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Pleistocene Geology of Block Island

Sirkin, Les

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by

Les Sirkin
Adelphi University

Abstract

The cliffs and surface features of Block Island offer us a unique opportunity to study Late Pleistocene glacial deposition and tectonism, as well as late-glacial recession of the continental ice sheet.

Introduction

Block Island lies about 20 km south of the Rhode Island coast and a similar distance east of Montauk Point, Long Island. In the classical correlation of end moraines in southern New England, Block Island is only a stepping stone between the Vineyard Moraine of Martha's Vineyard and the Ronkonkoma Moraine of Long Island (Flint and others, 1959). Recent studies show that this linear correlation is at best an oversimplification (Sirkin, 1976, 1981). The presence of two superposed drift sheets, with evidence of at least two glaciations and deposition from two glacial lobes, as well as recessional moraines and associated deposits attest to a more complicated glacial history than was previously envisioned (Sirkin, 1981). It is also apparent that both glaciations occurred during the Wisconsinan Glacial Stage of the Pleistocene (Fig. 1).

Geomorphology

Block Island has been formed from two relict morainal segments that now stand as highlands rising from the sea. The highlands are tied together by beach deposits in the form of a double tombolo. Coastal erosion has cut impressive cliffs into the moraines. These exposures offer a unique opportunity for us to study in cross section the glacial deposits and the evidence of glacial tectonics in both dip and strike directions and to directly relate structures, deposits and topography to glaciations. Surface features in both segments of the Island include the moraines, meltwater channels and the distinctive morainal topography. A cluster of north-northwest to south-southeast trending drumlins nearly encloses an embayment with a similar trend in the central area.

A large pond at the north end of the Island is bordered north and west by partially stabilized dunes and beach deposits. A north trending spit juts from the north end of the Island and can be traced for nearly 2 km toward the Rhode Island coast. A line of coastal dunes lies parallel to the eastern tombolo, which is supported, in turn, by glacial sediments. Erratics are scattered across the Island and lag bolder concentrations armor the outer beaches as well as those of the ponds. Multiple gravel berms up to one meter above sea level indicate seasonal and storm high water. These berms are often shaped in beach cusps.

