Bull. Min. Res. Exp. (2014) 149: 19-68

Bulletin of the
Mineral Research and Exploration

http://bulletin.mta.gov.tr

# NEOTECTONIC-PERIOD CHARACTERISTICS, SEISMICITY, GEOMETRY AND SEGMENTATION OF THE TUZ GÖLÜ FAULT ZONE

Akın KÜRÇER[a*] and Yaşar Ergun GÖKTEN[b]

[a] *Maden Tetkik ve Arama Genel Müdürlüğü, Jeoloji Etütleri Dairesi Başkanlığı, Yer Dinamikleri Araştırma ve Değerlendirme Koordinatörlüğü, Aktif Tektonik Araştırmalar Birimi, ANKARA*
[b] *Turgut Özal Mahallesi, 2204. Sokak, Erce Sitesi, C.1, Batıkent, ANKARA*

Keywords:
Tuz Gölü Fault Zone, Anatolia, Neotectonic, segment, seismicity

**ABSTRACT**

The Tuz Gölü Fault Zone (TGFZ) is one of the most important active intra-continental fault zones in central Anatolia. The TGFZ with nearly 200 km in length and 2-25 km in width is a NW trending, active normal fault zone with minor right-lateral strike-slip component. It extends between the north of Lake Tuz at NW and at Kemerhisar (Niğde) SE. This zone is a transition zone that separates the Central Anatolian Neotectonic Region into two-sub neotectonic regions, namely Kayseri-Sivas and Konya-Eskişehir neotectonic regions. In this study, Neotectonic-period characteristics, seismicity, geometry and segmentation of TGFZ are investigated. TGFZ is composed of a total of eleven parallel or sub-parallel geometric fault segments with length ranging from 9 to 30 km. In calculations based on empirical equations proposed for normal faults, TGFZ segments are found to generate earthquakes with maximum magnitudes of M=6.11-6.80 and during these earthquakes vertical displacements will be 0.34-1.41 m at maximum with average of 0.25-0.68 m. Fault kinematic analysis studies conducted on TGFZ showed that a NE-SW trending extensional tectonic regime is effective in the region. According to structural observations, stratigraphic relations and age data, neotectonic period for TGFZ started early Pliocene. TGFZ is a structure of NE-SW trending extensional tectonic regime that was activated by the early Pliocene. This structure borders the recent Tuz Gölü Plio-Quaternary basin to the east. By the early Pliocene, total normal slip is found 200-268 m. Based on geologic age and slip amount, average annual slip-rate on TGFZ is 0.046 mm.

## 1. Introduction

Owing to its special geotectonic setting, Turkey is one of the most active deformation regions in the eastern Mediterranean region. Neotectonic development of Turkey and its surroundings is closely associated with continental convergence resulting from collision between African-Arabian and Eurasian plates and subsequent geologic events. Neotectonic of are Turkey and nearby regions are controlled mainly by the right-lateral North Anatolian Fault System (NAFS), left-lateral East Anatolian Fault System (EAFS), Dead Sea Fault System (DSFS) and the active Aegean-Cyprus subduction zone.

As a result of progressing deformation, which is represented by a continental convergence between African-Arabian and Eurasian plates, four main neotectonic regions were developed that are separated from each other by aforementioned main structural elements. They are; East Anatolian compressional region, North Anatolian region, Western Anatolian extensional region and the Central Anatolia "Ova" province (Şengör et al., 1985). The East Anatolian compressional region has been deformed under an N-S trending compressional tectonics (Dewey et al., 1986). This region consistent with the compression direction is represented by E-W trending folds and reverse faults, NW-SE trending right-lateral, NE-SW

* *Corresponding author: Akın KÜRÇER, akin.kurcer@mta.gov.tr*

trending leftt-lateral strike-slip faults, N-S trending extensional fissures and young interplate volcanism. The Anatolian region stands for the area at north of NAFS and is represented by a series of strike-slip faults of significant reverse component. Western Anatolian extensional region which is represented by NNW-SSE trending continental extension has typical structures of E-W trending normal faults that shape horst and grabens (Şengör, 1980; Bozkurt, 2001). In central Anatolia, unparallel extensional basins (e.g. Tuz Gölü and Konya basins) bordered by oblique-slip faults are defined as “Ova” and this region is named “Central Anatolian Ova Province” (Şengör, 1980). This region is prolongation of Western Anatolian extensional region which weakens towards the east (Şengör, 1980). The Central Anatolian Ova Province also comprises the transition zone among three neotectonic regions (Dirik and Göncüoğlu 1996; Koçyiğit and Beyhan 1998; Dirik 2001; Koçyiğit and Erol 2001; Dirik and Erol 2003; Koçyiğit and Özacar 2003; Koçyiğit, 2005).

In addition to these main structures, there are secondary fault systems and fault zones that separate Anatolia into smaller blocks contributing to neotectonic development of Anatolia. Among them, left-lateral Central Anatolia Fault System, Tuz Gölü Fault Zone of oblique-slip character, İnönü-Eskişehir Fault System and Akşehir Fault Zone (Figure 1) (Dirik and Göncüoğlu, 1996; Koçyiğit and Beyhan, 1998; Dirik, 2001; Dirik and Erol, 2003; Koçyiğit, 2003; Koçyiğit and Özacar, 2003; Koçyiğit, 2005; Kürçer, 2012).

Due to its morphotectonic properties and recent micro-seismic activity, the Tuz Gölü Fault Zone (TGFZ) is one of the most important active fault zones in central Anatolia (Şaroğlu et al., 1987; Emre, 1991; Şaroğlu et al., 1992; Leventoğlu, 1994; Dirik and Göncüoğlu, 1996; Koçyiğit and Beyhan, 1998; Çemen et al., 1999; Dirik and Erol 2000; Koçyiğit, 2000; Toprak, 2000; Koçyiğit and Özacar, 2003; Özsayın and Dirik, 2007; Özmen, 2008; Kürçer, 2012; Kürçer and Gökten, 2012). TGFZ also separates the Kayseri-Sivas Neotectonic Region, which is represented by a transtensional neotectonic regime, from the Konya-Eskişehir Neotectonic Region which is represented by an extensional regime (Koçyiğit, 2000). TGFZ has been studied by several researchers regarding its potential to form a trap for oil accumulation and its effect on facies formation in the basin (Rigo de Righi and Contesini 1960; Arıkan 1975; Capraru 1977, 1991; Görür and Derman 1978; Derman 1980; Uygun 1981; Görür 1981; Uygun et al., 1982; Görür et al., 1984, 1998; Dellaloğlu and Aksu 1984; Çemen and Dirik 1992; Göncüoğlu et al., 1992, 1996; Çemen et al., 1999; Derman et al., 2000). In addition, neotectonic works were also carried out in certain parts of TGFZ (Leventoğlu 1994; Dirik and Göncüoğlu 1996; Toprak 2000). The age, geometry and nature of TGFZ are investigated by various researchers using different methods on different parts of the fault; however, results of these studies reach no agreement. Assessment of results from such works on certain parts of TGFZ considering the whole fault zone resulted in a literature chaos. In literature, issues on the age, geometry, segment structure, extent and nature of TGFZ are controversial and/or deficient.

Different ages have been proposed for TGFZ. According to some researchers, the age of TGFZ is as old as late Cretaceous (Görür and Derman 1978; Uygun et al., 1982; Görür et al., 1984; Çemen et al., 1999; Dirik and Erol 2000). Arıkan (1975) states that TGFZ is of Eocene age whilst Dellaloğlu and Aksu (1984) assert that it is Miocene in age. On the other hand, considering the recent character of TGFZ, Koçyiğit (2000) suggested that first activation of TGFZ might have postdated early Pliocene.

The character of TGFZ is also contradictive. For instance, according to Şengör et al. (1985) and Şaroğlu et al. (1987), TGFZ is a high-angle right-lateral strike slip fault with reverse component dipping to the NE which is also shown in the Active Fault Map of Turkey by Şaroğlu et al. (1992). Derman et al. (2000) asserted that TGFZ was initiated as a normal fault and then gained a left-lateral strike slip character in Eocene and changed to a normal faulting. A group of researchers (Emre, 1991; Toprak and Göncüoğlu, 1993; Dirik and Göncüoğlu, 1996; Koçyiğit and Beyhan, 1998; Toprak, 2000; Dirik and Erol, 2000; Koçyiğit, 2000), based on morphotectonic data and Çemen et al. (1999) based on seismic reflection profile, described the TGFZ in neotectonic period as a right-lateral strike-slip fault with a normal component dipping to SW which is high-angle at the surface but shows a listric character to the depth. On the other hand, Leventoğlu (1994), who studied 14-km long part of TGFZ in the Hanındağ region at SE of Şereflikoçhisar, states that fault zone is a normal fault with right-lateral strike-slip component.

It is widely accepted that TGFZ is a fault zone extending between Paşadağ at NW (north of Lake Tuz) and Bor (Niğde) at SE (Şaroğlu et al., 1987, 1992; Dirik and Göncüoğlu, 1996; Dirik and Erol,

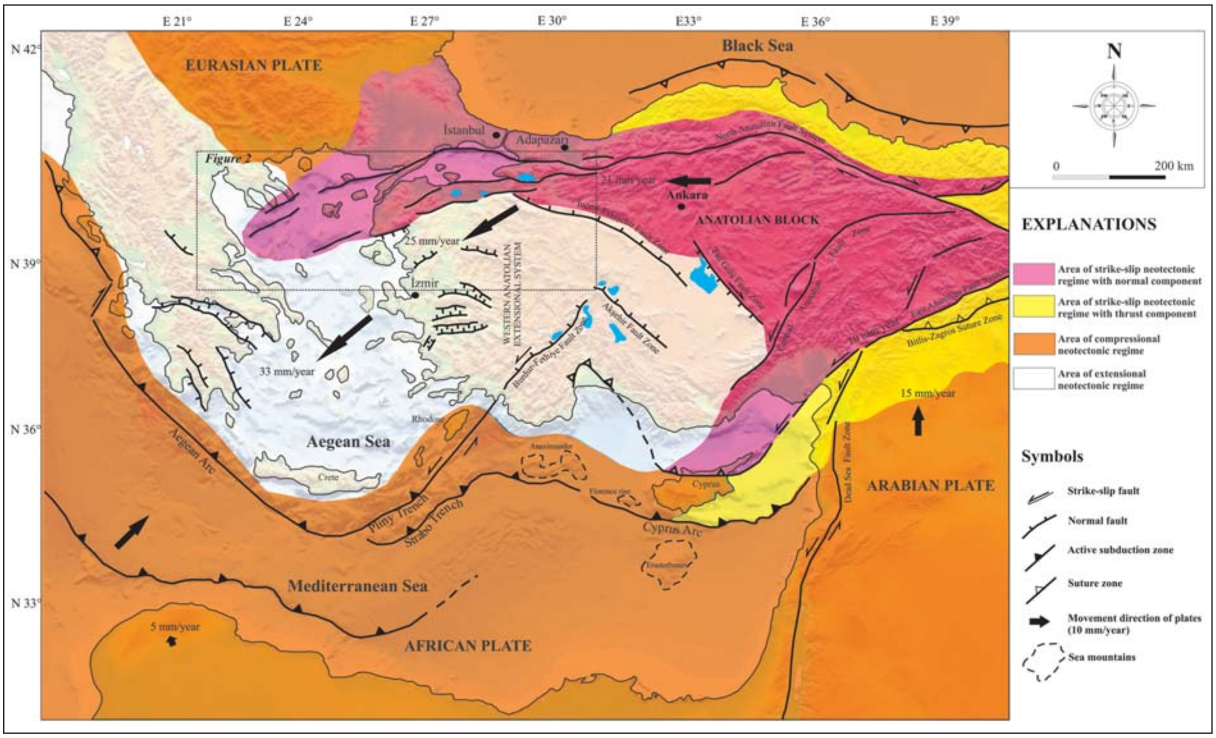


Figure 1- The main neotectonic elements and neotectonic regions in Turkey and neighboring areas (compiled by Kürçer, 2012 from Okay et al., 2000; Woodside et al., 2002; Koçyiğit and Özacar, 2003; Zitter et al., 2005; Çiftçi, 2007; Özsayın, 2007; Yolsal-Çevikbilen and Taymaz, 2012). Black arrows are GPS vectors, related numbers are GPS velocities (mm/y) (Reilinger et al., 2006). Shuttle Radar Topography Mission (SRTM) data were used for digital elevation model.

2000; Koçyiğit, 2000). On the contrary, Koçyiğit and Beyhan (1998) suggested that TGFZ extends to Çamardı (Niğde) at SE and in the area between Bor and Çamardı it gains a significant reverse character. These workers regarded the TGFZ as a strike-slip fault conjugating with left-lateral Central Anatolian Fault Zone.

In spite of studies conducted with various methods in different parts of TGFZ, a neotectonic work comprising the entire fault zone has not been performed as yet.

In this study, the age, extention, character and kinematic properties, geometry and segment structure of TGFZ and its relation to the Tuz Gölü Basin and its setting and importance in the regional neotectonic frame are discussed.

In this respect, field geology studies were conducted in an area of 250 km in length and 20 km in width. For the field study, a geological map of fault zone was constructed based on 1/5000.000 scaled Kayseri and Adana quadrangles. In addition, in two sub-areas which can elucidate the beginning of neotectonic period 1/25.000 scaled geology mapping was done. In order to manifest kinematic properties of the fault zone, detailed structural observations were made and fault plane slip data were collected. Segmentation model of TGFZ has been first described in this study and using empirical equations the largest earthquake to be generated by these segments and the largest and average displacements were calculated.

## 2. Regional Geology

In TGFZ region various rocks units with ages ranging from Paleozoic to recent time are exposed (Figure 2). Northern (east of Lake Tuz), central (around Aksaray and Hasan Dağı) and southern parts (between Niğde and Çamardı) display different tectono-stratigraphic characteristics (Figure 3a, b, c).

At north of the study area, the basement is comprised by Central Anatolian Crystalline Complex (CACC) (Göncüoğlu, 2010) which is continuation of the Anatolides in Anatolia. In the study area CACC is represented by Kaman Group Metamorphites of the Kırşehir Massif (Seymen, 1982). Above these units is the Central Anatolian Ophiolite Complex (CAOC)

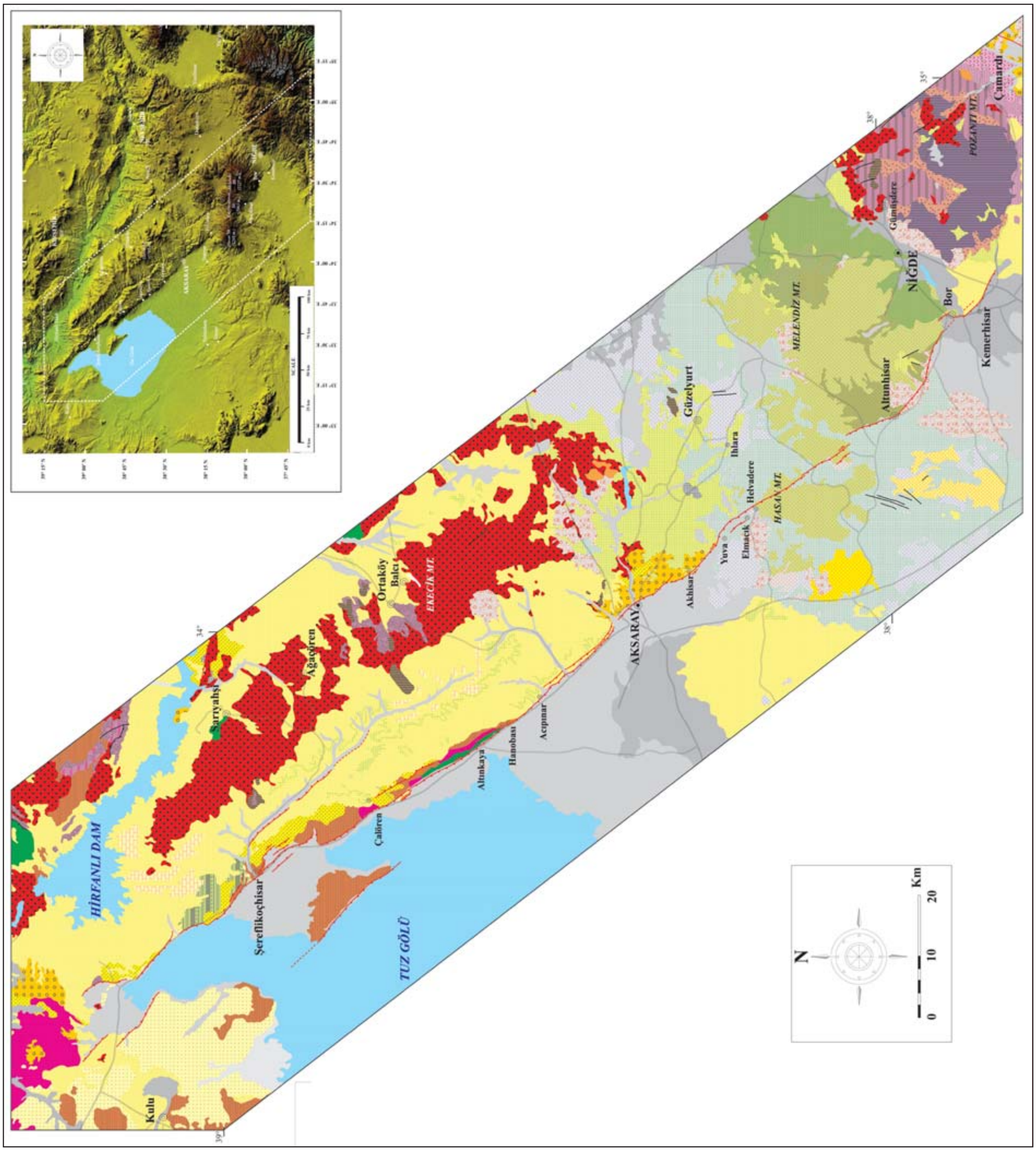


Figure 2- Geology map of the Tuz Gölü Fault Zone (compiled by Kürçer, 2012 from MTA, 2002).

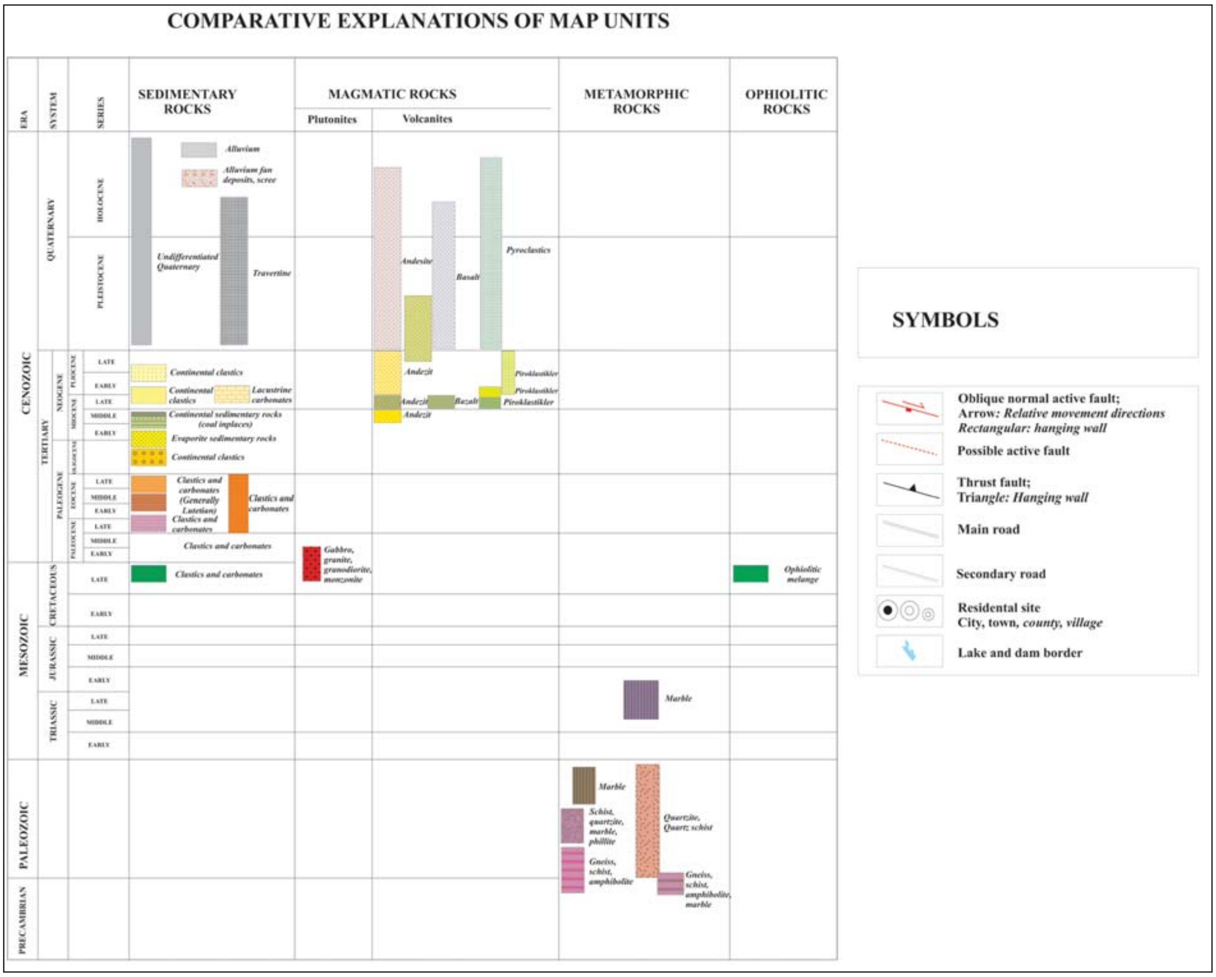


Figure 2- (continued)

(Göncüoğlu et al., 1991, 1992, 1993, 1994). CAOC is represented by accretionary prism material which is formed by the closure of İzmir - Ankara - Erzincan Ocean and obducted southwards onto the units of the Kütahya - Bolkardağ Belt (Dirik and Erol, 2000). The Kaman Group Metamorphites and Central Anatolian Ophiolite Complex are cut by late Cretaceous Ağaçören Granitoid (Kadıoğlu, 1991) which represents the Central Anatolian Granitoids consisting of collision-type granitoids and post-collisional alkalen magmatics (Göncüoğlu et al., 1991, 1992, 1993, 1994, 1996, 1997; Erler et al., 1991; Akiman et al., 1993; Türeli et al., 1993; Yalınız and Göncüoğlu, 1998; Yalınız et al., 1996, 2000; Dirik and Erol, 2000; Işık, 2009; Boztuğ et al., 2009).

The Tuz Gölü Basin was developed on CACC as a result of extensional tectonic activity in the upper Cretaceous (Dirik and Erol, 2000). In the Tuz Gölü Basin there is a sequence with thickness up to 10 km (Arıkan, 1975) deposited from late Cretaceous to recent. Sedimentation in the Tuz Gölü Basin was started with extensional tectonic activity during the upper Cretaceous and this tectonic regime was ended in the middle Eocene (Dirik and Erol, 2000). The basement of the Tuz Gölü Basin is composed of vertically and laterally transmissive Kartal formation of late Cretaceous – early Paleocene age and the Asmaboğazı formation. These formations are conformably overlain by Paleocene aged Çaldağ formation and have transitional contact with Karapınaryaylası formation of late Paleocene – early Eocene age (Dirik and Erol, 2000). The Karapınaryaylası formation concordantly passes to Eocene (Lutetian) Boyalı formation (Atabey et al., 1987). The basin which was subjected to compressional tectonism by the upper Eocene became shallow and it was disconnected to the open sea (Dirik and Erol, 2000). As a result, late Eocene – Oligocene aged Yassıpur formation consisting of clastics and thick evaporites were deposited on the

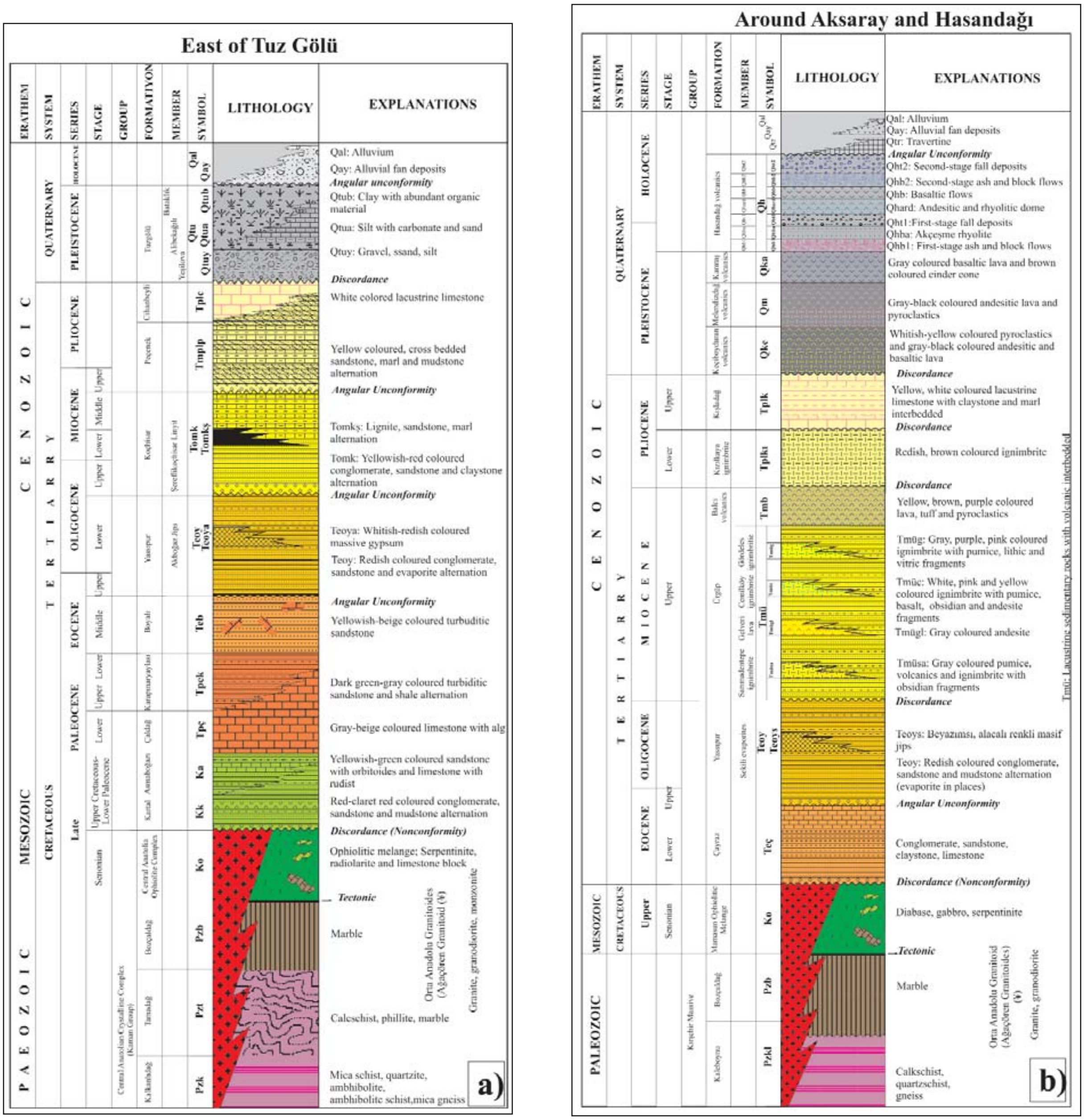


Figure 3- Generalized comparative tectonostratigraphic sections for northern, central and eastern parts of the Tuz Gölü Fault Zone region (not to scale); a) East of Lake Tuz (compiled by Kürçer, 2012 from Atabey et al., 1987; Göncüoğlu et al., 1996; Çemen et al., 1999; Dirik and Erol, 2000), b) Around Aksaray and Hasandağ (complied by Kürçer, 2012 from Dönmez et al., 2005).

Boyalı formation with an angular unconformity (Göncüoğlu et al., 1996; Çemen et al., 1999; Varol et al., 2000; Dirik and Erol, 2000). The Yassıpur formation is overlain with an angular unconformity by late Oligocene – middle Miocene Koçhisar formation of terrestrial origin that includes Şereflikoçhisar lignites (Dellaloğlu and Aksu, 1984). Following the uplift and subsequent erosion in upper Eocene-Oligocene, during lower-middle Miocene a plateau was formed in central Anatolia that covered a large area (Anatolian peneplain) (Dirik and Erol, 2000). During this period, horizontal-bedded Peçenek formation with an angular unconformity and Cihanbeyli formation that laterally and vertically interlayered with Peçenek formation were deposited on the Koçhisar formation. During the Quaternary, depending on climatic and seasonal changes and lacustrine, marsh, evaporation and arid conditions,

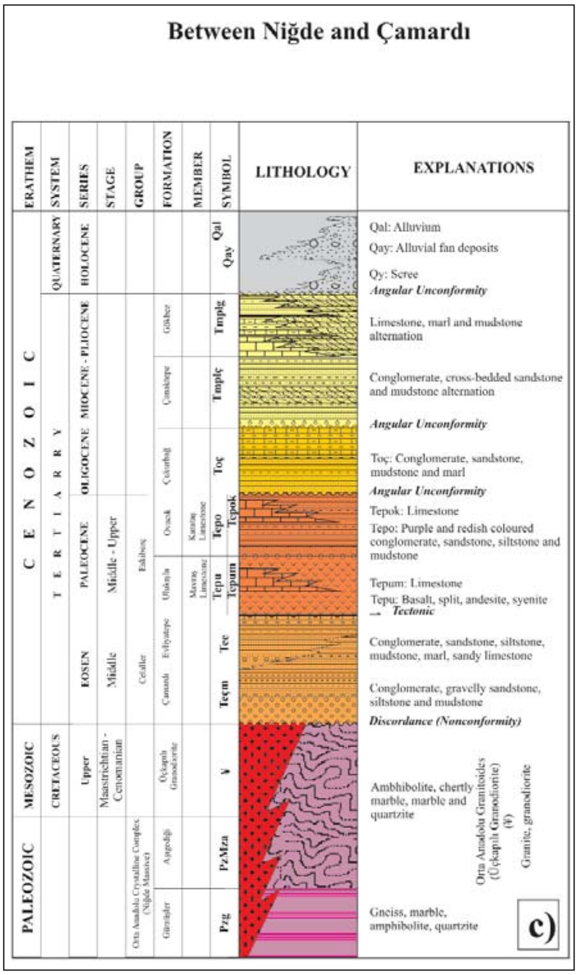


Figure 3c- Between Niğde and Çamardı (compiled by Kürçer, 2012 from Yetiş, 1978; Göncüoğlu et al., 1991; Demircioğlu and Eren, 2000; Parlar et al., 2006).

the Tuz Gölü formation was deposited in the Lake Tuz and around the surrounding areas. The most important structural elements in northern part of the study area are SW dipping fault segments of NW-SE trending TGFZ. Along these fault segments, several alluvial fan deposits are developed on downthrown blocks of the faults by the accumulation of sediments transported from ascending NE block. Alluvium formation is still continued along the margins of modern rivers and flood plains (Figure 3a).

In central part of the study area (around Aksaray and Hasan Dağı), metamorphites of the Paleozoic Kırşehir massif comprise the basement. These units are overlain by a tectonic contact by Mamasun Ophiolite Complex (Dönmez et al., 2005) which is an extension of Central Anatolian Ophiolite Complex in this region. Kırşehir massif metamorphites and Mamasun Ophiolite Complex are cut by the late Cretaceous Ağaçören Granitoid (Dönmez et al., 2005). These units are unconformably covered by Çayraz formation (Schmidt, 1960) of Eocene (Ypresian) age (Dönmez et al., 2005). The region which was subjected to compressional tectonism by the upper Eocene has become shallow and disconnected to the open sea (Dirik and Erol, 2000). During this period, late Eocene-Oligocene Yassıpur formation consisting of clastics and thick evaporites (Göncüoğlu et al., 1996; Çemen et al., 1999; Varol et al., 2000; Dirik and Erol, 2000) was unconformably deposited onto the Çayraz formation. The central part of study area comprising Aksaray and Hasan Dağ is located within the Central Anatolian Volcanic Province (CAVP). By the Miocene CAVP was formed as a result of convergence between the African-Arabian and Eurasian plates and subsequent subduction that resulted in extension of crust on the subducting lithospheric slab (Innocenti et al., 1975; Batum, 1978; Tokel et al., 1988; Toprak and Göncüoğlu, 1993). In this region various volcanic rocks are exposed with ages ranging from late Miocene to Holocene (including Holocene). Volcanites which are composed of lava, tuff and ignimbrites of the Keçikalesi, Keçiboyduran, Erciyes, Acıgöl, Göllüdağ, Melendiz and Hasan Dağı volcanism are accompanied laterally and vertically by lacustrine and terrestrial deposits. The initial deposits of this volcano-sedimentary sequence is the Ürgüp formation that is composed of terrestrial clastics, limestone, ignimbrite interlayers and andesitic lava (Pasquare, 1968). Various ignimbritic and andesitic lava levels in the Ürgüp formation are divided into four members as Sarımadentepe ignimbrite member, Gelveri lava member, Cemilköy ignimbrite member and Gördeles ignimbrite member (Dönmez et al., 2005).

