Morphotectonic positions and paleoseismic characteristics of basin faults on Karakova horst near Celtikci (Denizli-Turkey)

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Abstract

Denizli graben, which is one of the active graben structures of Western Anatolia, is a seismically active region. The Karakova horst is located in the middle of this graben. Recently, the earthquake epicenters have intensified on the Kaleköy-Uzerlik fault line that forms the two wings of the horst. In this study, geological, morphological and geophysical studies were carried out in order to determine the antithetic and synthetic of these faults. A fault belonging to the early graben phase and without any trace on the surface was observed. It was buried by the Neogene sediments while the others were covered by Quaternary sediments. Therefore, they were interpreted as paleosismologically possible active faults. These faults occur as a result of opening in NE-SW direction. They can be catastrophic for the buildings and have to be taken into account for microzoning studies.

Key words: *graben, horst, active fault, paleoseismology, Denizli, Karakova, Celtikci*

Introduction

West Anatolia is one of the most tectonically active regions of the world. Due to tectonic extention, many graben structures were developed in the region. The Büyük Menderes Graben extends in the direction of E-W and ends in Sarayköy in the east. The Gediz graben also extends in E-W and NW-SE directions just after Alasehir junction and it extends towards Sarıgöl. Then forms the Denizli graben in NW-SE direction. There is the Buldan ridge between Sarıgöl and Buldan (Hançer, 2013). Gediz and Büyük Menderes grabens intersect in Sarayköy-Buldan region.

The faults which limit the NW-SE trending Denizli basin are the Pamukkale fault in the northeast and the Babadag-Honaz fault in the southwest. Koçyigit (2005) has studied the Denizli basin as the Çürüksu graben which is of Denizli and Bozburun sub-grabens (Figure 1). There are many faults developed in parallel between basin edge faults between Babadağ and Pamukkale regions. Karakova horst is the elevation between the Çürüksu graben and the Denizli sub-graben and it is located between the edge faults of these two grabens. The fault zone in the area between the Uzerlik-Karakova region, which forms the NE edge of this elevation, is active and it hosts the epicenters of the earthquakes occurred especially in the years 2000 and 2004 (Hançer, 2013). In particular, the faults in the N-NE section of the basin are more active than the ones in the south.

In this study, the seismically active faults of Karakova horst in Denizli graben and the antithetic-synthetic fractures parallel to the main fault of the host have been examined by using morphotectonic data. The findings have also being checked by trench studies and geophysical methods.

