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Contents

SEISMIC REFLECTION PROFILES OF THE U.S. EAST COAST CONTINENTAL MARGIN

Bonnie A. McGregor

Abstract. Five profiles of seismic reflection data from the United States east coast are described. From these profiles, two localized areas of extensive slope deposition are identified, one seaward of Albemarle Sound and the other seaward of the Delaware-Maryland-Virginia coast. The profiles show levees along the lower slope and rise portions of some of the major submarine canyons. A regional unconformity on the rise extends from Georges Bank to Wilmington Canyon and is believed to be Pliocene in age. The upper slope between Cape Hatteras and Hudson Canyon is dissected by many small valleys which are believed to have been cut during the late Pleistocene, whereas northeast of Hudson Canyon the upper slope is cut only by major submarine canyons. The Florida-Hatteras slope and Blake Plateau have many unconformities with one in late Tertiary truncating an extensive sequence of foreset beds on the north end of the Blake Plateau. The shelf width and the deposition and erosion pattern of the Florida-Hatteras slope and the adjacent Blake Plateau appear to be controlled by the Gulf Stream.

1. INTRODUCTION

1.1 Rational Use of the Sea Floor: Program Objectives

The sea floor adjacent to the continent is an area important to our energy needs, and important for mineral utilization and waste disposal. The Rational Use of the Sea Floor (RUSEF) Program of the Atlantic Oceanographic and Meteorological Laboratories of NOAA is attempting to provide geological and geophysical information on the United States east coast continental margin. The program objectives are 1) the investigation of the geological and geophysical characteristics of the continental margin (outer shelf, slope, rise), 2) the definition of the sedimentary framework, and 3) the determination of the processes that have been active in the geologic past and are active at present. Also important is the assessment of the environmental variations, which occur laterally both parallel and perpendicular to the margin, and the variations that occur in time as shown within the sedimentary sequence. Variations of geomorphic features along the margin and the distribution of sediments, surficial and stratigraphic, are both means of determining the effect of bottom currents, internal waves, and gravitational forces (slumping, creep, turbidity flows) on the sea floor. The role of canyons as conduits for material to the deep sea is part of the system of sediment transport and distribution for the margin. The program also deals with slope stability to gain insight into those processes associated with sediment mass movement past and present and to delineate the "key" mechanisms responsible for submarine sediment stability-instability.

These geophysical investigations conducted parallel to the continental margin, have produced a unique set of data. They have characterized, by means of seismic reflection profiles, the variations in processes and environments parallel to the continent within each physiographic province. Through sediment distribution and unconformities, it is possible to distinguish between regional and localized events.

From the regional trackline coverage, portions of the margin with different bottom and subbottom characteristics (shaded areas, Fig. 1) have been selected for detailed study to determine the processes responsible for those differences. Two of those are discussed here.

1.2 Location of Studies

The resource potential of the United States Atlantic margin is being widely studied, and three areas, which lie on the continental shelf, have been singled out for oil exploration: Georges Bank, Baltimore Canyon Trough, and the Georgia Embayment. The data discussed here were obtained seaward of those exploration areas. The geographic location of RUSEF data coverage is the continental margin between Hydrographer Canyon on Georges Bank (40°N) and Cape Canaveral, Florida (28°N) (Fig. 1). The data are in the three physiographic provinces of the margin as defined by Heezen et al. (1959): the outer shelf, the slope, and the rise.

2. METHODS

2.1 Data Collection

Five track lines were run parallel to the continental margin from Cape Cod to Cape Canaveral (latitude 42°N to 28°N)—one on the outer shelf, two on the slope, and two on the rise (Fig. 1). Spacing between the track lines is approximately 20 km with navigational control based on Loran-C and satellite fixes. The lines were run in segments with at least 4-km overlap to insure continuity in the data. The data were collected during 1974, 1975, and 1976, with the NOAA ship *Researcher*. The data suite consists of seismic reflection profiles, some 3.5 kHz profiles, narrow beam bathmetry (NBES), magnetics, and some gravity.

Thirty-two transects of four piston cores each on the outer shelf, upper and lower slope, and rise were taken in conjunction with the geophysical data. The cores are being studied for their mineralogy and physical properties (Doyle et al., 1975, 1976; Keller et al., 1978). The sediment samples indicate the present and recent past processes and sedimentation history, while the seismic reflection data show the sedimentation history in the past, back to the Cretaceous.

2.2 Seismic Reflection Profiling System

The sound source for the seismic system consisted of a series of air guns with 10-in^3 ($160 \times 10^{-6} m^3$), 40-in^3 ($640 \times 10^{-6} m^3$), and 120-in^3 ($1920 \times 10^{-6} m^3$) chambers. The chamber size used was dependent on water depth. A 50-element hydrophone was used to receive the returning signal, which was filtered at 100–430 Hz. The filtered signal was printed on two recorders at 2- and 5-s sweep rates, respectively. Firing rate varied from 2-3 s on profile 1 on the outer shelf to 7-10 s for the remaining profiles with air pressure in the guns between 1800 and 2000 psi (12.4 and 13.8 kPa). Ship speed varied between 7 and 10 kn.

3. SEISMIC REFLECTION PROFILES

3.1 Profile 1

Profile 1 is located on the outer shelf in water depths of approximately 100 m. In general, the penetration was not very good, with multiples masking much of the subbottom return. Figure 2 shows a portion of the record from the northern part of the profile, the vicinity of Hydrographer and Hudson Canyons. Figure 3 is an interpretation of these records. A buried valley is present to the east of Hydrographer Canyon, and an unconformity is present on the west with truncation of reflecting horizons near the shelf surface and in the wall of the canyon. In the vicinity of Hudson Canyon, the reflecting horizons parallel the shelf surface. Both canyon heads can be seen to be erosional truncating and cutting reflecting horizons.

From Cape Hatteras (35°N) south to Cape Canaveral a 40-in^3 ($640 \times 10^{-6} m^3$) air gun was used. Although many multiples were present, the penetration was considerably greater than on

