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Evidence for Age and Evolution of Corner Seamounts and Great Meteor Seamount Chain From Multibeam Bathymetry

BRIAN E. TUCHOLKE

Woods Hole Oceanographic Institution, Woods Hole, Massachusetts

N. CHRISTIAN SMOOT

U. S. Naval Oceanographic Office, Stennis Space Center, Mississippi

The Corner seamounts in the western North Atlantic and Great Meteor seamount "chain" in the eastern North Atlantic are thought to progress in age from Late Cretaceous through late Cenozoic. They both presumably formed by volcanism above the New England hotspot when first the North American plate, and then the Mid-Atlantic Ridge axis and African plate, moved over the hotspot. High-resolution, multibeam bathymetry of the seamounts shows geomorphic features such as guyots, terraces, and a base level plateau (Cruiser plateau) that we interpret to have formed at sea level. We have backtracked these features to sea level along the North Atlantic crustal age-depth curve in order to estimate their ages. The derived age pattern of volcanism indicates formation of the Corner seamounts at ca. 80 Ma to 76 Ma, with migration of the Mid-Atlantic Ridge plate boundary over the hotspot and formation of the Cruiser plateau about 76 Ma. Seamount ages suggest that subsequent volcanism on the African plate moved first northward, in the Late Cretaceous to early Cenozoic (Plato, Tyro, and Atlantis seamount groups), then southward to Great Meteor Seamount in the late Cenozoic. Recurrent volcanism appears to have occurred at some seamounts up to 20-30 m.y. after their initial passage over the hotspot. It would thus appear that intralithospheric conduits can link the hotspot to old seamounts several hundred kilometers away.

INTRODUCTION

We have known for more than 30 years that the floor of the Atlantic Ocean exhibits numerous large seamounts [*Heezen et al.*, 1959] (see *Epp and Smoot* [1988] for a recent summary). Most existing knowledge of these seamounts is based on scattered echo sounding and seismic lines and, in a very few places, on detailed surveys. Sampling of the seamounts likewise is limited, but it has recovered both basaltic igneous rocks and sedimentary samples from the sedimentary caps that sometimes are present, particularly on flat-topped guyots. Most of the recovered igneous rocks have been exposed to seawater for long periods of time and are highly altered. Consequently, accurate radiometric age dating of the samples is difficult, and the derived geochronometric ages can be subject to large uncertainties. Samples of the sedimentary caps are useful in providing minimum ages for the seamounts, but it usually is difficult to estimate the period of time that elapsed between emplacement of the igneous rock and accumulation of the sampled sedimentary record. Despite the lack of detailed data on most seamounts, enough information exists to suggest general ages or age trends; these data have been used to predict larger-scale age relationships in the context of specific models for the origin of seamounts, particularly those seamounts found in linear chains. A number of models have been proposed for the origin of North Atlantic seamounts [*Vogt and Tucholke*, 1979]; the most successful models have been those that attribute formation of the seamount chains to passage of the lithosphere over a mantle plume or hotspot [e.g., *Morgan*, 1972, 1981; *Duncan*, 1984].

The best developed and best known seamount chain in the North Atlantic is the New England seamount chain (Figure 1). It appears to have formed as the North American plate migrated west-northwestward over the New England hotspot during the Cretaceous period. Radiometric age dating of seamount samples reported by *Duncan* [1984] suggests that a linear migration rate of 47mm/yr best fits the seamount age distribution and that the seamounts range in age from about 103 Ma in the west (Bear Seamount) to about 82 Ma at their southeastern terminus (Nashville Seamount). Although separated from the New England seamounts, the Corner seamount group farther east (Figure 1) also is interpreted as having been formed above the New England hotspot. The Corner seamounts have been thought to date to about 75-70 Ma, and they would thus fall along the same age-distance trend as the New England seamounts [*Duncan*, 1984]. Hotspot models such as those of *Duncan* [1984] and of *Morgan* [1983] predict that the westward migrating Mid-Atlantic Ridge axis overrode the New England hotspot in Late Cretaceous time; thereafter the hotspot volcanism formed seamounts on the African plate. Late Cretaceous to Recent absolute motion of the African plate with respect to the mantle is thought to have been slow and in a generally northerly and then easterly direction [*Morgan*, 1983; *Duncan*, 1984]. The volcanic edifices of the Atlantis, Plato, Tyro, Cruiser, and Great Meteor groups of seamounts, which form the Great Meteor "chain" (Figure 1), presumably were constructed above the New England hotspot during this period.

The above models imply that there should be an age progression toward younger volcanism from north to south on the African plate, terminating in the vicinity of Great Meteor Seamount. K-Ar ages on two volcanic samples from Great Meteor have been reported as 11 Ma and 16.3±0.4 Ma by *Wendt et al.* [1976]. *von Rad* [1974] deduced from study of carbonate sands that the flat summit of Great Meteor Seamount was in shallow water from late Miocene to early Pliocene time (<11 Ma). Seamounts farther north in the Great Meteor "chain" presently have no direct age data, although an indirect

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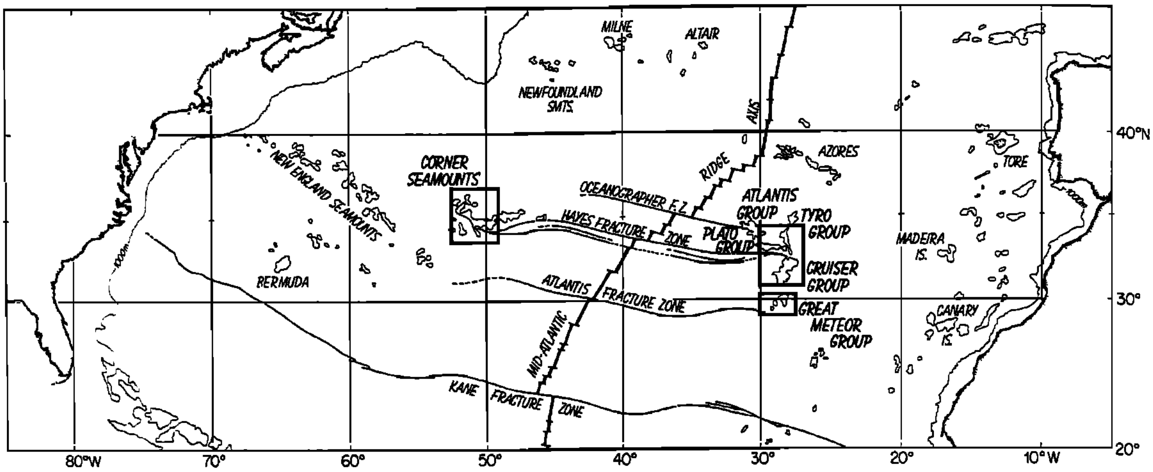

Fig. 1. Sketch map showing locations of major seamounts and volcanic islands in the North Atlantic and the positions of the Corner seamounts and eastern Atlantic groups of seamounts with respect to the Hayes Fracture Zone. Small boxes show the areas depicted by detailed bathymetry in Figures 2-4.

age determination has been noted for Hyeres Seamount. *Fermont and Troelstra* [1983] reported larger foraminifera of late Aquitanian/early Burdigalian age (ca. 23-19 Ma) in a turbidite bed that was piston-cored 50 km west of the seamount. It is likely that the foraminifera were derived from sediments deposited in shallow water (<50 m) on Hyeres' summit.

Verhoef [1984] made indirect age estimates of seamounts in the Great Meteor "chain" based on the relations between age and elastic thickness of the lithosphere as described by *Bodine et al.* [1981]. His greatest estimated age was 65 Ma for the Cruiser group of seamounts; estimated ages of most of the remaining seamounts, including Great Meteor, were in the range of 38-47 Ma. Subsequently, *Verhoef and Collette* [1985, 1987] recognized that these ages probably are too large because they do not consider effects of lithosphere thinning and thermal rejuvenation at the time of seamount formation [*Detrick and Crough*, 1978]. *Verhoef and Collette* [1985] also used age-depth backtracking to determine maximum ages of several seamounts in the Great Meteor "chain", with derived ages ranging from 37 to 23 Ma. There are large uncertainties in the ages derived in all these studies, so the presence or absence of age-progressive volcanism has been unresolved. However, *Verhoef and Collette* [1987] preferred the concept of generally simultaneous volcanism, possibly as a response to change in plate stress patterns, and they assumed an age of 22 Ma for the bulk of the seamount complex.

It is possible significantly to improve our understanding of the origin and age of these seamount groups through examination of their morphology, depths, and associations with one another in plate kinematic reconstructions. Consequently, we have studied detailed multibeam bathymetry over the Corner, Plato, Tyro, Cruiser, and Great Meteor seamount groups (Figures 1-4), obtained through swath-mapping surveys of the U.S. Naval Oceanographic Office. Aspects of the sonar data acquisition system have been discussed by *Smoot* [1986]. Navigation in the surveys was produced by merging inertial and satellite navigation with speed logs to produce accurate positioning.

We also examined plate kinematic reconstruction of the Corner and Cruiser seamounts to their Late Cretaceous positions along the Mid-Atlantic Ridge crest, based on the plate motion studies of *Klitgord and Schouten* [1986]. The two seamount groups lie in conjugate positions along the Hayes Fracture Zone. Although the fracture zone consisted of a single fracture valley at the time that the Corner and Cruiser seamounts were formed in Late Cretaceous time, it subsequently evolved into a triplet of fracture valleys in response to changes in relative plate motion (Figure 1; B.E. Tucholke and N.C. Smoot, manuscript in preparation, 1990).

In the ensuing discussion we briefly describe the morphology of the Corner and Cruiser seamounts, and we derive the apparent age (based on age-depth relations) of seamount geomorphic features that are thought to have formed at sea level. From these data we examine the patterns of volcanism in the seamount groups and consider the question of age-progressive volcanism above the New England hotspot. We conclude that the pattern of volcanism is consistent with sequential formation of the New England, Corner, and the Great Meteor "chain" seamounts above the New England hotspot. However, Late Cretaceous and Cenozoic absolute motion of the African plate over the hotspot differs significantly from predictions of existing hotspot models.

