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GEOLOGICAL SURVEY PROFESSIONAL PAPER 581-B

Prepared in cooperation with the Woods Hole Oceanographic Institution and the Joint Oceanographic Institutions' Deep Earth Sampling Program

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By JOBST HÜLSEMANN

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Analytical results and interpretations of organic constituents of core samples from the continental shelf, the Florida-Hatteras Slope, and the Blake Plateau

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DRILLING ON THE CONTINENTAL MARGIN OFF FLORIDA

Drilling on the continental margin off Jacksonville, Fla., in 1965 was the first project undertaken by the Joint Oceanographic Institutions' Deep Earth Sampling (JOIDES) Program, sponsored by the National Science Foundation. The U.S. Geological Survey cooperated with the Oceanographic Institutions in this undertaking and is publishing the results of these investigations in a series of professional papers.

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CALCIUM CARBONATE, ORGANIC CARBON, AND NITROGEN IN SEDIMENTS FROM DRILL HOLES ON THE CONTINENTAL MARGIN OFF FLORIDA[1]

By Jobst Hülsemann

ABSTRACT

The organic constituents of sediments (calcium carbonate, organic carbon, and nitrogen) from six drill holes off Florida were analyzed in 47 samples. The drill holes penetrated the continental shelf, the upper Florida-Hatteras Slope, and the Blake Plateau. Differences in distribution and abundance of the organic constituents strongly suggest that two facies were deposited during the span of geologic time (Paleocene to Recent) represented by the samples. One facies (low organic carbon and nitrogen, uniform carbon-nitrogen ratio, and high calcium carbonate content) is characteristic of the Blake Plateau; the other facies (higher organic carbon and nitrogen, a carbon-nitrogen ratio that increases with age, and relatively low calcium carbonate content) is typical of the shelf and of the upper Florida-Hatteras Slope.

Some significant differences in the concentrations of the organic constituents are correlated with changes in the rates of supply and accumulation of sediment. These changes appear to be related to tectonic movement of the sea floor or the adjacent lowland of Florida, rather than to climatic changes.

In the sampled parts of the offshore area, the upper Florida-Hatteras Slope is the most favorable site for the accumulation of organic matter.

INTRODUCTION

Organic matter is a common constituent of many marine sediments. It has been determined in previous studies for several thousand samples from the floors of the present oceans. Most of these samples are of surface sediment, and few data are available from samples taken deeper than several meters below the bottom of the ocean.

Organic matter in marine sediments can be derived from land as well as from the ocean. After burial, the original composition of organic matter is altered by diagenesis. Differences in composition, such as expressed by the carbon-nitrogen ratio, can help to identify the source and subsequent fate of the organic matter, and thus give clues to the environmental history of the area.

In the spring of 1965, the first JOIDES (Joint Oceanographic Institutions' Deep Earth Sampling) Program succeeded in drilling six holes off northern Florida (Joint Oceanographic Institutions' Deep Earth Sampling Program, 1965) to depths ranging from 120 to 320 meters below the sea floor. The following report presents analytical results and an interpretation of the origin and the diagenetic changes of organic matter based on 47 samples from JOIDES drill holes. Organic constituents were determined as (1) organic carbon, (2) nitrogen (Kjeldahl), and (3) total carbonate as calcium carbonate. The last is included because it is of biogenic origin.

The samples were collected by a team working on the drilling vessel M/V *Caldrill I* with John Schlee as principal scientist. Mrs. M. Hamilton performed most of the chemical analyses. My colleagues, in particular John Schlee and J. C. Hathaway, U.S. Geological Survey, promoted the work by their comments and discussions. Suggestions from Henry Berryhill, Jr., of the Survey also improved the manuscript. The help of all persons is gratefully acknowledged.

GEOGRAPHIC AND GEOLOGIC SETTING

The holes were drilled on the continental shelf, the upper Florida-Hatteras Slope, and the Blake Plateau, off northern Florida. At the outer edge of the shelf, the depth of water is only 60 meters, which is considerably less than depths of the shelf break in other parts of the world. The adjoining Florida-Hatteras Slope dips about 4°, leveling off at about 800 meters depth of water and connecting to the Blake Plateau. The plateau slopes generally seaward, at a rate comparable to the slope of the present shelf, to a depth of about 1,000–1,200 meters. Holes 1 and 2 (fig. 1) are on the continental shelf in less than 50 meters of water, and hole 5 is on the upper part of the Florida-Hatteras Slope at a depth

[1] Contribution No. 2042 of the Woods Hole Oceanographic Institution.

of 190 meters. Holes 3, 4, and 6 are on the Blake Plateau, between 200 and 400 kilometers offshore. Less than 50 kilometers seaward from the outermost hole (No. 3), the Blake Plateau joins the deep-sea floor by the Blake Escarpment, a slope that is slightly steeper than most other continental slopes.

The axis of the Gulf Stream crosses the line of JOIDES drill holes between holes 5 and 6. Although measurements of the velocity of the Gulf Stream indicate a marked decrease of velocity with depth (Swallow and Worthington, 1961), sediment samples and bottom photographs strongly suggest that the bottom current is sufficient to transport sediment both on the shelf and on the Blake Plateau (Pratt, 1963), Oriented bottom photographs of ripple marks led Hurley and Fink (1963) and Heezen, Hollister, and Ruddiman (1966) to believe that the bottom current flows predominantly southward, or opposite to the flow of the Gulf Stream.

Seismic-reflection profiles show upbuilding and prograding of the shelf and almost continuous deposition of sediments on the Blake Plateau since at least the early part of the Tertiary, although some areas have been eroded by currents (Emery and Zarudzki, 1967). The core records for holes 1 and 2 include strata of Eocene age, and those for holes 4 and 6 include Paleocene strata. Miocene strata are absent from holes 5 and 6, and incomplete Miocene and Eocene sequences were penetrated in holes 3 and 4. (Joint Oceanographic Institutions' Deep Earth Sampling Program, 1965).

With the exception of some nearshore Miocene silts and clays, the strata are chiefly calcarenites or limestones that are medium to coarse grained under the shelf and fine grained and less well sorted farther off shore. Phosphate pebbles were found only under the shelf. Several volcanic-ash beds were found beneath the Blake Plateau (Joint Oceanographic Institutions' Deep Earth Sampling Program, 1965).

