1. INTRODUCTION[1]

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From the beginning of the Deep Sea Drilling Project, the deep ocean floor immediately north-northeast of the Bahama Platform has been the target for finding and recovering some of the oldest sediments in the ocean basins. Favorable conditions in this area include (1) proximity to one of the oldest passive continental margins; (2) relatively shallow basement due to diminished clastics supply in front of the Bahama and Blake carbonate platforms, submarine erosion, and regional uplift; and (3) thorough scientific documentation prior to drilling, such as good seismic coverage.

Following in the wake of a decade of single-channel seismic profiling and piston coring, drilling results of DSDP Leg 1 (1968), Leg 11 (1971), Leg 44 (1975), and Leg 76 (1980) (1969; 1972; 1978; and this volume, respectively) have gradually and methodically documented the Mesozoic stratigraphy of this region. Initial studies focused on an area southeast of Cat Gap (Fig. 1), where single-channel seismic profiling showed outcrops of reflecting Horizons A and β. Apparently, erosion had prevented accumulation of much sediment. Horizon B coincided with smooth acoustic basement thought to be possibly very old sedimentary rocks. Piston coring in this region had recovered Hauterivian to Maestrichtian sediments (Ewing and Hollister, 1972).

At Sites 4 and 5 of DSDP Leg 1 (Fig. 1) in a water depth greater than 5 km, drilling penetrated 259 m and 281 m, respectively, below the seafloor. On the basis of limited coring and an abundance of hiatuses in an abbreviated section, perhaps unusual for the western Atlantic, Horizon A was correlated with a local Upper Cretaceous reflector, and Horizon β was thought to be a Middle Cretaceous unconformity. Horizon B, thought to be smooth basement, was not reached. Both sites bottomed in nannoplankton chalk with Tithonian chert (Site 5) and Tithonian–Valanginian chert (Site 4). Lack of overburden prevented much lithification. We now know these correlations of the acoustic stratigraphy are not widespread, but local only.

In 1969 these were the oldest rocks known from the deep oceans, but as the enthusiastic Leg 1 shipboard party wrote (Ewing, Worzel, et al., 1969; p. 640):

> It is the hope and expectation of the scientific staff aboard this first leg that this exciting project will continue to flourish and that with continued experience the capabilities will continue to increase for greater depth of coring.

Further research on the regional stratigraphy was accomplished during DSDP Leg 11 (Hollister, Ewing, et al., 1972) when Sites 99, 100, and 101 were drilled near Sites 4 and 5 in the Cat Gap region (Figs. 2 and 3). Hole 99A has 14 short cores to a depth of 248 m sub-bottom, most of which are composed of Oxfordian–Kimmeridgian reddish colored, shaly limestone and Tithonian–Neocomian light colored, nannoplankton chalk with chert. At Site 100, 13 cores were taken between 207 and 331 m sub-bottom; 42 m of Oxfordian gray limestone and 75 m of Oxfordian–Kimmeridgian reddish shaly limestone were recovered. At this locality Tithonian–Neocomian white limestones appear to be over 35 m thick, and the top of these rocks was correlated with Horizon β. Horizon B was penetrated at Site 100 and found to be basaltic basement, not ancient sedimentary rocks. The first detailed record of Middle Cretaceous dark shale facies in the western North Atlantic came from Site 101 (Figs. 2 and 3). Cores 4 to 8 were from a 350-m-thick unit of Barremian–Albian dark shales. Cores 9 and 10 bottomed at 691 m in Neocomian white to gray limestone. Also at Site 101, Horizon A was correlated with the unconformity between the Miocene and Cretaceous shales. This unconformity has since been called the A^u seismic horizon (Tucholke and Mountain, 1979). At Site 105, 1200 km to the north, a similar lithologic sequence was drilled overlying the same Upper Jurassic reddish clayey limestone as found at Sites 99 and 100. The basaltic oceanic basement underneath the Oxfordian limestone at Site 105 was also sampled, which led to better dating of Magnetic Anomaly M-25 in the Keathley Sequence. On the basis of Sites 100 and 105, M-25 was thought to be approximately 145 m.y. old.

The exciting discovery of at least three or more widespread Mesozoic lithofacies in the western Atlantic and their resemblance to deep marine lithologies in the eastern continuation of the Atlantic Ocean through southern Europe (Tethys) led to the first attempts at lithostratigraphic correlation (Lancelot et al., 1972; Bernoulli, 1972).

In the meantime, airborne and shipborne magnetic surveys of the marine magnetic anomalies had led to synthesis of the spreading evolution in the North Atlantic (Vogt et al., 1971, 1979; Pitman and Talwani, 1972). The Keathley Sequence of magnetic anomalies, M-25 to M-0 (between the Middle Jurassic and Middle Cretace-

[1] Sheridan, R. E., Gradstein, F. M., et al., *Init. Repts. DSDP*, 76: Washington (U.S. Govt. Printing Office).

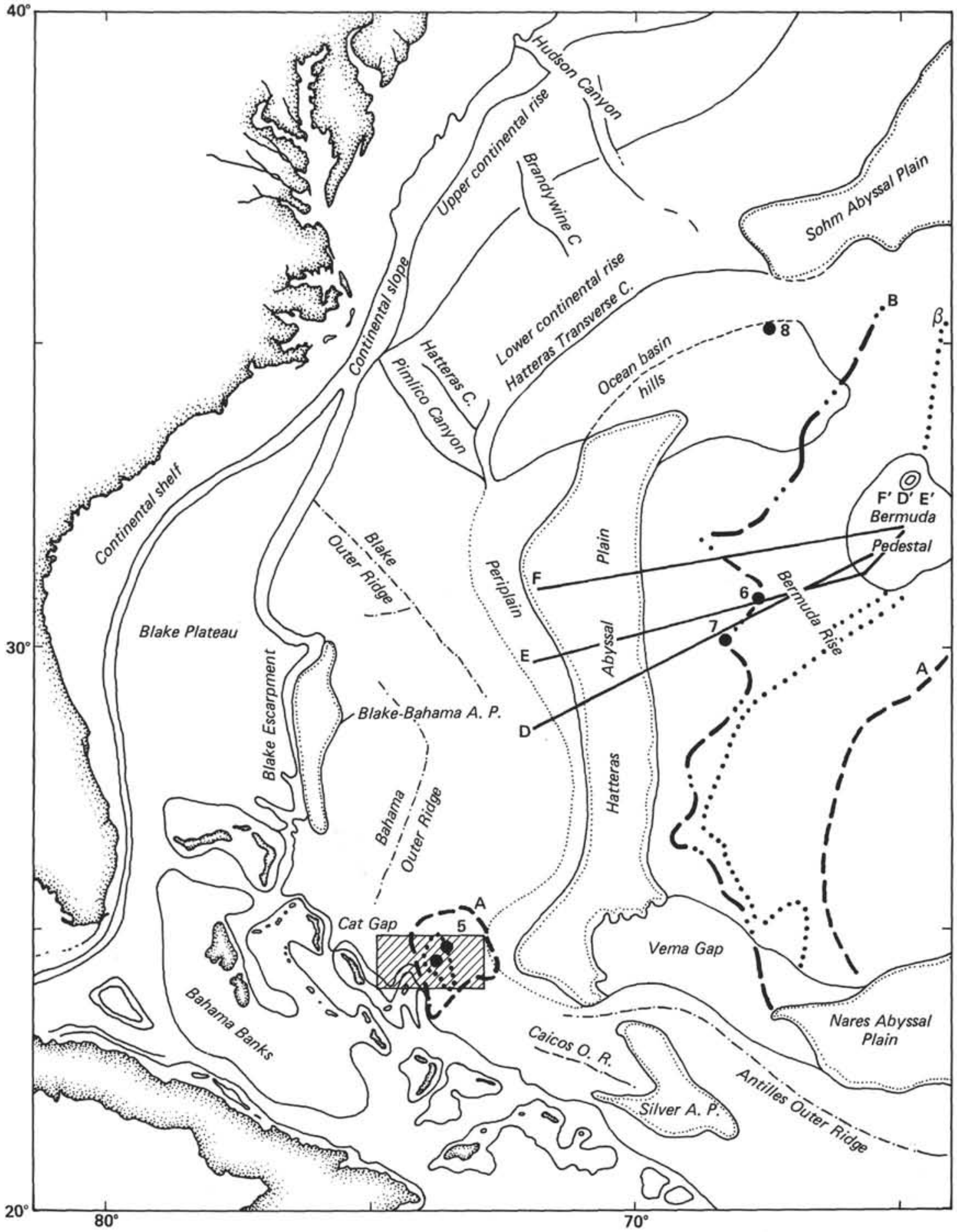

Figure 1. Regional chart of Bermuda Rise area showing locations of Sites 4 through 8 and the eastward limits of Horizons A, β, and B (after Ewing, Worzel, et al., 1969). (A. P. = abyssal plain. O. R. = outer ridge. C. = canyon.).

ous quiet zones), became well documented, as were the earliest spreading lineations, that is, the Blake Spur and East Coast magnetic anomalies (Fig. 4). Refinement of magnetic surveying in the Blake-Bahama Basin resulted in recognition of several low-amplitude anomalies between M-25 and the Blake Spur magnetic anomalies (Sheridan and Osburn, 1975). This recognition in turn posed questions about the exact nature of the magnetic quiet zone and promised refinement of the early spreading history of the Atlantic.

