The paleoenvironment and development of the eastern North American continental margin

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ABSTRACT

Geophysical studies (multichannel seismic reflection profiles, gravity and magnetic surveys) have been combined with drill hole data so that the major structural elements of the eastern North American continental margin and the seismic stratigraphy of the offshore sedimentary prism can be outlined. The sedimentary basins, trough and platforms are built over a zone of rifted and thinned crust of variable width (20-300 km). Upper Paleozoic and Triassic-Lower Jurassic red beds were deposited in northeast trending grabens that formed prior to or synchronous with rifting (pre- and synrift). During the late synrift phase, Upper Triassic and Lower Jurassic evaporitic sequences were precipitated in a southward encroaching Tethyan seaway. Studies of drill cores on the present shelf indicate that major marine incursions occurred during the Early and Late Middle Jurassic and culminated in the build up of a series of carbonate platforms and banks that continued to flourish into the Albian on the Eastern Blake Plateau. Off the eastern United States, these banks appear to have formed in the vicinity of the ocean-continent boundary, and may have been associated with secondary volcanic dikes and sills which were emplaced 20-30 m.y. after continental separation. Influxes of terrigenous detritus during the Early to middle Cretaceous broadly prograded the margin as deltaic and mixed inner shelf and nonmarine deposits. A series of marine transgressions in the Late Cretaceous and early Tertiary changed the shelf to a deep-water setting and resulted in the deposition of chalks and marly shale. Major marine regressions in the Oligocene, Miocene and Quaternary contributed to periodic cutback of shelf and slope; exposure of Cretaceous and lower Tertiary strata in submarine canyons, accentuation of the shelf-slope-rise profile, and construction of a broad sedimentary prism beneath the continental rise.


RÉSUMÉ

Le Paléoenvironnement et le développement de la marge continentale du nord-est de l’Amérique.

La combinaison des études géophysiques (sismique réflexion multitrace, levés gravimétriques et magnétiques) avec les données des forages permettent de définir les traits structuraux majeurs de la marge continentale du nord-est de l’Amérique et la stratigraphie sismique des dépôts sédimentaires. Les bassins sédimentaires, fosse et plates-formes, se sont développés sur une zone de rift de largeur variable (20-300 km) où la croûte est amincie. Les couches rouges du Périozozoïque supérieur et du Trias-Jurassique inférieur se sont déposées dans des grabens d’orientation NE-SW, créés avant et pendant la formation du rift. Durant la dernière phase synrift, des évaporites du Trias supérieur-Jurassique inférieur ont été précipitées dans un bras de mer, prolongement SW de la Tethys. L’étude des forages effectués sur le plateau
continental actuel montre que les principales incursions marines ont eu lieu durant le Jurassique inférieur et moyen tardif, et ont culminé avec le développement de plate-formes et bancs carbonatés qui ont continué à se développer jusqu'à l'Albien sur la partie orientale du plateau de Blake. A l'est des États-Unis, ces bancs semblent s'être formés au voisinage de la limite continent-ocean, et peuvent avoir été associés avec la mise en place de dikes et sills volcaniques secondaires, 20 à 30 millions d'années après la séparation des continents. La marge a ensuite progradé sous forme de dépôts deltaïques et de plate-forme interne intercalés avec des dépôts non marins, grâce à des apports terrigènes durant le Crétacé inférieur et moyen. Une série de transgressions marines durant le Crétacé supérieur et le Tertiaire inférieur ont fait évoluer la plate-forme vers un milieu plus profond où se sont déposées des craies et des argiles marneuses. Les régressions marines majeures de l'Oligocène, du Miocène et du Quaternaire, ont causé des érosions périodiques du plateau et de la pente, la mise à l'affleurement des couches du Crétacé et du Tertiaire inférieur dans les canyons sous-marins, l'accélération du profil plateau-pente-glacis et la construction de larges prismes sédimentaires sur le glaci continental.


