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Diapiric Structures off Niger Delta[1]

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Abstract—Several marine geophysical profiles off the southern part of the Niger delta reveal the presence of diapiric structures beneath the continental slope and rise. The origin of the diapiric material appears to be deep in the sedimentary section and is believed to be of Aptian-Albian age. If this hypothesis is correct, the presence of evaporite basins, known between Angola and Gabon, can be extended as far north as the Niger delta.—

Introduction

Several recent publications have described diapiric structures off the west African coast, principally near Angola, Congo, and Gabon, between lat. 2°N and 13°S (Reyre *et al.*, 1966; Baumgartner and van Andel, 1971; Leyden *et al.*, 1972; Von Herzen *et al.*, 1972). Hospers (1971) and Burke (1972) suggested the possibility of shale diapirs off the Niger delta, and Stoneley (1966) evaluated the likelihood of salt structures beneath the shelf and slope off Nigeria.

Off Angola these structures are found on the slope and rise, and are related to a sedimentary basin which Baumgartner and van Andel (1971) believed analogous to the coastal Cuanza basin. The latter, described by Brognon and Verrier (1966), contains several hundred meters of Aptian-Albian salt. If Baumgartner and van Andel's hypothesis is correct, the structures on the slope and rise probably represent salt diapirs of Aptian age. In addition, heat-flow measurements taken in the same area (Von Herzen *et al.*, 1972) suggest that these diapirs are of salt composition; their results appear to be comparable to those obtained by Epp *et al.* (1970) in the Gulf of Mexico, where the evaporitic composition of the diapirs is well established (Ewing *et al.*, 1969).

Reflection profiles off Gabon and Angola reveal diapiric features; oblique reflection studies give velocities of about 4.2 km/sec, falling within the expected range of evaporite formations (Leyden *et al.*, 1972). The results of their oblique reflection studies led them to conclude that the seaward extension of the Lambarene horst was not necessarily the northern limit of evaporite development, as previously had been proposed by Reyre (1966). A sedimentary horizon with a velocity of 4.8 km/sec is found on both sides of the horst and may correspond to an evaporite layer, the top of which is about 2.8 km below the bottom north of Cape San Juan. The high velocity obtained for this horizon did not permit them to state with certainty that this is an evaporite formation; it may represent continental Wealdian sediments known elsewhere in the area.

Several other profiles farther south show horizons with mean velocities of 3.85–4.8 km/sec under approximately 2–3 km of sediment (Leyden *et al.*, 1972). We believe these units are evaporitic in composition; the wide variation in the observed velocities is due to the steep inclinations of many of the reflectors in this area.

New Data

During the course of the Walda cruise of the R/V *Jean Charcot* (Fig. 1), several profiles were obtained off the Niger delta (Fig. 2). The use of the Flexotir seismic-reflection system permitted penetrations of up to 4 seconds. Several sonobuoy profiles were carried out, and continuous gravity and magnetic measurements were made. The ship's speed during profiling was 6 knots and positions were obtained by satellite navigation.

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This study is based on data collected by the R/V *Jean Charcot* of the Centre National pour l'Exploitation des Oceans during the Walda cruise to the west coast of Africa, June-August 1971.

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Profile A

Profile A (Figs. 1–3) is on the slope south of the Niger delta. Many important structures are clearly evident on this profile. These features are steep sided and show no internal reflectors; many are expressed by slight elevations of the sea floor. The sedimentary thicknesses between these structures are up to 2.5 seconds, and the reflectors rise steeply adjacent to the features. Several small faults cut the sedimentary zones, and the extremities of the profile show evidence of major tectonic activity.

The magnetic-anomaly profile, obtained by the removal of the regional field, is shown above Figure 3. The variation is between 40 and 100 γ; these low amplitudes are not characteristic of a volcanic origin.

From the velocity for the sediment overlying the probable salt layer given by Leyden *et al.* (1972) from farther south, we find a thickness of sediment in the order of 2.5 km. This is in good agreement with the results obtained north of Cape San Juan, and suggests that the origin of the material in these structures off the Niger delta is from a depth comparable to that described by Leyden *et al.* (1972).

