(Rkiz), and the youngest ones are in the south (Ferlo).

Sea-level data are also plotted in terms of distance from the present coast (Fig. 2c). This transect profiles the geoid at different times and shows little change in the parallelism of successive geoid surfaces. From 6500 years B.P. to the present, the tilting seems less than ± 1 m. No clear evidence of crustal tilting is observed for more recent geoids.

In conclusion, if the slight emergence simulated by models is in any way evident in this 120-km transect of West Africa, its seaward tilting is limited. This result seems to imply that the lithosphere is more rigid than has been assumed in models.

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Upper Wisconsinan Till Recovered on the Continental Shelf Southeast of New England

Abstract. *Basal till was identified in two sediment cores collected about 69 kilometers southeast of Nantucket Island on the east and west sides of Great South Channel. These are the first samples of till collected on the outer continental shelf off the northeastern United States. The carbon-14 age of the total organic carbon in the tills provides a "no older than" age of about 20,000 years before present and suggests that the tills were deposited during the late Wisconsinan glaciation. This conclusion is in support of the hypothesis of an extensive Laurentide ice sheet that extended to the northern side of Georges Bank.*

A number of features on the continental shelf off the northeastern United States have been cited as evidence for Pleistocene glacial ice in areas seaward of the present shoreline. The location of gravel in surface sediments has been used to estimate the southern limit of glacial ice on Nantucket Shoals and along the northern edge of Georges Bank (*1*). Moraine-like features have been observed in high-resolution, seismic-reflection profiles of the shelf south of Martha's Vineyard (*2*). Glacial ice in the Gulf of Maine has been inferred from the morphology of the deep closed basins in the central area of the gulf (*3*) and from the morphology of Northeast Channel, which resembles a glaciated valley (*4*).

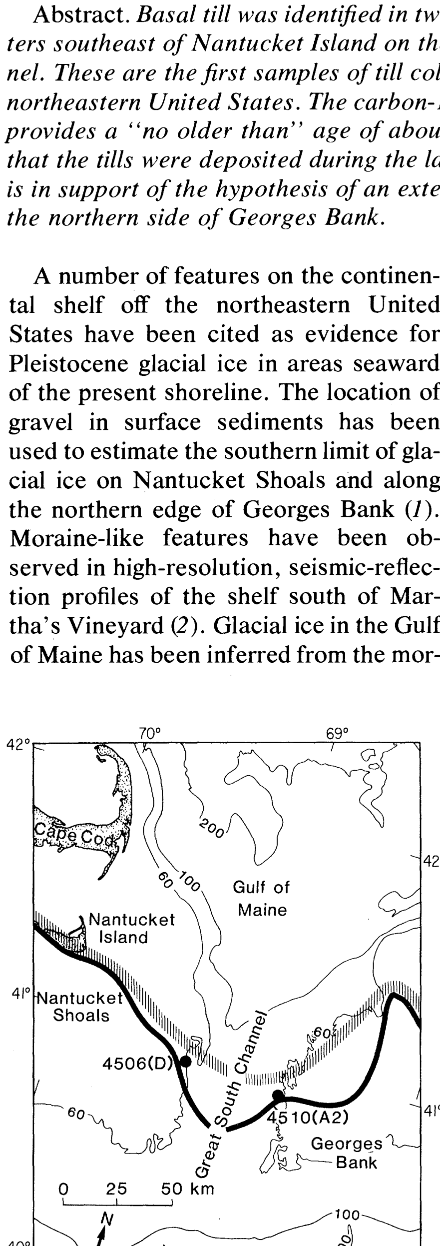

Fig. 1. The locations of vibrocores on the east and west sides of Great South Channel are indicated by the black circles. The heavy line designates the southern limit of abundant gravel, and the vertical series of short lines indicates the southern limit of probable late Wisconsinan ice advance (*1*). Bathymetric contours are in meters.