The Ürgüp formation is conformably overlain by Balcı Volcanite of late Miocene age (Türkecan et al., 2003) which consists of lava, tuff and various pyroclastics. The Kızılkaya Ignimbrite which is widely exposed in central part of the study area (Beekman, 1966) is in early Pliocene age, based on radiometric age data (Innocenti et al., 1975; Schumacher and Schumacher, 1996; Le Pennec et al., 2005 Aydar et al., 2012), and unconformably overlies the older units. The Kızılkaya Ignimbrite is unconformably covered by the Kışladağ formation which is composed of lake carbonates and accepted to be late in Pliocene age because of its stratigraphic position (Dönmez et al., 2005). Quaternary volcanism was quite effective in central part of the study area. The Keçiboyduran Volcanites consisting of andesite and basaltic andesite are the first products of Quaternary volcanism (Dönmez et al., 2005). Based on radiometric age data, Keçiboyduran Volcanites are of Pleistocene age (Dönmez et al., 2005). Above the Keçiboyduran Volcanites is the Melendiz Volcanites with radiometric age of early-middle Pleistocene Miocene (Türkecan et al., 2003). All these units are overlain by late Pleistocene aged Karataş Volcanites consisting of basaltic lava and scoria cones (Ercan et al., 1990). The Hasandağ Volcanites of Holocene age are the youngest volcanic products in the study area (e.g. Ercan et al., 1990). The Hasandağ Volcanites are made of ash and block flows, fall deposits and pyroclastic flows and andesitic-basaltic lavas (Dönmez et al., 2005). In Holocene in some areas travertines and alluvial fans were formed along TGFZ and alluvium deposition still continues (Figure 3b).

In farthermost southeast part of the study area possible extents of TGFZ are investigated. In southern part of the area basement is comprised by metamorphic rocks of the Niğde Massif which represents the CACC in this region (Yetiş, 1978, Göncüoğlu et al., 1991; Demircioğlu and Eren, 2000; Parlar et al., 2006). Metamorphic rocks are cut by Cenomanian-Maastrichtian aged Üçkapılı Granodiorite (Göncüoğlu, 1977, 1982, 1985; Kuşçu et al., 1993). These basement units unconformably are overlain by Celaller Group (Göncüoğlu et al., 1991) of middle Eocene age (Parlar et al., 2006). The Celaller Group is represented from bottom to the top by Çamardı and Evliyatepe formations. The Celaller Group is tectonically (Demircioğlu and Eren, 2000) overlain by Eskiburç Group Göncüoğlu et al., 1991) of middle-late Paleocene age (Parlar et al., 2006). The Eskiburç Group is represented at the bottom by Ulukışla formation and Ovacık formation that is alternated with the Ulukışla formation (Dellaloğlu ve Aksu, 1986). These units are overlain with an angular unconformity by terrestrial Çukurbağ formation of Oligocene age (Yetiş, 1978). The late Miocene-Pliocene Çanaktepe formation which consists of conglomerate, cross-bedded sandstone and mudstone alternation (Atabey and Ayhan, 1986) and the alternating Gökbez formation cover all the older units with an angular unconformity (Demircioğlu and Eren, 2000). Quaternary alluvial fan deposits and alluvium unconformably set above all the units (Figure 3c).

## 3. Segmentation of the Tuz Gölü Fault Zone and fault kinematic analysis studies on these segments

TGFZ with nearly 200 km in length and 2-25 km in width is a NW-SE trending, SW-dipping, active normal fault with right-lateral strike-slip component. It extends between the north of Lake Tuz at NW and Kemerhisar (Niğde) at SE (Figure 4). Sub-parts of a fault which can be separated from each other based on certain criteria are called segment.

Fault segments are categorized into five groups as (dePolo vd., 1989, 1991; McCalpin, 2009 compiled from Knuepfer, 1989);

- Earthquake segment
- Behavioral segment
- Structural segment
- Geologic segment
- Geometric segment

The earthquake segment represents fault sections which are limited by historical earthquake ruptures. The behavioral segment is a segmentation model that can be propounded as a result of paleoseismic studies. For this, earthquake information is needed that is well dated with multi-trench works. In order to apply behavioral segmentation, slip rate changes in segment borders should be well described and recurrence interval of earthquakes on different segments must be defined as much as possible. The structural segment explains fault sections that are interrupted by other faults, folds or structures perpendicular or transverse to the segment direction. The geologic segment may localize Quaternary basins, or volcanic terrains, only one metamorphic basement or unit. The geologic segments may also be localized some geophysical anomalies. In some cases, considering the geomorphologic characteristics geologic segment may be defined. The geometric segment may be described by changes in fault direction, jumps in fault branches, splits and gaps.

In this study, geometric segment model was applied to TGFZ. In this model, TGFZ is composed of parallel or sub-parallel 11 geometric fault segments with length ranging from 9 to 30 km (Figure 4 and Table 1). These segments are separated from each other by changes in fault direction, gradual jumps, step-overs and other geologic structures. According to surface geology data, lithology is the main factor controlling the start and end points of segments.

Although slip data on fault plane for certain parts of TGFZ are presented in previous studies (Leventoğlu, 1994; Toprak, 2000), such data are not sufficient to delineate kinematic properties of the

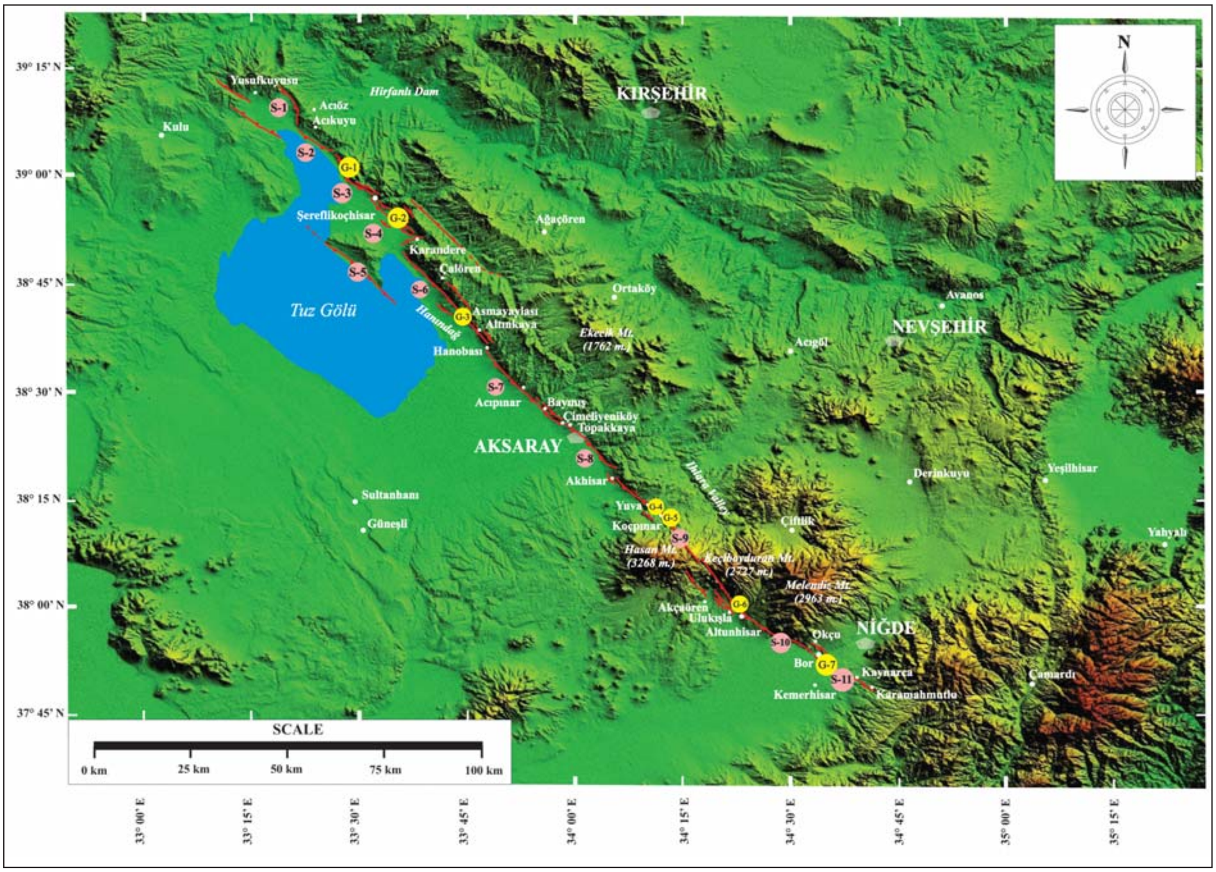


Figure 4- Positions of segments of the Tuz Gölü Fault Zone on the digital elevation model for the region (Kürçer, 2012). S-1/11 are segment numbers, G-1/7 are the structural observation points (see table 1 for coordinate information).

Table 1- Segments of the Tuz Gölü Fault Zone and their general characteristics.

| Segment number | Segment name | Segment length (km) | Segment direction |
|---|---|---|---|
| S - 1 | Yusufkuyusu | 9 | N 40° W / N-S |
| S - 2 | Acıkuyu | 10 | N 50° W |
| S - 3 | Akboğaz | 13 | N 30° W / N 40° W |
| S - 4 | Şereflikoçhisar | 14 | N 45° W |
| S - 5 | İnceburun | 23 | N 40° W |
| S - 6 | Tuz Gölü | 30 | N 35° W |
| S - 7 | Acıpınar | 26 | N 45° W |
| S - 8 | Aksaray | 13 | N 32° W |
| S - 9 | Akhisar-Kılıç | 27 | N 25° W / N 30° W |
| S - 10 | Altunhisar | 30 | N 30° W / N 70° W |
| S - 11 | Bor | 17 | N-G / N 55° W |

fault zone as whole. In order to fill this deficiency fault plane slip data were collected on 7 structural observation points on various segments of TGFZ (Tables 2 and 3). At these stations, a total of 32 fault planes, slickenlines and rake were measured. Data collected from each measurement point are evaluated separately and principal stress axes for each point are shown on six different hemispheric equal area projection nets.

Table 2- Information on observation sites along the Tuz Gölü Fault Zone where kinematic analysis were made.

| **Station code and name** | **Quadrangle no and coordinates (UTM)** | **Formation** | **Age** |
|---|---|---|---|
| G-1 Şereflikoçhisar | K 30 b2<br>542303 E - 4315245 N | Boyalı formation (Teb) | Middle Eocene |
| G-2<br>Deldah Düzü | K 31 a1<br>551800 E - 4308650 N | Yassıpur formation Akboğaz Gypsum Member (Teoya) | Upper Eocene – Lower Oligocene |
| G-3<br>Amayaylası | K31 c1<br>566270 E - 4278286 N | Asmaboğazı formation (Ka) | Upper Cretaceous – Lower Paleocene |
| G-4<br>Yuva | L 32 d2<br>601450 E – 4234000 N<br>601984 E – 4233726 N | Hasan Dağı volcanics<br>First-stage ash and block flows (Qhb1) | Quaternary |
| G-5<br>Koçpınar | L32 d2<br>604694 E- 4231266 N<br>606111 E - 4228966 N | Hasan Dağı volcanics<br>First-stage ash and block flows (Qhb1) | Quaternary |
| G-6<br>Altunhisar | L32 c4<br>619831 E - 4208270 N | Hasan Dağı volcanics<br>First-stage fall deposits (Qht1) | Quaternary |
| G-7<br>Bor | M33 a1<br>637592 E - 4193282 N | Gökbez formation | Upper Miocene - Pliocene |

Table 3- Fault plane slip data collected from stations.

| **Station name and no** | **Strike** | **Dip angle (°)** | **Dip direction** | **Rake (°)** | **Fault type** |
|---|---|---|---|---|---|
| Station A (Şereflikoçhisar) | K 70 B | 71 | SW | 78 | Normal fault with right-lateral strike-slip component |
| | K75 B | 78 | SW | 80 | Normal fault with right-lateral strike-slip component |
| | K 74 B | 75 | SW | 77 | Normal fault with right-lateral strike-slip component |
| | K 65 B | 67 | SW | 70 | Normal fault with right-lateral strike-slip component |
| | K 55 B | 73 | SW | 76 | Normal fault with right-lateral strike-slip component |
| Station B (Deldah Düzü) | K 40 B | 70 | SW | 88 | Normal fault with right-lateral strike-slip component |
| | K42 B | 74 | SW | 84 | Normal fault with right-lateral strike-slip component |
| | K 38 B | 79 | SW | 75 | Normal fault with right-lateral strike-slip component |
| | K 42 B | 81 | SW | 78 | Normal fault with right-lateral strike-slip component |
| | K 39 B | 78 | SW | 90 | Pure normal fault |
| Station C (Asmayaylası) | K 44 B | 54 | SW | 38 | Right-lateral strike-slip fault with normal component |
| | K36 B | 47 | SW | 23 | Right-lateral strike-slip fault with normal component |
| | K 40 B | 56 | SW | 37 | Right-lateral strike-slip fault with normal component |
| | K 42 B | 55 | SW | 32 | Right-lateral strike-slip fault with normal component |
| Station D (Yuva) | N 37 W | 71 | SW | 78 | Normal fault with right-lateral strike-slip component |
| | N 52 W | 68 | SW | 68 | Normal fault with right-lateral strike-slip component |
| | N 50 W | 71 | SW | 85 | Normal fault with right-lateral strike-slip component |
| | N 46 W | 70 | SW | 79 | Normal fault with right-lateral strike-slip component |
| Station E (Koçpınar) | N 35 W | 61 | SW | 84 | Normal fault with right-lateral strike-slip component |
| | N 35 W | 65 | SW | 81 | Normal fault with right-lateral strike-slip component |
| | N 38 W | 67 | SW | 85 | Normal fault with right-lateral strike-slip component |
| | N 35 W | 68 | SW | 83 | Normal fault with right-lateral strike-slip component |
| | N 30 W | 74 | SW | 78 | Normal fault with right-lateral strike-slip component |
| | N 26 W | 79 | SW | 75 | Normal fault with right-lateral strike-slip component |

Table 3- (continued)

| Station name and no | Strike | Dip angle (°) | Dip direction | Rake (°) | Fault type |
|---|---|---|---|---|---|
| Station F (Altunhisar) | N 40 W | 65 | SW | 90 | Pure Normal fault |
| | N50 W | 84 | SW | 85 | Normal fault with right-lateral strike-slip component |
| | N 70 W | 75 | SW | 88 | Normal fault with right-lateral strike-slip component |
| | N 60 W | 70 | SW | 90 | Pure Normal fault |
| | N 15 W | 61 | NE | 86 | Normal fault with right-lateral strike-slip component |
| | N 14 W | 69 | NE | 84 | Normal fault with right-lateral strike-slip component |
| Station G (Bor) | N 10 W | SW | SW | 80 | Normal fault with left-lateral strike-slip component |
| | N12 W | 82 | SW | 87 | Normal fault with right-lateral strike-slip component |
| | N 10 W | 81 | SW | 90 | Pure Normal fault |
| | N 16 W | 78 | SW | 87 | Normal fault with right-lateral strike-slip component |

For kinematic analysis of fault assemblages, single-plane solution (Marshak and Mitra, 1988) was used. For this, from fault planes measured at each station the measurement that is thought to represent station of interest was chosen and that plane was evaluated with the single-plane solution model of Marshak and Mitra (1988) to determine the principal stress axes (Table 4).

3.1. Yusufkuyusu segment (S-1)

The Yusufkuyusu segment with length of 9 km is the farther northwesternmost segment of TGFZ. It extends between the Yusufkuyusu village and NE corner of TGFZ (Figure 4). The Yusufkuyusu segment makes the contact between late Miocene-Pliocene Peçenek formation (Tmplp) and Quaternary alluvial deposits at east of Yusufkuyusu village. In this area fault strike is N40°W. In a narrow area at west of Acıöz village, the fault comprising the boundary between the alluvium and metamorphites of the Tamadağ formation (Pzt) that are a part of CACC bends towards the south. It extends nearly N-S between the northwest of Acıöz and northeastern corner of Lake Tuz where the Akboğaz Gypsum Member of the late Eocene-early Oligocene Yassıpur formation (Teoya) and the alluvium are in contact (Figure 2).

3.2. Acıkuyu segment (S-2)

The Acıkuyu segment starts from the NE corner of Lake Tuz and extends towards the Kocadere creek at SE. The segment with length of 10 km is mostly exposed parallel to the Ankara-Adana state highway (Figure 4). The fault in N50°W direction comprises the border at NW between the Akboğaz Gypsum Member of the late Eocene-early Oligocene Yassıpur formation (Teoya) and the alluvium and also the border at SE between late Miocene-Pliocene Peçenek formation (Tmplp) and the Quaternary alluvium (Figure 2).

3.3. Akboğaz segment (S-3)

The Akboğaz segment with length of 13 km extending between the south of Kocadere creek and the north of Şereflikoçhisar is composed of two parts (Figure 4). The northern part of Akboğaz segment that extends in N30°W direction comprises the area between Kocadere creek and Gökhöyük hill where it makes the boundary between late Oligocene – middle Miocene Koçhisar formation (Tomk) and the Quaternary alluvium (Figures 2 and 5a). Around the Gökhöyük hill the fault bends to the right and continues 10 km in SE direction with strike of N45°W and reaches at north of Şereflikoçhisar. In this area, it forms the contact between late Eocene-early Oligocene Yassıpur formation (Teoya) and the alluvium and then the contact between middle Eocene Boyalı formation (Teb) and Quaternary alluvium (Figure 6a).

The roadcut at 7 km NW of Şereflikoçhisar is the first observation site where the fault plane on TGFZ is exposed from NW (station 1 in Figure 5a). At this site, middle Eocene Boyalı formation (Teb) and Quaternary scree come across along the Akboğaz segment (Figures. 5a and 6a). Although we have no direct evidence on that if the Quaternary scree have been affected by the fault, regarding formation mechanics, it is expected that scree at the beginning might have smeared to the slope with angle of 15 to 17°. However, at station 1 scree rests against the fault

Table 4- Fault planes and slickenlines measured at all stations and principal stress axes acquired from selected measurements. Measurements with bold character are those used for single-plane solution.

| Station | Unit | Age | Measurement no | Strike (°N) | Dip angle / direction (°) | Rake (°) | Fault type | Principle stress axes |
|---|---|---|---|---|---|---|---|---|
| A | Boyalı fm | Middle Eocene | **1** | **290** | **71 S** | **78 W** | **Normal** | α1= 343° / 75° α2= 110° / 10° α3= 205° / 10° |
| | | | 2 | 285 | 78 S | 80 W | Normal | |
| | | | 3 | 284 | 75 S | 77 W | Normal | |
| | | | 4 | 295 | 67 S | 70 W | Normal | |
| | | | 5 | 305 | 73 S | 76 W | Normal | |
| B | Yassıpur fm Akboğaz Gypsum Member | Oligo-Miocene | 1 | 320 | 70 S | 88 W | Normal | α1= 026° / 74° α2= 140° / 06° α3= 232° / 14° |
| | | | **2** | **318** | **74 S** | **84 W** | **Normal** | |
| | | | 3 | 322 | 79 S | 75 W | Normal | |
| | | | 4 | 318 | 81 S | 78 W | Normal | |
| | | | 5 | 321 | 78 S | 89 W | Normal | |
| C | Asmaboğazı fm | Upper Cretaceous-Lower Paleocene | 1 | 316 | 54 S | 38 W | Right Latoral | α1=170°/ 07° α2= 254° / 49° α3= 070° /43° |
| | | | 2 | 324 | 47 S | 23 W | Right Latoral | |
| | | | 3 | 320 | 56 S | 37 W | Right Latoral | |
| | | | **4** | **318** | **55 S** | **32 W** | **Right Latoral** | |
| D | Hasandağ Volkanics | Quaternary | 1 | 323 | 71 S | 78 W | Normal | α1= N-S° / 75° α2= 137° / 10° α3= 230° / 10° |
| | | | 2 | 308 | 68 S | 68 W | Normal | |
| | | | 3 | 310 | 71 S | 85 W | Normal | |
| | | | **4** | **314** | **70 S** | **79 W** | **Normal** | |
| E | Hasandağ Volkanics | Quaternary | 1 | 325 | 61 S | 84 W | Normal | α1= 020° / 80° α2= 147°/ 08° α3= 240°/ 08° |
| | | | 2 | 325 | 65 S | 81 W | Normal | |
| | | | 3 | 322 | 67 S | 85 W | Normal | |
| | | | **4** | **325** | **68 S** | **83 W** | **Normal** | |
| F | Hasandağ Volkanics | Quaternary | 1 | 350 | 80 W | 80 N | Normal | α1= 075° / 67° α2= 167° / 03° α3= 260° / 23° |
| | | | **2** | **348** | **82 W** | **87 N** | **Normal** | |
| | | | 3 | 350 | 81 W | 89 N | Normal | |
| | | | 4 | 346 | 78 W | 87 N | Normal | |
| | | | 5 | 345 | 61 E | 86 S | Normal | |
| | | | 6 | 46 | 69 E | 84 S | Normal | |
| G | Gökbez fm | Upper Miocene-Pliocene | 1 | 350 | 80 W | 80 S | Normal | α1= 059° / 66° α2= 168 / 08° α3=260 / 22° |
| | | | **2** | **348** | **82 W** | **82 N** | **Normal** | |
| | | | 3 | 350 | 81 W | 81 N | Normal | |
| | | | 4 | 344 | 78 W | 78 N | Normal | |

in horizontal position (Figure 6b). In this case, it can be thought that the scree has gained its present state depending on the movement of Akboğaz segment later than its formation. The Akboğaz segment of TGFZ that controls the recent morphology is thought to be active.

Fault plane solutions at station 1 on the Akboğaz segment (Şereflikoçhisar station – G-1) showed that the Akboğaz segment is a normal fault with a minor right-lateral strike-slip component (Figure 6c; Table 3).

At station 1 (Şereflikoçhisar station) a total of 5 fault planes and slickenlines were measured. Among these measurements, measurement no.1 which is thought to best represent the station 1 was solved in accordance with Marshak and Mitra (1988) and then principal stress axes were found (Table 4; Figure 5b).

### 3.4. Şereflikoçhisar segment (S-4)

The 14-km part of TGFZ in the area between Şereflikoçhisar and Karandere village is called Şereflikoçhisar segment (Figure 4). The Şereflikoçhisar segment is composed of a main branch and a few fault sections parallel to this main branch (Figures 4 and 7a). The main branch extends in N45°W between the north of Şereflikoçhisar and Karandere village. From the north of Şereflikoçhisar,

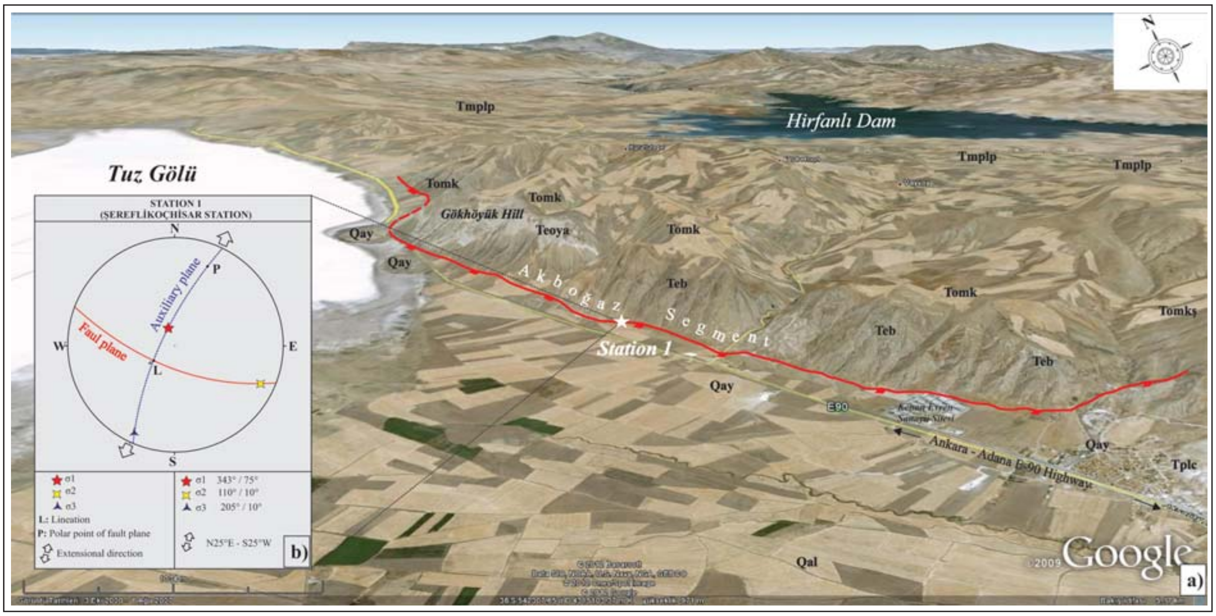


Figure 5- Google Earth view of the Akboğaz segment (vertical scale three times exaggerated, view to NE with oblique angle). Teb: Boyalı for., Tomk: Koçhisar for., Tomkş: Şeferlikoçhisar lignite member, Tmplp: Peçenek for., Tpcl: Cihanbeyli for., Qal: Alluvium, Qay: Alluvial fan, Station 1: Structural observation point on the Akboğaz segment (Şeferlikoçhisar station); b) Presentation on the lower hemisphere of Schmidt net projection of single-plane solution of fault plane no 1 measured at Station 1 (Şereflikoçhisar station) in accordance with Marshak and Mitra (1988). The arrow on the fault plane shows the relative movement direction of hanging wall.

it comprises the boundary between late Pliocene Cihanbeyli formation (Tplc) and Quaternary alluvial deposits and around Şereflikoçhisar and its near south it makes the contact between the middle Eocene Boyalı formation (Teb) and Quaternary alluvium. From the south of Şereflikoçhisar, fault enters to the alluvium Deldah Düzü site and the fault reappears from the NW of Karandere where it follows the contact between Akboğaz Gypsum Member (Teoya) of the late Eocene-early Oligocene Yassıpur formation and the alluvium. Around the Karandere village, Şereflikoçhisar segment is transferred to the Tuz Gölü segment via E-W trending Karandere normal fault of nearly 4 km in length (Figure 7a).

In the area between Şereflikoçhisar and Karandere village, another fault that extends parallel to the main branch of TGFZ surrounds to the east the Deldah Düzü site at SE of Şereflikoçhisar (Figure 7a). The fault in this area is called as eastern branch of Şereflikoçhisar segment. In this section, fault is observed in N45°W direction along a length of 4 km and it makes the contact between Akboğaz Gypsum Member (Teoya) of the late Eocene-early Oligocene Yassıpur formation and the alluvium.

Station 2 is the only measurement site where structural properties of TGFZ on the eastern branch of Şereflikoçhisar segment can be observed (Figure 7a). At this site, all structural properties of TGFZ were examined in an operated gypsum quarry in the Akboğaz Gypsum Member (Teoya) of Yassıpur formation (Figure 8).

Fault plane measurements at station 2 on the eastern branch of Şereflikoçhisar segment indicated that this segment is a normal fault with a minor right-lateral strike-slip component (Figure 8b, c, d; Table 3). Brecciated zone of about 1 m thickness and, in front of that, 30 cm-thickened fault gouge are observed on the fault plane (Figure 8e).

In previous studies on segment structure of Şereflikoçhisar part of TGFZ different arguments were propounded. For example, in Active Fault Map of Turkey by Şaroğlu et al. (1992), the area between NW Şereflikoçhisar (Kocadere) of Tuz Gölü Fault Zone and Karamandere village is taken as a single segment of 38 km in length extending in NW-SE direction (Şaroğlu et al., 1992). In Kayseri quadrangle of the 1/500.000 scaled Turkey Geology Map (MTA, 2002), interested part of Tuz Gölü Fault is shown as a 74-km long continuous segment extending from the north of Şereflikoçhisar to the Baymış village around Aksaray at SE. However, Koçyiğit (2000) states that TGFZ from south of Şereflikoçhisar first jumps to left

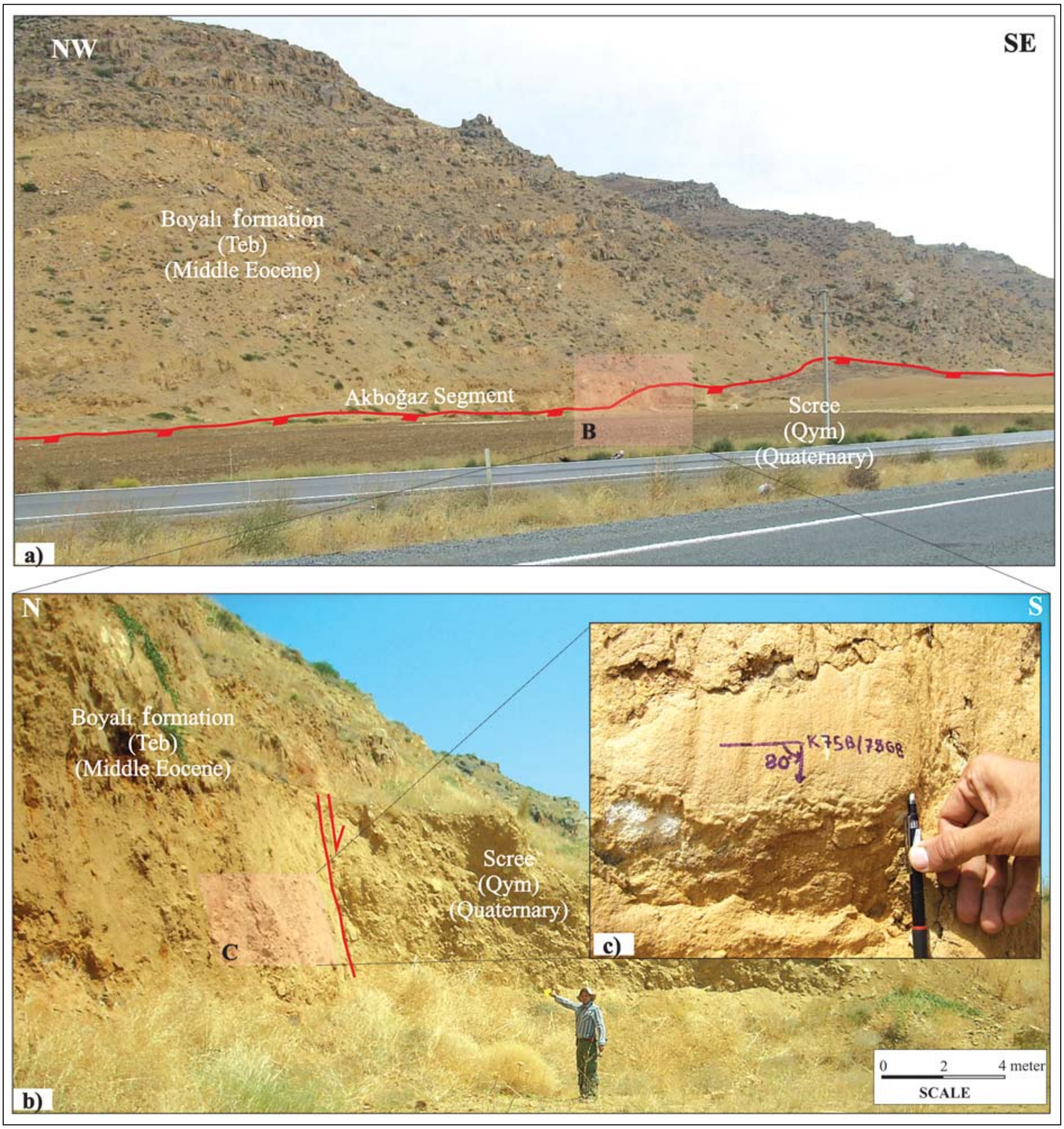


Figure 6- a) General view, b) close view of the Akboğaz segment that brings the middle Eocene Boyalı formation (Teb) and Quaternary talus deposit side-by-side at station 1 (K 30 b2 quadrangle; 542303 E – 4315245 N) and c) close view of fault plane.


Figure 7- Google Earth view of the Şeferlikoçhisar segment (vertical scale three times exaggerated, view to NE with oblique angle). Teb: Boyalı for., Teoya: Akboğaz Gypsum Member of the Yassıpur Formation, Tomkş: Şeferlikoçhisar lignite member, Tmplp: Peçenek for., Tpcl: Cihanbeyli for., Qtub: Bataklık Member of the Tuz Gölü formation, Qal: Alluvium, Station 1: Structural observation site on eastern branch of the Şeferlikoçhisar segment (Deldah düzü station), A-B: High Resolution Seismic Reflection Profile Line, TG-1: TPAO (1975) borehole location; b) Presentation on the lower hemisphere of Schmidt net projection of single-plane solution of fault plane no 2 measured at Station 2 (Deldah düzü station) in accordance with Marshak and Mitra (1988). The arrow on the fault plane shows the relative movement direction of hanging wall.

and then to right thus forming compressional and extensional structures specific to strike-slip faults.

In order to resolve literature chaos regarding Şereflikoçhisar part of TGFZ, two-dimensional high resolution seismic reflection profile work was conducted along a line of 7-km long (Kürçer, 2012; Kürçer et al., 2012) (for location of profile line see Figure 7a). The Şereflikoçhisar Two-Dimensional High Resolution Seismic Reflection Profile Section was integrated with well log of Turkish Petroleum Corporation (TPAO) (1975) and regional geology information and then evaluated (Kürçer, 2012; Kürçer et al., 2012) (Figures 9 and 10).

The Şereflikoçhisar segment was mapped based on surface geology information and geophysical data obtained from high resolution seismic reflection profile shown in figure 10 as well.

At station 2 (Deldah düzü station) a total of 5 fault planes and slickenlines were measured. Among them, measurement no 2 which is thought to best represent the station 2 was solved in accordance with Marshak and Mitra (1988) and then principal stress axes were found (Table 4; Figure 7b).

### 3.5. İnceburun segment (S-5)

N40°W trending 23-km long fault that morphologically surrounds the Şereflikoçhisar peninsula from SW is called as İnceburun segment (Figures 4 and 11). The İnceburun segment comprises the border between middle Eocene Boyalı formation (Teb) and alluvium deposits and causes morphologically uplift of Boyalı formation within the Tuz Gölü depression area (Figure 11).