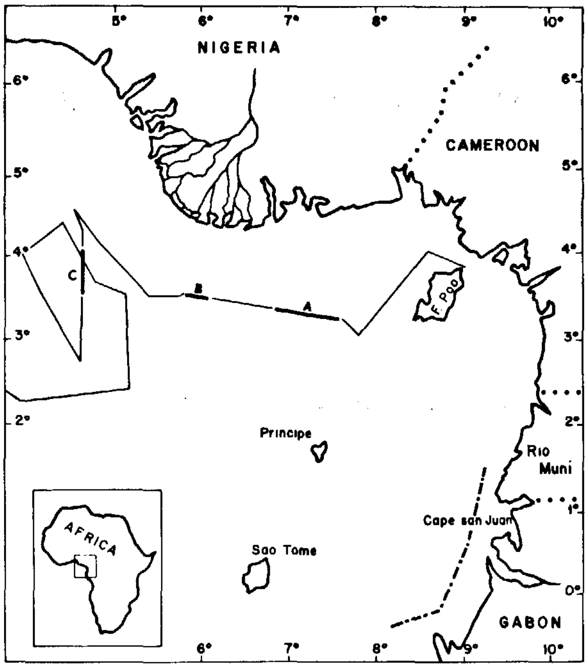

FIG. 1—Location map showing ship track (dashed line), seismic reflection profiles (solid lines), and observed diapiric structures. Profiles of Leyden *et al.* (1972) off Gabon are indicated.

Profile B

Profile B (Figs. 1, 4–5) is an east-west section west of Profile A. It shows an isolated structure, similar to those described previously, at the eastern end of the profile. The western end is marked by a highly disturbed zone exhibiting very few continuous reflectors. A deep, strong reflector (basement?) appears to rise beneath the western extremity of this zone.

The magnetic-anomaly profile ranges between 70 and 97 γ (Fig. 5). These small anomalies also are not characteristic of a volcanic source.

Sedimentary thicknesses in the east appear to be at least 2 seconds and, in the west, to be in excess of 3.5 seconds.

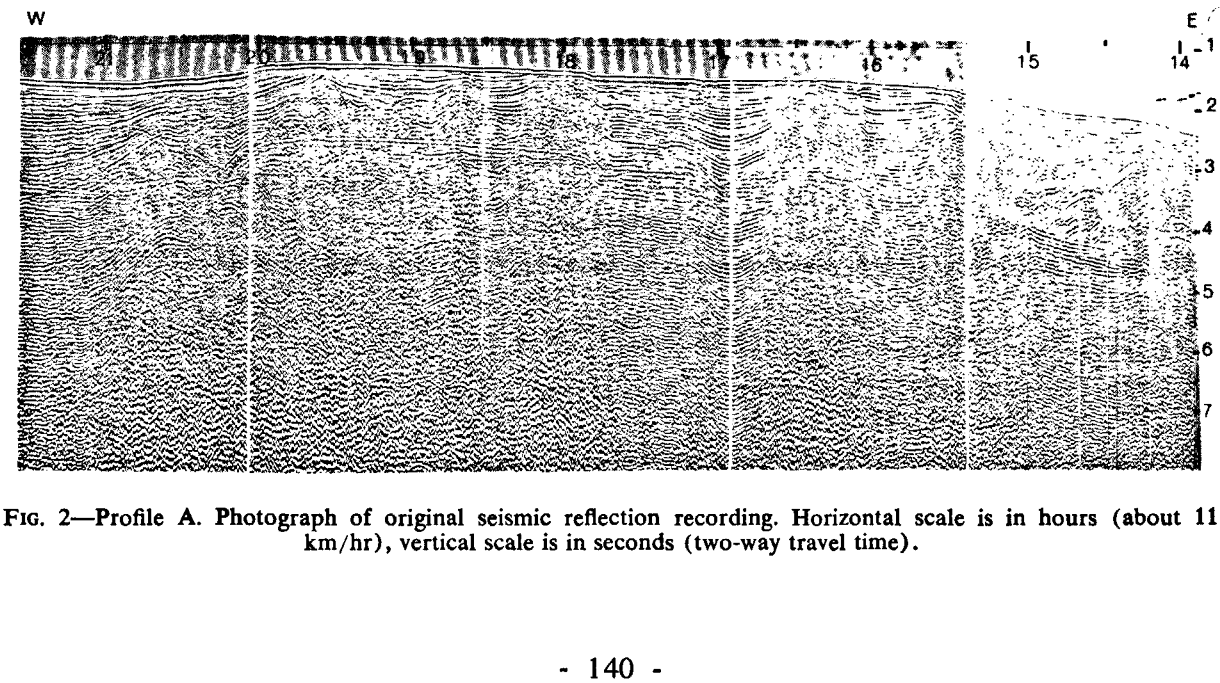

FIG. 2—Profile A. Photograph of original seismic reflection recording. Horizontal scale is in hours (about 11 km/hr), vertical scale is in seconds (two-way travel time).