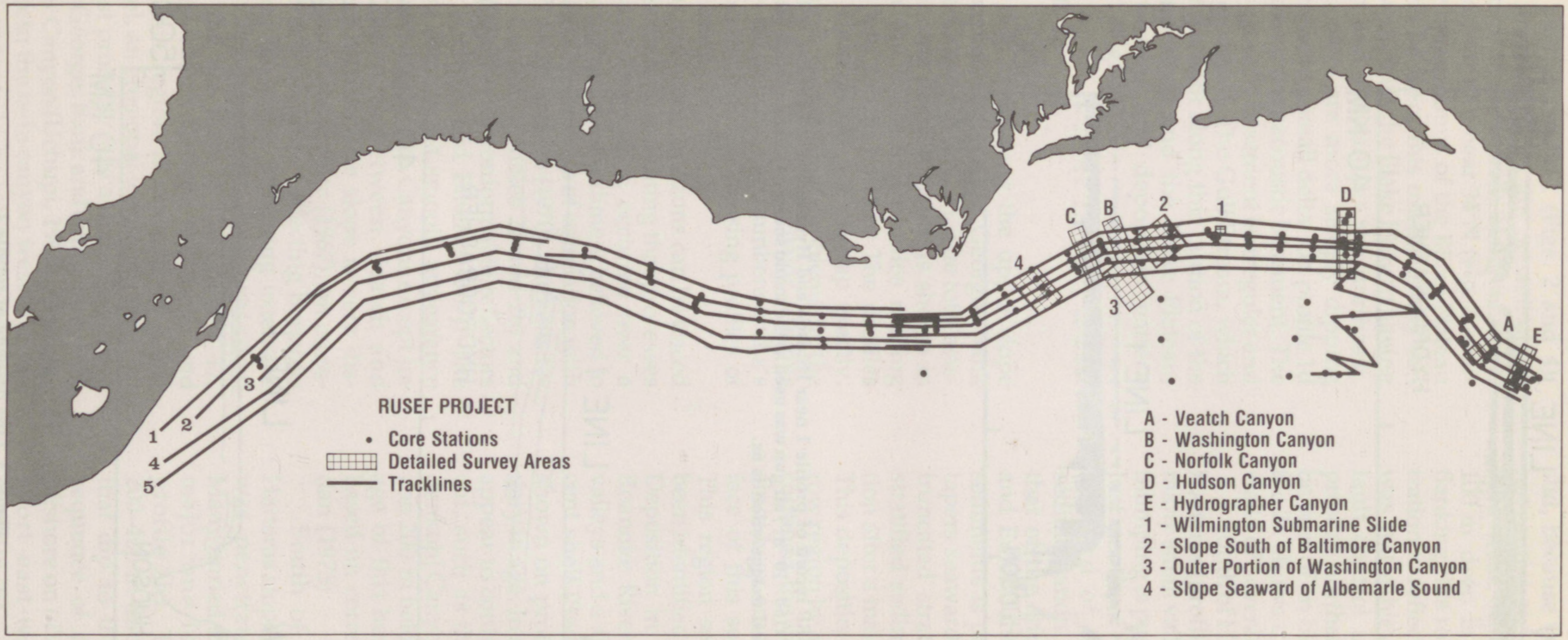

Figure 1. Index map (Uchupi, 1968) with track lines and core locations marked (adapted from McGregor, 1978).

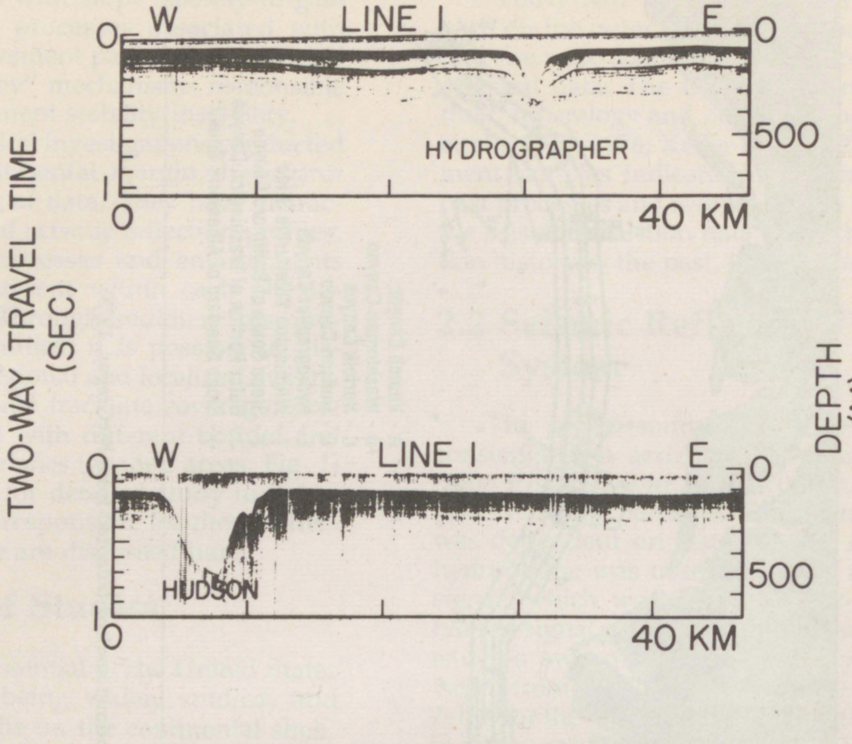

Figure 2. Original SRP record of profile 1 near Hudson and Hydrographer Canyons, with labels added. A 10-in^3 ($160 \times 10^{-6} m^3$) air gun was used as the sound source. Assumed sound velocity is 1500 m/s. Vertical exaggeration is 6x.

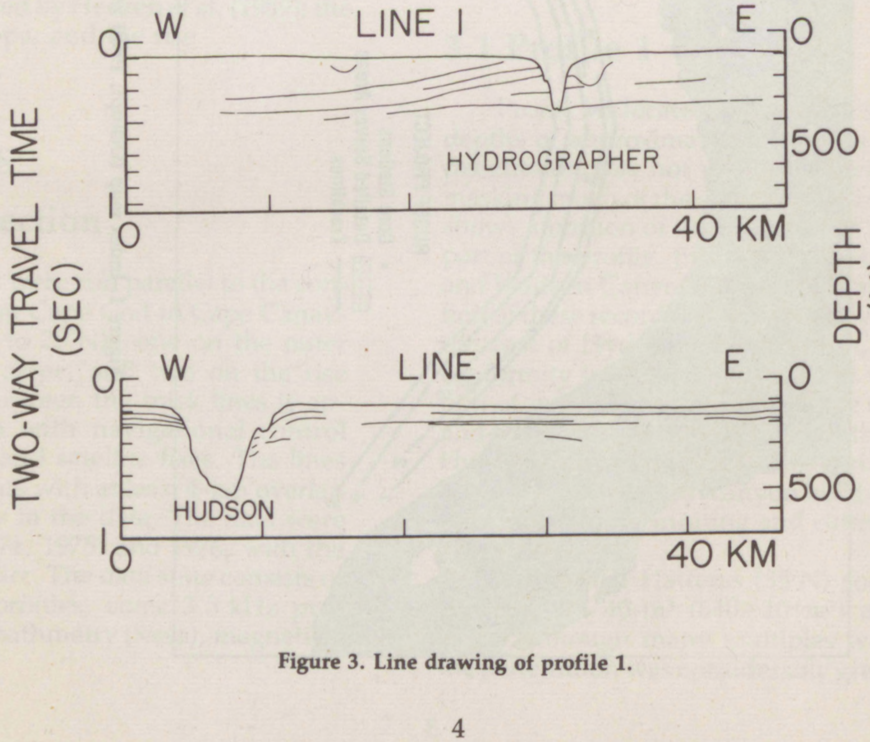

Figure 3. Line drawing of profile 1.

the northern part of profile 1 (Figs. 2 and 4). Many buried unconformities are present along the shelf adjacent to the Florida-Hatteras slope. The major unconformity near 34°N (Fig. 4, profile 1a) is near the terminus of the Blake Plateau (Fig. 1). As will be seen, this unconformity can be traced seaward, with the Blake Plateau having been built up and seaward to the northeast. Horizons near 34°N are more steeply dipping and appear similar to a small delta. On profile 1d the horizons lap up onto acoustic basement. The surface of this acoustic basement is irregular and appears to be erosional. The Gulf Stream, which influences the sea floor along this portion of the Florida-Hatteras slope and the Blake Plateau, controls the erosion and deposition pattern along profile 1 (Fig. 4).

3.2 Profile 2

Profile 2 (Fig. 5) is along the upper slope from Hydrographer Canyon on Georges Bank (40°N) to Cape Canaveral (Fig. 1). The total seismic record running north to south is shown in Figure 5 with the individual profiles reading from right to left, top to bottom. The profiles around Cape Hatteras do not overlap exactly, because of ship's navigational problems in the Gulf Stream. In each profile the major canyons are labeled for reference. (The numbers and x's refer to the locations of the crossing profiles of Uchupi and Emery [1967]).