The Tuz Gölü is divided into two sub-regions as shallow main lake region and deep region that are represented by different hydrochemical properties (Uygun and Şen, 1978) (Figure 11). The shallow main lake region has a depth of about 60-80 cm whilst deep region is a depth of 1.5-2 m (Uygun and Şen, 1978). The İnceburun segment is a barrier separating these two sub-regions. The deep region on rising foot wall of the İnceburun segment is at the same time on the hanging wall of the Tuz Gölü segment. Jointly operation of Tuz Gölü and İnceburun segments has given rise to deep region to deepen towards northeast (back tilting) and gain its recent morphology (Figure 11).


Figure 8- a) General view of the eastern branch of Şeferlikoçhisar segment that brings the Akboğaz Gypsum Member (Teoya) of the late Eocene-early Oligocene Yassıpur formation and alluvium side-by-side at station 2 (K 31 a1 quadrangle; 551800 E – 4308650 N), b) and c) general views of fault plane, d) close view of fault plane, e) fault breccia and fault gouge.

### 3.6. Tuz Gölü segment (S-6)

The Şereflikoçhisar segment which is transferred to the west from the Karandere village via an E-W extending normal fault of about 4 km-long (Karandere fault, see Figure 7a) extends 30 km from this point to the north of Hanobası in SE direction with strike of N35°W (Figure 12a). This part of TGFZ is called as Tuz Gölü segment (Figure 12a). In the part from NW starting point to the NW of Çalören village (Mezgit), the Tuz Gölü segment comprises the contact between middle Eocene Boyalı formation (Teb) and alluvial deposits and partly cuts alluvial fan deposits. The fault which cuts limestones of the early Paleocene Çaldağ formation (Tpç) from NW of Çalören village follows the contact between limestones and alluvium and cuts alluvial fan deposits to some extent. In the part from SW of Çalören to the north of Hanındağ, it comprises the contact between middle Eocene Boyalı formation and alluvial fan deposits and partly cuts alluvial fan deposits. At station 3 shown in figure 12a, the Tuz Gölü segment cuts an alluvial fan and this fan uplifted by fault (Figure 12c).

At east of Hanındağ, the Tuz Gölü segment brings the Boyalı formation (Teb) and Pliocene Peçenek formation side by side. Southwestern margin of Hanındağ Uplift where sandstones of the Boyalı formation are exposed is surrounded by a SW-dipping, N55ºW trending fault of about 5-km in length. The Hanındağ Fault which is sub-parallel to the Tuz Gölü segment has been appraised within the scope of Tuz Gölü segment.

In the part from SE of Hanındağ to the Asmayaylası village, the Tuz Gölü segment mostly

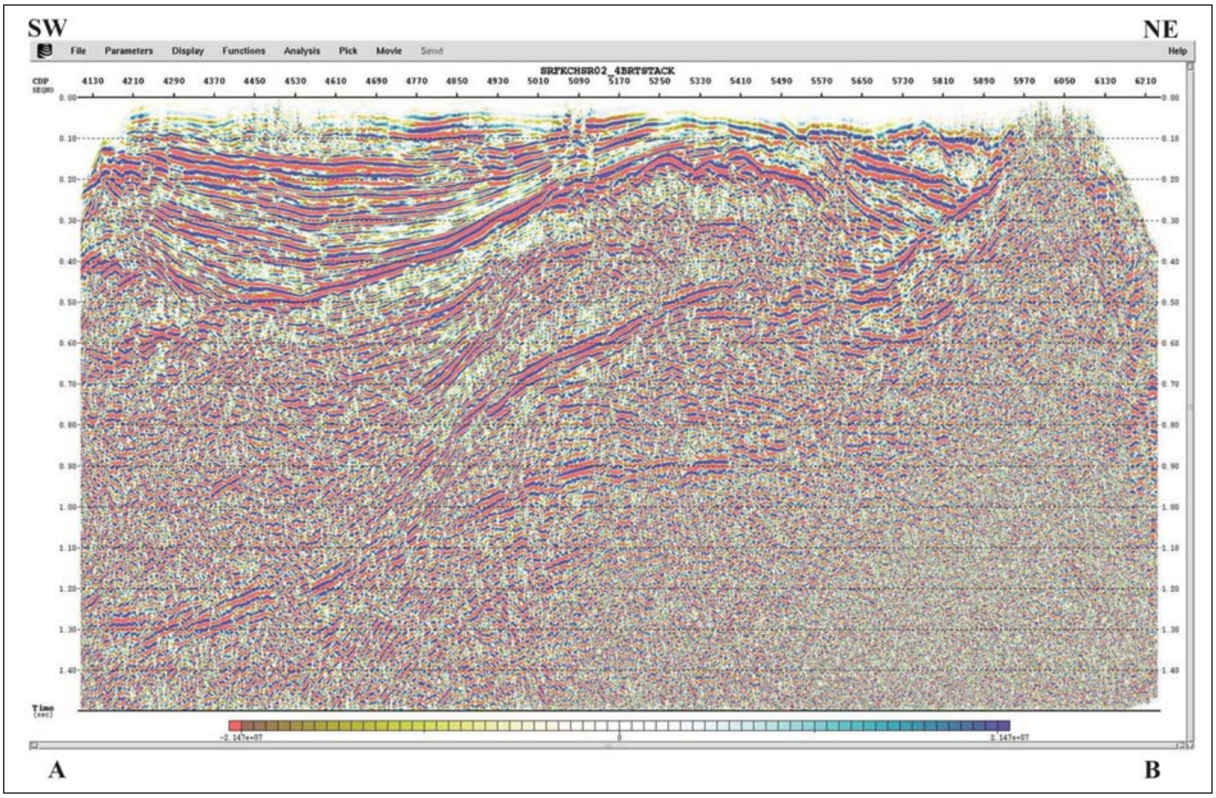


Figure 9- Migrated Two-Dimensional High Resolution Shallow Seismic Reflection Profile final section (with no geologic interpretation) taken in SW-NE direction at south of Şeferlikoçhisar (see figure 7a for profile location).

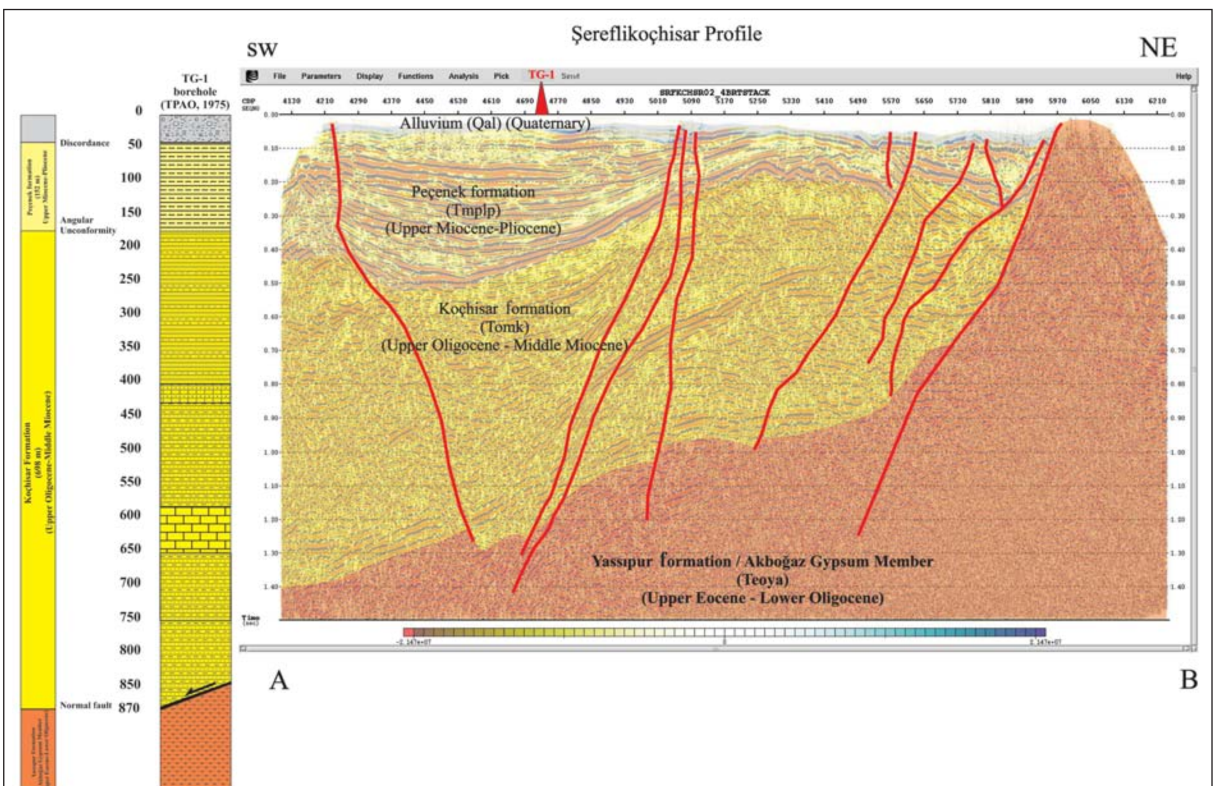


Figure 10- Migrated Two-Dimensional High Resolution Shallow Seismic Reflection Profile final section (interpreted) taken in SW-NE direction at south of Şeferlikoçhisar (see figure 7a for profile location).

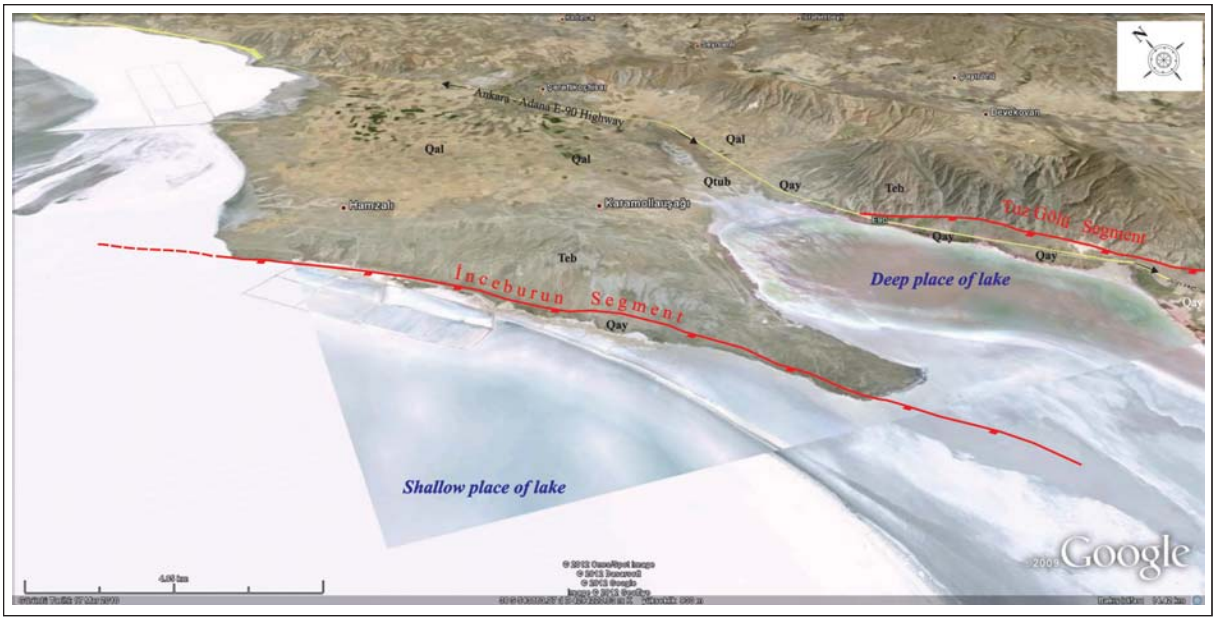


Figure 11- Google Earth view of the İnceburun segment (vertical scale three times exaggerated, view to NE with oblique angle). Teb: Boyalı Fm, Qtub: Bataklık Member of the Tuz Gölü formation, Qal: Alluvium, Qay: Alluvial fan.


Figure 12- a) Google Earth view of the Tuz Gölü segment (vertical scale three times exaggerated, view to NE with oblique angle). Kk: Kartal fm., Ka: Asmaboğazı fm, Tç; Çaldağ fm, Teb: Boyalı fm, Teoya: Akboğaz Gypsum Member of the Yassıpur fm, Teomk: Koçhisar fm, Tmplp: Peçenek fm, Tpcl: Cihanbeyli fm, Qtuy: Yeşilova Member of the Tuz Gölü formation, Qtub: Bataklık Member of the Tuz Gölü formation, Qal: Alluvium, Qay: Alluvial fan, Stations 3 and 4: structural observation sites on the Tuz Gölü segment; b) Presentation on the lower hemisphere of Schmidt net projection of single-plane solution of fault plane no 4 measured at Station 4 (Asmayaylası station) in accordance with Marshak and Mitra (1988). The arrows on the fault plane show the relative movement direction of hanging wall; c) An alluvial fan (Qay) cut by the Tuz Gölü segment at station 3 (K 31 a3 quadrangle; 558393 E – 4289644

cuts the alluvial fan deposits whilst in the Asmayaylası village it cuts units of the late Cretaceous-early Paleocene Asmaboğazı formation. At station 4 shown in Figure 12a (Asmaboğazı station), fault plane of Tuz Gölü segment is clearly observed in limestone level of the Asmaboğazı formation (Figure 13).

Fault plane solutions at station 4 (Asmayaylası station) showed that the Tuz Gölü segment is dominated by a right-lateral strike-slip component (Figure 13b and c; table 3).

At station 4 (Asmayaylası station) a total of 4 fault planes and slickenlines were measured. Among them, measurement no 4 which is thought to best represent the station 4 was solved in accordance with Marshak and Mitra (1988) and then principal stress axes were found (Table 4; figure 12b).

3.7. Acıpınar segment (S-7)

The Acıpınar segment is separated from the Tuz Gölü segment with a 500 m right step-over at north of Hanobası (Figure 12a). The Acıpınar segment with length of 26 km extends in N45°W direction between Hanobası and Çimeliyeniköy (north of Aksaray) (Figures 4 and 14). The segment which mostly forms the boundary between late Oligocene – middle Miocene Koçhisar formation (Tomk) and alluvial sediments, in a limited area between Baymış and Çimeliyeniköy, cuts the late Miocene-Pliocene Peçenek formation of terrestrial character with a secondary fault section that is parallel to the main fault (Figure 14a). Structural observations on Acıpınar segment of TGFZ are limited to station no 5 (Figure 14a). In an area within the Baymış village late Miocene-Pliocene Peçenek formation (Tmplp) is cut by the Acıpınar segment (Figures 14b and c).

3.8. Aksaray segment (S-8)

TGFZ which jumps 600 m to the left from the south of Çimeliyeniköy, crosses the city center of Aksaray in NW-SE direction and extends to the north of Akhisar village. Nearly N32°W extending 13-km long part of the fault is called Aksaray segment (Figures 4 and 15). In this area, the Aksaray segment forms the contact between terrestrial clastics of the

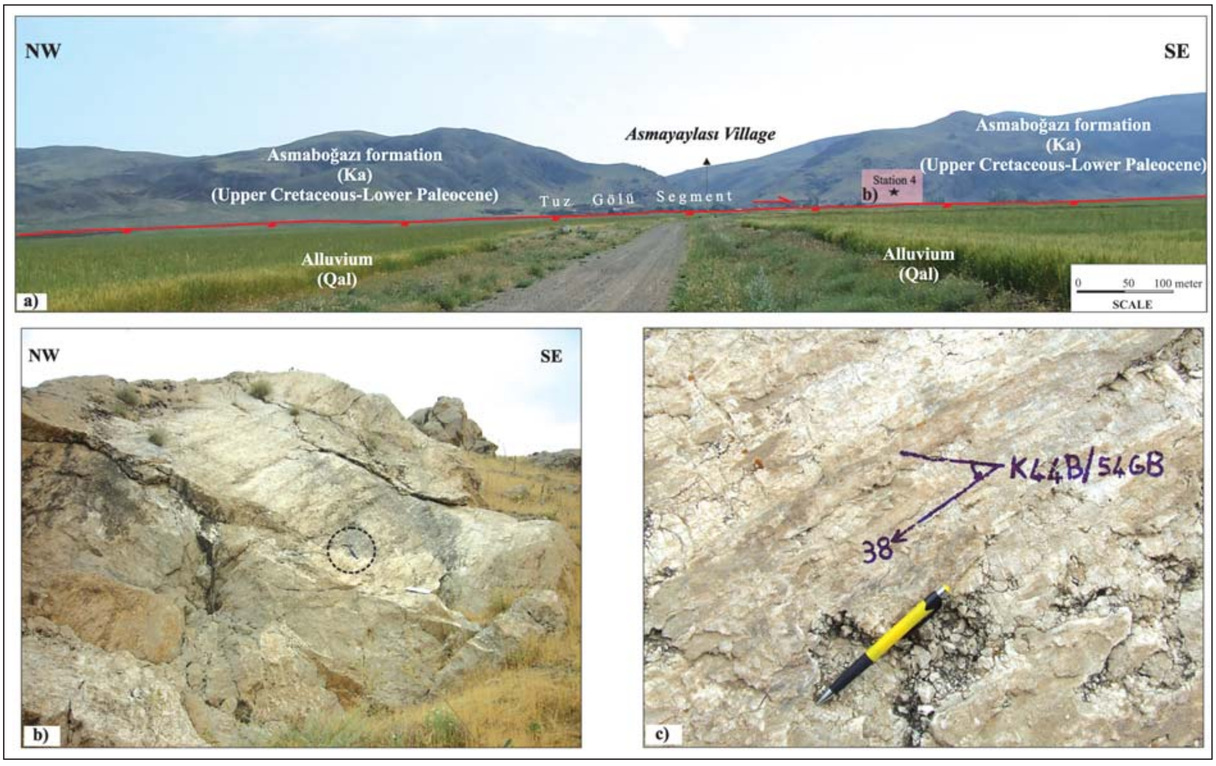


Figure 13- a) Panoramic view of Tuz Gölü segment that cuts a limestone level of the late Cretaceous-early Paleocene Asmaboğazı formation (Ka) and brings the Asmaboğazı formation and alluvium deposits (Qal) side-by-side at station 4 (Asmayaylası station) (K 31 c1 quadrangle; 566270 E – 4278286 N) (view to NE), b) General view of fault plane (view to NE, scale hummer is 33 cm), c) Close view of fault plane (view to NE, scale pen is 13 cm).

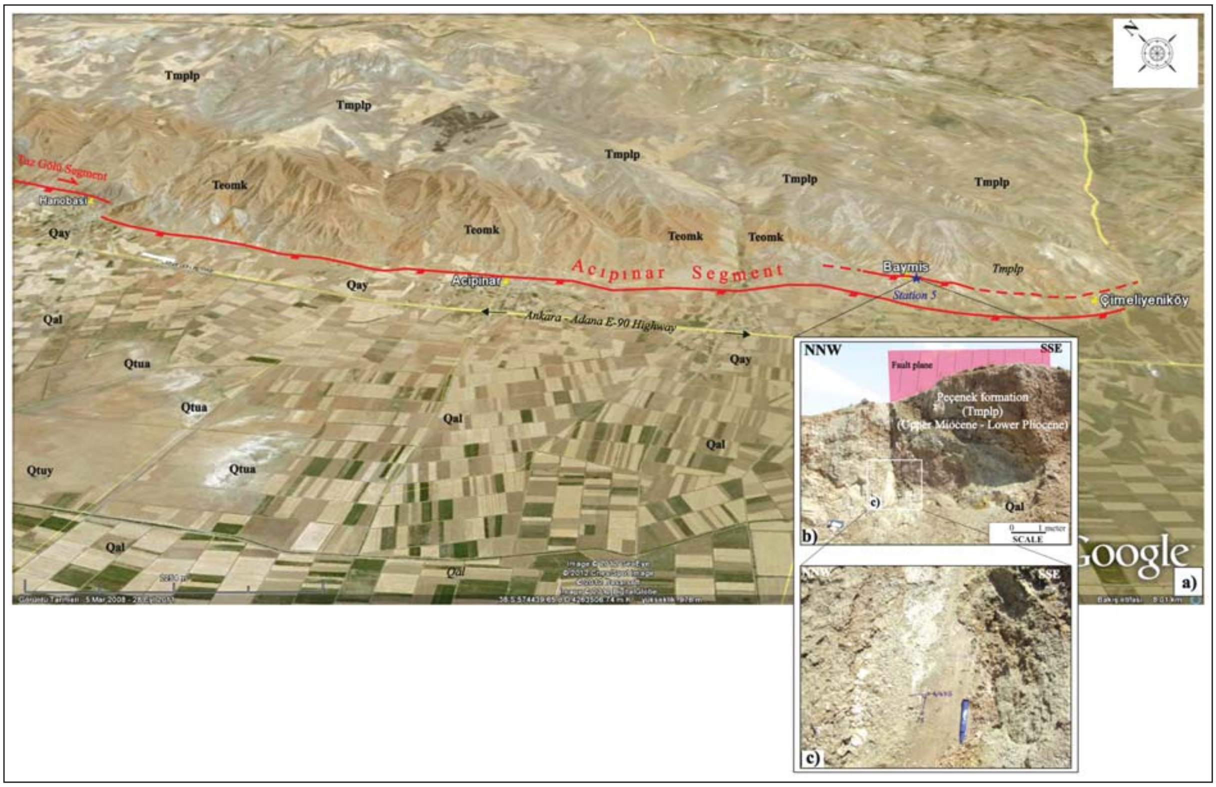


Figure 14- a) Google Earth view of the Acıpınar segment (vertical scale three times exaggerated, view to NE with oblique angle). Teomk: Koçhisar fm, Tmplp: Peçenek fm, Qtuy: Yeşilova Member of the Tuz Gölü formation, Qtua: Alibekağılı Member of the Tuz Gölü formation, Qal: Alluvium, Qay: Alluvial fan, Station 5: Structural observation point on the Acıpınar segment; b) Panoramic view of the Acıpınar segment that cuts terrestrial deposits of late Miocene-early Pliocene Peçenek formation (Tmplp) at station 5 (K 31 c3 quadrangle; 578097 E – 4262063 N) (view to NE), c) Close view of fault plane (view to NNE, scale pen is 13 cm).

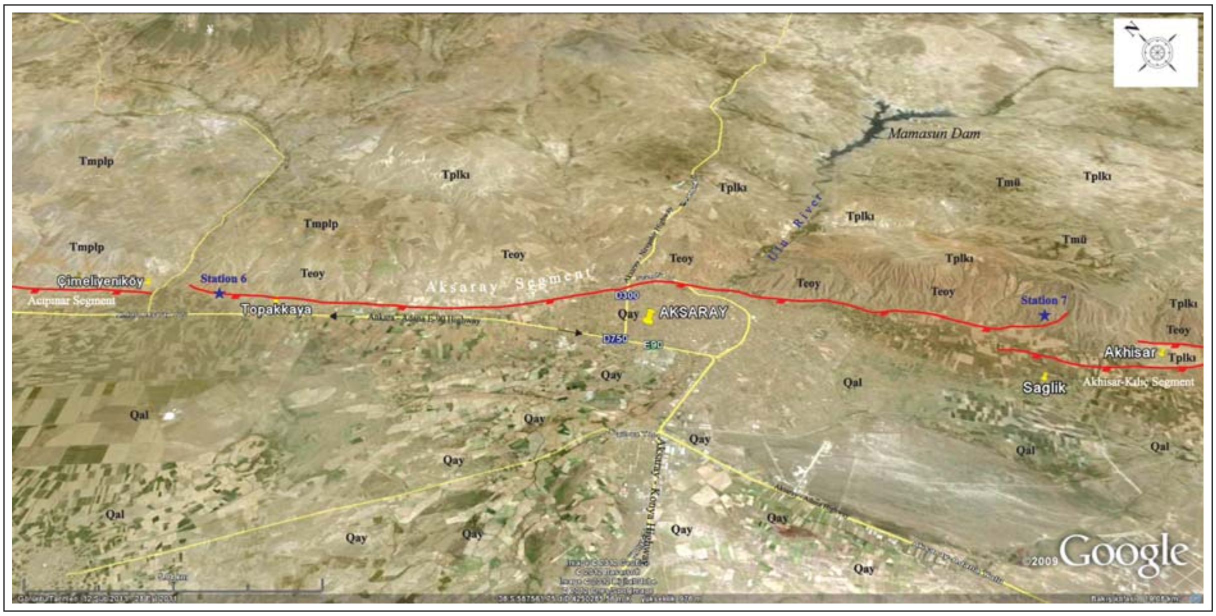


Figure 15- Google Earth view of the Aksaray segment (vertical scale three times exaggerated, view to NE with oblique angle). ¥: Ağaçören granitoid, Teoy: Yassıpur fm, Tmplp: Peçenek fm, Tplkı: Kızılkaya Ignimbrite, Qal: Alluvium, Qay: Alluvial fan (mostly Aksaray Alluvial fan), stations 6 and 7: structural observation sites on the Aksaray segment.

late Eocene – Oligocene aged Yassıpur formation (Teoy) and alluvial fan deposits. In the city center of Aksaray it cuts the Aksaray alluvial fan.

On the Aksaray segment structural observations were made at stations 6 and 7 as shown in figure 15. In a sand quarry opened on the flank of Çatak Hill 3 km NW of Topakkaya village (station 6 in Figure 15) the Aksaray segment cuts the terrestrial clastics of the late Eocene–Oligocene aged Yassıpur formation and caused them to dip nearly 40° towards the fault (to NE) (Figure 16).

The second observation site on the Aksaray segment is located at SE corner of the segment (station 7 in Figure 15). At this site, an antithetic fault that dips NE at foot wall of the Aksaray segment cuts terrestrial clastics of the late Eocene–Oligocene aged Yassıpur formation (Fig. 17). The main of Aksaray segment extends about 100 m SW of this point.

### 3.9. Akhisar-Kılıç segment (S-9)

TGFZ that jumps 750 m right at north of the Akhisar village continues 27 km in SE direction reaches at Kılıç ridge on east of the Hasan Mountain. This part of fault that extends in N25-30°W is called as Akhisar-Kılıç segment (Figures. 4 and 18). Around the Akhisar village the Akhisar-Kılıç segment cuts the early Pliocene Kızılkaya Ignimbrite which sets with an angular unconformity above the terrestrial clastics of the late Eocene–Oligocene aged Yassıpur

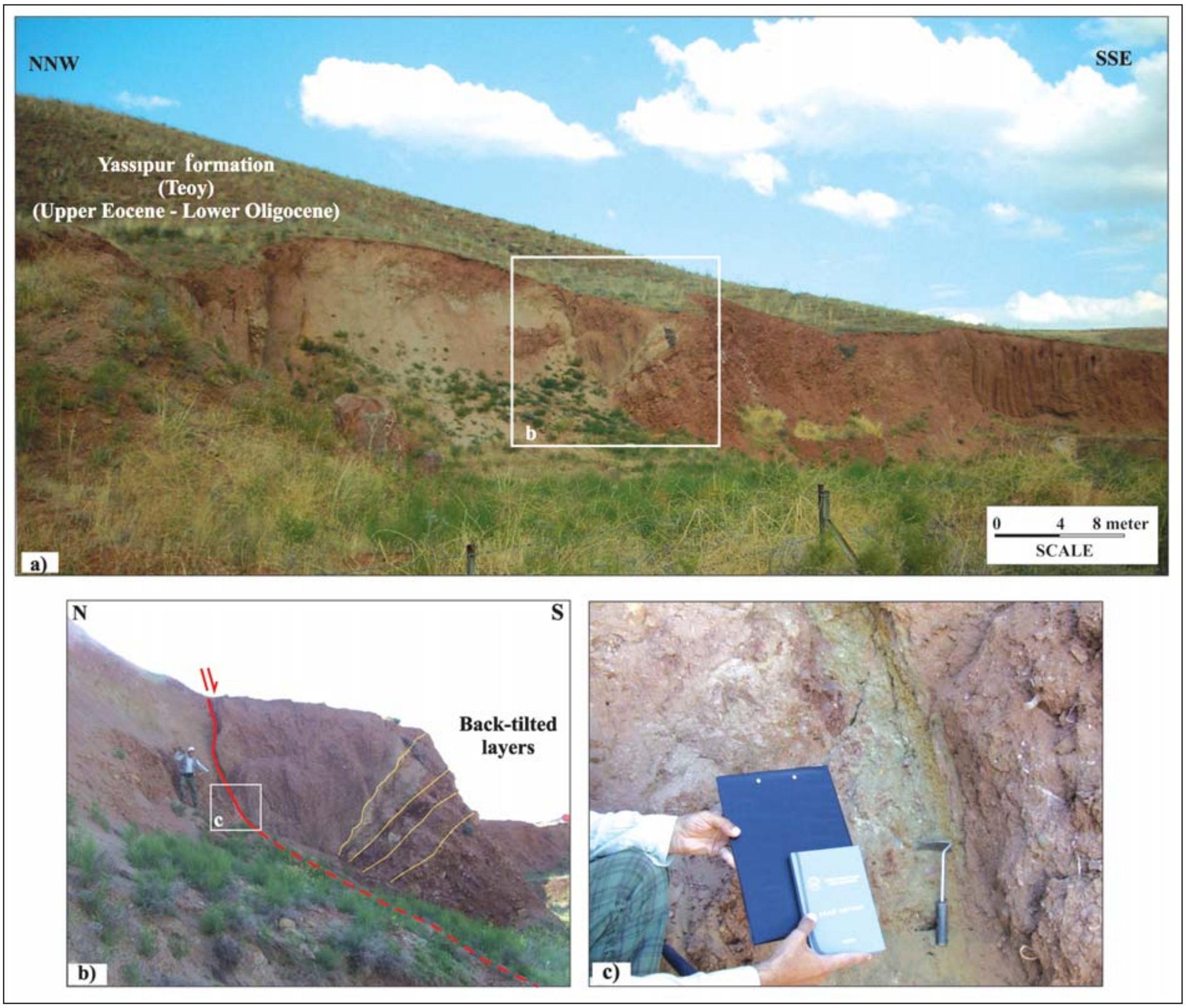


Figure 16- a) Panoramic view of Aksaray segment that cuts terrestrial deposits of late Eocene-early Oligocene Yassıpur formation (Teoy) at station 6 (L 31 b2 quadrangle; 579796 E – 4259575 N) (view to NNE), b) General view of layers dipping towards the fault (back-tilting) (view to t N, scale hummer is 1.8 m), c) Crushed zone along the fault plane (scale shovel is 22 cm).

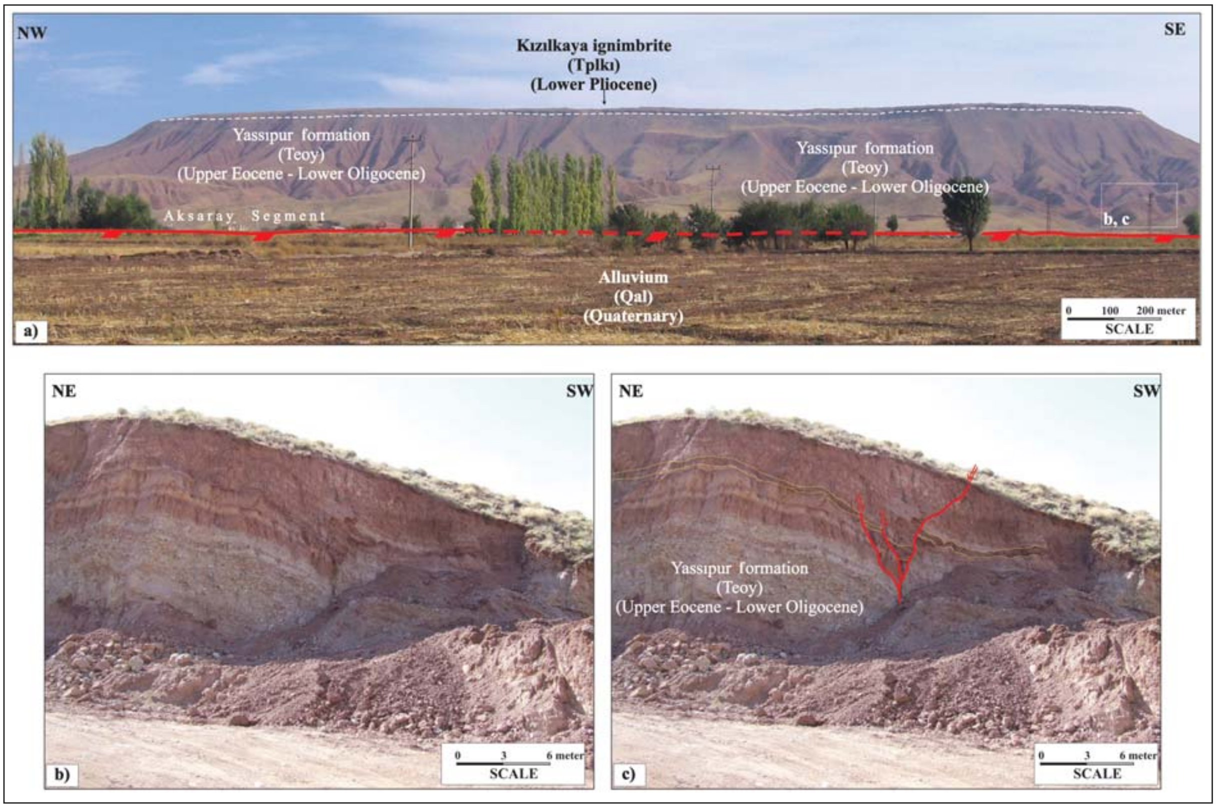


Figure 17- a) Panoramic view of Aksaray segment that cuts terrestrial deposits of late Eocene-early Oligocene Yassıpur formation (Teoy) at SE of Aksaray (view to NNE), b) Unprocessed view of an antithetic normal fault on foot wall of the Aksaray segment at station 7 (L 32 a4 quadrangle; 594475 E – 4243125 N), c) Processed view of normal fault at station 7 (view to SE).