Seismic mapping of the seafloor had also made significant advances with the introduction of higher-resolution single-channel profiling and of multichannel seismic arrays and refined processing (see Tucholke and Mountain, 1979; Dillon et al., 1976; Sheridan et al., 1978). Higher resolution of more deeply buried sections

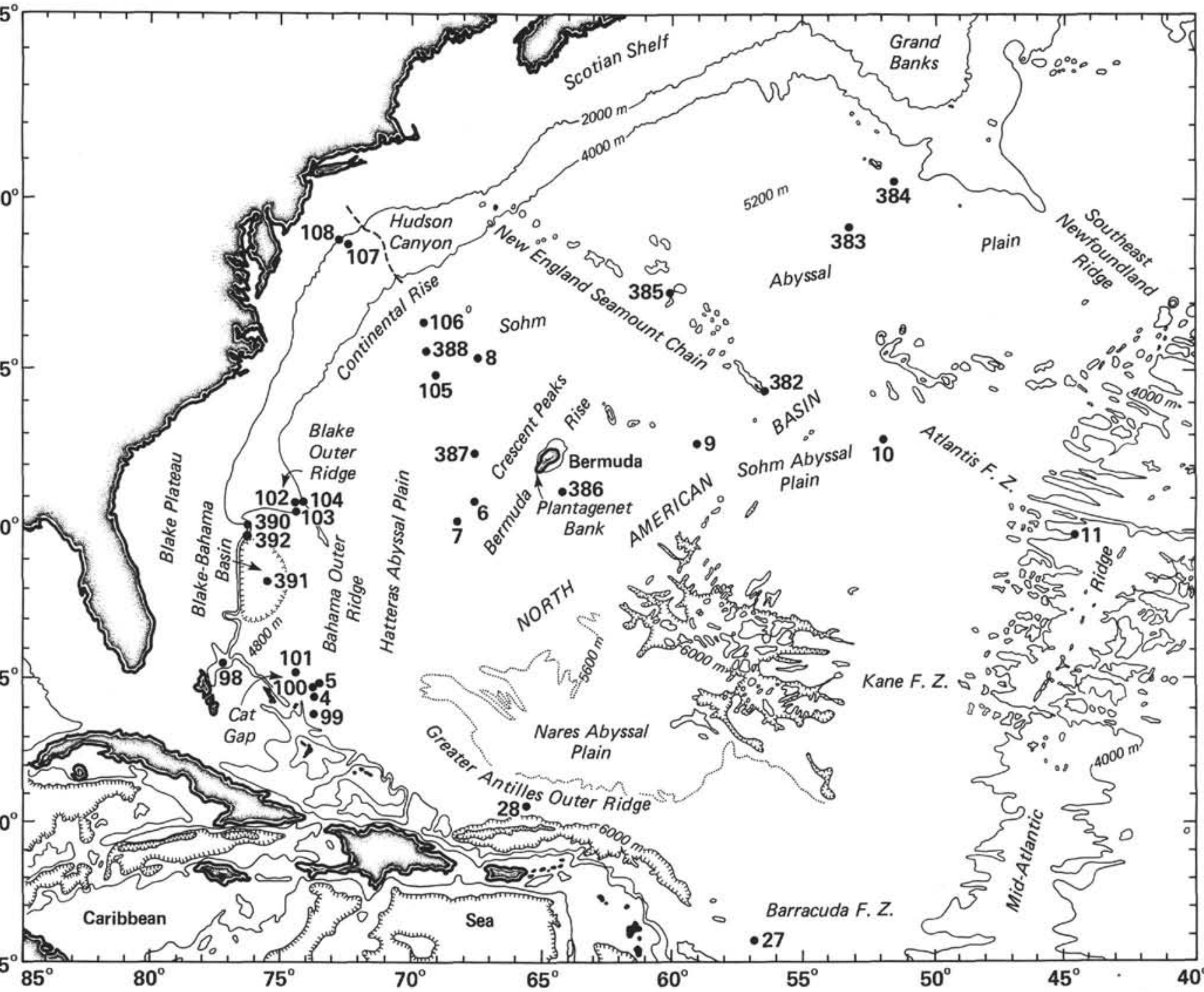

Figure 2. Location map with physiographic features of the North American Basin and location of Deep Sea Drilling Project sites (Legs 1, 2, 4, 11, 43, and 44) (from Jansa et al., 1979).

led to the recognition of seismic Horizon C, the next prominent and widespread reflector below β (Fig. 5).

Armed with this new geomagnetic and seismic knowledge, Leg 44 was the next attempt after Leg 11 to sample the oldest sediments in the Atlantic Ocean basin. Multichannel seismic mapping in the Blake-Bahama Basin, north of Cat Gap (Fig. 5), had identified a flat-lying sedimentary section with reflectors C, β, A^u, and M (Miocene) in the marine magnetic quiet zone (Dillon et al., 1976). Basement, estimated to be in excess of 150 m.y. old (Middle Jurassic), was within reach of the *Challenger's* drill string at 1600 to 2000 m sub-bottom in 5 km of water. The site selected to drill this section was Site 391. After mechanical failure of three reentry cones, single-bit drilling set a then-record penetration depth of 1412 m sub-bottom in Tithonian reddish shaly limestone (Benson, Sheridan, et al., 1978); these sediments were correlated with seismic Horizon C, but the destroyed bit failed to reach basement (Fig. 3). Leg 43, operating in the Sohm Abyssal Plain and Bermuda Rise region of the northwestern Atlantic Ocean, also met with considerable success (Tucholke, Vogt, et al., 1979). Drilling at 7 sites (382–388, Fig. 3) elucidated the complex Cretaceous history of the J-Anomaly Ridge, south of the Grand Banks, and the Tertiary history of the Bermuda Pedestal. Detailed documentation was devoted to the distribution and origin of the Neocomian limestones, Horizon β, Middle Cretaceous black shales and variegated shales, the correlations of Horizon A^c with Eocene chert, A* with Maestrichtian chalk, A^t with turbidites, and A^v with volcanics. Extensive volcaniclastic and siliceous sedimentation at the base of the Bermuda Rise was discovered to have occurred in the Early Tertiary, and the chronology of the Keathley Sequence of magnetic reversals was revised and applied to the North Atlantic spreading history.

Because of Legs 43 and 44, existing information on the temporal and spatial distribution of the successive Mesozoic and Cenozoic lithologies in the North American Basin of the western North Atlantic had grown con-