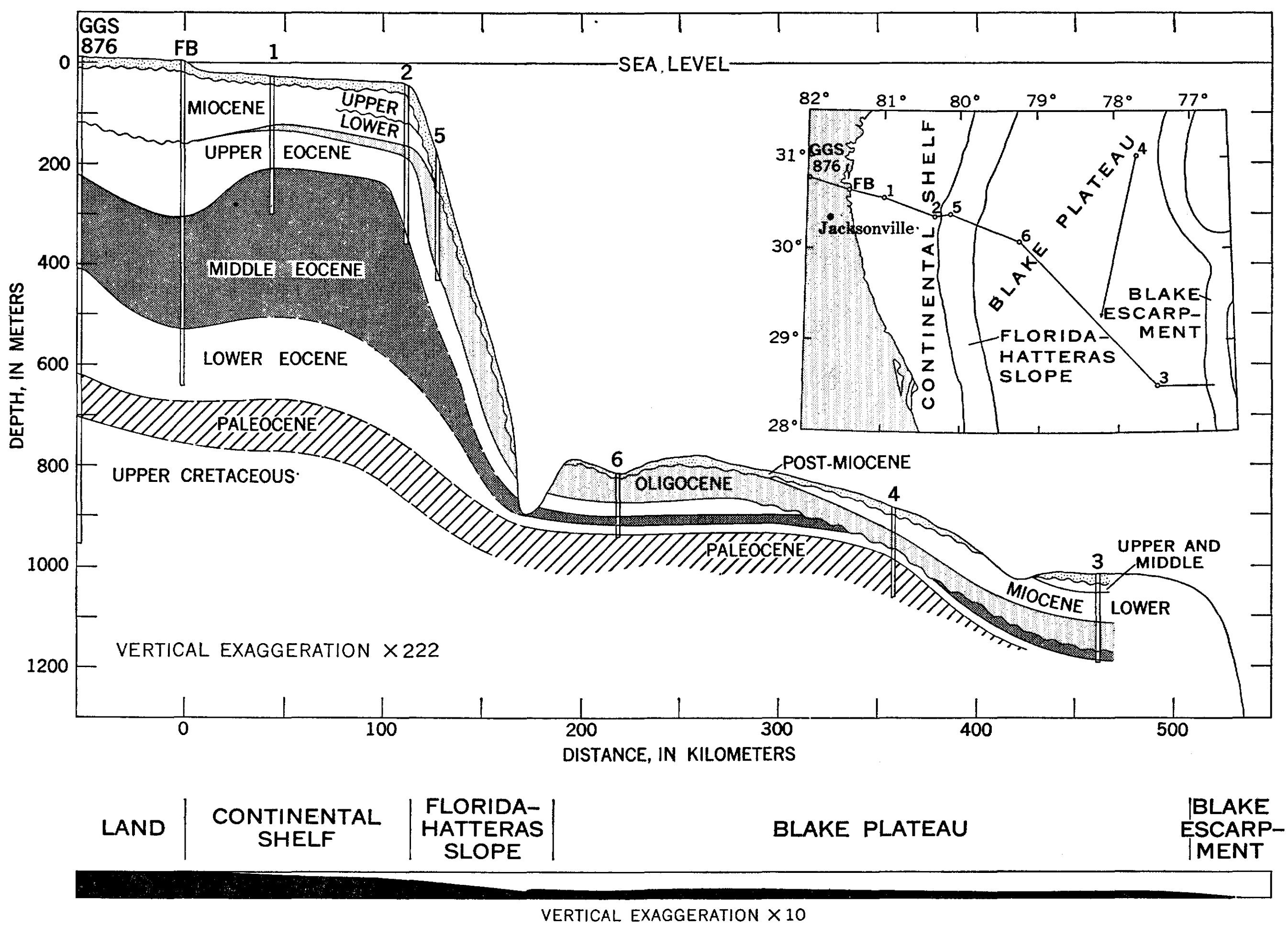

FIGURE 1.—Location of drill holes, JOIDES drill holes 1–6, 1965, and stratigraphic profile. Actual inclination of Florida-Hatteras Slope is about 4°. GGS 876 and FB refer to earlier drill holes in Florida. (Modified from Joint Oceanographic Institutions' Deep Earth Sampling Program, 1965.)

METHODS

Most samples were collected at depth intervals of 10–30 meters, with closer spacing near the surface. An effort was made to sample the sediment types most typical of the entire section; however, only one-third, on the average, of the total drilled section was recovered in the core barrel. Details of the coring procedure were given by Schlee and Gerard (1965).

Carbonate was determined by a gasometric method (Hülsemann, 1966). The amount of carbon dioxide generated by digestion of a sample with 2-normal hydrochloric acid was measured and computed as equivalent of calcium carbonate (table 1).

Organic carbon was determined by rapid dry combustion of the solid residue of the acid-treated sample in an induction furnace. As the sample is free of carbonate, the most common and abundant form of "inorganic" carbon, the carbon value obtained in this process is considered to be the "organic" carbon content of the sample (table 1).

Nitrogen was measured by micro-Kjeldahl analysis of sample fractions that were previously washed in distilled water. The quantities of nitrogen are reported as numerical values in percent dry weight of the original sediment in table 1. No attempt was made to convert the values of either nitrogen or organic carbon to total organic matter; however, the use of conversion factors for this purpose was discussed by Bader (1954).

