposits. The marine incursion, regression, and Holocene transgression represent the northward passage of an isostatically induced peripheral bulge following deglaciation. In turn, the bulge, a response to crustal loading and unloading, indicates thick glacier ice in the terminal zone and lends support to arguments for a maximum Laurentide ice model. Evidence for a late Wisconsin marine incursion, regression, and the passage of a peripheral bulge should be sought in the other bays and sounds of the New England terminal zone.

**Person et al. Pleistocene hydrogeology**

Pleistocene sea level 120 m low for 100-40 KY Average 40 m.

High recharge associated with ice-sheet aquifer interactions. Glacial recharge reorganized subsurface flow. Hydro heads up to 90% of ice thickness. Subglacial melting occurs in outer few hundred km. Permafrost could reach 100 m thick and extend 100 km upstream and downstream of ice front.

Glaciomarine unit

Extensive eskers in ME – ice wet-based with extensive subglacial drainage network.

Recharge from last two glacial maximums due to high subglacial meltwater. High meltwater heads beneath glacier. Plus drop sea level.

Max S extent 21 ka; retreated to mainland by 16 ka. Ice 600-1000 m near toe of ice. Thrust structures – suggest permafrost and high pore-fluid pressures.

120 m sea level lowering 15 ka, but significant variation along shore due to ice-sheet loading.

Mass - Oldale – sea level 33m higher than present shoreline at 14 ka – deposited thick. Peat on top at 12.3 ka indicate rapid sea-level lowstand as forebulge moved rapidly through. By 11 ka sea level 60m below in S ME and 65 in MA as ice retreated N and ice-sheet forebulge migrated N.

ACK hydrology – 40% of precip recharges GW aquifer. Similar on LI, Cape, MV. GW is shallow – water from Pleistocene unconsolidated outwash. Sands. LI also use Cretaceous aquifers as shallow water is contaminated.

ACK max water table elevation is 3.6 m above sea level. LI up to 24 M.

Can get freshwater lens pushed 80 km beyond W end of continental shelf and 30 km beyond mean sealevel. Can get out 150 km beyond coastline if confining layer etc. Not simply meteoric recharge. Thrusting due to ice may have opened deep confining beds (Oldale and OHara).

Cannot infer FW resources from modern sealevel. ACK – modern GW table at 2 m in center of island. Would expect fresh-sea interface at 80m. Actually not found in wells 100-120 m deep.

Below ice drainage would deliver water from very far away – due to bedrock.

### **Oldale 1988. Late Wisconsinan Incursion into Cape Cod Bay**

Late Wisconsinan marine deposit overlies glaciomarine mud that can be traced to Stellwagen Basin. Mud dates to about time that ice was in Boston – 14-13,000 yrs BP.

Crust isostatically depressed below LW eustatic sea level and so deglaciation and marine submergence occurred simultaneously. Marine incursion, regression and Holocene transgression due to northward passage of isostatically produced bulge following deglaciation. Ice retreat with submergence due to crustal depression – emergence then following ice retreat – transgression by sea during Holocene times. Initial submergence and emergence were isostatically controlled. Bulge = response to crustal loading and unloading – indicates thicker ice in the terminal zone. – so maximum Laurentide ice model. Ground rebounded crustally more rapidly than eustatic sea-level rise. Then got submergence as crustal rebound slowed and eustatic accelerated. As ice retreated got submergence due to isostatic depression – calving of floating glacier terminus resulted in rapid ice-front retreat – and glaciomarine mud plumes. Got Late Wisconsinan low stand when now submerged sediments were aerially exposed. Amount of submergence not well know – less than 35 M. Low stand was about 65 m. Peats date to about 12320 BP – with pollen much colder.

Originally interpreted as glaciolacustrine – associated with glacial lake developed between retreating ice and glacial drift on Cape Cod – Oldale 1982. But connects to glaciomarine sediments on Stellwagen.

CC drift overlain by glaciomarine mud overlain by delta that came from source kms in front of ice.

There was a proglacial lake in Cape Cod Bay during early stages of ice retreat. Could have drained catastrophically when marine incursion buoyed the ice – but no evidence. May have been rapid but not with much force.

LI Sounds may show same submergence, emergence, transgression.

### **Oldale 2009**

The origin of these valleys is complex. They most likely were formed by a process called spring sapping. This occurs when the water issuing from a spring carries away loose sand and gravel and causes the spring to migrate headward carving a long straight valley. In the case of the outwash plain valleys on Cape Cod, some special conditions were required. Presently, there are few springs on Cape Cod, because in almost all places the outwash deposits are very permeable and the upper part of the outwash plain deposits is dry. In order for the spring sapping to have occurred, a higher than present water table is required. This could be accomplished by glacial lakes with altitudes well above present sea level being dammed by the outwash plains. The best example would be Glacial Lake Cape Cod that was dammed by the outwash plains and the Sandwich moraine on upper Cape Cod. The high lake levels would cause a rise in the water table that, in turn, would cause springs to form on the outwash plains. There is evidence for a glacial lake to the east of the lower Cape Cod outwash plains in the form of the silt and clay beds exposed in the cliff below Highland Light in Truro. Nothing more is known of this lake, but it may have provided a higher than present water table to allow spring sapping to form the valleys in the lower Cape Cod outwash

plains.

The Pamet Valley in Truro (Fig. 13) is wider and deeper than all other valleys on Cape Cod. The original floor of the valley, made up of glacial outwash, is well below sea level and overlain by mostly salt marsh deposits. The Pamet Valley may have started out like all other spring sapping valleys, however, the extreme width and depth of the valley requires further explanation. It is likely, that headward erosion by spring sapping cut completely across the Wellfleet outwash plain, reaching the outwash dam holding in a glacial lake to the east of the lower Cape. The breach caused the lake to drain catastrophically.

This great flood carried away vast amounts of outwash to widened and deepened the original spring sapping valley.

At the end of glaciation and before the landscape was well covered with vegetation, winds blowing across the barren glacial deposits, including material from the exposed bottoms of drained glacial lakes, picked up sand, silt, and clay and deposited this material as a thin almost continuous blanket on the drift surface. Stones lying on the drift surface were cut, faceted, and polished by sand blasting. These stones, called ventifacts, have been moved into the windblown layer by frost action. They are distinctively shaped and some have been mistaken for tools of Indian origin (Fig. 16).

### **Oakley 2012 Discussion**

No significant erosion or deposition on landscape after LIS retreated

[Did not correct bathymetry to reflect post-glacial deposition. Thickness is <6m; also did not correct for ca 5m isostatic depression due to water loading]

Glacial marine deposition limit – just south of Boston into ME. Well constrained for over 100 years

Marginal forebulge – due to lateral displacement of mantle from beneath the ice. Estimates from others – goes out 30-250 km and 10-70m elevation). Would have migrated through SNE 12-17 ka – not recognized in Hudson or CT Valleys. So, either collapsing and non-migrating and 150 km out (beyond Cont Shelf)

Assume linear isostatic rebound and was delayed until after 16 ka; model fit requires less isostatic depression than previously assumed – 30 m; any more would have inundated the land; prior estimates go up to 50 m more;

Supports Koteff and Larsen “crustal block” model for delayed rebound; and thinner LIS – thin and relatively flat across Canadian Shield with thicker steeper profile in central portion of ice sheet.