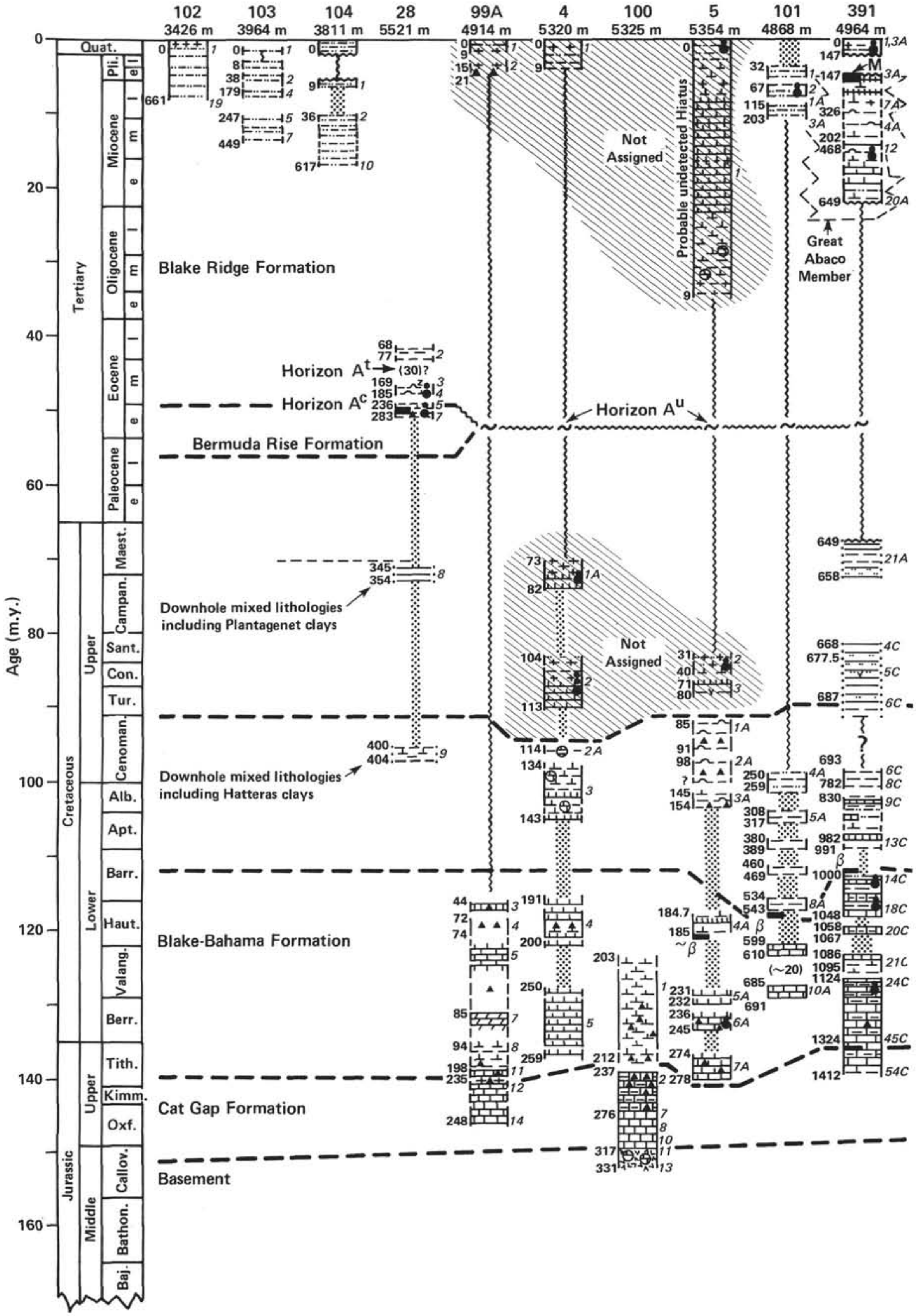

Figure 3. Correlation chart of DSDP sites in the North Atlantic Basin. (The chart shows schematic lithology of individual cores, sub-bottom depth, age, formation names and boundaries, and stratigraphic position of regionally important seismic markers. Quaternary nannofossil–foraminiferal oozes are not assigned to any formation [from Jansa et al., 1979]. If accumulation rate is greater than 20 m/m.y., rate is shown in parentheses.)

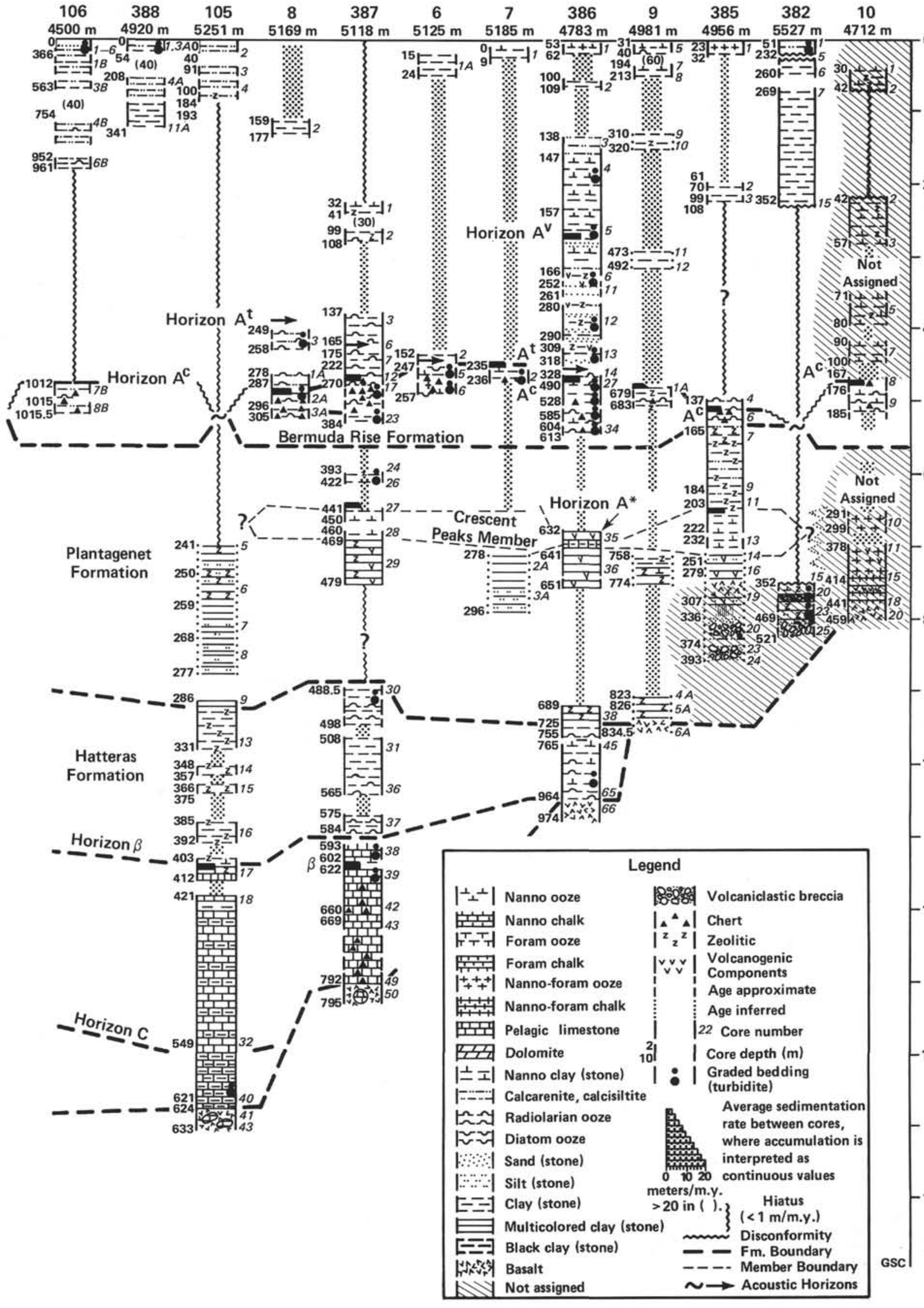

Figure 3. (Continued).

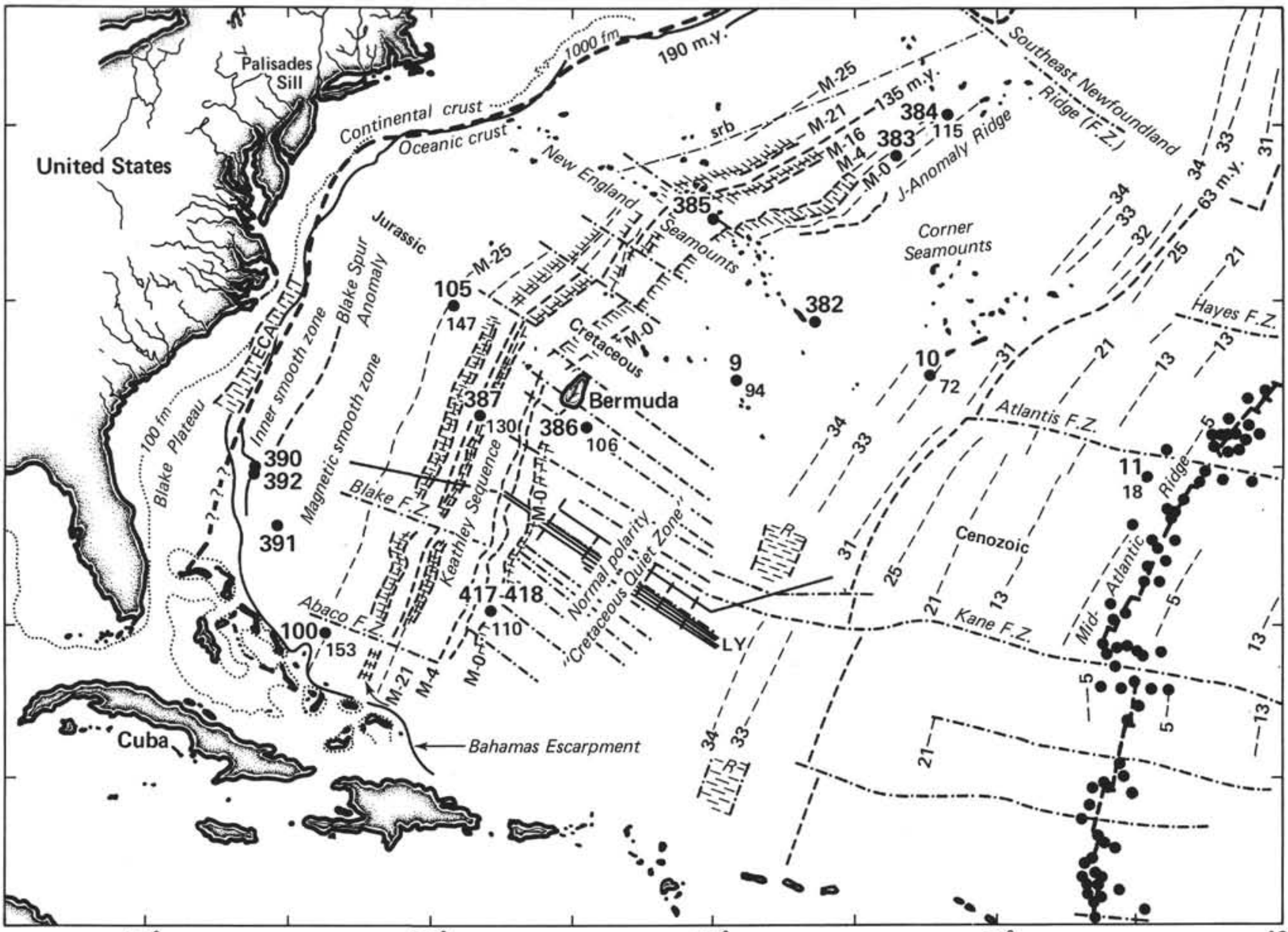

Figure 4. Magnetic lineations, DSDP sites, and basement lineations in the western North Atlantic (after Vogt and Einwich, 1979). (Smooth, rough boundary = srb.)

