AAPG Search and Discovery Article #90024©2000 AAPG Regional International Conference, Istanbul, Turkey, July 9-12, 2000 (2004)

TECTONIC EVOLUTION MODELS FOR THE BLACK SEA

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The Balck Sea is a 423 000 km^2 large Cretaceous-Tertiary basin surrounded by Alpide fold belts. It consists mainly of two large subbasins separated by the NW-SE trending Mid-Black Sea ridge (Fig. 1). The West Black Sea basin is floored by oceanic crust overlain by over 3 thick flat-lying sediments probably of Cretaceous and younger in age (Letouzey et al., 1977); Finetti et al., 1988; Okay et al., 1994; Robinson et al., 1996). The nortwest trending East Black Sea basin has a thinned continental or oceanic crust overlain by less than 10 km thick sediments, which are intersected by large number of faults. It is generally accepted that the Black Sea opened during the Mesozoic as a back-arc basin above the northward subducting Tethyan oceanic lithosphere (e.g., Boccaletti et al., 1974; Şengör and Yılmaz, 1981).

A kinematic model for the opening of the Black Sea, based largely on data from onshore areas, was suggested in 1994 by Okay et al. The model involved separate mechanisms for the origin of the West and East Black Sea basins. The West Black Sea basin was believed to have opened by orthogonal rifting of a continental fragment from the Odessa shelf starting in the Albanian-Cenomonian (Okay et al., 1994). This continental fragment, called the Istanbul Zone (Fig. 1), drifted south bounded by two major strike-slip faults, opening the oceanic West Black Sea basin in the north and closing the Tethyan ocean in the south (Fig. 2). During the Early Eocene the Istanbul Zone collided with the Sakarya Zone in the south, thereby causing a change-over from extension to compression in the Black Sea. Okay et al. (1994) suggested that the eastern half of the Black Sea including the East Black Sea basin, Mid- Black Sea ridge and the easternmost part of the West Black Sea basin (Fig. 1) opened through the anti-clockwise rotation of a large continental block around a pole situated in Crimea (Fig. 2). Such a mode of opening explained the Tertiary compression in the Caucasus, which diminishes northwestward towards the pole of rotation, as well as the segmented southern boundary of eastern Black Sea. The rotation was believed to have been contemporaneous with the rifting in the West Black Sea basin (Fig. 2).

Although the mechanisms for the opening of the West and East Black Sea basins suggested by Okay et al. (1994) have been generally accepted (e.g., Robinson et al., 1996; Banks and Robinson, 1997, Yılmaz, 1997), there have been important disagrements on the timing of opening of the Black Sea as well as the location of some of the faults in the model. There is unanimous agreement on the location of the dextral West Black Sea fault in the west, which is one of the two strike-slip faults that railroaded the Istanbul zone to its present position. The West Black Sea fault comes ashore west of Istanbul and forms the boundary between two very different tectonostratigraphic terrains, the Istanbul Zone in the east and the Strandja Zone in the west (Fig. 1, Okay et al., 1994). The actual fault plane is covered by undeformed Middle Eocene marine sediments, thus providing an upper time limit for the activity along the West Black Sea fault. In contrast the position of the West Crimean fault as shown in Okay et al. (1994) has generally been challenged. Robinson et al. (1996) and Banks and Robinson (1997) have located this sinistral strike-slip fault along the western boundary of the West Black Sea basin, and suggested a simple orthogonal rift type opening for the whole of the West Black Sea basin. Although this mode of opening has the advantage of simplicity, it encounters two serious difficulties. The first one is the space problem created during the southward drift of the continental fragment that opened the West Black Sea basin. The Istanbul Zone is at present about 365 km long along strike and when translated back to its pre-drift position adjacent to the Odessa shelf, it fits into the space between Crimea and the Balkanides. However, as the western boundary of the Mid- Black Sea ridge is not parallel to but diverges markedly from the direction of the West Black Sea fault (Fig. 1), a continental fragment that is translated south from the Odessa shelf and bounded by the west Black Sea fault and the Mid- Black Sea ridge fault, must undergo major east-west extention. The distance between the southern tip of the West Black Sea fault and that of the hypothetical southward onshore extention of the Mid- Black Sea ridge fault is more than 600 km (Banks and Robinson, 1997) implying more than 60% east-west extension during the southward drift of the continental fragment. The Cretaceous and Tertiary sequence of the Istanbul Zone and the Central Pontides do not show even a fraction of such an east-west extension.