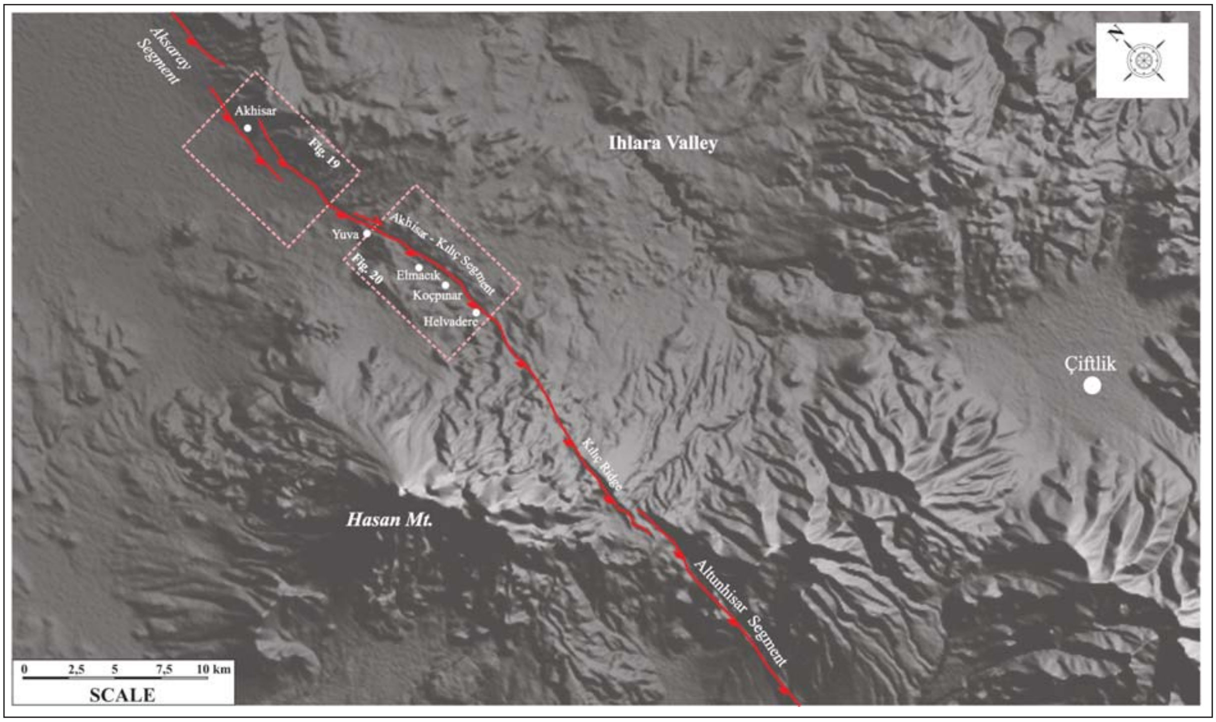


Figure 18- Digital Elevation Model (DEM) for the Akhisar-Kılıç segment. For DEM Shuttle Radar Topography Mission (SRTM) data were used (vertical scale three times exaggerated, view to NE).

formation lowering them to the plain altitude (Figure 19). The fault comprising the contact of terrestrial clastics of the Yassıpur formation and alluvium between the Akhisar and Yuva villages locally cuts the alluvial fan deposits. The fault that cuts first-stage ash and block flows of the Hasandağ Volcanites around NW of Yuva village surrounds the NW-SE extending depression area of an ellipsoidal geometry between Yuva and Helvadere villages at NE (Figure 20a). In this area the fault locally cuts the late Pleistocene-Holocene deposits and in the part from SE of Helvadere to the Kılıç ridge again cuts various units of Quaternary Hasandağ Volcanites (Qh) and ends up at the Kılıç ridge.

The Akhisar-Kılıç segment is characteristic with alluvial fans and linear fault scasrps that are aligned in parallel between Akhisar and Yuva villages. Starting from SE of the Yuva village, several structural observations were made on the fault (stations 8, 9, 10, 11 and 12 in figure 20a).

Station 8 is located on eastern flank of narrow and deep valley at east of the Yuva village (Figure 20a). At this site, the Akhisar-Kılıç segment cuts the first-stage ash and block flows of the Hasandağ Volcanites (Qhb1) and this relation is clearly shown on the exposure (Figure 21a and b).

Station 9 is located 600 m SE of the Yuva village (Figure 20a). At this point, the Akhisar-Kılıç segment cuts the first-stage ash and block flows of the Hasandağ Volcanites (Qhb1) and this relation is clearly shown on the exposure (Figure 21c and d).

Fault plane measurements on observation points 8 and 9 (Yuva station) at the Akhisar-Kılıç segment showed that this segment is an oblique-slip normal fault with right-lateral strike-slip component (Table 3).

On two different exposures 500 m in distance at E and SE of the Yuva village (stations 8 and 9 in figure 20a), the first-stage ash and block flows of the Quaternary Hasandağ Volcanites (Qhb1) is cut by the Akhisar-Kılıç segment. These two outcropes are evaluated jointly and named as the Yuva station. At the Yuva station a total of 5 fault planes and slickenlines scratches were measured. Among these measurements, measurement no. 4 which is thought to best represent the Yuva station was solved in accordance with Marshak and Mitra (1988) and then principal stress axes were found (Table 4; Figure 20b).

Another observation site where fault planes of the Akhisar-Kılıç segment are examined is found at east of Koçpınar village (Koçpınar station) (station 10 in Figure 20a). Similar to previous observation sites, at station 10, Akhisar-Kılıç segment cuts the first-stage ash and block flows of the Quaternary Hasandağ


Figure 19- Google Earth view of northern part of the Akhisar-Kılıç segment (see Figure 18 for location) (vertical scale three times exaggerated, view to NE). Teoy: Yassıpur fm, Tmü: Ürgüp fm, Tplkı: Kızılkaya Ignimbrite, Qka: Karataş volcanites, Qhb1: first-stage ash and block flows of the Hasandağ volcanites, Qal: Alluvium, Qay: Alluvial fan.

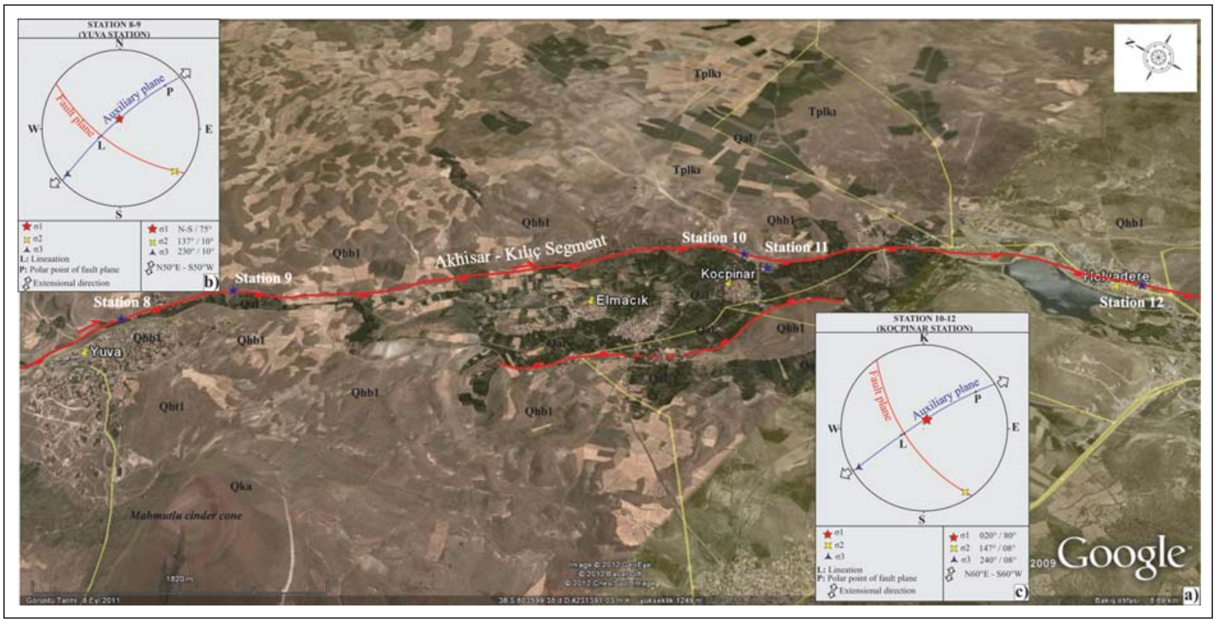


Figure 20- a) Google Earth view of central part of the Akhisar-Kılıç segment (see Figure 18 for location) (vertical scale three times exaggerated, view to NE). Tmü: Ürgüp fm, Tplkı: Kızılkaya Ignimbrite, Qka: Karataş Volcanites, Qht1: First-stage air fall and flow tuffs of the Hasandağ Volcanites, Qal: Alluvium, Stations 8, 9, 10, 11 and 12: structural observation site on the Akhisar-Kılıç segment, b) Presentation on the lower hemisphere of Schmidt net projection of single-plane solution of fault plane no 4 measured at Station 4 (Yuva station) in accordance with Marshak and Mitra (1988). The arrow on the fault plane shows the relative movement direction of hanging wall; c) Presentation on the lower hemisphere of Schmidt net projection of single-plane solution of fault plane no 4 measured at Stations 10-11 (Koçpınar station) in accordance with Marshak and Mitra (1988). The arrow on the fault plane shows the relative movement direction of hanging wall.

Volcanites (Qhb1) and this relation is clearly shown on the exposure (Figure 22a).

In the part of Akhisar-Kılıç segment between the Elmacık and Yuva villages, several gaseous and brackish water springs are issued. These springs are aligned along a zone of 50 m width parallel to the fault. Among them, the most important one is the Ayazma point within the Koçpınar village (station 11 in Figures 20 and 23). Assessment of water chemistry of Koçpınar springs is done by Afşin and Baş (1996). The results indicate that fractured and fissured marbles of the Paleozoic Bozçaldağ formation (Pzb) are the aquifer of Koçpınar springs. According to Afşin and Baş (1996), as a result of density decrease by endogenic $CO_2$, meteoric waters penetrating downward along discontinuities might have mixed with waters from the aquifer and moved upward into ignimbrite (Kızılkaya Ignimbrite), andesite and tuffs (Hasandağ Volcanites). During rise to the surface, waters are interacted with rocks which changed their chemical composition (Afşin and Baş, 1996). Chemical composition of spring waters is strongly affected by $CO_2$ dissolution. Temperature of waters rising from the aquifer should have been decreased due to mixing with shallow groundwater and atmospheric effects.

The last observation site where structural data on faults are examined on the Akhisar-Kılıç segment is located at east of artificial pond in the Helvadere town (station 12 in figure 20). At station 12, the Akhisar-Kılıç segment cuts the first-stage ash and block flows of the Quaternary Hasandağ Volcanites (Qhb1) (Figure 22c and d).

Fault plane measurements conducted on Koçpınar station at the Akhisar-Kılıç segment showed that this segment is an oblique-slip normal fault with right-lateral strike-slip component (Table 3).

At Koçpınar station a total of 4 fault planes and slickenlines were measured. Among them, measurement no 4 which is thought to best represent the Koçpınar station was solved in accordance with Marshak and Mitra (1988) and then principal stress axes were found (Table 4; Figure 20c).

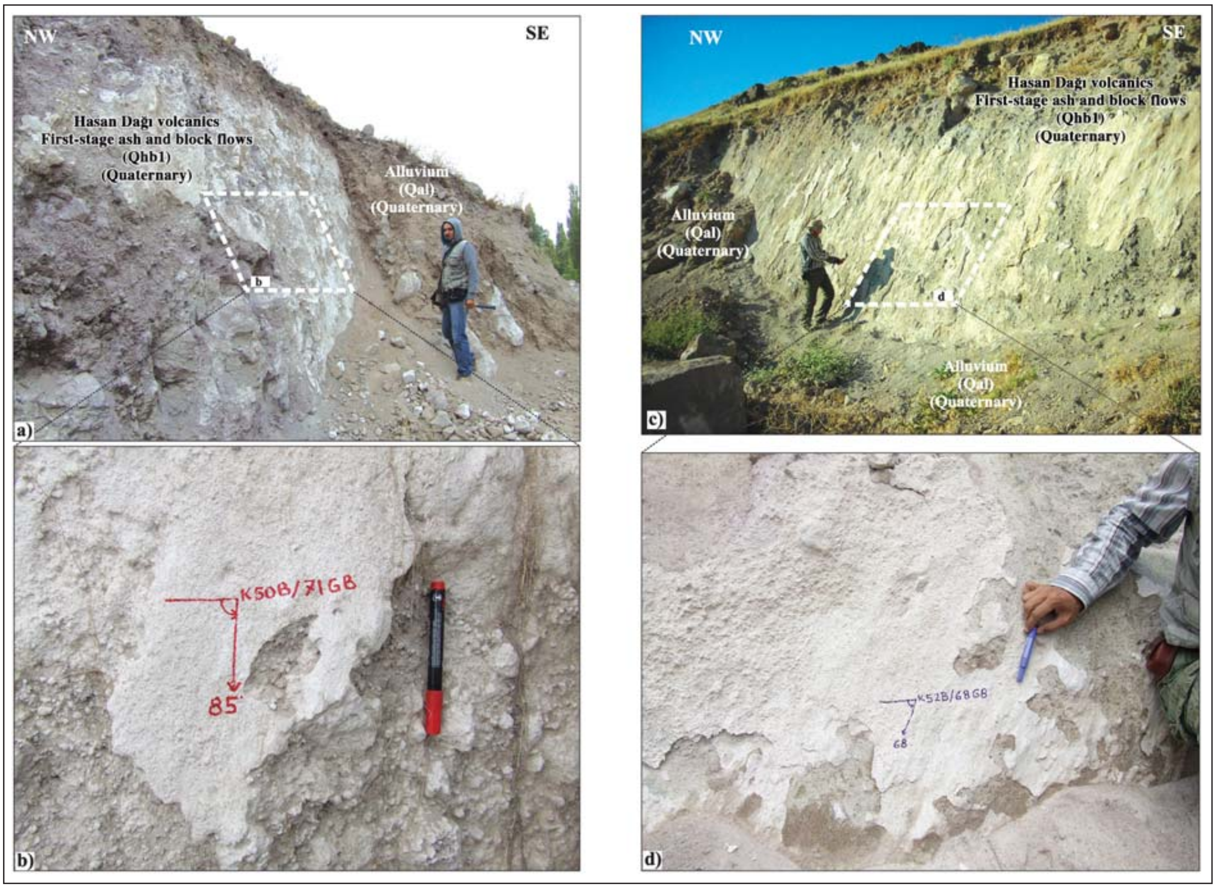


Figure 21- a) General view of fault plane of the Akhisar-Kılıç segment that cuts first-stage ash and block flow s of the Hasandağ Volcanites (Qhb1) at east of Yuva village (L 32 d2 quadrangle; 601450 E – 4234000 N) (view to NE scale geologist is 1.80 m), b) Close view of fault plane (view to NE scale pen is 12 cm), c) General view of fault plane of the Akhisar-Kılıç segment that cuts first-stage ash and block flow s of the Hasandağ Volcanites (Qhb1) at SE of Yuva village (L 32 d2 quadrangle; 601984 E – 4233726 N) (view to NE scale geologist is 1.80 m), d) close view of fault plane (view to NE scale pen is 12 cm).

3.10. Altunhisar segment (S-10)

TGFZ that jumps 500 m left from SE of Kılıç ridge extends in N20°W direction to Altunhisar via a few parallel fault sections. It bends to 30°SE around Altunhisar and continues in N50°W direction to the south of Tepeköy. From this location fault bends again to 20°SE and is ended at NW of Bor town. The 30-km part of the fault outlined above is called as Altunhisar segment (Figures 4 and 24a).

The Altunhisar segment cuts the first-stage ash and block flows of the Quaternary Hasandağ Volcanites (Qhb1) in the area between east of Kılıç ridge and Altunhisar and it cuts the Balcı Volcanite of late Miocene age (Tmb) at NW of Altunhisar. The fault cuts Quaternary alluvial fan deposits (Qay) and talus deposits and from this point to SE edge of segment if follows the border of Balcı Volcanite (Tmb) and alluvial deposits (Qal).

Structural observations were made on two points at the Altunhisar segment (stations 13 and 14 in figure 24). At station 13, the Altunhisar segment cuts the first-stage air-fall flow tuffs of the Quaternary Hasandağ Volcanites (Qht1). This relation is shown in a pumice quarry opened on the road from Altunhisar to Kirteli village (Figure 25).

Another measurement point at the Altunhisar segment is located about 1.5 km NW of Altunhisar. On a road cut between Altunhisar and Çiftlik, the Altunhisar segment is observed as a normal fault in a 30-m area (Figure 26). At this site, fault cuts the first-stage fall deposits and flow tuffs of the Quaternary Hasandağ Volcanites (Qht1).

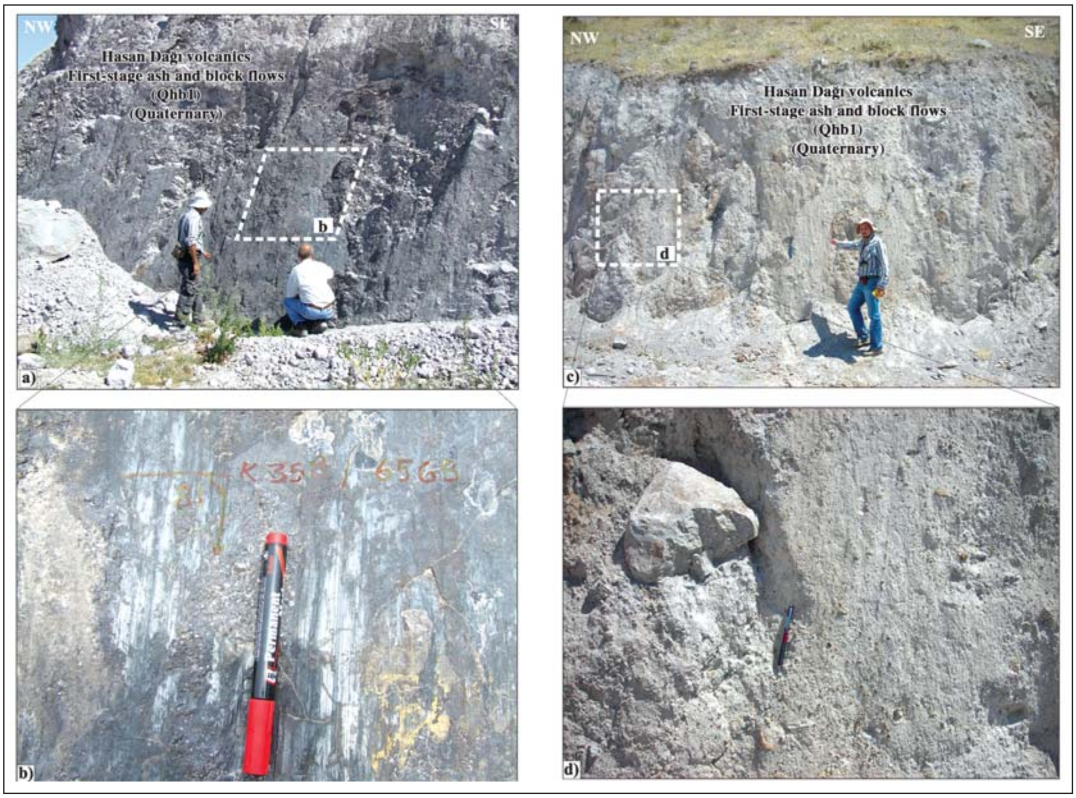


Figure 22- a) General view of fault plane of the Akhisar-Kılıç segment that cuts first-stage ash and block flow s of the Hasandağ Volcanites (Qhb1) at east of Koçpınar village (L 32 d2 quadrangle; 604694 E – 4231266 N) (view to NE scale geologist is 1.80 m), b) Close view of fault plane (view to NE scale pen is 12 cm), c) General view of fault plane of the Akhisar-Kılıç segment that cuts first-stage ash and block flow s of the Hasandağ Volcanites (Qhb1) at east of Helvadere pond (L 32 d2 quadrangle; 606111 E – 4228966 N) (view to NE scale geologist is 1.80 m), d) Close view of fault plane (view to NE scale pen is 12 cm).


Figure 23- Gaseous and brackish water manifestation point at Ayazma site in the Koçpınar village (L 32 d2 quadrangle; 604661 E – 4231053 N) (view to N scale geologist is 1.80 m).

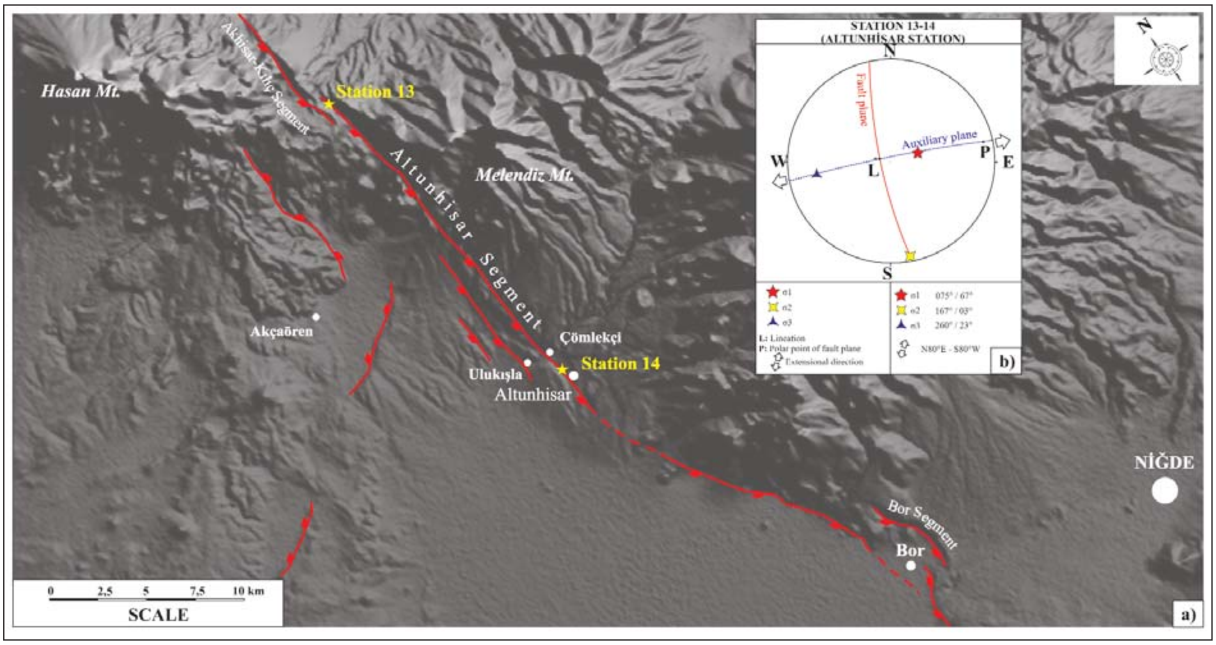


Figure 24- a) Digital Elevation Model (DEM) for the Altunhisar segment. For DEM Shuttle Radar Topography Mission (SRTM) data were used (vertical scale three times exaggerated, view to NE). Stations 13 and 14: structural observation points on the Altunhisar segment, b) Presentation on the lower hemisphere of Schmidt net projection of single-plane solution of fault plane no 2 measured at Stations 13-14 (Altunhisar) in accordance with Marshak and Mitra (1988). The arrow on the fault plane shows the relative movement direction of hanging wall.

Fault plane measurements conducted on Altunhisar segment (stations 13 and 14) showed that this segment is a normal fault with minor right-lateral strike-slip component (Table 3).

At Altunhisar station a total of 6 fault planes and slickenlines were measured. Among them, measurement no 2 which is thought to best represent the Altunhisar station was solved in accordance with Marshak and Mitra (1988) and then principal stress axes were found (Table 4; Figure 24b).

3.11. Bor segment (S-11)

The Bor segment represents the most SE part of TGFZ. The Bor segment with nearly 17 km in length is composed of two sub-parts (Figures 4 and 27a). The 4 km long northern part starts from SSW of Okçu village (Bor, Niğde) and extends to the Bor Çarşı Neighborhood. In this area, fault forms the boundary between pyroclastic rocks of Quaternary Melendiz Dağ Volcanites (Qm) and alluvial deposits (Qal). The Bor segment that jumps about 400 m right in the Çarşı Neighborhood continues to the south and then bends to SE around the Acıgöl graveyard (Bor) and reaches at Karamahmutlu village along N50ºW direction. In this area, the Bor segment cuts the lacustrine limestones of late Miocene-Pliocene Gökbez formation (Tmplg) and pyroclastic rocks of Quaternary Melendiz Dağ Volcanites (Qm) and brings the alluvium deposits and the Gökbez formation side by side. At NE of Kemerhisar, the Bor segment is represented by Holocene fault scarps.

The last observation point where structural features of TGFZ can be seen is located in central part of the Bor segment (station 15 in figure 27a). At station 15, fault plane of the Bor segment is observed on an outcrop 500 m east of Acıgöl graveyard in Bor town center. At this exposure, fault cuts late Miocene-Pliocene Gökbez formation (Tmplg) and unconformably overlying pyroclastic of Quaternary Melendiz Dağ Volcanites (Qm) (Figure 28).

Fault plane measurements conducted on the Bor segment (stations 15) showed that this segment is a normal fault with minor strike-slip component (Table 3).

At Bor station a total of 4 fault planes and slickenlines were measured. Among them, measurement no 2 which is thought to best represent the Bor station was solved in accordance with Marshak and Mitra (1988) and then principal stress axes were found (Table 4; Figure 27b). As a result of kinematic analysis conducted on TGFZ, an NE-SW

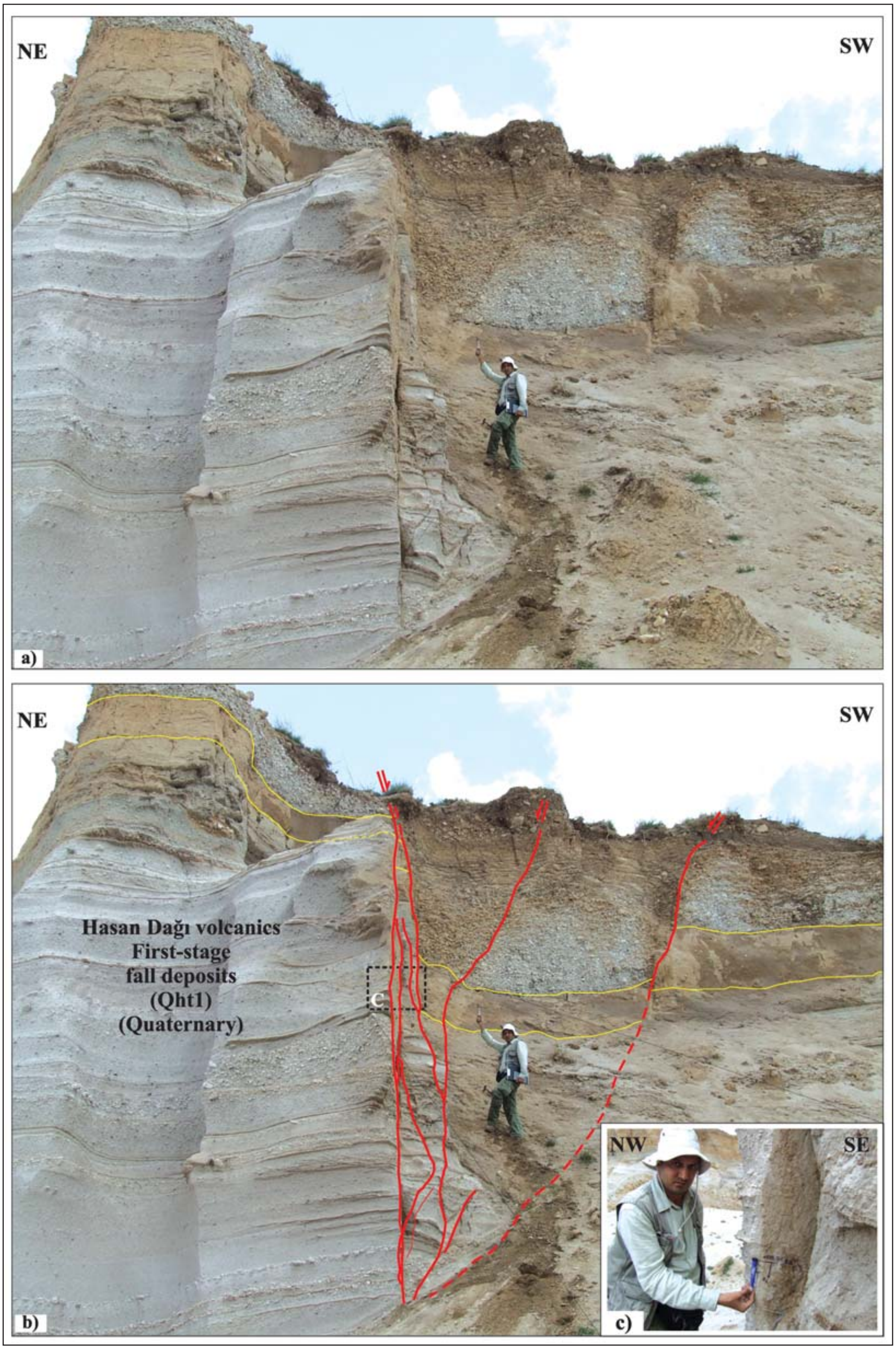


Figure 25- a) Uncommented section view of the Altunhisar segment (L 32 c4 quadrangle; 611968 E – 4220234 N) that cuts the first-stage air fall and flow tuffs of the Quaternary Hasandağ Volcanites (Qht1) in pumice quarry at east of the Kılıç ridge (Figure 24, station 13), b) Interprated section view, c) Close view of fault plane (view to SE for a and b, scale geologist is 1.80 m; view to NE for c, scale pen is 12 cm).

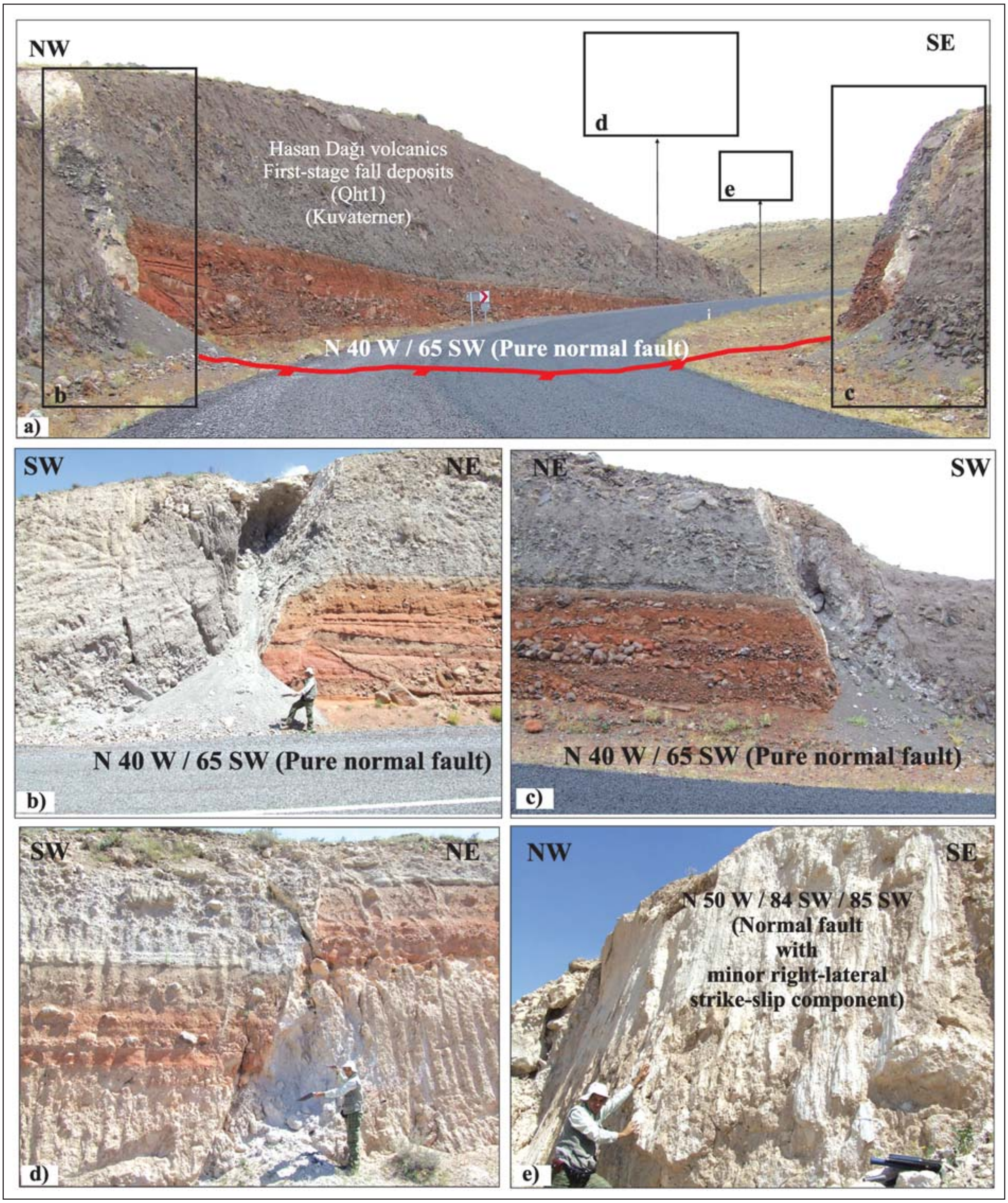


Figure 26- a) Panoramic view of Altunhisar segment (L 32 c4 quadrangle; 619831 E – 4208270 N) that cuts the first-stage air fall and flow tuffs of the Quaternary Hasandağ Volcanites (Qht1) on Altunhisar-Çiftlik road cut (Figure 24, station 14) (view to NE), b) General view of fault plane on NW side of road cut (view to NW), c) General view of fault plane on SE side of road cut (view to SE), d) A small-scale graben structure on NW side of the road, nearly 25 m NE of front fault (view to NW), e) A normal fault plane on NW side of road nearly 15 m NE of front fault (view to NE).

