The stratigraphical position of Kemiklitepe fossil locality (Eşme, Uşak) revised: Implications for the Late Cenozoic sedimentary basin development and extensional tectonics in western Turkey


With 7 figures

Introduction

Geographically, Western Turkey is the eastern continuation of the highly extended Aegean region. It consists of basement (the rocks of the Menderes Massif, Lycian nappes, the İzmir Ankara suture zone) and Late Cenozoic sedimentary basins (Fig. 1). The genetic relationship between western Turkey and the Cyclades in the Aegean Sea was documented in many studies (e.g. Candan et al. 1997; Ring et al. 1999; Thomson & Ring 2006). The Menderes Massif covers a significant portion of western Turkey with a NNE-SSW extension, and includes variable grade metamorphic rocks (gneisses, schists, marbles, and quartzites) and young granitoid intrusions. The latest studies of different parts of the Menderes Massif indicate that the massif formed as a metamorphic core complex by Cenozoic extensional tectonics in western Turkey (e.g. Bozkurt & Park 1994; Hetzell et al. 1995; Gessner et al. 2001; İskı & Tekeli 2001).

Recently, three region-wide models have been proposed to explain the exhumation of the Menderes Massif. Ring et al. (2003) suggest that the massif exhumed as a symmetrical core complex along south
dipping Lycian and north dipping Simav detachments during Late Oligocene – Early Miocene, and the central Menderes Massif was further exhumed along north dipping Alaçehir (Kuzey) and south dipping Büyük Menderes (Güney) detachments in the Pliocene.

According to Westaway (2006), however, mainly erosional processes are responsible for the exhumation of the massif, and its uplift is linked with the low angle subduction of the African Plate under the Aegean region.

Alternatively, Seyitoğlu et al. (2004) propose the north dipping Dağça – Kale main breakaway fault along which the Menderes Massif exhumed as an asymmetrical core complex where the Oligocene Kale and Gökova basins were developed in the hanging wall of the main breakaway. The Menderes Massif reached the surface during Early Miocene due to...
upward-bending of the Datça – Kale main breakaway and its northern part, known as the Simav Detachment. The dome-shaped massif was fragmented by E-W- and N-trending faults, and Neogene sedimentary basins developed in their hanging wall (SEYITOĞLU et al. 2004).

The E-W trending Alaşehir and Büyük Menderes grabens started to develop during Early Miocene, and their evolution throughout the Mio-Pliocene times is similar to the rolling hinge model (SEYITOĞLU & ŞEN 1998; GESSNER et al. 2001; SEYITOĞLU et al. 2002). Following Quaternary, the youngest high angle faults cut and displace the earlier structures (SEYITOĞLU et al. 2002; Fig. 10d).

Also N-trending basins such as Gördes, Demirci, Selendi and Uşak-Güre initiated during Early Miocene (Fig. 1). One of the well constrained stratigraphies belongs to the Selendi and Uşak-Güre basins in western Turkey. ERCAN et al. (1978, 1983) divided the basin fills into two groups. The lower Hacibekir Group is unconformably overlain by the Inay Group having Ahmetler and Ulubey formations. The Inay Group is unconformably overlain by the Asartepe Formation. Kula volcanics cover all earlier basin fill (Fig. 2a).

The reliable age data have been provided for these lithostratigraphical units by the isotopic dating of related volcanics and palynological analyses (SEYITOĞLU 1997; SEYITOĞLU et al. 1997; SEYITOĞLU & BENDA 1998). The Hacibekir Group is cut by 18.9 ± 0.6 Ma volcanics in the eastern Selendi Basin, indicating Early Miocene age (SEYITOĞLU 1997). This age is also confirmed by the presence of an Eskihisar sporomorph association (20-14 Ma) in the Hacibekir Group at the Pabuçlu location (SEYITOĞLU & BENDA 1998) (Fig. 2b). The Inay Group unconformably overlies the Hacibekir Group. Isotopically dated volcanic successions show cutting and interfingering relationship with the Inay Group, and the existence of the Eskihisar sporomorph association (20-14 Ma) at the Yeniköy, Ilyaslı, Çakıldak tepe and Ulucak locations indicates that the Inay Group is older than 14 Ma (SEYITOĞLU 1997; SEYITOĞLU et al. 1997; SEYITOĞLU & BENDA 1998) (Fig. 2b, c). On the other hand, the Late Miocene age for the Inay Group obtained from the Kemiylitepe locality by ŞEN et al. (1994) has been discussed and it has been noted that a re-examination is necessary for this fossil location (SEYITOĞLU 1997: 173).

