Trabajos de Geología, Universidad de Oviedo, 29 : 168-174 (2009)

Oviedo (Spain) 1-3 July 2008 International Meeting of Young Researchers in Structural Geology and Tectonics
ORSGET

A NNE-trending active graben in the Isparta Angle, SW Turkey: Karamık Graben, its geometry, age and earthquake potential

A. Çiçek[1*] and A. Koçyiğit[1]

[1]*Middle East Technical University, Engineering Faculty, Department of Geological Engineering. Active Tectonics and Earthquake Research Lab., Turkey.*

[*]*e-mail: aycicek@metu.edi.tr*

Abstract: the Karamık Graben is an approximately 6-14 km wide, 29 km long, NNE-trending, normal faults-bounded active depression within the Isparta angle included in southwest Turkey extensional domain. It has two graben infills separated by an angular unconformity: (a) a deformed graben infill of Late Early Miocene-Middle Pliocene age, and (b) an undeformed neotectonic infill of Plio-Quaternary age. These two graben infills reveal an episodic history for the Karamık Graben, and a Plio-Quaternary age for the extensional neotectonic period in the Isparta Angle. The northernmost marine boundary of the Karamık Graben was reactivated by the Mw=6.5 Çay earthquake (February, 3rd 2002). However, the rest of the Karamık Graben is a seismic gap threatening settlements in it.

Keywords: Isparta Angle, Karamık Graben, extensional neotectonic period.

Southwestern Turkey is one of the most well-known extensional areas in the world and has attracted not only national, but also international researchers, in particular since the second half of the 20th century. This is because the area has a great potential to study all branches of geology, especially tectonics.

Until now, four prominent models have been invoked to account for the extensional regime in southwestern Turkey. (1) *The tectonic escape (extrusion) model* (Dewey and Şengör, 1979): the extension in SW Turkey is originated as a result of intracontinental collision between the European plate to the north, the Arabian plate to the south, and related escape of the Anatolian plate along the North Anatolian and East Anatolian transform faults since Serravalian, (2) *Back-arc spreading model* (Le Pichôn and Angelier, 1979): the migration of the trench system to the south and southwest gave rise to an extensional regime in the back-arc region in the Hellenic arc, (3) *Orogenic collapse model* (Dewey, 1988; Seyitoğlu *et al.*, 1992): the extension has been taking place in relation to the cessation of the Paleogene shortening as a consequence of over thickening of the SW Turkey lithosphere since Late Oligocene-Early Miocene and still continues, (4) *Episodic two-stage extension model* (Koçyiğit *et al.*, 2000): the extensional regime is not continuous since Late Oligocene-Early Miocene; instead, in the development history of the SW Turkey graben horst system, the extension occurred in two phases separated by a short-lived contractional phase. *Phase-I* extension is restricted to Early Miocene to Early Pliocene and issued from the orogenic collapse, while *Phase-II* (current) extension is dominated by tectonic escape of the Anatolian plate and roll back process in the Hellenic trench since Late Pliocene. The short-lived intervening contractional phase is thought to prevailed in a time slice of Middle Miocene-Middle Pliocene (Koçyiğit and Özacar, 2003; Koçyiğit, 2005; Koçyiğit and Deveci, 2007).