SEAMOUNT MORPHOLOGY

Corner Seamounts

The Corner seamounts (Corner Rise) lie between about 34°N to 37°N and 47°00'W to 52°30'W (Figure 1). The seamounts are positioned mostly along the north side of the Hayes Fracture Zone, and in large part they parallel the fracture zone (Figure 2). The main volcanic edifice in the east central region is an east-west trending ridge near 34°45'N; it parallels the Late Cretaceous seafloor spreading direction and supports a series of four peaks (Figure 2). The two largest of these seamounts (9 and 11) have rounded tops and they rise to less than 600 fm (1100 m) depth. Both seamounts have terraces developed in their flanks at depths of about 1000-1100 fm (1875-2060 m).

At the western end of the ridge is another well-defined, linear ridge that extends across the Hayes Fracture Zone at an orientation of N25°W (Figure 2). This ridge is more than 230

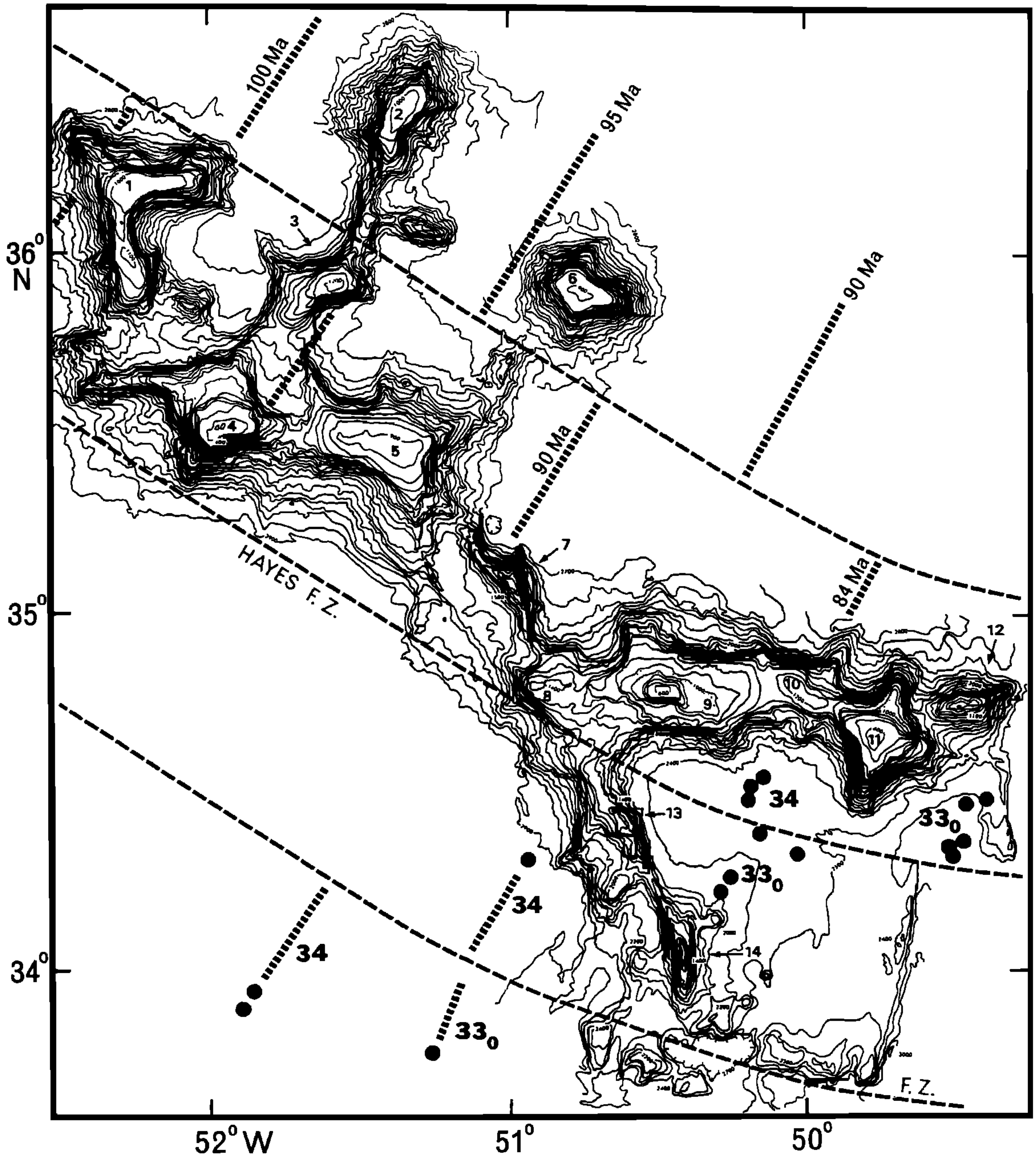

Fig. 2. Bathymetry of the western Corner seamounts from multibeam swath mapping. Depths are in uncorrected fathoms with a 100-fm (~190-m) contour interval. Magnetic anomaly identifications for both observed and rotated anomalies (bold dots and labels) are from *Klitgord and Schouten* [1986]. Seafloor isochrons (short-dashed lines) older than anomaly 34 (84 Ma) are interpolated between anomalies 34 and M0; all anomaly ages are taken from the DNAG time scale [*Kent and Gradstein*, 1986]. Long-dashed lines are plate flowlines from Klitgord and Schouten (1986). The southern two flowlines approximate the location of the Hayes Fracture Zone and an unnamed fracture zone; the exact position of a fracture zone in the vicinity of the northern flow line is uncertain. Seamounts are numbered as in Table 1. Stippling highlights terraces around seamounts 4, 9, and 11.

km long, reaching from 33°50'N to 35°40'N. The crests of peaks along the southern part of the ridge are at depths of about 1400 fm (2620 m). The northwest end of the ridge is imbedded within another group of seven major seamounts and connecting ridges. These latter features have WNW and NNE to NE trends, generally parallel and orthogonal to the direction of seafloor spreading at the time (Figure 2). Flat-topped seamount crests in this area are common, and they are at 840-1160 fm depth (1580-2180 m). Seamount 4 has a terrace at similar depth (1000 fm) (1875 m), but its crest is rounded and reaches to 400 fm (750 m). There is little seismically detectable sediment cover on any of the Corner seamounts [e.g., *McGregor et al.*, 1973], so the depths cited represent the depths of the volcanic crust.

The two linear volcanic ridges in the southeast part of the Corner seamounts form a morphologic bight that opens to the southeast and has seafloor depths of 2400-2500 fm (4525-4720 m; Figure 2). Sediment thickness within this bight is up to 400-500 m (*McGregor et al.*, 1973; *Tucholke et al.*, 1982). We can approximate the unloaded depth of oceanic basement

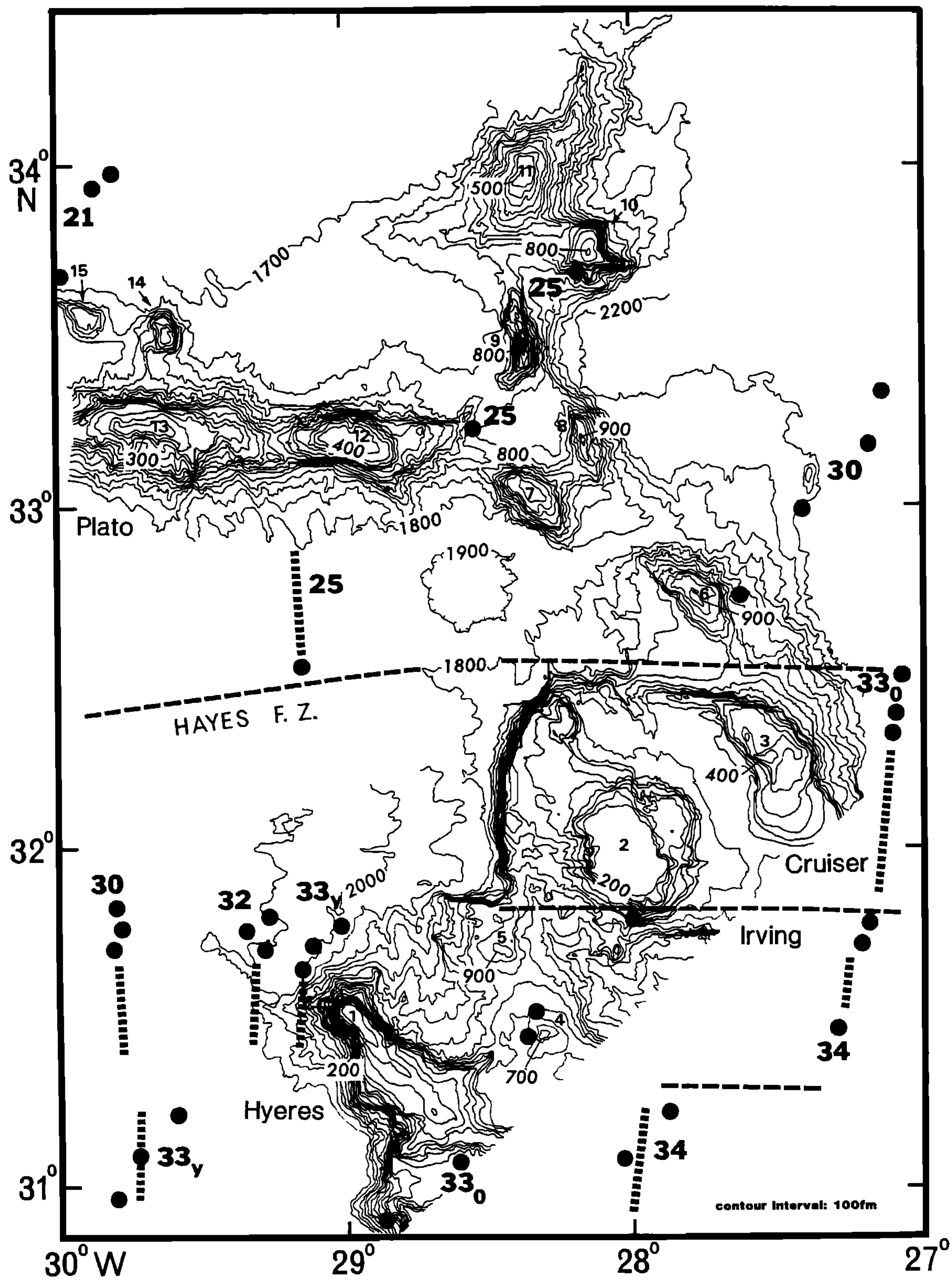

Fig. 3. Bathymetry of the Cruiser plateau, south of Hayes Fracture Zone, and adjacent seamounts as determined by multibeam swath mapping. Depths are in uncorrected fathoms with a 100-fm (~190-m) contour interval. Magnetic anomaly identifications (bold dots and labels) are from *Klitgord and Schouten* [1986]. Plate flow lines from Klitgord and Schouten (long dashes) approximate the location of the Hayes Fracture Zone and a probable fracture zone just south of Irving Seamount. Seamounts are numbered as in Table 2.

by adding 0.6 times sediment thickness to the water depth [*Crough*, 1983], giving a corrected basement depth of between 4800 and 5000 m. Similar considerations indicate that unloaded basement depth around the seamounts to the northwest would be about 5300-5500 m.