TABLE 1. *Calcium carbonate, organic carbon, and nitrogen contents, and carbon-nitrogen ratio of samples from JOIDES core holes 1–6*

[Analysts: Madalyn Hamilton and Jobst Hülsemann]

Depth below sea floor (meters)	Geologic age	Calcium carbonate ($CaCO_3$ in percent dry weight)	Organic carbon (percent dry weight)	Nitrogen (Kjeldahl) (percent dry weight)	Carbon-nitrogen ratio
		Core hole 1			
0	Post-Miocene	19.2	0.11	0.024	4.7
15	Miocene	68.2	.71	.041	17.3
23	do	46.1	1.03	.083	12.8
30	do	2.9	.90	.058	15.8
62	do	20.0	1.04	.108	9.8
93	do	59.7	1.20	.073	16.4
273	Middle Eocene	99.0	.17	.008	21.6
		Core hole 2			
0	Post-Miocene	39.8	0.13	0.012	11.8
68	Late Miocene	52.1	1.13	.063	17.9
101	Early Miocene	62.9	1.10	.082	13.4
134	Oligocene	81.4	.75	.040	18.6
152	Late Eocene	83.6	1.20	.060	20.1
184	do	89.7	.23	.011	20.9
214	do	84.9	.20	.015	13.3
276	Eocene	83.1	.48	.014	34.2

TABLE 1. *Calcium carbonate, organic carbon, and nitrogen contents, and carbon-nitrogen ratio of samples from JOIDES core holes 1–6*—Continued

Depth below sea floor (meters)	Geologic age	Calcium carbonate ($CaCO_3$ in percent dry weight)	Organic carbon (percent dry weight)	Nitrogen (Kjeldahl) (percent dry weight)	Carbon-nitrogen ratio
		Core hole 3			
0	Post-Miocene	93.3	0.05	0.010	5.3
15	Late(?) Miocene	87.6	.04	.012	3.2
23	Middle Miocene	91.8	.07	.009	7.8
30	do	89.5	.11	.011	10.1
61	Early Miocene	89.8	.15	.013	11.5
92	Oligocene	90.6	.05	.006	8.3
122	do	90.4	.04	.007	5.7
153	Middle Eocene	90.6	.07	.008	8.7
		Core hole 4			
0	Post-Miocene	95.6	0.11	0.012	9.2
21	Early Miocene	86.8	.11	.017	6.5
34	do	80.5	.21	.023	9.1
71	Oligocene	88.7	.09	.006	15.0
84	Early Eocene	49.9	.18	.014	12.8
135	Paleocene	58.9	.28	.020	14.0
154	do	48.9	.30	.031	9.7
168	do	66.1	.18	.021	8.6
		Core hole 5			
0	Post-Miocene	65.1	0.91	0.139	6.5
11	do	71.7	.14	.017	8.2
20	do	62.1	.55	.035	15.7
30	do	74.6	.44	.038	11.6
61	do	60.8	.93	.078	11.9
95	Oligocene	63.2	1.22	.067	18.2
124	do	66.1	1.18	.071	16.6
154	do	63.0	1.35	.072	18.7
199	do	78.1	1.13	.052	21.7
		Core hole 6			
0	Post-Miocene	94.6	0.08	0.022	3.6
8	Oligocene	88.1	.13	.006	21.6
15	do	91.3	.08	.009	8.9
23	do	91.9	.09	.005	18.0
30	do	87.6	.05	.007	7.1
61	Late Eocene	82.4	.03	.007	4.6
93	Middle Eocene	85.2	.07	.008	8.8

CONTINENTAL SHELF AND UPPER FLORIDA-HATTERAS SLOPE

RESULTS

The abundances of carbonate (as calcium carbonate), organic carbon, and nitrogen in sediments of the shelf and slope are plotted in figures 2 and 3 against depth of the samples below the sea floor for each of the drill holes. In figure 3 each sample value is coded to indicate

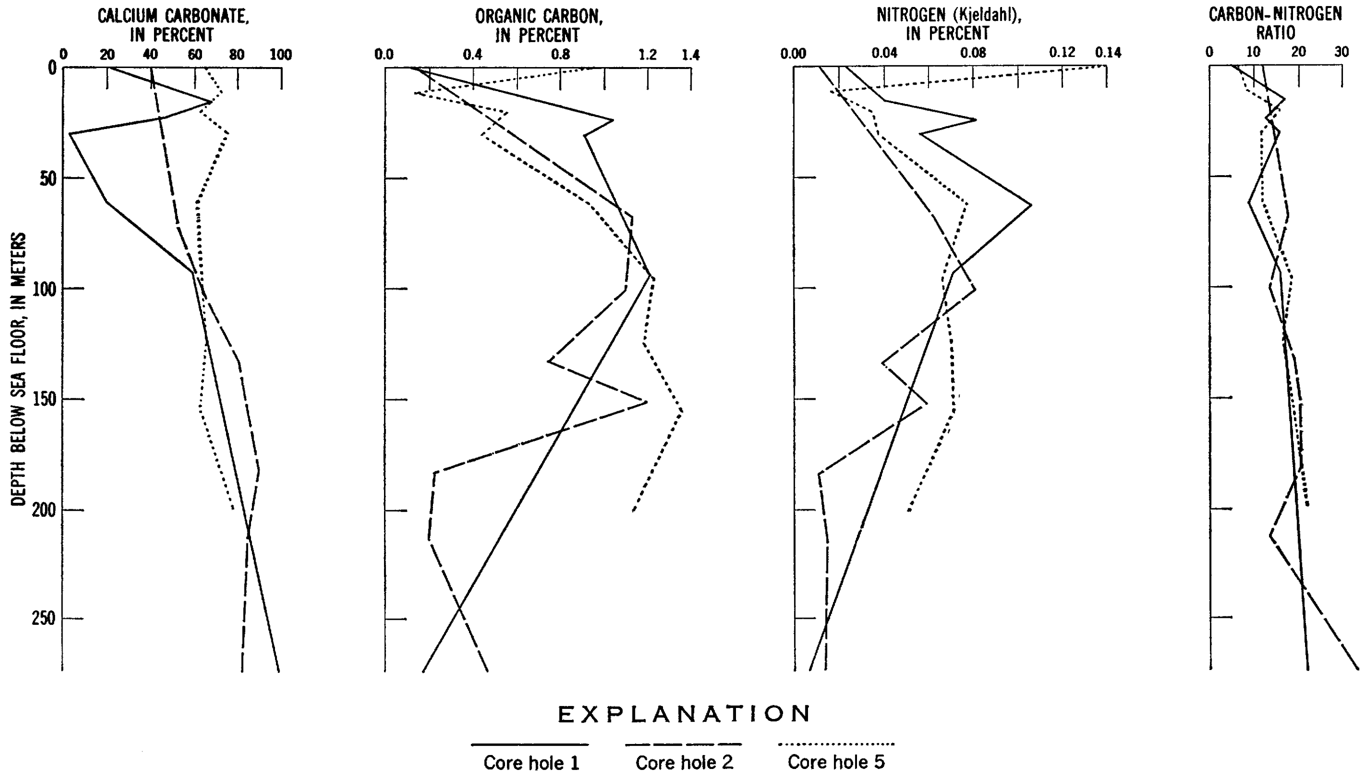

Figure 2.—Relation of organic constituents to depth in samples from JOIDES drill holes on the continental shelf and the upper Florida-Hatteras Slope.