INTRODUCTION

The analyses of data from deep exploratory and stratigraphic holes drilled over the past ten years, and from a grid of multichannel seismic reflection, magnetic and gravity surveys have provided a fresh insight of how the western North Atlantic continental margin has developed over the past 200 million years. Our purpose is to discuss the offshore structure and stratigraphy from southern Newfoundland to Florida — the geometry of the offshore basins, the ages and types of sedimentary rocks found in them, and the major stages in their development (Fig. 1).

TECTONIC FRAMEWORK

The Atlantic margin has been built over the fractured, edge of the North American continent in response to the latest opening of the North Atlantic Ocean (Wilson, 1966). Sedimentary infilling over basins and platforms has created a continental shelf (< 200 m depth) 2 km to 540 km wide; the shelf is widest seaward of southeastern Newfoundland (Grand Banks) and narrowest adjacent to southern Florida (Fig. 1). It encompasses a string of sedimentary basins of Mesozoic-Cenozoic age from the Blake Plateau basin in the south to the Scotian basin in the North. Adjacent to the

Figure 1
Index map of eastern North American margin. Upper map shows main tectonic elements. Lower map shows geography, isobaths and location of schematic cross sections (Fig. 8-10).
basins are platforms that are block faulted, and are bordered on their seaward sides by narrow troughs that form a transition to the adjacent basins. Many basins are further divided into smaller subbasins separated from one another by structural highs (arcs, ridges). Some basins and troughs contain zones of diapirs along the seaward sides (Carolina trough; Scotian basin). Deposits from these basins border and in part cover older Triassic and Late Paleozoic sedimentary basins (Fig. 1). These older basins chronicle a complex history of crustal movement during the separation of Africa and North America (see van Houten, 1977) in the Late Triassic — Early Jurassic. In part, the placement and orientation of offshore basins and platforms were influenced by earlier structural trends evident in the Appalachian mountain chain to the northwest. Major structural provinces (promontories and reentrants shown on Williams (1978) "Tectonic Lithofacies map of the Appalachian Orogen") are paralleled offshore along part of northeast and mid-Atlantic US margin by basins seaward of the reentrants and by platforms seaward of the promontories. Further, major shifts in the trend of the Appalachians appear to be matched in the offshore by changes in the orientation of the present shelf edge; the two most obvious matches are seen at the Georges Bank (east-west) area seaward of a east-west bend in orientation of the strike of the Appalachians, and at the Grand Banks of Newfoundland shelf (east-southwest shelf-edge trend) seaward of an east-west offset in the trend of Appalachian geology and geophysics (gravity and magnetic anomaly patterns) at the Gulf of St. Lawrence.

BASIN GEOMETRY

The varied geometry of the four sedimentary basins (Fig. 2-5) probably relates to their tectonic setting (see Grow, Sheridan, in press, for a discussion of deep crustal structure). The Blake Plateau basin (Fig. 2) is an equidimensional feature that formed between rift basins of Triassic age to the northwest and the complexly fractured Guinea Plateau of West Africa to the east (Klitgord, Behrendt, 1979; Lehner, De Ruijer, 1977). The basin is bounded by the extensions of major oceanic fracture zones (Fig. 1) to the northeast (where the Carolina trough [Fig. 2] begins) and to the southwest (Bahamas). Dillon et al. (1979, p. 40) inferred a change in the type of basement beneath the sedimentary section from mainly sialic crust intruded by basalt in the northeast (Carolina trough) to mantle derived sima, mixed with the sialic crustal blocks. Clearly the zone of transitional crust is broader here than along much of the rest of the eastern North America margin but why this should be is not clear.