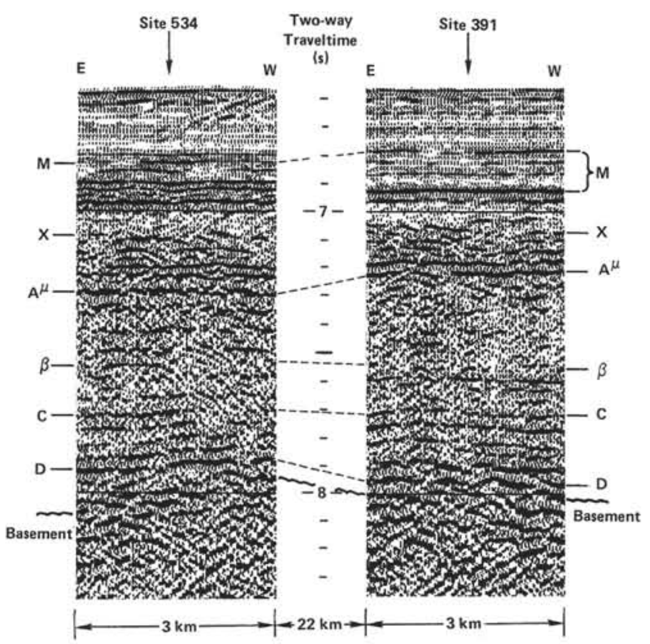

Figure 5. Identification of seismic reflections at Sites 391 and 534 in the Blake-Bahama Basin (from Bryan et al., 1980).

siderably. Enough holes had been drilled on Legs 1, 11, 43, and 44 to permit the formal identification of the formations of the Basin (Fig. 6; Jansa et al., 1979). (This synthesis was greatly aided by knowledge of homotaxial Mesozoic units in the eastern North Atlantic [Leg 41] and in the Mediterranean Tethys.) From oldest to youngest, these formations are the Cat Gap Formation, defined as Oxfordian–early Tithonian reddish brown and greenish shaly limestone; the Blake-Bahama Formation, a late Tithonian to Barremian white and gray limestone; the Hatteras Formation, a Barremian to Cenomanian dark greenish to black shale; the Plantagenet Formation, a variegated late Cenomanian to Paleocene shale and claystone; the Crescent Peaks Member of the Plantagenet Formation, a Maestrichtian chalk of deep-sea origin; the Bermuda Rise Formation, a green, gray, and brown siliceous claystone and chert of the late Paleocene to middle Eocene; the Blake Ridge Formation, a greenish gray to brown hemipelagic mud of the middle Eocene to Holocene; and the Great Abaco Member of the Blake Ridge Formation, a Miocene intraclastic chalk.

Three distinct kinds of seismic reflectors were documented during the decade of deep-sea drilling in the western North Atlantic: (1) Bedding plane reflections where high acoustic impedance contrasts occur at for-

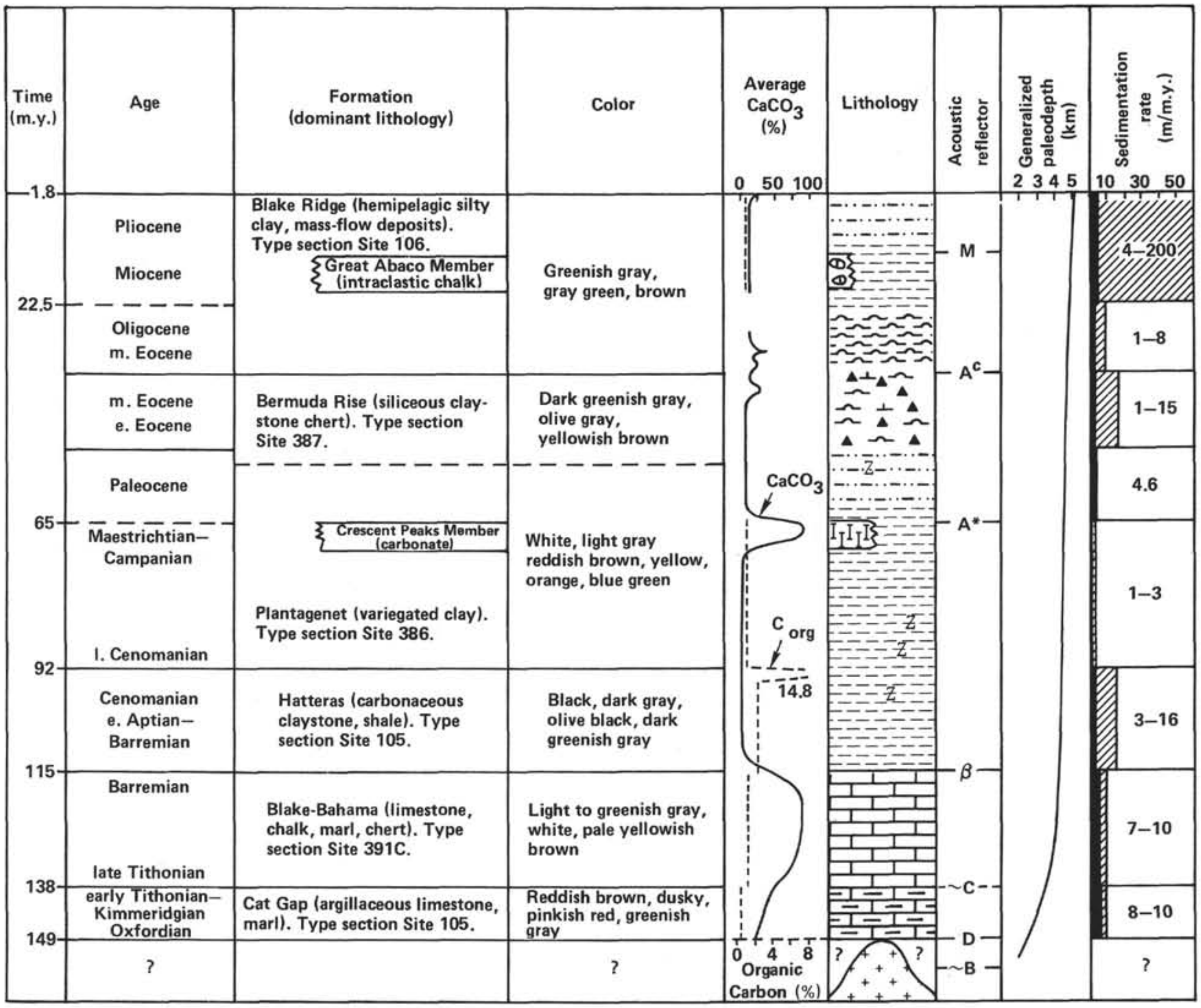

Figure 6. Schematic characteristics of sedimentary formations in the North American Basin (from Jansa et al., 1979). (For an explanation of the lithologic symbols, see Fig. 3.)

mation and at member boundaries (tops and bottoms) or elsewhere within formations, for example, Horizon M (Dillon et al., 1976; Benson, Sheridan, et al., 1978; Sheridan et al., 1978); Horizons A^v, A^c, A^t, and β (Tucholke and Mountain, 1979; Jansa et al., 1979); and Horizon C (Sheridan et al., 1978) (Figs. 3 and 4). (2) Unconformities caused by deep-sea erosion, for example, Horizon A^u (Tucholke and Mountain, 1979; Vail et al., 1980). (3) Acoustic impedance contrasts caused by diagenetic and geochemical boundaries controlling lithification across bedding planes or pore fluid states (gas-hydrate phase changes), for example, Horizon Y on the Blake Outer Ridge (Markl et al., 1970; Ewing and Hollister, 1972).

From this more sophisticated look at the North American Basin seismic stratigraphy, we now see that the Horizon A correlated off San Salvador on Leg 1 at Sites 4 and 5 was actually Horizon A^u, which overlies rocks of anywhere from the Eocene to the Neocomian. Whereas the Horizon A correlated at Sites 7 and 8 on Leg 1, it was actually Horizons A^c, A^t, and A^v, which better, more recent seismic-reflection techniques were finally able to resolve.

