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SHORT NOTE

The North Anatolian fault and complexities of continental escape

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Abstract—Before the Plio-Pleistocene, the proto North Anatolian fault zone was occupied by two separate faults: a WNW-striking right-lateral eastern segment which extended to the Black Sea, and a WSW-striking left-lateral western segment. During the Plio-Pleistocene most of the right-lateral displacement on the eastern fault was transferred from the Black Sea extension to the western fault, converting the latter to a right-lateral structure, and giving rise to the modern North Anatolian fault zone. This model explains the evidence first reported by Hancock & Barka for an apparent Plio-Pleistocene reversal of displacement along the western part of the fault. The model may also account for the Plio-Pleistocene change in regional stress in southwestern Anatolia.

Convergence between Arabia and Eurasia since the late Miocene has been forcing the continental wedge of Anatolia to the west, away from the convergent zone and toward the oceanic free face (Dewey & Şengör 1979). Most of this displacement has been accommodated (Fig. 1) along two major intracontinental transform faults which presently bound the wedge (McKenzie 1972): the right-lateral North Anatolian fault (Şengör 1979) and its complement, the left-lateral East Anatolian fault (McKenzie 1976). However, seismic data (Büyükaşikoglu 1979), LANDSAT analysis (Tchalenko 1977), and field studies indicate significant internal deformation within the wedge along numerous minor strike–slip faults oriented WNW–ESE (right-lateral) and WSW–ENE (left-lateral), subparallel to the North and East Anatolian faults, respectively.

Recently, from analyses of mesoscopic fractures cutting Neogene and Quaternary sediments contained in five basins overlying, or adjacent to the North Anatolian fault zone from Cerkes to Erbaa, Hancock & Barka (1980, 1981) have suggested that there were one or more episodes of left-lateral displacement (Fig. 2). Mesofractures related to left-lateral shear were observed in Pliocene to early Pleistocene deposits and it was concluded that most of them were formed in the early part of the interval. The majority are exposed in the three western basins which are aligned WSW–ENE. Mesofractures related to right-lateral shear were observed in early Pliocene to Holocene sediments and they generally offset those related to left-lateral slip. Mesofractures related to right-lateral slip are widely distributed in the three western basins and they are also abundant in the two eastern basins which are aligned WNW–ESE. Hancock & Barka (1981) concluded that the right-lateral structures formed throughout the Pliocene and into the Holocene. They also proposed that right-lateral shear has probably been the dominant mode of displacement along the entire North Anatolian fault zone since its inception.

As Hancock & Barka (1980, 1981) appreciated, the episode of left-lateral displacement is difficult to reconcile with the present-day right-lateral character of the fault. Explanations put forward by Hancock & Barka include reversal of transform shear, possibly related to events in the Aegean region; local reversal caused by mechanical constraints among fault zone blocks; and stress release fractures developed after right-lateral shear. Şengör (in Hancock & Barka 1981) suggested that the evidence for left-lateral shear was related to its parallel orientation to known left-lateral faults within the wedge.

I wish to propose a new model to account for the presence of the 'anomalously' oriented mesofractures. Before the Plio-Pleistocene the proto North Anatolian fault zone was occupied by two separate faults (Fig. 2a). The WNW-striking eastern fault was right-lateral, underlaid the eastern basins, and its outcrop extended as a straight trace to the Black Sea (Bergougnan *et al.* 1978). Evidence for the Black Sea extension includes juxtaposition of Upper Cretaceous volcanics and Liassic flysch and a well-developed fault-zone physiography. The fault formed the northeast boundary of a larger pre-Pleistocene Anatolian wedge. It probably accommodated most of the intracontinental strain although some was probably taken up along faults within the wedge. The WSW-striking western fault was left-lateral, underlaid the western basins, and occupied a position within the deforming Anatolian wedge. During the Plio-Pleistocene most of the right-lateral displacement on the eastern fault was transferred from the Black Sea extension to the western fault, converting the latter to right-lateral slip, and giving rise to the modern North Anatolian fault zone which now forms the northern boundary of the Anatolian wedge (Fig. 2b). Thus, I sug-