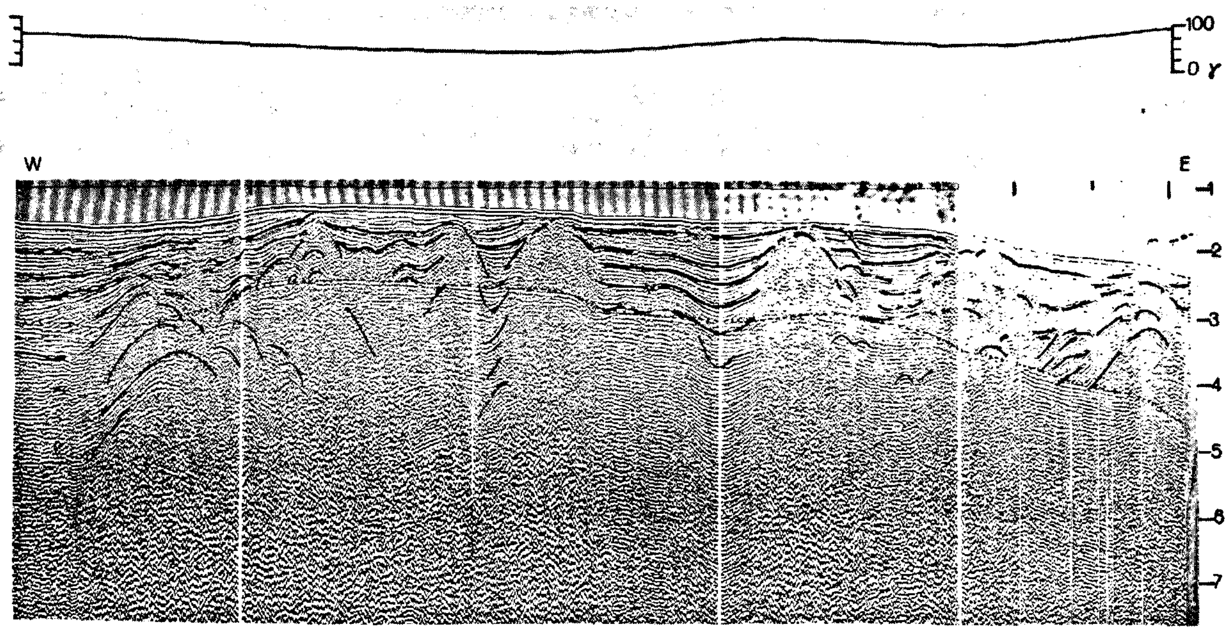

FIG. 3—Profile A. Interpretation of structure showing several diapiric structures and disturbed zones at extremities of profile. Magnetic-anomaly profile is given above section.