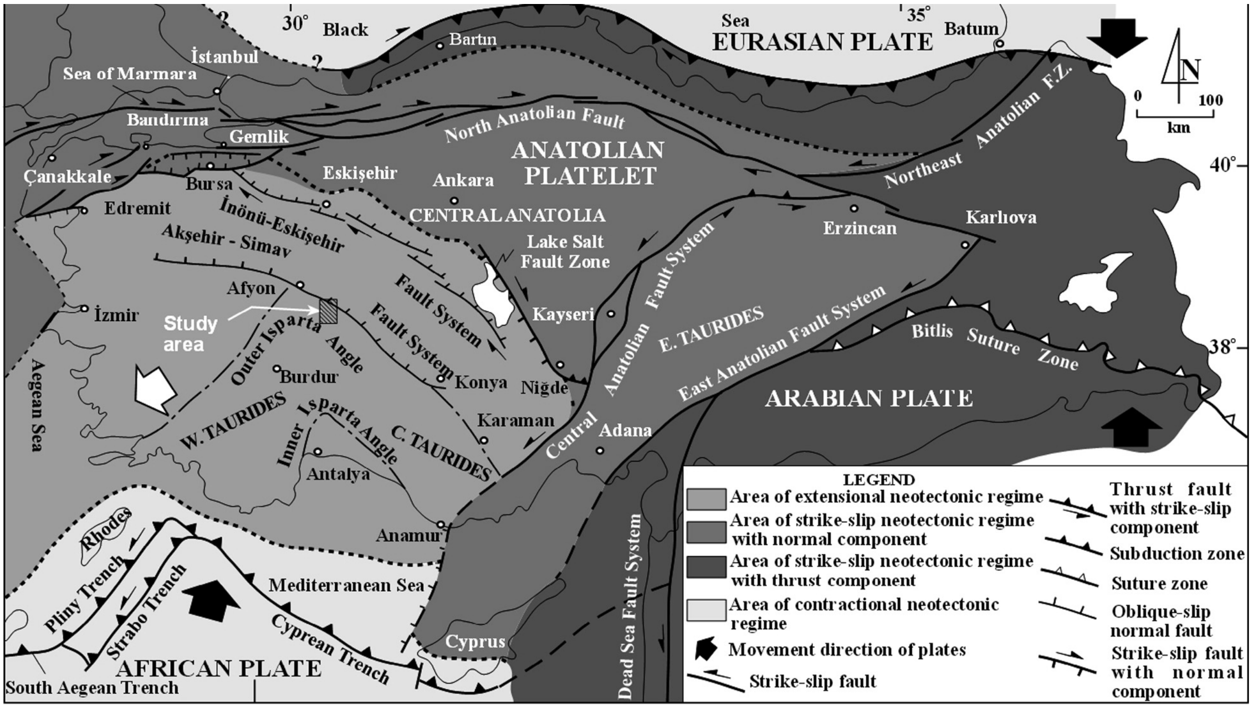

Figure 1. Simplified neotectonic map of Turkey (Koçyiğit and Özacar, 2003).

The main scope of this study is to present new field data collected in the Karamık Graben, located in the apex of the Isparta angle included in the SW Turkey extensional province.

Karamık Graben (KG)

The Karamık Graben is an approximately 6-14 km wide, 29 km long and NNE-trending active depression located within the Isparta angle included in the Lakes districts (Figs. 1 and 2). The Karamık Graben is bounded by the southern margin boundary fault and its northern margin-boundary fault in the SW, by the WNW-trending Ak ehir-Afyon graben in the NNE, by the Koçbeyli-Akkonak (Akharım) fault zone in the ESE, by the Karacaören fault zone in the SSE, and by the Devederesi fault zone in the WNW (Fig. 2). It is one of major extensional element characterizing the Lakes District sub-neotectonic domain of the regional Southwest Turkey extensional neotectonic province.

Stratigraphic Outline of the Karamık Graben

The rocks exposed in the area are classified into three out categories: (1) Old metamorphic rocks, (2) pre-graben infill units, and (3) modern graben infill units. The oldest rocks are made up of pre-Jurassic low-grade metamorphic rocks, Jurassic-Lower Cretaceous platform carbonates and Upper Cretaceous ophiolitic mélange. The basement rocks, which are well exposed at the all corners of the study area, consist mainly of quartz-mica-chlorite schist, slate, quartzite and marble. The Jurassic-Lower Cretaceous platform carbonates crop out along the southern margin of the Karamık Graben and consist of thick-bedded to massive and recrystallized shallow marine limestones. Both rock assemblages are overlain with an angular unconformity by both the pre-modern and modern graben infills.