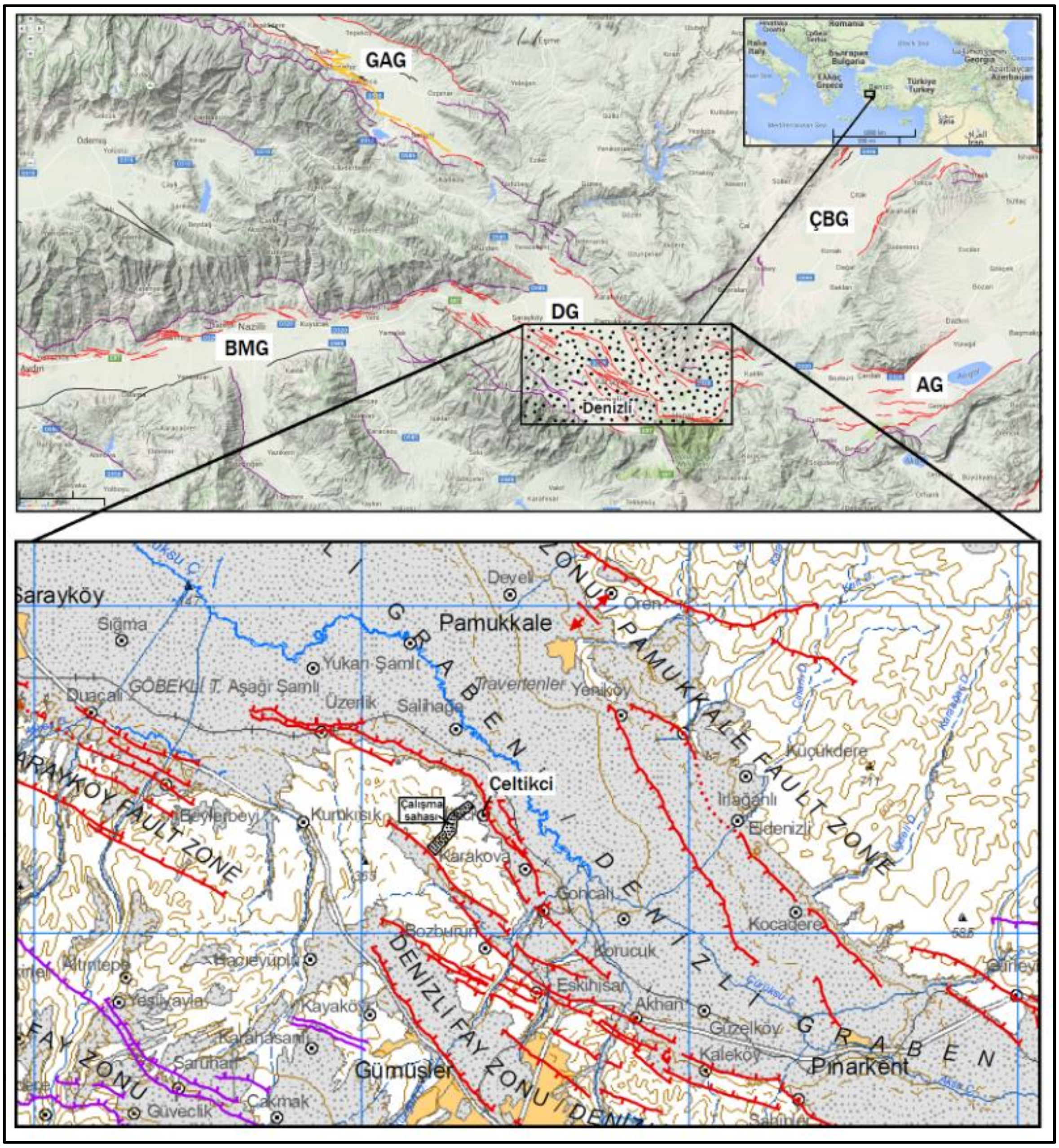

Figure l. The study area on active faults map of MTA (Emre et al., 2011); (BMG: Büyük Menderes Graben, KMG: Küçük Menderes Graben, GAG: Gediz (Alaşehir) Graben, DG: Denizli Graben, ÇBG: Civril Baklan Graben, AG: Acıgöl graben, BG: Burdur Graben)

Site Settings of Karakova Horst

The pre-Neogene basement rocks of the region are Paleozoic metamorphic rocks, crystallized limestones, alloctone nappes. The Neogene aged rocks are a sequence of Middle-Upper Miocene aged claystone, marl, conglomerate and lacustrinal limestone. The Quaternary travertines, alluviums and fan sediments are observed on the top.

Karakova horst (NW-SE) is about 20 km in length (Figure 1). Koçyigit (2005) emphasizes that the Bozburun sub-graben is within this horst. The SW wing of Karakova horst continues between Kumkısık village and Sevindik districts. The northern wing starts from Uzerlik village in NW, and extends to Celtikçi, Karakova, Goncali, Laodicea, Akhan and Kaleköy. This zone was mapped into five separate segments (Koçyigit, 2005). Especially in April-October 2000 earthquakes were concentrated on this zone (Demirtaş et al., 2000).

The study area is located in the middle part of the Karakova horst. The Uzerlik-Kaleköy fault zone forming the NE part of the horst positioned N70^0-80^{0}W between the Uzerlik-Celtikci, N40^0-50^{0}W between Celtikci-Goncali and N50^0-60^{0}W between Goncali-Korucuk. The fault that forms the SE of the horst starts from the east of Kumksık village and extends to the Eskihisar village and Sevindik district in N50^0-60^{0}W position. The study area is shown as an active fault zone between 300-400 m in width and 2 km in length on the active fault map of the MTA (Figure 1).

Paleoseismological studies

The NW-SE trending Karakova horst is bounded by the fault passing through Celtikci in the NE and the faults extending parallel to the ring road in SW. The study area is located on the Neogene aged sediments between the two faults. Therefore, the study area is under the control of antithetic and synthetic faults developed parallel to the main fault lines. For this reason, firstly, the continuity of the faults in the study area and its vicinity have been investigated.

On the SW boundary of the site, a fault line has been identified on the earth road linking Çeltikçi to the ring road. The fault position is N60^{0}W/80^{0}SW and developed within the Neogene unit (Figure 2). It is a syntetic fault developed parallel to the fault line and ring road in the SW boundary of Karakova horst and a brecciated zone is observed in this fault and.

Another major fault line was observed towards the central parts of the study area (Figure 3). The slope of the fault, which is the K700B direction, is towards the NE with angles ranging from 44^0 to 60^0. This fault is zone is 3 meters in length and consists of three main faults and many small fractures rather than a single line. The positions of the main faults are N80^{0}W/60^{0}NE, N58^{0}W/44^{0}NE and N65^{0}W/48^{0}NE. The length of the visible normal fault in the area is about 1 km in length and the NE block of it fell down.

Two more faults, inclined to SW with 50 meters intervals, were observed about 200 meters away from the study area. While these faults were clearly observed on the road cut, the continuation of these faults towards the study area could not be traced. These are of two normal faults developed parallel to each other with 2-3 meters intervals (Figure 4). The fault in the north is in N65^{0}W/60^{0}SW position and 40-50 meters in length with 0.5 meter slip rate. The fault in the south has approximately 1.5 meter slip rate and has a N700W/540SW position. Another fault (N65^{0}W/65^{0}SW) has also been detected in the NE of this fault (Figure 5). It is a normal fault and has about 10 meters slip rate. The SW block of it has fell down. Additionally, another fault set with 30 meters intervals was discovered about 200 m. away from the latter. The faults inclined to SW are listric shaped and in N68^{0}W/62^{0}SW position with 1.5 meter slip rate. The one inclined NW is in N60^{0}W/80^{0}NE position with 1.0 meter slip rate (Figure 6). These two faults of a small horst-like appearance of the terrain were joined with the fault in north in 30 meters distance.

