51. BLACK SEA: GEOLOGICAL SETTING AND RECENT DEPOSITS DISTRIBUTION FROM SEISMIC REFLECTION DATA

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ABSTRACT

The origin of the Black Sea is discussed in the framework of the evolution of the Mediterranean Alpine area since the beginning of the Mesozoic. The Black Sea is considered to be a marginal basin formed between Lias to Upper Cretaceous times, behind the Pontides Range relative to the consumption of the Tethys. Land geological data and multichannel seismic reflection profiles show that later compressional movements occurred at the northeastern and southern margin of the Black Sea depression. In the abyssal plain, basement reliefs are buried by a thick horizontal sequence of mainly post-Eocene sediments. Mud diapiric phenomena of deep layers, related to undercompaction, and covered by rapidly deposited thick sediments, are observed southeast of Crimea. It appears that, during Pliocene-Quaternary times, sedimentation and subsidence strongly increased. Sedimentation was controlled by fans related to the main deltas. Correlations of DSDP holes with seismic reflection profiles allow better interpretation of the sedimentation pattern in the Black Sea.

INTRODUCTION

In recent years, the numerous oceanographic surveys made in the different Mediterranean basins have led to great progress in our understanding of these basins. They have revealed the diversity of the basins and have pinpointed their particular features. Multichannel seismic reflection profiles in particular have provided a better definition of the structure and geometry of sedimentary bodies in the western and eastern Mediterranean (Biju-Duval et al., 1974, in press). In the Black Sea, geophysical prospecting has long since determined the general features: the deep structures shown by numerous seismic refraction surveys (Garkalenko et al., 1971; Goncharov et al., 1972; Neprochnov et al., 1974), the superficial structures shown by shallow-penetration seismic reflection (Ross et al., 1974; Ross, 1974). However, few data have been published about the overall sedimentary series and the detailed structure of the margins.

A multichannel seismic reflection cruise (Flexichoc seismic source, 2400% stack) was carried out in the Black Sea in 1973 by a CEPM-CNEXO French group. This survey, together with data from sparker profiles from the Woods Hole *Atlantis* II cruise (Ross, et al., 1974), enables the drilling data from Leg 42B to be better interpreted as to their structural context.

FORMER AND PRESENT STRUCTURES

The Black Sea is located to the south of the European craton. It occupies a complex position on several structural zones (Figure 1). To the north the Ukranian Shield plunges southward beneath Mesozoic and Cenozoic formations that form the Scythian Platform and thick-sectioned Karkinit and Indol Kuban basins. The relationships that may exist between the folded systems that outcrop the Dobrudja region in the Crimean Mountains, and in the Greater Caucasus, are still subject to discussion relative to the extension of the pre-Hercynian and Hercynian folded belt in the Caucasus (Khain and Milanovsky, 1963) and the relationships between the Crimea and the folded Dobrudja system during the Cimmerian orogeny (Goncharov et al., 1976). The effects of the Alpine phase and more recent deformations are now better known as the result of onshore geological studies and new offshore data. The folds and overthrustings appear oriented mainly southward in the direction of the Georgian basins and the east Black Sea basin. The movements and the shortening appear to be attenuated in the west where the structures of the Greater Caucasus plunge south of the Indol Kuban Basin and are masked by extensive mud diapirism phenomena. The movements continued until the present period, as shown by the seismicity (McKenzie, 1972).

In the south and southwest, the link between the Balkan and Srednogorie zones and the North Pontides zone is accepted by most authors (Boncev, 1951, 1975; Boccaletti et al., 1974; Brinkmann, 1974). In the Mesozioc, this zone formed the southern part of the European plate; it was separated from the Arabo-African plate and the present intermediary Apulian-

