Comment on 'Rockfall avalance deposits associated with normal faulting in the NW of the Çankırı basin: implications for the post-collisional tectonic evolution of the Neo-Tethyan suture zone' by G. Seyitoğlu, N. Kazancı, L. Karadenizli, Ş. Şen, B. Varol, and T. Karabıyıkoğlu

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ABSTRACT

Seyitoğlu *et al.* (2000) described their interpretation, based on a single fault surface and rockfall avalanche deposits previously mapped as a W-vergent thrust klippen above the Neogene successions in the Hançılı Basin, that in central Anatolia there was a single extensional basin throughout the Miocene – Early Pliocene. It was later fragmented by a structural high of Neo-Tethyan ophiolitic basement bounded by an E-vergent thrust fault in the east along the western margin of the Çankırı Basin and a west-dipping normal fault in the west along the eastern margin of the Hançılı Basin, into two sub-basins – Çankırı and Hançılı basins – subsequent to the activity along the Kırıkkale–Erbaa splay of the North Anatolian Fault Zone in the Late Pliocene (Fig. 1b). They also concluded that the crustal extension commenced in the Early Miocene and continued until the Early Pliocene without a break. They further claimed that their contention is supported by the recent works of Kaymakçı (2000) and Kaymakçı *et al.* (2000).

The western Margin of the Çankırı Basin lies within the İzmir–Ankara–Erzican Suture Zone, along which the Kırşehir Block in the south and the Sakarya Continent in the north collided during northward subduction of the intervening Neotethyan ocean crust under the Pontides during the Late Cretaceous to Early Tertiary (e.g. Şengör and Yılmaz, 1981; Görür *et al.*, 1984; Koçyiğit *et al.*, 1995; A. A. Dellaloğlu *et al.*, unpublished report). The late Tertiary stratigraphy of Turkey has not been established yet because of insufficient fossil records and the predominance of continental sediments. The established stratigraphy is mostly based on superposition and/or palynomorphs (e.g. Koçyiğit *et al.*, 1995) and therefore there are numerous points of view among scientists. The problem has become even worst with use of selective data collection in the field and selective use of available literature (Seyitoğlu *et al.*, 2000). Seyitoğlu *et al.* (2000) claimed that the recent works of Kaymakçı (2000) and Kaymakçı *et al.* (2000) support their contention that central Anatolia experienced an orogenic collapse-induced crustal extension during the Early Miocene – Early Pliocene; we feel this is a misinterpretation of ours and others work. I therefore would like to take this opportunity: (1) to describe the main difficulties with the field data, selective use of the literature and the interpretations made by Seyitoğlu *et al.* (2000); (2) to request clarifications and additional explanations to some points raised by them; and (3) to discuss the evolution of the western Margin of the Çankırı Basin.

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Geological setting

The western margin of the Çankırı Basin is delimited by a topographical high that separates the Early to Middle Miocene Hançılı Basin in the west from the Çankırı Basin in the east (Fig. 1b). Seyitoğlu *et al.* (2000) claimed that the Neogene (Lower Miocene – Lower Pliocene) successions in both basins are correlated and were deposited within a once connected basin that became separated by an ophiolitic high during the Late Pliocene. This assumption is based on the correlation of red conglomerates and (Altıntaş or Kumartaş Formation) exposed in the Hançılı Basin and red to pinkish conglomerates, sandstones and mudstones exposed in the Çankırı Basin (Çandır Formation: Kaymakçı, 2000; Kaymakçı *et al.*, 2001). However, this correlation seems impossible as the Çandır Formation (late Burdigalian to early Serrevalian; upper part of MN 5–6: Krijgsman, 1996; Kaymakçı, 2000; Kaymakçı *et al.*, 2001) is older than the Kumartaş Formation (Aquitanian; MN 2–3: Şen *et al.*, 1998). The Kumartaş Formation has lateral and vertical gradations with the overlying upper Burdigalian to Langhian (MN 4–5) Hançılı Formation, which is exposed only in the Hançılı Basin. The Hançılı Formation is partly the time equivalent of the Çandır Formation, which is exposed only in the Çankırı Basin. It includes very widespread tuffaceous and economical bentonite horizons, which are not observed in the Çandır Formation, although the two are less than a few hundred metres apart (Fig. 1). In addition, the Hançılı and Çandır formations include endemic rodent fauna (Krijgsman, 1996; Kaymakçı *et al.*, 2001) that are not correlated. Moreover, the Çandır Formation is overlain by the Tortonian (MN 10–12) Tuğlu Formation which, in turn, is overlain by Messinian (MN 13) red clastics (Süleymanlı Formation) and the Messinian to pre-Gelasian (MN 13 to pre-MN 17) Bozkır Formation, which comprises red clastics alternating with very thick evaporite horizons (Kaymakçı, 2000). It is important to note that all these formations are lacking in the Hançılı Basin and therefore there is no Miocene unit overlying the Hançılı Formation. Seyitoğlu *et al.* (2000) proposed that deposition in both the Hançılı and the