Now more recent and better-quality multichannel seismic-reflection profiles farther west in the Basin have shown two more pre-β seismic horizons (Grow and Markl, 1977; Bryan et al., 1980; Kiltgord and Grow, 1980). The prominent reflection Horizon D, within reach of *Glomar Challenger's* drill string in the Blake-Bahama Basin at Site 534 (Bryan et al., 1980) (Figure 5), is thought to be correlative with Horizon J_2 of Klitgord and Grow (1980) farther north off Cape Hatteras; and Horizon C is thought to be equivalent to their J_1 (Fig. 7). The deepest and oldest seismic horizon in the North American Basin is Horizon J_3 (Klitgord and Grow, 1980), which is beyond the present drill string capabilities of the *Glomar Challenger* everywhere. Penetration of J_3 will have to await more advanced deep-water drilling capabilities, such as those envisioned for the *Glomar Explorer*. Sampling of J_3 will clearly be in keeping with the goals of the founding fathers of the Deep Sea Drilling Project—to achieve "greater depth of coring" and

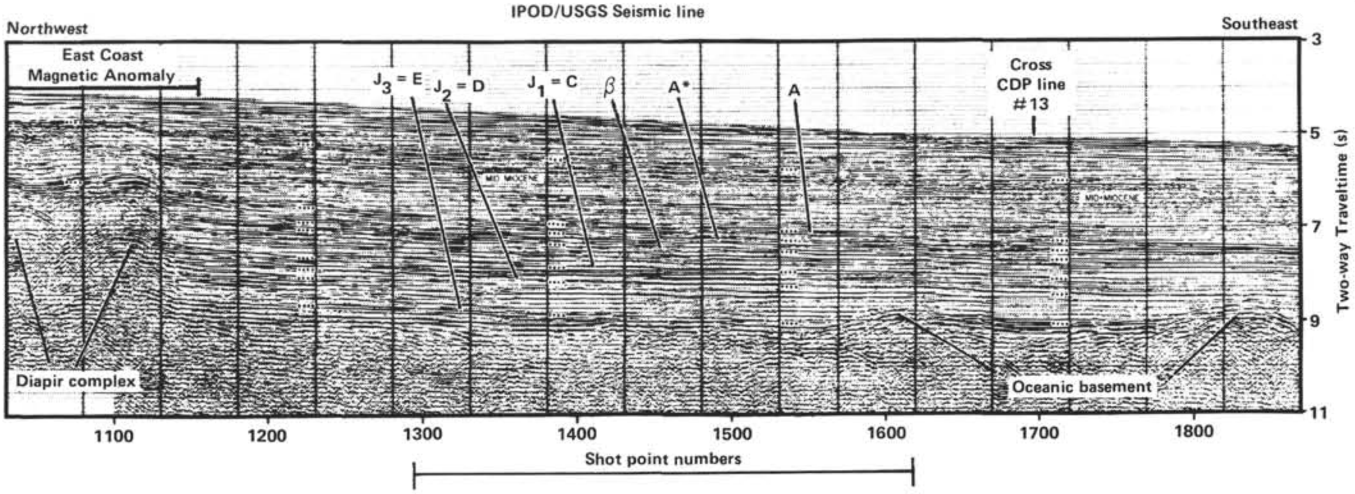

Figure 7. Multichannel seismic-reflection profile across Jurassic magnetic quiet zone of the western North Atlantic (after Grow and Markl, 1977; Klitgord and Grow, 1980). (Correlations are indicated between the nomenclature of Klitgord and Grow [1980]—J_1, J_2, and J_3—and that of Bryan et al. [1980]—C, D, and E.)

to refine a reconstruction of "the birth and growth of the Atlantic Ocean."

In the meantime, the drilling capacity of the *Glomar Challenger* and the perfected reentry technique permit drilling at more modest yet still demanding sites, such as Site 534 on Leg 76, in attempts to further our knowledge of the older stratigraphy of the western North Atlantic Ocean and eastern North American continental margin. This was one of the prime objectives of Leg 76, that is, the penetration through Horizon *D* to the basement as far landward in the Jurassic magnetic quiet zone as possible.

A second important objective was drilling into and testing with the pressure core barrel (PCB) the gas hydrates thought to exist on the Blake Outer Ridge (Fig. 8). Previous drilling on the ridge crests at Sites 102, 103, and 104 had indicated the presence of gas hydrates (Hollister et al., 1972). These sites gave data that demonstrated the diagenetic, time-transgressive nature of reflector Y (Fig. 8). This seismic reflector crossed stratigraphic bedding-parallel reflections and more or less paralleled the seafloor; hence the reflector was called a bottom simulating reflector (BSR).

One possible explanation for this BSR is that gas hydrates were present in pore space of the sediment above this interface; thus the seismic velocity of these hydrated, icelike sediments would be higher than those below (Ewing and Hollister, 1972). Such an hypothesis is in agreement with the geochemical considerations of the theoretical conditions under which gas hydrates occur. The pressure and temperature conditions of the stability field for gas hydrates were thought to be present between the seafloor and the BSR on the Blake Outer Ridge (Kvenvolden and McMenamin, 1980) (Fig. 9). In support of this hypothesis the drilling at Sites 102, 103, and 104 showed evidence of high amounts of methane gas; and drilling correlation indicated that the seismic velocity above the BSR was relatively high—2.0 km/s (Hollister, Ewing, et al., 1972).

On Leg 44, with a prototype PCB several attempts were made to sample under *in situ* pressure the gas hydrate on the eastern North American continental rise. Each time, however, the PCB failed to seal; thus no Leg 44 site in the Blake Outer Ridge area was tested for the presence of gas hydrates. This additional objective awaited Leg 76, on which a newly designed and tested PCB was used.

To address these two rather different, broad objectives, two sites were drilled on Leg 76: Site 533 on the Blake Outer Ridge and Site 534 in the Blake-Bahama Basin (Fig. 10). Detailed objectives and results of the drilling at these sites are discussed next.

SITE 533: BLAKE OUTER RIDGE

Summary of Objectives

1. To sample the gas hydrates with a pressure core barrel for quantitative tests of the gas pressures and volumes.
2. To sample the gas itself for compositional analyses, which can distinguish biogenic versus thermogenic origin (and therefore possible depth of source).
3. To sample and preserve under pressure natural samples of the gas hydrate.
4. To photograph and observe the gas hydrate before decomposition.
5. To obtain complete mechanical logs in the drill holes at Site 533 for a measure of the *in situ* physical properties (and to analyze these logs in comparison with available seismic data in the area and directly at the site).
6. To study the primary sedimentary structures in the cores in order to understand better the complex deposition of contourites and accretion of the Blake Outer Ridge.

Principal Results

A stratigraphically continuous record was obtained of middle Pliocene through Holocene gray green mudstone. The pre-Quaternary deposits have virtually no visible stratification. The rate of deposition decreases over 50% from Pliocene into Pleistocene, varying from

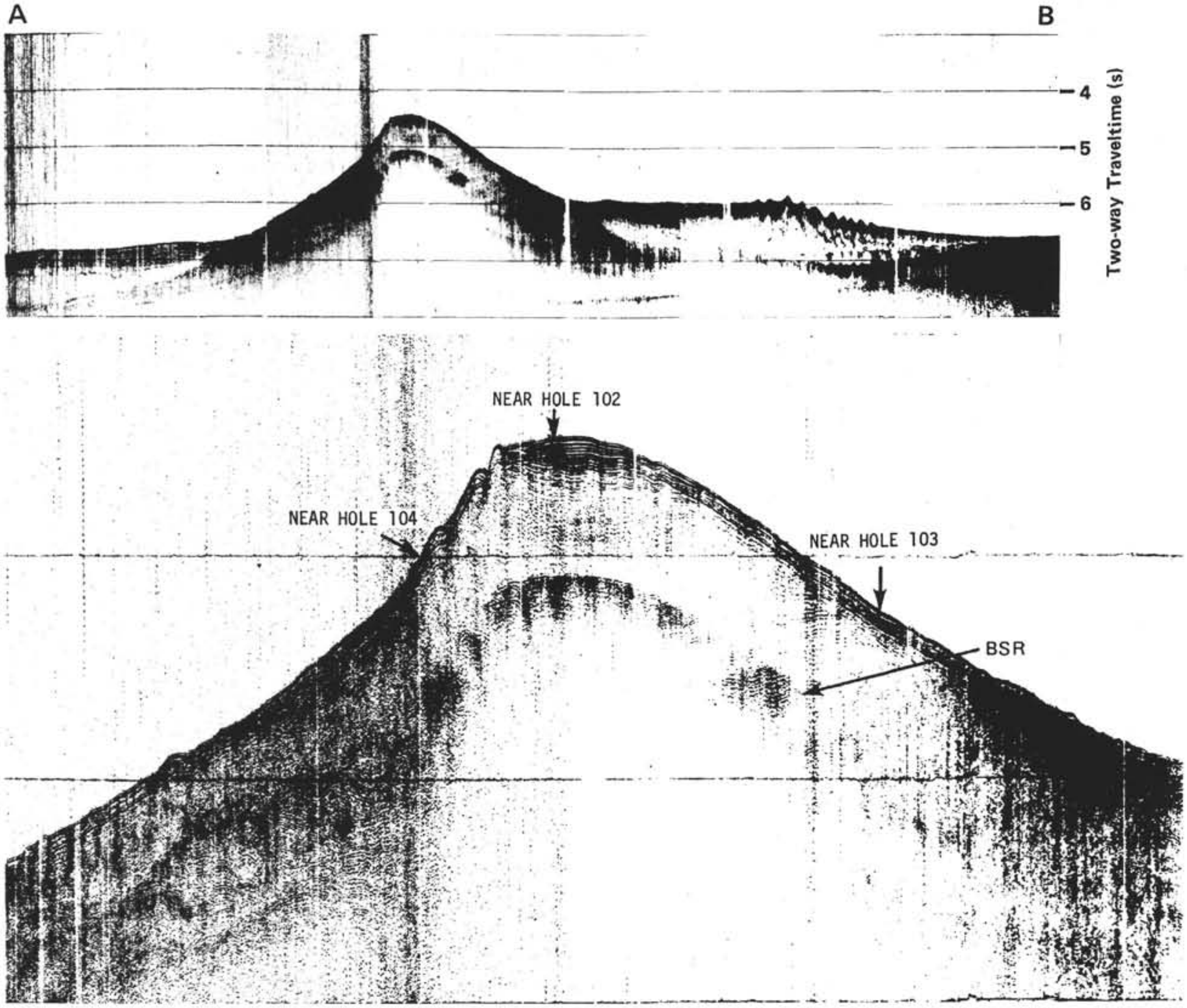

Figure 8. Single-channel seismic reflection profile across the Blake Outer Ridge near Sites 102, 103, and 104 (from Hollister et al., 1972). (BSR stands for bottom simulating reflector; the BSR is equivalent to reflector Y [Markl et al., 1970].)