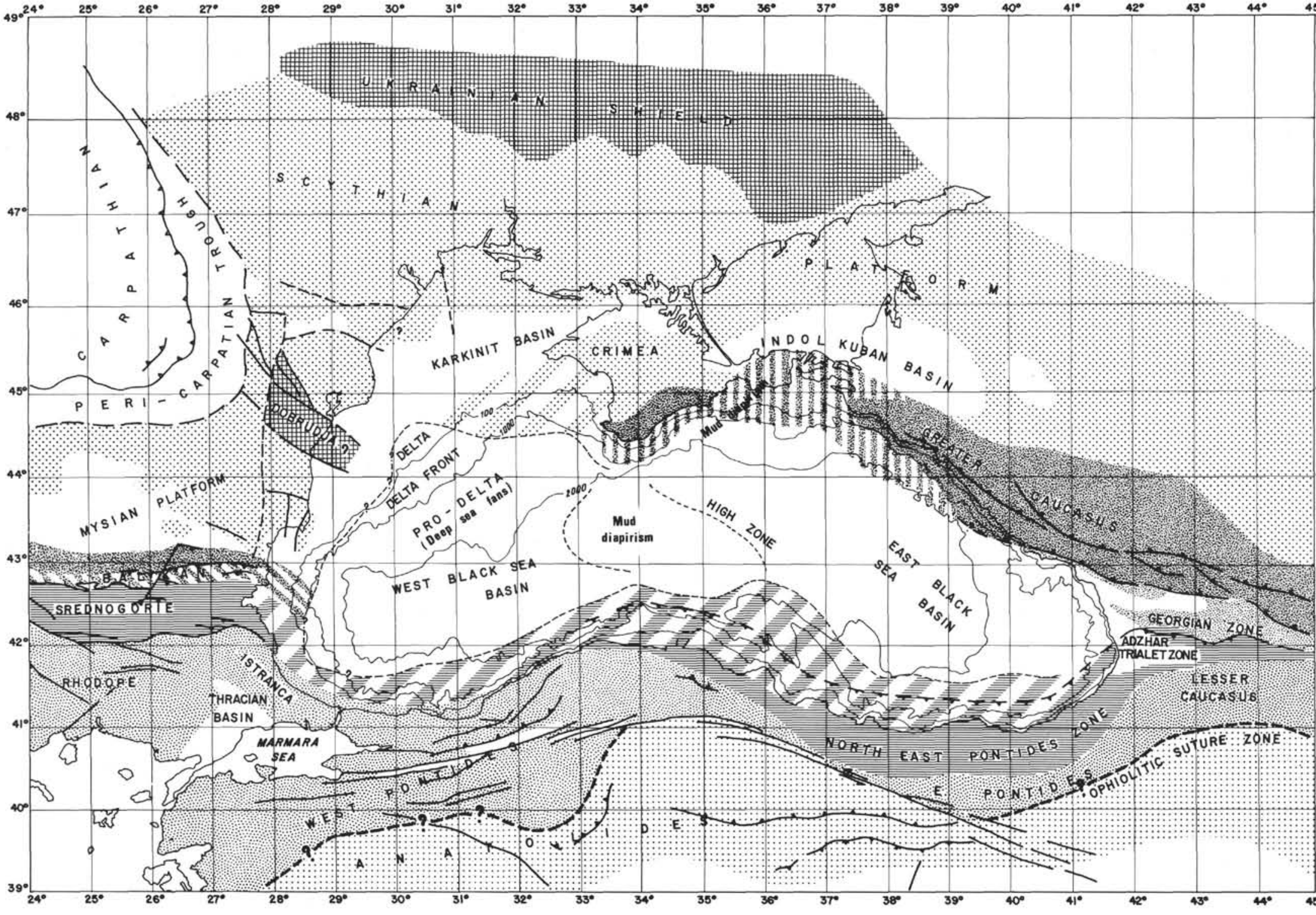

Figure 1. *Structural sketch map of the Black Sea region. Deep basins (>5 km sediments) are unshaded.*

Agean-Anatolian blocks by a wide ocean, the Tethys. During the Mesozoic the relative movements between Europe and Arabia-Africa caused the closing in of this ocean (Biju-Duval et al., 1976). The collision between Europe and the intermediary blocks caused, in turn, the obduction of the oceanic material which can now be found along the Ophiolitic Suture Zone (Figure 1). This collision can be temporally located between the end of the Jurassic in the west and in the Late Cretaceous south of the Pontides and the Lesser Caucasus. The age, nature, and distribution of volcanism north of this suture show that the Pontides and Lesser Caucasus area was an active margin between Europe and the Tethys Ocean during the closing up of the latter (Bellon et al., 1976). Because the oceanic crust of the Tethys was subducted toward the north, it can be supposed that the Black Sea is the result of the opening up of a marginal basin between Lias and Cretaceous times behind this subduction zone. During that time, the Pontides ranges migrated southward.