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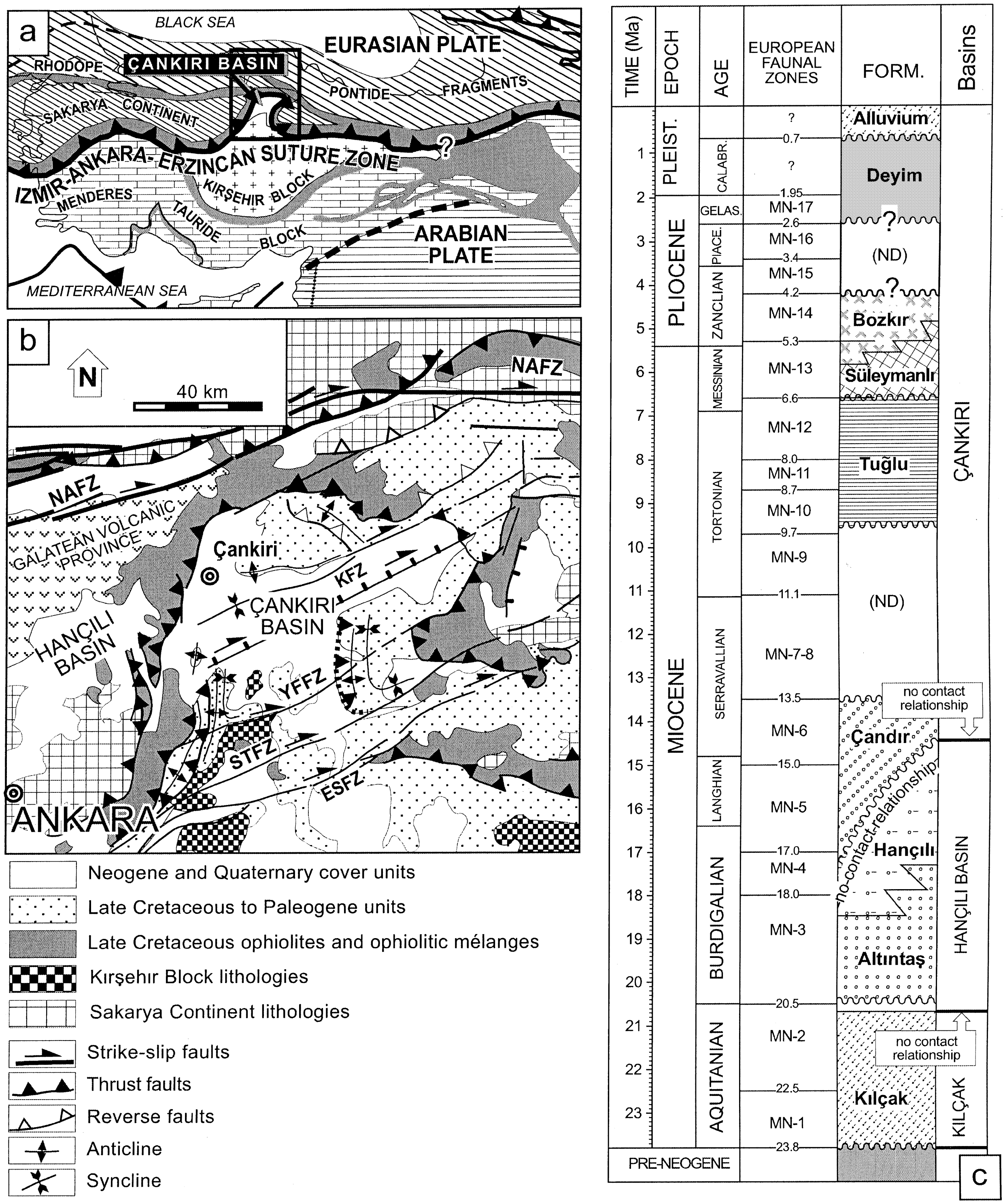

Fig. 1 (a) Neotethyan sutures and microcontinents involved in the evolution of Turkey (modified from Şengör *et al.*, 1984). (b) Simplified geological outline of the Çankırı and Hançılı basins. ESFZ: Ezinepazarı–Sungurlu Fault zone; NAFZ: North Anatolian Fault Zone; STFZ: Sivritepe Fault Zone; YFFZ: Yağbasan–Faraşlı Fault Zone (modified from Kaymakçı *et al.*, 2000). (c) Generalized stratigraphic column for the Çankırı and Hançılı basins. Note there are no contact relationships between the lithologies of the Çankırı and Hançılı basins.