The Baltimore Canyon trough is elongate and in places contains in sedimentary rock more than 18 km thick that is inferred to be Triassic and younger. The main part of the trough is outlined by a zone of rapid thickening (from 7 to 10 km) beneath the Continental Shelf (Fig. 3). Beneath and seaward of this zone, the trough is inferred to be underlain by thinned continental crust in a transition area from continental crust to oceanic crust that is narrower than that seen in the Blake Plateau basin. Thickness over the intervening Carolina platform is only 2-4 km, although immediately seaward of it, the thickness of the narrow Carolina trough (Fig. 2), is as much as 10 km. The Baltimore Canyon trough terminates near Cape Hatteras. Within the basin, thickness contours are irregular toward the Carolina platform and the Long Island platform because basement is faulted into grabens and horsts. In a reconstruction of North American and West Africa (Klitgord, Behrendt, 1979), the Baltimore Canyon trough is shown as opposite the Reguibat uplift of Western Sahara where sedimentary cover is thin (1 to 3 sec. penetration, two-way travel time, Uchupi et al., 1976).

Georges Bank basin (Fig. 4) is a series of northeast trending subbasins between the LaHave platform to the northeast and the Long Island platform to the west. An isopach map of the basin reveals an irregular pattern of sedimentary fill. The basement blocks are much larger and less deeply buried.
than are those in the other basins, so that they isolate the oldest infilling of sediment as subbasins. Blanketing these older deposits is a broad sedimentary wedge as much as 8 km thick that formed as the entire area subsided after crustal separation. Together with the earlier formed rift deposits, they aggregate to thicknesses similar to those in the other basins. In the prerift reconstruction of North America and Africa (Klitgord, Behrendt, 1979) Georges Bank is opposite the Cape Bojador marginal basin — a larger more open sedimentary basin where 12 to 15 km of Mesozoic and Cenozoic sedimentary rocks have accumulated beneath the shelf and slope in a broad seaward continuation of the Aaiun-Tarfaya basins (Von Rad, Einsele, 1980; Arthur et al., 1979).

The Scotian Basin (Fig. 5) is broadly built over both a divergent margin seaward of Nova Scotia and a transform margin south of the Newfoundland (Fig. 1) (King, 1975; Jansa, Wade, 1975b; Parsons, 1975; Given, 1977). Beneath the Scotian Shelf and the southern Grand Banks of Newfoundland, basement blocks break the periphery of the basin into several subbasins adjacent to the northeastern side of the LaHave platform, the Canso ridge and the Avalon uplift (Fig. 1). Sedimentary rocks (Late Triassic and younger) attain a maximum thickness of 10-11 km beneath the outer Shelf and Continental Slope. Off Nova Scotia, this area of maximum sediment thickness coincides in part with the “Sedimentary Ridge Province”, formed by an elongate zone of diapiric ridges of salt or shale, 64 km wide and 640 km long (Fig. 1). As in the Baltimore Canyon trough, a hinge marks the zone of abrupt thickening along the landward side of the basin. The basin thins to the northeast over the Avalon Uplift — a complexly faulted part of the Grand Banks that contains several northeast trending subbasins one of which (a northwest continuation of the Jeanne d’Arc basin) was the site of a rich petroleum discovery (Hibernia P-15 well drilled southeast of Newfoundland in 1979).

SEDIMENTARY FILL

Drill hole results

The Scotian basin is extensively drilled offshore area: approximately 70 holes have been drilled to the present. They reveal an older rift sequence of Late Triassic red beds overlying Palaeozoic metasediments and granite. The red beds grade laterally into interbedded halite-shale with only minor anhydrite (Jansa, Wade 1975a; 1975b; Given, 1977). Toward the shallower parts of the basin, the sequence is separated from an overlying sequence by a conspicuous unconformity which Jansa and Wade (1975b) correlated with the Early-Kimmerian tectonic event (late Triassic-early Jurassic age) of H. Stille (1924).