Stratigraphy

The glacial deposits of Block Island overlie Late Cretaceous sand and clay

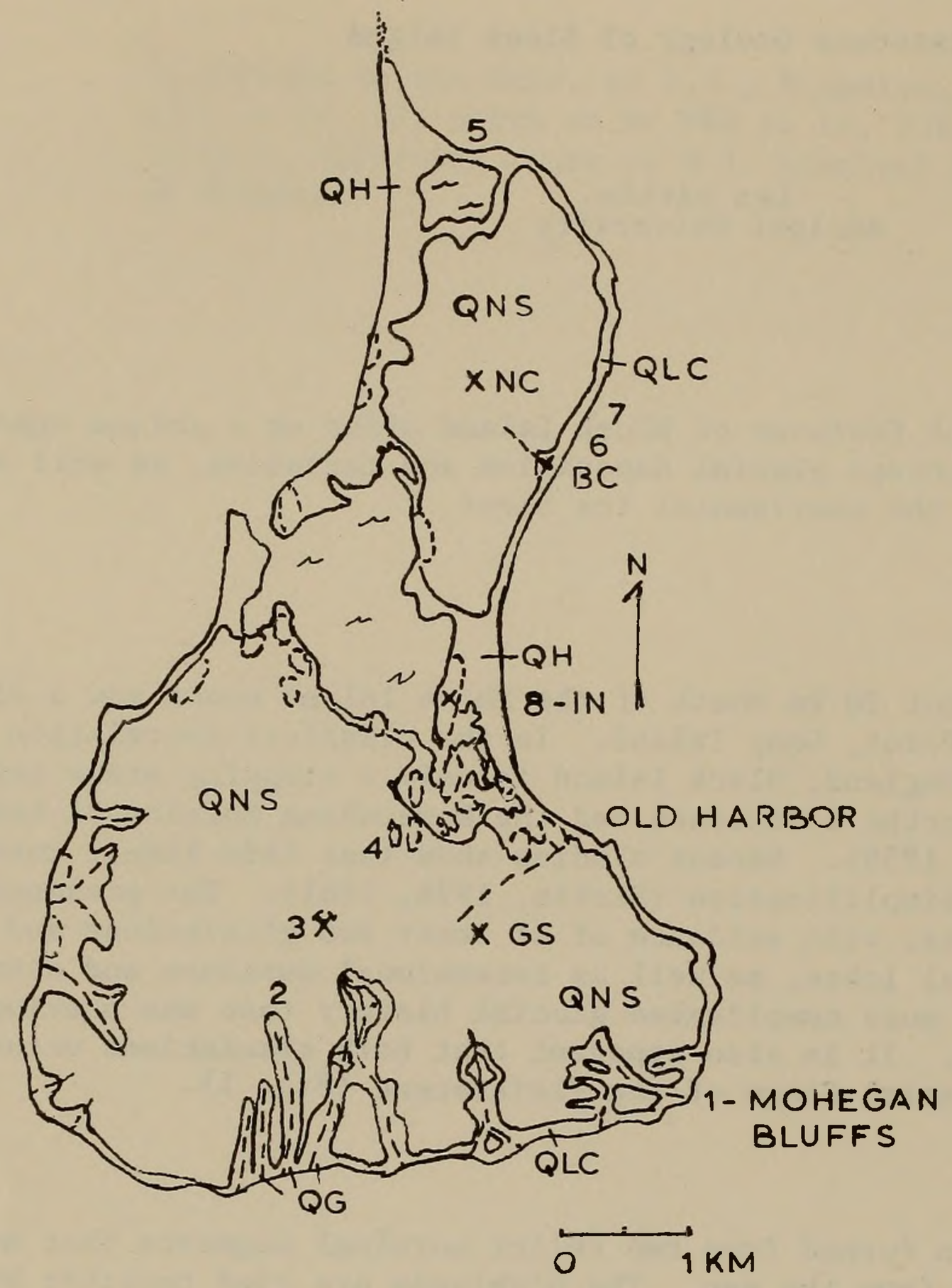

Figure 1. Surficial geology of Block Island. (Profile of NE Bluffs sketched in Fig. 2).

Rock Units

QH - Holocene deposits
QG - Meltwater channel gravel
QNS - New Shoreham Formation (Woodfordian)
QLC - Lighthouse Cove Formation (Altonian)
KR - Raritan Formation

Landforms

Drumlins
--- Meltwater channels
x Pollen sites
1,2.. Field trip stops

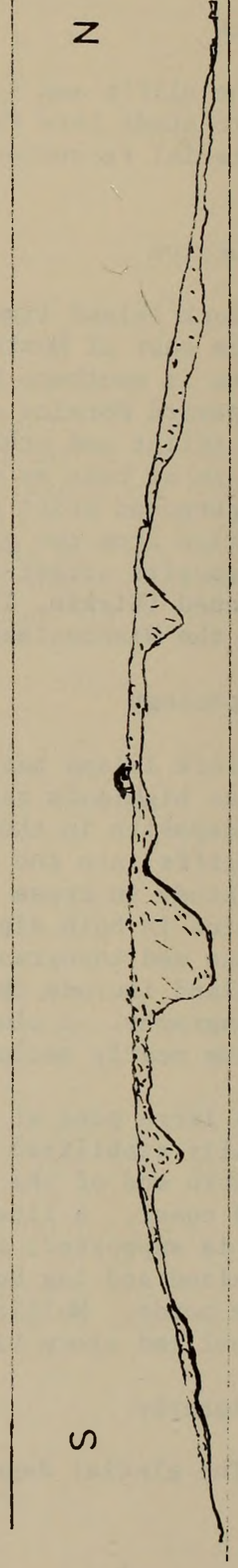

Figure 2. Sketched profile of the northeast cliffs. Sketch in the Geology.

with lignitic seams (Fig. 1). The lignites contain a microflora that represents Cretaceous pollen zone V, and thus they occur in strata that are equivalent to the South Amboy Fire Clay and related deposits in Long Island and New Jersey (Sirkin, 1974). Seismic refraction has shown that up to 41 m of Cretaceous strata underlie Block Island (Tuttle, 1961). Masses of Cretaceous sediment are redeposited in the Late Pleistocene moraines.