Maximum incursion in ME occurs about 15.1 ka about 400 km from LIS terminal margin; requires 340 m isostatic depression.

Accepts thin ice model of Clark et al and ICE-5G model of Peltier 2004.

Supports marine inundation Block Island Sound and Narragansett Bay in latest Pleistocene and Holocene (not earlier). Possibly into LI Sound through W end but moraine dam until 15 ka on E end.

So first order estimate of ice thickness based on isostatic depression and uplift – ice thickness of 100m near SE margin of LIS to 1000m at 300 km N of terminal margin in NE

Hi David: (Notes from Bryan Oakley)

Questions/statements in blue, my comments in red.

Good to know I'm not missing much there. Oldale, Ohare and others report sapping structures out into Vineyard Sound from the Sandwich plain and morainal deposits and shoals in Middle Ground and Lucas Shoals (which of course are shallow) and yet I haven't seen much about varved lake sediments.

Not so much that you are not missing much, I think everyone is missing something 😊 since there are varves there, and it would be cool to know the extent of the lake(s). As you probably recall from my thesis this entails finding the delta plain-delta slope contact of the deltas graded to the lake, comparing it to the lakefloor extent, maybe then popping it onto a pre-rebound terrain model. Maybe someday someone will get interested, or I'll actually have the time to wander east!

I guess my problem is understanding how meltwater is flowing across and depositing a mantle of material over such a strongly undulating terrain. When he says outwash over moraine does he really mean some combination of morainal deposits and outwash not that outwash actually covers most or all of the terrain.

He means stratified deposits, in this case alluvial fans (braided rivers). See below for the figure from Gustavson and Boothroyd, 1987). My *speculation is*, he is interpreting that this was draining southeast, from ice at the western moraine position. These deposits would have buried the lower elevation eastern moraine. If you look at Byron's surficial geology map available from Mass GIS, you will see he has it mapped as stratified sand and gravel, so he is interpreting that the moraine deposits are buried.

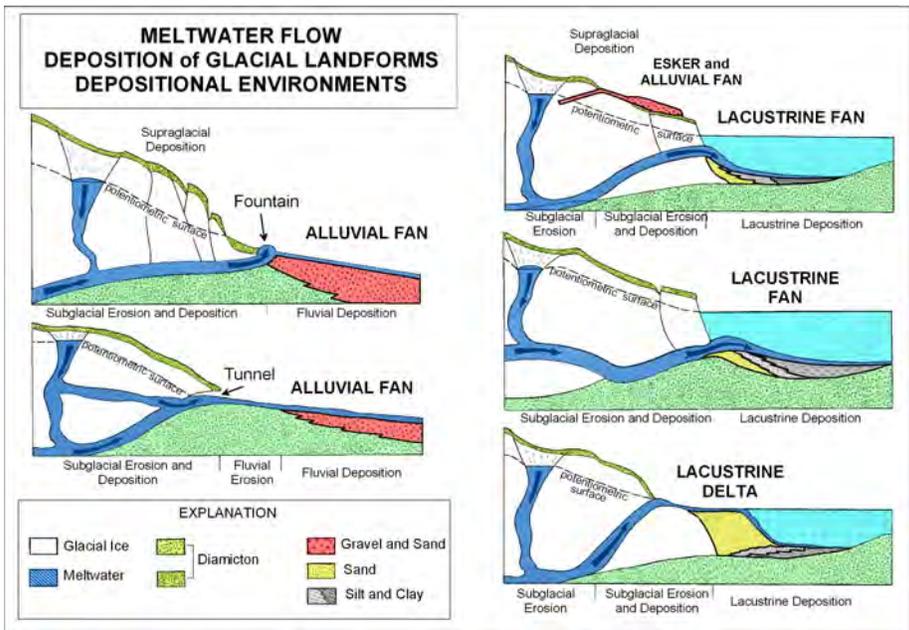
The source of the material in the two moraines is different and the behavior of the ice would likely be so, but it is so striking that no one actually says anything really about that eastern moraine. There are few depressions and none of the clay that is so thickly deposited in the western moraine and so there are essentially no ponds (one or two) or water-based upland features. Different source material but perhaps people don't focus on it because it is so less interesting than the western moraine, which has captured the imagination and incorrect speculation) of everyone from Shaler to Wigglesworth and on down the line until that thrusting and tectonic moraine interpretation emerged.

There probably are depressions, and clay, silt, till, and whatever else was in the thrust sheets, but if it is buried under stratified sand and gravel, there would be less surface expression, fewer perched ponds, and generally a flatter topography.

These are fascinating issues (and thoughts) and I am continually surprised that none of the various reports really focus in on these major depressions. Shaler did – calling them pre-glacial valleys along with the rest of his minimal impact of the glaciers theory but most others are quiet on what are two of the most distinctive features on the island. Our DEM came from NED so I'll see what we can get from LIDAR.

I'm always suspect on the minimal impact theory work, especially with relatively small features like those two places. The antecedent topography absolutely has some control on the landscape (i.e. the terminal moraine at Coxes ledge is lower than the Vineyard moraine, in all likelihood is simply because the topography the ice was on was lower in the sounds. The landform itself is probably the same relative thickness; Coxes just happens to be below sea level at the present! Check the LiDAR. The landscape is a combination of the underlying bedrock geology, modified by repeated glaciations during the Pleistocene (we have evidence for two, modeling suggests maybe as many as 9).

Let's see what plays out as far as job searches and such this spring on my end. If time allows, *maybe* we could figure out a way to do a sub-bottom survey in those places this summer if you will be out there anyways. It could be done for short money if you have access to a suitable boat; the equipment fits in the back of my truck, and I should still have access to the system at URI.



## **BOOTHROYD AND SIRKIN**

Block Island Geology – BI probably always separated from mainland; Glacial Lake Block Island; lake drained around 15.5 ka and marine incursion

Ice in S Canada by 10 ka

### **Winchell – The American Geologist 11**

On reading Shaler struck by similarity – MV and LI – especially “plain country”. But believes that Shaler is incorrect in interpreting stratified deposits were laid down in a sea. No marine shells.

Shaler believes that marine waters and fresh waters could have maintained separate existence – as escape ice front with velocity could scour channels.

LI was a littoral plain with shore 90 miles to south. Sea is nearer our door since it overflowed its ancient boundary. The island has remained about as it was, the only change being made by inroads of the sea along the coast. [Doesn't understand eustatic and isostatic changes in sea level]

“The Island [LI] remains very much the same as it came from the hand of the glacier, the only change being made by the inroads of the sea along the coast. There is not so much sinking as a wearing away of the superficial deposits of which the Island is chiefly composed.

As the sea invades the land, bays become part of the ocean, marshes become bays and swamps marshes; and this accounts for stumps of trees being found under water; for some of the swamps and other depressions go down below the present level of the ocean, and where the land barrier, which protects them, has been swept away, the trees, which grew in them, of course become submerged.