Fig. 2. Stratigraphy of the Selendi and Uşak-Güre basins. For locations of isotopically dated volcanics and palynological samples see SEYITOĞLU (1997), SEYITOĞLU et al. (1997) and SEYITOĞLU & BENDA (1998).
After using the overall undeformed nature of the early Middle Miocene İnay Group by Seyitoğlu et al. (1999) against the two-stage extension model of Koçygıt et al. (1999) – suggesting a regional compressional phase between Miocene and Pliocene interval – the age of the İnay Group is particularly discussed by other researchers. Westaway et al. (2003, 2004) examining the uplift history of western Turkey, using the Gediz River terraces capped by Kula volcanics, discuss the mammalian fossil content and magnetostratigraphy (~7 Ma) of the Kemiklitepe location (Şen et al. 1994) within the İnay Group, and suggest that river gorge incision started in the Late Pliocene around ~3 Ma after ending the deposition of the İnay Group (see also Westaway et al. 2005, Fig. 11; Westaway et al. 2006). They have modelled the uplift history of the region based on this assumption, dismissing of the NE-trending normal fault that limits the Uşak-Güre Basin as determined by Seyitoğlu (1997). Westaway et al. (2005, 2006) also questioned the validity of recent Ar40-Ar39 dating (18-16 Ma) by Purvis et al. (2005), obtained from the tuffs of the İnay Group in the Selendi Basin. Westaway et al. (2005; 2006) further speculate that the palynological analysis and mammalian fossil determinations/magnetostatigraphy (~7 Ma) for the Kemiklitepe fossils. The stratigraphical position of the fossil locality, however, was determined according to the earlier studies of Erkan et al. (1978, 1983). In the published geological map of MTA (Erkan et al. 1980), the Kemiklitepe fossil locality is shown within the Ahmetler Formation (Başçıkeldere Member) that is overlain by the Ulubey Formation, distinguished with horizontal limestones creating a plateau-like topography in the region (Fig. 3). Şen et al. (1994) adapted this information to determine the stratigraphical position of the Kemiklitepe locality (Fig. 2a).

The authors’ field investigation, however, indicates that the clastic unit where the Kemiklitepe fossil locality is situated lies on top of the uppermost part of the İnay Group, the Ulubey Formation (Figs. 2d, 4). The fossil-bearing clastic unit is composed of massive mudstones with matrix-supported, fine-grained conglomerate alternations representing subaerial deposition in distal alluvial-fan environments. The massive mudstones alternate with matrix-supported conglomerates, reddish to brownish in colour, fractured and including minor carbonate nodules, very fine-scattered granules and sand-granule lenses with abundant plant root-casts and bioturbation. The conglomeratic facies consist of pebbles to boulders derived from underlain metamorphic rocks, lacustrine Ulubey Formation and Beydağ volcanics. The mudstone units include scattered granules and pebbles, gravel conglomerate to coarse sandstone lenses with some organic-rich horizons. The fossil-bearing clastic unit fits the Asartepe Formation originally defined by Erkan et al. (1978) better than the Ahmetler Formation (Başçıkeldere Member).

The clastic unit of the Kemiklitepe locality must have been deposited after an erosional stage, because in the valley floor (coordinates: 35S 688 321, 4250 696) the contact between underlain Ulubey limestone and the overlying clastic unit is at 630 m, but 10 km to the NE of this location on top of the limestone plateau, the same contact (coordinates: 35S 696 128, 4254 659) is seen at a 740 m altitude without any sign of faulting visible that corresponds to a 0.5 degree dip of the erosional surface (Fig. 3). This observation is in agreement with the definition by Erkan et al. (1978).