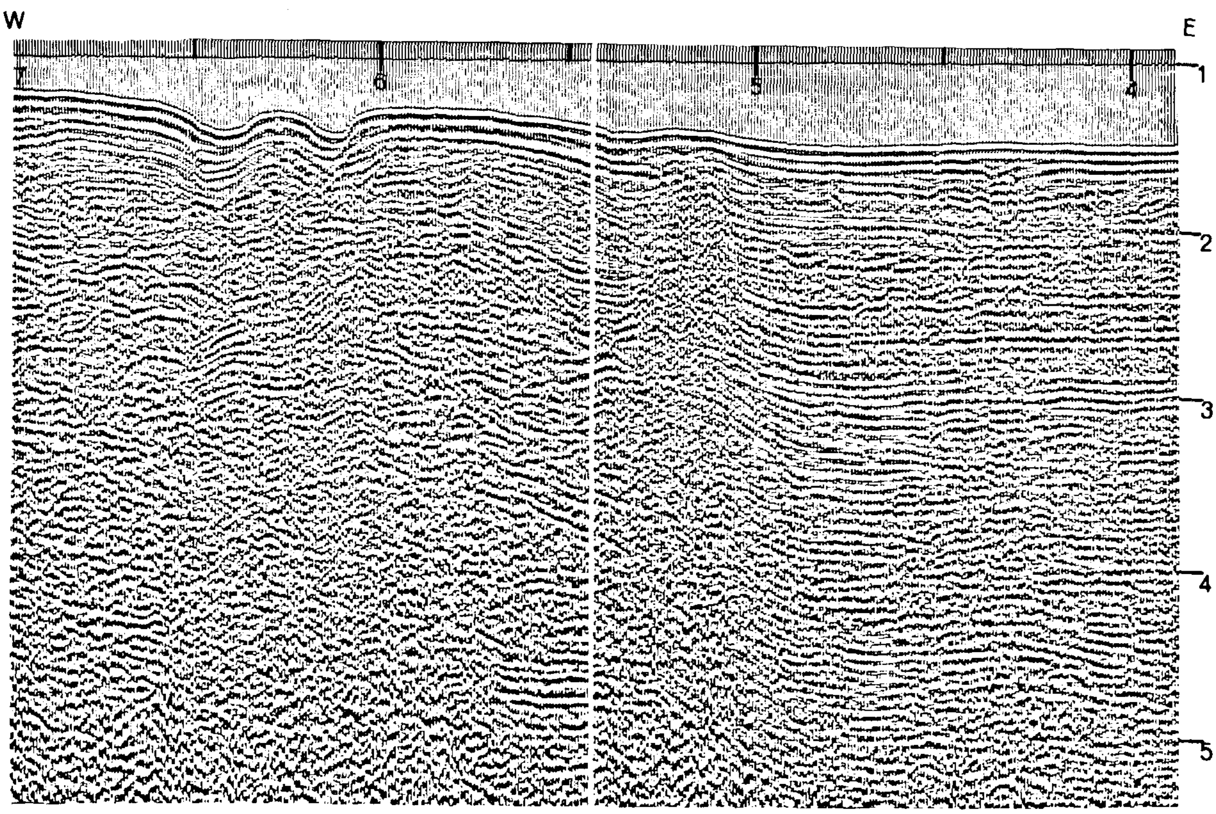

FIG. 4—Profile B. Photograph of original seismic reflection recording.