Above the unconformity, holes on the Scotian margin have encountered Lower-Upper Jurassic limestone and dolomite that interfinger with regressive wedges of sandstone, shale and interbedded coal. The carbonate rocks were covered during the latest Jurassic and Early Cretaceous by deltaic shales, sandstone, and siltstone. These types of rocks dominated until Late Cretaceous when a broad marine transgression drowned the shelf, as chalk and shale accumulated. Beneath the outer shelf, slope type conditions prevailed into the early Tertiary (Eocene-Oligocene), broad prograding wedges of mudstone filled in the area and eventually established the present configuration of the Scotian shelf. Rock types encountered in the two deep holes (Ascoli, 1976)
drilled in the Scotian basin (Fig. 6) show the changes already described; the Mohican I-100 well is located closer to the seaward part of the basin than is the Mic-Mac H-86 well; hence its section of Jurassic age contains a thicker section of limestone, dolomite, and evaporites. Well data off the eastern United States show similar rock sequences, though only in the cores of the Continental Offshore Stratigraphic Test (COST) No. G-2 well on Georges Bank, were the rocks old enough to contain a thick section of carbonates and evaporites drilled. In the COST No. B-3 well (slope hole seaward of New Jersey), probable shelf platform limestones and coastal shales of Late Jurassic age were found but the main mass of limestone was still deeper and farther seaward. Other holes such as the Cape Hatteras (Esso No. 1) and COST GE-1 wells, were drilled toward the landward part of the continental margin and thus most of the Jurassic section is probably missing, and the Late Jurassic-Early Cretaceous sediments overly Paleozoic basement (Fig. 6).

Seismic stratigraphy

To extend the drill-hole data throughout the basins, we need either additional wells or a grid of multichannel seismic reflection profiles. Off Canada, we have both present (Jansa, Wade, 1975a; 1975b; Given 1977; Etuk, 1978); off the US, a grid of 25,000 km of multichannel profiles augments the few holes drilled on the shelf. Figure 7 (Grow, 1980) shows a depth profile over the outer part of the Baltimore Canyon trough along part of the line of section indicated on Figure 1; dated stratigraphic units from two nearby COST wells have been tied into key reflectors on profile. The oldest rifted part of the trough can be seen as a group of strong continuous reflectors below the breakup, or postrift unconformity; some of the reflectors dip gently seaward (to the right) and are beveled by the unconformity. We infer the reflectors to be interbedded carbonate and evaporite sequences of Late Triassic and Early Jurassic age because of their strong intensity, high continuity, high interval velocity, and through analogy to the Scotian basin, their position in the trough. In the main part of the sedimentary prism (less than 12 km in depth) above the breakup unconformity, discontinuous to continuous parallel reflectors on the left give way in the central part of the section to a shingled group of reflectors that extend farther and farther to the right (35 km) in the younger part of the section (4 to 6 km in depth); these reflectors border an unstructured mass that underlies most of the outer shelf and slope. We interpret the shingled reflectors to be a prograding carbonate front that built progressively to the southeast, 20 km seaward of the present shelf edge. The prograding is most obvious in this part of the Baltimore Canyon trough, appears to have taken place during the Jurassic, and terminated in pronounced shelf edge during latest Jurassic or earliest Cretaceous time. The fact that deeper reflectors seaward of the carbonate buildup dip

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**Figure 6**

Lithologic sections from six wells drilled on the Atlantic continental margin. Only the Esso No. 1, drilled at Cape Hatteras was drilled on land. Datum is sea level.
landward toward the main trough, suggests to us that the zone lacking coherent reflectors beneath the outer shelf and slope, could be deeply buried older forereef and rise deposits whose internal geometry has been obscured by the progradational sequence of carbonates. The tilting of reflectors behind the buried shelf edge, back toward the main part of the trough, has helped to create a broad "slope anticline" beneath the slope similar to that described by Seibold and Hinz (1974) and by Von Rad and Einsele (1980) for the Cape Bojador marginal basin of West Africa. The truncation of reflectors immediately behind the buried shelf edge (Fig. 7) indicates that the carbonate platform edge subsided more slowly than did the basin behind it during the Late Jurassic. The profile also shows a broad progradation of the shelf during the Miocene (inclined reflectors beneath the outer shelf dipping to the right in upper kilometer of the record) following slope-type conditions in the area during the Late Cretaceous and early Tertiary (Poug, 1980). Hence conditions and rock types during much of the Mesozoic and Cenozoic of the Baltimore Canyon trough are broadly similar to those discussed by Jansa and Wade (1975a; 1975b), Graestein et al. (1975), Given (1977), and Eluik (1978) for the Scotian basin.

