Westward propagation of North Anatolian fault into the northern Aegean: Timing and kinematics: Comment and Reply

COMMENT

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Based on stratigraphical and structural evidence, Armijo et al. (1999) considered that the North Anatolian fault has 70–85 km total offset in the Marmara region of northwest Turkey. They also suggested that the fault reached the Marmara region 7–5 Ma. Their main stratigraphic evidence is a major angular unconformity between the Alçıtepe and Kirazlı formations dating the Messinian desiccation and hence providing a time constraint for the propagation of the fault. The structural evidence is a truncated anticline, observed on the Landsat image, separated by the movement of the fault. We disagree with both of these stratigraphic and structural relations.

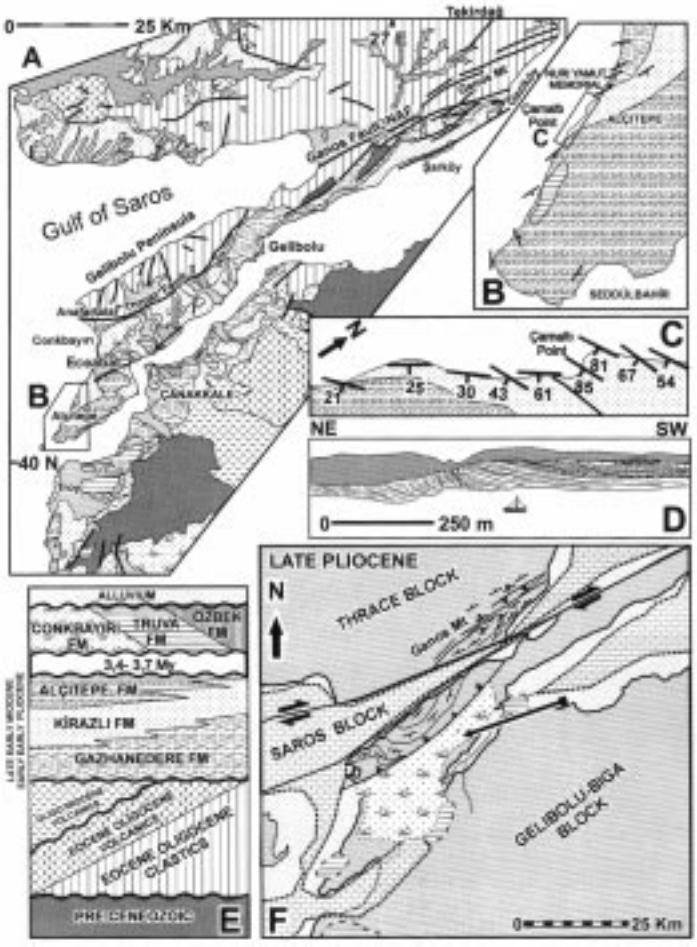

Figure 1. A: Geological map of the northeastern Aegean Region. B: Geological map of the area where the Kirazlı and Alçıtepe formations are interpreted to be unconformable and the location of the Çamaltı section. C: Detailed geological map of the Çamaltı coast. D: northeast-southwest–trending cross section of the Çamaltı coast seen from the west. E: Stratigraphical section of the Neogene sequence of the northeast Aegean region. F: Palinspastic palaeogeographical and tectonic map of the Gelibolu and surrounding areas.