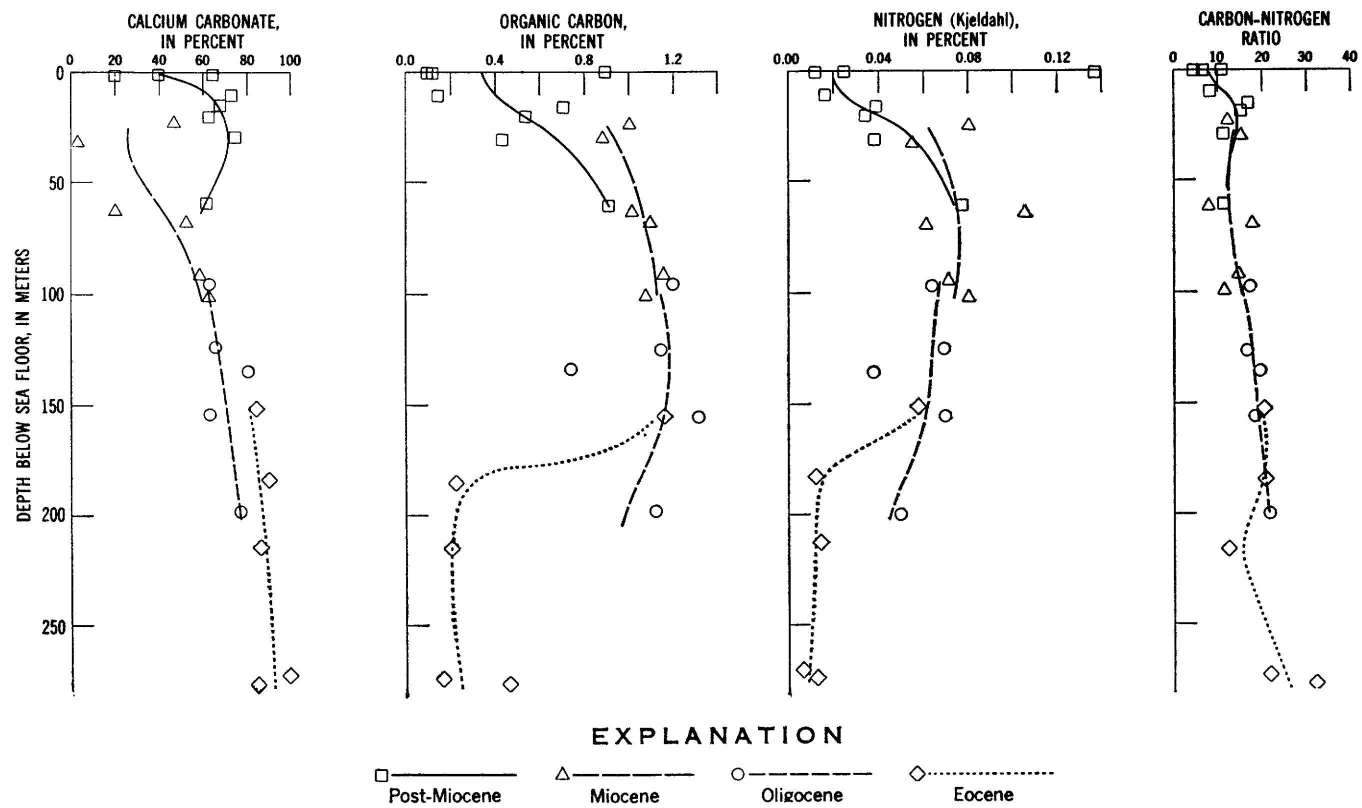

Figure 3.—Relation of organic constituents to depth and geologic age of sediments of the continental shelf and upper Florida-Hatteras Slope.

the geologic age that it represents; the curves are averaged for the different geologic epochs.

Calcium carbonate is moderately abundant to abundant in the strata beneath the shelf and ranges from 20 to 90 percent (fig. 3). The amount is most variable in sediments of post-Miocene age. The content is 20 percent in uppermost Miocene sediment and increases rather uniformly downward to 90 percent in the oldest strata of Eocene age. The apparent change in calcium carbonate abundance from moderately high concentrations in the post-Miocene to low concentrations in the Miocene is caused by averaging data from nearshore and offshore holes 1 and 5. The carbonate is derived chiefly from molluscan shell fragments, foraminiferal tests, algae, and coral debris (Joint Oceanographic Institutions' Deep Earth Sampling Program, 1965).

The concentrations of organic carbon and nitrogen vary by more than one order of magnitude: 0.1–1.4 percent and $<$0.01–0.14 percent, respectively (fig. 2). Carbon and nitrogen are least abundant in the oldest and in the youngest sediments of the nearshore holes (1 and 2), and they are generally most abundant in Oligocene and Miocene strata from both the nearshore and the offshore sholes (figs. 3, 7*A*). The largest concentration of nitrogen, however, was found in the surface sediment of hole 5 on the upper Florida-Hatteras Slope.

The carbon-nitrogen ratio is distinctly a function of age (figs. 2, 3) and reflects neither the absolute concentrations nor the pronounced changes in trend of the individual components. The average is less than 10 near the surface and slightly more than 20 in the deepest and oldest strata (Eocene). The range and trend of the carbon-nitrogen ratio are much the same for all three drill holes on the shelf and on the upper Florida–Hatteras Slope.

The curves in figure 3 were drawn for the averaged values of organic constituents separately by geologic epoch. This grouping reveals changes in the abundance of the components more clearly, particularly where the groupings are stretched out on a relative time scale as ordinate instead of a depth scale (fig. 6*B*). A fairly abrupt change in carbon and nitrogen contents occurs near the Eocene–Oligocene boundary, in contrast to the uniform gradient of calcium carbonate across the same boundary.