Many of the major acoustic reflectors sketched in Figure 7 coincide with apparent gaps in the sedimentary section drilled in the COST No. B-3 (and nearby COST No. B-2 well), and with shifts in the curve of relative onlap published by Vail et al. (1977; 1980). In cores of both wells, gaps are present between the Hauterivian and the Barremian, the late Cenomanian and Turonian, the Turonian and Coniacian, the Maestrichtian and early Eocene, the early Eocene and late Oligocene, and the early and Middle Miocene (Poug, 1980); smaller gaps also exist in one or the other of these holes. Major reflectors shown on Figure 7 and other nearby profiles, appear to tie with gaps in the Haurterivian-Barremian boundary, the Cenomanian, Cretaceous-Tertiary boundary and in the Oligocene section. Some of the same reflectors carry into the deep Atlantic basin (Oligocene, Tertiary-Cretaceous, and Cenomanian) where along with other conspicuous reflectors (M, Ac, A₄, B and J) they are used to divide the western North Atlantic basin section into several sedimentary formations (Jansa et al., 1979). The Vail curve of relative coastal onlap (Vail et al., 1977, pt. 4, Fig. 2) shows major worldwide shifts in relative sea level in the earliest Cretaceous (Valanginian), Aptian, Cenomanian, early Paleocene, middle Eocene, late Eocene, late Oligocene, earliest Miocene, and late Miocene. Along the southeastern US Atlantic margin, gaps are present in the COST No. GE-1 sedimentary record between the Turonian and Coniacian, Maestrichtian and Paleocene, Paleocene and early Eocene, late Eocene and the early Oligocene, middle Oligocene and the middle Miocene, and the late Miocene and Pleistocene. On the Scotian Shelf and western Grand Banks, Ascoli (1976, p. 726) recognized the main hiatuses to be in the Berriasian, Berriasian-Valanginian, Cenomanian-Turonian, Maestrichtian, late Maestrichtian, and late Eocene. Clearly some of the gaps seen in the wells match those seen in data obtained by means of seismic stratigraphic techniques and lend credence to the idea of worldwide synchronous shifts in sea level.

**POSTRIFT UNCONFORMITY**

The age and tectonic significance of the postrift unconformity is conjectural. As noted before, Jansa and Wade (1975a) recognized the presence of an Early Kimmerian event on the Scotian margin however they did not place it into a plate tectonic context. They thought that the postrift unconformity was related to the mid-Kimmerian (Bajocian-Bathonian) tectonic disturbance in the Scotian basin. The Early Kimmerian disturbance effected not only the periphery of the future central North Atlantic, but also extended into the northwest European rift including the North Sea (Ziegler, 1978). In all regions, the tectonism caused a mild accentuation of the major positive elements from which clastics were shed into intervening lows. At the eastern North American margin, it cannot be established with certainty if this disturbance separated two major

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**Figure 7**

A 96-km segment of USGS line 25 (depth section) over the outer shelf, slope, and upper continental rise to show major stratigraphic features of the northern part of the Baltimore Canyon Trough. Location of line is shown on Figure 1 as a part of the Baltimore Canyon line, Oligo. (Oligocene) / T (Tertiary) / K (Cretaceous) / J (Jurassic) / T₃ (Triassic) / Ceno. (Cenomanian) / A₄ (unconformity associated with Horizon A); B (top of a group of Neocomian age limestones). The profile is modified from Grow (1980; Fig. 6).
periods of evaporite deposition (late Triassic and late Rhaetian-Hettangian) or if it separated the thick later halite deposits from the overlying early Jurassic carbonates. The early Jurassic age for the postrift tectonic event is favored by the ages of basaltic lava extrusion and breakup of eastern North American basins (specifically the Newark basin of Pennsylvania-New York) compiled by Van Houten (1977, Fig. 2). He noted that salt accumulated in basins beneath the outer Scotian shelf prior to the initial opening of the Atlantic in the early-middle Liassic. To the south in the Baltimore Canyon trough and Georges Bank basin, interpretation of seismic profiles have indicated the presence of a similar unconformity (Fig. 7), where it has been interpreted to be the breakup unconformity of Falvey (1974) and is interpreted to be Early Jurassic in age (Schlee, Klitgord, 1980; Grow, 1980).