Although there is some sediment cover to mask trends, the fabric of normal oceanic crust can be observed at the southeastern corner of the map in Figure 2. In this area a steep, east facing scarp runs N10°E for more than 70 km. This orientation is parallel to the Late Cretaceous axis of the Mid-

Atlantic Ridge. At the southern edge of the contoured area, two short ridges and an intervening deep trend orthogonal to the scarp; we interpret these features as defining a fracture zone (Figure 2).

Eastern Atlantic Seamounts

The area studied in the eastern North Atlantic includes several groups of seamounts (Figures 1, 3, and 4). We refer to the large, central group just south of Hayes Fracture Zone (Figure 1) as the Cruiser seamount group. It includes three major peaks as shown in Figure 3: Hyeres Seamount in the southwest (crestal depth 160 fm, or 300 m); the large, flat-topped Irving Seamount in the north central area (140 fm; 265 m); and Cruiser Seamount in the northeast (390 fm, 735 m). All three of these seamounts, as well as several subsidiary peaks, sit atop an oceanic plateau (Cruiser plateau). The mean, unloaded depth of this plateau is difficult to determine because the plateau locally has accumulated large thicknesses of sediment between the major seamounts (Figure 5) [*Verhoef*, 1984; *Luyendyk et al.*, 1979]. By applying an average sound velocity of 2.0 km/s to observed reflection time thicknesses of sediment, and correcting for crustal loading by sediments as noted earlier, an average base level of the plateau of the order of 2400-2600 m is indicated.

There are two other levels at which terraces and seamount crests generally occur on Cruiser plateau. One level is at about 850 fm (1600 m). Both Irving and Cruiser seamounts have marked breaks in slope that, on average, appear to define terraces in this depth range (Figure 5). Two small seamounts (4 and 5, Figure 3) on the central Cruiser plateau have roughly similar peak depths. At a shallower level, the crest of Irving Seamount is nearly flat, and this volcanic feature can be considered a guyot or tablemount. It and the rounded crest of Hyeres Seamount mark another important bathymetric level at 140-160 fm (265-300 m). These terraces and seamount crests are mostly unsedimented (Figure 5), so their depth values reported here include negligible correction for sediment loading.

Immediately northwest of the Cruiser seamounts are the Plato seamounts, which as a group trend 5°-8° north of west (Figures 1 and 3). Plato Seamount has a minimum depth of 260 fm (490 m) and its eastern neighbors, seamounts 12 and 7, reach 360 fm (680 m) and <760 fm (<1430 m), respectively. The eastern end of the Plato seamounts is abutted by a linear series of three smaller seamounts that together trend N35°W (Figure 3). These seamounts are the southern part of the Tyro group, and they are colinear with the northeastern margin of Cruiser plateau. The large seamount at 34°N (seamount 11) and its companion to the southeast (seamount 10) are not on the same trend as the smaller seamounts to the south. Seamount 11 and Tyro seamount at 35°N (off the map in Figure 3) define another linear trend of about N35°E, roughly 70° to the trend in the southern part of the Tyro group.

The Atlantis seamounts lie just northwest of the map in Figure 3. They consist of a group of at least 10 peaks ranging in depth from about 1500 m to less than 500 m [*Verhoef*, 1984]. Their detailed geomorphology was not examined in the present study.

Great Meteor Seamount lies 150 km south of the Cruiser plateau and is a large, flat-topped guyot with a minimum crestal depth of 145 fm, or 275 m [*Ulrich*, 1971] (Figure 4). Great Meteor is capped by a sedimentary section about 400 m thick [*Hinz*, 1969]. It is flanked on the southwest by two smaller seamounts, the closer of which (Little Meteor) is also flat-topped and has a minimum depth less than 160 fm (300 m). These seamounts represent the southernmost volcanic peaks along the Great Meteor seamount "chain".

All the eastern Atlantic seamount groups discussed above occur on a broad basement swell on the flank of the Mid-Atlantic Ridge. The average depth anomaly of this swell is about 1500 m in the immediate vicinity of the seamount groups [*Verhoef*, 1984]. Outside the region of the swell,

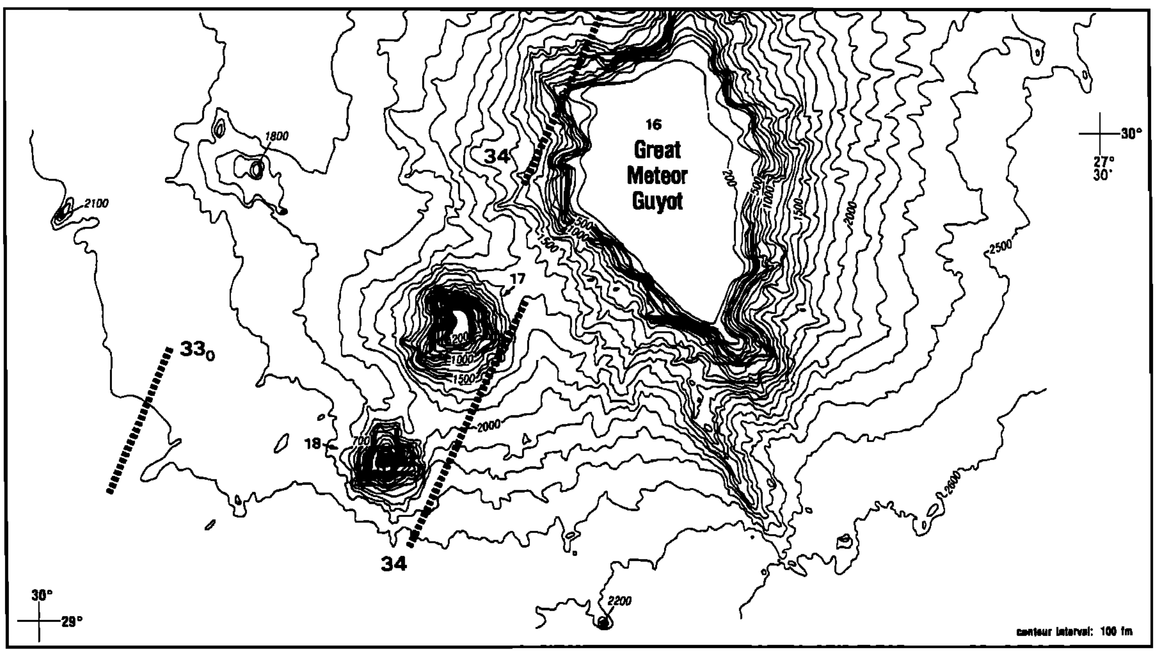

Fig. 4. Bathymetry of the Great Meteor seamount group from multibeam swath mapping. Depths are in uncorrected fathoms with a 100-fm (~190-m) contour interval. Magnetic anomaly identifications are based on *Klitgord and Schouten* [1986]. Numbers identify seamounts in Table 2.