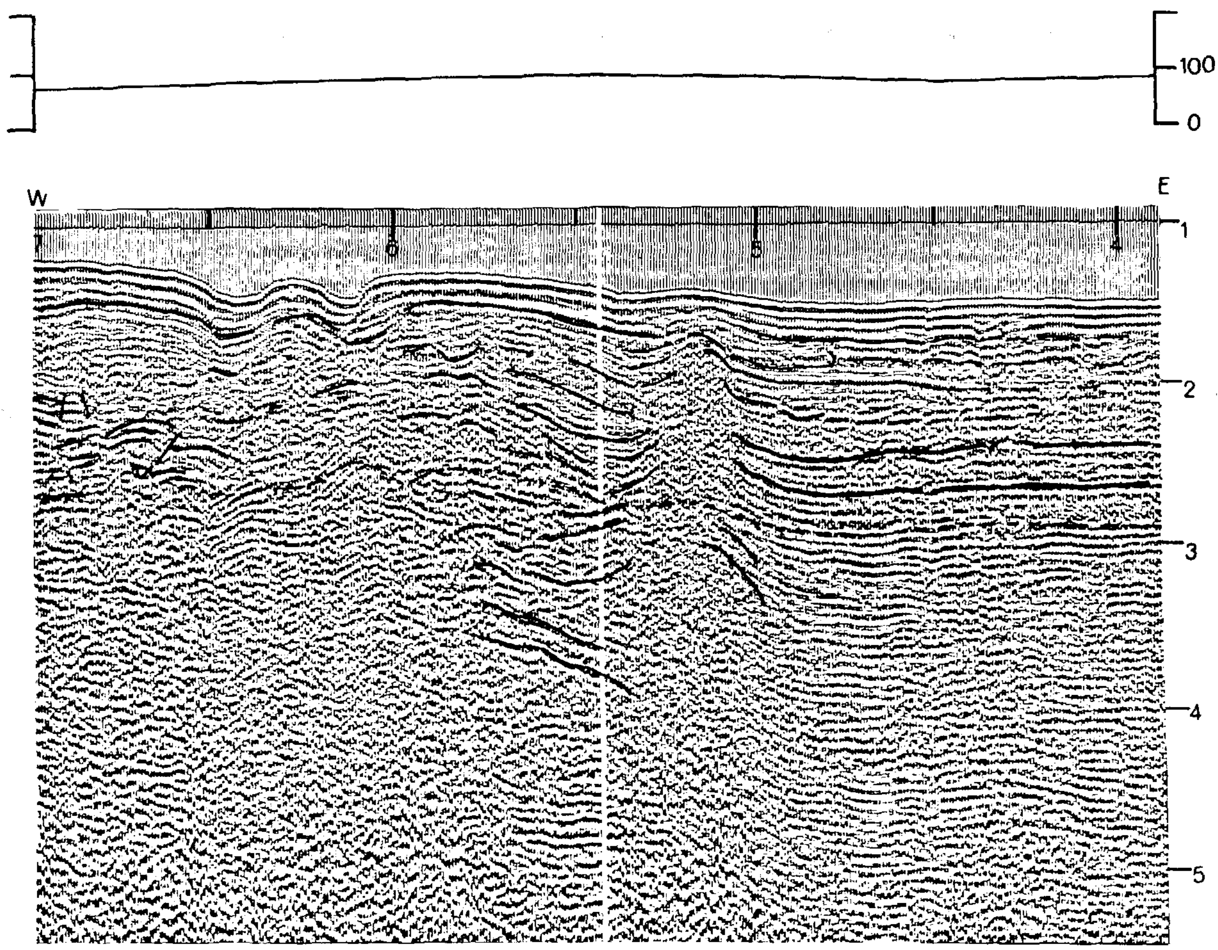

FIG. 5—Profile B. Interpretation of structure showing diapiric feature. Magnetic-anomaly profile is shown above section.

Profile C

Profile C (Figs. 1, 6–8) is a north-south section on the lower slope west of profiles A and B. Four major structures are clearly evident in this section. There is a marked topographic expression of up to 300 m over these features. Between the latter thick accumulations of sediment appear (up to 3 seconds). Many strong internal reflectors are present in this sequence, and correlations can be established throughout the section. Sediment thicknesses increase toward the base of the slope.

At the southern end of the profile a strong reflector under an accumulation of nearly 4 seconds of sediment rises abruptly toward the south. This reflector could be the eastward extension of an important marginal fracture zone.

The magnetic anomaly profile exhibits a variation of 80 γ. The maximum value (168 γ) does not correspond to any observed structure in the seismic reflection record.

Discussion

The absence of any notable magnetic signature over these features, the similarity with known diapiric structures, and the existence of a major diapir field between southern Angola and Gabon lead us to conclude that these structures are of diapiric origin.

Hospers (1971), on the basis of drillhole results from the Niger delta, believed that semidiapiric structures of clay-shale composition may be present, particularly offshore. All of the reported wells in this area, however, have stopped in a major clay-shale bed which probably is not older than Eocene (Hospers, 1971). By comparison with the other coastal basins of west Africa, evaporite layers, if present, would be Aptian-Albian age.

Stoneley (1966) has discussed structures beneath the offshore area of the Niger delta which could be interpreted as the result of salt movement at depth. He mentioned several fac-

FIG. 7—Profile C. Interpretation of structure showing several important diapiric features. Magnetic-anomaly profile is given.