**Revised Kemiklitepe fossil locality**

The Kemiklitepe fossil locality (coordinates: 35S 687 660, 4252 256; Sarac 2003) was first studied by Yalcinlar (1946) who reported the stratigraphical position of the locality as lying on top of lacustrine limestones and clays and under thick sandstone and conglomerates. After Ozansoy (1957, 1969), Sickenberg et al. (1975) and Tuna (1985), the fossil content of the Kemiklitepe locality was studied in detail by Şen et al. (1994) who examined every species excavated from the Kemiklitepe separately. These authors determined a Late Miocene age by biostratigraphy and magnetostatigraphy (~7 Ma) for the Kemiklitepe fossils. The stratigraphical position of the fossil locality, however, was determined according to the earlier studies of Erkan et al. (1978, 1983). In the published geological map of MTA (Erkan et al. 1980), the Kemiklitepe fossil locality is shown within the Ahmetler Formation (Başçıkeldere Member) that is overlain by the Ulubey Formation, distinguished with horizontal limestones creating a plateau-like topography in the region (Fig. 3). Şen et al. (1994) adapted this information to determine the stratigraphical position of the Kemiklitepe locality (Fig. 2a).

The authors’ field investigation, however, indicates that the clastic unit where the Kemiklitepe fossil locality is situated lies on top of the uppermost part of the İnay Group, the Ulubey Formation (Figs. 2d, 4). The fossil-bearing clastic unit is composed of massive mudstones with matrix-supported, fine-grained conglomerate alternations representing subaerial deposition in distal alluvial-fan environments. The massive mudstones alternate with matrix-supported conglomerates, reddish to brownish in colour, fractured and including minor carbonate nodules, very fine-scattered granules and sand-granule lenses with abundant plant root-casts and bioturbation. The conglomeratic facies consist of pebbles to boulders derived from underlain metamorphic rocks, lacustrine Ulubey Formation and Beydağ volcanics. The mudstone units include scattered granules and pebbles, gravel conglomerate to coarse sandstone lenses with some organic-rich horizons. The fossil-bearing clastic unit fits the Asartepe Formation originally defined by Erkan et al. (1978) better than the Ahmetler Formation (Başçıkeldere Member).

The clastic unit of the Kemiklitepe locality must have been deposited after an erosional stage, because in the valley floor (coordinates: 35S 688 321, 4250 696) the contact between underlain Ulubey limestone and the overlying clastic unit is at 630 m, but 10 km to the NE of this location on top of the limestone plateau, the same contact (coordinates: 35S 696 128, 4254 659) is seen at a 740 m altitude without any sign of faulting visible that corresponds to a 0.5 degree dip of the erosional surface (Fig. 3). This observation is in agreement with the definition by Erkan et al. (1978).
The stratigraphical position of Kemiklitepe fossil locality (Eşme, Uşak)

Fig. 3 (Legend see p. 4)
Fig. 4 (Legend see p. 7)
(1978:104) stating that the Asartepe Formation is deposited on an irregular topography. Moreover, the pebbles/cobbles of the Ulubey limestone in the fossil bearing clastic unit (Fig. 5) certainly demonstrate that the stratigraphical position of the clastic unit, containing the Kemiklitepe locality, is on top of the Inay Group and should be regarded as the Asartepe Formation separated by an unconformity (Fig. 2d).

**Correlation of the Asartepe Formation in the Uşak-Güre Basin**

The Asartepe Formation is a wide-spread lithostratigraphical unit in the Uşak-Güre Basin and can be mapped as isolated patches due to the latest erosion. This study demonstrates that the formation accumulated around ~7 Ma B.P. in Kemiklitepe (see above). The Asartepe Formation can be clearly tracked further north to NW of the Uşak, Hachhüseyinler – Karabeyli area (Fig. 6), due to a newly discovered fossil location (see below). There is no doubt that the Inay Group is unconformably overlain by the Asartepe Formation which is accumulated in the hanging wall of the NE-trending fault between Hachhüseyinler and Karabeyli villages (SEYITOĞLU 1997; Fig. 9).

Recently, WESTAWAY et al. (2003, 2004, 2005, 2006) argue that this fault and the Asartepe Formation do not exist in the field and the clastic unit around the Hachhüseyinler – Karabeyli area is included in the upper part of the Inay Group, by disturbing the original lithostratigraphical definitions of ERCAN et al. (1978, 1983) – because otherwise, the modelling of the uplift history of the region becomes more complex. Moreover, WESTAWAY et al. (2003, 2004) claim that the channel deposits in this area belong to the earlier Gediz River, without, however, presenting any paleocurrent directions. These might well be the distribution channels of alluvial fan deposits of the Asartepe Formation.