17 cm/1000 y. in the Pliocene to 8 cm/1000 y. in the Pleistocene. A local unconformity on the seismic record separates Pliocene from Pleistocene beds at 158 m subbottom (Fig. 11) and probably is an erosional event shaped by contour-following currents. The alkalinity shows a strong negative gradient across the local unconformity, suggesting diffusion control by closure. Patchy stratification on the seismic record in the Pliocene interval may be due to "concretions" of calcitic mudstone and thin gas-hydrate lenses. No explanation was found for the apparent acoustic transparency of the Pliocene section as seen on seismic profiles. The temperature gradient varies from 5.1°C/100 m near the seafloor to 3.6°C/100 m at the bottom of the hole, which agrees with the prediction that the strong bottom simulating reflector at 0.60 s is the result of hydrate inversion. Two sonobuoy profiles confirm a velocity inversion at this depth. Outgassing of mudstone cores increased downhole, and a few thin beds (3–5 cm) of gas hydrate were sampled at 240 m. The hydrate sample expanded 13 times its total volume (20 times its pore-space volume) upon decomposition, yielding mainly methane and significant concentrations of propane and isobutane. As expected, normal butane and higher molecular weight gases were in low concentrations, because these molecules are too large to be included in the gas-hydrate structure. The pressure core barrel (PCB) was deployed successfully four times; geochemical analyses of gases from this tool showed the presence of hydrocarbon gases, with C_1/C_2 ratios decreasing with depth toward the bottom of the hole. Initial analyses of the pressure release experiment from the PCB (Fig. 12) provide indirect evidence for gas hydrates in the sampled intervals, however, these experiments cannot determine the condition and the precise amounts of hydrates in the hydrated sediments. The only positively observed hydrates were in thin (< 10 cm) layers.

SITE 534: BLAKE-BAHAMA BASIN

Summary of Objectives

1. To extend lithostratigraphy below the Upper Jurassic and correlate to the Tethys facies of the same age. To provide multidisciplinary geological information on

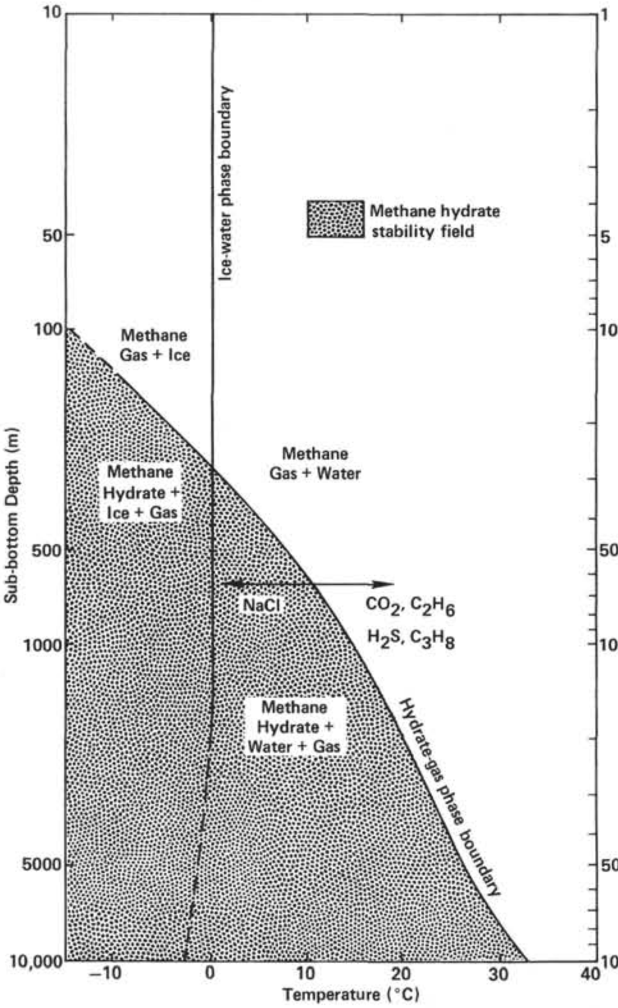

Figure 9. Phase boundary diagram showing free methane gas and methane hydrate for a fresh water-pure methane system. (Addition of NaCl to water lowers the temperature of hydrate formation, in effect shifting the gas-hydrate curve to the left. Addition of CO_2, H_2S, C_2H_6, or C_3H_8 raises the temperature of hydrate formation, in effect shifting the curve to the right. Therefore, impurities in natural gas will increase the area of the hydrate stability field. Depth scale is an approximation, assuming that lithostatic and hydrostatic pressure gradients are both 0.1 atmosphere per meter [10.1 kPa/m], but the true lithostatic gradient is slightly greater [after Kvenvolden and McMenamin, 1980].)

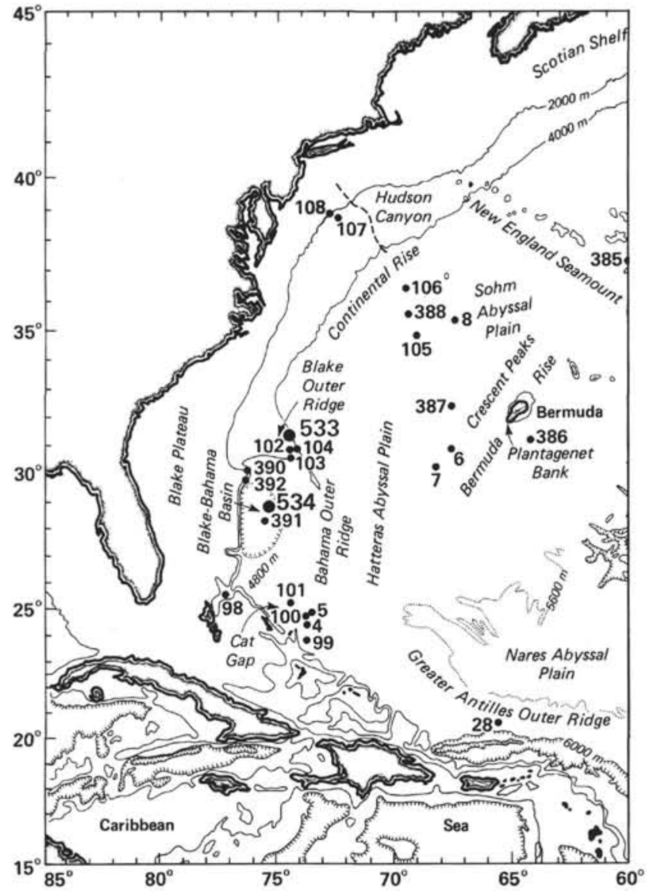

Figure 10. Location map showing Sites 533 and 534 of Leg 76 relative to previous DSDP and IPOD sites.

one of the thickest ocean sections of Cretaceous dark shales in order to further delineate its origin.

2. To establish a multiple Jurassic deep-marine biostratigraphy and attempt to resolve discrepancies in dating of Leg 11 deposits; also, to correlate to the Tethyan province eastward.

3. To date the seismic Horizon D and determine its genetic origin.

4. To make Jurassic, Cretaceous, and Cenozoic paleobathymetric estimates based on corrected backtracking; and to connect the subsidence with the history of sedimentation and biofacies as a function of the carbonate dissolution regime.

5. To relate the Site 534 geological-paleontological record to the paleogeography of the early ocean basin and to establish arguments for dating the early connection between the Tethys and Pacific.

6. To trace the evolution of the pelagic biota in the early Atlantic Ocean.

7. To correlate the magnetostratigraphic record at the base of and below the Keathley sequence with the biostratigraphy, sedimentation rates, and rates of seafloor spreading in order to furnish a more precise Jurassic time scale.

8. To date the Jurassic spreading-center jump associated with the Blake Spur Magnetic Anomaly in the western North Atlantic Ocean.

9. To compare the Jurassic and Cretaceous spreading rates and relate these to the temporal distribution of the magnetic quiet zones.