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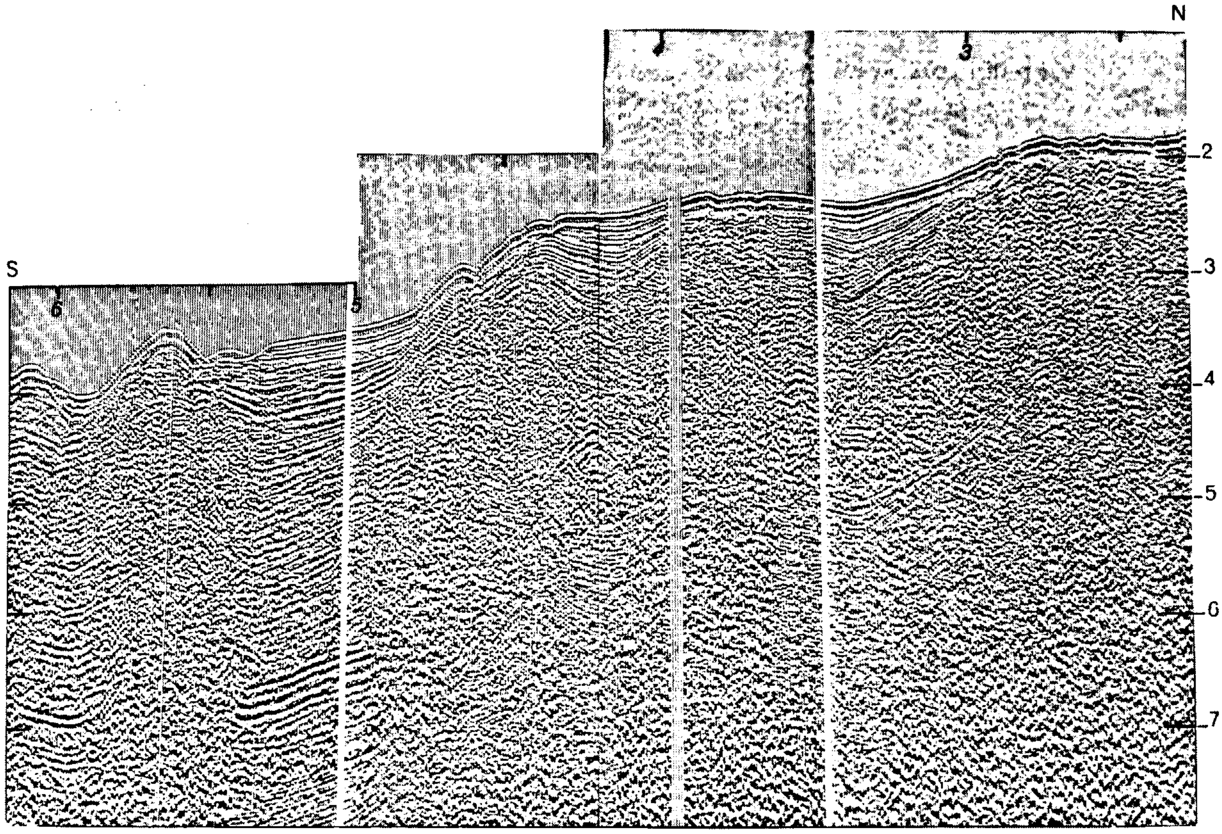

FIG. 6—Profile C. Photograph of original seismic reflection recording.

tors, however, which suggest that these features are not salt diapirs: (1) there is no indication of pre-Albian sediments in wells north of Gabon, and (2) there is no evidence of evaporites in outcrops of Albian rocks in Nigeria. As noted above, however, no holes have penetrated the Cretaceous in the Niger delta area. As in the Cuanza basin (Brognon and Verrier, 1966), a lateral facies change could explain easily the absence of evaporites in outcrops north of the delta.

As shown above, the sedimentary thicknesses at the southern end of Profile C are about 4 seconds; this represents at least 4 km of sediment. The deepest drilling indicates at most 4.4 km in the central part of the delta and a probable thinning offshore; this also is shown by models based on gravity data (Hospers, 1971). We, therefore, can conclude that the accumulation of 4 km of sediment on the lower slope and rise represents deposition since pre-Tertiary time. This same profile also shows (Fig. 8) that the diapiric material originated in the lower part of the sedimentary section. We believe, therefore, that this material is older than Cenozoic and is probably of Aptian-Albian age, as mentioned by Stoneley (1966) and Reyment (1969). Moreover, Francheteau and Le Pichon