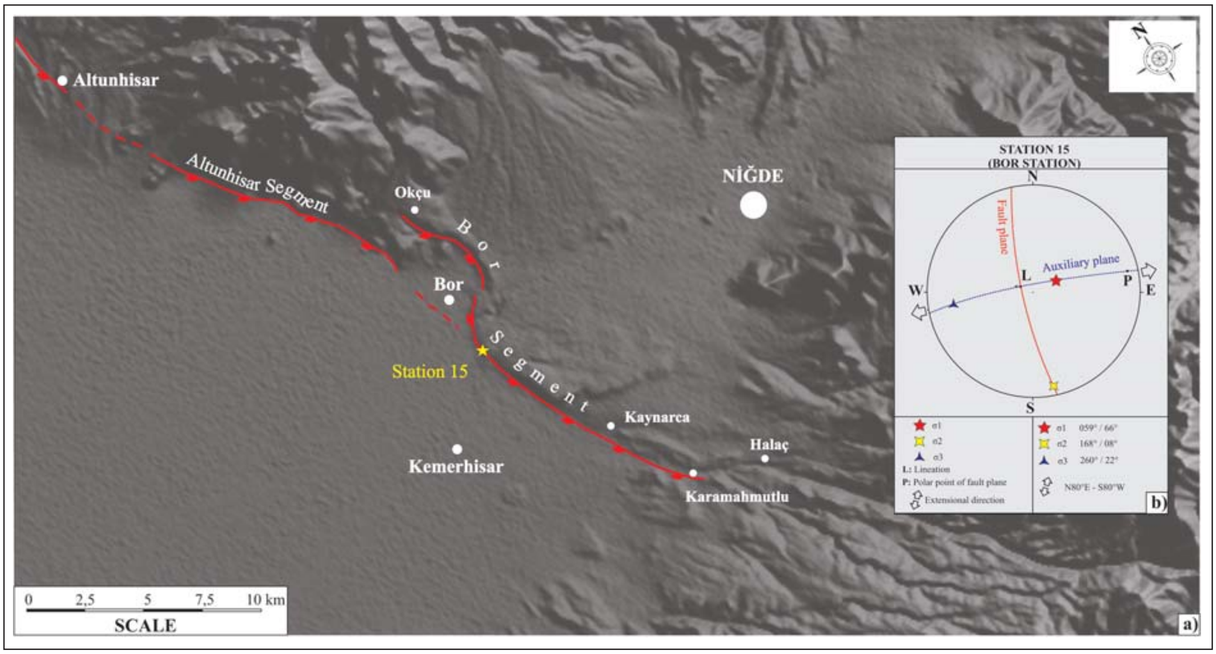


Figure 27- a) Digital Elevation Model (DEM) for the Bor segment. For DEM Shuttle Radar Topography Mission (SRTM) data were used (vertical scale three times exaggerated, view to NE). Stations 15: structural observation site on the Bor segment, b) Presentation on the lower hemisphere of Schmidt net projection of single-plane solution of fault plane no 2 measured at station 15 (Bor) in accordance with Marshak and Mitra (1988). The arrow on the fault plane shows the relative movement direction of hanging wall.

trending extensional regime was found to be effective in the region (Figure 29).

This result is consistent with NNE-SSW trending extensional regime deduced from studies on the Cihanbeyli and Yeniceoba Fault Zones at west of Lake Tuz (Özsayın, 2007; Özsayın and Dirik, 2007). In addition, moment tensor solution (Figure 30) of the 13 June 2011 Ataköy (Aksaray) earthquake (M=3.9) indicates (Kandilli Observatory and Earthquake Research Institute) that the Ataköy earthquake is produced by a N34ºW trending 80ºSW dipping oblique-slip normal fault with right-lateral strike-slip component. This finding is quite compatible with fault plane slip data on TGFZ.

## 4. Seismicity of the Tuz Gölü Fault Zone

### 4.1. Historical (before 1900) and Instrumental (after 1900) Seismicity of the Tuz Gölü Fault Zone

Morphotectonic properties, epicenter distributions of small and moderate-size earthquakes and structural data from this study indicate that TGFZ is seismically active.

In order to investigate historical (before 1900) earthquakes associated with TGFZ, a number of earthquake catalogs were examined (e.g. Ergin et al., 1967; Soysal et al., 1981, Ambraseys and Jackson, 1998; Tan et al., 2008). Among them, in Soysal et al. (1981) only one historical earthquake was found to be associated with TFGZ. In this catalog, based on study of Ambraseys (1970), a very strong earthquake was occurred ($I_0$=IX) in 1104 around Niğde and Adana which that killed 40.000 people. In the catalog coordinate of earthquake is not given and it is stated that literature on this earthquake is not sufficient.

Data on instrumental (after 1900) earthquakes occurred around TGFZ are compiled from the Kandilli Observatory and Earthquake Research Institute (Figure 31).

As shown in figure 31, a number of earthquakes were occurred around TGFZ. Among 4151 earthquakes shown in Figure 31, 203 earthquakes are selected that are possibly associated with TGFZ (Table 5; Figure 32). In addition to these earthquakes, Dirik and Erol (2000) suggest two other earthquakes associated with TGFZ. The first is the one that occurred in 1940 (M=5.2). This earthquake with

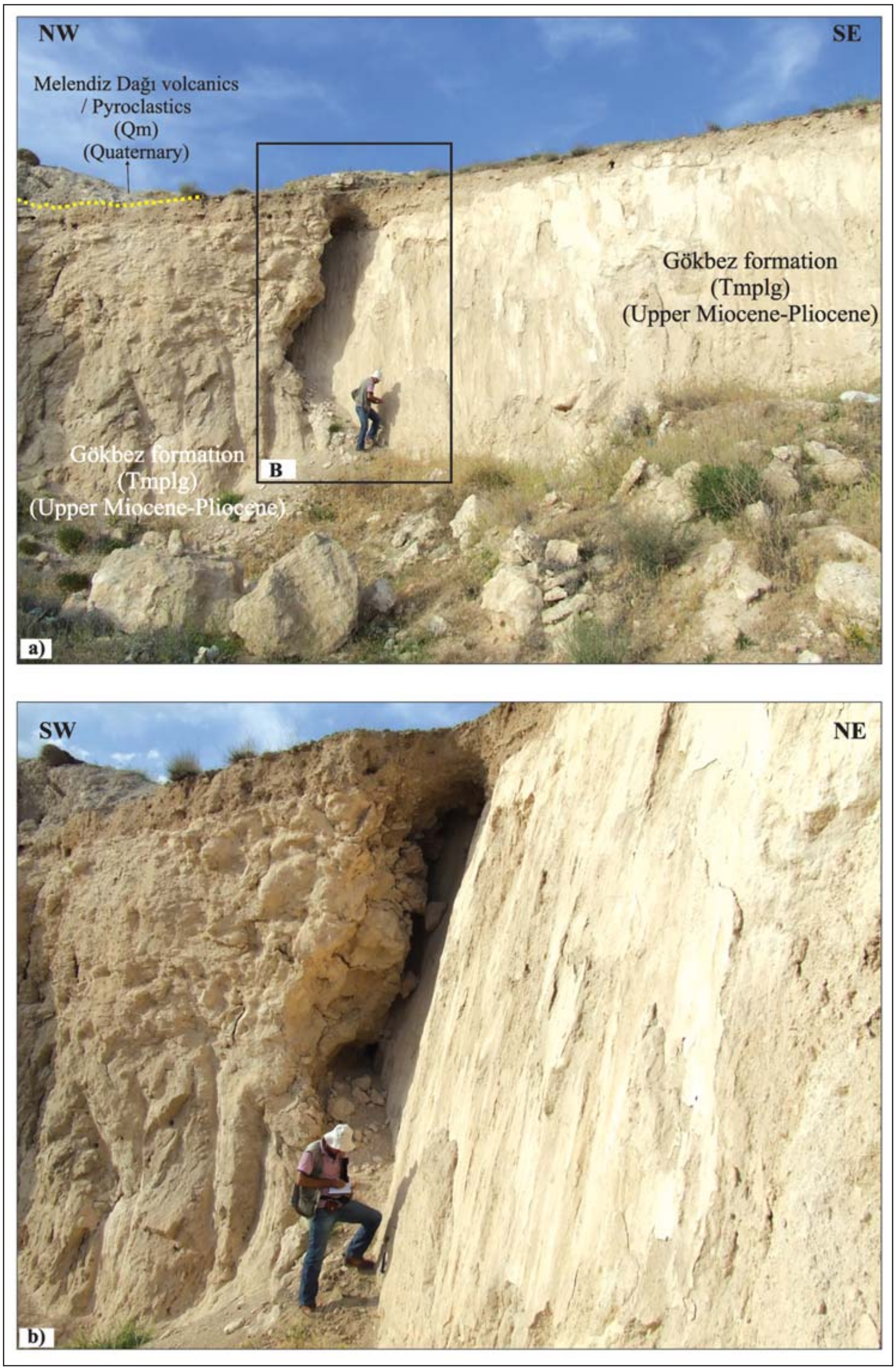


Figure 28- a) Panoramic view of Bor segment that cuts late Miocene-Pliocene Gökbez formation (Tmplg) and Quaternary Melendiz Dağı Volcanites (Qm) at east of Acıgöl graveyard in the Bor town center (Figure 27, station 15) (M 33 a1 quadrangle; 637592 E – 4193282 N) (view to NE), b) Section view of fault plane (view to NW; for both photos scale geologist is 1.80 m).

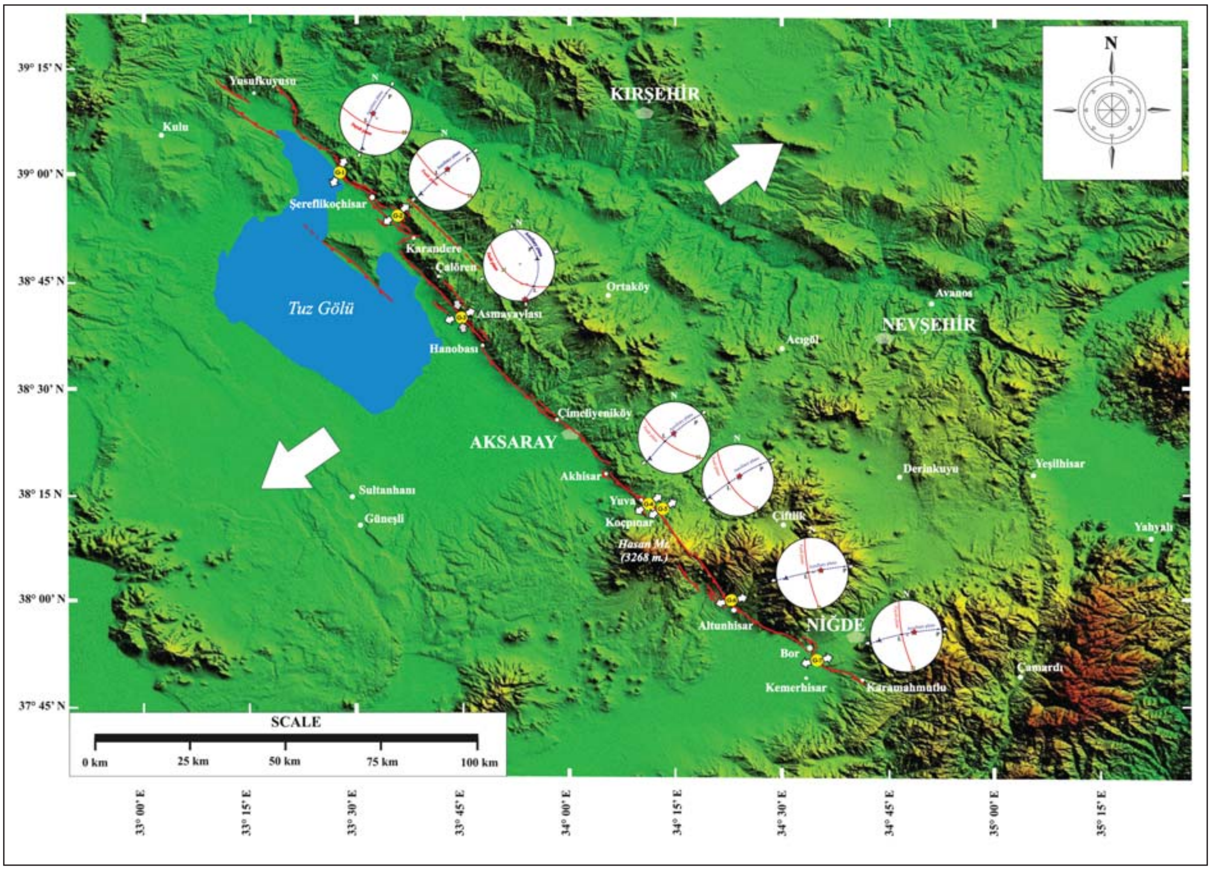


Figure 29- Collective presentation of kinematic analysis on the Tuz Gölü Fault Zone (Big arrows on the map represent for regional extension direction)

epicenter coordinates of 34.2 East – 38.0 North is located in Uluören village (west of Altunhisar) which is governed by the Altunhisar segment of TGFZ. The second one with magnitude of 4.0 was occurred on 22 October 1971. The epicenter coordinates of this earthquake is 33.9 East – 38.6 North which locates around Bostanlık village at east of Hanobası.

Statistical assessment of earthquake focal depths showed that earthquakes on TGFZ were occurred at an average depth of 10 km. It was shown that earthquakes around Hasandağ and Altunhisar have focal depths deeper than the average. This might indicate that some of earthquakes in the region are volcanogenic earthquakes.

Considering the statistical assessment of earthquake magnitudes, among 205 earthquakes (two earthquakes by Dirik and Erol (2000) are also taken into consideration), 136 are of M=1.3-2.9, 60 are of M=3.0-3.9, 7 are of M=4.0-4.9 and 1 is of M=5.2. The largest earthquake recorded during the instrumental period is the Uluören (Altunhisar) earthquake with magnitude of M=5.2 (Dirik and Erol, 2000). Additionally, 1924 Başaran (Eskil) (M=4.9), 1985 Şekerköy (Şereflikoçhisar) (M=4.3), 1998 Altunhisar (Niğde) (M=4.0), 2001 Ulukışla (Aksaray) (M=4.1), 2002 Taşpınar (Aksaray) and 2007 Acıkuyu (Kulu) (M=4.9) earthquakes are other important earthquakes recorded on TGFZ.

## 4.2. Earthquake potential of the Tuz Gölü Fault Zone segments

In paleoseismology works to be conducted active fault zones consisting of several fault segments such as TGFZ, geometric and structural characteristics of fault segments within the fault zone should be determined and deformed young deposits (Quaternary) should be mapped in detail. In Part 3 segmentation of TGFZ is presented with all details. In paleoseismology works, the length of fault segment and the largest earthquake to be occurred and the maximum and average displacements in each earthquake can be estimated with empirical equations. In this study, using the equations for

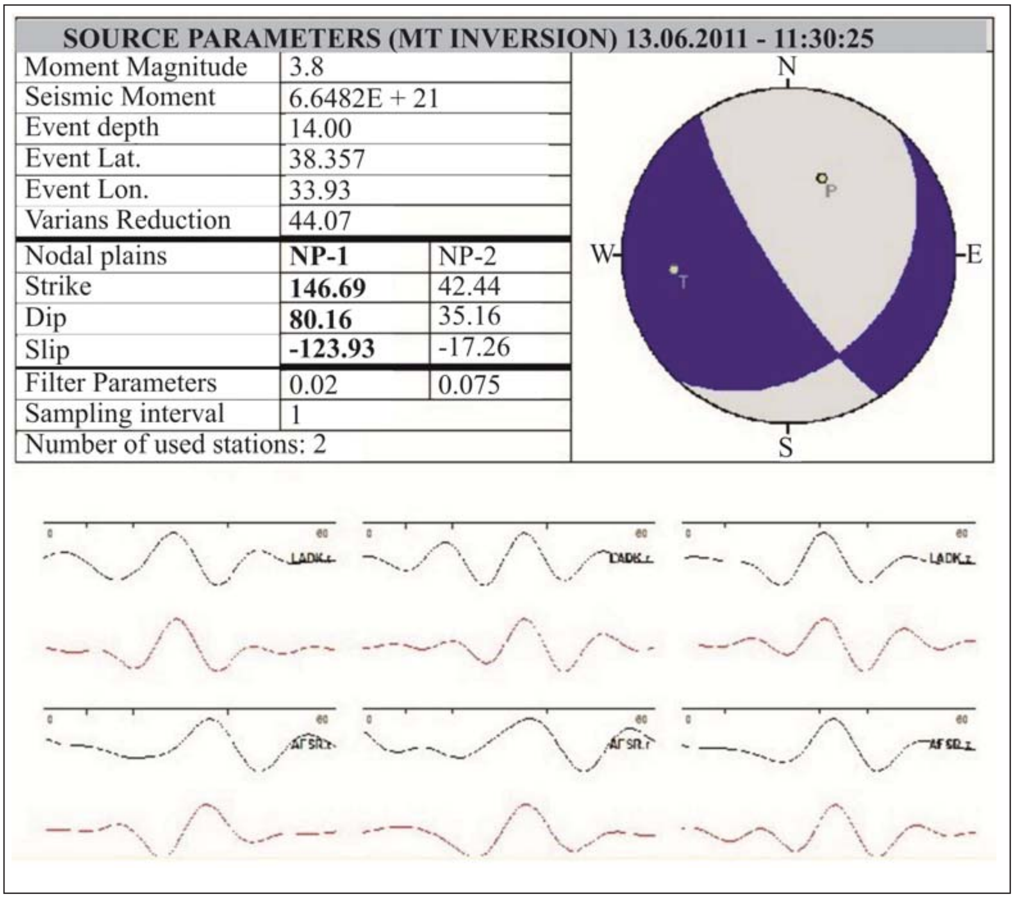


Figure 30- Moment tensor solution for 13 June 2011 Ataköy (Aksaray) earthquake (M=3.9).

normal faults suggested by Wells and Coppersmith (1994), the largest earthquake produced by each segment of TGFZ and the maximum and average displacements were calculated (Table 6). In the calculations following equations were used:

The empirical equation used for the largest earthquake magnitude (M):

M= a+b x log (SRL)

a= 4,86

b= 1,32

SRL= Surface rupture length, a and b are the standard error and coefficients.

The empirical equation used for the maximum displacement (MD) for each earthquake:

Log (MD) = a+b x M

a = -5,90

b = 0,89

MD= the maximum displacement, M= earthquake magnitude, a and b are the standard error and coefficients.

The empirical equation used for average displacement for any earthquake (AD):

Log (AD) = a+b x M

a= -4,45

b= 0,63

AD= average displacement, M= earthquake magnitude, a and b are the standard error and coefficients.

As shown in table 6, the Tuz Gölü, Altunhisar and Akhisar-Kılıç segments are the most important segments of TGFZ. In an assessment considering the length, morphotectonic properties of fault segments, deformed young geologic units, density of residential sites in the impact area and the presence of areas suitable for paleoseismic trench excavations on the segment, Tuz Gölü and Akhisar-Kılıç segments come into prominence.

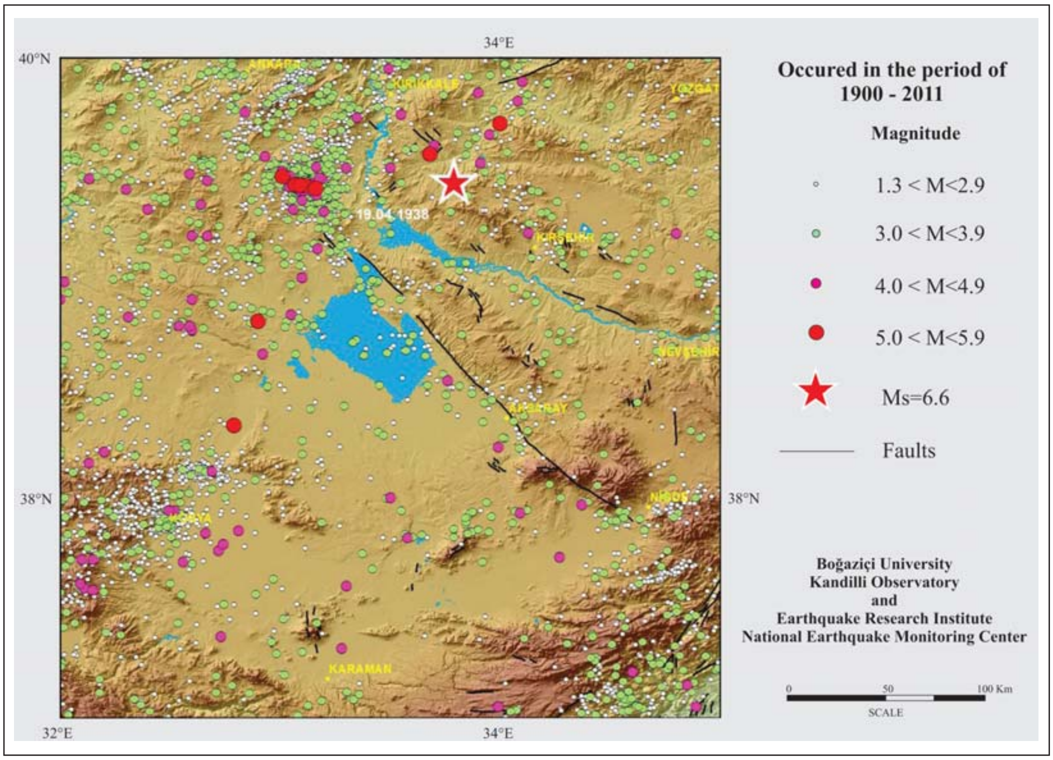


Figure 31- Epicenter distribution map for earthquakes (M ?1,3) occurred in the 1900-2011 period the Tuz Gölü Fault Zone and surrounding (data from the Kandilli Observatory and Earthquake Research Institute National Earthquake Monitoring Center).

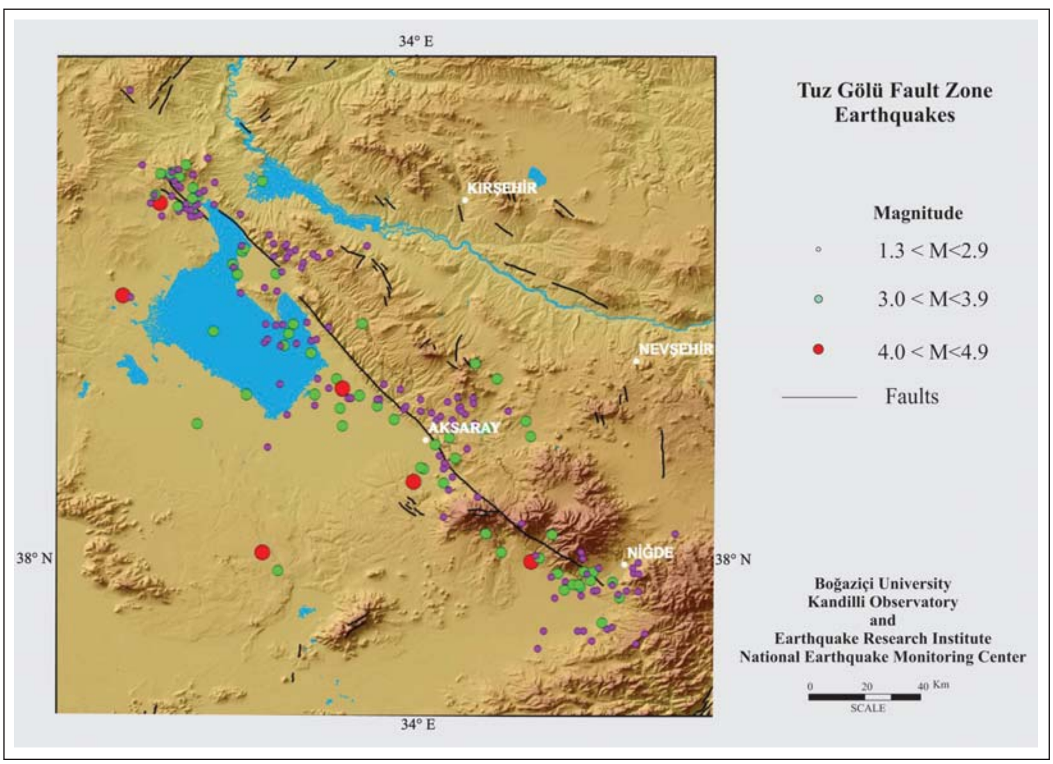


Figure 32- Epicenter distribution map for earthquakes (M ?1,3) occurred in the 1900-2011 period around the Tuz Gölü Fault Zone (data from the Kandilli Observatory and Earthquake Research Institute National Earthquake Monitoring Center).

Table 5- Earthquake parameters of earthquakes occurred along the Tuz Gölü Fault Zone during the 1900-2011 period (data from the Kandilli Observatory and Earthquake Research Institute National Earthquake Monitoring Center).

| No | Date | Time | Lat. | Lon. | M | MD | ML | MS | Mw | Mb | Depth (km) | Location |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 13.12.1924 | 18:53:30.00 | 38 | 33,5 | **4,9** | **4,9** | **4,9** | **4,9** | **5,2** | **4,9** | 30 | BAŞARAN-ESKİL (AKSARAY) [SW 3.8 km] |
| 2 | 24.04.1977 | 20:49:06.00 | 39,2 | 33,5 | **3,1** | | | | | | 5 | ŞANLIKIŞLA-ŞEREFLİKOÇHİSAR (ANKARA) [NE 6.1 km] |
| 3 | 14.05.1981 | 04:37:13.40 | 39,23 | 33,21 | **3,9** | | | | | | 10 | DOĞANKAYA-ŞEREFLİKOÇHİSAR (ANKARA) [NE 2.8 km] |
| 4 | 03.03.1985 | 13:02:12.90 | 39,13 | 33,17 | **4,3** | **4,3** | **4,2** | **4,0** | **4,4** | **4,3** | 10 | ŞEKERKÖY-ŞEREFLİKOÇHİSAR (ANKARA) [SW 3.6 km] |
| 5 | 17.07.1988 | 23:40:05.70 | 38,99 | 33,84 | **2,7** | | | | | | 10 | SARIYAHŞİ (AKSARAY) [NW 0.7 km] |
| 6 | 18.11.1991 | 19:48:50.70 | 38,9 | 33,42 | **3,9** | | | | | | 10 | HAMZALI-ŞEREFLİKOÇHİSAR (ANKARA) [NW 4.2 km] |
| 7 | 11.12.1993 | 05:21:21.40 | 38,51 | 33,45 | **3,3** | | | | | | 8 | ESKİL (AKSARAY) [NE 12.5 km] |
| 8 | 11.03.1994 | 08:15:26.00 | 38,51 | 33,67 | **3,8** | | | | | | 5 | ULUKIŞLA- (AKSARAY) [W 8.1 km] |
| 9 | 02.03.1997 | 21:07:52.10 | 38,61 | 34,19 | **3,4** | | | | | | 8 | SARIAĞIL- (AKSARAY) [N 1.0 km] |
| 10 | 01.10.1998 | 17:02:41.90 | 37,97 | 34,37 | **4,0** | **4,0** | **4,0** | **3,6** | **4,1** | **4,0** | 34 | ALTUNHİSAR (NİĞDE) [S 3.1 km] |
| 11 | 18.07.1999 | 10:51:44.80 | 38,56 | 33,74 | **3,6** | | | | | | 5 | ULUKIŞLA- (AKSARAY) [NW 6.8 km] |
| 12 | 18.05.2000 | 03:08:24.30 | 38,41 | 33,76 | **3,9** | | | | | | 33 | YEŞİLTEPE- (AKSARAY) [S 5.9 km] |
| 13 | 11.03.2001 | 19:21:45.60 | 38,53 | 33,76 | **4,1** | **4,1** | **4,0** | **3,6** | **4,1** | **4,0** | 4 | ULUKIŞLA- (AKSARAY) [N 3.2 km] |
| 14 | 07.03.2002 | 06:12:39.00 | 38,23 | 33,99 | **4,1** | **4,1** | **4,0** | **3,6** | **4,1** | **4,0** | 10 | TAŞPINAR- (AKSARAY) [NW 6.9 km] |
| 15 | 17.04.2002 | 06:52:01.00 | 38,418 | 33,289 | **3,0** | **3,0** | | | | | 6,9 | ESKİL (AKSARAY) [W 10.9 km] |
| 16 | 11.06.2002 | 09:30:05.00 | 37,932 | 34,456 | **3,4** | **3,4** | | | | | 5 | BALCI-BOR (NİĞDE) [S 4.5 km] |
| 17 | 18.07.2002 | 13:37:21.00 | 38,74 | 33,825 | **3,4** | **3,4** | | | | | 31,6 | GÖYNÜK-AĞAÇÖREN (AKSARAY) [SE 1.5 km] |
| 18 | 01.11.2003 | 19:40:05.00 | 38,426 | 34,354 | **3,8** | **3,8** | **3,6** | | | | 5 | GÜLPINAR-GÜLAĞAÇ (AKSARAY) [NW 1.2 km] |
| 19 | 02.11.2003 | 03:36:15.00 | 38,3757 | 34,368 | **3,3** | **3,3** | | | | | 5 | GÜLAĞAÇ (AKSARAY) [SE 2.8 km] |
| 20 | 18.02.2004 | 15:56:43.00 | 38,9743 | 33,436 | **3,5** | **3,5** | | | | | 5 | ŞEREFLİKOÇHİSAR (ANKARA) [NW 9.8 km] |
| 21 | 09.07.2004 | 11:23:46.00 | 38,0612 | 34,223 | **3,3** | **3,3** | | | | | 5 | ULUÖREN-ALTUNHİSAR (NİĞDE) [SE 3.2 km] |
| 22 | 11.07.2004 | 17:25:26.00 | 38,4008 | 34,226 | **3,0** | **3,0** | | | | | 8,1 | ÇATALSU-GÜLAĞAÇ (AKSARAY) [E 1.3 km] |
| 23 | 08.08.2004 | 18:58:30.00 | 37,9427 | 33,551 | **3,1** | **3,1** | | | | | 9,8 | BAŞARAN-ESKİL (AKSARAY) [S 8.3 km] |
| 24 | 02.09.2004 | 09:17:46.00 | 37,9382 | 34,542 | **3,1** | **3,1** | | | | | 5 | OKCU-BOR (NİĞDE) [S 0.2 km] |
| 25 | 11.11.2004 | 12:06:31.00 | 37,9352 | 34,57 | **3,1** | **3,1** | | | | | 2,4 | OKCU-BOR (NİĞDE) [SE 2.5 km] |
| 26 | 20.01.2005 | 00:51:11.79 | 38,5597 | 34,261 | **3,0** | **3,0** | | | | | 57,4 | TATLICA- (AKSARAY) [E 2.4 km] |
| 27 | 17.02.2005 | 10:33:51.56 | 37,888 | 34,528 | **3,3** | **3,3** | | | | | 8 | BOR (NİĞDE) [SW 3.0 km] |
| 28 | 29.06.2005 | 17:23:04.98 | 38,9633 | 33,665 | **2,7** | **2,7** | | | | | 0,1 | SEYMENLI- ŞEREFLİKOÇHİSAR (ANKARA) [E 2.1 km] |
| 29 | 18.07.2005 | 09:26:08.95 | 38,0577 | 34,44 | **3,0** | **3,0** | | | | | 18,3 | YEŞİLYURT-ALTUNHİSAR (NİĞDE) [NE 7.0 km] |
| 30 | 01.08.2005 | 05:34:11.01 | 39,178 | 33,236 | **2,7** | **2,7** | | | | | 8,9 | AKARCA- ŞEREFLİKOÇHİSAR (ANKARA) [NE 1.3 km] |
| 31 | 17.08.2005 | 12:30:27.98 | 39,094 | 33,431 | **2,8** | **2,8** | | | | | 32 | ACIKUYU- ŞEREFLİKOÇHİSAR (ANKARA) [SW 5.0 km] |
| 32 | 19.08.2005 | 10:18:36.24 | 39,211 | 33,202 | **2,6** | **2,6** | | | | | 26,7 | DOĞANKAYA- ŞEREFLİKOÇHİSAR (ANKARA) [NE 0.8 km] |
| 33 | 24.08.2005 | 15:55:22.54 | 38,9905 | 33,574 | **2,5** | **2,5** | | | | | 17,5 | SADIKLI- ŞEREFLİKOÇHİSAR (ANKARA) [S 2.5 km] |
| 34 | 31.08.2005 | 13:02:15.26 | 37,8782 | 34,476 | **3,1** | **3,1** | | | | | 9,8 | KAYI-BOR (NİĞDE) [SE 6.8 km] |
| 35 | 13.11.2005 | 22:14:36.33 | 39,088 | 33,176 | **2,9** | **2,9** | | | | | 5,3 | ŞEKERKÖY- ŞEREFLİKOÇHİSAR (ANKARA) [SW 7.9 km] |
| 36 | 20.12.2005 | 21:58:44.65 | 39,2538 | 33,112 | **2,7** | **2,7** | | | | | 20,7 | AKTAŞ- ŞEREFLİKOÇHİSAR (ANKARA) [NW 3.7 km] |
| 37 | 03.01.2006 | 13:55:33.73 | 38,4457 | 33,581 | **2,9** | **2,9** | | | | | 5,6 | ESKİL (AKSARAY) [NE 15.4 km] |
| 38 | 05.01.2006 | 07:18:38.60 | 38,9013 | 33,545 | **3,0** | **3,0** | | | | | 18,6 | ŞEREFLİKOÇHİSAR (ANKARA) [S 4.1 km] |
| 39 | 07.01.2006 | 05:49:44.08 | 39,0258 | 33,524 | **2,6** | **2,6** | | | | | 22,7 | HACIBEKTAŞLI- ŞEREFLİKOÇHİSAR (ANKARA) [SE 4.1 km] |
| 40 | 05.02.2006 | 17:33:28.12 | 39,1798 | 33,275 | **3,3** | **3,3** | | | | | 5,9 | BÜYÜKKIŞLA- ŞEREFLİKOÇHİSAR (ANKARA) [SE 2.4 km] |
| 41 | 01.05.2006 | 06:45:30.21 | 37,91 | 34,562 | **3,2** | **3,2** | | | | | 1,6 | BOR (NİĞDE) [N 1.8 km] |
| 42 | 08.05.2006 | 20:45:46.01 | 39,1523 | 33,294 | **3,0** | **3,0** | | | | | 5,3 | AKIN- ŞEREFLİKOÇHİSAR (ANKARA) [NE 4.5 km] |
| 43 | 03.06.2006 | 01:43:08.93 | 39,2145 | 33,232 | **3,2** | **3,2** | | | | | 5,5 | BÜYÜKKIŞLA- ŞEREFLİKOÇHİSAR (ANKARA) [NW 3.1 km] |
| 44 | 30.08.2006 | 02:59:40.24 | 38,2712 | 34,022 | **3,4** | **3,4** | | | | | 0,4 | BAĞLI- (AKSARAY) [NW 5.1 km] |
| 45 | 03.09.2006 | 14:25:00.84 | 38,9957 | 33,578 | **2,6** | **2,6** | | | | | 7,8 | SADIKLI- ŞEREFLİKOÇHİSAR (ANKARA) [SE 2.0 km] |
| 46 | 27.09.2006 | 11:23:53.61 | 39,0863 | 33,282 | **2,9** | **2,9** | | | | | 17,6 | AKIN- ŞEREFLİKOÇHİSAR (ANKARA) [SE 4.5 km] |
| 47 | 08.10.2006 | 15:54:18.49 | 38,9067 | 33,564 | **2,6** | **2,6** | | | | | 15,8 | ŞEREFLİKOÇHİSAR (ANKARA) [SE 4.1 km] |
| 48 | 06.01.2007 | 10:34:53.71 | 38,3498 | 34,061 | **3,0** | **3,0** | | | | | 16,9 | AKSARAY [SE 3.2 km] |
| 49 | 22.02.2007 | 14:06:42.56 | 37,9328 | 34,702 | **2,9** | **2,9** | | | | | 5,4 | NİĞDE [SE 4.1 km] |
| 50 | 17.03.2007 | 21:41:35.68 | 38,0003 | 34,274 | **3,1** | **3,1** | | | | | 8,6 | AKÇAÖREN-ALTUNHİSAR (NİĞDE) [S 2.0 km] |
| 51 | 08.05.2007 | 00:21:11.61 | 38,668 | 33,57 | **3,2** | **3,2** | | | | | 5,3 | ÇALÖREN- ŞEREFLİKOÇHİSAR (ANKARA) [SW 16.3 km] |
| 52 | 17.05.2007 | 06:31:10.23 | 37,9048 | 34,48 | **2,9** | **2,9** | | | | | 12 | OKCU-BOR (NİĞDE) [SW 6.7 km] |
| 53 | 26.07.2007 | 13:17:12.20 | 37,8955 | 34,506 | **3,0** | **3,0** | | | | | 5,4 | BOR (NİĞDE) [W 4.9 km] |
| 54 | 19.08.2007 | 09:26:24.08 | 38,9568 | 33,539 | **2,8** | **2,8** | | | | | 4,9 | ŞEREFLİKOÇHİSAR (ANKARA) [N 2.1 km] |