INTERPRETATION

Changes in the abundance of organic carbon and nitrogen with depth, or with time, may simply reflect changes in the amount of organic matter produced in the local waters. Several other factors, however, must be considered; for example, changes in the type of the original fauna and flora, changes in the rate of deposition, or changes in the physical and chemical conditions, such as temperature, pH, and Eh, that affect decomposition and diagenesis of the organic matter.

The data suggest that the variation in abundance of organic carbon and nitrogen, and, hence, of organic matter, in the sediments is chiefly a function of (1) the total amount of original supply, rather than the type of original supply, and (2) the degree of preservation. The main evidence in favor of this hypothesis is the systematic decrease in both the carbon-nitrogen ratio and the carbonate concentration from Eocene to post-Miocene, in contrast to variations in the abundance of organic carbon and nitrogen characterized by a sudden increase at the end of the Eocene and a gradual decrease since the Miocene Epoch.

A major climatic change at the end of the Eocene appears to be unlikely as a cause of the sudden increase in organic carbon and nitrogen because calcium carbonate (whose abundance in shelf sediments is largely a function of the climatic regime, particularly of the temperature of the water) changes so gradually. One factor that may affect only the amount of organic carbon and nitrogen preserved in the sediments but may not immediately change the carbon-nitrogen ratio nor the abundance of calcium carbonate is a change in the rate of sediment accumulation not related to a change in climate. Inasmuch as the Gulf Stream exerts a great influence on the rate of sediment accumulation off Florida, a shift of its axis or a change of its velocity may have changed the sedimentation rate enough to cause the observed variations in the abundance of organic carbon and nitrogen. An increased rate of sedimentation would tend to preserve a greater fraction of the organic carbon and nitrogen from oxidation, and may at the same time reduce the relative amount of calcium carbonate by dilution with clastic material.

Volume, velocity, and course of the Gulf Stream are affected by the extent to which areas of Florida are emerged or submerged. Basically, emergence would narrow the water passage and increase the velocity, whereas submergence would permit the water to spread over a wider area and move more slowly. That the water circulation has changed appreciably is evident from the closing of the Suwannee Channel (between the Apalachee Bay and the Georgia Bight) during the late Eocene (Chen, 1965; Maher, 1965). The depth of water probably did not change greatly, as suggested by uniform shallow-water fossil assemblages and as reflected by the rather straight line of the carbon-nitrogen ratio (figs. 2, 3). Thus, the following sequence of events can be postulated:

1. Crustal movements led to a change of the position or velocity of the Gulf Stream.
2. This change led to faster sediment accumulation in Eocene and Oligocene time in the area of the

shelf holes, owing to the relative increase of clastic noncarbonate detritus.

3. Rapid burial preserved a greater fraction of organic carbon and nitrogen.

The lithology of the cores (John Schlee, R. L. Wait, G. W. Leve, and Eugene Shuter, unpub. data) and the mineralogic studies of JOIDES samples (John C. Hathaway, P. F. McFarlin, and D. A. Ross, unpub. data) corroborate the above theory for the Miocene and post-Miocene samples, and possibly for Oligocene samples, as these have more quartz and feldspar than samples from older beds. The grain size of the noncarbonate fraction is coarser in Oligocene and younger deposits, and phosphate pebbles occur in younger strata.

The greatest abundance but also the greatest variation in the concentration of organic carbon occurs in hole 5, on the upper Florida-Hatteras Slope (Figs. 2, 7). Because the stability of sediments generally decreases with increasing slope and because slumps of large sediment masses have been found at the foot of many continental slopes, the high concentration of organic matter may be related to slumping. Incompletely decomposed organic matter suddenly buried under a slump mass should be cut off from the oxygen in the overlying water, so that the amount of further decomposition would be markedly reduced.

BLAKE PLATEAU

RESULTS

The abundances of calcium carbonate, organic carbon, and nitrogen, an the carbon-nitrogen ratio as a function of depth beneath the Blake Plateau are shown in figures 4 and 5. Figure 5 shows the relation of the organic constituents to geologic age and depth and presents curve segments that are averaged for the different geologic epochs.

The calcium carbonate concentration on and under the Blake Plateau is high. Nearly all post-Eocene samples have more than 80 percent calcium carbonate. The only exception is in the northernmost location (Eocene, hole 4), where calcium carbonate diminishes from about 90 percent at 71 meters depth to 50 percent at 84 meters (fig. 4). In all cores the calcium carbonate is chiefly the remains of pelagic plankton: foraminifers, pteropods, and coccolithophorids (Joint Oceanographic Institutions' Deep Earth Sampling Program, 1965).

The organic carbon and nitrogen contents on and under the Blake Plateau are low and extraordinarily uniform. Carbon ranges from 0.1 to 0.3 percent (figs. 4, 7*B*), and nitrogen from 0.01 to 0.03 percent (fig. 4). Most carbon-nitrogen ratios are about 10; only three samples had ratios of less than 5, and one sample had a ratio of slightly above 20. The highest ratios were in samples from the Oligocene in the inner Blake Plateau (hole 6); the oldest samples (Paleocene), however, had nearly the same carbon-nitrogen ratios as the youngest ones from the present sea floor. Some apparent variation in carbon-nitrogen ratios is probably a result of analytical inaccuracy due to the low absolute concentration of organic nitrogen.