Çankırı basins continued unbroken until the Early Pliocene. However, the stratigraphy of both basins as briefly described above simply precludes this interpretation. Therefore, Seyitoğlu and his co-authors need to explain the missing Miocene record above the Hançılı Formation although sedimentation in the Çankırı Basin was obviously continuous from late Serravalian to Messinian time (MN 6 to MN 13).

Seyitoğlu *et al.* (2000) also argued that eastwards thrusting in the western margin of the Çankırı Basin post-dates MN 13 based on correct but improper age data of Şen *et al.* (1998) who assigned an MN 13 age for the successions in the Süleymanlı locality without documenting the fauna. Interestingly, Seyitoğlu *et al.* (2000) did not cite Kaymakçı (2000) although a full list and correlation chart of the fauna from the same locality was supplied. There it is also documented that the red horizons (Süleymanlı Formation) below the Bozkır Formation are contemporaneous and of Messinian to Pliocene age. At the same locality, MN 10–12 Tuğlu Formation overlies the Çandır Formation with angular unconformity, and this is, in turn, overlain by the Süleymanlı and Bozkır formations with a pronounced angular unconformity (Kaymakçı *et al.*, 1998, 2000; Kaymakçı, 2000). The Tuğlu Formation is intensely deformed, as indicated by widespread overturned and recumbent folds and mesoscopic reverse faults not only along the major faults but throughout the Çankırı Basin. Recumbent folds were not observed in the underlying and overlying formations, where the Süleymanlı and Bozkır formations are only locally tilted. In addition, palaeostress configuration post-dating the deposition of the Tuğlu Formation indicates compressional deformation (Kaymakçı *et al.,* 2000). Therefore, deformation of the Tuğlu Formation is attributed to a compressional tectonic regime prevailing during the late Serravalian to Middle Tortonian (post-MN 6 to pre-MN 13) (Kaymakçı *et al.*, 1998, 2000, 2001) although Seyitoğlu *et al.* (2000) did not refer to these important structural data. Seyitoğlu *et al.* (2000) should therefore explain how compressional structures were developed within the Çankırı Basin in the late Serravalian to Middle Tortonian time interval if extensional deformation was continuous from the Early Miocene until the Pliocene.

Seyitoğlu *et al.* (2000) claimed that in the west (i.e. Hançı Basin)) NNE-trending Neo-Tethyan mélange always has west-dipping normal fault contact with the Neogene successions (i.e. Altıntaş and Hançılı formations). They have provided Schmidt Projections of the fault surfaces and striations and proposed that the eastern margin of the Hançılı Basin is delimited by a normal fault.

Kaymakçı *et al.* (1998, 2000) and Kaymakçı (2000) have carried out a detailed palaeostress analysis of the Çankırı and Hançılı basins, which Seyitoğlu *et al.* (2000) did not mention. The normal fault is a local structure and it is cut and displaced by a number of younger strike-slip faults (Kaymakçı *et al.*, 2003), and again these are not mentioned in Seyitoğlu *et al.* (2000). Seyitoğlu *et al.* need to explain how only one short fault surface could delimit the eastern margin of the Hançılı Basin.

Discussion and conclusions

Seyitoğlu *et al.* (2000) have documentated details of rockfall avalanche deposits, previously mapped as klippen in the eastern margin of the Hançılı Basin near Minkatı village. Their data contradict only one of a number of other reports (B. Akyürek *et al.*, unpubl. report; Koçyiğit *et al.*, 1995) that the eastern margin of the Hançılı Basin is characterized by a number of compressional fault segments. Seyitoğlu *et al.* (2000) have over interpreted their data and criticized the double vergent thrust model of Koçyiğit *et al.* (1995) although Kaymakci *et al.* (1998, 2000) have clearly documented that the western margin of the Çankırı Basin and the eastern margin of the Hançılı Basin are delimited by a very broad zone of high-angle reverse faults, locally inverted normal faults and sinistral and dextral oblique-slip faults during a period of sinistral transpressional deformation.

Seyitoğlu *et al.* (2000) have addressed two questions: (i) what kind of tectonic regime existed during the development of the Early Miocene – Early Pliocene basin? and (ii) what is the reason for eastward thrusting of the Neo-Tethyan basement that fragments this basin?

An extensional basin model was proposed to answer the first question based on a misinterpretation of Wilson *et al.* (1997). Then they assumed that the Early Miocene extension continued until the Early Pliocene although they give no evidence for this. Although it has been shown that extension prevailed only during the latest early Miocene to Middle Miocene time interval (see Kaymakçı *et al.*, 1998; 2000, see also Adiyaman *et al.*, 2001). This was then replaced by compressional deformation after the Middle Miocene.