Our field observations in the Hachhüseyinler – Karabeyli area (Fig. 6) confirm the existence of a NE-trending fault (cf. ŞENGÖR 1987; BOZKURT 2003) (Fig. 7a, b) with a well-developed cataclastic zone (Fig. 7c, d). In the hanging wall of this fault, the Asartepe Formation accumulated with local intra-formational unconformities. Recently, a new mammalian faunal assemblage has been discovered (MCA & HA – 35S 0698724 to 4293704) in the Asartepe Formation near the village of Karabeyli (Fig. 7e, f). The fossil-bearing unit consists of reddish to brownish massive mudstone. Preliminary research on the locality yielded unassociated tooth fragments and postcranial elements, a few maxillary-mandibular milk teeth, a single lower and an upper molar and a 2nd phalanx of a hippocionine horse. Most of the unclassified artiodactyla and some more carnivore material were left at the locality for future prospects.

The upper deciduous and permanent dentition of the Karabeyli equid is morphologically uniform. Deciduous teeth are characterized by their small size with moderate enamel plication, strong double-ply caballine on the upper dentition, and a developed protostylid.

Enamel plication on the upper check teeth has been used to distinguish primitive early Late Miocene (Vallesian) forms from more advanced Late Miocene (Turolian) and Pliocene ones (KOUFOS 1986). Basically, plication decreases from Vallesian to Turolian forms. Furthermore, medium- to large-sized, moderately high tooth crowns with rich enamel plication and crenulation are thought common characteristics of the European Pliocene members of Hipparion. The sole Turkish Pliocene Hipparion record, “Hipparion heintzi”, comes from the well-studied Ankara-Çalta fauna, which was dated to Early Pliocene (MN15) (EISENMANN & SONDAR 1998). The Karabeyli equid can easily be distinguished from the Çalta Hipparion with its considerably smaller size and moderately developed enamel plication.

Although Hipparion is the most common element of Turkish Neogene faunas, deciduous teeth characters are rarely mentioned, since the morphology remains quite similar across different species. However, the Karabeyli Hipparion can easily be distinguished from...
The Asartepe Formation bearing the Kemikletepe fossil locality contains cobbles of Ulubey Formation (limestone) indicating that the fossil location lies on top of the İnay Group.

b. Close-up view of the limestone cobble.  
c. Microscopic view of in-situ Ulubey Formation constituting the upper part of İnay Group.  
d. Microscopic view of the limestone cobble in the Asartepe Formation. Both thin sections are identical. They are porous, white yellowish peloidal wackestones and consist of root traces, coalescing carbonate glaebules, well-developed desiccation cracks, peloids, ostracods and algae-like aggregates.
the Vallesian forms by its metric and discrete dental characters. These characters closely follow those of Late Miocene (Turolian) forms, especially “H. mediterraneum” which is a medium-sized Hipparion known from various localities in Greece (Samos, Dytiko 1,3) and Turkey (Uşak-Kemiklitepe A-B, Muğla-Salihsuvaşalar, Kütahya-Bayat) (Kaya 1982; Kaya et al. 2005; Koufos 1987a, b; Koufos & Kostopoulos 1994). This interpretation also conforms well with the single 2nd phalanx record, which has the same proportions as that of H. matthewi which is also a very common small-sized Hipparion from SE Mediterranean (Greece: Samos, Dytiko; Turkey: Kemiklitepe A-B; Çanakkale-Gülpınar, Kütahya-Bayat) Late Miocene faunas (Koufos 1988).

Nevertheless, due to the scarcity of available material, we prefer to refer the Karabeyli equid under Hipparion sp. The presence of the small-sized Hipparion suggests a Late Miocene biochronological age for the Karabeyli locality. Thus, a Turolian age for Karabeyli seems quite plausible.

A well studied and unambiguous stratigraphical position of the Late Miocene Karabeyli fossil locality in the Asartepe Formation provides further evidence for both our claims on the revised stratigraphical position of Kemiklitepe locality and the activity of NE-trending faults during the Late Miocene.

Discussion

Before discussing the implications of the revised stratigraphical position of the Kemiklitepe fossil locality, it would be useful to review the arguments concerning the stratigraphy of the E-W trending grabens in western Turkey since similar claims (i.e. the reworked nature of palynological data and inconsistencies between palynological and mammalian data) exist in the literature about the stratigraphy of both E-W and N-trending basins.