Table 5- (continued)

| No | Date | Time | Lat. | Lon. | M | MD | ML | MS | Mw | Mb | Depth (km) | Location |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 55 | 19.08.2007 | 23:07:28.52 | 38,275 | 34,012 | **3,6** | **3,6** | | | | | 0,3 | SAĞLIK- (AKSARAY) [SW 5.9 km] |
| 56 | 07.09.2007 | 13:39:30.21 | 38,0008 | 34,532 | **2,9** | **2,9** | | | | | 2,2 | FESLEĞEN- (NİĞDE) [NW 2.6 km] |
| 57 | 28.09.2007 | 13:01:25.07 | 38,667 | 33,561 | **2,8** | **2,8** | | | | | 5,3 | ÇALÖREN- ŞEREFLİKOÇHİSAR (ANKARA) [SW 17.0 km] |
| 58 | 03.10.2007 | 11:28:31.43 | 37,9047 | 34,633 | **3,0** | **3,0** | | | | | 0,2 | SAZLICA- (NİĞDE) [NW 0.7 km] |
| 59 | 13.12.2007 | 18:06:18.70 | 38,83 | 33,05 | **4,9** | **4,5** | **4,8** | **4,9** | **4,9** | **4,8** | 5 | ACIKUYU-KULU (KONYA) [E 5.2 km] |
| 60 | 13.12.2007 | 21:40:00.42 | 38,8257 | 33,075 | **2,9** | **2,9** | | | | | 10,6 | ACIKUYU-KULU (KONYA) [E 7.4 km] |
| 61 | 17.12.2007 | 06:50:18.06 | 37,8962 | 34,525 | **3,1** | **3,1** | | | | | 5,4 | BOR (NİĞDE) [W 3.2 km] |
| 62 | 23.12.2007 | 15:21:32.53 | 38,9827 | 33,442 | **3,0** | **3,0** | | | | | 3,3 | ŞEREFLİKOÇHİSAR (ANKARA) [NW 9.8 km] |
| 63 | 28.12.2007 | 09:28:52.26 | 39,1025 | 33,231 | **2,9** | **2,9** | | | | | 14,3 | AKIN- ŞEREFLİKOÇHİSAR (ANKARA) [SW 3.3 km] |
| 64 | 29.12.2007 | 06:33:15.52 | 39,1995 | 33,218 | **2,7** | **2,7** | | | | | 9,2 | DOĞANKAYA- ŞEREFLİKOÇHİSAR (ANKARA) [SE 2.3 km] |
| 65 | 30.12.2007 | 00:04:21.47 | 39,2522 | 33,254 | **3,3** | **3,3** | | | | | 8,5 | ODUNBOĞAZI- ŞEREFLİKOÇHİSAR (ANKARA) [W 3.7 km] |
| 66 | 04.01.2008 | 10:24:28.91 | 39,2238 | 33,176 | **2,8** | **2,8** | | | | | 9,9 | DOĞANKAYA- ŞEREFLİKOÇHİSAR (ANKARA) [NW 2.3 km] |
| 67 | 24.01.2008 | 08:41:31.13 | 38,7142 | 33,343 | **3,0** | **3,0** | | | | | 4,2 | ÇAVUŞKÖY- ŞEREFLİKOÇHİSAR (ANKARA) [SW 19.6 km] |
| 68 | 28.01.2008 | 12:35:46.66 | 37,8733 | 34,716 | **2,9** | **2,9** | | | | | 6,3 | HALAÇ-BOR (NİĞDE) [NE 5.3 km] |
| 69 | 06.02.2008 | 11:55:52.06 | 38,3797 | 34,108 | **2,7** | **2,7** | | | | | 0,3 | SEVİNÇLİ- (AKSARAY) [NW 2.0 km] |
| 70 | 10.02.2008 | 01:52:08.44 | 37,9812 | 34,398 | **3,0** | **3,0** | | | | | 5,5 | ALTUNHİSAR (NİĞDE) [SE 3.0 km] |
| 71 | 10.04.2008 | 13:08:29.34 | 38,4583 | 34,014 | **2,7** | **2,7** | | | | | 0,5 | AKIN- (AKSARAY) [NW 2.9 km] |
| 72 | 22.04.2008 | 13:25:04.91 | 37,9297 | 34,718 | **2,9** | **2,9** | | | | | 5,2 | NİĞDE [SE 5.3 km] |
| 73 | 18.09.2008 | 09:18:44.51 | 39,1865 | 33,228 | **2,7** | **2,7** | | | | | 14,8 | AKARCA- ŞEREFLİKOÇHİSAR (ANKARA) [NE 1.4 km] |
| 74 | 18.09.2008 | 12:29:43.42 | 37,9503 | 34,699 | **2,7** | **2,7** | | | | | 1,1 | NİĞDE [SE 2.6 km] |
| 75 | 05.12.2008 | 12:44:04.68 | 38,735 | 33,567 | **2,9** | **2,9** | | | | | 17,8 | KARAMOLLAUŞAĞI- ŞEREFLİKOÇHİSAR (ANKARA) [SE 12.4 km] |
| 76 | 15.01.2009 | 15:36:37.45 | 38,728 | 33,716 | **2,7** | **2,7** | | | | | 7,3 | ÇALÖREN- ŞEREFLİKOÇHİSAR (ANKARA) [SE 4.8 km] |
| 77 | 23.01.2009 | 10:47:14.74 | 37,7453 | 34,411 | **2,6** | **2,6** | | | | | 37,8 | BADAK-BOR (NİĞDE) [North West 1.9 km] |
| 78 | 31.01.2009 | 07:14:49.25 | 38,7345 | 33,544 | **2,9** | **2,9** | | | | | 5,4 | KARAMOLLAUŞAĞI-ŞEREFLİKOÇHİSAR (ANKARA) [S 12.0 km] |
| 79 | 03.02.2009 | 14:07:23.14 | 37,9668 | 34,717 | **2,9** | **2,9** | | | | | 8,1 | NİĞDE (NİĞDE) [E 3.6 km] |
| 80 | 18.02.2009 | 10:52:52.41 | 37,7135 | 34,566 | **2,6** | **2,6** | | | | | 5,6 | BEREKET-BOR (NİĞDE) [SE 2.4 km] |
| 81 | 03.03.2009 | 18:20:29.76 | 38,5598 | 33,681 | **2,7** | **2,7** | | | | | 12,4 | ULUKIŞLA- (AKSARAY) [NW 9.7 km] |
| 82 | 03.03.2009 | 19:08:59.09 | 38,4972 | 33,88 | **2,7** | **2,7** | | | | | 16,5 | BAYMIŞ- (AKSARAY) [SW 0.9 km] |
| 83 | 11.03.2009 | 16:27:37.38 | 37,7728 | 34,599 | **3,0** | **3,0** | | | | | 5,8 | HAVUZLU-BOR (NİĞDE) [SW 3.5 km] |
| 84 | 31.03.2009 | 10:00:27.50 | 37,7513 | 34,616 | **2,8** | **2,8** | | | | | 8,5 | GÖNWEZ-BOR (NİĞDE) [W 3.7 km] |
| 85 | 02.05.2009 | 13:41:12.50 | 38,179 | 34,198 | **2,9** | **2,9** | | | | | 9,5 | HELVADERE- (AKSARAY) [SW 1.8 km] |
| 86 | 30.05.2009 | 23:28:53.79 | 38,6432 | 33,658 | **3,4** | **3,4** | | | | | 5,2 | ALTINKAYA- (AKSARAY) [NW 11.3 km] |
| 87 | 10.06.2009 | 10:30:15.18 | 37,8533 | 34,447 | **2,8** | **2,8** | | | | | 2,2 | EMEN-BOR (NİĞDE) [N 4.0 km] |
| 88 | 20.06.2009 | 22:12:03.42 | 39,109 | 33,275 | **3,0** | **3,0** | | | | | 6,2 | AKIN- ŞEREFLİKOÇHİSAR (ANKARA) [SE 2.1 km] |
| 89 | 23.06.2009 | 15:03:33.53 | 37,7575 | 34,631 | **2,8** | **2,8** | | | | | 7,5 | GÖNWEZ-BOR (NİĞDE) [NW 2.5 km] |
| 90 | 09.07.2009 | 15:39:59.05 | 37,6893 | 34,392 | **2,4** | **2,4** | | | | | 2,7 | BADAK-BOR (NİĞDE) [SW 5.8 km] |
| 91 | 01.08.2009 | 04:15:20.84 | 39,1448 | 33,276 | **2,9** | **2,9** | | | | | 7,3 | AKIN- ŞEREFLİKOÇHİSAR (ANKARA) [NE 2.9 km] |
| 92 | 25.08.2009 | 12:18:19.09 | 38,7438 | 33,645 | **2,8** | **2,8** | | | | | 0 | ÇALÖREN- ŞEREFLİKOÇHİSAR (ANKARA) [SW 6.0 km] |
| 93 | 29.09.2009 | 13:50:58.54 | 37,7457 | 34,521 | **2,5** | **2,5** | | | | | 4,5 | BEREKET-BOR (NİĞDE) [NW 3.0 km] |
| 94 | 02.11.2009 | 12:24:49.40 | 39,2237 | 33,204 | **3,3** | **3,3** | | | | | 7,1 | DOĞANKAYA- ŞEREFLİKOÇHİSAR (ANKARA) [NE 2.0 km] |
| 95 | 06.11.2009 | 11:45:35.00 | 37,7455 | 34,54 | **2,7** | **2,7** | | | | | 15,1 | BEREKET-BOR (NİĞDE) [NW 1.8 km] |
| 96 | 25.11.2009 | 10:42:32.36 | 37,9492 | 34,589 | **2,8** | **2,8** | | | | | 0,1 | KOYUNLU- (NİĞDE) [S 3.7 km] |
| 97 | 17.12.2009 | 16:13:10.43 | 37,8748 | 34,573 | **2,7** | **2,7** | | | | | 12,6 | BOR (NİĞDE) [SE 2.3 km] |
| 98 | 25.12.2009 | 13:53:12.24 | 38,28 | 34,097 | **2,9** | **2,9** | | | | | 10 | AKHİSAR- (AKSARAY) [S 1.4 km] |
| 99 | 17.01.2010 | 19:37:24.85 | 38,7063 | 33,587 | **3,1** | **3,1** | | | | | 7,6 | ÇALÖREN- ŞEREFLİKOÇHİSAR (ANKARA) [SW 12.4 km] |
| 100 | 22.01.2010 | 17:48:15.50 | 39,1552 | 33,154 | **3,0** | **3,0** | | | | | 10,6 | ŞEKERKÖY- ŞEREFLİKOÇHİSAR (ANKARA) [W 3.3 km] |
| 101 | 26.01.2010 | 13:45:27.99 | 38,115 | 34,088 | **2,6** | **2,6** | | | | | 24 | KARACAÖREN- (AKSARAY) [SE 2.6 km] |
| 102 | 08.02.2010 | 23:34:10.41 | 38,6778 | 33,508 | **2,9** | **2,9** | | | | | 10,9 | KARAMOLLAUŞAĞI- ŞEREFLİKOÇHİSAR (ANKARA) [S 18.2 km] |
| 103 | 10.02.2010 | 12:04:58.67 | 38,6883 | 33,517 | **2,4** | **2,4** | | | | | 4,7 | KARAMOLLAUŞAĞI- ŞEREFLİKOÇHİSAR (ANKARA) [S 17.0 km] |
| 104 | 04.03.2010 | 21:10:44.67 | 39,1285 | 33,139 | **2,9** | **2,9** | | | | | 16,7 | ŞEKERKÖY- ŞEREFLİKOÇHİSAR (ANKARA) [SW 5.6 km] |
| 105 | 14.03.2010 | 23:07:12.38 | 39,157 | 33,153 | **2,8** | **2,8** | | | | | 19,4 | ŞEKERKÖY- ŞEREFLİKOÇHİSAR (ANKARA) [W 3.4 km] |
| 106 | 28.04.2010 | 10:56:15.74 | 38,4873 | 34,1 | **2,8** | **2,8** | | | | | 3,9 | EKECİKTOLU- (AKSARAY) [S 2.1 km] |
| 107 | 04.05.2010 | 12:34:13.21 | 38,225 | 34,087 | **3,2** | **3,2** | | | | | 8 | KARATAŞ- (AKSARAY) [SW 3.0 km] |
| 108 | 11.05.2010 | 11:27:16.39 | 37,8762 | 34,585 | **2,6** | **2,6** | | | | | 17,7 | BOR (NİĞDE) [SE 2.8 km] |
| 109 | 25.05.2010 | 09:10:24.73 | 37,8535 | 34,655 | **3,0** | **3,0** | | | | | 3,6 | KAYNARCA-BOR (NİĞDE) [E 1.6 km] |
| 110 | 29.05.2010 | 13:11:36.38 | 38,8548 | 33,508 | **2,8** | **2,8** | | | | | 4 | KARAMOLLAUŞAĞI- ŞEREFLİKOÇHİSAR (ANKARA) [NW 2.1 km] |

Table 5- (continued)

| No | Date | Time | Lat. | Lon. | M | MD | ML | MS | Mw | Mb | Depth (km) | Location |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 111 | 27.06.2010 | 03:22:30.52 | 39,1247 | 33,292 | **2,4** | **2,4** | | | | | 5,8 | AKIN- ŞEREFLİKOÇHİSAR (ANKARA) [E 2.9 km] |
| 112 | 29.06.2010 | 15:33:08.09 | 39,1133 | 33,248 | **2,8** | **2,8** | | | | | 6,6 | AKIN- ŞEREFLİKOÇHİSAR (ANKARA) [SW 1.4 km] |
| 113 | 01.07.2010 | 17:21:06.25 | 38,9207 | 33,629 | **2,2** | **2,2** | | | | | 5 | FADILLI- ŞEREFLİKOÇHİSAR (ANKARA) [W 2.6 km] |
| 114 | 01.07.2010 | 20:48:11.79 | 39,095 | 33,271 | **2,7** | **2,7** | | | | | 15,1 | AKIN- ŞEREFLİKOÇHİSAR (ANKARA) [SE 3.3 km] |
| 115 | 02.07.2010 | 00:41:30.45 | 39,1252 | 33,262 | **3,0** | **3,0** | | | | | 8,7 | AKIN- ŞEREFLİKOÇHİSAR (ANKARA) [NE 0.4 km] |
| 116 | 02.07.2010 | 02:25:46.67 | 39,1087 | 33,26 | **2,3** | **2,3** | | | | | 5 | AKIN- ŞEREFLİKOÇHİSAR (ANKARA) [S 1.6 km] |
| 117 | 04.07.2010 | 02:01:52.08 | 39,1058 | 33,271 | **2,5** | **2,5** | | | | | 8,5 | AKIN- ŞEREFLİKOÇHİSAR (ANKARA) [SE 2.2 km] |
| 118 | 10.07.2010 | 15:46:00.25 | 38,9767 | 33,606 | **2,6** | **2,6** | | | | | 18,6 | KARABÜK- ŞEREFLİKOÇHİSAR (ANKARA) [SW 2.1 km] |
| 119 | 16.07.2010 | 00:17:41.51 | 38,6837 | 33,658 | **2,2** | **2,2** | | | | | 24,5 | ÇALÖREN- ŞEREFLİKOÇHİSAR (ANKARA) [SW 10.5 km] |
| 120 | 17.07.2010 | 07:41:10.23 | 39,1207 | 33,284 | **2,6** | **2,6** | | | | | 2,6 | AKIN- ŞEREFLİKOÇHİSAR (ANKARA) [E 2.2 km] |
| 121 | 19.07.2010 | 18:06:37.00 | 39,0858 | 33,269 | **2,7** | **2,7** | | | | | 9,9 | AKIN- ŞEREFLİKOÇHİSAR (ANKARA) [SE 4.2 km] |
| 122 | 20.07.2010 | 04:22:10.29 | 39,1275 | 33,255 | **2,7** | **2,7** | | | | | 5,2 | AKIN- ŞEREFLİKOÇHİSAR (ANKARA) [NW 0.6 km] |
| 123 | 20.07.2010 | 22:55:56.28 | 39,0922 | 33,298 | **2,8** | **2,8** | | | | | 5,3 | AKIN- ŞEREFLİKOÇHİSAR (ANKARA) [SE 4.8 km] |
| 124 | 22.07.2010 | 09:12:05.22 | 37,8758 | 34,678 | **2,4** | **2,4** | | | | | 17,2 | KAYNARCA-BOR (NİĞDE) [NE 4.5 km] |
| 125 | 27.07.2010 | 19:58:17.28 | 39,1172 | 33,227 | **3,3** | | **3,3** | | | | 2,3 | AKIN- ŞEREFLİKOÇHİSAR (ANKARA) [SW 2.8 km] |
| 126 | 27.07.2010 | 20:56:30.50 | 39,1597 | 33,295 | **2,8** | **2,8** | | | | | 8,5 | YUSUFKUYUSU- ŞEREFLİKOÇHİSAR (ANKARA) [S 4.1 km] |
| 127 | 28.07.2010 | 12:52:43.14 | 39,1448 | 33,274 | **3,2** | **3,2** | | | | | 1,5 | AKIN- ŞEREFLİKOÇHİSAR (ANKARA) [NE 2.8 km] |
| 128 | 05.08.2010 | 04:18:16.78 | 38,7368 | 33,512 | **2,2** | **2,2** | | | | | 11,7 | KARAMOLLAUŞAĞI- ŞEREFLİKOÇHİSAR (ANKARA) [S 11.7 km] |
| 129 | 06.08.2010 | 13:22:33.35 | 38,244 | 34,115 | **2,7** | **2,7** | | | | | 14,2 | KARAÖREN- (AKSARAY) [W 1.5 km] |
| 130 | 08.08.2010 | 07:25:16.77 | 38,5023 | 34,132 | **2,2** | **2,2** | | | | | 3,5 | EKECİKYENİ- (AKSARAY) [SE 2.9 km] |
| 131 | 08.08.2010 | 11:14:13.73 | 38,9367 | 33,634 | **2,8** | **2,8** | | | | | 3,3 | FADILLI- ŞEREFLİKOÇHİSAR (ANKARA) [NW 2.6 km] |
| 132 | 09.08.2010 | 16:24:36.87 | 38,4098 | 34,119 | **2,4** | **2,4** | | | | | 11,5 | GÜCÜNKAYA- (AKSARAY) [NW 1.9 km] |
| 133 | 17.08.2010 | 08:16:10.78 | 38,5252 | 33,948 | **2,5** | **2,5** | | | | | 4,7 | BAĞLIKAYA- (AKSARAY) [N 2.5 km] |
| 134 | 17.08.2010 | 11:45:51.84 | 38,4637 | 33,96 | **2,4** | **2,4** | | | | | 7,9 | TOPAKKAYA- (AKSARAY) [NE 3.0 km] |
| 135 | 21.08.2010 | 23:55:21.17 | 39,2292 | 33,208 | **2,5** | **2,5** | | | | | 6,9 | DOĞANKAYA- ŞEREFLİKOÇHİSAR (ANKARA) [NE 2.7 km] |
| 136 | 29.08.2010 | 05:33:14.09 | 38,4298 | 34,065 | **2,6** | **2,6** | | | | | 7,5 | GENÇOSMAN- (AKSARAY) [N 1.7 km] |
| 137 | 03.09.2010 | 20:51:49.08 | 38,0948 | 34,339 | **2,6** | **2,6** | | | | | 6,8 | ÇÖMLEKÇİ-ALTUNHİSAR (NİĞDE) [N 4.4 km] |
| 138 | 15.09.2010 | 12:01:55.34 | 38,9672 | 33,72 | **2,4** | **2,4** | | | | | 9,9 | İBRAHİMBEYLİ-EVREN (ANKARA) [E 1.6 km] |
| 139 | 18.09.2010 | 13:22:21.57 | 38,3408 | 33,517 | **2,3** | **2,3** | | | | | 0,7 | YEŞİLTÖMEK- (AKSARAY) [N 5.4 km] |
| 140 | 29.09.2010 | 00:59:44.74 | 39,2185 | 33,18 | **2,9** | **2,9** | | | | | 5,4 | DOĞANKAYA- ŞEREFLİKOÇHİSAR (ANKARA) [NW 1.7 km] |
| 141 | 29.09.2010 | 03:04:21.83 | 39,2387 | 33,228 | **2,7** | **2,7** | | | | | 5,2 | DOĞANKAYA- ŞEREFLİKOÇHİSAR (ANKARA) [NE 4.5 km] |
| 142 | 01.10.2010 | 17:35:01.48 | 39,225 | 33,172 | **3,3** | **3,3** | | | | | 6 | DOĞANKAYA- ŞEREFLİKOÇHİSAR (ANKARA) [NW 2.7 km] |
| 143 | 05.10.2010 | 17:02:40.80 | 38,844 | 33,549 | **2,3** | **2,3** | | | | | 13,7 | KARAMOLLAUŞAĞI- ŞEREFLİKOÇHİSAR (ANKARA) [E 2.0 km] |
| 144 | 07.10.2010 | 01:52:10.48 | 39,1527 | 33,209 | **2,5** | **2,5** | | | | | 7,9 | ŞEKERKÖY- ŞEREFLİKOÇHİSAR (ANKARA) [SE 1.5 km] |
| 145 | 12.10.2010 | 04:57:43.63 | 38,4397 | 34,078 | **2,0** | **2,0** | | | | | 2,2 | GENÇOSMAN- (AKSARAY) [NE 2.9 km] |
| 146 | 12.10.2010 | 14:55:22.01 | 38,3133 | 34,074 | **2,9** | **2,9** | | | | | 4,3 | SAĞLIK- (AKSARAY) [NE 1.3 km] |
| 147 | 15.10.2010 | 11:02:03.87 | 38,9547 | 33,68 | **2,3** | **2,3** | | | | | 11,1 | İBRAHİMBEYLİ-EVREN (ANKARA) [SW 2.4 km] |
| 148 | 16.10.2010 | 09:26:52.11 | 37,8605 | 34,533 | **2,6** | **2,6** | | | | | 24,7 | BOR (NİĞDE) [SW 4.5 km] |
| 149 | 11.11.2010 | 11:13:10.16 | 37,7368 | 34,738 | **2,9** | **2,9** | | | | | 8,4 | POSTALLI-BOR (NİĞDE) [NW 1.3 km] |
| 150 | 27.11.2010 | 04:41:15.64 | 37,99 | 34,386 | **2,6** | **2,6** | | | | | 5,4 | ALTUNHİSAR (NİĞDE) [SE 1.5 km] |
| 151 | 02.12.2010 | 00:20:09.63 | 39,1235 | 33,345 | **2,1** | **2,1** | | | | | 8,8 | ACIÖZ- ŞEREFLİKOÇHİSAR (ANKARA) [SW 6.9 km] |
| 152 | 07.12.2010 | 14:35:15.13 | 38,2708 | 34,086 | **2,8** | **2,8** | | | | | 6,5 | BAĞLI- (AKSARAY) [NE 1.4 km] |
| 153 | 11.12.2010 | 10:39:40.14 | 38,5 | 34,182 | **2,8** | **2,8** | | | | | 7,3 | YALNIZCEVİZ- (AKSARAY) [NE 1.9 km] |
| 154 | 15.12.2010 | 08:51:29.72 | 38,417 | 34,188 | **2,7** | **2,7** | | | | | 0,1 | GÖKÇE- (AKSARAY) [E 1.3 km] |
| 155 | 27.12.2010 | 14:22:31.41 | 38,9703 | 33,588 | **2,0** | **2,0** | | | | | 5,2 | KARABÜK- ŞEREFLİKOÇHİSAR (ANKARA) [SW 3.7 km] |
| 156 | 28.12.2010 | 09:23:48.06 | 39,275 | 33,324 | **2,4** | **2,4** | | | | | 19,8 | ODUNBOĞAZI- ŞEREFLİKOÇHİSAR (ANKARA) [NE 3.3 km] |
| 157 | 31.12.2010 | 09:55:04.88 | 38,4732 | 33,966 | **2,8** | **2,8** | | | | | 7,2 | BAĞLIKAYA- (AKSARAY) [SE 3.9 km] |
| 158 | 31.12.2010 | 10:24:27.85 | 38,4312 | 33,928 | **3,0** | **3,0** | | | | | 0 | TOPAKKAYA- (AKSARAY) [S 2.5 km] |
| 159 | 04.01.2011 | 12:48:29.13 | 38,2907 | 34,088 | **2,5** | **2,5** | | | | | 13,3 | AKHİSAR- (AKSARAY) [SW 0.9 km] |
| 160 | 24.01.2011 | 09:17:07.07 | 38,6887 | 33,675 | **2,5** | **2,5** | | | | | 5,3 | ÇALÖREN- ŞEREFLİKOÇHİSAR (ANKARA) [SW 9.5 km] |
| 161 | 28.01.2011 | 11:00:52.23 | 38,6753 | 33,612 | **2,4** | **2,4** | | | | | 14,5 | ÇALÖREN- ŞEREFLİKOÇHİSAR (ANKARA) [SW 13.3 km] |
| 162 | 01.02.2011 | 02:06:27.13 | 38,5428 | 33,895 | **2,7** | **2,7** | | | | | 11 | SAPMAZ- (AKSARAY) [NE 2.0 km] |
| 163 | 01.02.2011 | 11:48:07.29 | 37,7032 | 34,71 | **2,5** | **2,5** | | | | | 4,1 | KÜRKÇÜ-BOR (NİĞDE) [SW 1.4 km] |
| 164 | 03.02.2011 | 09:17:11.30 | 37,9803 | 34,538 | **2,6** | **2,6** | | | | | 12,7 | FESLEĞEN- (NİĞDE) [SW 1.7 km] |
| 165 | 16.02.2011 | 14:33:54.15 | 38,06 | 34,836 | **2,8** | **2,8** | | | | | 5,7 | YEŞİLOVA- (NİĞDE) [SW 0.6 km] |
| 166 | 24.02.2011 | 08:22:03.75 | 37,9208 | 34,436 | **2,9** | **2,9** | | | | | 0,4 | KAYI-BOR (NİĞDE) [NE 3.6 km] |

Table 5- (continued)

| No | Date | Time | Lat. | Lon. | M | MD | ML | MS | Mw | Mb | Depth (km) | Location |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 167 | 26.02.2011 | 09:14:59.44 | 37,9302 | 34,552 | **2,8** | **2,8** | | | | | 11,6 | OKCU-BOR (NİĞDE) [SE 1.4 km] |
| 168 | 07.04.2011 | 11:15:27.14 | 38,4512 | 34,049 | **2,6** | **2,6** | | | | | 5,4 | AKIN- (AKSARAY) [NE 1.6 km] |
| 169 | 08.04.2011 | 13:24:27.60 | 38,202 | 34,103 | **2,8** | **2,8** | | | | | 20,1 | GÖZLÜKUYU- (AKSARAY) [N 2.4 km] |
| 170 | 23.04.2011 | 21:39:36.18 | 38,8387 | 33,431 | **2,7** | **2,7** | | | | | 5,4 | HAMZALI- ŞEREFLİKOÇHİSAR (ANKARA) [SW 4.2 km] |
| 171 | 05.05.2011 | 16:00:18.74 | 39,1687 | 33,311 | **2,9** | **2,9** | | | | | 12,8 | YUSUFKUYUSU- ŞEREFLİKOÇHİSAR (ANKARA) [SE 3.3 km] |
| 172 | 13.05.2011 | 10:57:57.05 | 38,9985 | 33,537 | **2,1** | **2,1** | | | | | 3,2 | SADIKLI- ŞEREFLİKOÇHİSAR (ANKARA) [SW 3.4 km] |
| 173 | 24.05.2011 | 13:46:29.75 | 38,3353 | 34,164 | **2,7** | **2,7** | | | | | 18,3 | ÇELTEK- (AKSARAY) [NE 2.1 km] |
| 174 | 28.05.2011 | 15:23:52.38 | 38,4825 | 34,183 | **2,4** | **2,4** | | | | | 3,3 | YALNIZCEVİZ- (AKSARAY) [SE 1.3 km] |
| 175 | 29.05.2011 | 02:12:14.86 | 38,5 | 33,778 | **2,9** | **2,9** | | | | | 8,1 | ULUKIŞLA- (AKSARAY) [E 1.3 km] |
| 176 | 29.05.2011 | 02:13:38.93 | 38,4925 | 33,879 | **2,8** | **2,8** | | | | | 5,4 | BAYMIŞ- (AKSARAY) [SW 1.3 km] |
| 177 | 29.05.2011 | 02:17:53.29 | 38,5 | 33,789 | **2,9** | **2,9** | | | | | 7,9 | ULUKIŞLA- (AKSARAY) [E 2.2 km] |
| 178 | 29.05.2011 | 02:19:39.89 | 38,5307 | 33,716 | **2,8** | **2,8** | | | | | 6,1 | ULUKIŞLA- (AKSARAY) [NW 5.3 km] |
| 179 | 29.05.2011 | 02:25:55.50 | 38,507 | 33,814 | **3,3** | **3,3** | | | | | 0,1 | ACIPINAR- (AKSARAY) [SW 4.1 km] |
| 180 | 29.05.2011 | 02:28:05.80 | 38,4747 | 33,872 | **3,0** | **3,0** | | | | | 5,3 | ÇİMELİYENİKÖY- (AKSARAY) [SW 3.3 km] |
| 181 | 29.05.2011 | 02:57:22.34 | 38,4757 | 33,671 | **2,9** | **2,9** | | | | | 12,6 | YEŞİLTEPE- (AKSARAY) [W 8.4 km] |
| 182 | 29.05.2011 | 05:08:25.52 | 38,468 | 33,752 | **3,2** | **3,2** | | | | | 8 | YEŞİLTEPE- (AKSARAY) [NW 1.3 km] |
| 183 | 29.05.2011 | 16:14:31.61 | 38,9318 | 33,406 | **3,4** | **3,4** | | | | | 5,4 | HAMZALI- ŞEREFLİKOÇHİSAR (ANKARA) [NW 7.8 km] |
| 184 | 05.06.2011 | 01:54:59.90 | 38,7372 | 33,602 | **3,2** | **3,2** | | | | | 0,1 | ÇALÖREN- ŞEREFLİKOÇHİSAR (ANKARA) [SW 9.6 km] |
| **185** | 13.06.2011 | 11:30:25.89 | 38,3463 | 33,9202 | **3,9** | | **3,9** | | | | 0,1 | ATAKÖY – AKSARAY [SE 1,0 km] |
| 186 | 05.07.2011 | 08:09:44.20 | 38,465 | 34,136 | **2,5** | **2,5** | | | | | 5,2 | AĞZIKARAHAN- (AKSARAY) [N 2.3 km] |
| 187 | 05.07.2011 | 13:28:57.84 | 38,4955 | 33,871 | **2,5** | **2,5** | | | | | 24,8 | BAYMIŞ- (AKSARAY) [SW 1.7 km] |
| 188 | 09.07.2011 | 10:01:37.95 | 38,4485 | 34,157 | **2,6** | **2,6** | | | | | 0,2 | AĞZIKARAHAN- (AKSARAY) [NE 1.6 km] |
| 189 | 19.07.2011 | 11:21:03.20 | 38,4712 | 34,142 | **2,9** | **2,9** | | | | | 1,9 | YALNIZCEVİZ- (AKSARAY) [SW 2.9 km] |
| 190 | 21.07.2011 | 09:51:49.45 | 38,9907 | 33,434 | **2,5** | **2,5** | | | | | 19,9 | HACIBEKTAŞLI- ŞEREFLİKOÇHİSAR (ANKARA) [SW 9.9 km] |
| 191 | 30.07.2011 | 10:24:30.80 | 38,9525 | 33,581 | **2,0** | **2,0** | | | | | 14 | ŞEREFLİKOÇHİSAR (ANKARA) [NE 3.9 km] |
| 192 | 01.08.2011 | 12:40:13.00 | 38,5423 | 33,557 | **1,9** | | **1,9** | | | | 0,1 | ULUKIŞLA- (AKSARAY) [NW 18.5 km] |
| 193 | 05.08.2011 | 13:54:23.04 | 38,305 | 34,125 | **3,0** | **3,0** | | | | | 9,3 | AKHİSAR- (AKSARAY) [NE 2.7 km] |
| 194 | 16.08.2011 | 09:05:55.20 | 38,458 | 34,297 | **2,6** | **2,6** | | | | | 4,6 | AKMEZAR-GÜLAĞAÇ (AKSARAY) [SW 1.5 km] |
| 195 | 23.08.2011 | 11:35:51.46 | 38,4573 | 34,144 | **2,5** | **2,5** | | | | | 11,6 | AĞZIKARAHAN- (AKSARAY) [NE 1.5 km] |
| 196 | 09.09.2011 | 01:05:14.19 | 39,22 | 33,276 | **2,7** | **2,7** | | | | | 17,5 | BÜYÜKKIŞLA- ŞEREFLİKOÇHİSAR (ANKARA) [NE 2.6 km] |
| 197 | 14.09.2011 | 07:40:11.06 | 37,8948 | 34,634 | **1,9** | | **1,9** | | | | 10,9 | SAZLICA- (NİĞDE) [SW 0.5 km] |
| 198 | 15.09.2011 | 14:20:06.26 | 38,4282 | 34,115 | **2,6** | **2,6** | | | | | 2,3 | AĞZIKARAHAN- (AKSARAY) [SW 2.8 km] |
| 199 | 21.09.2011 | 12:25:40.13 | 37,8635 | 34,652 | **2,7** | **2,7** | | | | | 0,6 | KAYNARCA-BOR (NİĞDE) [NE 1.9 km] |
| 200 | 26.09.2011 | 20:17:42.07 | 38,9227 | 33,408 | **2,8** | **2,8** | | | | | 5,5 | HAMZALI- ŞEREFLİKOÇHİSAR (ANKARA) [NW 6.8 km] |
| 201 | 29.10.2011 | 04:16:32.84 | 39,1968 | 33,347 | **2,8** | **2,8** | | | | | 8 | BÜYÜNEAMLACIK- ŞEREFLİKOÇHİSAR (ANKARA) [SE 2.1 km] |
| 202 | 06.12.2011 | 13:05:29.95 | 38,3718 | 34,106 | **3,0** | **3,0** | | | | | 9,7 | SEVİNÇLİ- (AKSARAY) NW 1.3 km] |
| 203 | 21.12.2011 | 13:14:46.90 | 38,4958 | 34,013 | **2,1** | | **2,1** | | | | | GÜLTEPE- (AKSARAY) [NW 4.7 km] |

Kürçer (2012) conducted 4 paleoseismic trench works (two for each segment) on the Tuz Gölü and Akhisar-Kılıç segments. Paleoseismic results of these studies are published in several journal (Kürçer and Gökten, 2012; Kürçer et al. (2012); Kürçer and Gökten, 2014).