That these marsh lands existed at one time south of the present sea beach is evident from the quantities of turf that are washed upon shore during heavy storms. It seems certain that the streams that laid down the stratified deposits on the south side of Long Island and Martha's Vineyard came from the mainland; I think I was the first to notice this fact, and it seems to be confirmed by professor Shaler as he says in his report: "That the material transported by sub- glacial streams, and accumulated in the kame and terrace deposits, was transported for a greater distance than the detritus that was carried in the body of the ice."

[He tries to connect stream channels back to the mainland. Relates N inlets on MV to southern ones – according to Shaler]. Disagrees with Shaler on postglacial impacts on island or on sea influence during deposition.

USGS HA - 618: Groundwater Hydrology of Martha's Vineyard.

USGS Thematic Maps Hydrologic Investigations in Massachusetts (All HA's are \$8.00 each)

Spring sapping origin of the enigmatic relict valleys of Cape Cod and Martha's Vineyard and Nantucket Islands, Massachusetts .

### **Geomorphology**

Volume 9, Issue 2, April 1994, Pages 83. Elazar Uchupia<sup>a</sup> and Robert N. Oldale<sup>b</sup>

Steep-sided, flat-floored linear valleys that lack well developed tributaries and end in amphitheater-like heads are eroded on the outwash plains of Cape Cod, Martha's Vineyard and Nantucket Island. The valleys are restricted from the mid to the distal ends of the outwash plains and show no connection to possible water sources at the updip end of the plains. Their distribution and morphology lead us to propose that they were eroded by groundwater seeps fed by proglacial lakes (the high hydrostatic heads of the lakes led to the elevation of the water table) dammed by the outwash plains and associated moraines. The valleys on Cape Cod were initiated by seeps along the foreset surfaces of sandy deltas emplaced in lakes in Nantucket Sound and Cape Cod Bay after these lakes drained. Those on Martha's Vineyard and Nantucket islands were either eroded by seeps at the distal ends of outwash plain wedges emplaced atop the subareal continental shelf south of the islands or along the foreset surfaces of sandy deltas emplaced on a lake behind a peripheral crustal bulge south of the glacial front. Valley erosion terminated after the lakes were drained and the water table dropped.

***GSA Bulletin*; October 1973; v. 84; no. 10; p. 3279-3296; Late Wisconsin Glaciation of the Southwestern Gulf of Maine: New Evidence from the Marine Environment  
BRIAN E. TUCHOLKE<sup>1</sup> and CHARLES D. HOLLISTER<sup>1</sup>**

<sup>1</sup> Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543  
Data from cores and 1.4- and 3.5-kHz sub-bottom profiles from the western Gulf of Maine are used to interpret the late Wisconsin (<23,000 yr B.P.) and Holocene geologic history of the area. Radiocarbon dates and analyses of sediments in two cores containing a continuous sequence of sediments down to 22 m beneath the sea floor in Stellwagen Basin suggest that grounded glacial ice advanced through the southwestern Gulf of Maine no earlier than 18,900 ± 600 yr B.P. The ice probably persisted on Martha's Vineyard until 15,300 ± 800 yr B.P. During this time, scour and deposition of till occurred in the former marine basins to the north. The lobate character of the glacial margin was accentuated during deglaciation, resulting in the accumulation of glacial sediment as interlobate deposits on outer Cape Cod and perhaps on Stellwagen Bank. Marine transgression and ice degrounding occurred in Stellwagen Basin prior to 14,250 ± 250 yr B.P., and rapid glaciomarine sedimentation followed. Continuous marine deposition in the basin since that time indicates that crustal rebound in the present marine provinces was never rapid enough to raise the sills between the western basins above sea level. Fine-grained sediment winnowed from areas of elevated submarine topography by marine action eventually replaced glaciomarine detritus as the primary sediment source for the basins. A warming trend about 13,000 yr B.P. is indicated by the disappearance of the frigid-water pelecypod *Yoldia arctica*. Sedimentation rates in the present marine basins

have steadily decreased since 13,000 yr B.P. to a modern rate of a few centimeters per thousand years.

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Wikipedia Entry on **Agassiz**

## Ice age

In 1837 Agassiz was the first to scientifically propose that the Earth had been subject to a past ice age.<sup>[3]</sup> In the same year, he was elected a foreign member of the [Royal Swedish Academy of Sciences](#). Prior to this proposal, [Goethe](#), [de Saussure](#), [Venetz](#), [Jean de Charpentier](#), [Karl Friedrich Schimper](#) and others had made the [glaciers](#) of the Alps the subjects of special study, and [Goethe](#),<sup>[4]</sup> [Charpentier](#) as well as [Schimper](#)<sup>[3]</sup> had even arrived at the conclusion that the erratic blocks of alpine rocks scattered over the slopes and summits of the [Jura Mountains](#) had been moved there by glaciers. The question having attracted the attention of Agassiz, he not only discussed it with [Charpentier](#) and [Schimper](#) and made successive journeys to the alpine regions in company with them,

but he had a hut constructed upon one of the [Aar Glaciers](#), which for a time he made his home, in order to investigate the structure and movements of the ice.

These labours resulted, in 1840, in the publication of his work in two volumes entitled *Etudes sur les glaciers* ("Study on Glaciers").<sup>[5]</sup> In it he discussed the movements of the glaciers, their [moraines](#), their influence in grooving and rounding the rocks over which they travelled, and in producing the striations *androches moutonnees* seen in Alpine-style landscapes. He not only accepted Charpentier's and Schimper's idea that some of the alpine glaciers had extended across the wide plains and valleys drained by the [Aar](#) and the [Rhône](#), but he went still farther. He concluded that, in the relatively recent past, Switzerland had been another [Greenland](#); that instead of a few glaciers stretching across the areas referred to, one vast sheet of ice, originating in the higher Alps, had extended over the entire valley of northwestern Switzerland until it reached the southern slopes of the Jura, which, though they checked and deflected its further extension, did not prevent the ice from reaching in many places the summit of the range. The publication of this work gave a fresh impetus to the study of glacial phenomena in all parts of the world.

Thus familiarized with the phenomena associated with the movements of recent glaciers, Agassiz was prepared for a discovery which he made in 1840, in conjunction with [William Buckland](#). The two visited the mountains of Scotland together, and found in different locations clear evidence of ancient glacial action. The discovery was announced to the Geological Society of London in successive communications. The mountainous districts of [England](#), [Wales](#), and [Ireland](#) were also considered to constitute centres for the dispersion of glacial debris; and Agassiz remarked "that great sheets of ice, resembling those now existing in Greenland, once covered all the countries in which unstratified gravel (boulder drift) is found; that this gravel was in general produced by the trituration of the sheets of ice upon the subjacent surface, etc."

## MEMORIAL OF EDWARD WIGGLESWORTH

Charles Palanche Harvard University Cambridge, Massachusetts

The death of Edward Wigglesworth on May 6, 1945 brought to an untimely close a life unselfishly devoted to mineralogy and its related sciences. Few members of our Society have joined to the responsibilities of large means and inherited business affairs such varied and burdensome scientific occupations.