Following 2000, some papers have implied that there is a serious problem in the evidence concerning reliability of age, particularly in evidence obtained from E-W trending grabens fill (e.g. Sarica 2000; Yilmaz et al. 2000; Bozkurt 2000). The absence of tolerance towards the idea of a possibility of wide age range of lithostatigraphical units, and the strong refutation of an earlier age database is probably due to scholars desiring to show the validity of their tectonic models. Until only recently, the age of these grabens was particularly important because they were regarded to be revolutionary structures (Şengör et al. 1985) and believed to represent the initiation of extensional tectonics in western Turkey. Now it is clear that they play only a secondary role on the exhumation of the Menderes Massif (see Seyitoğlu et al. 2004) and future discussions on the age of these grabens would be expected to be more sensible.

The E-W trending Alaşehir and Büyük Menderes grabens have three sedimentary packages (Seyitoğlu et al. 2002; Sözüllü & Emre 1990). The first sedimentary packages in both grabens are well dated by palynological analysis (Eskihisar sporomorph association: 20-14 Ma), providing an Early Miocene age (Seyitoğlu & Scott 1992; Ediger et al. 1996). Although sedimentological (Cohen et al. 1995) and structural (Seyitoğlu et al. 2002) evidence, and wedge geometry in the seismic sections (see Yılmaz & Gelişli 2003), demonstrate that the first sedimentary package is controlled by the E-W trending graben bounding faults, other studies argue that this sedimentary unit belongs to the N-trending basins and was trapped later in the E-W trending structure (Yılmaz et al. 2000; Yılmaz & Gelişli 2003).

The second sedimentary package in the E-W trending Alaşehir Graben has an Eskihisar sporomorph association (20-14 Ma) (Seyitoğlu & Scott 1996) but the reworked nature of the sample is claimed by Sarica (2000) and Yilmaz et al. (2000). Moreover, the palynological analyses of Ediger et al. (1996) reported much younger results (Yeni Eskihisar 14-11 Ma or Kızılıhisar 11-5 Ma sporomorph associations) by examining three samples from the second sedimentary package of the Alaşehir Graben. Their results, however, have been evaluated as typical for the Eskihisar association by L. Benda, who was the

Fig. 5. d. (Cont.) Glaebules include homogeneous micrite and alveolar textures. In a few places, they show partial bioturbation and hematite replacements of carbonate matrix. These deposits were formed in a marginal lake environment where the water level temporarily fluctuated. As a result of this, reworked micritic peloids and intraclasts were commonly accumulated and graded from the lake margin to the lake flat, whereas drying processes involved formation of mud cracks, weak soil zones and alveolar textures.
founder of sporomorph associations in the Aegean region (Benda, written communication 1998). As a result, all palynological analyses based on a total of four samples – the reworking possibly for all of them is very low – indicate that at least the lower part of the second sedimentary package accumulated between 20-14 Ma B.P., but the accumulation of the sedimentary package may well have continued until Late Miocene or even Pliocene. This result is also supported by the magnetostratigraphical work of Şenk & Seyitoğlu (2002, 2009) who reported the transition from the first sedimentary package to the second one to have taken place between 16.6 and 14.6 Ma B. P. in the Alaşehir Graben and between 15.97 and 14.88 Ma in the Büyük Menderes Graben. These data are compatible with the recent U-Pb ages of syn-extensional granodiorites (16.1 ± 0.2 Ma and 15.0 ± 0.3 Ma; Glodny & Hetzel 2007) from the Alaşehir Graben, indicating that extensional tectonics were already in progress in the Early to Middle Miocene interval (İşik et al. 2003; Glodny & Hetzel 2007).

An inconsistency between palynological and micro-mammalian results in the Büyük Menderes Graben as claimed by Bozkurt (2000) is simply not given because the palynological results (Eskihisar sporomorph association 20-14 Ma) were obtained from the
Fig. 7. a. Geological cross section of Hacıhüseyin-Karabeyli area (after SEYITOĞLU 1997). b. Fault zone from the west of Hacıhüseyinler between the Asartepe Formation (hanging wall) and the basement (footwall). This tectonic contact has been omitted by WESTAWAY et al. (2003, 2004). c. Exposed fault scarp (strike-dip N7E, 61NW) with weathered surface formed in the footwall rocks. d. Close-up view of the surface in c. The polished surface of the fault, common in the marbles, was removed by weathering processes, characteristics of the fault rock are preserved. The surface includes clasts with variable-sized matrix material representing breccia.
first sedimentary package but the Pliocene micro-
mammalian results at the Şevketin dağı location 
(ÜNAY et al. 1995) were based on the third sedimen-
tary package.