The second difficulty with the model that opens the West Black Sea basin utilising Mid- Black Sea ridge fault is the non-recognition of this fault onshore. The Mid- Black Sea ridge fault should come onshore in the Eastern Pontides near Ünye, however, no such a strike-slip fault have been mapped in this region. In contrast, recent studies in the Central Pontides have shown the presence of north-south trending sinistral strike-slip fault separating Istanbul Zone from the Sakarya Zone in the central Pontides. Tüysüz (1999) and Okay and Tüysüz (1999) show that the mid-Cretaceous turbidites near the eastern boundary of the Istanbul Zone in the central Pontides are strongly deformed and have micro and meso-scale structures indicative for sinistral transpressive deformation. This transpressive deformation has apparently not affected Senonian and younger rocks. Thus, new field evidence as well as space considerations indicates that the West Crimean fault rather than the Mid- Black Sea ridge fault was responsible for the opening of the western West Black Sea basin. The eastern part of the West Black Sea basin was probably formed at the same period through the anticlockwise rotation (Fig. 2). The northern part of the West Crimean fault was mapped from seismic sections by Finetti et al. (19989, however, the southern half of the fault does not show up in the seismic sections or in the gravity and magnetic maps. A possible reason for this is that the West Crimean fault became passive before Senonian, rather than by the Early Eocene as suggested by Okay et al. (1994), and was engulfed by more than 10 km thick Senonian and younger rift sediments.

A prolonged opening for both the West and East Black Sea basins spanning the period from mid-Cretaceous to early Eocene was suggested by Okay et al. (1994). In contrast, Banks and Robinson (1997) claim shorter and discordant periods of opening for the West and East Black Sea basins. Based largely on onshore evidence they suggest for the West Black Sea basin rifting by Aptian (Görür, 1988) and complete development by Senonian. This shorter and earlier period of opening of the West Black Sea basin is compatible with the age of the strik-slip related structures found around the onshore continuation of the West Crimean fault; these structures are found in the Aptian turbidites but not in the Senonian volcanosedimentary rocks in the Central Pontides. This earlier timing for the formation of the West Black Sea basin implies that the Senonian magmatic arc, which is prominent along the whole southern Black Sea coast, post-dates the opening of the West Black Sea basin.

A late Paleocene age for the opening of the East Black Sea basin was suggested by Robinson et al. (1996) largely based on well data from the Shatsky ridge. Onshore geology of the Eastern Pontides also support a somewhat later age than suggested by Okay et al. (1994). The geology of the Eastern Pontide is dominated by a Senonian magmatic arc with over two kilometers thick volcano-sediments. The volcanosedimentary rocks host numerous Maastrichtian Kuruko-type sulfide ore deposits, which typically form during the arc volcanism around the volcanic centers. The distribution of the Kuruko-type sulfide deposits in the Eastern Pontides indicates that the magmatic arc was located close to the present day Black Sea coast during the Maastrichtian (Okay and Şahintürk, 1997). At present the Black Sea shelf off the Eastern Pontides is very narrow with no indication of a thick and extensive volcanic apron. This observation suggest that the East Black Sea basin opened after the Maastrichtian removing the northern half of the magmatic arc. Considering that the collision between the Eastern Pontide magmatic arc and the Anatolide-Tauride block occured during the Late Paleocene-Early Eocene (Okay and Şahintürk, 1997), the opening of the East Black Sea basin is constrained to the Maastrichtian-Paleocene interval. It is here suggested that the rotational mode of opening for the eastern half of the Black Sea basin was episodic. The eastern half of the West Black Sea basin opened during the Aptian-Turonian contemporaneously with the orthogonal rift-related opening of the rest of the West Black Sea basin, whereas the East Black Sea basin opened later during the Maastrichtian-Paleocene.

Interpretation of new data obtained since 1994 substantiate the mechanisms of opening for the West and East Black Sea basins suggested by Okay et al. (1994) but require important revision regarding the timing of opening. The West Black Sea basin appears to have opened in a short interval during the Aptian-Cenomanian largely through rifting of a continental sliver from the Odessa shelf. This orthogonal rift type opening has preceeded the development of the Pontide magmatic arc. In contrast, the East Black Sea basin has formed through anticlockwise rotation of a large continental block during the Maastrichtian-Paleocene. This revision in the timing of opening of the West and East Black Sea basins has direct implications on the age of the sediments in these basins.

References

Banks, C.J. and A.G. Robinson, 1997, Mesozoic strike-slip back-arc basins of the western Black Sea region,in A.G. Robinson,ed.,Recional and petroleum geology of the Black Sea and surrounding region, American Association of Petroleum Geologists (AAPG) Memoir No. 68, p. 53-62.