Principal Results

Continuous coring between 534 and 1666 m below the seafloor yielded a detailed ocean basement and overlying sedimentary record spanning over 140 m.y. of Atlantic Ocean history. Callovian through Albian, Maestrichtian, late Eocene, and early Miocene sediments were recovered (Fig. 13). The post-early Miocene section can be extrapolated from near Site 391. The sedimentary sequence reflects largely continuous, quiescent 0.1 cm/10^3 y. or less, hemipelagic sedimentation most-

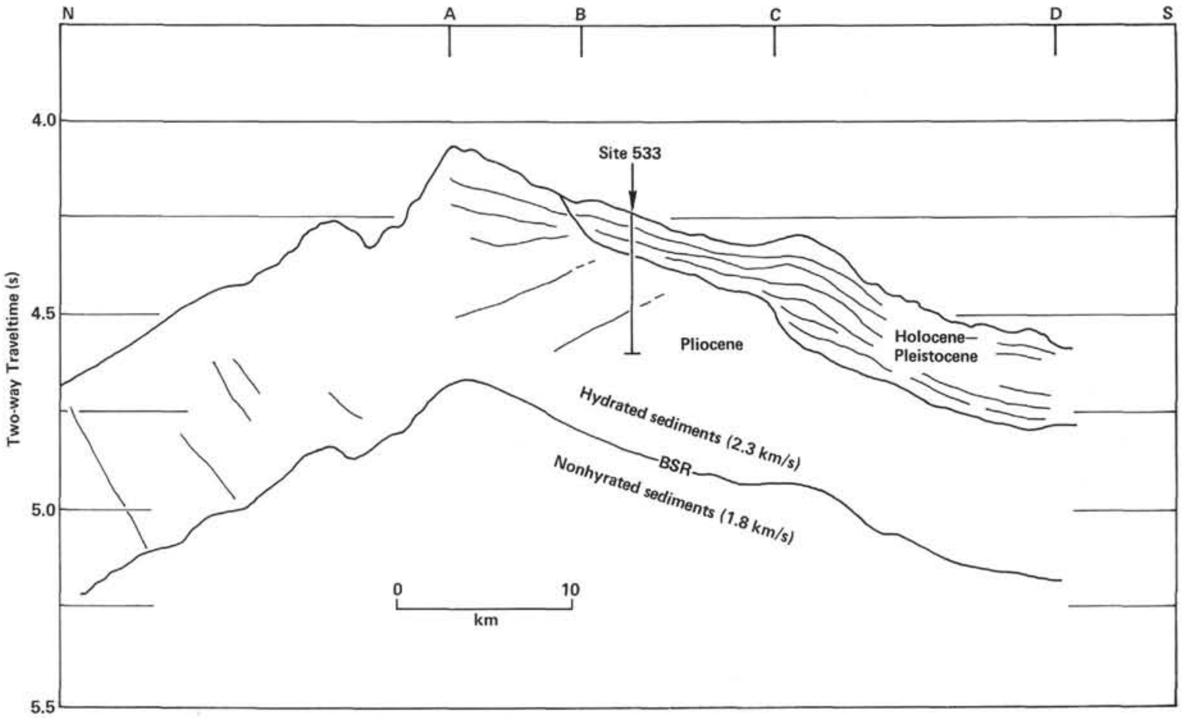

Figure 11. Interpreted seismic reflection profile at Site 533.

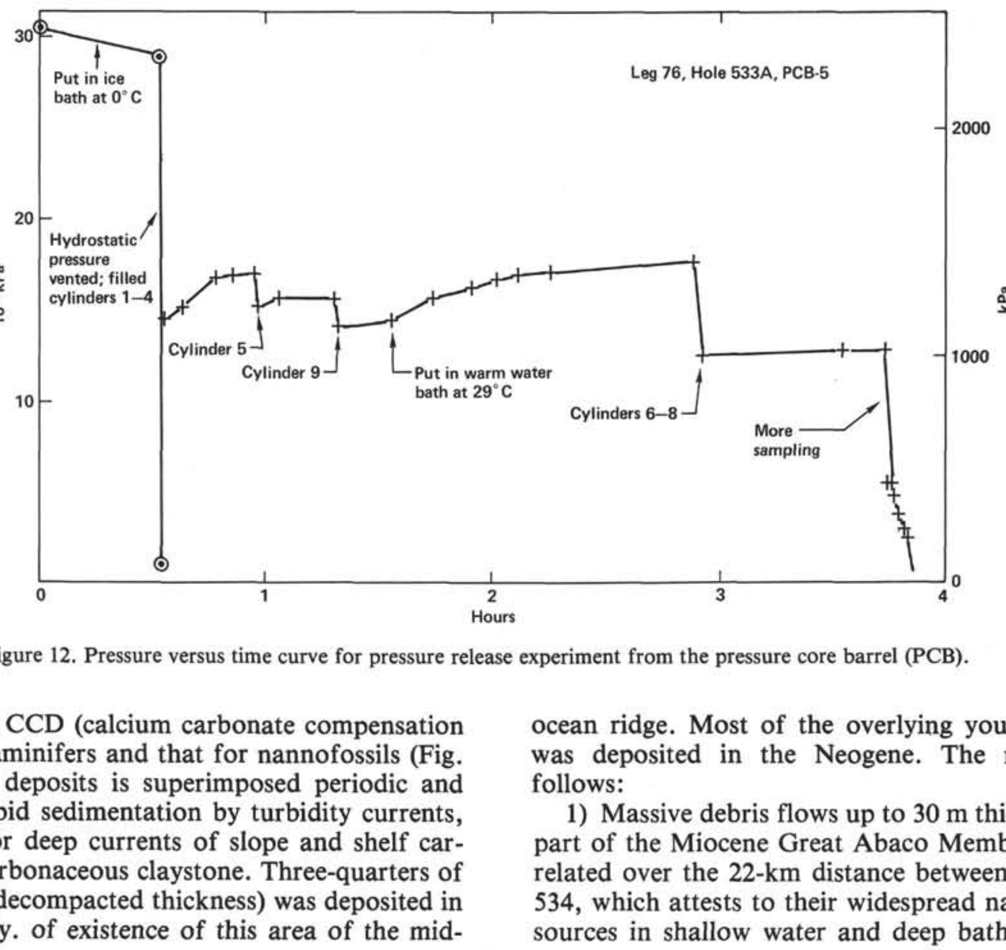

Figure 12. Pressure versus time curve for pressure release experiment from the pressure core barrel (PCB).

ly between the CCD (calcium carbonate compensation depth) for foraminifers and that for nannofossils (Fig. 14). On these deposits is superimposed periodic and much more rapid sedimentation by turbidity currents, debris flows, or deep currents of slope and shelf carbonates and carbonaceous claystone. Three-quarters of this sediment (decompacted thickness) was deposited in the first 50 m.y. of existence of this area of the mid-ocean ridge. Most of the overlying younger sediment was deposited in the Neogene. The results are as follows:

1) Massive debris flows up to 30 m thick in the lower part of the Miocene Great Abaco Member can be correlated over the 22-km distance between Sites 391 and 534, which attests to their widespread nature. Multiple sources in shallow water and deep bathyal areas sup-

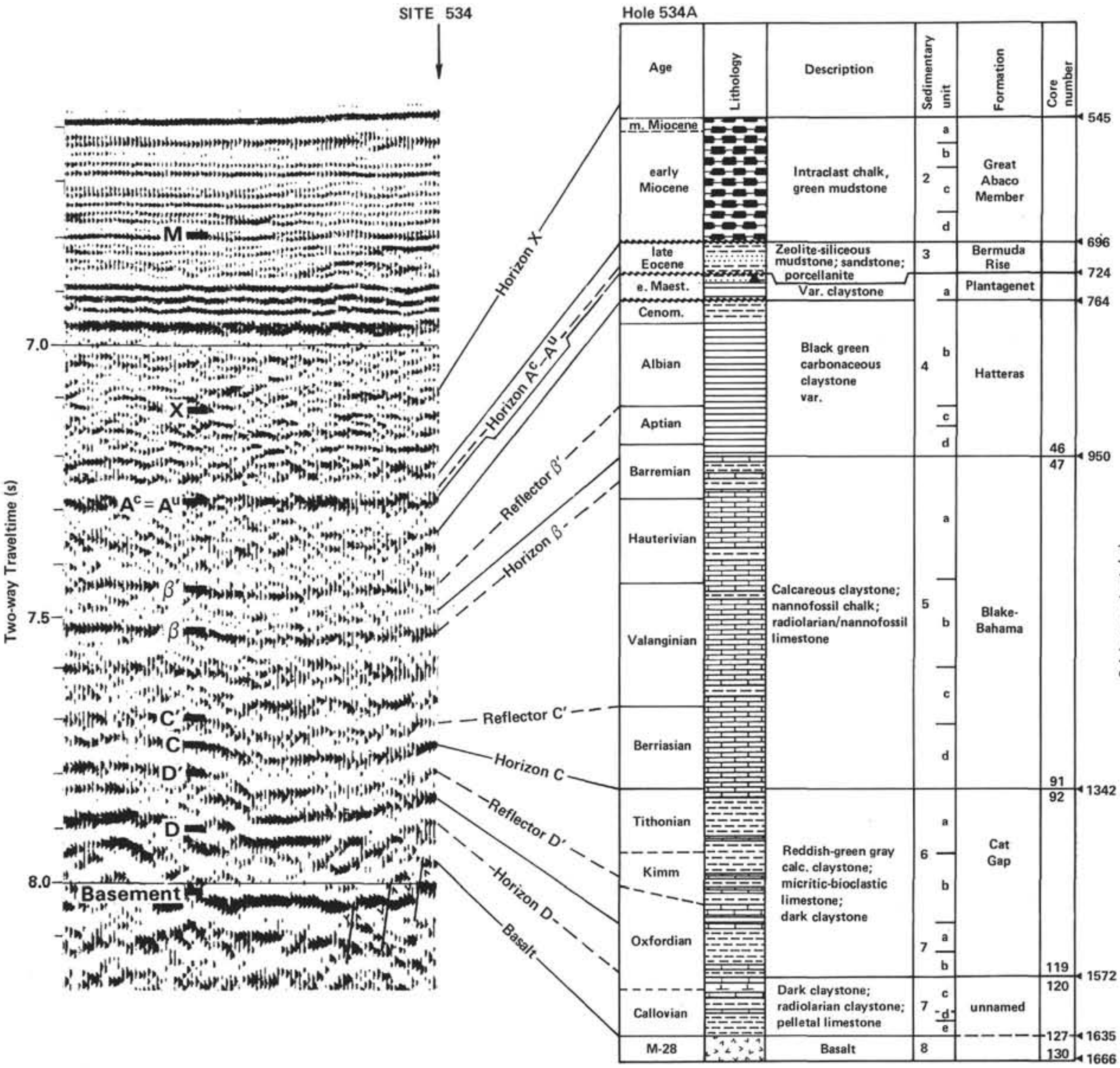

Figure 13. Summary of stratigraphy at Site 534. (Correlations to the nearby seismic-reflection profile are tentative and based on shipboard work.)

plied the transported material, which disrupted the indigenous, basinal, hemipelagic clay sediments and incorporated the clasts in this lower Miocene deposit.