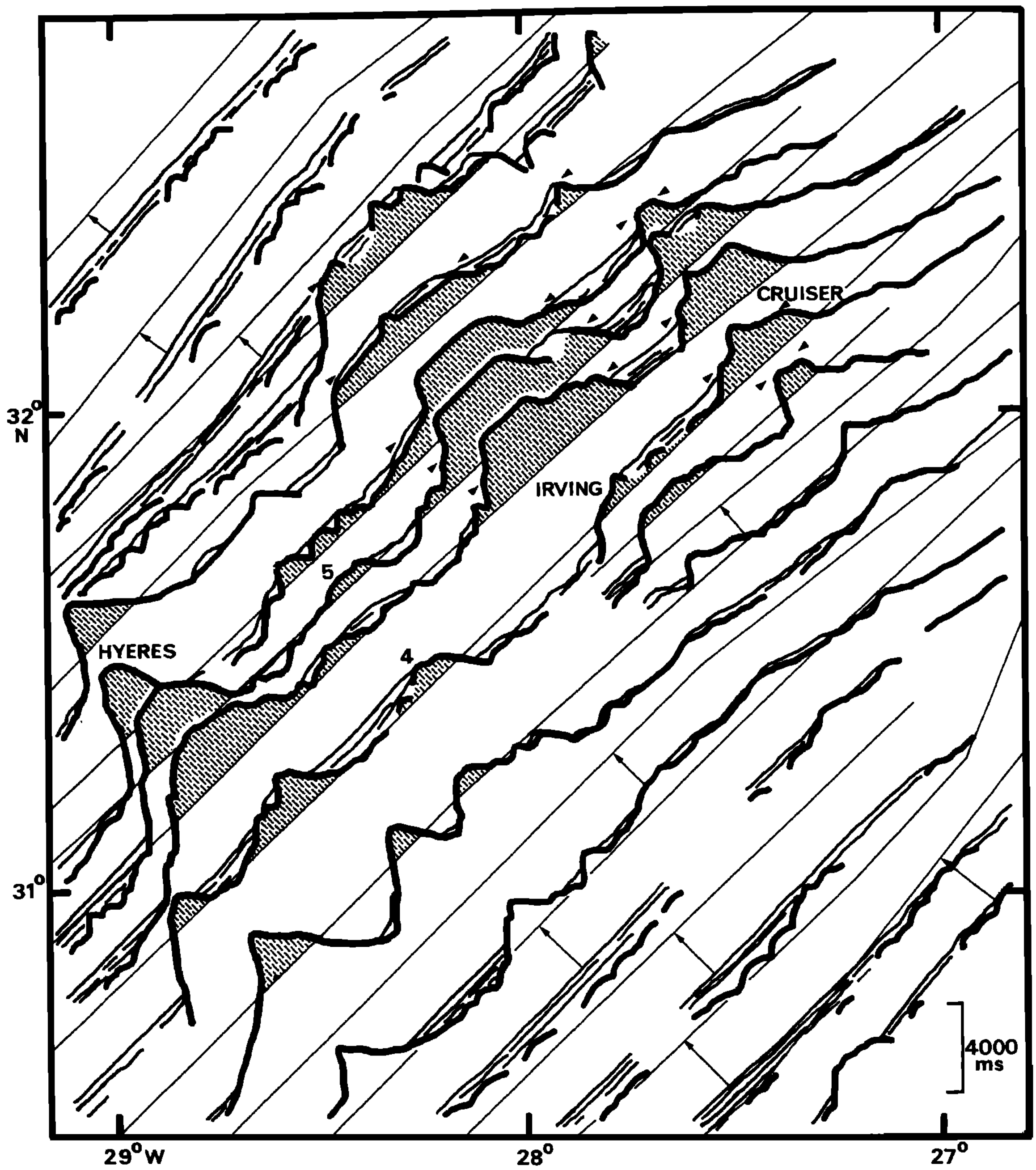

Fig. 5. Tracings of seismic reflection profiles (vertical exaggeration ~7) across the Cruiser plateau region, adapted from *Verhoef* [1984]. Light, straight lines show ship tracks. Profiles are plotted with respect to these tracks, with an offset of 3333 ms (2500 m). Basement (bold lines) shallower than the 2500 m level is shaded; arrows provide reference between other tracks and their associated profiles. The average depth of the base level Cruiser plateau basement is about 2500 m when corrected for sediment thickness and sediment loading. Seamounts on Cruiser plateau are identified by name and number as in Table 2. Unshafted arrows around Cruiser and Irving seamounts show 850-fm level (1600 m) where, on average, terracing is observed.

approximately 50-150 km to the east, the depth of oceanic basement corrected for sediment overburden is between 5000 and 5500 m. This is the normal depth for oceanic crust of middle to Late Cretaceous age.

DETERMINATION OF SEAMOUNT AGES

Among the geomorphic features of the seamounts, three kinds appear to have been formed near sea level either during or immediately following major volcanic events. Because we know the present depth of these features, the age of the underlying crust, and the age-depth relation for Atlantic Ocean crust, we can backtrack the features from their present depths to derive the times when they were at sea level, and thus the approximate ages of their origin.

The three geomorphic features thought to have originated at or near sea level are (1) flat-topped guyots or tablemounts, (2) terraces, and (3) the Cruiser base level plateau. Bevelling of seamount crests at wave base, often accompanied by reef growth, is a well documented phenomenon in the Pacific [e.g., *Hamilton*, 1956; *Schlanger et al.*, 1987] but is less well known in the Atlantic. The best examples in the present study are Great Meteor and Little Meteor seamounts (Figure 4), Irving Seamount (Figure 3), and seamounts 1, 2, 5, and 6 in the Corner group (Figure 2). Some seamounts have more rounded tops (e.g., seamounts 9 and 11, Figure 2); we infer that these were also eroded at sea level, but they were not beveled flat or did not support levelling reef growth. Both the flat- and rounded-top seamounts differ markedly in cross section from more peaked seamounts which probably never were subaerially exposed (e.g., seamounts 7, 13, and 14, Figure 2; seamounts 8 and 9, Figure 3).

The observed terraces are relatively level benches in flanks of seamounts (Figures 2, 3, and 5). They are presumed to have originated by erosion at sea level in one of two ways: (1) bevelling of a seamount top to form a guyot, with subsequent volcanism that built the seamount to a higher level but did not entirely eradicate the existing guyot morphology, thus leaving it manifested as a terrace, or (2) terrace cutting in the seamount flank during a period when the seamount either was only very slowly subsiding or was being uplifted, followed by rapid subsidence and drowning. In either case the terraces imply thermal and/or volcanic events that allowed the seamount to be eroded at wave base. Terraces are developed at seamounts 4, 9, and 11 in the Corner group (Figure 2) and on the flanks of Irving and Cruiser seamounts in the eastern Atlantic (Figures 3 and 5).

The Cruiser base level plateau around Cruiser, Irving, and Hyeres seamounts averages about 2500 m (1330 fm) deep and covers an area of approximately 14,000 km^2 (Figures 3 and 5). There is little diagnostic bevelling to support an origin near sea level, although we assume this to be the case because it is such a large and level volcanic plateau. Subsequent arguments will be made about the position of the plateau in plate reconstructions and the resulting implications for probable ages of volcanism; these arguments support but do not prove our assumption.

Using the empirical age-depth curve for Atlantic Ocean crust derived by *Tucholke and Vogt* [1979], we have backtracked sea-level-related features of the seamounts to determine their apparent ages. The empirical curve used is virtually identical to *Parsons and Sclater's* [1977] relation of crustal depth with age, $d(t)=2500+350t^{1/2}$ (where d is depth in meters, and t is time in m.y.), but it assumes an initial ridge-crest elevation of 2700 m. At the time that most of the seamounts being considered here were formed, long-term level was about 200±50 m higher than at present [*Haq et al.*, 1987]. Thus the practical effect of using the *Tucholke and Vogt* [1979] subsidence curve (initial depth 2700 m, or 200 m below Parsons and Sclater's initial depth) is that no correction for long-term sea level change is necessary, or justifiable. With respect to higher-frequency changes in eustatic sea level, our resolution of seamount ages is inadequate to allow assessment of their impact, and we therefore have ignored any effects of more rapid sea level variations. The actual error that would be introduced by sea level fluctuations of the order of ±50 m would be about ±5% in derived ages of seamount features.

It could be questioned whether the subsidence constant (350) in the age-depth relation is appropriate to use where the lithosphere has been affected by hotspot volcanism. For example, *Johansen et al.* [1984] derived a constant of 273±30 for the Reykjanes Ridge near Iceland. However, in determining this value they assumed that the ridge axis had not subsided in the past 15 m.y., a questionable assumption according to tectonic interpretations of *Tucholke and Mountain* [1986], and their profiles extended out only to 10-15 Ma crust. On longer profiles discussed by *Sclater et al.* [1975] for the same area, the subsidence constant is very close to 350. Furthermore, lithosphere that is thinned and "reset" to a new thermal age by passage over a hotspot appears to follow the *Parsons and Sclater* [1977] depth relation for the new thermal age [*Detrick and Crough*, 1978]. Based on the above considerations, we conclude that use of the *Tucholke and Vogt* [1979] age-depth relation should yield reliable estimates of ages of seamount features which were developed at sea level.

Seamount ages are constrained only by minimum and maximum values, derived in the following way. Minimum ages are determined by assuming that the seamount feature subsided at the maximum allowable rate, that is as if the surrounding crust had been totally reset to zero thermal age; in such instances we would expect to see concomitant development of a thermal swell. Conversely, derived maximum ages are based on subsidence at the rate of surrounding normal ocean crust; consequently, they assume no thermal reset and imply no development of a thermal swell.

In making age determinations for the Corner seamounts (Table 1), we assumed that subsidence followed the age-depth relation for the underlying crust at each seamount, and that no uplift or thermal age reset of the crust occurred during volcanic episodes (Figure 6). This assumption may seem surprising, but it appears to be reasonable because the adjacent oceanic crust is at the expected depth (corrected for sediment loading) for its age. Any uplift or thermal reset would have caused the crust to have a positive depth anomaly. We also assume that crustal loading by each volcanic edifice was synchronous with seamount construction and that no significant load-induced subsidence occurred after construction. It is possible that limited thermal uplift in fact did occur during volcanic construction and that this was roughly offset by load-induced subsidence to give the correct crustal depth for crustal age. More rapid subsidence would accompany any such thermal reset, and it would have the effect of decreasing the calculated ages of volcanism. For this reason we consider the ages in Table 1 to be maximum ages, although they probably are close to true ages. For peaked seamounts in the Corner group, only maximum ages can be given (parentheses, Table 1), since the seamounts could have formed below wave base at any time after their supporting crust subsided to depths greater than their heights.

Calculation of ages of volcanism in the eastern Atlantic (Table 2) is more involved because the seamounts are located on a positive depth anomaly of about 1500 m [*Verhoef*, 1984] and because some seamounts appear to exhibit several volcanic phases. Figure 7, constructed for Irving Seamount on the Cruiser plateau, illustrates our methodology. The Cruiser plateau (base level) is assumed to have formed near sea level. It has a maximum average age of 78 Ma, which is the average age of the underlying crust; this age is permissible because the anomalously shallow depth of the crust could have been caused by uplift and thermal reset during succeeding volcanic episodes. The minimum age of the plateau is about 65 Ma, determined by assuming that the crust experienced a total thermal reset (and thus subsided like new lithosphere) and had no subsequent thermal reset (dotted PMIN line, Figure 7). We estimate an actual age of 76 Ma, based on likely distribution of volcanic patterns in the Late Cretaceous (see Plate Reconstruction). We further assume that the massive volcanic

TABLE 1. Corner Seamount Characteristics In Western North Atlantic

Peak+	Nature	Crustal Age, Ma	Depth,* fm	Depth,* m	Age,† Ma
1-Rockaway	Flat top	99	920	1730	82
2-Castle Rock	Flat top	98	960	1805	82
3	Flat top	95	1160	2180	86
4	Rounded peak	95	400	750	50
4	Terrace	95	1000	1875	81
5	Flat top	93	840	1580	73
6	Flat top	94	900	1690	77
7	Peak	90	1450	2720	(89)
8	Peak	88	1400	2620	(86)
9	Rounded peak	86	600	1130	56
9	Terrace	86	1000	1875	74
10	Flat top	84	1150	2160	76
11-Caloosahatchee	Rounded peak	82	600	1130	53
11	Terrace	82	1050	1970	72
12	Peak	81	1200	2250	(76)
13	Peak	83	1400	2620	(82)
14	Peak	80	1400	2620	(79)

+ Numbers identify volcanic edifices from Figure 2.
* Depths in fathoms to nearest 20 fm; corresponding depths in meters rounded to nearest 5 m.
† Only maximum ages, in parentheses, are indicated for peaked seamounts.

episode which constructed the plateau also created most of the observed depth anomaly (Figure 7).

A second volcanic or thermal event, during which the Irving terrace formed, has a maximum age of 65 Ma; if the event were any older, the Cruiser base level plateau could not have subsided far enough below sea level to accommodate the observed 850 m construction of the terrace above the plateau (dot-dashed C850 m line, Figure 7). Note that for this maximum age to be applicable, the crust would later have to experience thermal reset or it could not reach its present elevation (e.g., dot-dashed TMAX line, Figure 7). The minimum age of the terrace is 30 Ma, assuming total thermal reset of the crust (dot-dashed TMIN line, Figure 7); this age is unrealistically young, however, because uplift of the plateau to its former sea-level position, which might be expected in the case of total thermal reset, could not have occurred.