At this writing no Early Pleistocene glacial or interglacial deposits have been identified in Block Island. The glacial drift of the Island is believed to be entirely Wisconsinan in age; it may be separated into two sequences of Early Wisconsinan or Altonian and Late Wisconsinan or Woodfordian age (Sirkin, 1976, 1981) (Table 1).

Altonian

The lower drift sheet is exposed in the sea cliff sections of the Island. The best section occurs in the Mohegan Bluffs in the southeast. Here the Altonian deposits are structurally and lithologically complex, but they may be divided into three units. The lowest is a dark gray or olive gray till (5Y4/1) that contains about 65 percent dark-colored till stones, has a northeasterly till fabric, and is crudely stratified. The middle unit consists of tightly folded, rhythmically bedded clay and silt layers and thin lenses of yellowish brown till (10YR5/4) and gravel. These are overlain by olive gray till (5Y4/1) that resembles the lower till of this section. Kaye (1960) proposed that the section developed through ablation processes coupled with ice movements, both recession and readvance. North of Mohegan Bluffs the Altonian drift grades into a single till unit about 3.0 m thick that overlies outwash.

Kaye's suggested ablation mechanism for the Mohegan Bluffs section appears plausible. The thrusts and folds in the drift are undoubtedly due to glacial tectonism and show agreement in the southerly trend of deformational axes. The Altonian ice was also active in redepositing masses of Cretaceous and Altonian sediment. The tightly folded rhythmites, for example, are probably proglacial lake beds that were deformed and incorporated in the drift. Woodfordian glacial tectonics have complicated the Altonian section by lifting and thrusting large blocks of till. Sand and gravel from the Woodfordian ice sluiced into the openings and engulfed the Altonian clasts.

The northeasterly till fabrics and the large proportion of till stones derived from strata in the Narragansett Embayment in the Altonian till indicate that deposition came from a glacial lobe that crossed the Narragansett lowland. The Altonian till section in the Mohegan Bluffs of Block Island is similar to the corresponding section at Montauk Point, which contains the Montauk Till. This apparent correlation was used by Sirkin (1976) who referred the Early Wisconsinan deposits of Block Island to the Montauk Drift. However, due to the physical separation of these sections and the recognition of an outwash unit beneath the till, the two sections may be differentiated. Thus, the Altonian till in Block Island has been designated the Mohegan Bluffs Till and the underlying outwash is named the Old Harbor Sand. Both the till and outwash are members of the Lighthouse Cove Formation (Table 1).

The Altonian moraine of Block Island, recognized in the topographic high of the deposits at Mohegan Bluffs, is probably not the end moraine of the Altonian glaciation (Fig. 3A). The Altonian ice appears to have advanced

Stage	Substage	Rock Units	Age, Yr BP
WISCONSINAN	Woodfordian	New Shoreham Formation: Old Town Till; Issacs Corner Sand	-20,000
	Farmdalian	(Represented in Long Island)	-21,750
	Portwashingtonian		-28,000
	Nassauan	(Inferred in L.I.)	-33,000
	Altonian	Lighthouse Cove Fm.: Mohegan Bluffs Till; Old Harbor Point Sand	>43,000

Table 1. Wisconsinan stratigraphy in Block Island.