Wigglesworth was born in Boston in 1885 in a family with traditions reaching far back to colonial times. He was the seventh successive member of the family to bear the name of Edward. He entered Harvard in 1904 and, coming early under the influence of the late Professor Woodworth whose summer field courses attracted many young students into his science, he concentrated in Geology and graduated in 1908. He received the A.M. degree in the following year and in 1910 associated himself with the Harvard instructing staff by accepting the Curatorship of the Gardner Collection of photographs, an honorary position which he held for seven years. From 1911 to 1915 he was also Assistant in elementary geology courses under Professor Woodworth. Wigglesworth's early interests were in Petrology and Glacial Geology. With the late Professor Wolfi he studied the serpentine rocks

of Vermont, a field and laboratory study, published in 1915. With Woodworth he devoted several field seasons to the study of the geology of the Island of Martha's Vineyard. This work was finally developed into a thesis, presented in 1917, for the degree of Ph.D. It was not published until many years later. Woodworth's glacial studies of the southern New England region were collected and edited by Wigglesworth after Woodworth's death in 1925, and the thesis became an important part of the volume published in 1934 as a Memoir, No.52, of the Museum of Comparative Zoology at Harvard under joint authorship.

Meanwhile Wigglesworth became interested in Mineralogy. In 1914 he became Honorary Custodian of Mineralogy for the Boston Society of Natural History. He established an office in the Museum building on Berkeley Street and gave a large part of his time for many years to the improvement and increase of the mineralogical and geological collections.

In 1919 he became Director of the Museum, now known as the New England Museum of Natural History, and so remained until 1940. His principal aim during his long Directorship, so far at least as regards the mineral collection concerning which the writer was not infrequently called into consultation, was to transform it from a general display of minerals into a strictly New England collection. He exchanged most of the materials on exhibition which were derived from sources outside of New England for those of local origin. He purchased with his private means several local New England collections and many individual specimens; he rearranged and recased these in an attractive way and succeeded in gathering together a very remarkable display of the products of New England's mines and quarries. He particularly improved the display of gem minerals, both cut and uncut, sparing no expense or time to make it complete.

It was the difficulties Wigglesworth encountered in thoroughly identifying his cut stones that led him into his last and perhaps most absorbing mineralogical study, that of Gemology. He took the courses established by the American Gem Society for the identification of gems by optical and physical tests and became a certified Gemologist in 1939. He organized a series of loan exhibitions of gems at the Museum with the cooperation of Boston jewelry firms. He became closely associated with Robert M. Shipley, Jr., founder of the Gemological Institute of America in Los Angeles; he established a New England center of the Institute in Boston, where he taught many students of the subject; and on withdrawing from the New England Museum in 1940 he opened an office on Newbury Street as the eastern headquarters of the Institute. At the time of his death he was President of the Institute and Secretary of its Examination

Board. With Mr. Shipley he compiled a dictionary of gems and gemology. Thus his personality and influence was known to a country- wide group of gem students and dealers.

Wigglesworth kept up an association with his Harvard teachers and friends by accepting membership in the Visiting Committee for the Geological Sciences through the years 1919-1945. He was a faithful attendant at the committee's annual meetings and maintained an active interest in the development of the Division and particularly in the

Mineralogical Museum. He was a charter member of the Mineralogical Society of America, became a life Fellow in 1925 and was Vice-President in 1929. Dr. Wigglesworth endeared himself to his many friends by his simplicity and charm of manner. He was all too humble in estimating his very real accomplishments, insisting, as he always did, that he was but an amateur in the mineralogical field. The science has lost by his death an able worker and the Society a worthy and valued member. The writer mourns the loss of a tried and true friend. Our acquaintance began when

he was an undergraduate in the elementary course in Mineralogy and it ripened into a lasting friendship.

### **Combined Notes and Excerpts on Edward Hitchcock**

American Journal of Arts & Sciences 7. 1824.  
VOL. VII. GEOLOGY, MINERALOGY, TOPOGRAPHY, &c.

#### **Notices of the Geology of Martha's Vineyard, and the Elizabeth Islands, by Rev. Edward Hitchcock, A. M., - 240-248**

ART. III.—*Notices of the Geology of Martha's Vineyard, and the Elizabeth Islands.*

A short visit to the island of Martha's Vineyard, in the summer of the present year, (1823,) enables me to say something of its geology ; with that of the adjacent islands. I am the more induced to do this, since those islands are not coloured in the map of Maclure; and they may not soon be visited by a geologist, who will have an) better opportunity to examine their structure than I had, although I confess my researches were hasty and imperfect. This sketch however, may furnish some assistance to succeeding observers.

Martha's Vineyard is about twenty one miles in its greatest length, and from six to eight in its greatest breadth. It is divided into three townships , Edgartown, the most populous, occupying the south eastern part of the island ; Tisbury, embracing the north western part, and Chilmark the western and southwestern parts. The name of this island, given by the aborigines, is Nope, or Capawock. These natives have long been celebrated in the annals of missions. But those, whose blood runs pure from foreign mixture, are now nearly extinct. A hybrid race, however, descended chiefly from the intermarriages of negroes and Indians, are yet considerably numerous, perhaps about four hundred, who inhabit the western extremity of the island, in the vicinity of Gay head; and among them, there exists an organized Christian church. The small island of Chabaquiddick, lies at a little distance from the east end of the vineyard, and Noman's land not far from the south western extremity. The Elizabeth islands being about sixteen in number, are situated a few miles from the north west end of Martha's Vineyard ; and form a part of the south east barrier of Buzzards Bay. They contain a few scattered inhabitants.

In my route from the city of Boston, I passed over the well known puddingstone of Roxbury and Dorchester; the argillite and greenstone of Quincy; the sienite and sieoitic granite of Braintree and Wey mouth, with its beautiful dykes of basalt, or greenstone; the gray wacke slate? of Abington ; the diluvium of East and South Bridgewater; the gray wacke slate, diluvium and singular talcous rock, containing feldspar, of Middleboro ; and struck at New Bedford, upon mica slate, hornblende slate, and gneiss, inter-stratified, and containing beds and veins of granite. In sailing out of New Bedford harbour, these latter rocks appeared occasionally, for several miles along the shore ; and I was led to anticipate their continuance as far as Elizabeth Islands and Martha's Vineyard: but on passing the former, I perceived a diluvial coat to be spread over their somewhat hilly surface; while the shores, in many places, exhibited steep declivities of sand. And on reaching the north western shore of Martha's vineyard, I found its aspect to be very similar. These islands so far as I have examined them, appear to be made up of the three following formations: 1 Alluvial: 2 Diluvial : 3 Plastic Clay. I use these terms in the Modern restricted sense; that is, as the latest writers employ them, in describing the strata of England and France. I take for a standard, the late work of Conybeare and Phillips, on the geology of England and Wales.