In general, reflecting horizons can be traced over tens of kilometers, indicating that processes governing the sedimentation occurred over a wide area. A large wedge of sediment believed to be Tertiary in age, on the basis of correlation with Hoskins (1967) and Garrison (1970), thickens toward Hudson Canyon (profiles 2a and 2b) and also slopes seaward with conformable reflectors on the slope (Uchupi and Emery, 1967). The sediment gives the slope a smooth appearance between Hudson and Veatch Canyons except for a few large canyons. Between Veatch and Hydrographer Canyons, the slope is very dissected, and Uchupi and Emery (1967), on crossing profiles 55 and 56, show reflecting horizons outcropping on the slope, indicating extensive erosion. Late Cretaceous age material was cored 100 m below the sea floor at Caldrill Site 17, located east of Veatch Canyon (Manheim and Hall, 1967). This region is seaward of Great South Channel, an erosional feature on the shelf that in the past probably was a drainage system going around Georges Bank and connecting with Hydrographer Canyon (Uchupi, 1968). The large stratified block in the twin canyon west of crossing profile 62 appears to be rotated or to have slid, because the reflectors within the block are not continuous with those on either wall as is the case with other canyons. Fill approximately 100 m deep is present in each of the valleys flanking this rotated central block. Sound penetration to reflecting horizons beneath the valleys was not achieved to demonstrate conclusively fault control in this area. Buried valleys are present northeast of Hudson Canyon and may be part of an old Hudson drainage system. Profile 2a shows that slumping has occurred in the walls of several canyons.

South of Hudson Canyon and north of Cape Hatteras (profiles 2c–2f) the slope is dissected by many small valleys, as well as by major canyons. Slumping is present in many of the canyon walls. Just south of crossing profile 126 (profile 2e) seaward of Albemarle Sound (36°N), the sedimentation pattern has been different from that of the adjacent areas. Profile 126 (Uchupi and Emery, 1967) shows the zone of stratified sediments is part of a wedge of sediments that tapers seaward, but to landward it laps up onto truncated strata in the continental slope. The stratified sediments represent renewed deposition after a major period of erosion on the slope. This deposition appears to be confined to a narrow region by a physical barrier on the north that confined the multilayered sequence, which has since been eroded. The small channel in the surface of this sequence suggests recent erosion. This region seaward of Albemarle Sound has been identified for detailed study (Fig. 1, area 4). Deposition in this area may be related to the Roanoke River or the James River, since shelf valleys and a shelf delta are present on the adjacent shelf (Swift, 1976). The reflecting horizons shown on profiles 2c–2e are believed to be Tertiary in age. In some cases the reflecting horizons appear to control the depth to which valleys are cut, such as the four valleys southwest of Lindenkohl Canyon, which all terminate at the horizon 200 m below the surrounding sea floor. The age of this horizon is believed to be Miocene, based on correlation with the profiles of Sheridan (1975).

South of Cape Hatteras on the Florida-Hatteras slope, a maximum of 800 m of sediment was penetrated seismically (profiles 2g–2k). Many buried uncomformities are present, with a major one located north of 33°N (Fig. 5, profile 2h). The unconformity truncates a 200–400 m thick sequence of reflecting horizons that dip to the north. This unconformity and sequence of dipping horizons can be traced offshore on other profiles, as will be seen. On the short east-west segment at kilometer 450 (profile 2i), an erosional unconformity is

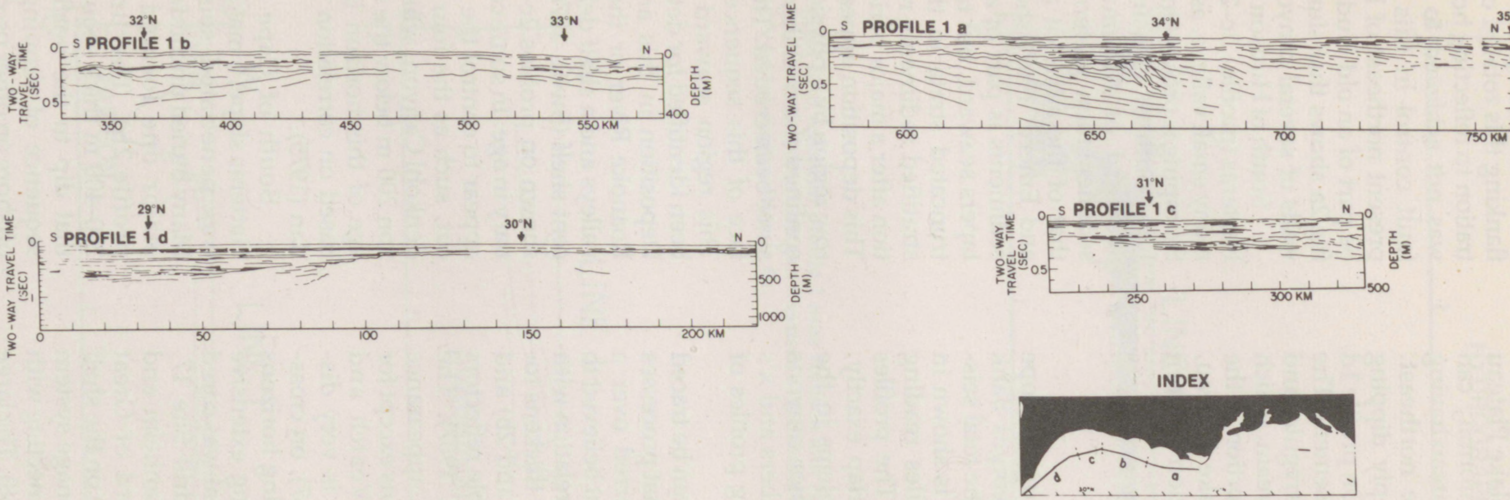

Figure 4. Line drawing of original SRP record of profile 1 between Cape Hatteras and Cape Canaveral. See map inset for profile location. A 40-in^3 (640 × 10^{-6}m^3) air gun was used. Assumed sound velocity is 1500 m/s. Vertical exaggeration is between 2x and 4x.