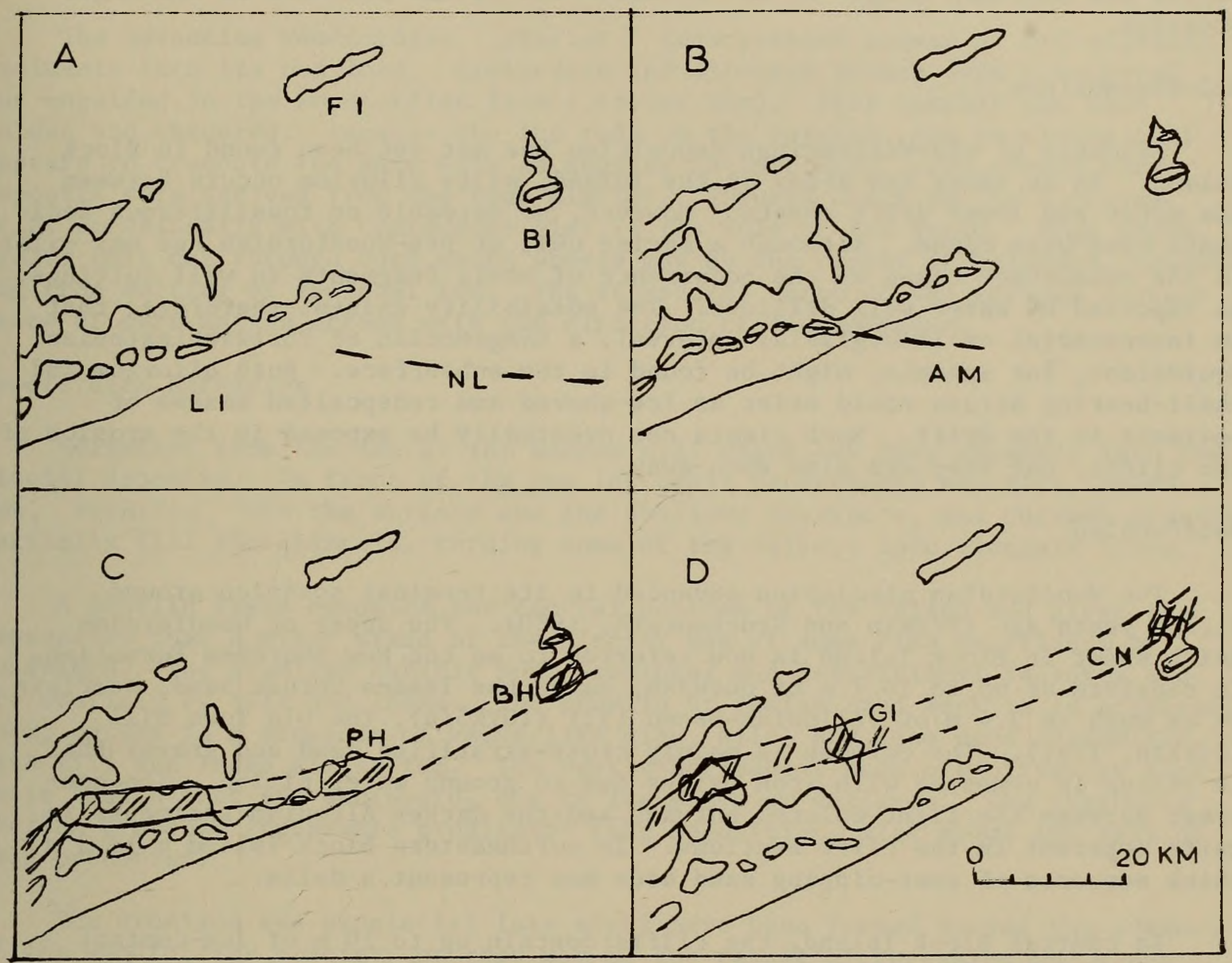

Figure 3. Correlation of drift and morainal envelopes, Block Island to eastern Long Island. A) Altonian: position of end moraine of the Narragansett Lobe (NL) is believed to be well south of Block Island and Montauk Point. B) Woodfordian end moraine: the Amagansett Moraine (AM): its counterpart would lie south of Block Island. C) Recessional morainal envelope: the Prospect Hill Moraine (PH) of Long Island, Beacon Hill Moraine (BH) of Block Island. D) Recessional morainal envelope: the Gardiners Island Moraine (GI), Corn Neck Moraine (CN) of Block Island.

beyond the southern margin of the Island based on the presence of submerged erratics.

Mid-Wisconsinan

Evidence of mid-Wisconsinan deposition has not yet been found in Block Island. In at least two areas of the Island, silty alluvium occurs between the upper and lower drift sheets. However, no dateable or fossiliferous sediments have been found. Although a marine unit of pre-Woodfordian age may exist in the subsurface based on the occurrence of shell fragments in well cuttings, as reported by water well drillers. The possibility exists, therefore, that an interstadial or interglacial interval, a Sangamonian or Portwashingtonian equivalent, for example, might be found in the subsurface. Both alluvium and shell-bearing strata could exist as ice-shoved and redeposited masses of sediment in the drift. Such clasts can eventually be exposed in the erosion of the cliffs, but they are also worn away.