A major fault line was observed 30 m north of these two faults. There are a number of antithetic and synthetic fractures around this normal fault. It was followed up on the surface towards the study area. The morphotectonic lineaments were observed parallel to the direction of the fault in the Kocaderesi area where the fault is possibly lies to. It was determined that these lineaments continued in accordance with V rule in Kocaderesi valley, changes in layer positions and partial crush zones were noted during linearity. There are also sudden increases in crack density within the Neogene units when approaching this line. It was decided that N70^{0}W/65^{0}NE positioned fractures were followed up further to SW and then they were not longer traced in alluvium. All these clarifications were taken into account during the mapping of this fault. In this case, the length of the studied fault is more than 1 km.

A fault was detected in the north of the mentioned fault above that is about 600-700 meters away. It is at the NE end zone of the study area and at the edge of the urban area. It is a normal fault and has N50^{0}W/60^{0}NE position (Figure 7). This fault was followed towards NW and SE. The continuation of the fault was examined in detail in NW. In the Kocaderesi area, the location where the fault is likely to pass in the reservoir was identified and a zone in 3-4 meters width is determined (Figure 8). The fractures in this zone are inclined to NE and the dominant position is N48^{0}W/70^{0}NE. Considering the marl and sandstone-conglomerate contacts in the Neogene units during the continuation of this location, the level changes indicate the presence of the fault (Figure 9). The precise route of this fault within the urban area was confirmed by geophysical and trench.

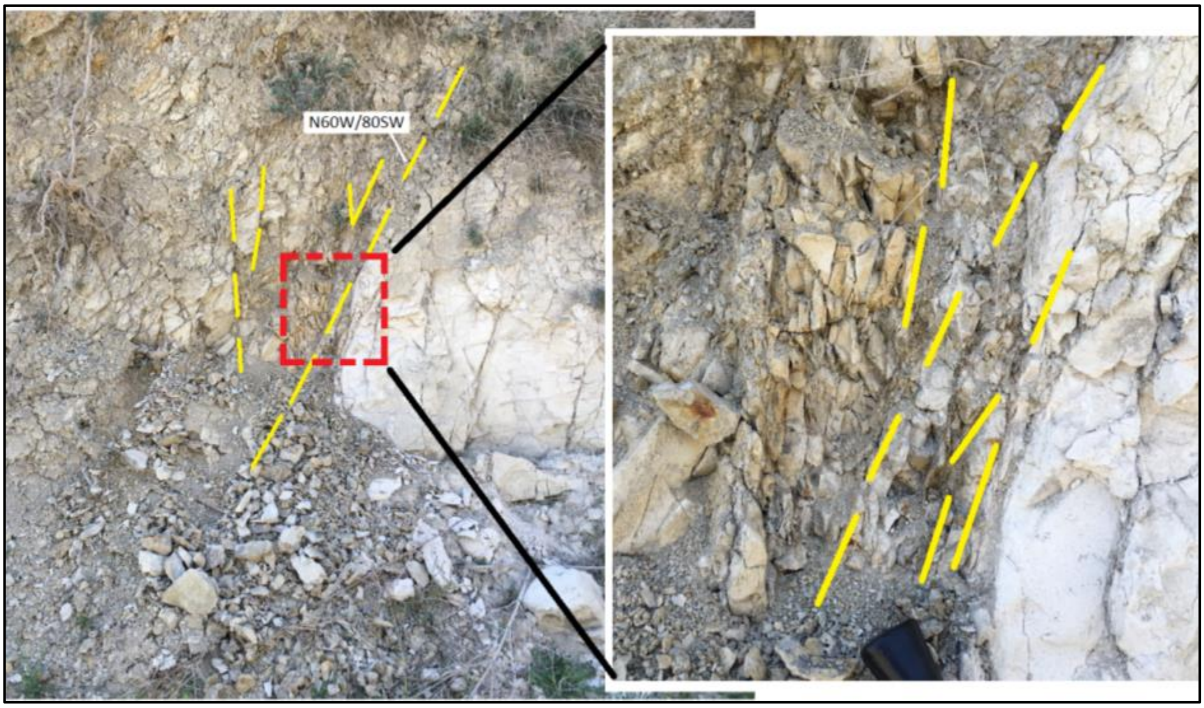

Figure 2. General and close view of the fault at the SW end of the urban area (look to NW)