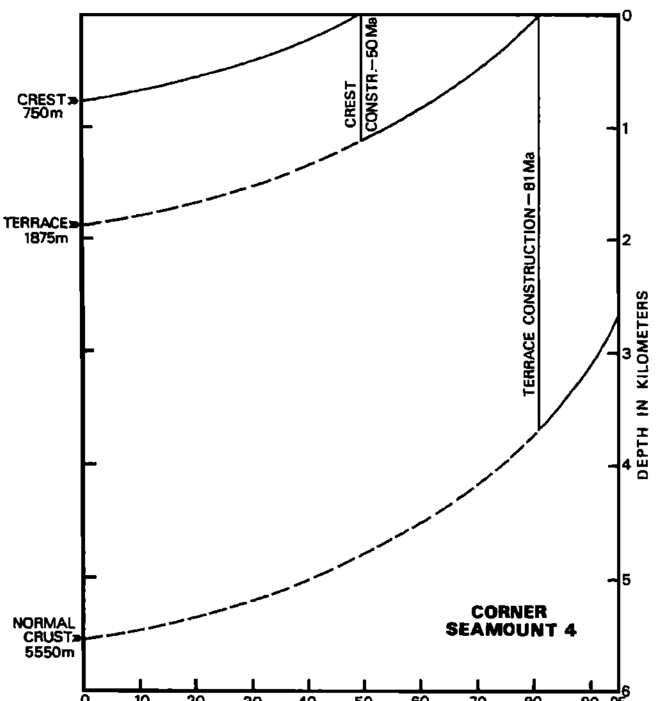

Fig. 6. Age-depth reconstruction for seamount 4 in the Corner seamounts. The subsidence curve used is for 95 Ma crust and assumes no thermal reset during construction of the seamount (see text).

The final event, associated with formation of the flat top on Irving guyot, has minimum and maximum ages of 3 Ma and 17 Ma, respectively (GMIN and GMAX, Figure 7), controlled by the maximum and minimum possible subsidence rates. The minimum age again is unrealistically young since total thermal reset of the crust is unlikely to have occurred. Likewise, the maximum age may be unrealistically old, since it assumes no thermal effects at all (i.e., subsidence at the rate of normal ocean crust of that age). Within the acceptable age ranges for their formation, the solid terrace and guyot lines in Figure 7 give an example of partial thermal uplift and crustal age reset accompanying each phase of volcanic construction. The specific ages of the events implied in this example are not significant; the ages will shift depending on how thermal effects are apportioned between the two events.

An independent estimate of the age of formation of Irving guyot can be derived from the known age and depth of Great Meteor Seamount (guyot) farther south in the Great Meteor "chain". The unloaded depth of basaltic basement at the crest of the guyot is about 515 m (Table 2). If we take 11 Ma as the age of most recent volcanism on the seamount [*Wendt et al.*, 1976], then the subsequent average subsidence rate was 47 m/m.y. Great Meteor Seamount is on 86 Ma crust [*Klitgord and Schouten*, 1986]. Practically speaking, this crust would be subsiding at the same rate as the 78 Ma crust beneath the Cruiser plateau, in the absence of any thermal perturbations.

TABLE 2. Seamount Characteristics In Eastern North Atlantic

Peak+	Nature	Crustal Age, Ma	Depth,* fm	Depth,* m	Maximum Age, Ma	Minimum Age, Ma	Actual Minimum Age,† Ma
1-Hyeres	Rounded peak	76	160	300	19	3	6
2-Irving	Flat top	78	140	265	17	3	6
3-Cruiser	Peak	78	390	735	37	0	<16
2/3	Terrace	~78	850-900	1600-1690	65	30	-
2/3	Basal plateau	~78	1300-1400‡	2440-2620‡	~78	65	-
4	Peak	80	700	1320	57	0	-
5	Peak	78	900	1690	64	0	-
6	Peak	66	850	1600	53	0	-
7	Rounded peak	61	760	1430	47	24	-
8	Peak	61	900	1690	52	0	-
9	Peak	59	800	1500	47	0	-
10	Peak	59	800	1500	47	0	-
11	Rounded peak	57	440	830	31	11	18
12	Flat top	57	360	680	26	9	14
13-Plato	Rounded peak	53	260	490	20	6	10
14	Rounded peak	52	880	1655	45	30	-
15	Flat top	51	1180	2220	51	51	-
16-Great Meteor	Flat top	86	270‡	515‡	33	6	11
17-Little Meteor	Flat top	83	160	300	21	3	6
18	Peak	83	700	1315	59	0	-

+Numbers identify volcanic edifices from Figures 3 and 4.
*Depths in fathoms to nearest 20 fm unless specified more precisely from published literature; corresponding depths in meters rounded to nearest 5 m.
†Based on 47 m/m.y. linear subsidence rate derived from Great Meteor Seamount.
‡Basement depth corrected for sediment loading.

However, the Great Meteor crust probably experienced a major thermal reset when it was formed, thus accounting for its present 1500 m depth anomaly; this reset was younger than that of Cruiser plateau crust, so its subsidence rate may be greater than that of Irving guyot. Thus, if we apply the 47 m/m.y. rate to Irving guyot, we obtain an actual minimum age of 6 Ma for Irving volcanism (Table 2). The applied subsidence, of course, is a linear rate rather than the exponential rate that would be expected from thermal decay; however, over the short time span involved in the calculations, it provides a reasonable approximation that probably is within about 10% of values that would be derived if it were possible to define an exponential curve.

Similar analyses for the other seamounts in the eastern North Atlantic yield the ages summarized in Table 2. We point out that ages derived for the final phase of volcanism at Irving and Cruiser seamounts and for volcanic events at all other seamounts are straightforward calculations that are not affected by the complexities in the foregoing example. However, both the minimum and maximum ages are considered unrealistic in each case, the former because total reset of the subsidence relation would be required without associated uplift to former crustal levels, the latter because subsidence would be assumed to have been unaffected by thermal uplift, even though thermal uplift is known to have caused a depth anomaly of ~ 1500 m. The "actual minimum" ages (Table 2) are derived by applying the Great Meteor subsidence rate, as noted above, to seamounts younger than about 30 Ma.

Aside from uncertainties in thermal history, all ages in the above analyses also are subject to errors caused by practical uncertainties in age of the underlying crust and in absolute depth of seamount features on which the calculations were based. Potential errors caused by these latter factors are conservatively estimated to be ±3 m.y.

LATE CRETACEOUS PLATE RECONSTRUCTION AND PATTERN OF VOLCANISM

Late Cretaceous reconstruction of the Corner seamounts and Cruiser plateau at anomaly 33y (~74.5 Ma) is shown in Figure 8, based on plate motion studies of *Klitgord and Schouten* [1986]. The northern margin of Cruiser plateau, bounded by the Hayes Fracture Zone (FZ), closes to the southern edge of the east-west ridge in the east central Corner seamounts. The fracture zone inferred to be present at the southern edge of the Corner seamounts aligns with the large structural offset through the Cruiser plateau between Hyeres and Irving seamounts. We presume that this offset marks the continuation of a fracture zone trace that now is mostly buried below volcanic rocks of Cruiser plateau.

The illustrated position of the spreading-ridge axis between Hayes FZ and the fracture zone immediately to the south is conjectural, and it is not symmetrically situated between conjugate anomalies 33o (Figure 8). It is, however, midway between the steep, apparently fault-controlled western scarp of Cruiser plateau and the similarly steep-walled southern volcanic ridge of the Corner seamounts. More complete closure of the seamount groups, to about 76 Ma, would butt these features against one another. We infer that a spreading ridge jump occurred ~76 Ma, abandoning a spreading center that was formerly beneath Cruiser plateau midway between anomalies 33o (dashed lines, Figure 8). The ridge jump may have been facilitated by the fact that relative plate motion was changing at this time [*Klitgord and Schouten*, 1986] and by the presence of the New England hotspot beneath the spreading axis, as discussed below.

There is a clear trend in apparent ages of volcanism in the Corner seamounts, progressing from maximum ages of 86-81 Ma in the northwest to 76-72 Ma in the southeast (Table 1 and Figure 2). We interpret this trend to be caused by north-

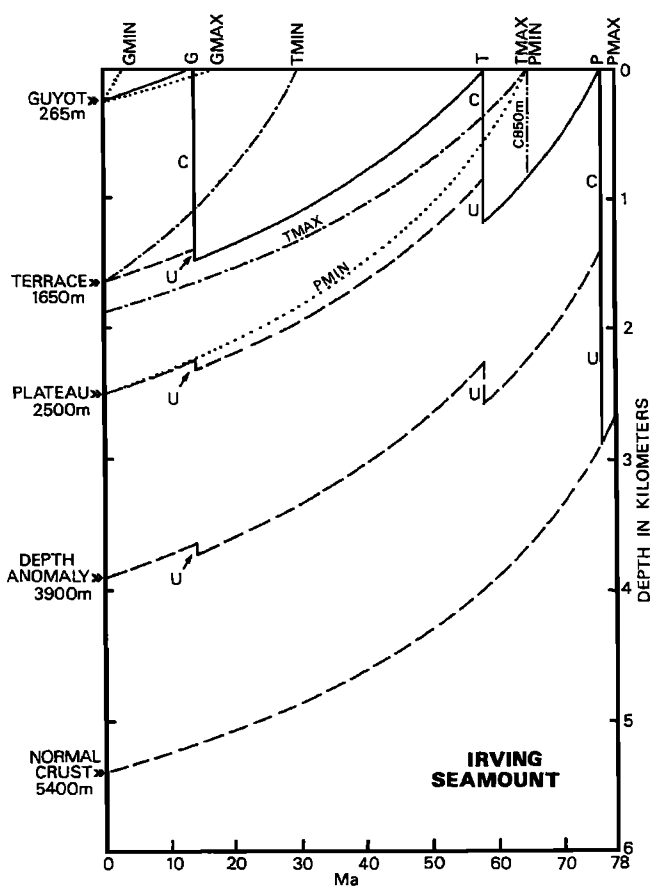

Fig. 7. Age-depth reconstruction for Irving Seamount on the Cruiser plateau. The solid line at the top of the graph gives an example of the age-depth history of the seamount crest, including construction (C) and net uplift (U) at the time of each volcanic episode; net uplift includes the effect of crustal loading by the volcanic pile. The deeper, dashed lines trace the age-depth history of deeper levels on the seamount and of normal, 78 Ma ocean crust. Construction of Cruiser plateau (C), with total thermal reset of crust and associated net uplift (U), is thought to have occurred ~76 Ma (labelled P at top). Maximum age of construction (PMAX) is age of underlying crust (~78 Ma); minimum age (PMIN) is 65 Ma, based on total thermal reset and allowing for no subsequent uplift/thermal reset (dotted PMIN line). Maximum age of construction of shallower terrace is 65 Ma (TMAX at top), limited by 850 m of construction (C850 m line) between the plateau and terrace levels and assuming no thermal reset; this maximum age would require later uplift/thermal reset to bring the terrace to its present level (see, e.g., dot-dashed TMAX line). Minimum terrace age (TMIN at top) assumes total thermal reset (dot-dashed subsidence curve). Maximum and minimum ages of guyot construction (GMAX, GMIN at top) assume no thermal reset and total thermal reset, respectively (dotted subsidence curves). See text for fuller discussion.