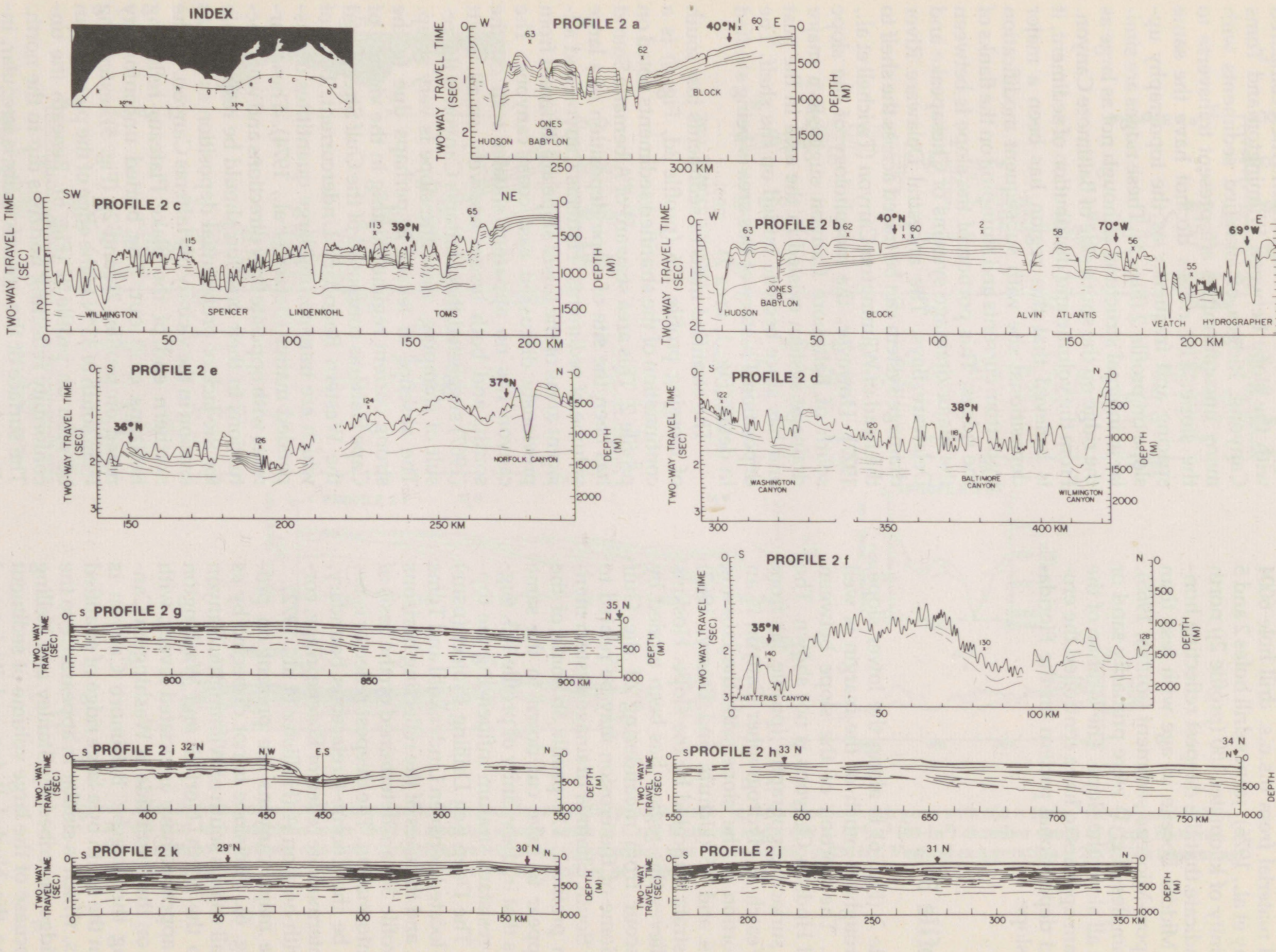

Figure 5. Line drawing of original seismic reflection profile record for profile 2 (see Fig. 1 for location). Air guns with $160 \times 10^{-6} m^3$ ($10 in^3$) and $1920 \times 10^{-6} m^3$ ($120 in^3$) chambers were used as the sound source north of Cape Hatteras and a $640 \times 10^{-6} m^3$ ($40 in^3$) chamber south of Cape Hatteras. A 50-element hydrophone was used to receive the returning signal which was filtered at 100 to 430 Hz. Vertical exaggeration is 30x (assuming 1500 m/s velocity). X's and numbers refer to crossing profiles of Uchupi and Emery (1967).

present, and the Florida-Hatteras slope can be seen to have prograded seaward about 25 km. The unconformity 300 m below the sea floor near 32°N (profile 2i) is Late Cretaceous in age, based on drilled material from U.S.G.S. drill hole 6004 (Hathaway et al., 1976). JOIDES drill holes 2 and 5 in the vicinity of kilometer 180 (profile 2j) north of 30°N indicate that the deepest reflecting horizons are Middle Eocene in age with less than 100 m of post-Miocene sediment (JOIDES, 1965). Bottom samples (Fig. 1) were primarily sand or sandy silt all along the slope. The location of the Gulf Stream appears to have controlled the erosional and depositional pattern on the Florida-Hatteras slope.

3.3 Profile 3

Profile 3 (Fig. 6) is along the lower slope, which throughout much of the margin is well dissected. The portion of the slope between Block and Hudson Canyons is not shown. The irregular surface topography (profile 3a) from west of Veatch to Hydrographer Canyon is an eroded portion of the slope with the crossing profiles 56 and 55 (Uchupi and Emery, 1967) showing strata truncated by the slope. Hoskins (1967) believes this region has been eroded by current scour from meandering of the Gulf Stream. Some of the erosion may be related to the Great South Channel drainage system mentioned on profile 2. On profile 3b some of the valleys appear to have cut down to the same horizon as that in the vicinity of profile 113, suggesting a resistant stratum influencing the topography. The Deep Sea Drilling Project (DSDP) site 108 is located between Lindenkohl and Toms Canyons, and the ages of the reflecting horizons (Fig. 6, profile 3b) are determined on the basis of the drill information. The deepest reflector is believed to be the Eocene-Cretaceous boundary, and the intermediate reflector Eocene in age, correlated with horizon A (Hollister et al., 1972).

Three major canyons are present on profile 3c (Fig. 6). The slope is not dissected by as many small valleys south of Wilmington Canyon as it is to the north. Norfolk and Washington Canyons appear to have associated levees, with the levee on the south side of Washington Canyon being the largest. Baltimore Canyon is flanked on the south by a large ridge of stratified sediments, which is similar in appearance to the Nyckel Ridge described by Stanley and Kelling (1970). Becuase of the large volume of sediment composing the Nyckel Ridge and its internal structure, Stanley and Kelling (1970) believe it is pre-Quaternary in age and not formed by overbank deposition. The slope between Washington and Baltimore Canyons has a different morphology and sedimentation pattern when compared with the slope between Wilmington and Toms Canyons. Ridges of stratified sediments with many unconformities are present transverse to the slope. The ridges do not have the same spacing and frequency as the topography upslope on profile 2 (Fig. 5). These ridges are similar in internal structure, although not as large as the ridge on the south side of Baltimore Canyon. From the volume and distribution of sediment, it is believed that this region has been a major depositional site with subsequent modification by bottom currents and slumping on the flanks of the ridges. This portion of the slope is between the major drainage systems of Chesapeake and Delaware Bays. The ancestral Delaware River drainage system can be traced across the shelf to the head of Wilmington Canyon (Twichell et al., 1977). However, the morphology of the slope south of Baltimore Canyon suggests a major drainage system existed in the area in the past and has since become buried on the shelf. The depositional history of this area is being studied in detail (Fig. 1, area 2).

The stratified mass of sediments just south of crossing profile 126 (profile 3d, Fig. 6) is a continuation of the stratified sediments noted on profile 2. This area seaward of Albemarle Sound has been the site of slope deposition of a large volume of sediments. Hatteras Canyon and adjacent areas of the lower slope are different from previously discussed east coast canyons. The canyon has no apparent shoaler wall on the south, and both levees are very small. Pratt (1967) suggested that Hatteras Canyon is the result of slumping, since the slope is very steep. The absence of levees is perhaps due to the strong current regime existing in the vicinity of Cape Hatteras composed of the Gulf Stream and the Western Boundary Undercurrent, both of which are transporting large quantitites of suspended matter (Betzer et al., 1974). These currents with opposite flow directions and with fluctuations in their position should be responsible for the lack of preferential deposition as well as erosion in the vicinity of Hatteras Canyon. At the northern end of the Blake Plateau, reflecting horizons crop out. The buried unconformity noted on profiles 2h and 2g (Fig. 5), extending from south of 33°N to the edge of the plateau, can be seen on profile 3f (Fig. 6). Beneath the unconformity reflecting horizons dip to the north. The surface of the unconformity is irregular, indicating varying resistance of the truncated horizons. The age of this unconformity is believed to