Pre-modern graben infill

The oldest graben units consist of very thick volcano-sedimentary sequences exposed over a broad area at the western margin of the Karamık Graben. Even though the bottom of the volcano-sedimentary package is not observable, it crops out within some other grabens, such as uhut, Dombayova and Sandıklı grabens in southwest Turkey (Cihan, 2000; Özacar, 2001; Koçyiğit and Deveci, 2007). A lacustrine sedimentary sequence crops out in the vicinity of Kılıçyaka and Bulanık Villages near the southwestern tip of the graben. The unit is made up of, white, gray, green and red, laminated to thin-bedded beds of clayey limestone, marl, limestone, siltstone, sandstone, silica layers, tuff and tuffite alternation.

Figure 2. Simplified neotectonic map of the Karamık Graben. a- pre-Late Pliocene rocks; b- Plio-Quaternary terraced deposits; c- Lower Quaternary fan-apron deposits; d- Lower Quaternary alluvium; e- recent alluvium; f- recent swamp deposits; g- recent swamp; h- bedding plane; i- foliation plane; j- fold axis; k- possible fault trace; l- oblique-slip normal fault; m- stream; n- town centrum; o- village centrum; p- fault-slip data location; q- local maximum stress direction; r- local moderate stress direction; s- local minimum stress direction; t- local extension direction; u- local contraction direction; v- alluvial fan; w- horizontal beds.

This sedimentary sequence is conformably overlain by a 200 m thick volcanic assemblage of alkaline to calc-alkaline Afyon Strato-volcanic Complex and comprises tuffite, tuff, volcanic breccia, ignimbrite, block-ash flows, lahar, basaltic-andesitic-trachyandesitic-and trachytic lavas, and domes cut by a series of basaltic dykes. 14.75±0.3 Ma and 8±0.6 Ma radiometric ages were obtained from different levels of the Afyon strato-volcanic complex (Keller and Villari, 1972). Therefore, Middle-Late Miocene age is assigned to the complex.

The Afyon strato-volcanic complex is conformably overlain by a second sedimentary sequence: the medium to very thick-bedded porous lacustrine limestone. It starts with a basal conglomerate followed by green-blue marl succeeded by lacustrine limestone. The sequence directly rests on the metamorphic basement such as in the NW tip of the Karamık Graben. The upper most section of this unit is composed of very fine grained red beds that are full off in Mammalian fossils. According to the fossil content, a Middle Pliocene age is assigned to the top most part of the second sedimentary sequence (Saraç, 2003). Consequently, the age of the volcano-sedimentary assemblage is restricted to a time slice of Late Early Miocene and Middle Pliocene.

Modern graben infill

The pre-modern graben infill is overlain with an angular unconformity by the fluvio-lacustrine sedimentary sequence of Plio-Quaternary age. It is subdivided into two categories: (1) coarse-grained marginal deposits, (2) fine-grained depocentral deposits. The first unit is composed of the fragments of the oldest rocks and represents the lower part of the sequence. It is widely exposed on both sides of the nli road near nli town along the western margin of the Karamık Graben (Fig. 2). The second unit, however, is made up of Quaternary reddish, pinkish in places grey colored older alluvial fans and Upper Quaternary white to grey younger alluvial fans. The younger alluvial fan-apron deposits were developed on top of the older alluvial fans and are exposed along all margins of the Karamık Graben (Fig. 2). The thickness of the modern graben infill is about 200 m in the vicinity of Akkonak (Akharım). A Late Pliocene to recent age is assigned to the all modern package. As a result, the inception age of the neotectonic period in Karamık Graben is Latest Pliocene.

Graben Structures

The structures characterizing the Karamık Graben are essentially of two groups: (1) paleotectonic structures of pre-Late Pliocene age, and (2) Plio-Quaternary neotectonic structures.

Paleotectonic structures

The paleotectonic structures shaping the Karamık Graben are folds and strike-slip faults.

Folds: they occur within the older graben infill of Miocene-Middle Pliocene age. They are mostly anticlines and synclines with axes trending NW to NNW. The folds are well-exposed along the western margin of the Karamık Graben, and indicate a NE to ENE contraction during Middle Pliocene (Figs. 2 and 3).

Strike slip faults: no mapable strike-slip faults could be observed in the field. However, a number of well-preserved small scale conjugate strike-slip faults were observed in the laminated to thin-bedded lacustrine pre-modern graben infill in the vicinity of Bulanık Village located along the southern margin-boundary fault. Fault slip data measured from the older graben infill indicate that the older graben infill experienced a NE-SW short-term phase of contraction after the sedimentation (Figs. 2 and 3).