STRATIGRAPHIC EVIDENCE

A large number of studies have described Kirazlı and the Alçıtepe formations as conformable (Yaltırak, 1996; Görür et al., 1997; Yaltırak et al., 1998; Tüysüz et al., 1998; Çağatay et al., 1998; Sakınç et al., 1999). The gradational change can be clearly observed at the Çamaltı point in the south of Gelibolu Peninsula where Armijo et al. (1999) put the unconformity (Fig. 1 A, B). In this locality, the strata of Kirazlı Formation are steeply dipping to the southeast. The dip of the strata becomes gradually shallower southward along the coast (Fig. 1 C, D). Armijo et al. (1999) also reported a lateral passage between the Conkbayırı and the Alçıtepe formations. However, the stratigraphical relation between these two units is unconformable in the west and disconformable in the east, as has been determined in several previous investigations (Yaltırak, 1996; Yaltırak et al., 1998; Tüysüz et al.,1998; Sakınç et al., 1999). The tectonics related to the North Anatolian fault took place during the deposition of the Conkbayırı Formation in an alluvial fan environment in front of the transpressional Anafartalar fault (Yaltırak, 1996). These stratigraphical data indicate that folding and denudation of the area did not take place during the Messinian as suggested by Armijo et al.(1999), but occurred in the mid-Pliocene period (3.7–3.4 Ma; Fig. 1E). Taking recent GPS measurements (1.7 mm/yr; Straub and Kahle, 1997) into account, the total displacement of the the North Anatolian fault in this segment is calculated as 57–63 km (Fig. 1F).

STRUCTURAL EVIDENCE

The model put forward by Armijo et al. (1999) principally depends on the observation that Mount Ganos and the northern part of Gelibolu Peninsula are the halves of an anticlinal structure sliced by the Ganos fault. The internal structure of Mount Ganos is syncline faulted in the northern limb (Yaltırak., 1996) with the synclinal axis observed along the crest of the mountain (Fig. 1F). In this region, the strata are not dipping to the north-northeast as Armijo et al. (1999) stated, but are dipping to the northwest (Fig. 14 of Okay et al.,1999). This clearly indicates a syncline, not an anticline. The internal structure of the northern part of the Gelibolu Peninsula is a half anticline bordered by the Anafartalar fault (Yaltırak, 1996) (Fig. 1F).

The sedimentary sequence observed in the Mount Ganos and the Gelibolu Peninsula, considered to be equivalent by Armijo et al. (1999), differs both in the thickness and in the environment of deposition. The thickness of the Middle Eocene–Upper Oligocene sequence is about 3.5 km at Mount Ganos (Yaltırak, 1995) with the Middle Eocene period being represented by deep marine turbidites. In the Gelibolu area, however, the sequence of similar age is about 2.2 km thick, with the Middle Eocene deposits made up of reefal limestones and calciturbidites. There are also some serpentinite blocks, which are not seen in the Mount Ganos sequence. In the Gelibolu area, braided fluviatile and deltaic deposition is recorded during the Oligocene, whereas prodeltaic shales and swamp deposits occur in Mount Ganos.

We conclude that the suggested timing and kinematics of the the North Anatolian fault in the Marmara region put forward by Armijo et al. (1999) are not suggested by our field observations.

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REPLY

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In a recent paper (Armijo et al., 1999), we presented evidence for young folding and for a large (70 km) right-lateral offset across the main branch of the North Anatolian fault in the Dardanelles Straits area. We used this information to make a reconstruction of the entire Sea of Marmara region, prior to the fault propagation across it. This reconstruction implies total dextral slip of 85 km in the past 5 m.y., an inference that appears critical to our understanding of the North Anatolian fault.

Different structural interpretations had been previously proposed for the Dardanelles area (e.g., Şengör et al., 1985; Barka and Kadinsky-Cade, 1988; Barka, 1992; Sümengen and Terlemez, 1991; Yaltırak, 1996; Görür et al., 1998; Tüysüz et al., 1998; Okay et al., 1999). Yaltırak et al. refer to some of this previous work. We critically revised the existing geological literature and remapped the main features in the field to clarify their significance in relation to the development of the North Anatolian fault. We specifically disagree with the views of Yaltırak et al. on two important points: (1) Despite minor complexities, the Ganos and the Gelibolu folds appear to be two large anticlines that are truncated by the North Anatolian fault; and (2) Concerning the folded structure in the Dardanelles area, the most significant, traceable unconformity is at the base of the Alçitepe Formation (top of the Miocene, base of the Pliocene), not at the top of this formation, nor at the base of the Ghazhanedere Formation, as suggested in their Figure 1E.