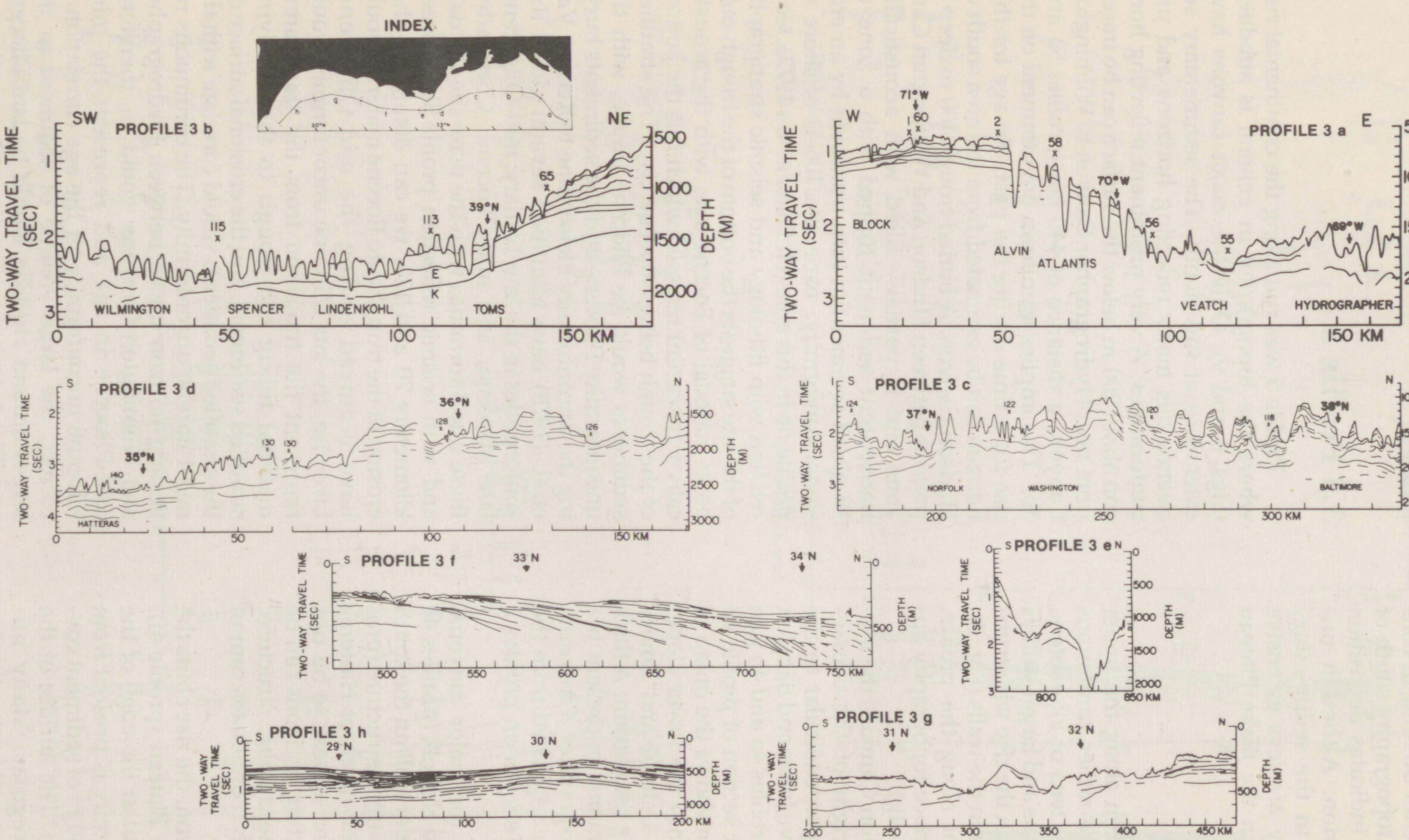

Figure 6. Line drawing of original seismic reflection profile record for profile 3 (see Fig. 1 for location). Air guns with 160 × $10^{-6}m^3$ (10-in^3) and 1920 × $10^{-6}m^3$ (120-in^3) chambers were used as a sound source north of Cape Hatteras and a 640 × $10^{-6}m^3$ (40-in^3) chamber south of Cape Hatteras. A 50-element hydrophone was used to receive the returning signal which was filtered at 100 to 430 Hz. Vertical exaggeration is 20x to 30x (assuming 1500 m/s velocity). X's and numbers refer to crossing profiles of Uchupi and Emery (1967).

be Late Miocene or Pliocene and will be discussed in the section on profile 5. Between 30°30′N and 32°45′N (profiles 3f–3h), the surface topography is very irregular, suggesting erosion and nondeposition by the Gulf Stream. In contrast is the smooth surface topography south of 30°30′N (profile 3h) which indicates deposition has dominated over erosion. Although unconformities are present in the sedimentary sequence (profile 3h), they are less extensive than those farther north on the Blake Plateau (profile 3f).

3.4 Profile 4

Profile 4 (Fig. 7) was run along the upper rise. Reflecting horizons are rather continuous and can be traced for many tens of kilometers. The major submarine canyons and larger valleys extend to this water depth on the rise with truncation of reflecting horizons in the walls (Fig. 7). Unconformities are present along the profile, and in many places the surface topography appears erosional (profiles 4a–4g).

Just northeast of Hudson Canyon, the section of profile 4b to the right of the course-change notation was run perpendicular to the slope. The heavy arrow above Jones and Babylon Canyons indicates where profiles 4a and 4b join to be continuous. The short section of profile 4b perpendicular to the margin shows the onlap of sediments from the rise onto the lower slope, which, as also shown by Uchupi and Emery (1967), occurs in places along the margin. A thick sequence of stratified sediments is present between Veatch and Hydrographer Canyons. These sediments may have originated from the adjacent very eroded slope shown on profiles 2 and 3 (Figs. 5 and 6).

South of Wilmington, the major canyons, Baltimore, Washington, and Norfolk (profiles 4c and 4d, Fig. 7), have a shoaler wall on the south side than on the north. A diapiric structure (profile 4e) is present just to the north of Hatteras Canyon. Reflecting horizons appear to be upturned against it. No reflecting horizons can be seen within or beneath the diapiric structure, and the horizon from which it originates cannot be identified.

South of Hatteras Canyon, the rise abuts the northern end of the Blake Plateau (profile 4f). Reflecting horizons crop out at the edge of the plateau. A major unconformity is present from 32°30′N to 34°N with 100–150 m of sediment covering it (profiles 4f and 4g). The surface of the unconformity is very irregular. Many unconformities are also present within the dipping stratified sequence beneath this major unconformity. The surface of the Blake Plateau between 32°N and 28°N (profile 4h) is irregular and appears erosional. Possible ages for the unconformities will be discussed in the section on profile 5.

3.5 Profile 5

Profile 5 was run along the continental rise where the topography in general is subdued (Figs. 8 and 9). Only the major canyons have extensions at this depth. The sedimentary sequence has many reflecting horizons and unconformities. A very prominent reflecting horizon about 200 m below the surface can be traced from near Hydrographer Canyon to Wilmington Canyon, a distance of 440 km (profiles 5a and 5b). This implies a uniform environment on the rise for a time during the past. An age for this horizon can be estimated from the area south of Hudson Canyon. A buried trough 400 m deep is present between Hudson and Wilmington Canyons and is partially filled with acoustically transparent sediment topped with a zone of stratified sediment in turn truncated by an erosional conformity. DSDP site 106 is offshore of profile 5b in this area (Hollister et al., 1972). Correlation with lithology and seismic stratigraphy of the site suggests the bottom of the trough may be in material of Eocene age, with the acoustically transparent material which fills the bottom of the trough being Miocene clay. The stratified sediments would be Pliocene in age, with the unconformity Pliocene and the sediments burying the unconformity Pleistocene to Recent. Vail et al. (1978) have identified several global unconformities in the late Tertiary: mid-Oligocene, late Miocene, and mid-Pliocene. Correlating these unconformities with the DSDP site 106 data and with seismic reflection profile 5b between kilometers 70 and 120, we can determine that erosion of the trough into Eocene material would have occurred during the mid-Oligocene. Likewise, the late Miocene unconformity would represent the transition from the transparent material filling the trough to the overlying stratified sediments, and the erosional surface on the stratified sediments would correlate with the mid-Pliocene unconformity. The continuous reflecting horizon traced between Hydrographer and Wilmington Canyons would be, therefore, mid-Pliocene in age and represent the mid-Pliocene unconformity. If the age correlation is correct, the large volume of sediment in the levees around Hudson would be late Pliocene and Pleistocene in age, since the continuous horizon can be traced beneath them. This portion