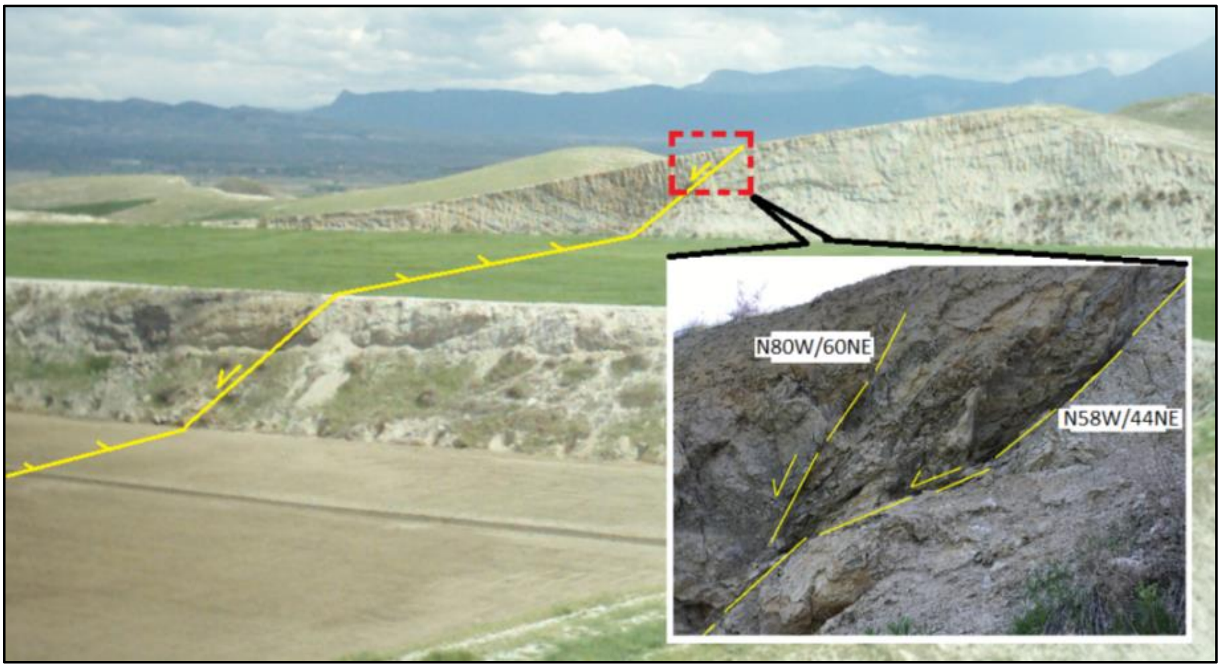

Figure 3. General and close view of the fault at SW of Celtikci earth road (look to E)

Figure 4. Two parallel fault lines at the west of Karakova (look to E)