Bocceletti, M., Gocev, P. and Manetti, P., 1974, Mesozoic isopic zones in the Black Sea region: Bolletino Soc Geologica Ital,v. 93, p. 547-565.

Finetti, I., G. Bricchi, A. Del Ben, M. Pipan and Z. Xuan, 1988, Geophysical study of the Black Sea: Bolletino di Geofisica Teorica ed Applicata: v. 30, p. 197-324.

Görür,N., 1988, Timing of opening of the Black Sea basin: Tectonophysics, v. 147, p. 247-262.

Letouzey J, B. Biju-Duval, A. Dorkel, R. Gonnard, K. Kristchev, L. Montadert, O. Sungurlu, 1977, The Black Sea: a marginal basin-Geophysical and geological data, in B. Biju-Duval and L. Montadert, eds., Structural history of the Mediterranean basins. Editions Technip, Paris, p. 363-3376.

Okay A.I., A.M.C. Şengör, N. Görür, 1994, Kinematic history of the opening of the Black Sea and its effects on the surrounding regions. Geology, v. 22, p. 267-270.

Okay,A.I. and Ö. Şahintürk, Ö., 1997, Geology of the Eastern Pontides. in A.G. Robinson, ed., Regional and petroleum geology of the Black Sea and surrounding region, American Associatian of Petroleum Geologists (AAPG) Memoir No. 68, p. 291-311.

Okay,A.I., and O. Tüysüz, 1999, Tehtyan sutures of northern Turkey, in B. Durand, L. Jolivet, F. Horvath and M. Seranne, eds., The Meditarranean basins: Tertiary extension within the Alpine orogen, Geological Society of London, Special Publication 156 (in press).

Robinson, A.G., 1996, Petroleum geology of the Black Sea: marine and Petroleum Geology, v. 13, p. 195-223.

Şengör,A.M.C. and Yılmaz, Y., 1981, Tethyan evolution of Turkey: a plate tectonic approach: Tectonophysics, v. 75, p. 181-241.

Tüysüz, P., 1999, Cretaceous basins of the Pontides and the opening of the West Black Sea basin, in E. Bozkurt, J.A. Winchester and J. Piper, eds., Tectonics and magmatism in Turkey and its surroundings: Geological Society of London Special Publication (in press).

Yılmaz,Y., O. Tüysüz, E. Yiğitbaş, Ş. Can Genç and A.M.C. Şengör, 1997, Geology and tectonic evolution of the Pontides, in, A.G. Robinson, ed., Regional and petroleum geology of the Black Sea and surrounding region, American association of Petroleum Geologists (AAPG) Memoir No. 68, p. 183-226.