#### *1 Alluvial.*

This formation occupies a considerable portion of the southern part of the Vineyard; reaching in some places, even beyond the centre of the island. Where I crossed it, it consists of a perfectly level, sandy tract, uninhabited and uninhabitable. I have rarely seen as extensive a region, that was so cheerless and barren. It is covered by stunted shrub oaks, rarely exceeding five feet in height, and when I saw them, they were entirely leafless, presenting to the eye, , a cheerless, wintry waste. On my right as I crossed this plain, at a distance, appeared a ridge of high land and rounded eminences: but on my left, nothing was to be seen, except this uniform unrelieved barrenness. I was immediately struck with the idea, that this sandy desert must have been formed by the action of the waves of the vast Atlantic, which have beat upon this shore, without obstruction, for so' many centuries. In the south westerly part of the island, the high perpendicular cliffs indicate that the waves have encroached upon the hilly part of the island; and it would seem not altogether improbable, that the sands and clays, thence worn down, might have been driven by tides and currents, into this their retired bosom. I am aware, however, that no in stance is known, in any other part of the world, of so extensive an alluvial deposition from this cause: and perhaps if I had been able to spend more time in its examination, especially its south eastern margin, I might have discovered positive proofs of the incorrectness of such an hypothesis. In short, although this part of the island is coloured as alluvial, I am strongly inclined to believe, that it is referable to an older and distinct formation. Its inferior level, however, the perfect evenness of its surface, and the entire absence of diluvial detritus, so abundant in every other part of the island, clearly discriminate this from the Plastic Clay Formation, about to be described. But as I am not prepared, even to conjecture, with what other European stratum this is identical, it must, for the present, be denominated alluvial.

#### *2 Diluvial.*

This formation invests, in a very conspicuous manner, the whole of the Vineyard, with the exception of the part just described. All the north western extent of the island, several miles in width, is hilly and uneven : with no abrupt precipices, however, but rising into rounded eminences, which together constitute a ridge of considerable extent, and nearly as long as the island. I should judge that in some places, (his rises three hundred, or even four hundred feet above the ocean; and the quantity of huge boulder stones, scattered over these hills on every side, is immense. The land is mostly cleared, and the rounded masses are chiefly granitic, and of course, of a white colour; so that they may be seen at a great distance to good advantage. I had no' doubt, for a time, that the boulders I saw so numerous, and so large, on the remote hills, were ledges of granitic rocks; and I could hardly believe the inhabitants who told me, that no rocks were found in place on the island. But wherever I had an opportunity to examine, these ledge like appearances vanished on a nearer approach ; and the diluvial character of the surface became manifest. So that I feel a good degree of confidence, that the same will be found to be the case, with those eminences, that I did not visit. These loose stones vary in size, from that of the smallest pebbles, to that of masses, ten or even fifteen feet in diameter. They are almost without exception, of a primitive character; consisting of granite, gneiss, mica slate and quartz. I saw a few masses of a pudding stone, similar to that of Roxbury ; but no other secondary rock. In short, the detritus of this formation appears obviously, to have been derived from the rocks, that occur in place along the coast, on the mainland.

The thickness of this diluvial mantle is not great. The sand from the plastic clay formation beneath it, is indeed so mingled with this, as to give a predominant character to the soil, and even the clay beneath the sand, is sometimes seen at the surface. In some tracts of considerable extent, little else, but the sand is seen: the diluvial boulders and pebbles being very rare. It is obvious from this description that the soil of the island must be very light and poor, and so indeed it is. Some fertile tracts, however^ occur along the margin of the small streams, or brooks, and also in some instances, in the immediate vicinity of the sea : and probably the soil in general, is of much the same character, as that along the adjacent shores of the continent.

The character of the 'diluvium of the Elizabeth islands, appeared so precisely like that of the Vinyard, that I have no doubt of their identity I say *appeared*, for I did not land on these islands; but having passed among them at two places remote from each other, and approached often within a few rods of the shore. I could not but be struck with their exact resemblance to the Vineyard, in the contour of the hills and vallies, in the colour, siz.', and quantity of the boulder stones, in the sandy aspect of the soil, and in the high sloping sand banks so frequent along the shore. I have accordingly coloured several of these islands on the subjoined map as diluvial. It may be thought I do this on very slight grounds, but as I have plainly stated what those grounds are, geologists will place that degree of confidence in the opinions advanced, which they consider them as deserving. Besides it must be recollected, that this paper does not profess to give a finished sketch of the regions it embraces, but only to furnish hints towards their geology.

The diluvial bowlders, occurring along the south-eastern coast of Massachusetts, are often in immense quantities; and of a character, very similar to those on the above named islands.

I was told, by unquestionable authority, that a rocking stone exists in Chilmark, a mile or two south-west of the congregational meeting-house. But I could not visit it.

### *3. Plastic Clay Formation.*

The Plastic Clay Formation in England, is composed of an indefinite number of sand, clay, and pebble beds irregularly alternating. It contains also, lignite, imperfect coal, amber, organic remains, &c. Taking these characters as the criterion of that formation, we must conclude, that it underlies all the diluvial of Martha's Vineyard. Where- ever the shores of that island are elevated, and the ocean has encroached upon them so as to present perpendicular cliffs, a series of strata answering to the above description, are exhibited usually in great perfection and beauty. Gay Head is well known for the bright and variegated colours of its clay, sand and pebble strata ; which present a naked front, of 200 feet in height. I was so unfortunate, however, through circumstances beyond my control, as not able to visit those cliffs; although I passed within two or three miles of them. But I felt my disappointment somewhat mitigated, by having an opportunity to examine, what I suppose to be a continuation of these cliffs, in Chilmark, five or six miles from Gay Head, and probably near their north-eastern termination. Immediately beneath a thin stratum of diluvial soil, lies a bed of shells, only a few inches thick, and mostly in fragments. Below this is a stratum of white sand, with some pebbles, often several feet thick. Next occur irregularly alternating beds of variously coloured clays, sand, ferruginous sand, pebbles, clay and pebbles, and clay and sand intermixed. The clay beds are while, brown, blackish, red, light and deep yellow, and finely variegated with spots of white, red, and yellow. The ferruginous pebble beds are brown, or reddish, sometimes a deep blood red, and they are generally cemented by the oxide of iron, so as, in some instances, to require a considerable blow of the hammer to separate the fragments. This is particularly the case in the lower part of these strata ; where the iron ore, which appears to be the argillaceous, is sufficiently pure to be wrought, although penetrated by pebbles throughout. Some of the clay beds are nearly half made up of small plates of silver coloured mica, intimately mixed with the clay, which appears to be kaolin. In this clay, beneath the ferruginous pebble beds, I found good specimens of well characterised lignite. It consists of flattened trunks, or branches, several inches in diameter, of a clove brown colour, retaining, very distinctly, its longitudinal, fibrous structure: but the cross fracture is conchoidal and shining, and the concentric rings are invisible. The bark is a mere line in thickness. It burns without much difficulty, with considerable flame, and emits a pungent rather unpleasant odour. It lies horizontal in the bed of clay, and is one of the exogenites of A. Brongniart, (vid. Vol. VII, No. 1, Journ. Sci. p. 178.) In other beds of clay, small masses of lignite occur, some of which exactly resemble common charcoal, and burn as freely. I saw no other organic remains in these strata, except a single shell, in the ferruginous sand, which I lost.

Viewed on a general scale, the beds, above described, are nearly horizontal. But numerous minor irregularities, in the dip of the strata, occur in the cliff, which I examined. Indeed, instances may be seen of almost every possible degree of declination : in some places, the beds arch upwards, and in others they arch downwards. Whether this irregularity does not proceed from a partial sliding down of large masses of the cliff, I could not determine ; though inclined to believe it does not.