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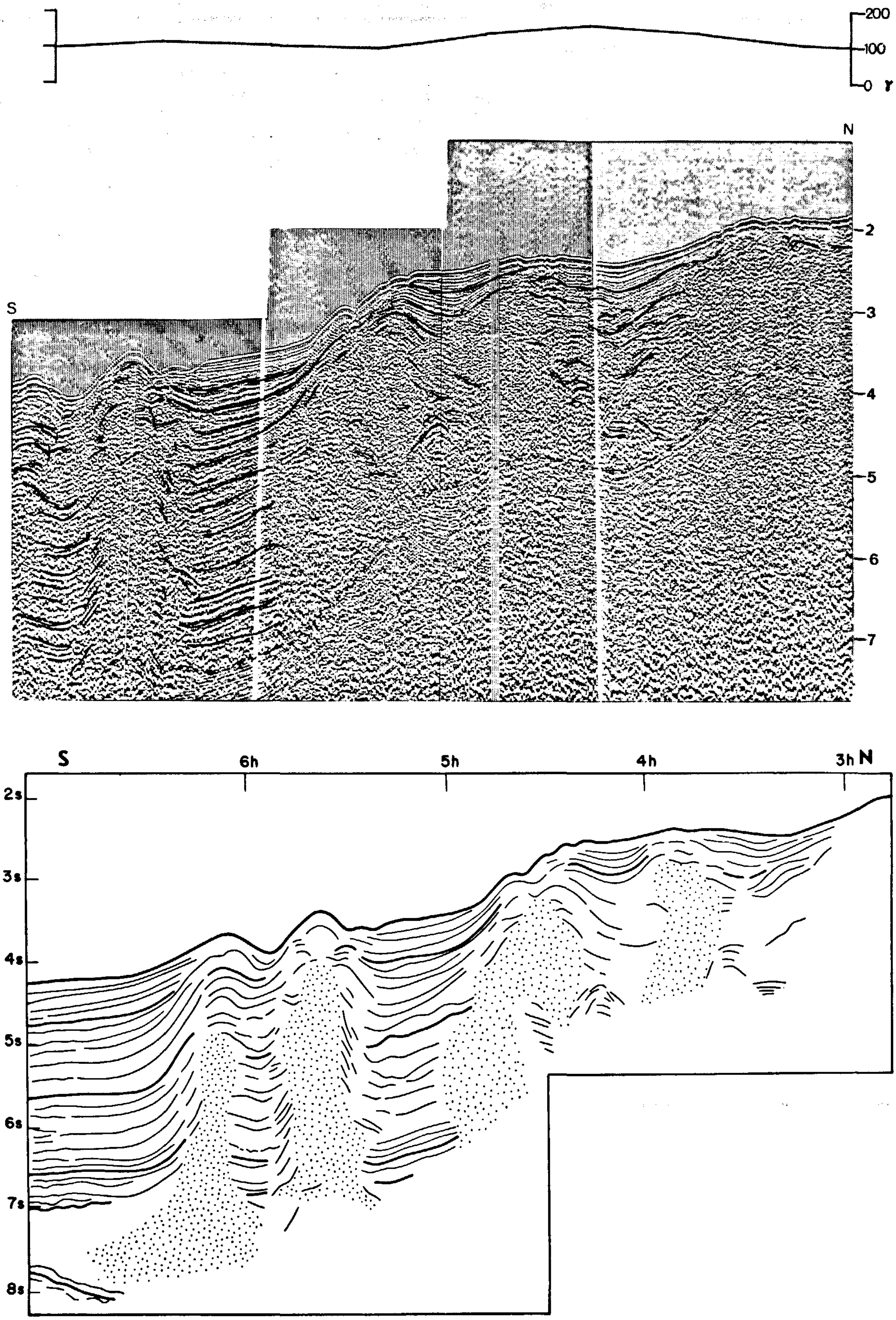
FIG. 8—Profile C. Schematic interpretation of structure showing thick sedimentary sequence, horizon without any internal reflectors, and beginning of probable basement rise.



200
100
0 γ
S
N
2
3
4
5
6
7
S
6h
5h
4h
3h
N
2s
3s
4s
5s
6s
7s
8s

(1972) believed that the subsidence in this area was facilitated by the existence of equatorial fracture-zones extensions and a true marine sedimentary phase began only during this period.

Before the creation of the Annobon-Cameroun line (Upper Cretaceous-Holocene), there is no reason to believe that the Gabon evaporite basin did not extend farther north (as shown by Bullard *et al.*, 1965) and that the same conditions favorable for the development of evaporites also did not exist off the Niger delta.

The depth of the mother layer off the Niger delta seems to be in good agreement with the 4.0 km/sec layer which was described by Leyden *et al.* (1972) farther south and which they believed to be salt of Aptian age, as in the coastal basins.

Conclusions

We believe that diapiric structures off the Niger delta are of the same origin as those described from farther south and that they are probably of evaporite composition and of Aptian-Albian age. The development during the Tertiary of the Niger delta and the tremendous volume of sediment contributed to the offshore areas probably facilitated the creation of the observed structures. This does not preclude the existence of clay-shale diapirs in younger sediments, as suggested by Hospers (1971) and Burke (1972).

The diapirs off Gabon and Angola therefore can be extended northward at least to the southern part of the Niger delta. This is compatible with the fit of the South American and African continents during the Cretaceous and with the postulated opening of the South Atlantic. The development of a major evaporite basin system during the early opening of the South Atlantic appears to correspond quite well to the ideas of Pautot *et al.* (1970) for the early phase of rifting in the North Atlantic, which they relate to a continuous deep-sea salt layer along the margin.

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