Lower Eocene and Paleocene rocks were reached by the drill only under the Blake Plateau, and the thickest section of these strata was penetrated in hole 4 (fig. 1). A distinct relation of the abundance of organic constituents to age is evident if data are adjusted to geologic age (fig. 6*B*). For example, the high values for the

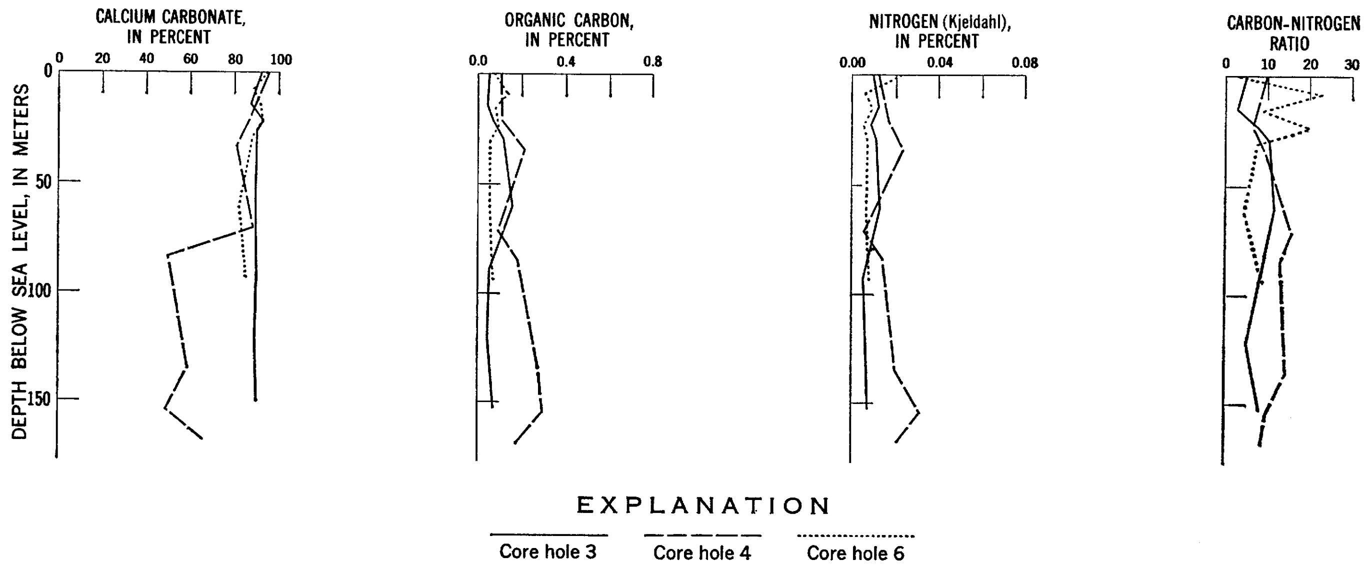

FIGURE 4.—Relation of organic constituents to depth in samples from JOIDES drill holes on the Blake Plateau.

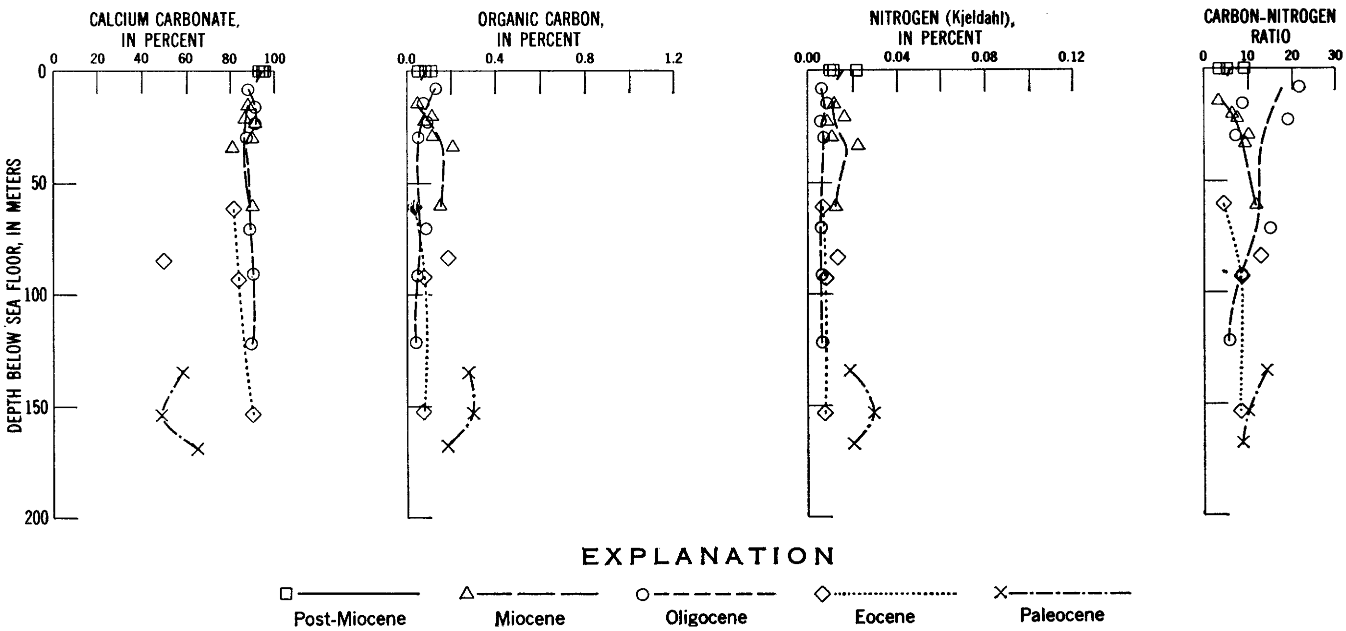

FIGURE 5.—Relation of organic constituents to depth and geologic age of sediments of the Blake Plateau.

lower Eocene sample at 84 meters depth in hole 4 that seem anomalous in figure 5 are not abnormal when adjusted for age in figure 6*B*. The contents of organic constituents are relatively uniform downward to the lower Eocene strata, where the amounts of all three change abruptly. Calcium carbonate content is reduced markedly in Paleocene and lower Eocene rocks to 50 percent, whereas in younger strata it is considerably higher. Conversely, both organic carbon and nitrogen contents are lower in post-lower Eocene strata.

INTERPRETATION

According to its fossil content and distance from shore, the Blake Plateau represents deep-water marine conditions, as opposed to shallow-water conditions, typical of the shelf. The low calcium carbonate values of the lower Eocene and Paleocene strata, however, appear to be somewhat less typical for a pelagic environment than the higher values of the younger strata. The increase in calcium carbonate content parallel with the distinct decrease in organic carbon and nitrogen contents in post-lower Eocene strata could be a result of a shift to more typical pelagic conditions such as are characterized by one or more of the following circumstances:

1. A decrease in the rate of accumulation of noncarbonate detritus.
2. Less preservation of organic material.
3. A greater distance from the continent.