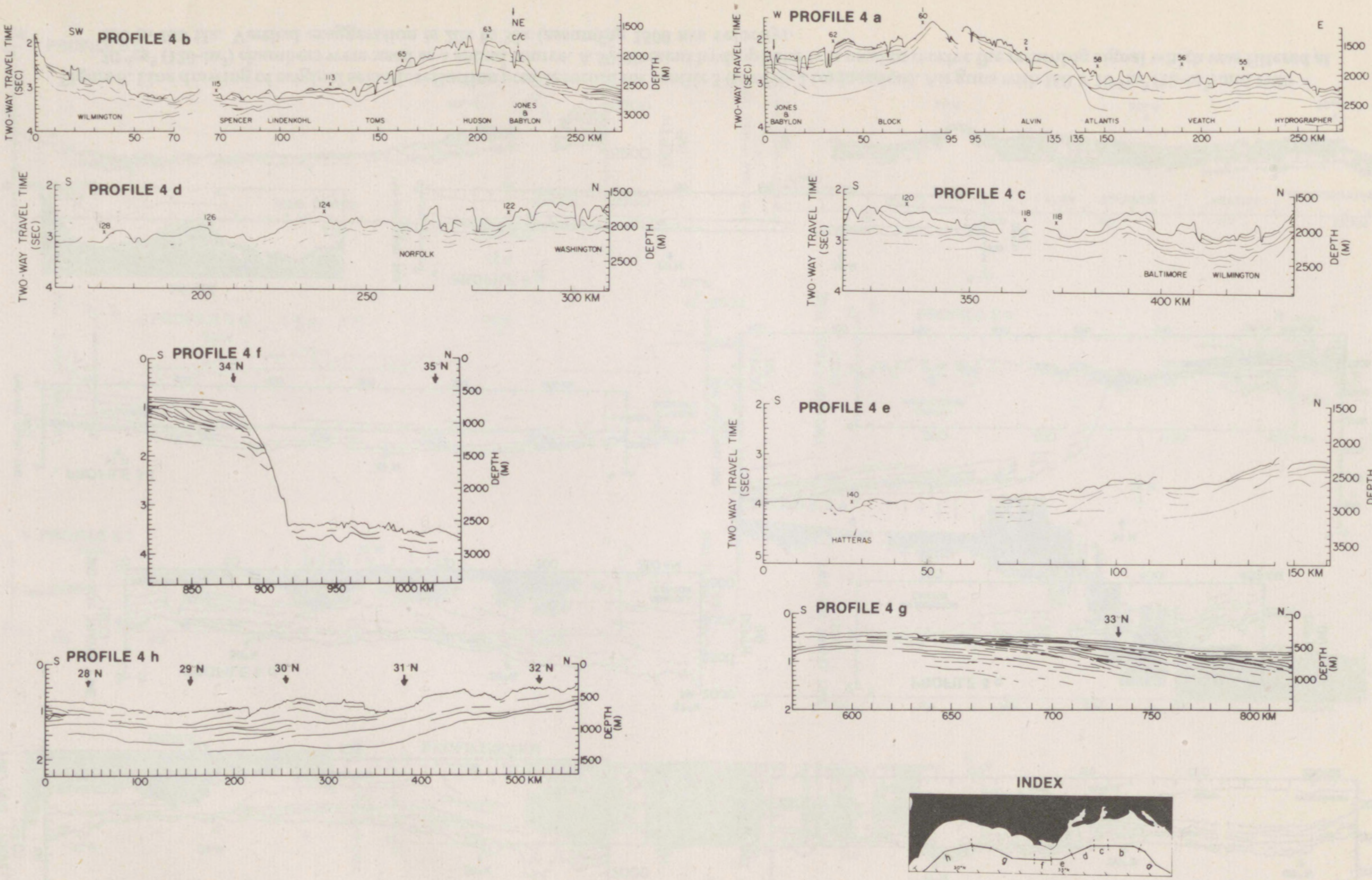

Figure 7. Line drawing of original seismic reflection profile record for profile 4 (see Fig. 1 for location). Air guns with $160 \times 10^{-6}m^3$ ($10\text{-}in^3$) and $1920 \times 10^{-6}m^3$ ($120\text{-}in^3$) chambers were used as a sound source north of Cape Hatteras and $640 \times 10^{-6}m^3$ ($40\text{-}in^3$) and $1920 \times 10^{-6}m^3$ ($120\text{-}in^3$) chambers south of Cape Hatteras. A 50-element hydrophone was used to receive the returning signal which was filtered at 100 to 430 Hz. Vertical exaggeration is 20x to 30x (assuming 1500 m/s velocity). X's and numbers refer to crossing profiles of Uchupi and Emery (1967).