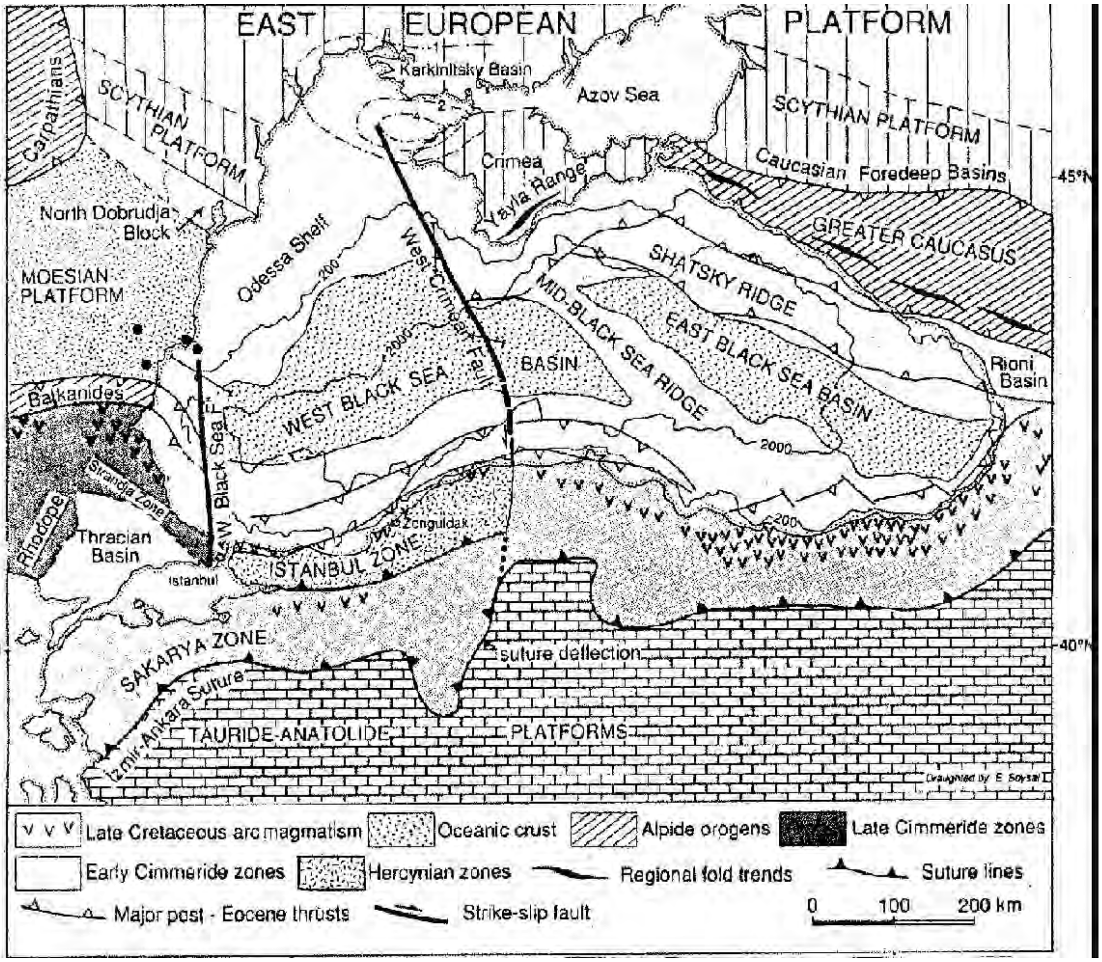

Figure 1. Tectonic map of Black Sea region (after Okay et al., 1994). In the models of Robinson et al. (1996) and Banks and Robinson (1977) the sinistral strike-slip fault that opened the West Black Sea basin follow the westren margin of the Mid-Black sea ridge.

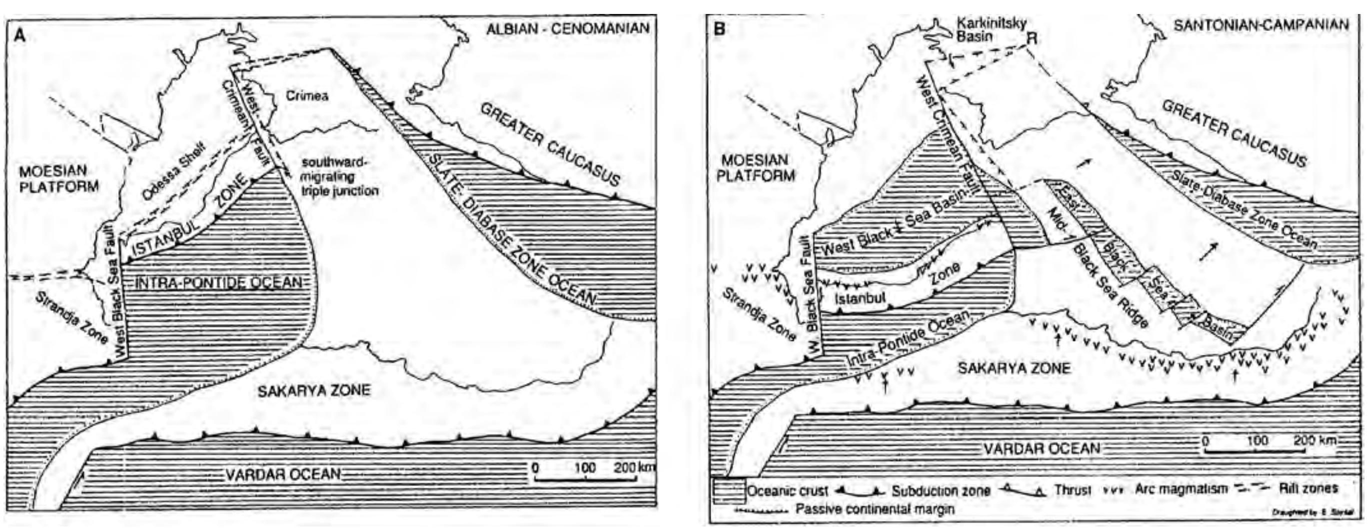

Figure 2. Paleotectonic reconstructions of the Black Sea region for the Cretaceous (from Okay et al., 1994). A. for the Albian-Cenomanian. B. Santonian-Campanian. Note that in the revised timing of opening the West Black Sea basins opens during a short interval in Albian-Cenomanian, while the East Black Sea basin forms later during the Maastrichtian-Paleocene. See text for further explanations. R is the pole of rotation.