The answer to the second question is explained by the activity of the Kırıkkale–Erbaa Fault Zone-KEFZ (Ezinepazarı-Sungurlu Fault Zone-ESFZ of Kaymakçı *et al.*, 1998, 2000) although it was shown by mapping that, in addition to ESFZ, the Çankırı and Hançılı basins are dissected by a number of strike-slip faults branching off the NAFZ and transferring strike-slip deformation deep into the Anatolian block (Kaymakçı, 2000; Kaymakçı *et al.*, 2000, 2001). Accordingly, Seyitoğlu *et al.* (2000) proposed that a NW–SE-orientated major compressive stress (σ_1) is responsible for the east-vergent thrusting – a conclusion already reached by Kaymakçı *et al.* (1998, 2000). The authors also discussed that east-vergent thrusting and west-vergent normal faulting either side of the marginal high were coeval. Seyitoğlu *et al.* (2000) failed to explain how the normal fault in the eastern margin of the Hançılı Basin could survive as a normal fault (possibly without reactivation or inversion) under the same stress regime that reactivated the western margin-bounding structures of the Çankırı Basin as an east-directed thrust fault, although these faults are subparallel to each other and they strike at a high angle to the regional major compressive stress (σ_1) and are locally separated by less than 100 m.

Moreover, some of the beds, along the eastern boundary of the Hançılı Basin dip as much as 90°, although most of the beds in the northern part of the basin are overturned into synclines which are very evident in the field. This relationship is also attributed to the normal faulting. Seyitoğlu *et al.* should also provide an explanation of how vertical and overturned beds could be developed in an extensional setting along a normal fault of around 30° dip (as appears on the Schmidt plot in their Fig. 4).

Another contentious issue concerns the handling of the results of Kaymakçı *et al.* (2000). Seyitoğlu *et al.* (2000) concluded that:

1 The Early Miocene to Early Pliocene was a continuous period of an extensional deformation.
2 The Çankırı and Hançılı basins formed as a single basin and they were only separated after the inception of the Kırıkkale–Erbaa Fault Zone in the Late Pliocene.
3 The normal fault along the eastern margin of the Hançılı Basin has been active since the Early Miocene; and the western margin of the Çankırı Basin is delimited by an east-vergent thrust fault.

I would like to emphasize that none of these conclusions are shared by Kaymakçı *et al.* (2000). In contrast, we cocluded that:

1 The Early Tertiary collisional processes lasted until the Aquitanian (MN 1–2, Early Miocene). The Middle Miocene (MN 3–6) is characterized by an extensional regime under tri-axial strain conditions exerted by post-orogenic collapse. Extensional deformation was replaced by a compressional phase in the Tortonian. There is no fossil record for MN 7–9. This interval corresponds approximately to the collision of the Arabian Plate and the Eurasian Plate, which drives the current strike-slip regime in Turkey (Şengör and Yılmaz, 1981; Şengör *et al.*, 1985). Therefore, this compressional deformation phase may be extrapolated to the end of the Middle Miocene and beginning of the Late Miocene (MN 8, MN 9 boundary, 11.1 Ma). This phase corresponds to the latest deformation phase of Kaymakçı *et al.* (1998, 2000, 2001, 2003) and it is characterized by vertical σ_2 and horizontal NW–SE-directed σ_1 and NE–SW-directed σ_3 patterns, indicating regional transcurrent tectonics.

The bounding faults (Eldivan Fault Zone – EFZ) along the western margin of the Çankırı basin have different orientations and characters, each of which were discussed in Kaymakçı *et al.* (1998, 2000, 2001, 2003). The EFZ displays a Reidel pattern of geometry developed under NW–SE-directed σ_1 and vertical σ_2, which is conformable with the presently active strike-slip system. The sinistral oblique-slip reverse fault within the EFZ that controls the eastern margin of the Çankırı Basin makes an approximately 75° angle with the regional σ_1, which possibly explains its reverse component. Therefore, the western margin of the Çankırı Basin is not delimited simply by a thrust fault, rather it is a transpressional zone and the thrust fault traced by Seyitoğlu *et al.* (2000) is actually a sinistral oblique-slip reverse fault.

Careful examination and reassessment of the data provided by Seyitoğlu *et al.* (2000) has shown that the evidence provided cannot be used to suggest that in central Anatolia there was a period of continuous crustal extension during the Early Miocene to Early Pliocene time, or that the Çankırı and Hançılı Basins were once a single basin that later fragmented. Their paper has selectively used the available literature and misinterpreted others' work in the favour of their presented model.

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