Neotectonic structures

The neotectonic structures are oblique-slip normal faults. They control and determine the margins of the Karamık Graben.

A series of oblique-slip normal faults of various sizes were observed, mapped and named separately. These are the Aydoğmuş-Armutlu, Koçbeyli-Akkonak (Akharım), Akşehir-Afyon and Devedersi fault zones (Fig. 2). The curvilinear and steep fault scarps, triangular facets, offset drainage system, line of older and recent alluvial fans, fault-suspended terrace conglomerates, back-tilting of fault blocks, tectonic juxtaposition of Plio-Quaternary neotectonic infill with the pre-Pliocene rocks, crushed to brecciated rocks and slickensides are common morphotectonic and fault-plane related data used to identify fault segments comprising these fault zones.

The Karacaören fault zone is 4-6 km wide, 80 km (24 km in the study area) long and ENE-trending

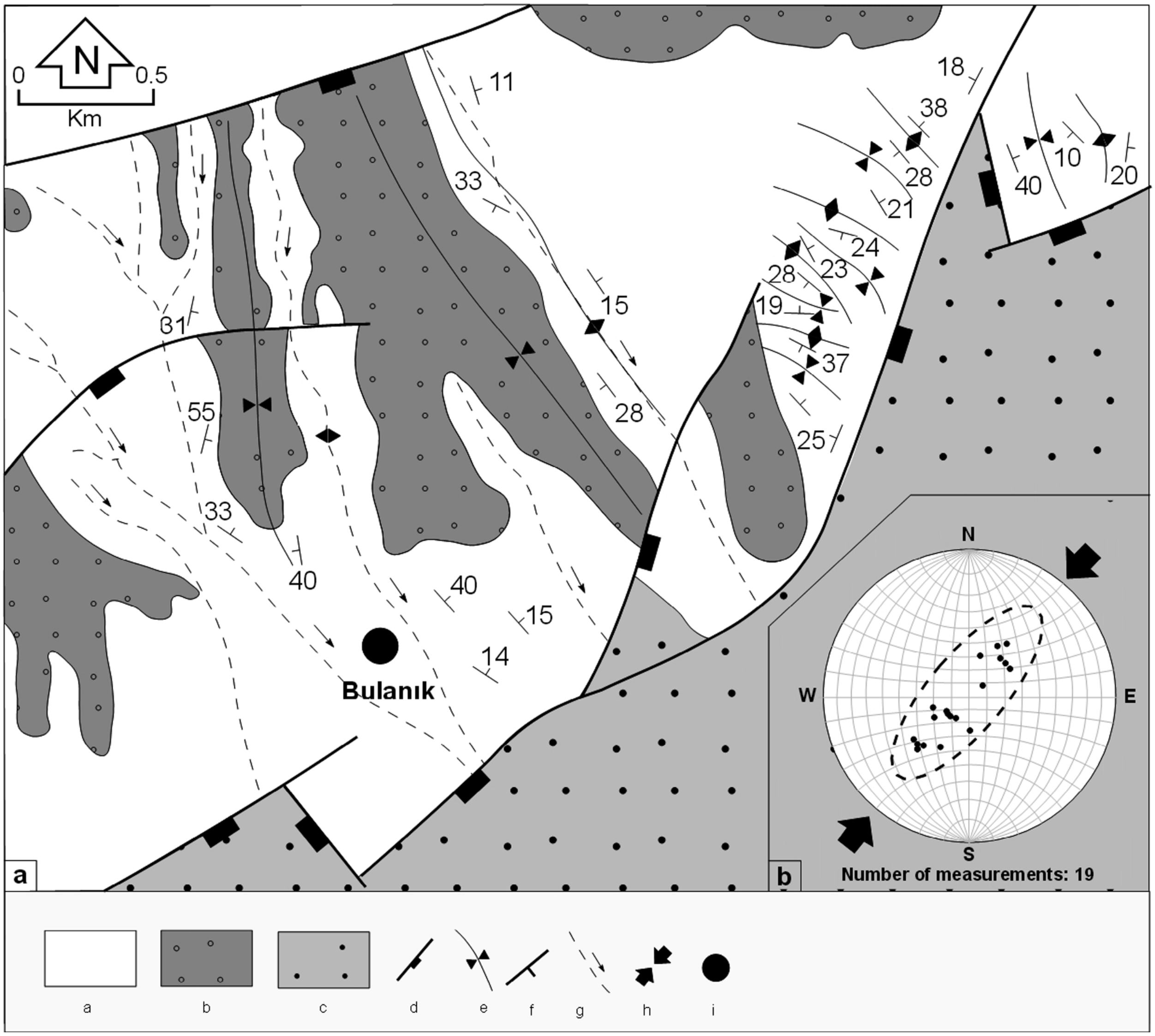

Figure 3. (a) Geological map of the Kılıçyaka and Bulanık Villages. a- pre-Late Pliocene rocks; b- Plio-Quaternary terraced deposits; c- Lower Quaternary fan-apron deposits; d- oblique-slip normal fault; f- fold axis; f- bedding plane; g- stream course; h- stress direction; i- village centrum, (b) poles to bedding on the Schmidt's lower hemisphere net. Large black arrows show the shortening direction of the contractional phase that deformed pre-modern graben infill at the end of the Middle Pliocene (last phase of paleotectonic period).

deformation zone. It determines and controls the southern margin of the Karamık Graben (Fig. 2). It consists of a number of closely-spaced, parallel to sub-parallel fault segments of dissimilar length. The fault segments display steep fault scarps, grabenward-facing step-like morphology and well preserved slickensides. In places, the stereographic plots of fault-slip data indicate a localized NW-SE extension direction (Fig. 2).

The Koçbeyli-Akkonak fault zone is 1-3 km wide, 18 km long and NNE-trending shear zone. It determines and controls the eastern margin of the Karamık Graben (Fig. 2). This fault zone is made up of parallel to sub-parallel basinward verging oblique-slip normal faults.