We recognized that the early Kimmerian unconformity signifies a major change in the structural behavior of the margin, when the vertical tectonics associated with the development of the grabens, was replaced by the combined effects of crustal stretching and loading, as incipient crustal bending led to the formation of a series of broadly subsiding basins. This change of forces could mark the late rifting stage of the plate tectonic cycle, or it could indicate the decoupling of continental plates; the latter interpretation would associate this unconformity with the breakup unconformity of Falvey. The tectonic disturbance was followed by a series of marine transgressions that brought about fully marine conditions to the eastern North American margin in the Early Jurassic.

TECTORIC-STRATIGRAPHIC CROSS SECTIONS

Using the interpretation of many profiles such as the segment shown in Figure 7 and the data from offshore holes, it was possible to construct schematic cross sections through the major basins to summarize their main tectonic and stratigraphic elements (Fig. 8, 9, 10). Though the basins vary in size, they share several features in common. All appear to be built over a rifted thinned continental crust, floored by Upper Triassic and Lower Jurassic synrift deposits. All basins have a hinge zone where thickening takes place at the maximum rate, and they commonly have a postrift unconformity, particularly toward the periphery of the basin. The presence of a pronounced basement ridge is conjectural; we see no evidence for it but must in all fairness point out that a narrow zone lacking coherent reflectors does exist beneath the zone of carbonate deposition in areas such as the Baltimore Canyon trough (Fig. 7). On Figure 9, we have attempted to reconcile the conflict between shallow (7 to 9 km) depth estimates to magnetic basement and deeper sedimentary (7) reflectors present on Figure 7, by inferring a zone of intrusive rocks into the main part of the Baltimore Canyon trough; only drill holes 7-9 km deep will give new data on this enigmatic zone.

![Schematic section through the Blake Plateau basin to indicate the thickness, age, and types of rocks through to compose it. Location of section is shown on Figure 1. Section modified from Dillon et al. (1979).](image8)

![Schematic section through the Baltimore Canyon trough to indicate the ages, types, and thickness of rock thought to compose it. Section is a composite of features interpreted from several multichannel seismic-reflection profiles; its location is shown on Figure 1.](image9)

![Schematic section through the Scotian basin along line shown in Figure 1. Section indicates the major stratigraphic and tectonic features of the basin.](image10)
Earliest postrift deposits are either evaporites interbedded with carbonate rocks (COST G-2 well) or carbonate rocks alone (Scotian Basin). To the south (Fig. 8), they were deposited in a broad platform bordered along the seaward side by a discontinuous reef. In the Scotian basin and the Baltimore Canyon trough (Fig. 9 and 10), the postrift sediments appear to give way to nonmarine clastic beds toward the northwest and to deep-water deposits to the southeast. The Scotian basin has a broad mobile base of salt whose flowage has formed the Sedimentary Ridge Province beneath the upper continental rise (Jansa, Wade, 1975 b). A similar, though much narrower, zone of diapirs is present along the Carolina trough, also beneath the upper rise. But in the intervening Baltimore Canyon trough and Georges Bank basin, diapiric structures are much less prevalent and appear to be restricted to the outer shelf in the deepest part of the trough.