The above description, it will be perceived, corresponds in its general characters, to the European Plastic Clay Formation ; and therefore the strata it embraces have been thus denominated. But in order to establish their identity with perfect certainty, a comparison must be instituted between the organic remains, occurring in each series of strata. It is not therefore, without some doubt, that I have denominated the formation, above described, the Plastic

Clay Formation.\* It cannot, however, be referred to any other European formation, of which I have seen a description. It is coloured, on the accompanying map, only as a belt along the coast, in those parts where I have noticed it to be more or less distinctly laid bare; although, as before observed, it probably constitutes the basis of all the diluvial part of the island. But the diluvial is so remarkable, that it seemed to deserve a place. Probably, also, the Plastic Clay underlies the diluvium of the Elizabeth Islands: although the clay beds are not so distinct in the cliffs, and are in general, hid by the sand. And from all I can learn of Nantucket, this island is, with little doubt, referable to the same formation: if so, where, but to the same place in the geological scale, shall we refer the sands of Cape Cod ? unless, indeed, they may belong to a formation still more recent. Long Island, in those places where I have seen it, is unquestionably very similar in its geological structure to Martha's Vineyard; and probably belongs to the same era. I take it for granted, that the vast region along the sea coast in the middle and southern states, marked on Maclure's map as alluvial, can no longer be considered such, in the modern sense of that term. He describes a part of it, at least, as consisting of sandstone and limestone, and regular beds of sand, gravel and clay; and some of this gravel is cemented by oxide of iron: and, therefore, it cannot be alluvial; but agrees with the European strata above the chalk. If we take his map, and prolong the line, or rather curve, that separates the alluvial tract above named from the primitive towards the north-east, we shall find that it passes between Martha's Vineyard and the continent, and crosses Cape Cod, leaving us to conclude that the Vineyard and Nantucket are a continuation of that extensive formation, hitherto called alluvial, of which Long-Island has been regarded the north-eastern limit. If we prolong this curve still further, it will include within it Nova Scotia, and, at least, a part of Newfoundland. Here we are reminded of the vast sand banks along that coast, and

\* The remarks of Mr. Finch, (who appears to be ocularly acquainted with similar formations in England,) on the tertiary formations of North America in Vol. VII No. I of the Journal of Science, tend very much to remove these doubts, and to establish me in the belief of the existence of the Plastic Clay Formation in the Vineyard. I feel indebted to that gentleman for the important hints he has thrown out.

also, of the cliffs of gypsum and sandstone in Nova Scotia, and the enquiry arises whether that gypsum is not identical with the same rock in the vicinity of Paris, where it occurs in the lower Fresh Water Formations? If so, it forms a continuation of the vast tertiary formations, stretching through the eastern border of the United States, and embracing some of the West India Islands, and adds to them an interesting link. Finally, if we carry this curve across the Atlantic, it will pass not far from the northern extremity of Great Britain, and include within it the tertiary formations of England and France, and, indeed, of all Europe. The enquiry then, immediately suggests itself, can it be, that the tertiary formations of Europe and of the United States, are merely the extremities of the same vast basin; the intermediate parts of which, have been swept away by the currents and waves of the ocean, or by some mighty catastrophe? Whether such questions deserve any serious consideration, or not, it is obvious, that there are facts enough brought to light, to induce our geologists to subject those parts of our country, hitherto called alluvial, to a thorough re-examination. And there is reason to anticipate, as the fruit of such researches, the discovery of many more beds of gypsum, than are now known; and also, of chalk? If this latter substance exist immediately below Plastic Clay in England and France, why may we not expect, that when the same formation in this country is penetrated, chalk will be found beneath it? In England, the Plastic Clay is not usual more than 100 feet in thickness: but in Martha's Vineyard, (if it really exist there,) the ocean has already laid open this formation nearly 200 feet in depth; so that the bottom of it might probably be reached without much difficulty.

I visited the Vineyard in the early part of June; and the season being unusually late, I am unable to say much of its botany, if it be proper, in this place, to say any thing. A species of oak exists abundantly there, which I have never seen upon the continent: but it was not the season of its flowers, or fruit; and the leaves were but just opening, so that I could determine nothing concerning the species. A species of *Ranunculus* also occurs, which, is stemless, and, I believe, undescribed. Very many of the boulder stones contain, on their surface, large quantities of the elegant *Sorrera chrysophthalma*:—a lichen very rare in most parts of New-England. Associated with this, is abundance of yellow and beautiful species of *Parmelia*, with which I am unacquainted: the same, that is so frequent on the pudding-stone of Roxbury, and the petrosilex of Lynn. On the south-east shore of the island, where the waves of the Atlantic incessantly beat, I observed an unusual number of species of *Fucus*, *Ulva*, *Spongia*, and other genera of zoophytes, unknown to me. The testacea were neither numerous nor interesting. . . .

It may not be amiss to remark, that in passing from New- Bedford in Massachusetts, to Tiverton in Rhode Island, in a pond, nearly on the line between the states, I found a delicate species of *Hottonia*, that answers well, to the *H. inflata* of Elliot; but is certainly not the *H. pulustris* of Linnaeus.

**E.A. Hitchcock. 1832. American Journal of Science.**

**Diluvium**

“This occupies more of the surface in Massachusetts than any other stratum...made up commonly of large pebbles, or rounded stones, mixed with sand and fragments of every size, which are often piled up in rounded hills to a considerable height...as preclude the probability that it could have resulted from existing streams...[It] appear to have resulted from some powerful current of water, which, in early times, swept over the globe...It was evidently deposited by currents rushing violently over the surface; since only the coarser material, which were driven along, were left; while the finer particles were kept suspended by the agitation of the waters.”

“It is most abundant in the south east part of the State; the counties of Plymouth, Barnstable, Dukes, and Nantucket, being almost entirely overspread by it...”

**Porcelain Clay.** This is the purest of all clays, and is the only one employed in the manufacture of porcelain, or China ware. A part of the extensive clay beds on Martha’s Vineyard, appears to be porcelain clay; especially in Chilmark: though a large proportion of mica is mixed in it.

**Potter’s Clay.** This is the clay so extensively employed for common pottery, pipes, tiles and brick...The purest, sometimes call pipe clay, is found almost exclusively on Martha’s Vineyard. This is white, and contains so little iron, that when burnt, it becomes whited still, and will resist a high degree of heat. Hence it is employed for making what are called fire bricks, which are used for lining furnaces. White pottery is also made from it. But the more common clay turns red on burning, in consequences of the oxide of iron in it; and this renders it much easier to be melted by the heat, and consequently diminishes its value....good bricks can be made from it...it exists so abundantly in almost every town...

The white clay of Martha’s Vineyard, is employed extensively in the manufacture of alum, in Salem...the details are, I believe, kept secret.

**Peat** – [describes it as extensively used on ACK and the Cape. Fuel and soil amendment – peat moss]. I cannot but regard the existence of so large quantities of peat, on Cape Cod and Nantucket, as a great blessing to the inhabitants. Yet from the little of it, which I observed to be dug there, I am apprehensive they do not realize its value...If the peat swamps could be drained, and after removal of a portion of the peat, be covered with lighter and warmer soil, but few years would pass before they would become fine grass plats...