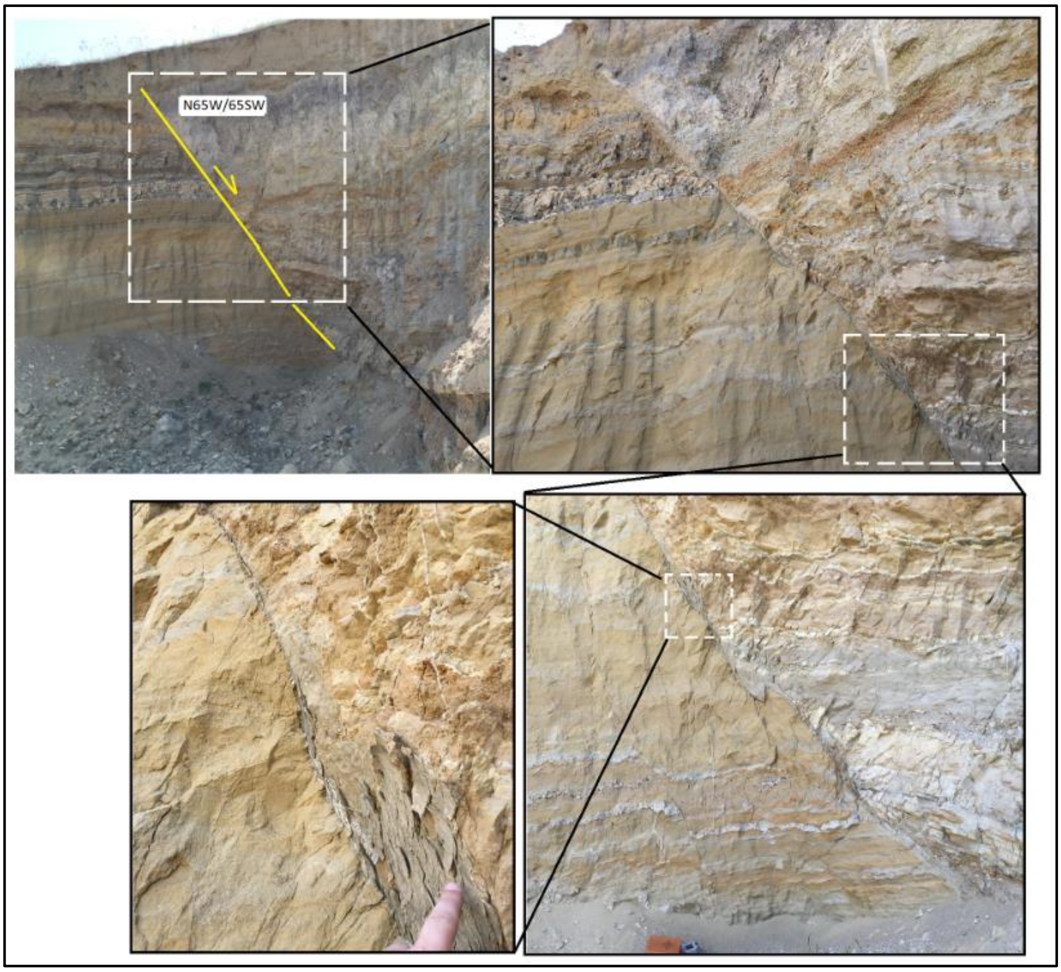

Figure 5. General and close view of the fault that 50 m away from above (look to E)

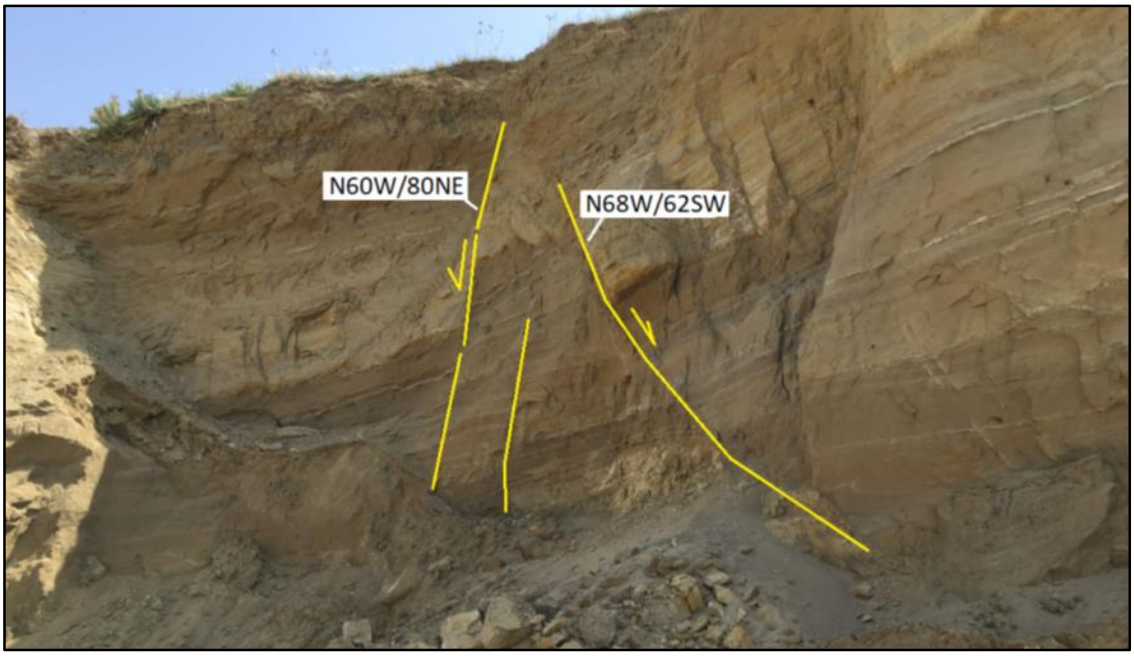

Figure 6. A fault set forms a mini horst at the west of Celtikci (look to E)