The collision produced folds and overthrusts to the north, and affected the northern part of the Lesser Caucasus, the Adzhar Trialet zone, the northern part of the Pontides, and the Balkans. The present margin of the Black Sea is located on the northern front of these overthrusts. Onshore, various Mesozoic formations can be seen to be unconformable on the metamorphic and/or Paleozoic basement, for example, Lias rocks in the Sinop region, and Upper Cretaceous rocks east of Istanbul. On this margin, the most apparent tectonic phase occurred in the late Eocene (Gonnard et al., 1974). The tectonized sedimentary series that can be seen on the seismic profiles from the margin must correspond, in addition to various Mesozoic members, to an Upper Cretaceous volcanic series and to Cretaceous and Eocene flyschs. An Eocene flysch and Late Cretaceous limestone, overlying a possibly Paleozoic basement, have been drilled on the Black Sea margin northeast of the Thracian Basin on the other side of the Istranca Ridge. After the Eocene, the Istranca Ridge appears to have played the role of a barrier between the Black Sea and the Thracian Basin. Littoral Oligocene facies are known southwest of the ridge. Continental Miocene deposits, lying unconformably on Oligocene (?) or directly on Eocene rocks, were encountered in offshore boreholes on the margin of the Black Sea. The Pliocene is transgressive on this margin which had subsided.

In the west, on the Bulgarian and Rumanian margins, the substratum (Paleozoic, Mesozoic) lies beneath a thick Cenozoic series that was partly derived from deltas.

The Black Sea Basin itself appears to be a large depression infilled by a thick, little-disturbed sedimentary series burying the pre-existing relief. In the abyssal plain, interval velocities in the sediments, calculated from multichannel seismic reflection profiles, are particularly low compared with those found in other basins (western Mediterranean, Atlantic). Undercompaction phenomena (mud diapirism) also appear south of the thick Indol Kuban Basin (Maikopian series) as well as on the margin of the Black Sea south of Kerg and beneath the abyssal plain south of the Crimea (Figures 2 and 3D). Considering the low velocities in the sediments, the acoustic substratum observed on the seismic reflection profiles generally appears shallower than the one calculated from the major seismic refraction profiles. This raises the problem of the nature of this acoustic substratum (Mesozoic sedimentary series, volcanic series ?). Seismic reflection shows that the West Black Sea Basin (Figure 1) is bounded, southeast of the Crimea, by a high zone forming reliefs of approximately one to several kilometers that are completely buried beneath Recent sediments (Figure 3D).

DISTRIBUTION OF RECENT SEDIMENTS

The present morphology of the Black Sea reflects fairly well the different mechanisms and types of Recent sedimentation.

The narrow margins show steep prograding structures (Figure 3C) cut by sedimentary channels with intermediary ridges that are affected by numerous sliding phenomena. On seismic sections, the channels and ridges appear to have migrated; the low or gently sloping edges of the channels having moved laterally while the deposit increased in thickness during sedimentation. On seismic lines this gives the illusion of an unconformable or erosion surface across the series. This is even further accentuated by the fact that the deposits inside the channel probably have a different lithology from that of the lateral deposits, as suggested by their seismic character. This image, which disturbs seismic correlations, can often be seen either in modern or Recent deposits on the edge of the abyssal plain (Figure 3C, dotted lines). The phenomenon is not caused by contour currents but by the arrival in the abyssal plain of the outlet of the canyons. Mainly observed in Pliocene-Quaternary series at the foot of the slopes of the Turkish margin, it might correspond to a period when rates of subsidence and sedimentation increased.

Major Prograding Systems

The sediment cones observed by their bathymetry in front of the Danube, Sea of Azov, Sukhumi, Batum, and Samsun areas (Figure 2) are located in front of the present main sediment sources (Shimkus and Trimonis, 1974). Beneath these cones, as shown by seismic reflection profiles, are wide prograding systems corresponding to "pro-deltas" or "fans." They are sometimes highlighted by disturbed seismic horizons, marked by numerous diffractions, that spread out beneath the abyssal plain and correspond to slumps (Figure 3B).