## 5. Comments on the Age of Neotectonic Period in the Tuz Gölü Fault Zone Region

In this study, 1/25.000 scaled geology maps of two different areas have been renewed to clarify the age of Neotectonic period in the TGFZ region (Figure 33). After rectification, produced geology maps were spread out in the Google Earth program and relief geology maps were acquired for the sub-regions (Figures 34 and 35).

For the renewal of geology maps, 1/25.000 scaled geology maps in the archives of Geology Department of the General Directorate of the Mineral Research and Exploration of Turkey (MTA) were referenced and renewed in detail in accordance with the aim of study.

In renewal of geology maps for Şereflikoçhisar and surrounding areas studies of Uygun et al. (1982), Atabey (1986), Atabey et al. (1987) and Atabey

Table 6- The maximum earthquake magnitudes, the maximum and average displacements generated by the segments of the Tuz Gölü Fault Zone (in calculations equations by Wells and Coppersmith (1994) suggested for normal faults are used).

| **Segment name** | **Segment length (km)** | **The largest eartquake expected from the segment (M)** | **The largest displacement expected from each eartquake (m)** | **The average displacement expected from each eartquake (m)** |
|---|---|---|---|---|
| Yusufkuyusu | 9 | 6,11 | 0,34 | 0,25 |
| Acıkuyu | 10 | 6,18 | 0,39 | 0,27 |
| Akboğaz | 13 | 6,33 | 0,54 | 0,34 |
| Şereflikoçhisar | 14 | 6,37 | 0,58 | 0,36 |
| İnceburun | 23 | 6,65 | 1,04 | 0,54 |
| Tuz Gölü | 30 | 6,80 | 1,41 | 0,68 |
| Acıpınar | 26 | 6,72 | 1,20 | 0,60 |
| Aksaray | 13 | 6,33 | 0,54 | 0,34 |
| Akhisar-Kılıç | 27 | 6,74 | 1,25 | 0,62 |
| Altunhisar | 30 | 6,80 | 1,41 | 0,68 |
| Bor | 17 | 6,48 | 0,73 | 0,42 |

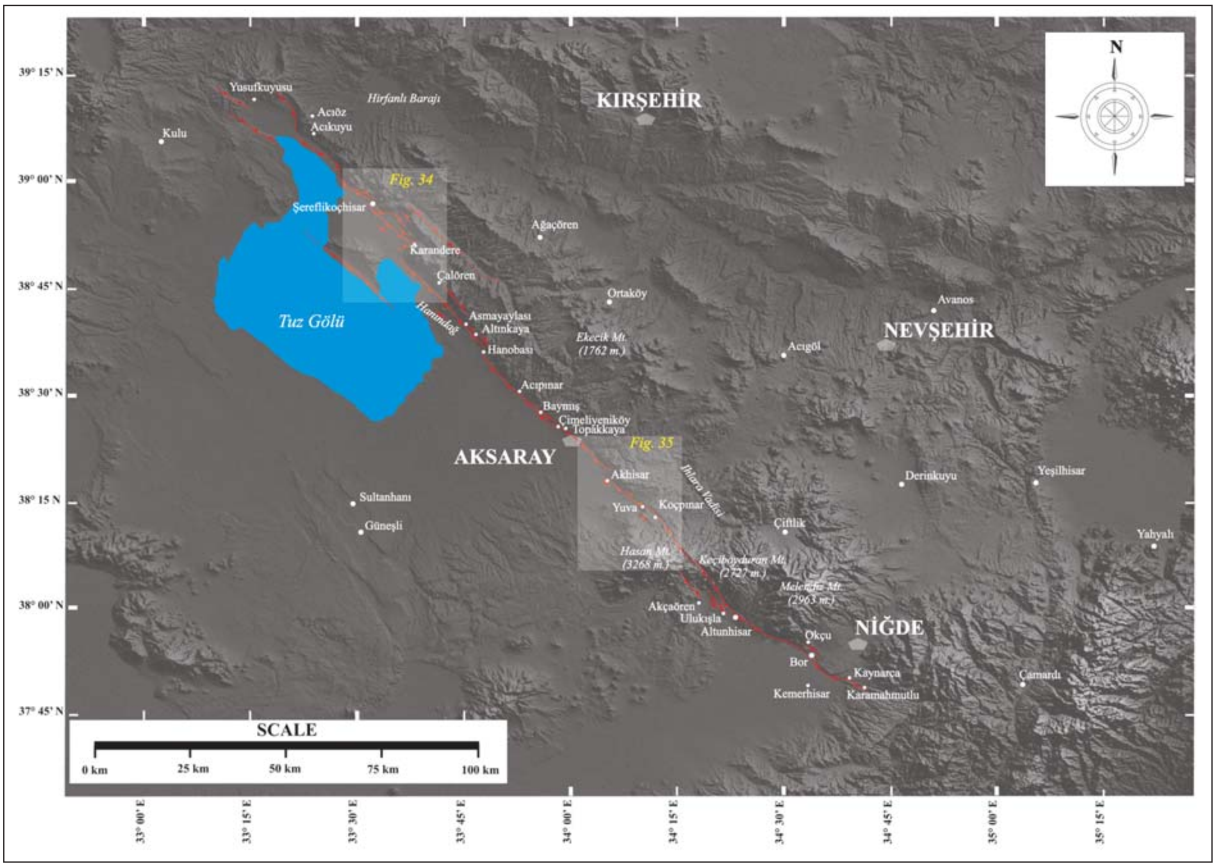


Figure 33- Map showing sub-areas where 1/25.000 scaled geological map renewal was done in the Tuz Gölü Fault Zone region

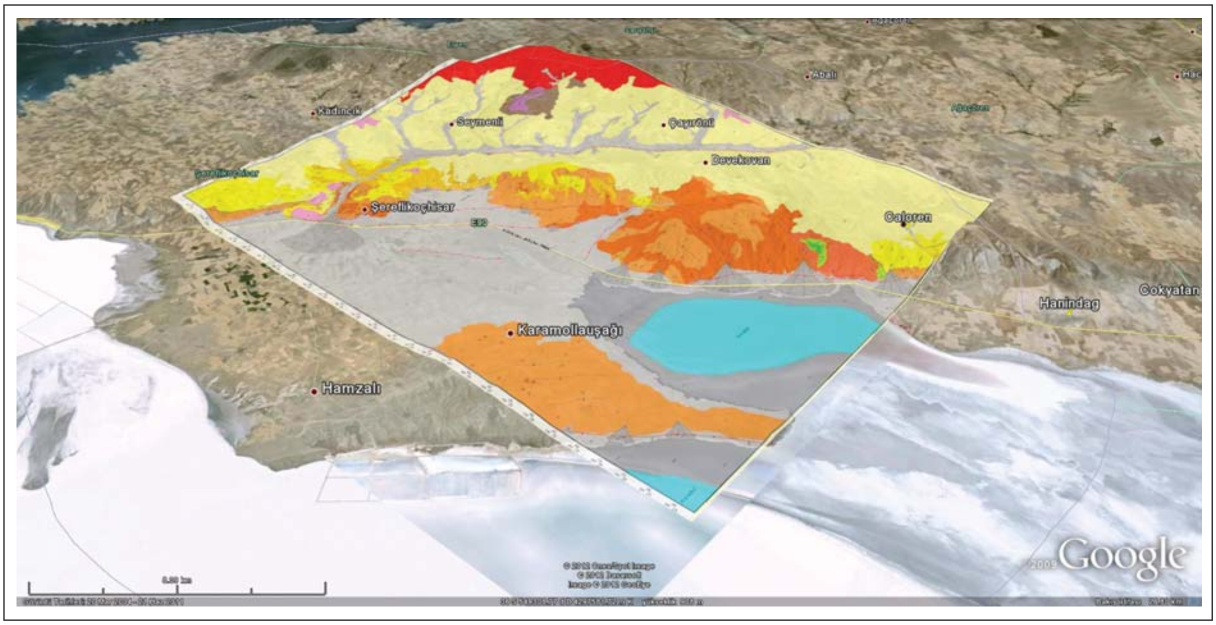


Figure 34- Relief geology map of Şereflikoçhisar and surrounding (K31 a1,a2,a3,a4) (in the Google Earth image vertical scale three times exaggerated, view to NE with oblique angle)

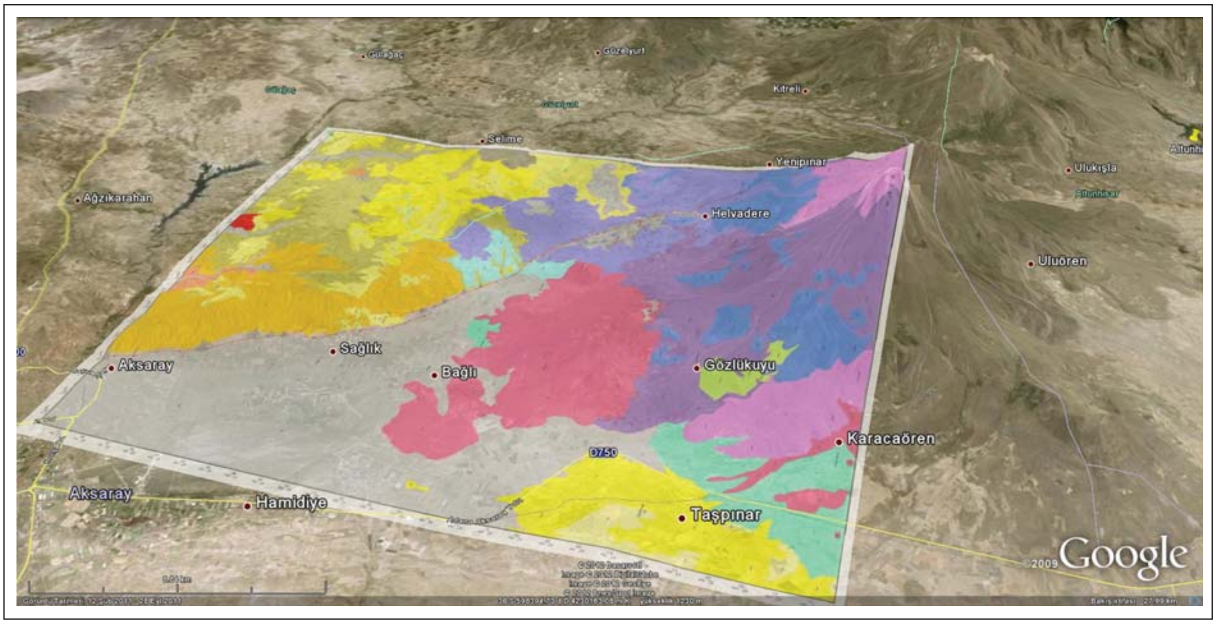


Figure 35- Relief geology map of the area between Aksaray and Hasandağı (L32 a3,a4,d1,d2) (in the Google Earth image vertical scale three times exaggerated, view to NE with oblique angle)

(1989) were utilized. In renewal of geology maps for the area between Aksaray and Hasandağı, geology maps of Beekman (1965), Erdem (1985), Papak (1985) and Dönmez et al. (2005) were used.

The first area of map renewal comprises Şereflikoçhisar and surrounding (K31 a1,a2, a3 and a4 quadrangles) (Figure 34). Structural elements in the map area indicate that more than one tectonic regime are effective. In units below the late Miocene-Pliocene Peçenek formation (Tmplp) and Pliocene Cihanbeyli formation (Tplc) fold axes in three different directions are noticeable. Among them, E-W trending fold axis is the relatively oldest one that is observed in the Paleozoic Tamadağ formation (Pzt) and Bozçaldağ formation (Pzb). In Mesozoic and Cenozoic sedimentary rocks between the Paleozoic metamorphic basement and late Miocene-Pliocene neotectonic units (Peçenek and Cihanbeyli formations) fold axis in two different directions (N15°E and N50°W) are observed. N15°E-trending folding was effective in relatively older units (Kartal, Asmaboğazı, Çaldağ, Karapınaryaylası and Boyalı formations). N50ºW-trending folding axis is dominated in relatively younger units (Karapınaryaylası, Boyalı, Yassıpur and Koçhisar formations).

The Peçenek formation and laterally and vertically interlayered Cihanbeyli formation cover the older units with an angular unconformity. This stratigraphic relation is well seen around the Ağasivri Hill NE of Şereflikoçhisar (Figure 36). At the Ağasivri Hill (1180 m) Pliocene aged Cihanbeyli formation is exposed. The unit is cut and lowered to the 950-m elevation by a series of SW-dipping normal faults that belong to TGFZ that is generated during the neotectonic period (Figure 37). In an assessment considering the basement of Cihanbeyli formation, total oblique slip rate on TGFZ following the deposition of Cihanbeyli formation (Paleocene to recent) is found 200 m (1078 m – 878 m).

In this study, due to aforementioned stratigraphic relation, the Peçenek and Cihanbeyli formations are regarded as neotectonic units. Although there has been no absolute age on the Cihanbeyli formation, Tunoğlu et al. (1995) and Beker (2002) determined the following ostracode species in samples collected from limestone levels of the Cihanbeyli formation: *Cyprideis torosa* Jones, 1850; *Candona (Candona) neglecta* Sars, 1888; *Candona (Candona) paralella pannonica* Zalanyi; *Candona (Candona) altoides Petkovski,* 1961; *Candona (Pseudocandona) compressa* Koch 1837; *Heterocypris ponticus* Krstic, 1973. Based on this fossil assemblage, the Cihanbeyli formation is of Pliocene age (Tunoğlu et al., 1995; Beker 2002).

Another area where geology map renewal has been made is the region between Aksaray and Hasandağı (L32 a3, a4, d1 and d2 quadrangles) (Figure 35). Stratigraphic relations in the map area indicate that at least two different tectonic regimes are effective in the region. Horizontally bedded early Pliocene Kızılkaya Ignimbrites around Akhisar village SE of Aksaray set above the late Eocene – Oligocene aged, 45-60º NE-dipping Yassıpur formation with an angular unconformity. At east of Akhisar village, the base of Kızılkaya Ignimbrite is exposed at an elevation of 1293 m. The unit is cut and lowered to the plain altitude (1025 m) around the Akhisar village by TGFZ which is generated during the neotectonic period (Figure 38). In an assessment considering the base of Kızılkaya Ignimbrite, total slip rate on TGFZ following the deposition of unit (early Pliocene to recent) is found 268 m (1293 m - 1025 m).

As a result of geology map renewal studies, beginning of neotectonic period for TGFZ region is found as early Pliocene (around 5 million years). The total slip rate on TGFZ which is a structure of neotectonic period is 200 m at north (around


Figure 36- A panoramic view showing stratigraphic relations of units on the Ağasivri Hill at northeast of Şereflikoçhisar (view to NW)

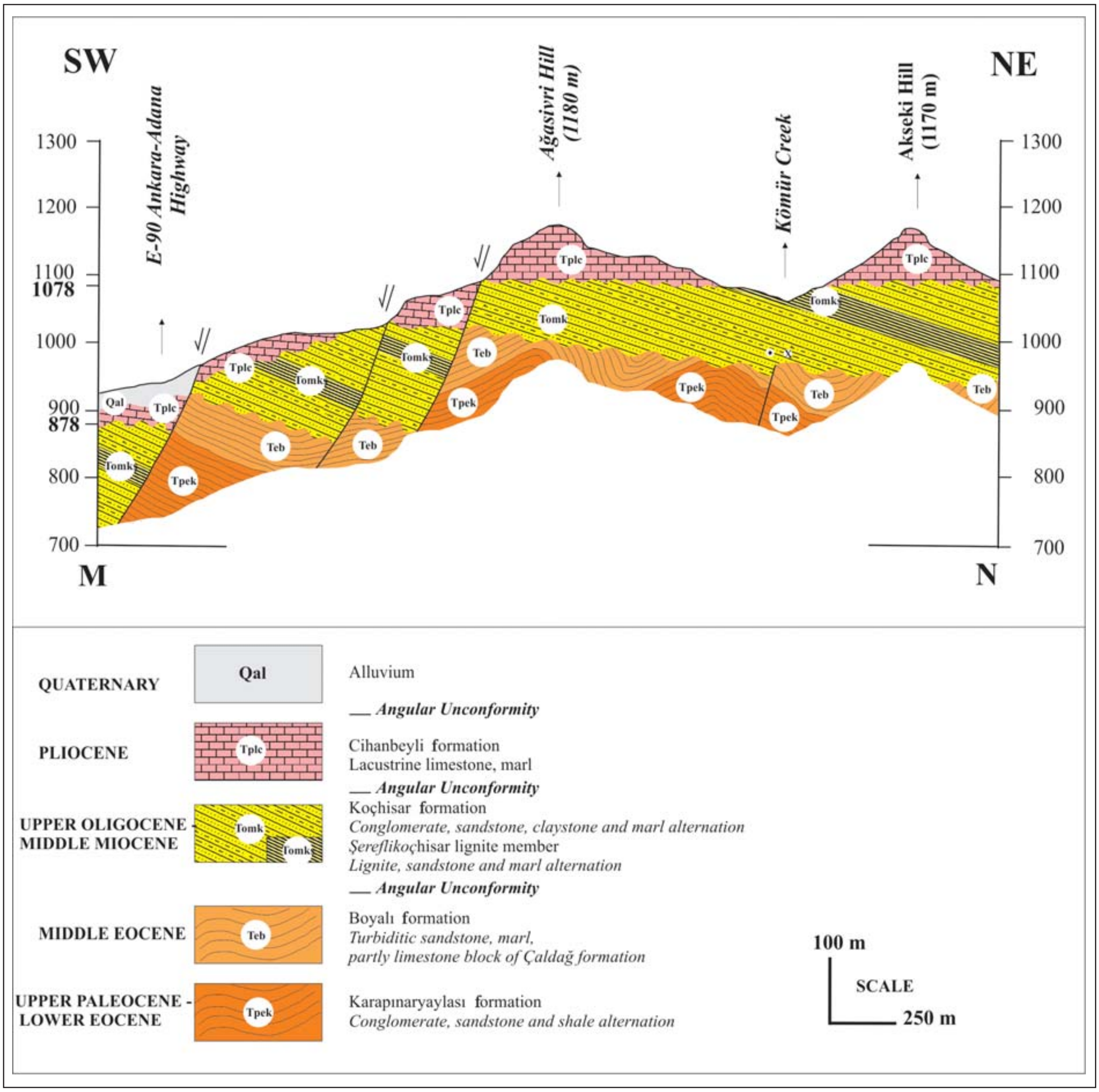


Figure 37- Geological cross section taken from the Ağasivri Hill at northeast of Şereflikoçhisar

Şereflikoçhisar) and 268 m at south (around Akhisar village). Evaluation of paleontological and radiometric age data of previous studies together with total slip rates deduced from this work reveals that the annual slip on TGFZ in the last 5 years has been found as 0,040 – 0,053 mm (average 0,046 mm).

## 6. Results and Discussion

1- In mapping studies conducted around Şereflikoçhisar to examine the age of TGFZ and beginning age of neotectonic period in the region, it was found that the Pliocene Cihanbeyli formation and laterally and vertically interlayered Peçenek formation cover the older units with an angular unconformity (Figures 36 and 37). The base of Pliocene Cihanbeyli formation is exposed at an elevation of 1078 m on the Ağasivri hill NE of Şereflikoçhisar. The unit is cut and lowered to the 878-m elevation by a series of SW-dipping normal faults that belong to TGFZ that is generated during the neotectonic period (Figure 37). In an assessment considering the basement of Cihanbeyli formation, total oblique slip rate on TGFZ following the deposition of Cihanbeyli formation (Paleocene to recent) is found 200 m (1078 m – 878 m).

Stratigraphic relations of the units between Aksaray and Hasandağı, which is another area where geology map renewal has been made, indicate that at least two different tectonic regimes are effective in the region. Horizontally bedded early Pliocene Kızılkaya Ignimbrites around Akhisar village SE of Aksaray set above the late Eocene – Oligocene aged, 45-60° NE-dipping Yassıpur formation with an angular unconformity. At east of Akhisar village, the base of Kızılkaya Ignimbrite is exposed at an elevation of 1293 m. The unit is cut and lowered to the plain altitude (1025 m) around the Akhisar village by TGFZ (Figure 38). In an assessment considering the base of Kızılkaya Ignimbrite, total slip rate on TGFZ following the deposition of unit (early Pliocene to recent) is found 268 m (1293 m - 1025 m).

Considering these stratigraphic relations and structural data, the initiation age of neotectonic period for TGFZ region is early Pliocene (around 5 million years). The total slip rate on TGFZ is 200 m at north (around Şereflikoçhisar) and 268 m at south (around Akhisar village). Evaluation of paleontological and radiometric age data of previous studies together with total slip rates deduced from this work yields that the annual slip on TGFZ in the last 5 years has been found as 0,040 – 0,053 mm (average 0,046 mm).

In literature different ages are suggested for TGFZ. According to Görür and Derman (1978), Uygun et al. (1982), Görür et al. (1984), Çemen et al. (1999), Dirik and Erol (2000), the age of TGFZ is as old as late Cretaceous. Arıkan (1975) states that TGFZ is of Eocene age whilst Dellaloğlu and Aksu (1984) assert that it is Miocene in age. On the other hand, considering the recent character of TGFZ, Koçyiğit (2000) suggested that first activation of TGFZ might have postdated early Pliocene. Data from this work for the initiation age of neotectonic period for TGFZ are in support of post early Pliocene age suggested by Koçyiğit (2000).

In various paleoseismic studies conducted on TGFZ, recent period (late Pleistocene/Holocene – recent) annual slip rate of TGFZ is found to range from 0.034 mm (Kürçer and Gökten, 2014) to 0.0536 mm (Kürçer and Gökten, 2012) and the average earthquake recurrence interval is determined as 10,930 years (Kürçer and Gökten, 2014). Average long-period (Pliocene to recent) slip rate deduced from this work are consistent with recent period slip rate acquired from paleoseismological studies.

2- Dirik and Erol (2000) pointed out that the Tuz Gölü Basin was developed on the Central Anatolian Crystalline Complex in association with extensional tectonic movements in the upper Cretaceous time and the basin floor is represented by late Cretaceous-early Paleocene Kartal formation and laterally-vertically interbedded Asmaboğazı formation. In addition, in


Figure 38- Processed Google Earth image showing stratigraphic relations of units around the Akhisar village (vertical scale three times exaggerated, view to NE with oblique angle)

studies on the Tuz Gölü Basin, TGFZ is indicated to be a structural element bordering the basin from the east (Arıkan 1975, Görür et al., 1984; Şaroğlu et al., 1987; Emre 1991; Çemen et al., 1999; Koçyiğit 2000; Genç and Yürür 2010).

According to geological map for prepared along the TGFZ, Kartal and Asmaboğazı formations are exposed on foot wall of SW-dipping TGFZ (Figure 2). Therefore, TGFZ which is a neotectonic period structure, cannot border the Tuz Gölü Basin from the east. Kartal and Asmaboğazı formations, which are the first deposits of the Tuz Gölü Basin, are thought to be deposited during the first stage of basin formation in front of a normal fault (probably a detachment fault) that borders the basin from the east and facilitated the uplift of Kırşehir Massif. During the period from upper Cretaceous to recent time, the Tuz Gölü Basin has continued its development and the today's TGFZ gained its recent character far after the basin development (post early Pliocene) and broke down the basin. In other words, the Tuz Gölü Fault Zone is a structural element bordering not the Tuz Gölü Basin but the recent Tuz Gölü Quaternary depression area from the east.

3- In general, it is commonly accepted that TGFZ is a fault zone extending in between Paşadağ at NW (north of Lake Tuz) and Bor (Niğde) at SE (Şaroğlu et al., 1987, 1992; Dirik and Göncüoğlu 1996; Dirik and Erol 2000; Koçyiğit 2000). Moreover, Koçyiğit and Beyhan (1998) suggested that TGFZ extends to Çamardı (Niğde) at SE and in the area between Bor and Çamardı it gains a significant reverse component. These authors regarded TGFZ and the left-lateral Central Anatolian Fault Zone as a conjugate strike-slip fault.

In this study, field studies carried out along TGFZ yielded that TGFZ starts from Lake Tuz at NW and ends around Kemerihisar (Niğde) at SE. In the part from Kemerihisar to Çamardı no field data were found for the prolongation of TGFZ.

4- The character of TGFZ is still debated. For example, Şengör et al. (1985) and Şaroğlu et al. (1987) regarded TGFZ a NE-dipping, right-lateral strike-slip fault with a high-angle reverse component and this was shown in the Active Fault Map of Turkey by Şaroğlu et al. (1992). Derman et al. (2000) suggested that TGFZ was first started as a normal fault and then in Eocene gained a left-lateral strike-slip character and later achieved again a normal faulting character. A group of researchers (Emre 1991; Toprak and Göncüoğlu 1993; Dirik and Göncüoğlu 1996; Koçyiğit and Beyhan 1998; Toprak 2000; Dirik and Erol 2000; Koçyiğit 2000), based on morphotectonic data, and Çemen et al. (1999) based on seismic reflection profile, pointed out that TGFZ operated in the neotectonic period as a right-lateral strike-slip fault with a high-angle normal component. On the other hand, Leventoğlu et al. (1994) who studied 14-km part of TGFZ in Hanındağ area at SE of Şereflikoçhisar concludes that TGFZ is a normal fault with a right-lateral strike-slip component.

In this study, based on direct fault plane measurements, a total of 32 fault plane slip data were taken at 7 stations along TGFZ. As a result of kinematic analysis of these data, it was shown that an NE-SW trending extensional regime is active in the TGFZ region (Figure 29). This finding is consistent with NNE-SSW trending extensional regime deduced from studies on the Cihanbeyli and Yeniceoba Fault Zones at west of Lake Tuz (Özsayın, 2007; Özsayın and Dirik, 2007). In addition, moment tensor solution of the 13 June 2011 Ataköy (Aksaray) earthquake (M=3.9) indicates the presence of a N34ºW trending 80ºSW dipping oblique-slip normal fault with right-lateral strike-slip component. This result is quite compatible with fault plane slip data on TGFZ.

According to structural observations conducted to determine the character of TGFZ, TGFZ was regarded as a NW-SE trending, SW-dipping, active, 200-km long, 2-25 km width normal fault zone with a minor right-lateral strike-slip component.

5- Geometry and segmentation of TGFZ is debated. There are different suggestions particularly for segmentation of Şereflikoçhisar part. For example, in Active Fault Map of Turkey by Şaroğlu et al. (1992), the area between NW Şereflikoçhisar (Kocadere) of Tuz Gölü Fault and Karamandere village is shown as a single segment of 38 km in length (Şaroğlu et al., 1992). In Kayseri quadrangle of the 1/500.000 scaled Turkey Geology Map (MTA, 2002), that part of Tuz Gölü Fault is mapped as a 74-km long continuous segment extending from the north of Şereflikoçhisar to the Baymış village around Aksaray at SE. However, Koçyiğit (2000) states that TGFZ from south of Şereflikoçhisar first jumps to left and then to right thus forming compressional and extensional structures specific to strike-slip faults.

In order to resolve literature chaos regarding Şereflikoçhisar part of TGFZ, two-dimensional high resolution seismic reflection profile work was conducted along a 7-km long line (Kürçer, 2012; Kürçer et al., 2012) (for location of profile line Figure 7). The Şereflikoçhisar Two-Dimensional High Resolution Seismic Reflection Profile Section was integrated with well log of Turkish Petroleum Corporation (TPAO) (1975) and regional geology information and then evaluated (Figure 10). The Şereflikoçhisar segment was mapped based on surface geology information and geophysical data obtained from high resolution seismic reflection profile shown in figure 10 and then geometry of this segment was propounded in detail.

In addition, field and laboratory (air photo and remote sensing) studies conducted on TGFZ yield that TGFZ is composed of parallel or sub-parallel 11 geometric fault segments. The length of segments is between 9 and 30 km.

6- According to Koçyiğit and Beyhan (1998), TZFZ is a conjugate fault of left-lateral Central Anatolian Fault Zone. In the present study, we have no data to indicate that TGFZ is a pure right-lateral strike-slip fault. Most of fault plane slip data measured on TGFZ show signs of normal faulting. Along the fault planes, chronologic faulting tracks as one on top of another are also absent. Considering the TGFZ is a structure formed in the neotectonic period, it is clear that this zone have no connection with the Central Anatolian Fault Zone since the beginning of neotectonic period. Today TGFZ is a normal fault zone with a minor right-lateral strike-slip shaping the Tuz Gölü Quaternary Basin

7- On the other hand, in all neotectonic works regarding Central Anatolia, TGFZ is accepted as an active structure but seismicity of TGFZ and earthquake potential of segments have not been examined.

In the present study, instrumental-period earthquakes (1900-2011) for a large area comprising the TGFZ region were compiled from the Kandilli Observatory and Earthquake Research Institute and they were evaluated. Statistical assessment of earthquake focal depths showed that earthquakes on TGFZ were occurred at an average depth of 10 km. It was shown that earthquakes around Hasandağ and Altunhisar have focal depths deeper than the average. This might indicate that some of earthquakes in the region are volcanogenic earthquakes.