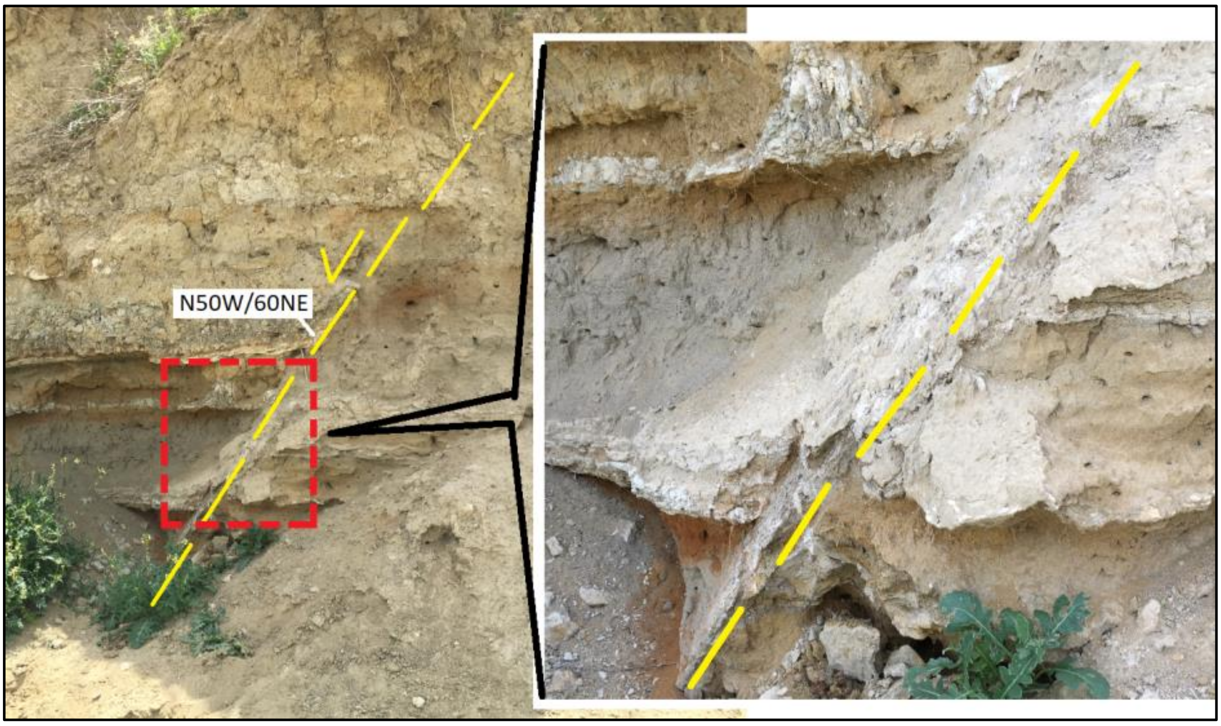

Figure 7. General and close view of fault at edge of urban area near Celtikci (look to E)

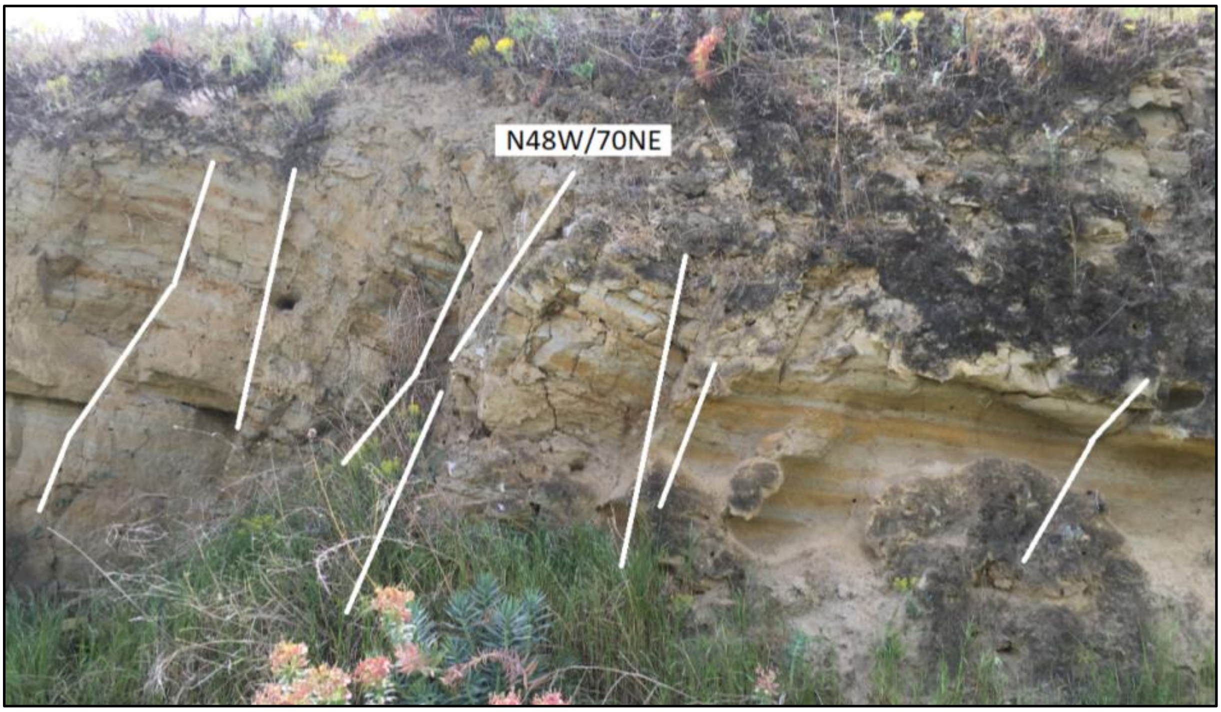

Figure 8. Fractures and fault zone on Kocadetre at west of Celtikci (look to E)