Lignite exists in small quantities in the clay of the Vineyard...

Bog ore – many towns in the state including MV...dredged from ponds

Ochres etc used in paints – doesn’t mention MV or much of anything.

**Address to Association of American Geographers – 1841. Second Annual Meeting. Hitchcock was Geologist to the State of MA and Chariman of the Association for 1840. Professor of Chemistry and Natural History, Amherst College. Talk in Philadelphia**

Identifies similarities between NA and European recent geology – striations, gravel, boulders, drift,

“It is well known that theory of drift has for some years been the most unsettled part of geology. The mass of geologists have, indeed admitted that in some way or other, currents of water have been the principal agency employed, because they witness somewhat analogous effects form aqueous action; and, until recently, no other power of adequate energy and extent has been known to exist. Hence they have been willing to retain the term diluvial, as a generic expression, implying simply aqueous agency in general.

Many skeptics, including himself, so he lays out inferences:

- general force in same direction – to the S or SE; modified valleys
- operated at all altitudes – up to 4000 feet; and without any smoothing of their angles
- equally fresh at all altitudes – synchronous
- less and less powerful as go to south; few reports from S NA
- not much disturbed since laid down
- occurred after continent out of ocean
- water was one of forces; he includes in here the movement of boulders
- ice must have been one agent; long transport and on high ridges; mounds
- occurred before man on the continent as would have destroyed life
- must have been relatively recent
- more powerful than any force now operating on earth

Glacial theory – originally suggested by M. Venetz, adopted by M. Charpentier and more fully developed by Agassiz – now of great interest in Europe – Agassiz’ *Etude sur les Glaciers* give new aspect – 5 summers’ of observations in the Alps.

“While reading this work and the abstracts of some papers by Agassiz, Buckland and Lyell on the evidence of ancient glaciers in Scotland and England, I seemed to be acquiring a *new geological sense*; and I look upon our smoothed and striated rocks, our accumulations of gravel, and the *tout ensemble* of diluvial phenomena, with new eyes.

[Footnote indicates that EAH has changed his text from what he presented in person – as he had not seen Agassiz’ work. “A flood of light having thus been unexpectedly thrown in upon my mind...the great mass of evidence in its favor...has led me to express a warmer admiration of its leading features and a greater readiness to adopt its leading principles...”]

From year to year, the evidence has been increasing, of the prevalence of intense cold in northern regions in the period immediately preceding the historic...all northern countries were covered with a vast sheet of ice, filling valleys and extending southerly..." "It is almost certain that the sheet of ice which covered the surface, according to this theory, must have been at least three or four thousand feet thick, because our mountains have been to that height, swept over."

He could not understand how moraines were made in flat country so far from the ice – in SE Mass.

### **E.A. Hitchcock. 1841 – Final Report on Geology of Massachusetts**

To his Excellence Governor Edward Everett:

"For 20 years I have spend a principal portion of time wandering the state—climbed all her mountains, penetrated her most sequestered valleys and glens, travelling more than 10,000 miles, not with railroad speed but geological speed. Synonymous with a pedestrian's pace."

Since writing the deluvium section written has read Agassiz's work due to Prof Silliman. Quotes from his talk in Philadelphia.

"But how came such enormous moraines to be found in the and comparatively level country where they exist? Is it possible that the whole of Cape Cod is nothing but a vast terminal moraine, produced by a glacier advancing through Massachusetts Bay, and scooping out the materials that now form the Cape? In this case the moraines at Plymouth and Truro would form a part of the lateral moraines, and probably most of Nantucket and Martha's Vineyard might be regarded as moraines of the same glacier, when it extended farther south....I forbear: for enough of dreamy hypotheses on this subject have already had an ephemeral existence, and passed onward into the caves of oblivion."

To conclude : the theory of glacial action has imparted a fresh and a lively interest to the diluvial phenomena of this country. It certainly explains most of those phenomena in a satisfactory manner. It seems to me, however, that the term *Glacio-aqueous action* more accurately express this agency than the term *glacial action*: for the effects referrible to water are scarcely less than those produced by ice. I could wish that the theory gave a more satisfactory explanation of the southerly direction taken by the drift. Perhaps this is a point which can be only hypothetically solved. It may have been connected with the cause which introduced the glacial epoch. Whether this came in suddenly, as Agassiz supposes, or slowly, as Lyell maintains, we know of no cause now in operation that could have produced the change from a tropical to more than an arctic climate, and then back again to a temperate climate. Is it possible that the earth, after having assumed its present spheroidal form, and nourished successive races of animals and plants in some genial sphere, was suddenly deprived of external light and heat, and of its motion on its axis, and exposed to the severe cold of the celestial spaces (—53° Fahr.) Its waters would

retreat towards the poles and become ice. Let it next be placed in its present orbit and commence its present motions: and would not the ice, as it melted, both from its expansive and centrifugal force, take a southerly direction ? *But I forbear : for enough of dreamy hypotheses on this subject have already had an ephemeral existence, and passed onward into the caves of oblivion.*

Improving barren soil – add clay, peat, muds; Belgians plant broom, pine;

I noticed that in the old fields upon Cape Cod, which had been cultivated until the geine was nearly exhausted, that large patches of the *Hudsonia ericoides* or *false heath plant*, and of *H. lomentosa*, or *poverty grass*, were frequent.”

He suggests that they may help improve soils.

### Scenographical Geology

**The idea that a large part of our soil is absolutely unfit for cultivation, and incapable of improvement, which has discouraged so many of our young men, and driven them away from their paternal homes, is contradicted at every step of a fair investigation of the subject. As I have approached one of our beautiful villages, and seen all around it such prolific crops, I have frequently enquired why such a difference exists between the fertility there, and the wide region over which I have been passing since I left the last village? For in the natural character of the soil I could perceive no essential difference. The conclusion would be, that cultivation has made all the difference. And yet, in that village are probably many young men who feel as if all the valuable land around them were taken up, and that they must seek their fortunes in some distant and more fertile region. It is true that our soil will yield to nothing but persevering industry and skill. But the habits of diligence and endurance which will be acquired in subduing it, are of far more value to the possessor, both for the promotion of his fortune and his happiness, than the richest manor that yields almost spontaneously. The very object of Providence apparently in giving us a soil by nature comparatively sterile, yet capable by cultivation of yielding an abundance, was to call into exercise that**

**industry and energy, without which man becomes a mere drone, or the miserable slave of indolence and the low appetites.**

**I do not doubt but the Government and every intelligent reflecting citizen will feel the vast importance of energetic efforts to improve our soils so that they may sustain a larger population. This is the only way to check the tide of emigration that sets so strongly to the great West. For if our sons can be made to see the soil of New England doubling its increase, as I verily believe they might in one or two decades of years, the rich alluvia and prairies of the West will not be able to draw them away from the graves of their fathers; especially if they learn that those fertile regions will at length become exhausted of their geine and salts, and then will probably require as much labor to cultivate them as the soils of Massachusetts.**

**Some, however, may contend, that it is more important to transfer the New England character to the unsettled West, than to multiply our numbers and wealth at home. But the history of the world leads us to fear, that New England character cannot long be preserved except upon New England soil; or upon a soil that requires equal industry for its cultivation. Place New England men where the earth yields spontaneously, and the locks of their strength will soon be shorn. If we look over the map of the world, and the history of the past, we shall find as a general fact, that the brightest exhibitions of human character have been made, in regions where nature has done less, but art and industry more. If, therefore, we wish to increase the moral power of New England, it must be done by improving her soil, and increasing her resources and her population. If these views are correct, which I acknowledge do not fall in with the prevailing notions, they furnish a new stimulus for vigorous effort in the improvement of our soils.\***

Peat use described in Chilmark as perhaps 100 acres

Nantucket – 985 acres 9 of peat) owned by Jared Coffin 1-14 feet thick

Clay – only Dukes County has white clay with no iron so good fir fire bricks – can take a powerful heat without vitrification. Any iron turns it red.