Correlation Between DSDP Holes and Seismic Reflection Data

Site 381 is located at the bottom of a channel on the Turkish margin. The sedimentary talus between the abyssal plain and this borehole, and the absence of multichannel seismic reflection profiles, prevent correlation with profiles from the abyssal plain. However, profiles 15, 21, and 25, made by the Woods

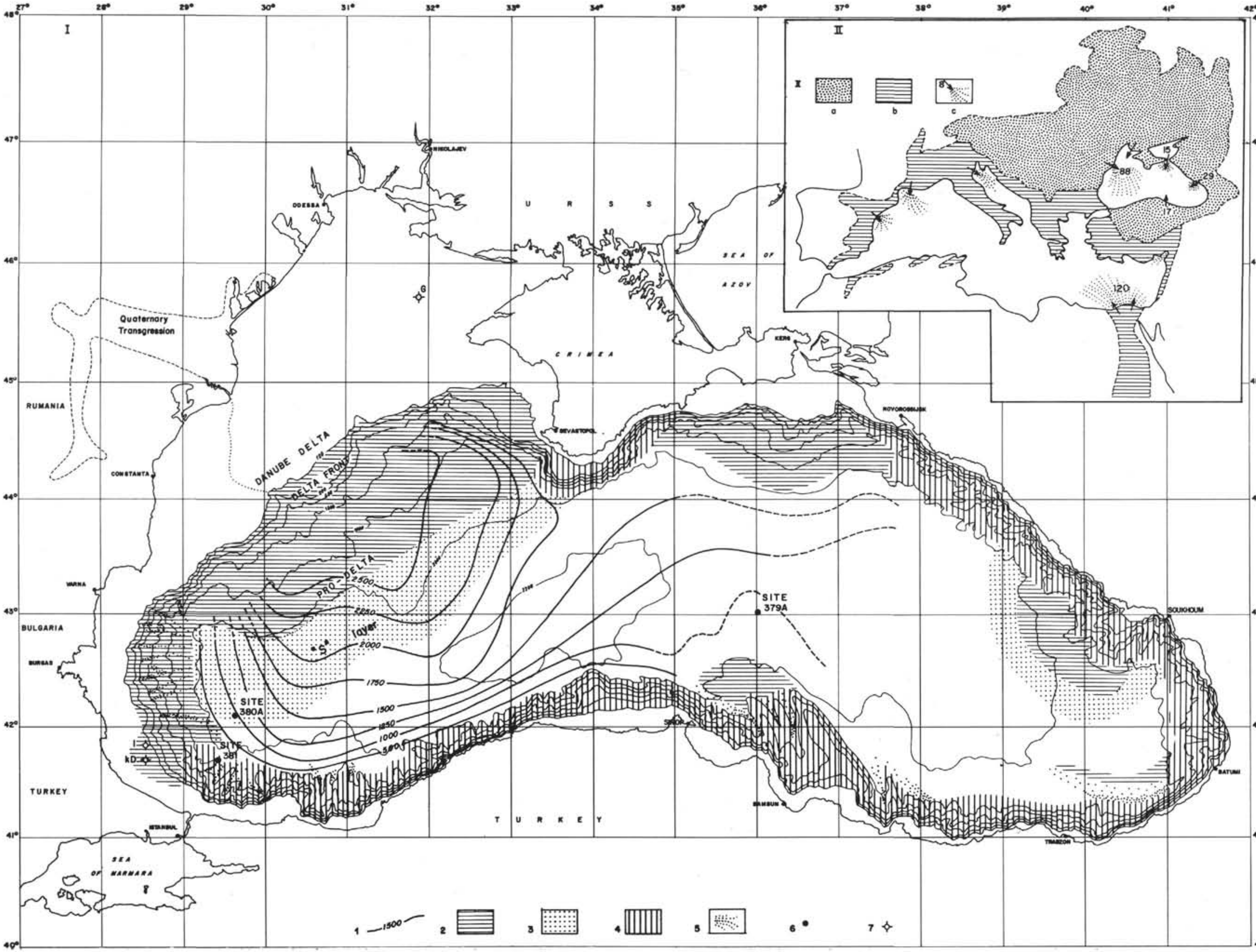

Figure 2. *1: Recent deposit distribution in the Black Sea: (1) Thickness of Pliocene-Quaternary sediments (more recent than reflector K), contour interval 250 miles; (2) Fans or gentle prograding formations; (3) Maximum extension of slump formations; (4) Steep marginal slope with channels, canyons and rises; (5) Main channels or canyons; (6) DSDP sites; (7) Oil boreholes. II: (a) Black Sea drainage basin; (b) Mediterranean drainage basin; (c) Solid decharge of rivers (10^6 t).*