Woodfordian

The Woodfordian glaciation advanced to its terminal position around 21,750 years ago (Sirkin and Stuckenrath, 1980). The upper or Woodfordian drift sheet in Block Island is now referred to as the New Shoreham Formation. It consists of up to 16.7 m of outwash, named the Isaacs Corner Sand, overlain by as much as 3.4 m of yellowish-brown till (10YR5/4), the Old Town Till (Sirkin, 1981). The outwash is mainly cross-stratified sand and gravel that in places is cemented with iron oxides due to ground water piping. The contrast between the light-colored outwash and the darker Altonian sediments is quite apparent in the cliff sections. In northeastern Block Island a 13.3 m thick sequence of east-dipping sand beds may represent a delta.

In central Block Island, the cliffs contain up to 10 m of ice-contact rubble and outwash. Much of this material has been folded and thrusted by the Woodfordian ice. The outwash and related deposits are generally overlain by till. Till fabrics have a north-northwest to south-southeast preferred orientation (Sirkin, 1976). About 34 percent of the till stones are granites rich in K-feldspars. The fabric and rock type indicate a source in the granites of southeastern Connecticut and southern Rhode Island, and therefore, deposition from an Eastern Connecticut-Western Rhode Island Lobe of the glacier.

Moraines

The New Shoreham Formation mantles the Lighthouse Cove Formation throughout most of the Island. As discussed, the lower drift forms conspicuous high areas that may be relicts of Altonian moraines, so that the Mohegan Bluffs section incorporates a recessional moraine of Altonian age, draped over by ground moraine deposits of Woodfordian age. This Woodfordian drift is included in the envelope of the Beacon Hill Moraine in the absence of a Woodfordian end moraine south of Mohegan Bluffs (Fig. 3B and 3C). The Beacon Hill Moraine, which forms a prominent ridge across the southern half of the Island, marks the crest of the recessional envelope of the Eastern Connecticut-Western Rhode Island Lobe in southern Block Island and is the eastward continuation of the Prospect Hill Moraine of the Montauk Peninsula (Sirkin, 1981).

Deformation

The advancing Woodfordian glacier incorporated masses of pre-existing sediments into its bed load. Cretaceous and Altonian strata were ice-shoved and engulfed in the Woodfordian Isaacs Corner Sand. This outwash was also folded and thrusted. Because the ice rode on the outwash, the overlying till appears to truncate the sand with an angular unconformity, even though these deposits were derived from the same glacier. Thrusts occur on the Altonian drift occasionally with Cretaceous clay in the sole of the fault. High angle faults that cut through both drift sheets may be the result of collapse, resulting from melting of residual ice. The structural sense of the various expressions of deformation agrees with the direction of ice movement.

Woodfordian Recession

Meltwater from the ice at the Beacon Hill stand cut deep channels into the glacial deposits. In front of the ice lay small recessional deposits, kames. Now, erratics dot the surface and the shallows nearshore, and outwash gravels partially fill the channels, turning some of the valleys into elongate lakes.

A drumlin field occupies the central portion of the Island and gives the impression that a minor stand of the glacier was at some time overridden by a readvance. The drumlins exhibit both erosional and depositional features and are overlain by till and loess. The drumlin at Indian Head Neck is an erosional form, carved in a sequence of varve-like clay, silt, and fine sand rhythmites, with till and loess at the top. The nearly-horizontal beds are offset by high-angle faults that dip southward, due to ice shove or collapse. The rhythmite section probably represents proglacial lake deposition, with about 100 sets of beds preserved.

The drumlins and proglacial lake might have been formed during the advance of the Woodfordian glacier, or they may be the result of recession and minor readvance during deglaciation. Judging from the style and intensity of deformation associated with the main advance of the Woodfordian glacier as compared with the minor, ice-shove and collapse features and the size of the drumlins, fluctuation of the receding ice front seems a more likely mechanism in this case.