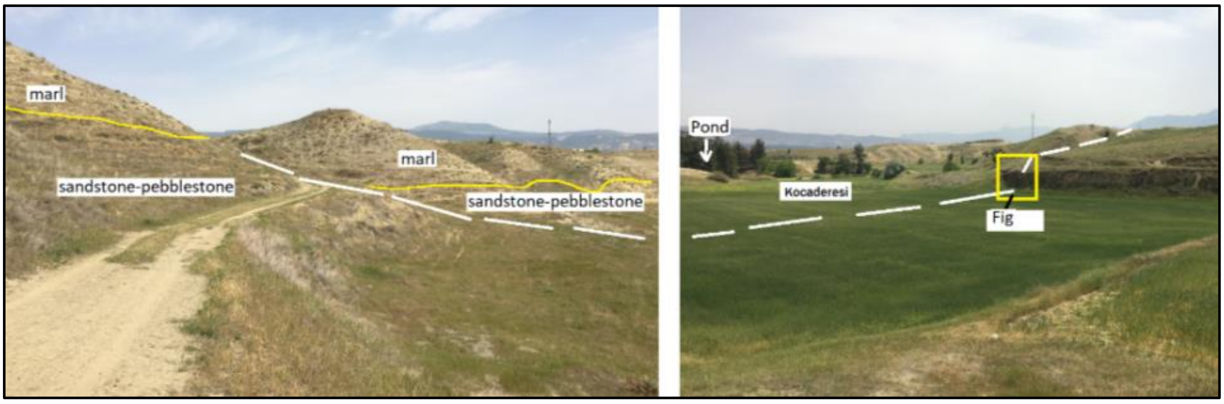

Figure 9. The fault line and lithological units at west of Celtikci (look to E-NE)

Trench #1 (H-1)

Firstly the geophysical section line was specified to determine the continuity of the fault in the NE area of the site and then a trench study was conducted from an appropriate location. Geophysical section with multiple electrode method (Figure 10) was employed to detect the buried fault line and some anomalies were recorded. In the light of this data and the geological observations, it was decided to open the trench #2 at a suitable location. This trench location is covered by the Holocene aged soil cover and the Neogene aged sediments in the trench (Figure 11).

The SE wall of the trench has been studied in detail and the fault detected (Figure 12). Therefore, it was verified that the fault line crossed the urban areas. The fault is covered by natural soil on the surface. In addition, its continuation into the alluvium cannot be clearly observed