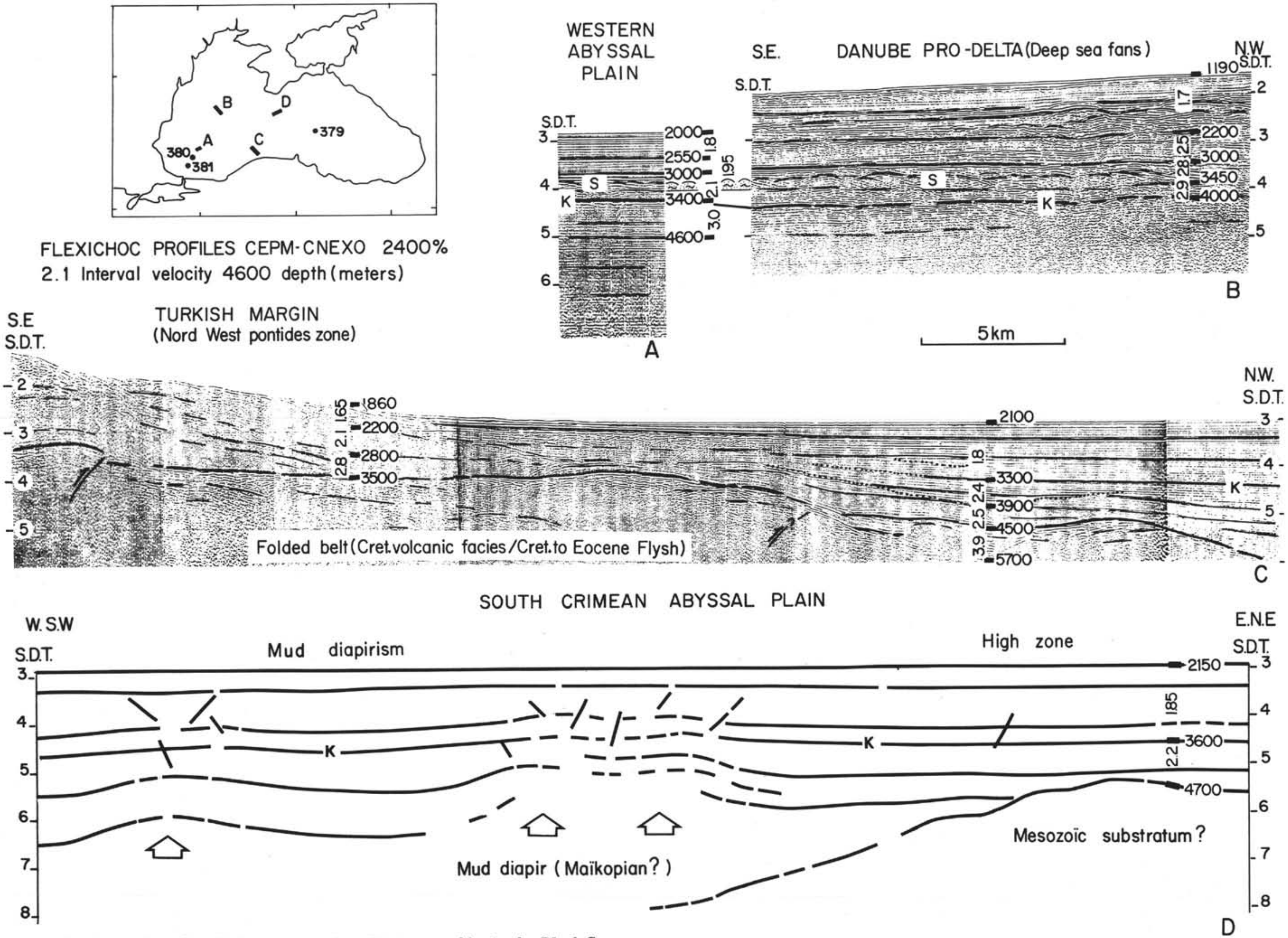

Figure 3. *Examples of multichannel seismic reflection profiles in the Black Sea.*

Hole Oceanographic Institution (Ross et al., 1974) can be used to correlate Holes 380, 380A, and Site 379 with the superficial horizons from the Flexichoc profiles (Figure 4).