The Akşehir-Afyon fault zone is the structure bounding the northern margin of the Karamık Graben. This fault zone trends WNW and separates the NNE-trending Karamık Graben from the WNW-trending Akşehir-Afyon graben (Koçyiğit *et al.*, 2000; Koçyiğit and Özacar, 2003; Koçyiğit and Deveci, 2007). The fault-slip data obtained from the Gözsüzlü fault segment indicates a NW-SE extension direction which coincides with the focal mechanism solution of the February, 3rd 2002 Çay (Afyon) earthquake of Mw=6.5 near the Karamık Graben (Harvard, 2002) that caused the loss of more than ten lives and economic damage. In addition, along this fault zone, a 4 km long surface rupture with 22 cm vertical amount was reported (Koçyiğit *et al.*, 2002).

The Devederesi fault zone is 1-3 km wide, 29 km long and NNE-trending shear zone. It determines and controls the western margin of the Karamık Graben (Fig. 2). It consists of numerous parallel to sub-parallel basin-ward verging oblique-slip normal fault segments. The oblique-slip nature of the fault segments is also evidenced not only morphotectonic features but also by the fault-slip data measured using slickensides along faults. The stereographic plots reveal a NW-SE directed localized extension along the western margin of the Karamık Graben (Fig. 2).

Discussion and conclusion

The Karamık Graben has two basin infills: (1) a pre-Late Pliocene older graben infill and (2) a Plio-Quaternary modern graben infill. The older graben infill consists of two fluvio-lacustrine sedimentary sequences and one intervening strato-volcanic complex. These sequences have both vertical and lateral transitional boundary relationships. The older graben infill has been deposited under the control of a tensional tectonic regime (first phase of extension). After the sedimentation (possibly Late Middle Pliocene), it has been deformed into a series of anticlines and synclines due to a NE-SW compression (intervening short phase of contraction) as indicated by a series of fold axes trending in NNW direction and the strike slip faults documented in the sedimentary sequence (Figs. 2 and 3). The Plio-Quaternary graben infill, that rests with an angular unconformity on the older graben infill and other older rocks, and consists of older and recent alluvial fan deposits superimposed to each other, fan-apron deposits, fault-suspended terrace conglomerates and fine-grained depocentral alluvial sediments. The modern graben infill is nearly flat lying, and its sedimentation has been continuous since Late Pliocene under the control of an extensional neotectonic regime (second phase of extension) as indicated by the stereographic plot of the fault-slip data measured from the margin-boundary faults (Figs. 2 and 3).