westward migration of the North American plate over the New England hotspot, with arrival of the plate boundary over the hotspot about 76 Ma. The part of the plate boundary that first crossed the mantle plume was the western ridge-transform intersection of the Hayes FZ (Figure 8). Volcanism probably occurred both north and south of Hayes FZ on the North American plate but only south of the fracture zone on the African plate. The Mid-Atlantic Ridge crest presumably was uplifted, and volcanism at the ridge axis formed the Cruiser base level plateau near sea level. The "volcanic footprint" of the hotspot at this time appears to have been about 100 km in radius. The inferred ridge jump shortly following 76 Ma separated Cruiser plateau from the Corner seamounts. Hotspot volcanism appears to have continued on the North American plate for several million years more, to ages at least as young as 72 Ma on the north side of the Hayes transform (Table 1). Two unsurveyed seamounts at the northeastern end of the Corner group (dashed contours, Figure 8) may have been included in this late volcanic phase. If so, they imply either a slight northward shift in locus of Late Cretaceous volcanism, or an expansion of the hotspot footprint to ~150 km radius. The former seems more likely because, following initial construction of the base level Cruiser plateau, there appears to have been little significant volcanism on the African plate within the remainder of Late Cretaceous time (Table 2).

CENOZOIC VOLCANISM

Determining patterns of volcanism on the African plate is complicated by the large uncertainties in calculated ages (Table 2). Nonetheless, there are consistent trends. The oldest Cenozoic volcanism is interpreted to be that which formed the Irving and Cruiser terraces sometime between 65 and 30 Ma (Figure 9). As noted above, northward migration of volcanism may have commenced during the Late Cretaceous. If this occurred, and if the Irving/Cruiser seamounts on the African plate and the unsurveyed eastern Corner seamounts on the North American plate were contained within a ~100-km-radius volcanic footprint, then these seamounts cannot postdate the earliest Cenozoic (~64-65 Ma); with subsequent seafloor spreading the seamount locations became separated well outside this footprint size. Subsequent volcanism more clearly migrated northward, eventually forming the Tyro group of seamounts, and part of the Plato group of seamounts, at ages less than about 50 Ma. The northward migration also accounts for formation of the Atlantis seamounts, which must be younger than the crust on which they reside (40-31 Ma north of Oceanographer Fracture Zone and 48-42 Ma south of the fracture zone; Figures 1 and 9). Subsequent southward migration caused construction and rejuvenated volcanism in the Plato seamounts, as well as rejuvenated volcanism on Cruiser plateau (Irving, Hyeres, and probably Cruiser seamount) sometime after about 25 Ma. Further southward migration formed Great Meteor Seamount by 16-11 Ma and constructed its southerly companions at probably younger ages. The age spread of recurrent volcanism in the seamounts on Cruiser plateau is at least 60 m.y., ranging from the ca. 76 Ma basal plateau to 17 Ma or less on Irving guyot.

Recurrent volcanism also appeared about 50-56 Ma in the Corner seamounts at peaks 4, 9, and 11 (Table 1). These events postdate the original volcanism by some 18-31 m.y. The peaks would have been about 800 km from the New England hotspot at the time, and on the opposite side of the Mid-Atlantic Ridge axis.

DISCUSSION AND CONCLUSIONS

Detailed morphology of the Corner seamounts and the seamounts in the Great Meteor "chain" shows that local trends of volcanic ridges and individual seamounts largely are controlled by the structural fabric of the supporting oceanic crust. Primary trends in crustal structure that are parallel and perpendicular to plate flowlines, for example, are mirrored in volcanic edifices of both the Corner- and Plato-group seamounts north of Hayes Fracture Zone (Figures 2 and 3). However, there also are well developed oblique edifices that typically strike 30° to 45° to plate flowlines. The best

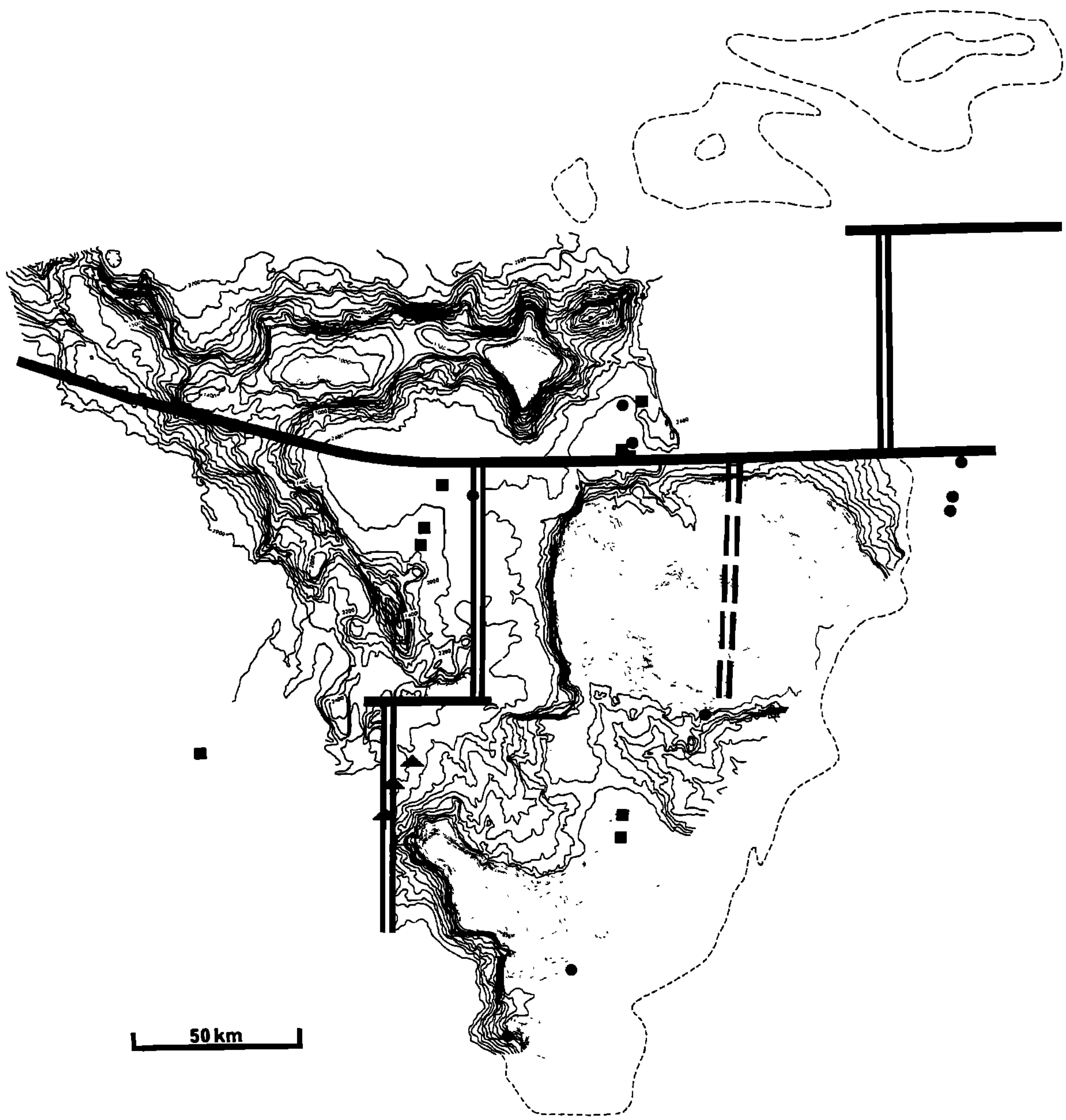

Fig. 8. Plate reconstruction of the Corner and Cruiser groups of seamounts to the time of magnetic anomaly 33y (~74.5 Ma) based on *Klitgord and Schouten* [1986]. Triangles identify picks of anomaly 33y, and anomaly 33o picks are shown by dots (observed) and squares (rotated). Seamount features younger than 74.5 Ma are shown by lightly stippled contours. The position of the Hayes Fracture Zone is approximated by a synthetic flow line of relative plate motion (bold line), and the Mid-Atlantic Ridge axis is indicated by parallel lines. Dashed parallel lines on Cruiser plateau mark the inferred position of a defunct spreading axis, presumed to be abandoned ~76 Ma (see text). Note the coincidence of the structural offset in Cruiser plateau south of Irving Seamount with the presumed fracture zone at the southern edge of Corner seamounts. Dashed contours outside the area of multibeam bathymetry are 1000 and 2000 fm depths derived from *Canadian Hydrographic Service* [1984].

examples of these puzzling trends are the volcanic ridge at and south of Hayes FZ in the Corner seamounts (Figure 2), the southern Tyro group seamounts (Figure 3), and the seamount margin and volcanic ridges along the western side of Great Meteor guyot (Figure 4). The same kinds of trends also appear in Hyeres, Irving, and Cruiser seamounts on Cruiser plateau.