This readvance may also have enhanced the form of the depression in central Block Island that has become the Great Salt Pond. Embayments with this northwest-southeast orientation are also common in Long Island, for example, in the Montauk Peninsula where similar embayments are cut into an equally similar morainal setting. The Sandy Hill kame on the west side may also have been deposited as the ice receded from the Beacon Hill Moraine, or this deposit may have formed during the minor readvance. Kames also occur in similar positions with respect to embayments in western Long Island (Sirkin, 1981).

The ice receded to the position of the Corn Neck Moraine which forms an east-west ridge across northern Block Island and creates the hummocky topography of the northern portion of the Island. This moraine has its apparent western counterpart in the Shelter Island-Gardiners Island Moraine of Long Island (Fig. 3D). The deltaic sediments of the northeast coast of the Island may have been deposited during or just after this stand as the ice withdrew from the Block Island position.

In viewing the distribution of modern landforms, no additional moraines or islands appear in Block Island Sound between the Corn Neck morainal envelope and the Charlestown Moraine on the mainland Rhode Island coast. Perhaps glacial debris exists in the subsurface sediment of the Sound, but only lacustrine sediment, representing deposition in a proglacial lake dammed between the end moraines and the mainland ice, is reported (Bertoni and others, 1977). In any case, a fairly thick loess blanket covers Block Island, particularly in the north, where up to 1.5 m of silt have been observed. Periglacial phenomena, such as solifluction, have also been seen in cellar excavations.

Pollen Stratigraphy and Environments

The oldest Pleistocene pollen data for Block Island are derived from the rhythmites in the Indian Head Neck Section, as reported by Sirkin (1976). A few specimens of pine, birch, willow, alder, sedge, grass, Polygonum, Dryas (?) pollen in these sediments suggest that tundra existed in Block Island even as the ice receded to the Corn Neck position. Thus, a Late Woodfordian herb pollen zone with an age in the 20,000 yr B.P. range (a median age for the Woodfordian glaciation) may be inferred for Block Island. The late- and postglacial pollen record has been obtained from bog core samples. The sites, one in the southern morainal envelope and one in the north, have yielded a pollen zonation comparable to that of southern New England and southern New York. The record begins with the late-glacial herb pollen zone which is interpreted from pollen spectra in the basal sediments of the southern bog, the Great Swamp. The spruce, pine, and oak pollen zones are found consecutively in both sections (Sirkin, 1976).

While the age of the rhythmites and of the basal Great Swamp sediments can only be approximated, a radiocarbon-dated pollen record has been obtained from a peat bog exposed in section by erosion along the northeast coast. The pollen record contains at the base, herb pollen zone spectra characteristic initiall of a shrub tundra and then succeeded by a park tundra sequence (James Cotter, personal communication, 1979). Spruce, pine, and oak zone spectra follow the herb zone. A sample from the upper part of the spruce zone has an age of 11,900 $\pm$ 100 yr B.P. (W-4312, Meyer Rubin, personal communication, 1979).

Summary

The Pleistocene history of Block Island is interpreted from evidence that includes two drift sheets, moraines and surface features. The older drift which is placed in the Altonian Glacial Substage of the Wisconsinan Stage, was apparently deposited by the Narragansett Lobe of the glacier. During the Woodfordian Substage, the younger glacial lobe came from a more north-northwesterly direction. Both ice sheets formed end moraines and recessional moraines in the vicinity of Block Island. Two recessional morainal envelopes separated by a zone of glacial fluctuation form the Island's dominant topography. Excellent sea cliff exposures reveal the superposition of the Altonian and Woodfordian glacial sediments and the structural complexities of glacial tectonics. The Island was probably deglaciated and ice free in mid-Woodfordian time, around 20,000 years ago. A loess blanket of varying thickness mantles the glacial deposits. The record of vegetation begins with tundra, which was probably established during deglaciation. Spruce, pine, and oak forests succeeded the tundra. Postglacial geologic processes have modified the Island's topography, especially in the coastal zone.

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Itinerary

The field trip to Block Island will leave from the State Ferry Dock at Point Judith, Rhode Island. The ferry trip to Block Island takes about 1-1/2 hours. As we approach Block Island, and the northeast cliffs come into view, sketch in the geology, as you see it, on the sketched topographic profile (Fig. 2).