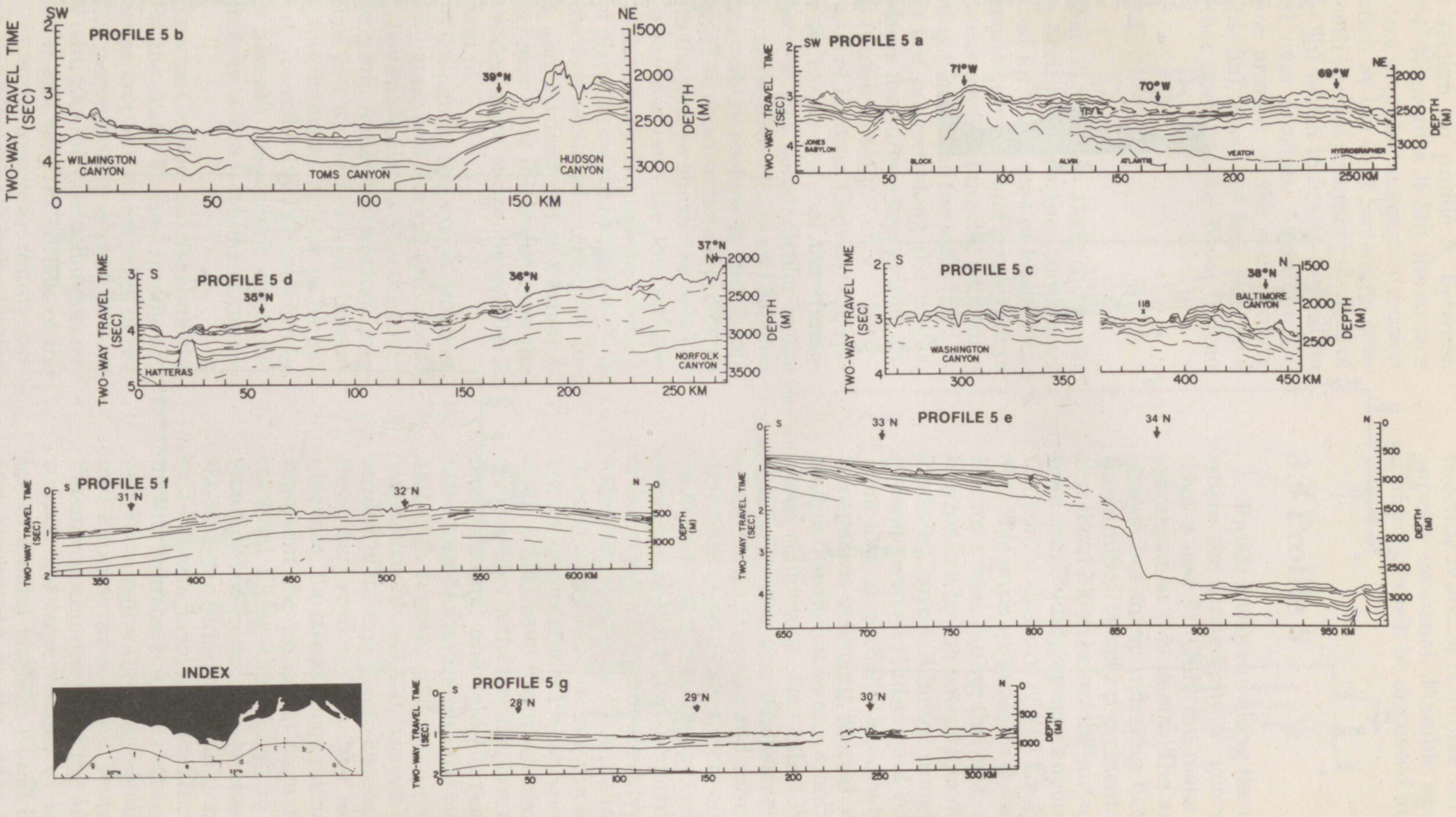

Figure 8. Line drawing of original seismic reflection profile record for profile 5 (see Fig. 1 for location). Air guns with $160 \times 10^{-6} m^3$ (10-in^3) and $1920 \times 10^{-6} m^3$ (120-in^3) chambers were used as a sound source. A 50-element hydrophone was used to receive the returning signal which was filtered at 100 to 430 Hz. Vertical exaggeration is 20x to 30x (assuming 1500 m/s velocity).

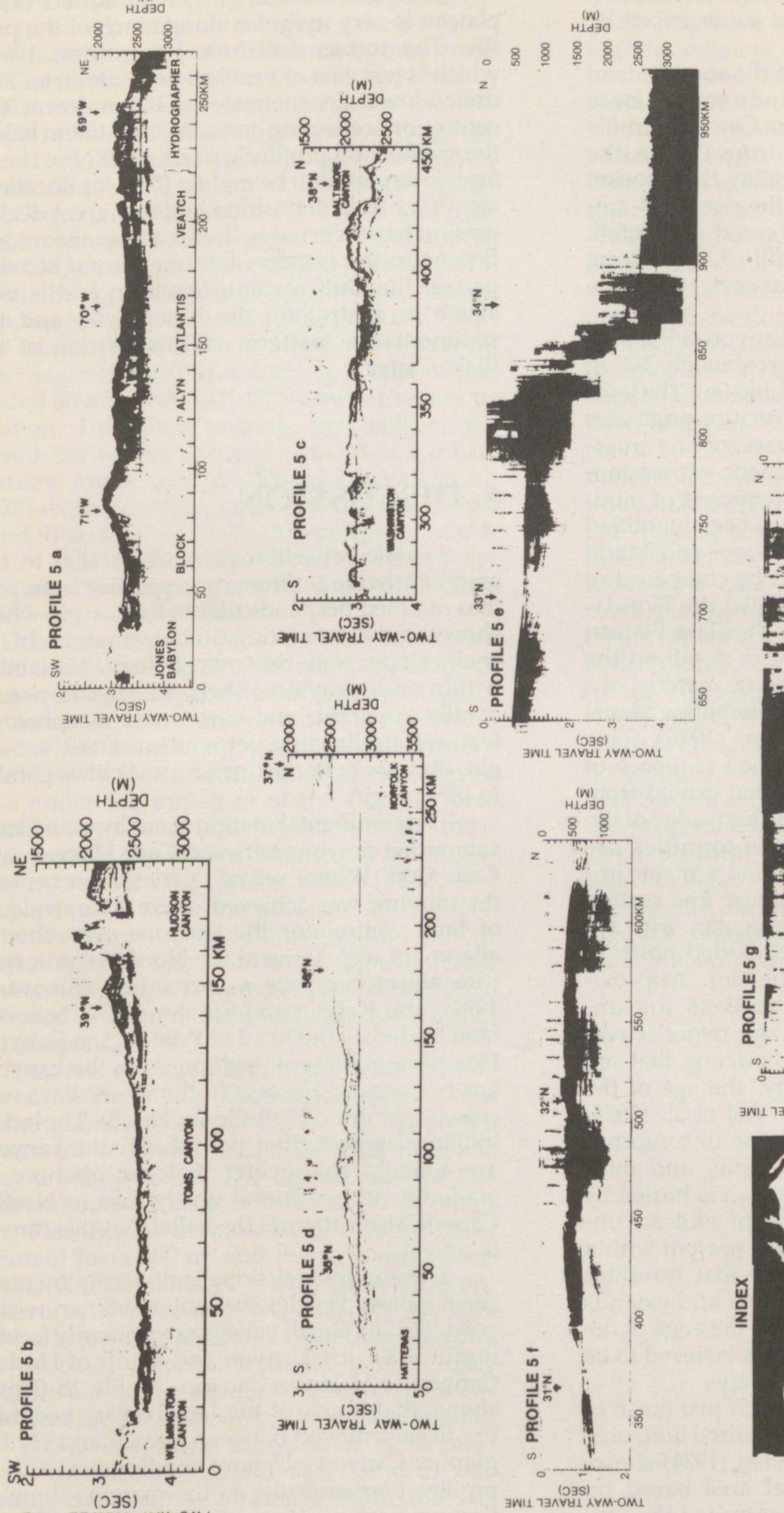

Figure 9. Photograph of original seismic reflection profile record for profile 5.

of Hudson Canyon was formed by both depositional and erosional processes, as described by Nelson and Kulm (1973).

A large levee is present on the south side of Baltimore Canyon (profile 5c) and a smaller levee on the south side of Wilmington Canyon (profile 5b). Reflecting horizons are truncated in the walls of all the canyons, indicating that erosion has occurred at this depth on the rise. A 14-cm-thick graded sand layer was cored in Norfolk Canyon just seaward of profile 5, indicating transport of coarse sand this far seaward on the rise.

Just north of Hatteras Canyon a diapiric structure is present, with approximately 100 m of sediment over it (profiles 5d and 5e). The level or horizon from which the structure originates cannot be identified. On the basis of one crossing, it has no gravity or magnetic expression, indicating that it probably is composed of mud. More deeply buried diapirs have been identified in this area on CDP data by Grow and Markl (1977) and are also believed to be composed of mud. Continuing south to parallel the Florida-Hatteras slope, one encounters the Blake Plateau (profile 5e). Near 34°N at 2000-m depth on the edge of the Plateau, middle Eocene material of a very friable texture was cored (Florentine Maurrasse, personal communication, 1976). This cored sample is from the stratified sequence of horizons dipping to the north that extend from 32°30′N and crop out on the northern edge of the Blake Plateau. Erosional unconformities are present within this sequence, and a major unconformity truncates the sequence. The surface of this unconformity is very irregular, with approximately 100 m of material eroded north of 33°N at kilometer 730 (profile 5e). Approximately 150 m of sediment blankets the unconformity. Because Eocene age material was cored within a sequence of horizons that are truncated by the unconformity, the age of the unconformity is post-Eocene. Vail et al. (1978) have identified three post-Eocene unconformities, mid-Oligocene, late Miocene, and mid-Pliocene. Since the Eocene horizon is buried by approxmately 500 m of sediment and an unconformity near kilometer 800 is present within the sequence, the unconformity that truncates this sequence of dipping horizons and extends from 32°30′N off Cape Romain to the edge of the Blake Plateau off Cape Lookout is believed to be late Miocene or mid-Pliocene in age.