In order to correlate the geological units drilled with the seismic horizons, we investigated the depth variation of the RMS sound velocities as calculated from multichannel seismic reflection. We then plotted these velocity/depth relations for the entire abyssal plain. The curve obtained (Figure 4) is expressed in depth (m)/two-way time (sec). The correlation between the calculated velocities and the ones obtained in core samples from Holes 380/380A is good. This analysis shows that, in the first 2000 meters of the abyssal-plain series, there are no meaningful variations in the velocities as a function of pinchouts or thickening of layers; on the contrary the main factor in velocity variation is the depth below sea bottom, i.e., compaction. The velocity/depth curves obtained in other abyssal plains (western Mediterranean-Atlantic) also show the influence of compaction. However, a comparison of these curves shows highly significant differences according to the basins. In particular, the velocities obtained in the Black Sea are much lower than those in other basins. This is probably due to the influence of a rapid sedimentation rate causing undercompaction phenomena, and to the influence of the lithology (nature of clays ?, poor drainage in sand lenses ?, etc.). It would be useful to take the compaction into consideration when calculating the sedimentation rates.

The most continuous and strong superficial seismic reflector that we succeeded in following the abyssal plain is called reflector K (Figure 3). According to Woods Hole profiles 15 and 21 (Ross et al., 1974), this reflector should be near the bottom of Hole 380A (Figure 4). The series located above this horizon should thus be mainly Pliocene-Quaternary.[1] The isopachs of this series (Figure 2[1]) show that it gets thicker in the direction of the slope of the Danube delta where the Pliocene-Quaternary may be more than 2500 meters thick. This confirms the preponderant influence of the sedimentary influxes from the Danube and Dnieper on the entire west Black Sea Basin. This observation is in agreement with the figures for the annual supply of sedimentary material now observed (Figure 2-II) (Shimkus and Trimonis, 1974).

In Hole 380A, the top of the units containing slump breccias (490 m) (Figure 4) correlates well with the top of Unit S, which is present as a series of diffractions on the seismic profiles (Figure 3A, B). The bottom of Unit S (880 m in the hole) is difficult to pick on the seismic profiles because of disturbances created by these diffractions. The extension of Unit S (Figure 2-I) shows that the slump breccias may be related to deltaic phenomena. Similar less extensive features can also be seen at other levels in the Pleistocene series beneath the pro-delta of the Danube or in the superficial horizons of the abyssal plain west of Sukhumi.

[1]Editors Footnote: Shore-based studies indicate that upper Miocene was reached.

The seismic correlation between Holes 380, 380A, and 379 are not very good because there are no strong and continuous reflectors in the upper sediments, like reflector K, but only a series of small parallel reflectors. However, it can be seen that the seismics do not appear to confirm the correlation made onboard.[2] Indeed, great thickness variations can be seen in the superficial series, in particular toward the deltas, but seismic correlations seem to indicate comparable rates of sedimentation, at least for the first 350 meters in Holes 380, 380A, and 379.

CONCLUSIONS

The Black Sea could, according to our studies, be an example of the late evolution of a former marginal basin. This basin probably was created during the closing of the Tethys Ocean in the Mesozioc, Multitrace seismic profiles confirm that, after the continental collision stage at the end of the Late Cretaceous, compression phases found onshore also affected the Black Sea margins, with overthrusting of the Pontides toward the north, and of the Greater Caucasus toward the south. The seismic profiles show the relief beneath the abyssal plain to be buried under a thick sedimentary series. A high zone southeast of the Crimea is hidden by this overburden. As opposed to the western and eastern Mediterranean, no Messinian salt deposits are found in the Black Sea. During this period the inflows of fresh water via the rivers must have brought about brackish water conditions in the Black Sea. According to observations on the margins, the subsidence and the sedimentation appear to have speeded up at the end of the Miocene (?) and in the Pliocene-Quaternary. The tectonic phases affecting the margins do not appear to have appreciably disturbed the sediments on the abyssal plain; they appear to have been disturbed only by mud diapirism phenomena. Moreover, the sonic velocities in the most recent sediments are seen to be particularly low compared with the velocities observed beneath other abyssal plains. This might also be related to the nature of the sediments and especially to the high rates of sedimentation.

In the Recent epoch, prograding structures of the pro-delta extend widely toward the abyssal plain. The largest of these structures is the Danube-Dnieper fan which covers the entire western basin. In Holes 380/380A various sedimentary phenomena and especially the slump breccias are probably related to the deltaic deposits. The thickness of the Pliocene-Quaternary (according to dating from the holes) could be more than 2500 meters beneath the front of the Danube delta.