The glacial features presently recognizable on the continental shelf are generally assumed to be of late Wisconsinan age because multiple regressions and transgressions of sea level would have tended to obliterate evidence of earlier glaciations. Evidence confirming the existence of late Wisconsinan ice on the continental shelf off New England is lacking, however, because ice-contact sediments have not been recovered for dating.

The presence of late Wisconsinan ice seaward of Cape Cod is documented from reworked, carbonitized wood found in glacial outwash on the outer cape. The wood has a radiocarbon age of 26,000 ± 2,000 years before present (B.P.) (*5*) and gives a maximum age of the last advance of ice. On Martha's Vineyard, leaves in clay stratigraphically below till are dated at 15,300 ± 800 years B.P. (*6*).

We describe here till recovered in two sediment cores (*7*) from the continental shelf southeast of Nantucket Island at water depths of 49 and 60 m (Fig. 1). We discuss the interpretation of ^{14}C ages determined on the total organic carbon in these sediments.

The sediment texture throughout core 4506(D) is similar to that of till. Samples consist primarily of sand, but measurable quantities of gravel, silt, and clay are also present (*8*). Scattered subangular and subrounded cobbles, as much as 8 cm in diameter and having sharp irregular edges, were found in this

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Table 1. Radiocarbon ages of organic carbon in glacial till from the continental shelf off southeastern New England.

Depth in core (cm)	Laboratory No.	Bulk density (g/cm³)	Total organic carbon (%)	^{14}C age (years B.P.)	Estimated coal and graphite* (%)	Corrected ^{14}C age (years B.P.)
			Core 4506(D); water depth, 49 m			
120 to 150	W-3968	1.9	0.11	20,350 ± 450	10	19,500
195 to 225	W-3899	1.5	0.20	30,800 ± 700	10	30,000
413 to 438	W-3890	2.2	0.15	28,700 ± 700	20	26,900
555 to 583	W-3883	2.1	0.15	35,300 ± 1,100	10	34,500
			Core 4510(A2); water depth, 60 m			
449 to 479	W-3953	1.7	0.24	26,600 ± 500	25	24,290

*As a percentage of the total organic carbon.

core. The sorting of this material (Fig. 2) (>3.0 ϕ units) is poorer than the sorting measured in tills on Cape Cod [2.3 ϕ units (*9*)] or in southern Massachusetts [2.9 ϕ units (*10*)].

The surfaces of most quartz sand grains are shiny and have sharp irregular edges. Geotechnical measurements indicate that the sediments in this core are precompressed by pressures equivalent to a weight of 15 m of ice (*11*); this compression is evidence against the possibility of deposition by ice-rafting. On the basis of texture, poor sorting, the angularity of sediment grains, and results of precompression tests, we conclude that the section of sediment recovered in core 4506(D) is basal till.

In core 4510(A2) the upper 400 cm of sediment contain well-sorted sand and gravel with less than 7 percent silt plus clay (*8*). At a depth of about 430 cm, the clay and silt content increases to more than 45 percent. In the interval from 430 to 450 cm, the sorting (Fig. 2) and the biomodal distribution of sand, silt, and clay are very similar to those of the till in core 4506(D). Till is also present in the lower 20 cm of this core.

Throughout most of the till of both cores, calcareous and siliceous fossils are absent, which suggests nonmarine deposition. However, in a sample at 580 cm in core 4506(D), the following poorly preserved fossils were found in very low concentrations: calcareous nannofossil *Transversopontis* aff. *pulcher* (*12*) of Paleocene and Eocene age, bryozoan colonies associated with glauconite, shallow-water marine benthic foraminifers of probable Pleistocene age or younger, mollusk shell fragments, and fish teeth (*13*). We interpret this fossil material to be glacially reworked from Eocene sediments similar to those found in drilled cores on the northern margin of Georges Bank (*14*) and in outwash of outer Cape Cod (*5*).

Material conventionally used for ^{14}C dating such as wood, peat, or shells was absent in the till, and therefore ^{14}C measurements were made on the total organic carbon contained in the sediment (Table 1) (*15*); the ages ranged from about 20,000 to 35,000 years B.P. The oldest date in core 4506(D) occurs at the deepest level of the core in till containing reworked Eocene fossils and possibly reworked organic carbon from the same period.