Considering the statistical assessment of earthquake magnitudes, among 205 earthquakes, 136 are of M=1.3-2.9, 60 are of M=3.0-3.9, 7 are of M=4.0-4.9 and 1 is of M=5.2. The largest earthquake recorded during the instrumental period is the Uluören (Altunhisar) earthquake with magnitude of M=5.2. Additionally, 1924 Başaran (Eskil) (M=4.9), 1985 Şekerköy (Şereflikoçhisar) (M=4.3), 1998 Altunhisar (Niğde) (M=4.0), 2001 Ulukışla (Aksaray) (M=4.1), 2002 Taşpınar (Aksaray) and 2007 Acıkuyu (Kulu) (M=4.9) earthquakes are other important earthquakes recorded on TGFZ.

In this study, using the equations for normal faults suggested by Wells and Coppersmith (1994), the largest earthquake produced by each segment of TGFZ and the maximum and average displacements were calculated. The largest earthquakes generated by TGFZ segments are in the range of M = 6.11-6.80 and the maximum displacement is between 0.34 – 1.41 m and average displacements are between 0.25- 0.68 m.

8- According to stratigraphic and structural data from areas where geology map renewal studies are conducted, the beginning of neotectonic period for TGFZ region is found as early Pliocene (around 5 million years). The total slip rate on TGFZ is 200 m at north (around Şereflikoçhisar) and 268 m at south (around Akhisar village). Evaluation of paleontological and radiometric age data of previous studies together with total slip rates deduced from this work reveals that the annual slip on TGFZ in the last 5 years (early Pliocene) has been found as 0,040 – 0,053 mm (average 0,046 mm).

9- TGFZ is a fault zone with a quite low annual slip rate (average 0,046 mm/y) and consistently a relatively wide earthquake recurrence interval (10,390 years; Kürçer and Gökten, 2014).

There is a relation among the average earthquake recurrence interval, earthquake magnitude and annual slip rate of active faults (Slemmons, 1982). These relations for TGFZ were examined on a chart developed by (Slemmons, 1982) (Figure 39). In this respect, for an earthquake of M=6.11-6.80 with recurrence interval of 10,000 years, the annual slip rate on the source fault is 0.05 mm. This value is quite consistent with the value of 0.046 mm/y from the present study.

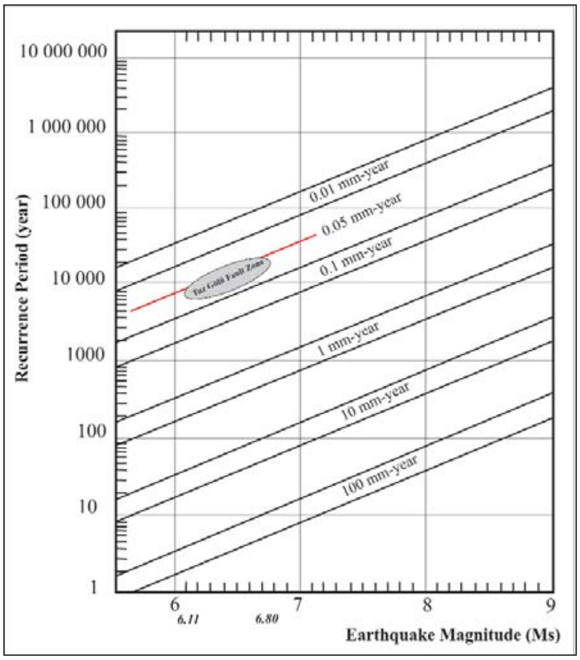


Figure 39- Average earthquake recurrence interval vs. magnitude and slip rate graphic (Slemmons, 1982). Ellipse shows the area of overlap that was acquired by adapting the Slemmons (1982) graphic to the TGFZ.

Yıldırım (2014) made a great contribution to tectonic activity of TGFZ. Using some morphologic indices such as the mountain front sinuosity and the valley-width to valley-height ratio, he investigated tectonic activity of TGFZ. Based on classification by Bull and McFadden (1977), TGFZ segments are “moderately active fault zone” with vertical uplift rate between 0.05 – 0.5 mm/y corresponding to class 2.

## Acknowledgement

This study was implemented in the frame of “Neotectonic-Period Characteristics and Paleoseismology of the Tuz Gölü Fault Zone, Central Anatolia, Turkey” project (2010-30-14-02-3) carried out by the Geology Department of the General Directorate of the Mineral Research and Exploration of Turkey (MTA). The Şereflikoçhisar Two-Dimensional High Resolution Shallow Seismic Reflection Profile study was conducted by the Geophysics Department of the General Directorate of MTA. The instrumental earthquakes occurred in the study area were evaluated by Dr. Doğan Kalafat of the Kandilli Observatory and Earthquake Research Institute. Authors thank to these organizations and persons. Prof. Erdin Bozkurt (METU) and Prof. Nureddin Kaymakçı (METU) are greatly acknowledged for their helpful comments which improved the manuscript.

*Received: 20.11.2013*
*Accepted: 01.08.2014*
*Published: December 2014*

## References

Afşin, M., Baş, H. 1996. Koçpınar (Aksaray) kaynaklarının su kimyası açısından değerlendirilmesi. *Türkiye Jeoloji Kurumu Bülteni*, 39(1), 75-86.

Akıman, O., Erler, A., Göncüoğlu, M.C., Güleç, N., Güven, A., Türeli, T.K., Kadıoğlu, Y. 1993. Geochemical characteristics of granitoides along the western margin of the Central Anatolian Crystalline Complex and their tectonic implications. *Geological Journal*, 28, 371-382.

Ambraseys, N. N., Jackson, J.A. 1998. Historical recent earthquakes Eastern Mediterranean. *Geophy. J. Int*. (1998), 133, 390-406.

Andreasyan, H. 1970. Ermeni kaynaklarından derlenmiş deprem listesi. Prof. Dr. H. Soysal’s personal archive, (unpublished), İstanbul.

Arıkan, Y. 1975. Tuzgölü havzasının jeolojisi ve petrol imkanları. *Maden Tetkik ve Arama Dergisi*, 85, 17-38.

Atabey, E. 1986. Maden Tetkik ve Arama 1/25 000 ölçekli arşiv haritaları Aksaray K 31 a1, a2, a3 ve a4 paftaları, Ankara, (unpublished).

Atabey, E. 1989. Maden Tetkik ve Arama 1/100 000 Ölçekli açınsama nitelikli Türkiye Jeoloji Haritaları Serisi, Aksaray-H 17 (K 31) paftası, Ankara.

Atabey, E., Ayhan, A. 1986. Niğde, Ulukışla, Çamardı, Çiftehan yöresinin jeolojisi, *Maden Tetkik ve Arama Genel Müdürlüğü Report* No: 8064, 60 s. Ankara, (unpublished).

Atabey, E., Tarhan, N., Akarsu, B., Taşkıran, M.A. 1987. Şereflikoçhisar, Panlı (Ankara) – Acıpınar (Niğde) yöresinin jeolojisi. *Maden Tetkik ve Arama Genel Müdürlüğü Report* No: 8155. 69 s. Ankara, (unpublished).

Aydar, E, Schmitt, A.K.., Çubukçu, H.E., Akın, L., Ersoy, O., Şen, E., Duncan, R.A., Atici, G. 2012. Correlation of ignimbrites in the central Anatolian volcanic province using zircon and plagioclase ages and zircon compositions. *Journal of Volcanology and Geothermal Research* 213-214, 83–97.

Batum, İ. 1978. Nevşehir güneybatısındaki Göllüdağ ve Acıgöl volkanitlerinin jeokimyası ve petrolojisi. *Yerbilimleri*, 4/1-2, 70-88.

Beker, K. 2002. İnsuyu Kireçtaşları (Karapınar/Konya) Ostrakod Topluluğunun Biyostratigrafik ve

Kronostratigrafik İncelenmesi. Hacettepe Üniversitesi Fen Bilimleri Enstitüsü, Ankara, Yüksek Mühendislik Tezi, 93s. (unpublished).

Beekman, P.H. 1965. Maden Tetkik ve Arama Genel Müdürlüğü, 1/25.000 ölçekli arşiv haritaları Aksaray L 32 d1 ve d2 paftaları, Ankara, (unpublished).

Beekman, P.H. 1966. Hasandağı-Melendiz dağı bölgesinde Pliyosen ve Kuvaterner volkanizma faaliyetleri. *Maden Tetkik ve Arama Dergisi* 66, 88-103.

Bozkurt, E. 2001. Neotectonics of Turkey–a synthesis. *Geodinamica Acta* 14, 3–30.

Boztuğ, D., Joncheere, R.C., Heizler, M., Ratschbacher, L., Harlavan, Y., Tichomirova, M. 2009. Timing of post-obduction granitoids from intrusion through cooling to exumation in central Anatolia, Turkey. *Tectonophysics* 473, 223-233.

Bull, W.B., McFadden, L.D. 1977. Tectonic geomorphology north and south of the Garlock fault, California. In: Doehering, D.O. (Ed.), Geomorphology in arid regions. *Proceedings at the Eighth Annual Geomorphology Symposium*. State University of New York, Binghamton, NY, pp. 115–138.

Capraru, C. 1977. Considerations regarding the oil possibilities of Tuz Gölü Basin. *TPAO Report*, Ankara, (unpublished).

Capraru, C. 1991. Hydrocarbon trap types in the structural units of the Tuz Gölü Basin. *Ozan Sungurlu Sempozyumu*, Proceedings, 156-173.

Çemen, İ., Dirik, K. 1992. Tuzgölü havzasının kuzeydoğu kısmının stratigrafisi, yapısal jeolojisi ve jeoloji tarihi. *TPAO Report No*: 3115 (unpublished).

Çemen, İ., Göncüoğlu, M.C., Dirik, K. 1999. Structural evolution of the Tuzgölü basin in Central Anatolia, Turkey. *Journal of Geologys*, 107, 693-706.

Çiftçi, B. 2007. Geological Evolution of the Gediz Graben, SW Turkey: Temporal and Spatial Variation of the Graben. *ODTÜ Fen Bilimleri Enstitüsü, Ankara*, Doktora Tezi, 290 s.

Dellaloğlu, A., Aksu, R. 1984. Kulu-Şereflikoçhisar-Aksaray dolayının jeolojisi ve petrol olanakları. *TPAO Report No:* 2020, Ankara, (unpublished).

Dellaloğlu, A.A., Aksu, R. 1986, Ereğli (Konya)- Ulukışla-Çiftehan-Çamardı (Niğde) Dolayının Jeolojisi ve Petrol Olanakları, *TPAO Report No*. 2205, Ankara, (unpublished).

Demircioğlu, R., Eren, Y. 2000, Çamardı (Niğde) civarında Niğde Masifi örtü birimlerinin yapısal özellikleri, *N.Ü. Aksaray Mühendislik Fakültesi, Haymana-Tuzgölü-Ulukışla basenleri uygulamalı çalışma (Workshop), Bildiri özleri*, s. 6.

dePolo, C. M., Clark, D. G., Slemmons, D. B., Aymand, W. H. 1989. Historical Basin and Range Province surface faulting and fault segmentation. In Fault Segmentation and Controls of Rupture Initiation and Termination (D. P. Schwartz, and R. H. Sibson, Eds.), *U.S. Geol. Surv. Open File Rep*. 89–315, pp. 131–162.

DePolo, C.M., Claek, D.C., Slemmons, D.B., Ramelli, A.R. 1991. Historical surface faulting in the basin and range province, Western North America: İmplications for fault segmentation, *J. Struct. Geol*. 13. 123-136.

Derman, A.S. 1980. Tuz Gölü ve kuzeyinin jeolojisi, *TPAO Report No*: 1512, Ankara, (unpublished).

Derman, A.S., Rojay, B., Güney, H., Yıldız, M. 2000. Koçhisar-Aksaray fay zonu'nun evrimi hakkında yeni veriler. *Haymana-Tuzgölü-Ulukışla basenlerinin uygulamalı çalışması. Bildiri Özleri*, 1, Aksaray.

Dewey J.F., Hempton M.R., Kidd W.S.F., Şaroğlu F., Şengör A.M.C. 1986. Shortening of continental lithosphere: the neotectonics of eastern Anatolia – a young collision zone, in: Coward M.O., Ries A.C. (Eds.), Collisional Tectonics, *Geological Society Special Publication no*: 19, pp. 3–36.

Dirik, K. 2001. Neotectonic evolution of the northwestward arched segment of the Central Anatolian fault zone, Central Anatolia, Turkey. *Geodinamica Acta* 14, 147-158.

Dirik, K., Göncüoğlu, M.C. 1996. Neotectonic characteristics of Central Anatolia, *Int. Geology Review* 38, 807-817.

Dirik, K., Erol, O. 2000. Tuzgölü ve civarının tektonomorfolojik evrimi Orta Anadolu, Türkiye. *Haymana-Tuzgölü-Ulukışla Basenleri Uygulamalı Çalışma (Workshop), TPJD Bülteni*, Özel sayı 5.

Dirik, K., Erol, O. 2003. Tectonomorphologic evolution of Tuzgölü and surrounding area, central Anatolia-Turkey. *Turkish Association of Petroleum Goelogists Special Publication* 5, 27-46.

Dönmez, M., Akçay, A.E., Kara, H., Türkecan, A., Yergök, A.F., Esentürk, K., 2005. MTA 1/100.000 Ölçekli açınsama nitelikli Türkiye Jeoloji Haritaları Serisi. Aksaray-L 32 paftası, Ankara

Emre, Ö. 1991. Hasandağı-Keçiboyduran dağı yöresi volkanizmasının jeomorfolojisi, *İstanbul Üniversitesi, Deniz bilimleri ve Coğrafya Enstitüsü Doktora tezi*, 198 s., İstanbul.

Erdem, E. 1985. Maden Tetkik ve Arama Genel Müdürlüğü, 1/25.000 ölçekli arşiv haritaları Aksaray L 32 a4 ve d1 paftaları, Ankara, (unpublished).

Ercan ,T., Ercan, T., Fujitani, T., Matsuda, J.I., Tokel, S., Notsu, K., Ul, T., Can, B., Selvi, Y., Yıldırım, T., Fişekçi, A., Ölmez, M., Akbaşlı, A. 1990. Hasandağı-Karacadağı bölgesi (Orta Anadolu) Senozoyik volkanizmasının başlangıcı ve evrimi, *Jeomorfoloji Dergisi* 18, 39-54.

Ergin, K., Güçlü, Ü., Aksay, G. 1967. A Cataloques of Earthquakes of Turkey and Surrounding Area, 1965-1970. *Arz. Fiziği Enst. Yayın., No:*28, Maden Fakültesi, İstanbul Teknik Üniversitesi, İstanbul.

Erler, A., Akıman, O., Unan, C., Dalkılıç, B., Geven, A., Önen, P. 1991. Petrology and geochemistry of the magmatic rokcs of the Kırşehir Massive in the Kaman (Kırşehir) and Yozgat regions. *TUBİTAK, Doğa-Tr. Journal of Engineering and Environmental Science*, 15, 76-100 (Türkçe).

Genç, Y., Yürür, T. 2010. Coeval extension and compression in Late Mesozoice Recent thin–skinned extensional tectonics in central Anatolia, Turkey. *Journal of Structural Geology* 32, 623-640.

Göncüoğlu, M.C. 1977. Geologie des Westlichen Niğde - Massivs: *Bonn Univ., Doktora tezi,* (unpublished).

Göncüoğlu, M.C. 1982. Niğde Masifi peragnayslarında U/Pb yaşları. *Türkiye Jeoloji Kurumu Bülteni* 25, 61-66.

Göncüoğlu, M.C. 1985. Niğde Masifi batı yarısının jeolojisi, *Maden Tetkik ve Arama Genel Müdürlüğü, Report* No: 5883 (unpublished), Ankara.

Göncüoğlu, M.C., 2010. Türkiye Jeolojisine Giriş: Alpin ve Alpin öncesi tektonik birliklerin jeodinamik evrimi. *Maden Tetkik ve Arama Genel Müdürlüğü, Monografi serisi No*: 5, 69 s., (Ankara).

Göncüoğlu, M.C., Toprak, G.M.V., Kuşçu, I., Erler, A., Olgun, E. 1991. Orta Anadolu Masifinin Batı Bölümünün Jeolojisi, Bölüm 1: Güney Kesim. *TPAO Report No*. 2909 (unpublished).

Göncüoğlu, M.C., Erler, A., Toprak, V., Yalınız, K., Olgun, E., Rojay, B. 1992. Orta Anadolu Masifi'nin batı bölümünün jeolojisi, Bölüm 2: Orta Kesim. *TPAO Report No*. 3535, Ankara, (unpublished).

Göncüoğlu, M.C., Erler, A., Toprak, V., Olgun, E., Yalınız, K., Kuşçu, İ., Köksal, S., Dirik, K. 1993. Orta Anadolu Masifinin Orta Bölümünün Jeolojisi,Bölüm 3: Orta Kızılırmak Tersiyer Baseninin Jeolojik Evrimi. *TPAO Report No*: 3313, 104 s., Ankara, (unpublished).

Göncüoğlu, M.C., Dirik, K., Erler, A.,Yalınız, K. 1994. Orta Anadolu Masifi doğu bölümünün jeolojisi Bölüm 4: Orta Anadolu masifinin Sivas baseni ile ilişkisi, *TPAO Report No*: 3535, 135p.

Göncüoğlu, M.C., Dirik, K., Erler, A., Yalınız, K., Özgül, L., Çemen, İ. 1996. Tuzgölü havzası batı kısmının temel jeolojik sorunları: *TPAO Report No*: 3753, Ankara, (unpublished).

Göncüoğlu, M.C., Kozlu, H., Dirik, K. 1997. Pre-Alpine and Alpine terranes in Turkey: explanotary notes to the terane map of Turkey. *Ann. Geol. Pays Helleniques*, 37, 515-536.

Görür, N. 1981, Tuzgölü Haymana havzasının stratigrafik analizi, İç Anadolu"nun Jeolojisi Sempozyumu, *TJK 35. Bilimsel ve Teknik Kurultayı Bildiriler Kitabı*, 60-65.

Görür, N., Derman, A. S. 1978. Tuz Gölü-Haymana havzasının stratigrafik ve tektonik analizi. *TPAO Report* No: 1514, Ankara, (unpublished).

Görür, N., Oktay, F.Y., Seymen, İ., Şengör, A.M.C. 1984. Paleotectonic evolution of the Tuzgölü basin complex, Central Turkey: Sedimentary record of a Neo-Tethyan closure, in Dixon, J.E. and Robertson, A.H.F. eds., The Geological evolution of the Eastern Mediterranean: *Geol.Soc.London. Spec. Publ. no:* 17, 467-482.

Görür, N., Tüysüz, O., Şengör, A.M.C. 1998. Tectonic evolution of the Central Anatolian Basins. *International Geology Review* 40, 831-850.

Innocenti, F., Mazzuoli, G., Pasquare, F., Radicati di Brozola, F., Villari, L. 1975. Neogene calk-alcaline volcanism of Central Anatolia: Geo-chronological data on Kayseri-Niğde area. *Geol. Mag*. 112, 349-360.

Işık, V. 2009. The ductile shear zone in granitoid of the Central Anatolian Crystalline Complex, Turkey: Implications for the origins of the Tuzgolu basin during the Late Cretaceous extensional deformation. *Journal of Asian Earth Sciences* 34, 507-521.

Kadıoğlu, Y. K. 1991. Geology, petrography and geochemistry of Ağaçören (Aksaray) magmatic rocks. Msc. *Thesis Middle East Technical University*. Ankara, 144 p.

Knuepfer, P. L. K. 1989. Implications of the characteristics of end-points of historical surface fault ruptures for the nature of fault segmentation. *U.S. Geol. Surv. Open File Rep*. 89–315, pp. 193–228.

Koçyiğit, A. 2000. Orta Anadolu'nun Genel Neotektonik Özellikleri ve Depremselliği. *Haymana-Tuzgölü-Ulukışla basenlerinin uygulamalı çalışması. Bildiri Özleri, TPJD Bülteni*, Özel sayı 5, 1-26, Aksaray.

Koçyiğit, A. 2003. General neotectonic characteristics and seismicity of central Anatolia. *Turkish Association of Petroleum Geologist Special Publication* 5, 1-26.

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. *Geodinamica Acta* 18 (3-4), 167-208.

Koçyiğit, A. Beyhan, A. 1998. A new intracontinental transcurrent structure: the Central Anatolian fault zone, Turkey. *Tectonophysics* 284, 317?336.

Koçyiğit, A., Erol, O. 2001. A tectonic escape structure: Erciyes pull-apart basin, Kayseri, Central Anatolia, Turkey. *Geodinamica Acta*, 14, 1-13.

Koçyiğit, A., Özacar, A. 2003. Extensional neotectonic regime through the NE edge of the Outer Isparta Angle, SW Turkey: New Field an Seismic Data. *Turkish Journal of Earth Sciences* 12, 67-90.

Kuşcu, İ., Erler, A., Göncüoğlu, M.C. 1993. Geology Of The Çamardı (Niğde) *Region. Geosound*, 23, 1-16.

Kürçer, A., 2012. Tuz Gölü Fay Zonu'nun Neotektonik Özellikleri ve Paleosismolojisi, Orta Anadolu, Türkiye. Doktora Tezi, Tez no: 318203, Ankara Üniversitesi, Fen Bilimleri Enstitüsü, 318 sayfa, Ankara. (unpublished).

Kürçer, A., Gökten, Y.E. 2012. A New Photography Method for Paleoseismological Trenching: "Paleoseismological Three Dimensional Virtual Photography Method", A Case Study: Tuzgölü Fault Zone, Central Anatolia, Turkey, Tectonics - Recent Advances, Evgenii Sharkov (Ed.), ISBN: 978-953-51-0675-3, InTech, Available from: http://www.intechopen.com/books/tectonics-recent-advances/paleoseismological-three-dimensional-virtual-photography-method-a-case-study-ba-larkayas-2010-trench

Kürçer, A., Yeleser, L., Karzaoğlu, H., Izladı, E., Aykaç, S., Kutlu, S., Köse, K., Bostan, S., Kurdal, S. 2012. Tuz Gölü Fay Zonu'nun Neotektonik Dönem Özellikleri ve Paleosismolojisi, Orta Anadolu, Türkiye. *Maden Tetkik ve Arama Genel Müdürlüğü Report No*: 11573, Ankara, (unpublished).

Kürçer, A., Gökten, Y.E. 2014. Paleosismolojik Üç Boyutlu Sanal Fotoğraflama Yöntemi, Örnek Çalışma: Duru-2011 Hendeği, Tuz Gölü Fay Zonu, Orta Anadolu, Türkiye. *Türkiye Jeoloji Bülteni*, 57-1, s:45-71.

Le Pennec, J.-L., Temel, A., Froger, J.-L., Sen, S., Gourgaud, A., Bourdier, J.-L. 2005. Stratigraphy and age of the Cappadocia ignimbrites, Turkey : reconciling field constraints with paleontologic, radiochronologic, geochemical and paleomagnetic data. *Journal of Volcanology and Geothermal Research* 141, 45–64.s

Leventoğlu, H. 1994. Neotectonic characteristics of the central part of the Tuzgölü fault zone around Mezgit (Aksaray), *METÜ M.Sc. thesis*, 86 p.

Marshak, S., Mitra, G. 1988. Basic methods of Structural Geology. *Prentice Hall, New Jersey*, 446 p.

McCalpin, J.P., Nelson, A.R. 2009. Introduction to Paleoseismology. *In Paleoseismology, International Geophysics Series vol*. 95. James P. McCalpin (ed). Academic Pres is an imprint of Elsevier, pp. 1-25., California, USA.

MTA, 2002. 1/500 000 Ölçekli Türkiye Diri Fay Haritası Serisi, Kayseri ve Adana Paftaları.

Okay, A.İ., Kaşlılar-Özcan, A., İmren, C., Boztepe-Güney, A., Demirbağ, E., Kuşçu, İ. 2000. Active faults and evolving strike-slip basins in the Marmara Sea, NW Turkey: a multichannel seismic re£lectives study. *Tectonophysics* 321, 189-218.

Özmen, B. 2008, Ankara için deprem senaryosu, Ankara'nın Deprem Tehlikesi ve Riski çalıştayı Bildiriler kitabı. (Editörler: Prof. Dr. Süleyman Pampal, Bülent Özmen) *Gazi Üniversitesi Mimar Kemaleddin Salonu*, 19 Mart, s. 87-103, Ankara.

Özsayın, E. 2007. İnönü-Eskişehir fay sisteminin Yeniceoba - Cihanbeyli (Konya - Türkiye) arasındaki bölümünün Neojen-Kuvaterner yapısal evrimi, Doktora Tezi, Hacettepe Üniversitesi, Fen Bilimleri Enstitüsü Jeoloji Mühendisliği Anabilim Dalı, 120 s., Ankara, (unpublished).

Özsayın, E., Dirik, K. 2007. Quaternary activity of the Cihanbeyli and Yeniceoba Fault Zones: İnönü-Eskişehir Fault System, Central Anatolia. *Turkish Journal of Earth Sciences* 16, 471-492.

Papak, İ. 1985. Maden Tetkik ve Arama 1/25 000 ölçekli arşiv haritaları Aksaray L 32 a3 ve d2 paftaları Ankara, (unpublished).

Parlar, Ş., Görmüş, M., Eren, Y. 2006. Çamardı (Niğde) çevresinde Paleosen-Eosen yaşlı kayaların stratigrafisi, iri bentik foraminifer sayısal verileri ve biyofabriği, *İstanbul Üniversitesi, Mühendislik Fakültesi Yerbilimleri Dergisi* 19-1, 1-25.

Pasquare, G. 1968. Geology of the Cenozoic volcanic area of Central Anatolia. *Atti Accad. Naz. Lincei*, 9, 53-204.

Reilinger, R., McClusky, S., Vernant, P., Lawrence, S., Ergintav, S., Çakmak, R., Özener, H., Kadırov, F., Guliev, I., Stepanyan, R., Nadarıya, M., Hahubia, G., Mahmoud, S., Sakr, K., ArRajehı, A., Paradissis, D., Al-Aydrus, A., Prilepin, M., Guseva, T., Evren, E., Dmitrotsa, A., Filikov, S.V., Gomez, F., Al-Ghazzi, R., Karam, G. 2006. GPS constraints on continental deformation in the Africa-Arabia-Eurasia continental collision zone and implications for the dynamics of plate interactions. *Journal of Geophysical Research* 111, B05411.

Rigo de Righi, M., Cortesini, A. 1960. Regional studies of the Central Anatolian basins progress report. *PDR Turkish Gulf Oil Co. Report No*. II / 11-12 (unpublished).

Schmidt, C. C. 1960. AR/MEM/365-366-367 sahalarının nihai terk raporu, Pet. İş. Gn. Müd., Ankara, (unpublished).

Schumacher, R., Mues-Schumacher, U. 1996. The Kizilkaya ignimbrite—an unusual low-aspect-ratio ignimbrite from Cappadocia, Central Turkey. *Journal of Volcanology and Geothermal Research* 70, 107–121.

Seymen, İ. 1982. Kaman dolayında Kırşehir masifinin jeolojisi, *İTÜ Maden Fak. Doç. Tezi* s. 164, İstanbul, (unpublished).

Slemmons, D. B. 1982. Determination of design earthquakes magnitudes for microzonation. In *Proceedings of the 3rd International Earthquake Microzonation Conference, Seattle, WA*, vol. 1, pp. 110–130.

Soysal, H., Sipahioğlu, S., Kolçak, D., Altınok, Y. 1981. Türkiye ve çevresinin tarihsel deprem kataloğu. *TUBİTAK Report no*: TBAG 341. 86 s.

Şaroğlu, F., Boray, A., Emre, Ö. 1987. Türkiye'nin aktif fayları. *Maden Tetkik ve Arama Genel Müdürlüğü Report No*. 8643. 394 s., Ankara, (unpublished).

Şaroğlu, F., Emre, Ö., Kuşçu, İ. 1992. Türkiye Diri Fay Haritası, *Maden Tetkik ve Arama Genel Müdürlüğü*, Ankara.

Şengör A.M.C. 1980. Türkiye'nin Neotektoniği'nin Esasları, *Türkiye Jeoloji Kurumu Konferans Serisi* 2.

Şengör, A.M.C., Yılmaz, Y., Sungurlu, O. 1985. Tectonics of the Mediterranean Cimmerides: nature and evolution of the western termination of Palaeotethys. In: Robertson, A.H.F. and Dixon, J.E. (eds) The Geological Evolution of the Eastern Mediterranean, *Geological Society, London, Special Publications*, 17, 77-112.

Tan, O., Tpırdamaz, C., Yörük, A. 2008. The Earthquakes cataloques for Turkey. *Turkish Journal of Earth Sciences* 17, 405-418.

Tokel, S., Ercan, T., Akbaşlı, A., Yıldırım, T., Fişekçi, A., Selvi, Y., Ölmez, M., Can, B. 1988. Neogene Tholeitic province of central Anatolia: Implication for magma genesis and post-collision lithosferic Dynamics, METU *Journal of Pure and Applied Sciences. Series A "Geosciences"* I, 21, 1-3, 461-477.

Toprak, V. 2000. Tuzgölü Fay Kuşağı Hasandağ Kesiminin Özellikleri, Haymana-Tuzgölü-Ulukışla Basenleri Uygulamalı Çalışma 9-11 Ekim, 2000, *Türkiye Petrol Jeologları Derneği* Özel sayı: 5, 71-84.

Toprak, V., Göncüoğlu, C. 1993. Keçiboyduran-Melendiz fayı ve bölgesel anlamı (Orta Anadolu). *Yerbilimleri,* 16, 55-65.

Tunoğlu, C., Temel, A., Gençoğlu, H. 1995. Pliocene ostracoda association and environmental characteristics of Sivrihisar (Eskişehir)-Central Anatolia; 12nd. Inter. Ostracoda Symp., ostracoda and Biostratigraphy (Ed. Riha, J.) Belkama/Rotterdam, 265-275.

Türeli, T.K, Göncüoğlu, M.C. ve Akıman, O. 1993. Origin and petrology of Ekecikdag granitoid in western Central Anatolian Crystalline Complex. *Maden Tetkik ve Arama Genel Müdürlüğü Dergisi* 115, 15-28.

Türkecan, A., Akçay, A. E., Satır, M., Dönmez, M., Ercan, T. 2003. Melendiz dağları (Niğde) volkanizması, 56. Türkiye *Jeoloji Kurultayı Bildiri Özleri Kitabı* 16.

Uygun, A. 1981. Tuz Gölü havzasının jeolojisi, evaporit oluşumları ve hidrokarbon olanakları. *İç Anadolu'nun Jeolojisi Sempozyumu*. 66-71.

Uygun, A., Yaşar M., Erkan, M.C., Baş, H., Çelik, E., Aygün, M., Bilgiç, T., Kayakıran, S., Ayok, F. 1982. Tuzgölü Havzası projesi, Cilt 2. *Maden Tetkik ve Arama Genel Müdürlüğü Report No*: 6859, Ankara, (unpublished).

Uygun, A., Şen, E. 1978. Tuz Gölü Havzası ve Doğal Kaynakları I: Tuz Gölü Suyunun Jeokimyası. *Türkiye Jeoloji Kurumu Bülteni* 21, 113-130.

Varol, B. Kazancı, N., Gültekin, F., 2000. Tuzgölü ve yakın civarı Eosen-Oligosen jipslerinin sedimantolojik ve izotopik özellikleri. *Haymana-Tuzgölü-Ulukışla basenlerinin uygulamalı çalışması. Bildiri Özleri*, 19, Aksaray.

Yalınız, K. Göncüoğlu, M.C., Floyd, P.A. 1996. Supra-subduction zone ophiolites of Central Anatolia: Geochemical evidence from the Sarıkaraman ophiolite, Aksaray, Turkey. *Mineral Mag*. 60, 697-710.

Yalınız, K. Göncüoğlu, M.C. 1998. General geological characteristics and distribution of the Central Anatolian Ophiolites. *Yerbilimleri* 20, 19-30.

Yalınız, K. Göncüoğlu, M.C., Özkan-Altıner, S., Parlak, O., 2000. Formation and emplacement ages of the SSZ-type Neotethyan Ophiolites in Central Anatolia, Turkey: Paleotectonic implications. *Geological Journal*, 35, 53-68.

Yetiş, C. 1978, Çamardı (Niğde) Yakın ve Uzak Dolayının Jeoloji İncelemesi ve Ecemiş Yarılım Kuşağı'nın Maden Boğazı-Kamışlı Arasındaki Özellikleri, *Doktora Tezi: İstanbul Üniversitesi*, 164 s. (unpublished).

Yıldırım, C. 2014. Relative tectonic activity assessment of the Tuz Gölü Fault Zone; Central Anatolia, Turkey. *Tectonophysics*, http://dx.doi.org/10.1016/j.tecto.2014.05.023

Yolsal, Ç., Taymaz, T. 2012. Earthquake source parameters along the Hellenic subduction zone and numerical simulations of historical tsunamis in the Eastern Mediterranean. *Tectonophysics*, 536-537, 61-100.

Wells, D.L., Coppersmith, K.J. 1994. New Empirical Relationships among Magnitude, Rupture Length, Rupture Width, Rupture Area, and Surface Displacement. *Bulletin of the Seismological Society of America*, 84-4, 974-1002.

Woodside, J.M., Mascle, J., Zitter, T.A.C., Limonov, A.F., Ergün, M., Volkonskaia, A. 2002. Shipboard Scientists of the PRISMED II Expedition, The Florence Rise, the western bend of the Cyprus arc. *Marine Geology*, 185, 177-194.

Zitter, T.A.C., Huguen, C., Woodside, J.M. 2005, Geology of mud volcanoes in the eastern Mediterranean from combined sidescan sonar and submersible surveys. *Deep-Sea Research* I 52, 457–475.