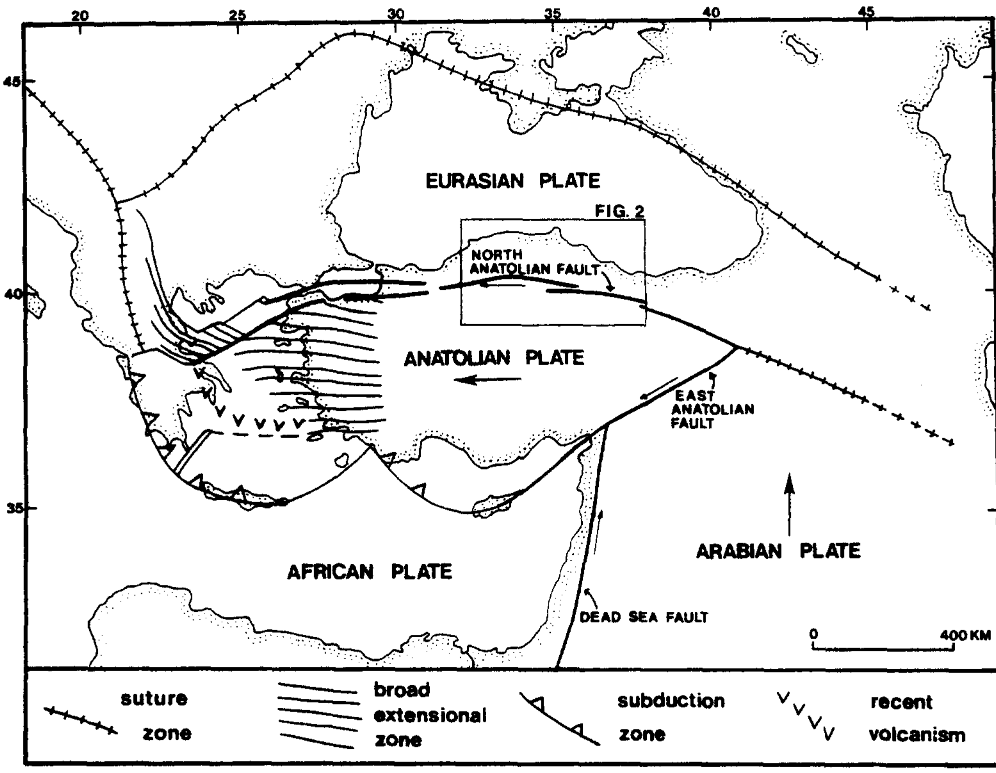

Fig. 1. Tectonic setting of the westward-escaping continental wedge of Anatolia (after Dewey & Şengor 1979, Fig. 2c and Hancock & Barka 1981, Fig. 1a).

gest that the present North Anatolian fault zone is a composite structure. The eastern segment is older and has always been right-lateral. The western segment is younger and was left-lateral before the reversal of displacement in the Plio-Pleistocene. Since the time of the reversal it has formed part of the right-lateral fault zone. There is no need to think that right-lateral shear has been the dominant mode of displacement along the entire fault zone since its inception (Hancock & Barka 1981).

The new model explains the WSW–ENE alignment of the three western basins and the relative abundance and age of mesofractures related to left-lateral slip within them. After the Plio-Pleistocene reversal, right-lateral mesofractures formed in the three western basins, as well as in the two eastern basins, offset the earlier left-lateral mesostructures, and continued to form during the Holocene. The new model also accounts for the anomalously large arcuate trace of the fault zone. It is arcuate because the western segment is young and the fault zone as a whole has not had time to become rectilinear.

The changing configuration of the northern margin of the escaping continental wedge may have influenced the regional stress configuration in the Aegean region of Anatolia, which has had a three-part history since the late Miocene (Angelier 1981).

1. N–S extension from the late Miocene to the Plio-Pleistocene.
2. NW–SE compression, NE–SW extension during the Plio-Pleistocene.

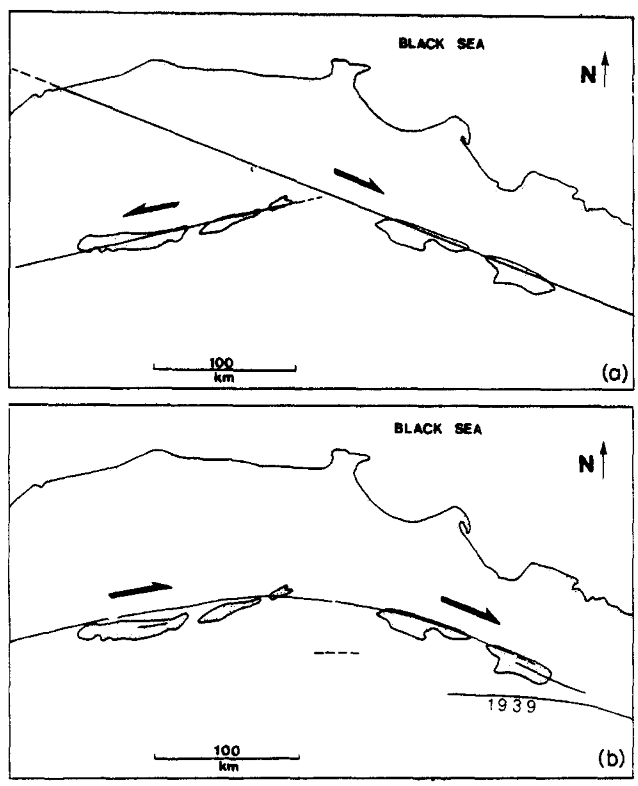

Fig. 2. (a). Neogene basins (stippled) and proposed general configuration of the proto North Anatolian fault zone before the Plio-Pleistocene (after Hancock & Barka 1981, Fig. 1b and Bergougnan *et al.* 1978, Fig. 1). (b). Neogene basins and recent earthquake faults defining the modern North Anatolian fault zone (after Hancock & Barka 1980, Fig. 1b). The fault break associated with the 1939 earthquake is also shown on the map.

3. NE–SW extension from the late Pleistocene to the present.

The first phase may have reflected stress conditions within the Anatolian wedge when its northeast boundary was the eastern segment of the proto North Anatolian fault zone and its extension to the Black Sea. The second phase may have corresponded to transfer of right-lateral displacement to the western segment of the proto North Anatolian fault zone. The third phase, which is still continuing, may reflect the readjustment to the new northern boundary condition.

The changing boundary configuration may indicate that the Anatolian wedge is losing area inwards from the convergent jaws, at least in the central and eastern regions of the wedge. In this connection, it is therefore interesting to note that some active faults along the North Anatolian fault zone, such as the 1939 earthquake break (Fig. 2b), curve away from the fault zone and into the wedge. This inward shift of the margin of the wedge is probably a method of accommodating the space problems inherent in its westward escape from the convergent zone to the east. Such a mechanism may be applicable to other escaping continental wedges in tectonically analogous regions, and may account for other apparent plate motion 'reversals' along transform boundaries.

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