2) The upper Eocene cherts and porcellanites of the Bermuda Rise Formation (27 m thick) discovered at Site 534 indicate that Oligocene erosion in the Blake-Bahama Basin did not totally remove the Paleogene sediments. The remnants of these slowly deposited sediments indicate that a long period of slow deposition in the Paleogene resulted in only a thin deposit of sediments. This deposition history contradicts previous conclusions (based on vitrinite reflectance of the Cretaceous black shale of Site 391) that 800 m of post-Cenomanian to pre-Miocene sediments were eroded. The presence of chert indicates that seismic Horizon A^c is merged with Horizon A^u as a single wavelet in the Blake-Bahama Basin.

3) Continuous coring of the shales of the Maestrichtian Plantagenet and the Albian–Barremian Hatteras Formations (186 m thick) reveals the slow accumulation (< 1 cm/10^3 y.) of clay mineral and organic matter in depths beneath the CCD. Green clays alternating with black shale in the carbonaceous parts of the Hatteras Formation suggest low-oxygen or anoxic conditions, which were brought about when the possibly poorly oxygenated ocean basin was overwhelmed with organic matter. Peaks in organic matter concentrations are found in the Aptian and Albian. The variegated claystones of the Maestrichtian Plantagenet Formation are interpreted as due to the basin-wide oxygenation in the presence of sluggish bottom-water currents. Similar variegated claystone, this time with winnowed silt beds, in the middle of the Hatteras Formation is attributed to another previous oxygenation episode under the influ-

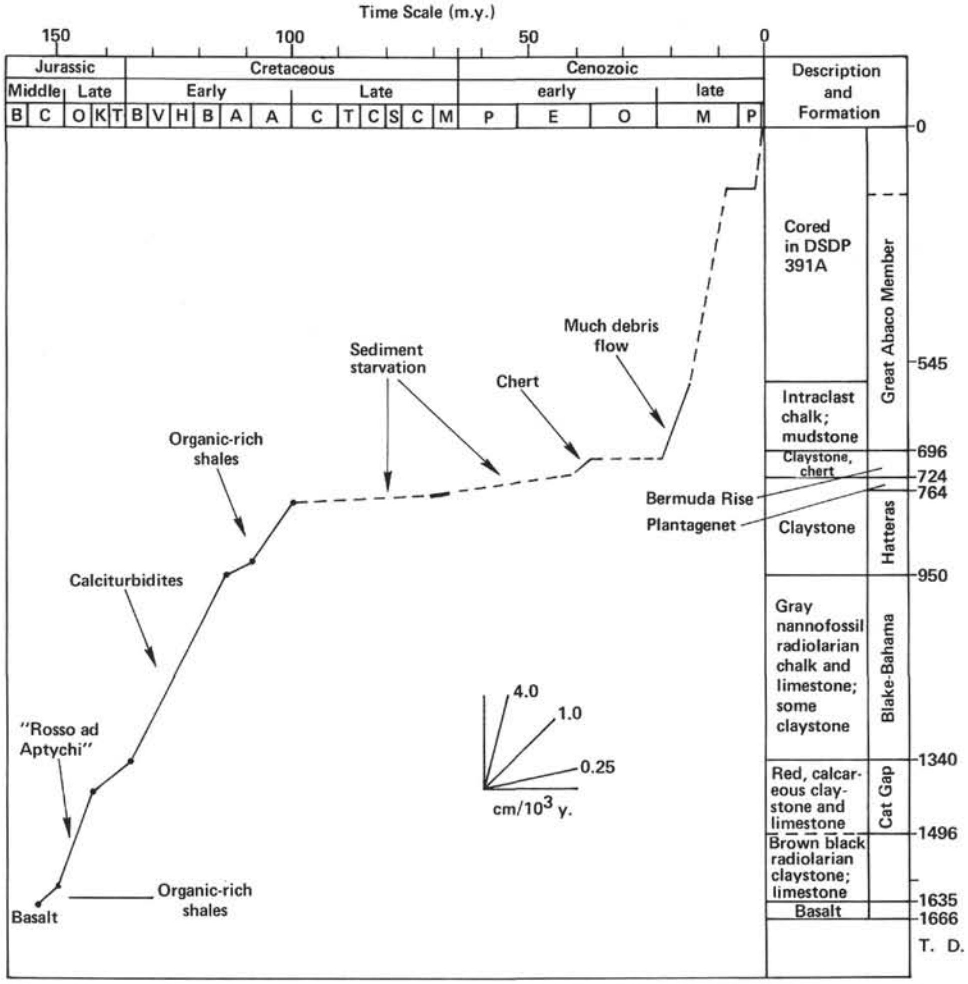

Figure 14. Net sediment accumulation at Site 534. (Note that the upper 530 m is extrapolated from Site 391. See Fig. 13 for a guide to stage abbreviations.)

ence of improved bottom circulation. A weak reflector is associated with this older variegated claystone and is called β', which might be an unconformity caused by the oxygenating currents.

4) Continuous coring of the Berriasian to Barremian Blake-Bahama Formation (392 m thick) indicates sedimentation of alternating turbiditic (detrital to organoclastic) and pelagic biogenic deposits well above the CCD. The organic shale and terrigenous, quartz-rich sands and silts occur in greater quantities in the Blake-Bahama Formation at Site 534 than at Site 391, indicating a lateral facies transition from clastic- to limestone-dominated sedimentation. Seismic Horizon β is correlated with the Barremian turbiditic limestone near the top of the Blake-Bahama Formation, and another prominent reflector called C′ is correlated with the Berriasian limestones at the bottom of the formation.

5) Continuous coring of the Cat Gap Formation (153 m thick) indicates deposition of red calcareous claystone and transported limestone in an environment near the CCD and ACD (aragonite compensation depth). Relatively detailed biostratigraphy using nannofossils, foraminifers, and calpionellids shows the Cretaceous/Jurassic boundary to be at the top of the Cat Gap Formation. The top of the red shaly limestones of the Cat Gap correlates with seismic Horizon C. Another possible unconformity in the Kimmeridgian separates the red shales of the Cat Gap from the lower, limestone-rich subunit of the same formation. This unconformity is seismic reflector D′.

6) Continuous coring of the oldest sediments (140 m thick) of the Callovian and Oxfordian reveals a stratigraphic transition from an organic, phosphatic dark red, green, and black Callovian shale to Oxfordian siliceous radiolarian-rich, green black, silty claystone mixed with displaced turbiditic slope limestones. The oldest sedimentary unit reflects above-average organic input and bottom-water conditions, which depleted oxygen content at the sediment/water interface. Evidence for at least some deep circulation comes from current ripple laminations and seismic evidence at Site 534 that indicates the existence of current-deposited bed forms below Horizon D. Horizon D itself is correlated with the Oxfordian turbiditic limestones.

7) Fractured oceanic basalt (31.5 m thick) with several 1 to 5 cm thin, silicified, red limestone beds was recovered from below a strong clear basement reflector that agrees with the sharp contact observed at the base

of Core 127. Well-healed and -cemented basalt breccia zones and well-developed mineral veins attest to the long period of diagenesis that this oldest basement rock has undergone. This finding proves a normal oceanic crust exists under the outer (Jurassic) magnetic quiet zone.

8) Dating the sediments just above oceanic basement at marine Magnetic Anomaly M-28 as middle Callovian yields a spreading rate of approximately 3.8 cm/y. for the Blake-Bahama Basin between the Blake Spur and M-22 anomalies. This constant spreading rate agrees reasonably with the paleomagnetic dating of Anomalies M-22 and M-25 by Ogg (1981). This rate establishes an age of latest Oxfordian for Anomaly M-25 (143 m.y.), 2 to 6 m.y. younger than previous estimates. Projecting this relatively high spreading rate backward in time yields an age of early Callovian (±155 m.y.) for the Blake Spur Magnetic Anomaly, which is 20 m.y. younger than previously thought. Thus the major spreading-center jump associated with the Blake Spur Anomaly and the opening of the modern North Atlantic are judged to be much younger than previously postulated.

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