As indicated by the short review of the age data 
inventory from the E-W trending grabens, these pro-
blems can be eliminated as soon as the age deter-
minations were checked by means of different dating
tools, and as all available age determinations were taken into account because the lithostratigraphic units might have developed over a longer period.

The present study therefore offers a solution to the main stratigraphical problem with the N-trending basins in western Turkey. In the Uşak-Güre Basin, the İlany Group is separated by an unconformity from the Asarztepe Formation. This formation bears the Kemiklitepe fossil locality – of Late Miocene age (~7 Ma) assigned by biostratigraphy and magnetostratigraphy – rather than the İnay Group as stated by ERCAN et al. (1978, 1983) and ŞEN et al. (1994) (Fig. 2a, d). This conclusion is in agreement with the age of the İlany Group (early Middle Miocene) as determined by isotopic dating and palynological analysis (SEYITOĞLU et al. 1997; SEYITOĞLU & BENDA 1998; PURVIS et al. 2005) and evidences that no inconsistency exists between isotopic dating/palynological data and mammalian ages in western Turkey. The redefined stratigraphical position of the Kemiklitepe fossil locality is also qualified to refute the recent claims by WESTAWAY et al. (2006) that the palynological samples were reworked and that the isotopic dating procedure in the Selendi and Uşak-Güre Basins were inaccurate.

Conclusion

The Kemiklitepe fossil locality, dated as ~7 Ma B. P. (Late Miocene) by biostratigraphy and magnetostratigraphy (ŞEN et al. 1994), is located in the Asarztepe Formation overlying the İlany Group (Fig. 2d). This is also confirmed by the stratigraphical position of the newly discovered Karabeyli fossil locality in the Hacıhüseyinler – Karabeyli area. These observations indicate the precision of early Middle Miocene age of the İlany Group as previously determined by isotopic dating and palynological analyses (SEYITOĞLU 1997; SEYITOĞLU et al. 1997; SEYITOĞLU & BENDA 1998).

The early Middle Miocene age of the overall undeformed İlany Group does not seem to be explained by the two-stage extension model of KOÇYIGIT et al. (1999) who claim a regional compressional phase in the Miocene – Pliocene interval, and the reservations of SEYITOĞLU (1999) on this model are still applicable.

The early Middle Miocene age of the İlany Group also requires revision of the uplift models of WESTAWAY et al. (2003, 2004, 2005, 2006), because the incision of the İlany Group starts in the Late Pliocene (~3Ma) in their models. The modelling of the uplift history of the region is also more complex due to active N-trending faults during the Late Miocene.

Acknowledgements

The field work for this paper was supported by TÜBİTAK-104Y156 and 105Y280 research grants. We thank ŞEVKET ŞEN and GERCEK SARAC for their encouragement to study the stratigraphical position of the Kemiklitepe fossil locality. We also thank UWE RING, Mainz, and two anonymous referees for their constructive comments.

References


SEYITOĞLU, G., & ŞEN, Ş. (1998): The contribution of first magnetostratigraphical data from E-W trending grabens fill to the style of late Cenozoic extensional tectonics in western Turkey. – Third International Turkish Geology Symposium, Abstracts: 188.


Addresses of the authors:

Prof. Dr. GÜROL SEYITOĞLU, Ass. Prof. Dr. VEYSEL İŞIK and KORHAN ESAT, Ankara University, Department of Geological Engineering, Tectonics Research Group, TR-06100 Ankara, Turkey.

Ass. Prof. Dr. M. CHATALÇIÇEK and Ass. Prof. Dr. HÜLYA ALÇIÇEK, Pamukkale University, Dept. of Geological Eng. Denizli, Turkey.

Dr. SERDAR MAYDA, Ege University, Natural History Research and Application Centre, TR-35100 İzmir, Turkey. Prof. Dr. BAKI VAROL, Ankara University, Dept. of Geological Eng. TR-06100 Ankara, Turkey.

IBRAHIM YILMAZ, General Directorate of Mineral Research and Exploration, TR-06520 Ankara, Turkey.