This theory of a shift to more pelagic conditions is supported by mineralogical results: most of the small amount of detrital quartz, the volcanic minerals, and the layers of chert under the Blake Plateau occur in lower Tertiary sediments (J. C. Hathaway, P. F. McFarlin, and D. A. Ross, unpub. data). Perhaps, the Blake Plateau was closer to the Paleocene-Eocene shoreline, and the Florida-Hatteras Slope may not have existed. The development of the Florida-Hatteras Slope may have led in post-early Eocene time to a water circulation pattern that intercepted part of the land-derived detritus before it reached the Blake Plateau. The volcanic minerals in the lower Tertiary strata may indicate that volcanism was associated with the crustal movements.

If the increase of biogenic calcium carbonate in late Eocene time resulted from greater surface production, for instance related to a climatic amelioration, then a similar increase in the production of organic carbon and nitrogen could be expected. However, the percentage of organic carbon and nitrogen did not increase after early Eocene time. Also, there was no increase in the carbon-nitrogen ratio as would be expected if the organic matter had been more completely decomposed. Conceivably, the calcium carbonate production was great enough to overshadow an increase in the production of organic carbon and nitrogen, and the calcium carbonate diluted these constituents. If so, one would expect a marked increase in the rate of sedimentation. However, on the basis of the drill-hole and seismic records, the sedimentation rate did not increase.

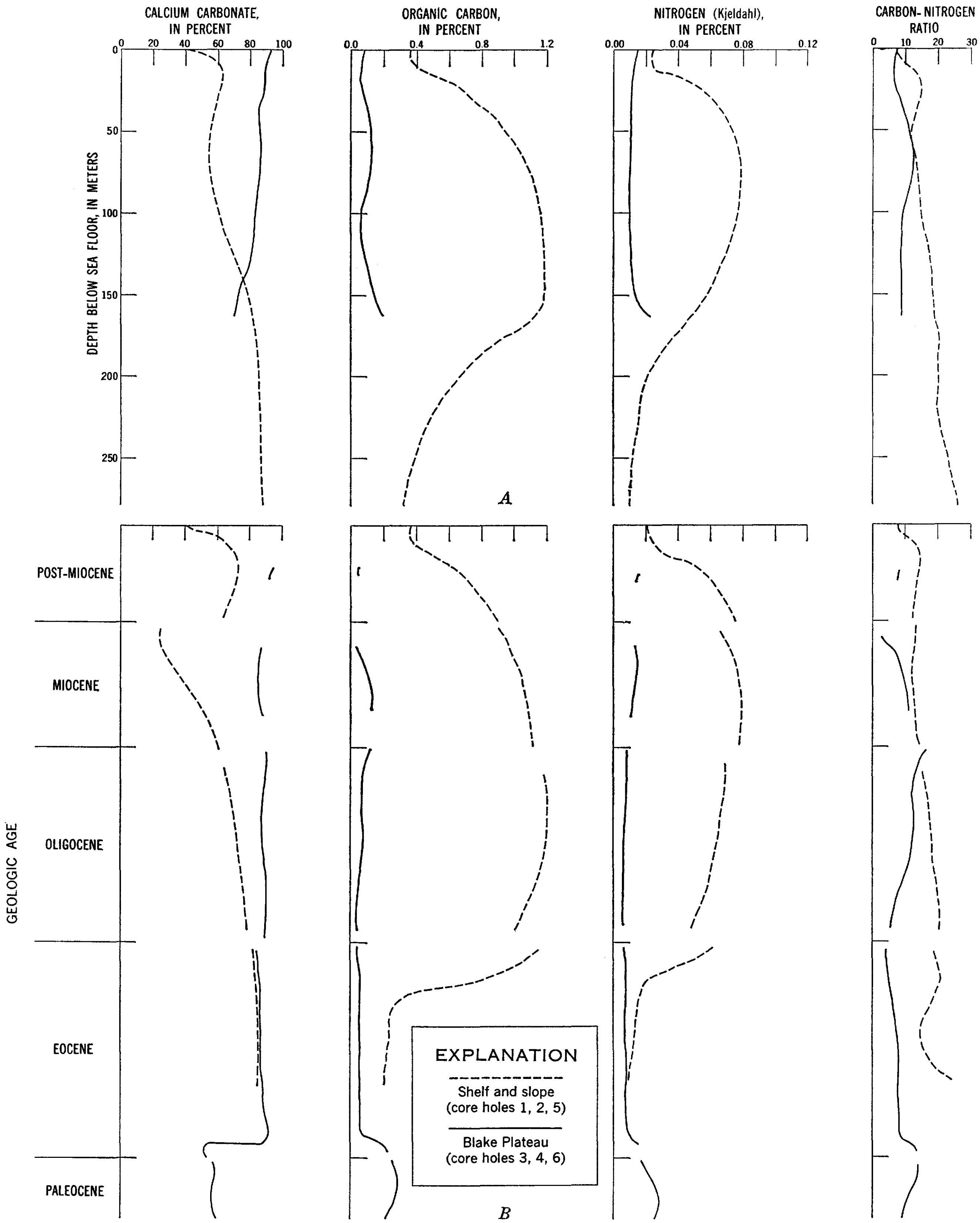

FIGURE 6.—Comparison of average percentage of organic constituents in sediments of the shelf and the slope with that in sediments of the Blake Plateau. *A*, Plotted against depth. *B*, Plotted against geologic age.