Recent sedimentation rates, which are much higher in the Black Sea than in other Mediterranean basins, can easily be explained by the drainage area of the Black Sea rivers which is about five times greater than

[2]Editors Footnote: Unconformities have been noted from Site 380; see papers by Stoffers et al., this volume, and Hsü, this volume.

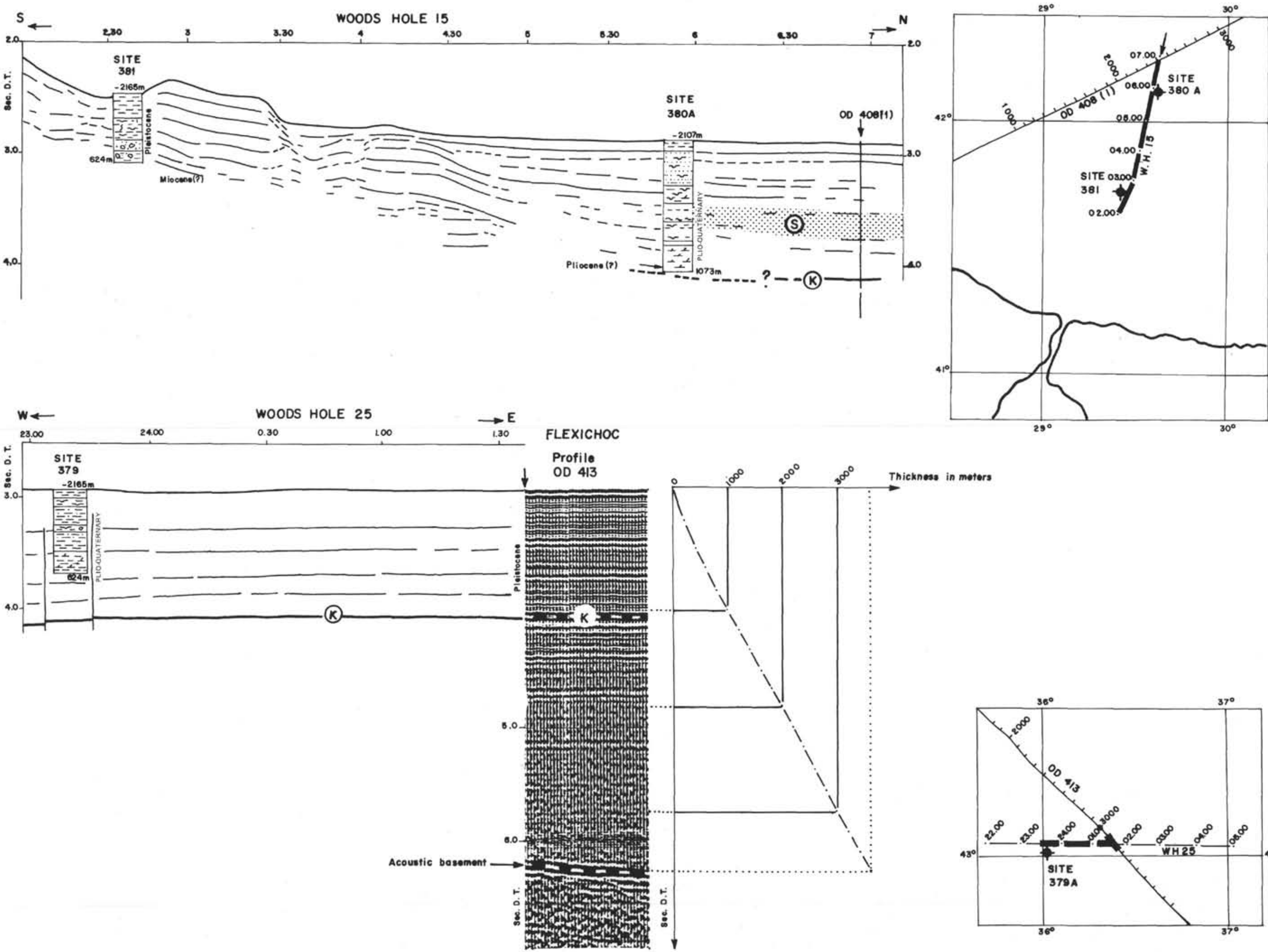

Figure 4. *Correlations between DSDP sites and seismic profiles.*

the drainage area of Mediterranean rivers (except for the Nile).

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