“There are but very few towns in the state, and those are very mountainous, where this clay [for bricks] does not occur in a state more or less pure”. “The non-ferruginous clay of MV, however, is quite abundant”. Chemical analysis – 62% Silica; 29% Aluminae; 0.45% Mg.

Amber – some from Gay Head; a one pound piece form ACK

Hydrate of iron mixed with clay – richest at Gay Head – nodules up to one foot diameter; best locality – Minimshi [sic – Menemsha] Bite 3 miles E of Gay Head.

The white clay of Martha's Vineyard, described on a preceeding page, has been somewhat extensively employed on the continent, in the manufacture of alum—of which alumina forms the basis; and for fire bricks, pipes, &c. And since that is the only deposit of this kind of clay known in New England, it can hardly be doubted but the demand for it will increase.

From these and other considerations that might be named, we may safely assume, that the peculiarities of natural scenery depend chiefly upon geological causes; and hence I have thought it would not be a misnomer, to denominate a description of natural scenery, *Scenographical Geology*. With the modifications of natural scenery by human agency, I have little or nothing to do in this place. My chief object will be to call the attention of men of intelligence and taste, to those striking features of our scenery, that are the result chiefly of geological changes, and which produce landscapes abounding in beauty and sublimity. A few of the more frequented of these spots are well known: but very many of them have cost me much time and labor to discover; quite as much indeed, as to find out new localities of rocks and minerals: although the two objects could be conveniently prosecuted together. Some of them are yet too little known to have received a name; and in a few instances I have ventured to supply this deficiency. It will not be expected that I should describe these spots with the vividness and minuteness of the poet and the painter. My chief object has been to direct the attention of gentlemen of taste, intelligence, and leisure, to these spots; that sometime or other, their beauties and sublimities may be faithfully depicted, both on canvass and in language. In this way I hope that many of our citizens, in their excursions for relaxation and health, instead of following the beaten track to places of fashionable resort, where more is often lost in morals than is gained in health, may be induced to climb our own mountains, and traverse our own deep glens and gorges, where they will find unsophisticated nature, with the dress given her by her Creator, scarcely marred by the hand of man. In order to excite more interest in our scenery, I have

It should be remarked here, that many of the sketches were taken with a view to illustrate the geological features, as well as the scenery; and wherever it was possible to unite these two things, I have done it. This is especially the case in those sketches that contain exhibitions of diluvial phenomena. And I cannot but observe here, how superior must be the pleasure which the geologist derives from scenery, above that of the man who knows nothing of the mighty agencies by which the striking features of that scenery have been produced or modified. The latter derives all his pleasure from the simple beauty or sublimity of the spot. But along with that emotion, the mind of the former is stimulated and regaled by numerous rich and delightful associations. It is carried back through immense periods of past time, during which natural causes were operating to produce the scenery before him: and he witnesses in imagination that spot, assuming peculiar and widely diverse aspects; and sees how wisely each change was adapted to bring it into its present state. It may be too, that his mind reaches forward into futurity; and perceives other changes passing over the spot, no less interesting; and the necessary consequence of the unalterable laws which God has established.

Saddle Mountain; Graylock  
Hoosac Mountain  
Taconic Range  
Tom Ball  
Beartown Mountain  
Alum Hill, South Mountain, East Mountain  
Monument Mountain

Etc – Valleys, Coast Scenery, Cape, MV (Gay Head), ACK

Images

Notes for box, not used directly

Despite the satisfaction with the mechanistic explanation Hitchcock did note the absence of satisfactory understanding of many driving forces: how did the earth plunge into the bitter freeze that sustained the glaciers. How did life persist on earth with such vast ice sheets? How did the ice expand and move so far and how did ice move uphill?

And why did the greatest moraines in New England occur at the coast rather than in the great valleys?

“During the longer period in which this Report has been in press, some developments have been made important enough in my opinion to deserve a Postscript.”

“After reading the works of Agassiz on Glaciers...I cannot doubt but ancient moraines are scattered all over New England.”

Unwilling my Report should go out of my hands unaccompanied by a brief view of the facts and inferences concerning it.”

In a country like ours, where no glaciers exist except in very high latitudes...it is not strange that this attempt to explain the vast phenomena of diluvial action by such an agency, should appear at first view, fanciful, and even puerile. But the recent work of Agassiz, entitled “*Etudes sur les Glaciers*,” gives a new aspect to the subject...

“Having hovered so long over the shoreless and troubled ocean of uncertainty and doubt, I may be too ready to alight on what looks like *terra firma*.”

Henceforth, however, glacial action must form an important part of the chapter.”

These sections of his Postscript are direct quotes and section form his presentation.

**April 5 1841**

**Second Annual Meeting of the Association of American Geologists**

**Edward Hitchcock – Chairman for 1840**

Sketches most important parts of American geology

Term diluvium used because water involved

“...it explains satisfactorily the origins of those singular accumulations of gravel and bowlders...the smoothing , polishing and furrowing of the rocks at different altitudes...the transportation of bowlders, and their lodgment upon the crests and narrow summits of mountains; and that often without having their angles rounded...the existence of deposits of clay and sand above the drift...water to fill valleys...why these deposits of clay and sand are almost completely destitute of organic remains...that the northern slopes of some mountains in New England...exhibit scratches and furrows.”

“Is it possible that the earth, after having assumed its present spheroidal form, and nourished successive races of animals and plants in some genial sphere, was suddenly deprived of external light and heat, and of its motion on its axis, and exposed to the severe cold of the celestial spaces.”

Hitchcock on MV -- Great Plain, Agricultural Decline,

**Hitchcock on MV -- Great Plain, Agricultural Decline,**

1 *Alluvial*. This formation occupies a considerable portion of the southern part of the Vineyard; reaching in some places, even beyond the centre of the island. Where I crossed it, it consists of a perfectly level, sandy tract, uninhabited and uninhabitable. I have rarely seen as extensive a region, that was so cheerless and barren. It is covered by stunted shrub oaks, rarely exceeding five feet in height, and when I saw them, they were entirely leafless, presenting to the eye, , a cheerless, wintry waste. On my right as I crossed this plain, at a distance, appeared a ridge of high land and rounded eminences: but on my left, nothing was to be seen, except this uniform unrelieved barrenness. I was immediately struck with the idea, that this sandy desert must have been formed by the action of the waves of the vast Atlantic, which have beat upon this shore, without obstruction, for so' many centuries.