There are several sources of error associated with the use of total organic carbon for dating this till. The origin of the organic carbon in the till is somewhat uncertain. It was probably derived from soils and plant material in the path of the glacier and incorporated into the till during the ice advance. Recent soils typically have ^{14}C ages of at least 1000 years (*16*). Fossil soil and plant remains may also have been incorporated into the till. The till obviously contains some coal and graphite of presumably infinite ^{14}C age. We estimated (*17*) the elemental carbon content of each dated horizon and corrected the ^{14}C ages for its effect (Table 1). In view of these sources of error, the dates are interpreted as an upper limit for the time of deposition. Thus the youngest date gives the best estimate of the age of the till, suggesting that it is no older than 20,000 years and is of late Wisconsinan age.

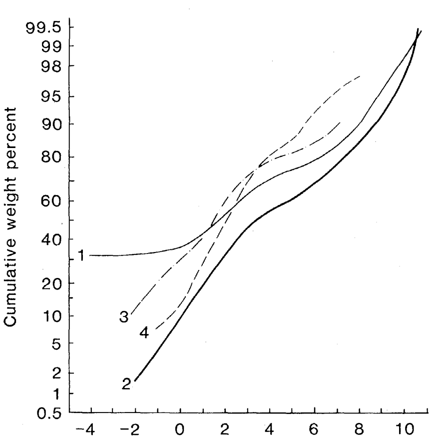

Fig. 2. A set of cumulative grain size curves: curve 1, core 4506(D), 500 cm; curve 2, core 4510(A2), 449 to 479 cm; curve 3, till from southern Massachusetts (*10*); and curve 4, till from Cape Cod, Massachusetts (*9*); ϕ is $-\ln_2$ (grain diameter in millimeters).

Another potential source of contamination is younger roots and humic material from a subsequent forest. There is evidence of forest growth on Georges Bank during the last low stand of the sea level. Pollen from spruce, fir, and pine was identified in peat dredged from the northern side of Georges Bank that has a ^{14}C age of about 11,000 years B.P. (*18*). Although spruce and fir have an estimated maximum root penetration of less than 1 m, pine has a tap root that may extend considerably farther.

Root penetration is significantly retarded in tills that are precompressed. Root penetration is retarded in sediments with a bulk density of 1.5 g/cm³, and root penetration is prevented in sediments with bulk densities of 2.0 g/cm³ or more (*19*). The bulk densities of the cored sediments range from 1.5 to 2.2 g/cm³ (Table 1) and suggest minimal root penetration, particularly in the lower section. In addition, the till may have been buried at the time of forest growth by additional overburden, which was later eroded away during transgression of the sea; therefore, the till may have been even farther away from a root horizon.

The possibility of pine-root penetration as well as of the percolation of soluble organic carbon through the till along joints or other zones of weakness cannot be ruled out, although joints were not evident where the core sections were sampled. The magnitude of the effect of this relatively young carbon is potentially significant because of the low organic carbon content of the till. For example, if infinitely old carbon were contaminated by a 25 percent component of 11,000-year-old carbon, the resultant ^{14}C age of the mixture would be approximately 22,000 years. Because such a mixture could be responsible for the observed ^{14}C dates, we cannot conclude without reservation that these ages are simply upper limits. However, on the basis of the bulk density data discussed above, the absence of joints, and the fact that the section exhibited no roots, peat, or organic-rich horizon, we believe that these sediments are not contaminated with young carbon.

The ^{14}C ages on the total organic carbon in till from two locations on the continental shelf southeast of Nantucket Island suggest that at least part of the texturally correlated ice limit (Fig. 1) is a result of the late Wisconsinan glacial advance. This conclusion also is in support of the hypothesis (*20*) of an extensive Laurentide ice sheet that may have extended to Georges Bank during the late Wisconsinan.