Distance (In Miles)		Route and Stops
Point to Point	Total	
0	0	Arrive at Old Harbor, Block Island, ferry landing. Board bus. Leave parking lot, turn south on Water Street, proceed counterclockwise 180° around the glorietta, a statue of the temperance symbol, Rebecca. Follow Spring Street southward. Pass the Spring House Hotel on west side, note pond on the east side. Spring fed pond sits on a bench on Cretaceous lignite and clay. Follow Spring Street into Southeast Light Road. The road ascends the morainal surface- scenic hummocky topography with cottages on hilltops- as it crosses the Beacon Hill morainal envelope. Pass the Southeast Lighthouse.
1.9	1.9	Stop 1. Mohegan Bluffs. The trail down the cliffs to the beach cuts across the Woodfordian New Shoreham Formation (till and outwash) and the Altonian Mohegan Bluffs Till section. From the beach the complex stratigraphic and structural relationships can be discussed. Note the sense of deformational axes, color differences between and within the drift sheets, infilling around Altonian clasts by Woodfordian sediments, the probable contact between the drift sheets, and the variety of till stone and erratic rock types. Return to bus.
1.2	3.1	Proceed westward on Mohegan Trail to Lakeside Road.
1.2	4.3	North on Lakeside Road. Pass Fresh Pond, a lake in a meltwater channel, probably dammed by outwash gravel, on the west side of the road. Turn west on Cherry Hill Road.
0.8	5.1	Stop 2. Rodman's Hollow. This is a south trending meltwater channel. The channel is over-deepened in the near distance, plugged with gravel at the southern end at Tom's Point. Small hills adjacent to channel are probably kames. Trace the channel northward on the distal slope of the Beacon Hill Moraine. Return east on Cherry Hill Road

		to Center Road. North on Center Road to gravel pit.
1.0	6.1	Stop 3. Block Island Gravel Pit. The excavation is mainly in the New Shoreham Formation (Old Town Till, Isaacs Corner Sand). Occasionally, masses of Altonian sediments are seen in the core of the excavations. Note soil profile developed on loess over till.
0.8	6.9	Proceed on Center Road northward to Beach Avenue.
		Take Beach Avenue east to Harbor Road intersection.
0.4	7.3	Stop(s) 4. Scenic views at this stop of the drumlin field, with cottages and homes on the hilltops. Look southward at the proximal slope of the Beacon Hill Moraine. Note DOE windmill southeast of the corner of Beach Ave. and Ocean Ave. Great Salt Pond and New Harbor are north of this intersection.
0.8	8.1	Continue east on Beach Road. Turn north on Corn Neck Road. Follow Corn Neck Road northward. The road follows the tombolo and then crosses the envelope of the Corn Neck Moraine. Great Salt Pond lies to the west of Corn Neck Road.
4.4	12.5	Stop 5. Settler's Rock. A monument to the Island's colonists of 1661. Note dune field to the north and west; spit prograding northward beyond the North Lighthouse; Rhode Island mainland to the north. Look southward toward the proximal slope of the Corn Neck Moraine.
2.0	14.5	Return southward on Corn Neck Road to Crescent Beach Road.
0.5	15.0	Crescent Beach Road east to Mansion foundation.
0.5	15.5	Walk to Ball's Cove along beach below northeast cliffs.
		Stop 6. Wave cut late-glacial bog. Ball's Cove.
		Stop 7. Ball's Cove-Ball's Point. Sea cliff exposure. Note New Shoreham Formation over Lighthouse Cove Formation (check your sketches). Note south dipping thrust on Cretaceous clay; "Pots and Kettles", outwash gravel cemented by groundwater piping.
0.5	16.0	Return to Mansion.

0.5	16.5	Return to Corn Neck Road. Follow Corn Neck Road south to Indian Head Neck.
1.2	17.7	Stop 8. Indian Head Neck Rhythmites. Very fragile section. Do not dig. Note view of Harbor, moraines to north and south. Return to Corn Neck Road. Turn South. Turn east on Dodge Street at intersection. Turn south on Water Street and east at entrance to ferry parking lot.
1.8	19.5	End of trip. Ferry to Point Judith.