A fault is present on profile 5f just north of 32°N at kilometer 522, offsetting buried horizons, as well as the sea floor. Sheridan (1974) shows several faults in this general area based on magnetic anomaly patterns. Because of the activity of the Gulf Stream, the general surface of the plateau is very irregular along much of the profile. The JOIDES drill hole J–6 (JOIDES, 1965), which is just east of profile 5 near kilometer 280, drilled lower Eocene material 100 m down. The continuous reflecting horizon about 100 m below the sea floor on profile 5g north of 30°N is, therefore, interpreted to be middle to lower Eocene in age. Very little deposition and/or a great deal of erosion has occurred in the area from the middle Eocene to the present. Bottom current activity, part of the Gulf Stream, has been and is very active in controlling the topography and the sedimentation pattern on this portion of the Blake Plateau.

4. DISCUSSION

Seismic reflection profiles parallel to the margin provide a different perspective from profiles oriented perpendicular to the margin which show the characteristic gradient variations of the shelf, slope, and rise morphology. Variability within each province, shelf, slope, and rise, is readily apparent, and since most morphologic features are lineated perpendicular to the margin, they are better defined by track lines parallel to the margin.

The continental margin is cut by many large submarine canyons between Cape Hatteras and Cape Cod. Where seismic penetration beneath the canyons was achieved, there is no evidence of fault control for the canyons even though alignment with some of the North Atlantic fracture zones suggests a correlation (Sheridan, 1974), and Kelling and Stanley (1970) believe a fault underlies the head of Wilmington Canyon. Extensive infilling of sediments in the canyons has not occurred except in the two valleys near crossing profile 62 (profile 2a, Fig. 5). The lack of infilling suggests that periodically the canyons are actively channeling material offshore. A graded sand bed found on the rise in Norfolk Canyon also supports the belief that this canyon is active.

The continental slope is dissected by many small valleys besides the major submarine canyons (Fig. 5). Small valleys are primarily located north of Veatch Canyon and south of Hudson Canyon to Hatteras Canyon. Profile 2b (Fig. 5) shows that much of the late Tertiary sediment has been removed between Veatch and Hydrographer Canyons. Uchupi and Emery (1967), on profiles perpendicular to the margin, show reflecting horizons truncated by the continental slope, indicating erosion, as on their profile 55. On profiles parallel to the slope, these eroded areas can be seen to be dissected by numerous small valleys that indicate the major process by which the erosion occurred. The age of this erosion is inferred to be Pleistocene, correlating with the valleys northeast of Wilmington Canyon on profile 2c (Fig. 5), which are Pleistocene in age (McGregor and Bennett, 1977). The lack of infilling in the valleys also suggests that they are not very old, since, according to Doyle et al. (1975, 1976), the upper slope is a region of rapid deposition, based on the cores shown in Figure 1. Grow and Markl (1977) have found that the present shelf edge off New Jersey and Cape Hatteras was eroded 30 km landward of its Lower Cretaceous location. This major erosion, they believe, occurred during the Tertiary. Several of the Late Tertiary unconformities found by Vail et al. (1978) were identified on the rise (profile 5, Figs. 8 and 9) and on the Blake Plateau (profiles 3, 4, and 5, Figs. 6, 7, and 8); however, the major erosion of the slope found by Grow and Markl (1977) was not identified.

The large levees on the south side of the rise portions of Washington, Norfolk, and Baltimore Canyons suggest deposition of sediments under the influence of a north-south flowing current parallel to the margin, possibly the Western Boundary Undercurrent, and/or down-canyon flow under the influence of the Coriolis force described by Komar (1969). Current meter measurements in the United States east coast canyons by Fenner et al. (1971), Keller (1975), and Shepard (1975) show the predominant motions to be oscillatory, with both up- and down-canyon flow in response to tides and internal waves; however, net transport down-canyon is indicated by bottom features (Keller, 1975; Keller and Shepard, 1978).

Regions of major deposition have also occurred on the slope. Between Baltimore and Washington Canyons (profile 3c, Fig. 6), a large volume of sediment in the form of ridges is present on the slope. The age of some of this sedimentary sequence is believed to be older than Pleistocene, because of the thickness of sediment (over 600 m) and the similarity to the Nyckel Ridge south of Wilmington Canyon, which is believed to be pre-Quaternary (Stanley and Kelling, 1970). Drainage from Delaware Bay was probably responsible in the Late Tertiary and Pleistocene for a large volume of sediment deposited on the continental slope (McGregor et al., 1977). The slope seaward of Albemarle Sound (profiles 2e and 3d, Figs 5 and 6) was another depocenter. Drainage from the Albemarle River or the James River, both shown by Swift (1976) to have been present on the adjacent shelf, may have been responsible for transporting the sediment and depositing it on the slope near the shelf edge. Since deposition, these sediments have undergone erosion. A detailed study of this area is presently underway, using bottom samples and geophysical techniques. Deposition seaward of Albemarle took place on the upper slope, whereas between Baltimore and Washington Canyons, deposition was primarily on the mid- and lower slope.

The northern portion of the Blake Plateau, north of Cape Romain, can be seen to have built up and to the northeast by a series of foreset beds (profiles 2h, 3f, 4f, 4g, and 5e, Figs. 5–8). This depositional pattern lasted for most of the Tertiary, based on the middle Eocene age of material cored at 2000 m on the northern edge of the Plateau (Florentine Maurrasse, personal communication, 1976). This Eocene horizon is within the dipping sequence of horizons, with older material beneath it, and it is believed to be truncated by a Late Miocene or mid-Pliocene unconformity found by Vail et al. (1978). Many unconformities are present all along the Blake Plateau; even the surface topography is variable (profiles 3g and 3h, Fig. 6). Pratt and Heezen (1964) believe the Gulf Stream is the controlling factor for determining the topography and locations of sediment deposition. The position of the Gulf Stream in the vicinity of 32°N has permitted the progradation of the Florida-Hatteras Slope 25 km seaward (profile 2i, Fig. 5), while on the adjacent Blake Plateau erosion is occurring (profiles 3g and 5f, Figs 6 and 8), producing a very irregular topography with less than 100 m of sediment overlying lower Eocene material.

5. SUMMARY

The physiographic provinces of the shelf, slope, and rise are very different in morphology and erosional and depositional history. The morphology of the continental margin changes as one moves offshore from the outer shelf to the rise. The outer shelf is flat, except where cut by the heads of the major submarine canyons. The continental slope has been well dissected with a very irregular topography as far south as Cape Hatteras. Major submarine canyons and numerous small valleys are present. On the basis of the detailed study of the slope north of Wilmington Canyon, the general dissection of the upper slope by the small valleys appears to have occurred in the Pleistocene. The rise is smoother in morphology with only the major canyons having extensions at this depth.

Noteworthy are the variations, not only between the margin provinces, but also within each physiographic province, parallel to the margin, where regional variations in the erosional and depositional history show up on strike lines. The Florida-Hatteras slope and adjacent portions of the Blake Plateau have been and still are actively influenced by the Gulf Stream. The interaction of the Gulf Stream and the Western Boundary Undercurrent with the sea floor has exposed or inhibited deposition on Eocene age material in the north end of the Blake Plateau near Cape Hatteras. Also this same interaction has influenced the deposition in the vicinity of Hatteras Canyon, since it has very small levees compared with the other east coast canyons. A graded sand layer with coarse to fine sand on the rise in Norfolk Canyon suggests that this canyon is serving as a conduit in transporting sediment to the rise. Several other portions of the slope, besides the vicinities of canyons, have been deposition sites for large volumes of sediment in the past. These areas are seaward of the Delaware-Maryland-Virginia coast and Albemarle Sound.

During the mid-Pliocene, the rise between Hydrographer and Wilmington Canyons appears to have had a very uniform environment of erosion followed by deposition. This unconformity can be traced beneath the levees of Hudson Canyon, suggesting that they are Pleistocene to Recent in age.

Based on strike line profiles, variations in morphology and sedimentation history along the continental margin can be readily assessed with identification of regional versus localized events and processes.

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