In our paper, we showed that the shortening strain in the Dardanelles affects sedimentary sequences of Eocene to Quaternary age and appears to be associated with a restraining bend along the North Anatolian fault. This bend seems to have acted as a long-lived, compressional buttress between two transtensional regions, the Sea of Marmara pull-apart and the Gulf of Saros. One important finding was the apparent offset of the Ganos-Gelibolu anticline, not seen before but very clear (see Fig. 3 in Armijo et al., 1999). The implied lateral displacement across the North Anatolian fault in this region is much larger than previously proposed (Barka, 1992). Another finding was the dramatic contrast in tectonic style in the Dardanelles area, between the strongly folded strata of late Miocene age (Ghazhanedere and Kirazlı Formations) and the overlaying, nearly flat layers of possible early Pliocene age (Alçitepe Formation). This major feature, unmapped previously, may be more easily seen from a distance, in the satellite imagery (e.g., Fig. 1). In addition, we found strong evidence suggesting that the folds in the Dardanelles area were well eroded, possibly during the Messinian crisis (Ryan and Cita, 1978). The erosion precedes a significant, possibly early Pliocene, marine transgression connecting the Black Sea through the Sea of Marmara with the Aegean Sea and the Mediterranean. The evidence thus implies that most of the folding in the Dardanelles Straits occurred in the latest Miocene, during a short period of time ($<10^6$ yrs), an observation that seems fundamental when trying to understand the nature of the processes involved in the propagation of the North Anatolian fault.

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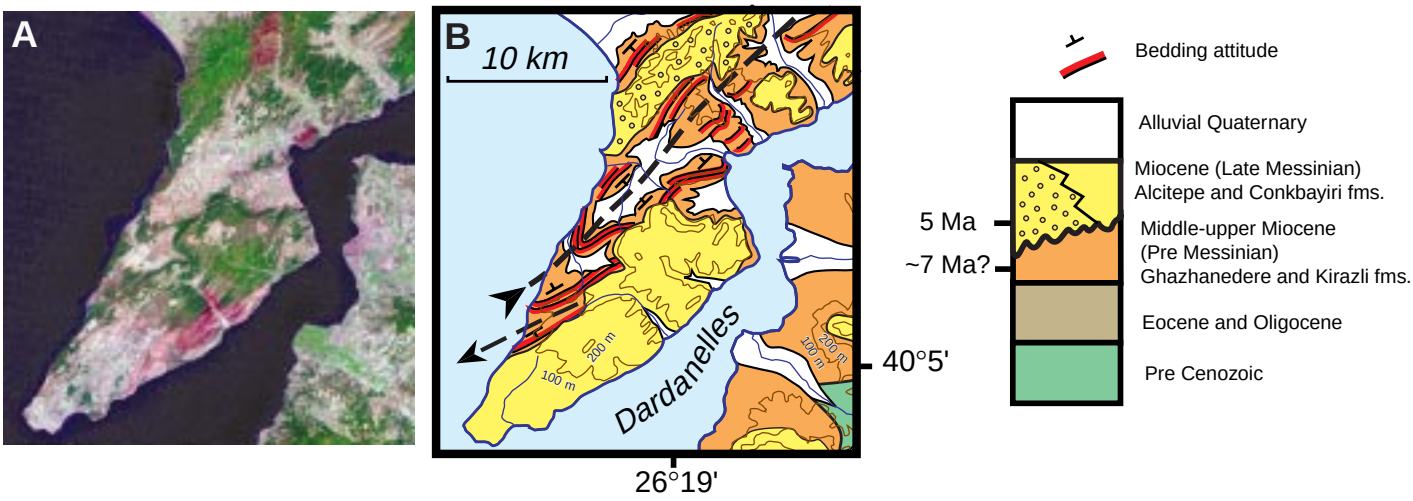

Figure 1. Folds and main unconformity in the Dardanelles Straits. A: Landsat image. The kilometer-scale, tightly-folded structure in Miocene strata is deeply eroded and unconformably overlain by nearly flat clastic deposits and transgressive marine sediments of Messinian–early Pliocene age. B: Simplified geologic map of the same area.

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