The manner in which carbonate rocks built up during the Jurassic varies considerably from basin to basin and within a basin (Eluik, 1978; Schlee et al., 1979). In limited segments of both the Baltimore of the Continent and Georges Bank basin, the carbonate platform edge appears to have built seaward over earlier-formed slope deposits from a structurally more restricted basin. Along other segments of the margin, the carbonate buildup shows no progradation, but only a well-defined shelf edge and an obvious onlapping of probable forereef facies along the seaward side on the platform. For the Scotian basin, the form of the ancient carbonate shelf edge and a depositional model has been described in great detail by Eluik (1978); he found both the prograding and platform type of carbonate shelf edge plus a ramp type, which lacks the high energy shelf edge facies. He drew analogies to the present day Great Bahama Bank and to Pleistocene deposits of the Florida Keys: the bank is analogous to those beds of limestone deposited in a platform away from deltaic input of large amounts of noncarbonate clastic sediments, whereas the Florida Keys deposits show the input mud to the ancestral Florida Bay—similar to an ancient delta that affected Jurassic age carbonate deposition on the northern Scotian shelf, and caused the ancient shelf edge to prograde.

With the exception of the Blake Plateau basin, post-Jurassic sedimentation was mainly noncarbonate and buried older carbonate platforms. Off Nova Scotia, a system of delta deposited sequences of sandstone, siltstone and shale: in the Baltimore Canyon trough, equivalent-aged deposits were laid down in a shelf milieu in broad transgressive-regressive cycles. On the Blake Plateau, reef-platform buildup persisted until the Alban. As based on cores from the Deep Sea Drilling Project (DSDP), the reef-bank edge stepped back (west) in the Alban and died out shortly thereafter (Benson et al., 1978; Sheridan, Enos, 1979). During the Late Cretaceous, in response to a long term rise in sea level that affected all the basins, the shelf edge in the Blake Plateau area, retreated 300 km west to the Florida Platform. At the beginning of the Tertiary, the Blake Plateau was affected by erosion and reduced sedimentation as flow of the ancestral Gulf Stream shifted to the west.

In the basins north of the Blake Plateau a series of marine regressions in the Oligocene, Miocene and Quaternary has cut back the shelf and slope to expose rocks as old as Early Cretaceous (Ryan et al., 1978; Jansa et al., 1979). These erosional intervals have been followed by shelf buildup as deltaic lobes and as broad wedge-like progradation of the shelf into deeper water.

CONCLUSIONS

Boreholes and interpretation of multichannel seismic-reflection profiles indicate that the basins and platforms of the eastern North American margin (Fig. 11) have developed in two stages 1) a rift stage during which continental crust was fractured and distended; and 2) a broad subsidence stage following continental separation, during which major marine incursions (starting in the early Jurassic) resulted in buildup of carbonate and evaporitic rocks, and later sandstones, shales and siltstone. Synrift deposits are continental red beds (shales, arkoses) that give way to the southeast to interbedded carbonates and evaporites. These rocks formed in a sabkha environment as restricted marine waters from the Tethys Sea encroached into the area from the northeast (Bernoulli, 1972; Given, 1977; Jansa et al., 1980). Continued marine transgressions during the rest of the Jurassic allowed thick limestone sequences to build up along most of the margin; probable carbonate shelf deposits are inferred to occupy most of the Blake Plateau basin, but outer shelf platform facies filled basins to the north. In response to influxes of terrigenous debris, a slowing rate of sediment accumulation, and fluctuations in relative sea level (widespread unconformities), the margin built over the older carbonate deposits during the Cretaceous for the basins north of the Blake Plateau. In the Blake Plateau

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Figure 11

Stages of development of the western North Atlantic continental margin. Stage A shows the rift phase and B-D show a generalized view of the subsidence phase as the margin built upward and outward during the Mesozoic and Cenozoic. As shown in Figures 8-10, the basins have somewhat different stratigraphic patterns owing to differing climatic-oceanographic settings, sediment inputs, and histories of basin subsidence.
basin, shallow water carbonate platforms flourished until the Albanian, after which the shelf edge moved 300 km west to the Florida Platform. Slope type conditions prevailed over much of the Atlantic shelf during the Late Cretaceous and early Tertiary as relative sea level height reached a maximum. For the remainder of the Cenozoic, as relative sea level fell in a series of major shifts, the Continental Slope was eroded and steepened in a complex history of canyon cutting (Eocene, Oligocene, Miocene, Quaternary), slope retreat and shelf-edge progradation (Fig. 11).

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