Consequently, the above-mentioned episodic evolutionary history of the Karamık Graben strongly supports the model of two phases of extension interrupted by an intervening short phase of contraction for the development history of the southwestern graben-horst system (Koçyiğit *et al.*, 2000; Koçyiğit and Özacar, 2003; Koçyiğit, 2005; Koçyiğit and Deveci, 2007).

References

CIHAN, M. (2000): *Neotectonic Characteristics and Seismicity of the Sandıklı Graben*. MSc Thesis, Middle East Technical University, Turkey.

DEWEY, J. F. (1988): Extensional collapse of orogenes. *Tectonics*, 7: 1123-1139.

DEWEY, J. F. and ŞENGÖR, A. M. C. (1979): Aegean and surrounding regions - complex multi-plate and continuum tectonics in a convergent zone. *Geol. Soc. Am. Bull.*, 90: 84-92.

HARVARD UNIVERSITY (2002): *Global Centroid-Moment-Tensor (CMT) Project*. www.globalcmt.org. February, 3rd 2002.

KELLER, J. and VILLARI, L. (1972): Rhyolitic ignimbrites in the region of Afyon (Central Anatolia). *B. Volcanol.*, 36: 342-358.

KOÇYIĞIT, A. (2005): The Denizli graben-horst system and the eastern limit of western Anatolian continental extension: basin fill, structure, deformational mode, throw amount and episodic evolutionary history, SW Turkey, *Geodin. Acta*, 18: 3-4.

KOÇYIĞIT, A. and DEVECI, S. (2007): A N-S-trending active extensional structure, the Suhut (Afyon) graben: Commencement age of the extensional neotectonic period in the Isparta Angle, SW Turkey. *Turkish J. Earth Sci.*, 16: 391-416.

KOÇYIĞIT, A. and ÖZACAR, A. A. (2003): Extensional Neotectonic Regime through the NE Edge of the Outer Isparta Angle, SW Turkey: New field and seismic data. *Turkish J. Earth Sci.*, 12: 67-90.

KOÇYIĞIT, A., ERDIN, B., KAYMAKÇI, N. and ŞAROĞLU, F. (2002): 3 Şubat 2002 Çay-Afyon Depreminin kaynağı ve Ağır Hasarın Nedenleri: Akşehir Fay Zonu. *Jeoloji Mühendisliği Bölümü*, ODTU, Şubat 2002.

KOÇYIĞIT, A., ÜNAY, E. and SARAC, G. (2000): Episodic graben formation and extensional neotectonic regime in west central Anatolia and the Isparta Angle; a case study in the Aksehir-Afyon Graben, Turkey. In: E. BOZKURT, J. A. WINCHESTER and D. A. J. PIPER (eds): *Tectonics and magmatism in Turkey and the surrounding area*. Geological Society of London. London, U.K.

LE PICHÔN, X. and ANGELIER, J. (1979): Hellenic arc and trench system – key to the neotectonic evolution of the Eastern Mediterranean area. *Tectonophysics*, 60, 1, 2: 1-42.

ÖZACAR, A. A. (2001): *Neotectonic Characteristics and Seismicity of the Dombayova Graben*, MSc Thesis, Middle East Technical University, Turkey.

SARAÇ, G. (2003): *Turkiye Omurgalı Fosil Yatakları (Mammalian Fossils Localities in Turkey)*. Mineral Research and Exploration Institute (MTA) of Turkey Report no. 10609 (in Turkish, unpublished).

SEYITOĞLU, G., SCOTT, B. C. and RUNDLE, C. C. (1992): Timing of Cenozoic extensional tectonics in west Turkey. *J. Geol. Soc. London*, 149: 533-538.