The origin of the oblique trends is problematic. *Verhoef* [1984] suggested that the eastern North Atlantic region north of the Cruiser plateau experienced NE-SW oriented tension as a result of horizontal contraction of the cooling lithosphere, and tensional gashes could have provided sites for the observed volcanism. However, Verhoef felt that the extension was localized and may have been related to the presence of the nearby Europe-Africa plate boundary along the Azores-Gibraltar line. The fact that we see the same phenomenon around Great Meteor Seamount farther south, and around the Corner seamounts in the western North Atlantic, suggests that the oblique trends are more widespread and that large-scale lithospheric stresses (e.g., from plate motion change or lithosphere cooling) may be responsible. On the other hand, we cannot dismiss the possibility that the oblique trends are unique to seamounts and that they are generated by only local

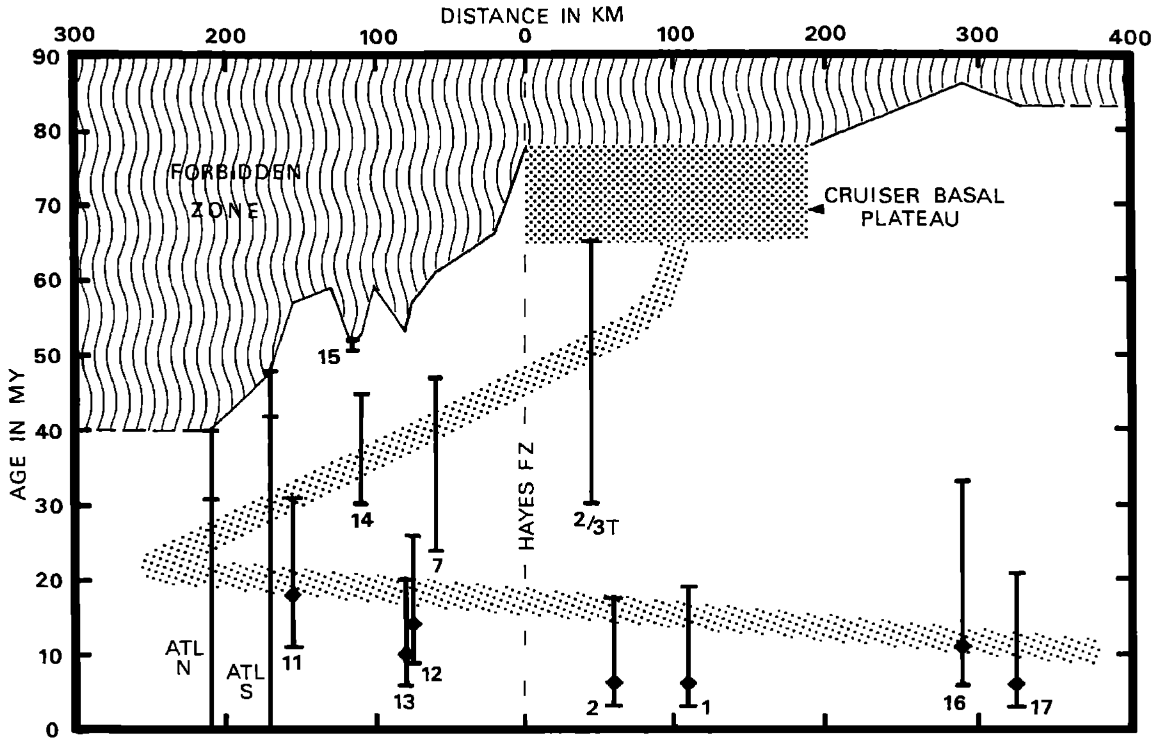

Fig. 9. Plot of eastern North Atlantic seamount ages (from Table 2) versus distance north and south of Hayes Fracture Zone. Vertical bars extend between age minima and maxima for each seamount, with "actual minimum" age indicated by a black diamond along the bar where appropriate. Seamounts are numbered as in Table 2; the Cruiser and Irving terraces are indicated by 2/3T. The Atlantis seamounts north and south of Oceanographer Fracture Zone are ATL N and ATL S; the upper parts of the bars, between horizontal dashes, show the age range of oceanic crust beneath the seamounts. The only existing age constraint on these seamounts is that they are younger than their supporting crust. Other seamounts for which we have calculated only maximum ages (Table 2) are not shown in this figure. The possible age range and the latitudinal extent of Cruiser basal plateau are indicated by the dot-shaded box. "Forbidden zone" signifies that seamounts cannot be older than the crust on which they reside. The broad dot-shaded bar shows our interpretation of first northward, then southward migration of volcanism. Northward and southward components of volcanic migration rates are 10 and 56 mm/yr, respectively, but these rates are not well constrained by existing data on seamount ages. Only the age datum for seamount 15 in the Plato group is unexplained by the proposed pattern of volcanic migration (although it could fit within the kind of 200 km volcanic footprint noted in text); the seamount appears to have formed at the Mid-Atlantic Ridge axis at 51 Ma.

lithosphere response to passage over the hotspot. We unfortunately have little information about the distribution of oblique features in the adjacent basins. Until the necessary detailed surveys are conducted in these basins, we can only speculate about whether the oblique trends have plate-wide significance.

On the seamounts themselves, we have interpreted geomorphic features such as terraces and guyots to have formed at sea level, concurrent with major episodes of volcanic construction. By tracking these features from their present depth back along the North Atlantic crustal age-depth curve, we have calculated the approximate ages of these events. The ages of initial volcanism at the Corner seamounts are generally consistent with models of North America plate motion across the New England hotspot (Figure 10) [*Duncan*, 1984]. The rate of migration of volcanism from Nashville Seamount (southeast end of New England seamounts) through the Corner Seamounts, however, must have been greater than the average rate of 47 mm/yr that *Duncan* [1984] determined within the New England seamounts. A rate of 112 mm/yr best fits the age data of both the eastern New England seamounts and the Corner seamounts (Figure 10). This interpretation implies that a significant rate change occurred ~85 Ma. The timing of such a rate change is consistent with a large change in relative plate motion (and necessarily in absolute plate motion) that most likely occurred in the North Atlantic near the end of the Cretaceous long normal-polarity interval [e.g., *Klitgord and Schouten*, 1986; *Tucholke and Schouten*, 1988]. Application of the 112 mm/yr rate also places the Mid-Atlantic Ridge plate boundary over the hotspot at ~76 Ma.

The Late Cretaceous plate boundary intersected the New England hotspot at the western end of the ~50-km offset which then comprised the Hayes transform fault. The principal locus of volcanism appears to have been on the ridge axis immediately south of the fracture zone (Figure 8). In that location extensive volcanism and uplift of the Mid-Atlantic Ridge axis is interpreted to have formed the 14,000 km^2 basal Cruiser plateau near sea level. Shortly thereafter, a westward jump of the spreading ridge axis just south of Hayes FZ probably moved the plate boundary west of the hotspot center (thus increasing the transform offset to ~120 km) and caused final separation of the Corner and Cruiser seamount groups.

It is interesting to note that there was very little volcanic construction within the Hayes FZ. An exception is the southern arm of the Corner seamounts, which probably was constructed across the fracture valley at or slightly west of the western ridge-transform intersection (Figure 8). In contrast, the lithosphere of the adjacent North American plate supported development of the major east-west volcanic ridge just to the north of the fracture zone. This observation is somewhat counterintuitive because the North American lithosphere would have been colder and thicker than that within the fracture zone

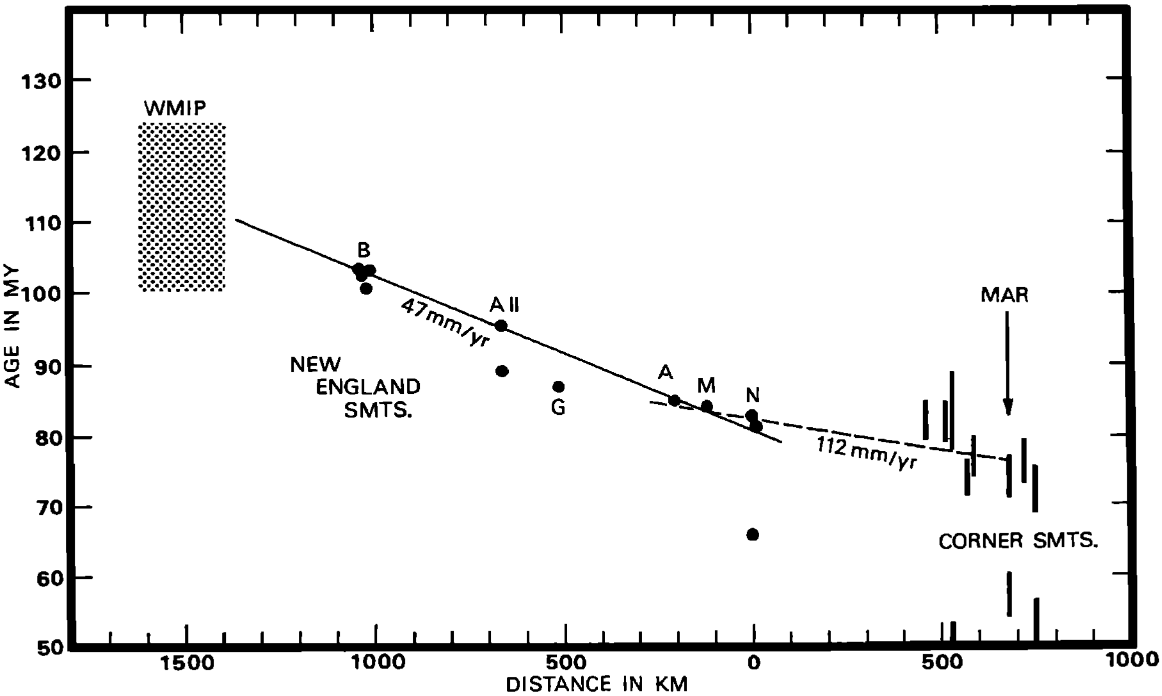

Fig. 10. Plot of seamount ages versus distance for the New England and Corner seamounts in the western North Atlantic. Solid dots are ^{40}Ar-^{39}Ar ages of New England Seamounts from *Duncan* [1984]. Seamounts are B, Bear; AII, Atlantis II; G, Gosnold; A, Allegheny; M, Michael; and N, Nashville. WMIP is the youngest series in the White Mountain Igneous Province. *Duncan's* [1984] best fit linear migration rate of 47mm/yr for the New England Seamounts is shown by a solid line. The dashed line indicates a 112mm/yr migration rate to the Corner Seamounts, intersecting the Mid-Atlantic Ridge plate boundary about 76 Ma (arrow, see text). Ages shown for the Corner seamounts are from Table 1, with 3-m.y. error bars as noted in text. All distances are measured from Nashville Seamount, except that distances within Corner Seamounts are measured along plate flow lines beginning at the westernmost seamount.