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War Gases as Olfactory Probes

Abstract. *The tear gas ethyl bromoacetate is a fruity-smelling alkylating agent that blocks the ability of the frog nose to respond to esters and a variety of other odorants, but leaves sensitivity to amines unimpaired. Lachrymators and chemical warfare agents of other functional types such as sulfides (mustard gas) and amines (nitrogen mustards) may have similarly specific actions that will enable their use as chemical probes of the sense of smell.*

The initial step in odor recognition by the nose is the momentary binding of odorant molecules to receptor sites embedded in the dendritic membranes of olfactory receptor cells. The interaction between odorant molecules and at least some receptor sites must be highly specific, because humans and animals can discriminate odorants with a high degree of chemical similarity, for example between optical isomers of the same compound (*1*). Even single olfactory receptor cells respond differently to molecules as similar as ethyl and methyl acetate (*2*), propanol and butanol (*3*), or stereoisomers of the same complex alcohol molecule (*4*).

The physiological function and biochemistry of receptor proteins is most effectively studied when specific and irreversible inhibitors are available for use as chemical probes, for example, when α-bungarotoxin is used to inhibit and tag acetylcholine receptors (*5*). Getchell and Gesteland (*6*) pioneered studies of olfactory receptors using the group-specific sulfhydryl reagent *N*-ethylmaleimide (NEM). The NEM blocked the electrical responses of the frog olfactory epithelium to a variety of odors, presumably by inactivating receptor proteins through attack on sulfhydryl groups near the odorant binding site. When the fruity-smelling ester ethyl-*n*-butyrate was applied before and during NEM treatment, responses to it and to similar esters were maintained and those to dissimilar odorants abolished (*7*).

We adopted Getchell and Gesteland's approach, but searched for reagents that would not require application in liquid solution and would not require the simultaneous application of other chemicals to protect specific receptor sites from the effects of the inhibitor. Vaporous inhibitors are preferable for olfactory studies since application of any liquid agent to the olfactory mucosa impairs responses to odors for a time and prevents monitoring the progressive effect of the inhibitor. We used volatile alkylating agents from a novel source—obsolete war gases of pre–World War II vintage. The agent most studied to date, ethyl bromoacetate, inhibits olfactory responses in a specific and unexpected way.

More than 50 different chemical agents were tested for antipersonnel use during World War I (*8*). Many are alkylating agents that attack proteins by forming covalent bonds with sulfhydryl and amino groups (*9*). We sought chemical agents with distinctive odor qualities associated with the functional groups they contain, expecting that such agents would more selectively attack receptors for those specific odor qualities (*10*). Ethyl bromoacetate (EBA) was chosen for our first tests because it is a fast-acting tear gas with a high vapor pressure and an identifiable fruity odor. We reasoned that a fruity-smelling alkylating agent should preferentially bind to receptors for fruity-smelling compounds and deactivate them, leaving responses to other classes of odorants unaffected. Haloacetates such as EBA have been widely used for modification of enzymes and other proteins. They are much more reactive to sulfhydryl groups than amino groups (*11*), and in this regard are similar to NEM.

Electroolfactogram (EOG) potentials of the frog (*Rana pipiens*) olfactory epithelium were recorded with an automatic, programmable stimulating and recording system (*12*). The system delivered 0.5-second test pulses of a reference odorant, isoamyl acetate, at 100-second intervals. Frogs were immobilized with curare, and EOG responses were detected with Ag-AgCl Ringer-agar-filled glass electrodes in contact with surface of the surgically exposed olfactory mucosa (*13*).

The EOG response recorded at the epithelial surface is a mass potential or summated d-c voltage change composed of many individual receptor potentials produced by tens to hundreds of olfactory neurons in the vicinity of the recording electrode (*14*). Single 0.5-second pulses of a variety of odorants—including alcohols, aldehydes, amines, esters, ketones, organic acids, and sulfides—generally produced EOG amplitudes of 2 to 6 mV. A typical experiment included a 40- to 60-minute period of stimulation with the reference odorant (0.5-second test pulses at 100-second intervals) until a stable baseline (amplitude variation of

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