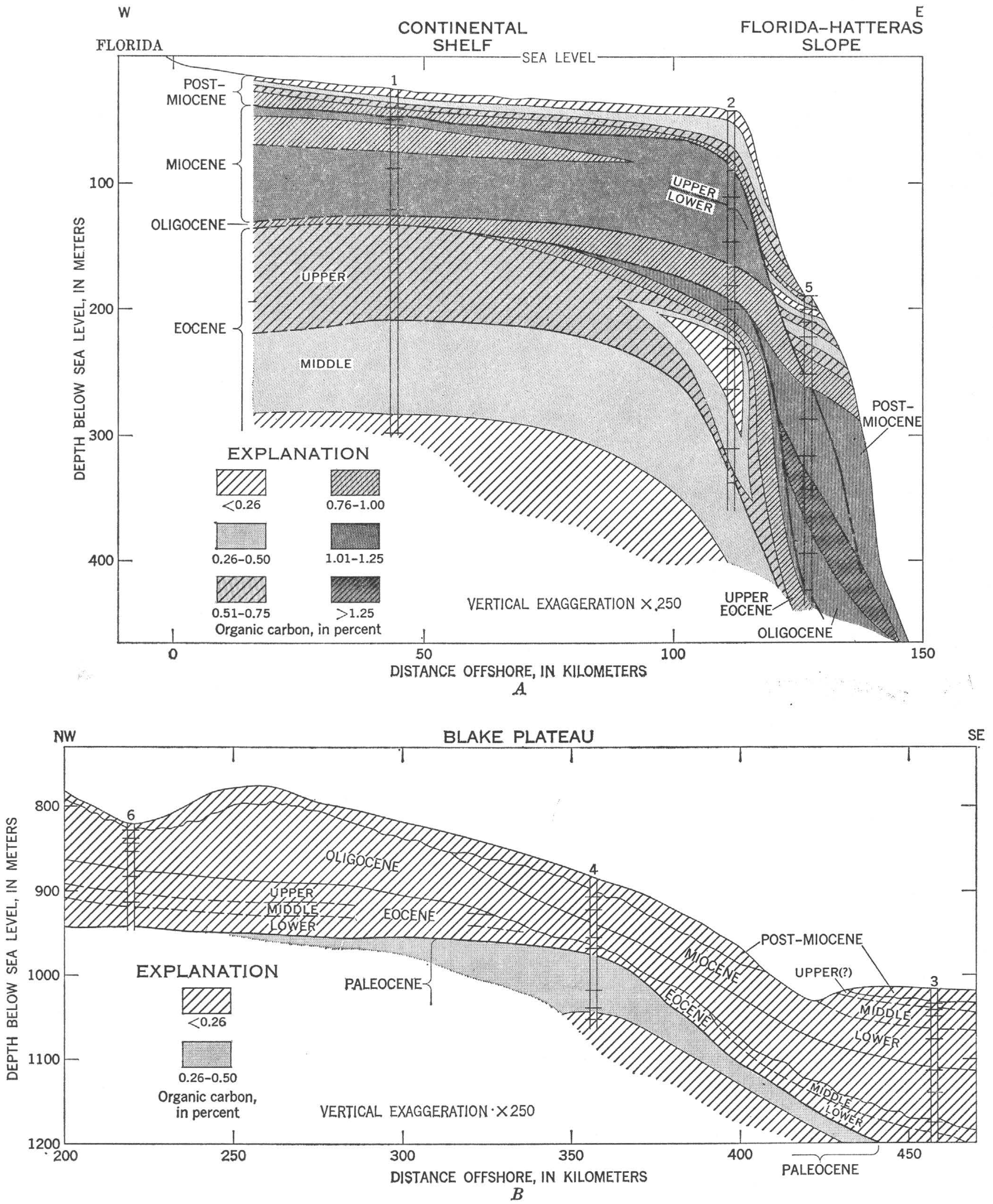

FIGURE 7.—Percentage distribution of organic carbon in sediments of the continental shelf, upper Florida-Hatteras Slope, and Blake Plateau, projected from drill holes. *A*, Shelf to upper Florida-Hatteras Slope. *B*, Blake Plateau. (Stratigraphic profile modified from Joint Oceanographic Institutions' Deep Earth Sampling Program, 1965.)

SUMMARY AND CONCLUSIONS

The distribution of organic constituents in samples from the JOIDES drill holes shows that two distinct facies are represented by the cores (figs. 6, 7): one, on and beneath the present shelf and the upper Florida-Hatteras Slope, is typical of shallow-water conditions, and the other, on and beneath the Blake Plateau, is typical of deep-water conditions. The variations in the abundances of the organic constituents are systematically related to depth and age.

The following explanation is suggested for the abundances of the organic constituents in the sediments and the changes in abundances with time. During Paleocene time the area of the Blake Plateau was less typically pelagic (pelagic in the sense used by Hedgpeth, 1957, p. 17–27) than at present and perhaps closer to shore, and the rate of accumulation of sediment (including volcanic material) was greater. In early Eocene time the Blake Plateau became more clearly defined as a pelagic region, characterized by an increase in calcium carbonate in the sediments and a decrease in organic carbon and nitrogen contents. Sediment accumulated more slowly. The abruptness of this change may reflect a tectonic movement along the present site of the Florida-Hatteras Slope, movement that lowered the Blake Plateau or raised part of the shelf and created the slope as a more pronounced boundary between the shelf and Blake Plateau. The seismic profiling records, as interpreted by Emery and Zarudzki (1967), do not reveal evidence for faulting. However, the records do not rule out the possibility of changes in the depth of the sea floor; in fact, these records suggest that some tectonic activity occurred in Paleocene and early Eocene time near the Florida-Hatteras Slope. In addition, ash layers, zeolites, and other indications of volcanic activity were noted by J. C. Hathaway, P. F. McFarlin, and D. A. Ross (unpub. data) to be most abundant in lower Tertiary samples.

During the late Eocene and early Oligocene, conditions on the shelf became more neritic. This is shown by an increase of organic carbon and nitrogen, accompanied by a decrease of calcium carbonate and an increase in quartz and feldspar, in the shelf sediments. Again, the change of conditions was sudden enough to suggest differential crustal movement of the land or shallow sea floor, movement which may have caused a shift of the axis or velocity of the Gulf Stream. The Blake Plateau was apparently not affected by this event.

In Miocene and post-Miocene time, conditions on the Blake Plateau did not change significantly. Sediment accumulated considerably more slowly than on the shelf; hence, there was little accumulation of organic carbon and nitrogen. On the shelf, the more gradual changes in the abundances of the organic constituents in the Miocene and post-Miocene strata may be explained by changes in the axial position, velocity, and volume of the Gulf Stream.

The most favorable site for the accumulation of organic matter, as indicated by organic carbon and nitrogen abundance, has been the upper Florida-Hatteras Slope. Mass slumping of sediment and burial of younger by older sediments may have provided the mechanism for the preservation of a large amount of organic matter in an area remote from the mainland where the rate of deposition of terrestrially derived clastic material is generally low.

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