[e.g., *Fox and Gallo*, 1986], and the thicker lithosphere could be expected to be less readily penetrated by mantle melts. A possible explanation is that because the fracture valley is highly faulted, its crust and upper mantle were penetrated, cooled, and altered by seawater, effectively insulating the valley from significant magmatism. Indeed, such invasive alteration of the upper lithosphere has been used to explain anomalously low seismic velocities in transform valleys, as well as the occurrence of median ridges that presumably were created by serpentinite diapirism [*Fox and Gallo*, 1989]. Another factor that may have hindered fracture valley volcanism was plate-motion change. Counterclockwise changes in relative plate motion were occurring at the time the Hayes transform valley overrode the hotspot [*Tucholke and Schouten*, 1988]; this would have subjected the right-lateral offset of the transform to compression, perhaps limiting the potential for intratransform volcanism.

Following the initial, ~76 Ma volcanism that constructed the Cruiser base level plateau, there appears to have been no significant volcanism on the African plate until the Irving and Cruiser terraces were formed <65 Ma (Figure 9). The fact that this volcanism recurred on Cruiser plateau near Hayes FZ suggests relative stability or slow southward motion of the African plate with respect to the hotspot for at least 10 m.y. A slow, northward shift of volcanism also could be responsible for formation of the two easternmost Corner seamounts north of Hayes FZ on the North American plate (Figure 8). Following the Irving-Cruiser terracing event, the seamount age data clearly indicate northward migration of volcanism to the Atlantis seamounts at a rate (northerly component) of about 10 mm/yr (Figure 9). Subsequent southward migration to the Great Meteor seamount group probably occurred after about 25 Ma and at a rate of 50-60 mm/yr (southerly component). These observations conflict with existing models of African plate motion in the hotspot reference frame [*Morgan*, 1983; *Duncan*, 1984], which suggest only southward migration of volcanism over the New England hotspot (Figure 11). The existing models also have the shortcoming that at 70-80 Ma they transfer the hotspot from the North American to the African plate at the latitude of the Plato and Cruiser seamounts; thus they cannot explain either the position or the unquestionable youth (<48 Ma) of the Atlantis seamounts. We conclude that the existing hotspot models require revision for motion of the African plate at ages younger than about 80 Ma.

As to whether the northward and then southward migration of volcanism in Figure 9 indeed reflects "absolute" motion of the African plate, the answer is not clear. There are two other possibilities: (1) while the African plate was "stalled" over the New England hotspot, the hotspot was able to expand its sphere of influence to a radius of more than 300 kilometers (i.e. Atlantis, Plato, and Tyro seamount groups), or (2) that the New England hotspot migrated independently with respect to other hotspots beneath the African plate. The first alternative does not seem reasonable. Although *Schilling* [1986] has suggested that hotspot influence accounts for geochemical anomalies up to 700 km from actual plume location, this relation appears to apply only along "hotspot flow lines" that connect a hotspot to a spreading-ridge crest. Such would not have been the case for the northerly positioned Atlantis and Tyro seamounts. In the present instance it is also difficult to explain how a hotspot that was centered roughly beneath the Cruiser plateau would have engendered extensive volcanism

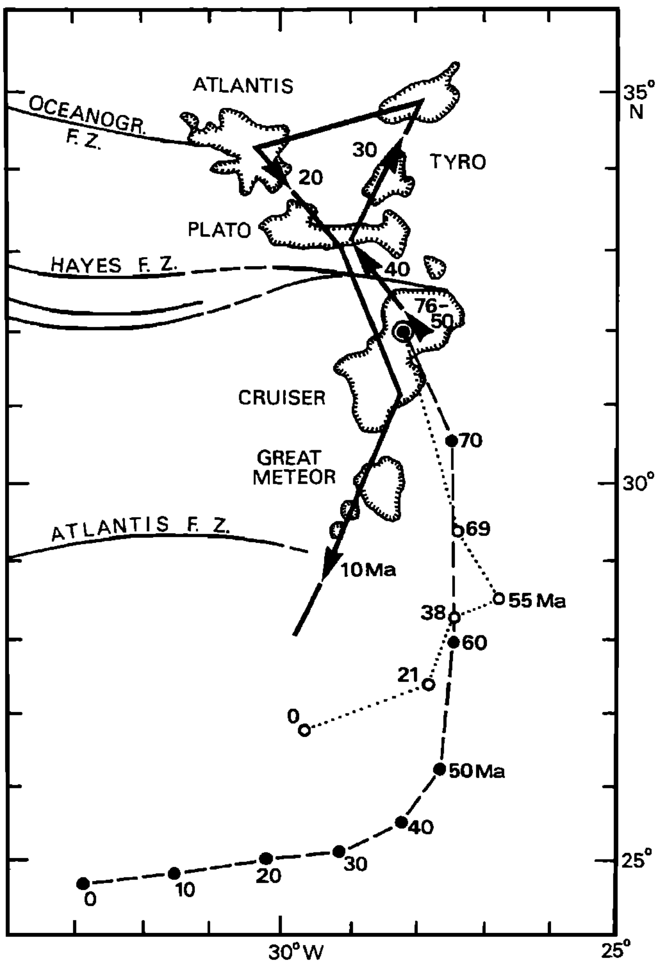

Fig. 11. Schematized migration of volcanism on the African plate, beginning on the central Cruiser plateau, as suggested by this study (bold arrows; see Table 2). The track of the New England hotspot on the African plate as calculated from the model of *Morgan* [1983] is shown by a dashed line, and the dotted line shows the track based on *Duncan's* [1984] model. For ease of comparison both are also constrained here to pass through central Cruiser plateau at 76 Ma. Irrespective of starting and endpoints of the hotspot on the African plate, however, neither model satisfactorily approximates the observed distribution of volcanism in space and time.

200-300 km to the north but apparently did not cause concurrent volcanism on the Cruiser plateau itself or within a similar radius to the south (Figure 9).

The second alternative is more difficult to evaluate. Northward migration of volcanism could have been as slow as 6-8mm/yr (Figure 9). This is close to the ~5 mm/yr limit that normally is considered to define "fixed" hotspots [*Morgan*, 1981], and it is well within the 10-20 mm/yr rate at which a number of widely separated hotspots have been calculated to move with respect to the Hawaiian hotspot [*Molnar and Stock*, 1987]. Thus it is conceivable that the northward migration represents independent motion of the New England hotspot. Evaluation of this possibility, as well as improved modelling of post-80 Ma African plate motion, will require use of both better age data and improved morphologic analysis for volcanic edifices along other Atlantic hotspot traces.

The local recurrence of volcanism suggested by the present study has two important implications. First, it is apparent that volcanism above the hotspot is episodic, illustrated, for example, by the hiatus between the plateau and terrace volcanic phases at Irving Seamount and by the >6 m.y. age difference between seamounts 14 and 15 in the Plato group. This, of course, is no surprise, since hotspot traces commonly are manifested by chains of individual volcanoes rather than by continuous volcanic ridges, and episodic volcanism spanning up to 20 m.y. has been documented elsewhere in the Atlantic [e.g., *Baker*, 1973; *Vogt and Tucholke*, 1979]. One factor we cannot evaluate with presently available data, however, is how continuous or discontinuous lower-intensity volcanism may have been at any given location. For example, it is possible that minor volcanic activity occurred more or less continuously at Cruiser plateau between about 76 and 55 Ma; it could be manifested in such subsidiary volcanoes as seamounts 4 and 5 (Table 2 and Figure 3), or in other basement irregularities occurring roughly at plateau "base level".

A second implication of observed recurrence is that significant, edifice-building volcanism can occur long after a region has passed over a hotspot. The best examples in the present study are seamounts 4, 9, and 11 in the Corner seamount group (Figures 2 and 10) where late stage volcanism postdated passage of the hotspot by 18-31 m.y. and was some 800 km distant from it. Within the age uncertainty of events in the Great Meteor "chain", it is also possible that the final volcanic phase at Hyeres, Irving, and Cruiser seamounts was occurring simultaneously with the ~16-11 Ma construction of the Great Meteor seamounts, which presumably were above the New England hotspot at the time. These edifices are 200-300 km apart. These examples suggest that lithosphere passing over a hotspot is conditioned so that plume flow can reach large distances back along the hotspot track to engender later volcanic episodes.

A phenomenon slightly different in mechanism, but similar in scale, has been suggested by *Morgan* [1978] to explain geochemical anomalies on spreading ridges that once passed over hotspots. In this model a sublithospheric channel develops and extends to maintain continuity between the hotspot and the ridge crest as the two migrate away from one another. For the South Atlantic, ridge-crest geochemical anomalies and hotspots as far as 700 km apart have been cited by *Schilling et al.* [1985] in support of this model. *Schilling* [1985, 1986] suggested that with increasing distance between hotspot and ridge crest, both geochemical and ridge elevation anomalies decrease, the latter disappearing first, until the hotspot manifestation becomes totally intraplate. *Duncan* [1984] and *Schilling* [1986] also noted that geochemical anomalies occur in basalts along the "flow line" of the New England hotspot to the Mid-Atlantic Ridge crest at 35°N latitude; the present separation of ridge crest and hotspot is more than 1000 km. In the context of these indications of long-distance sublithospheric and intralithospheric plume flow, it would be worthwhile to sample successive episodes of volcanism in the Corner Seamounts and Great Meteor seamount "chain" and to compare them geochemically with ridge-crest and ridge-flank basalts along the flow line from hotspot to ridge crest.

In conclusion, we have investigated a little used, geomorphologic method of estimating ages of seamount volcanism in the North Atlantic. The technique clearly lacks precision, but just as obviously can provide some important constraints on patterns of volcanism and migration of hotspots. There is a need to determine ages along a large number of hotspot traces in order to examine questions of hotspot fixity and to optimize models of "absolute" plate motion. Interpretation of detailed seamount geomorphology is a presently underutilized resource that can contribute significantly to this process.

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B.E. Tucholke, Woods Hole Oceanographic Institution, Woods Hole, MA 02543.

N.C. Smoot, U.S. Naval Oceanographic Office, Stennis Space Center, MS 39522.

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