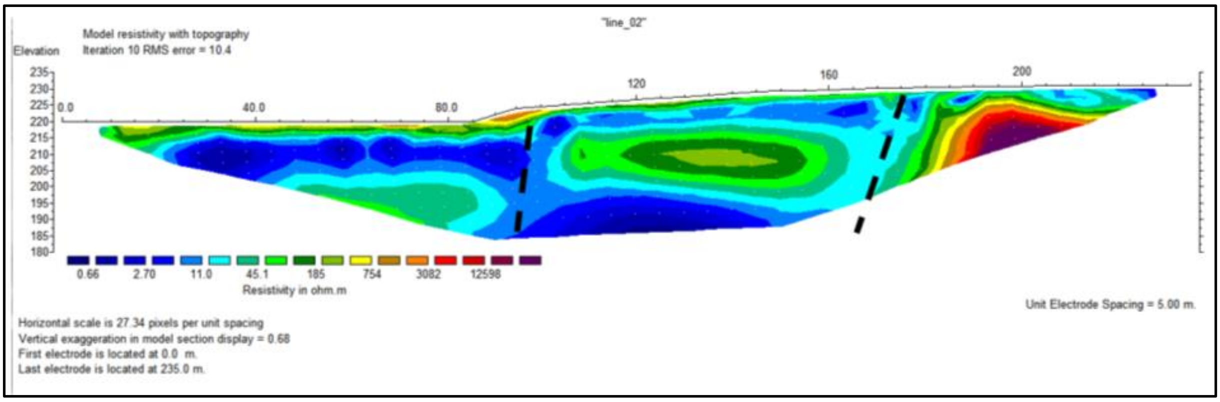

Figure 10. The resistivity cross section of northeastern part of the study area

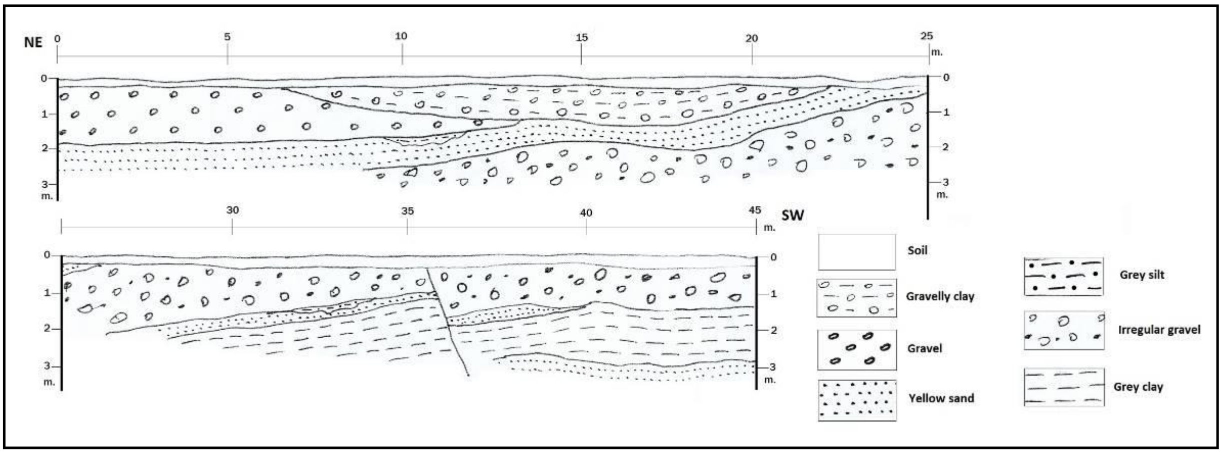

Figure 11. Lithological cross section of #1 trench (SE wall)

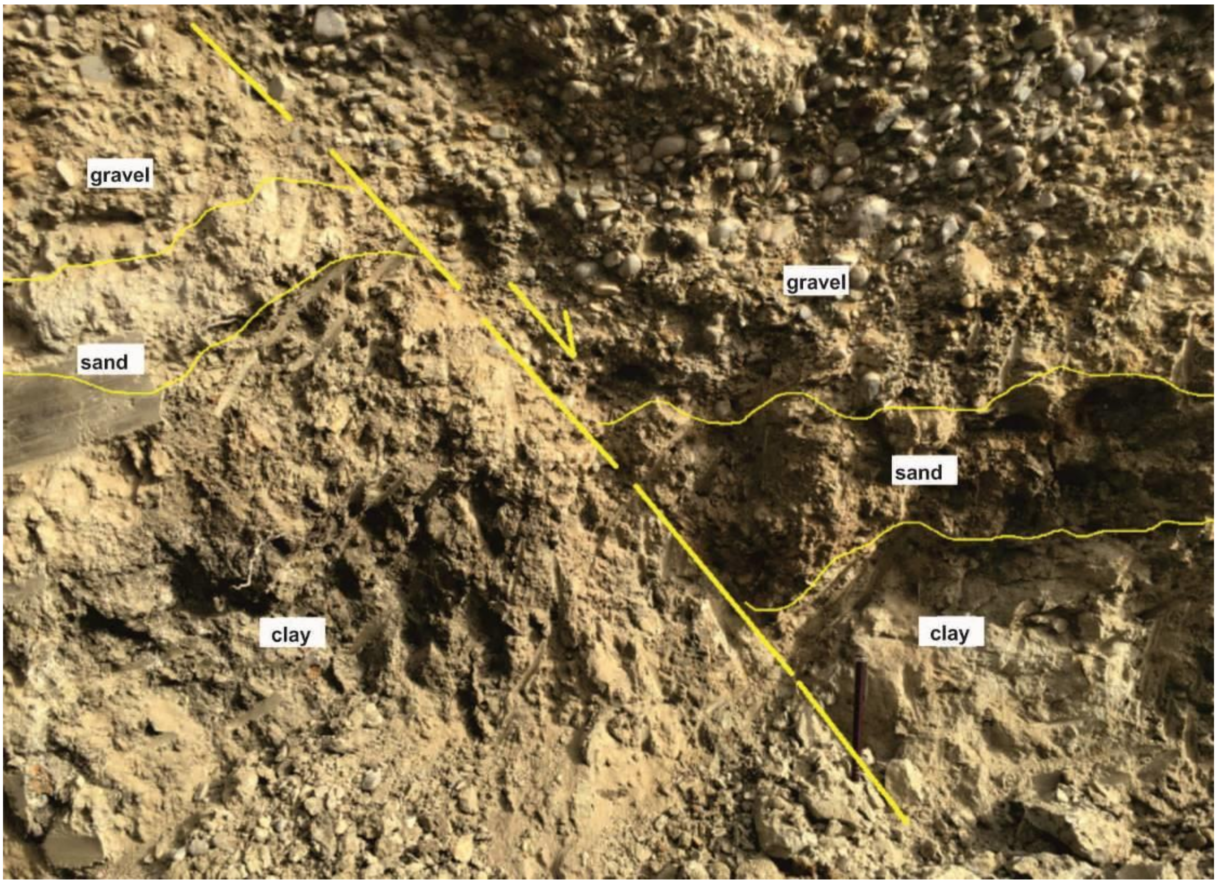

Figure 12. Fault traced 36 m away from #1 trench (look to E)

Trench #2 (H-2)

A second fault anomaly was recorded during the geophysical study (Figure 10) at the NE end of the urban area. The geological and morphological observations did not reveal any signs, but due to the presence of such geophysical data, the second trench was dug at this location (H-2 trench). The lithology of this trench is identical to #1 (Figure 13). The SE wall of the trench was examined in detail.

The NW-SE trending fault or fault systems were expected within the trench #2 because of the dominant inclination orientation and there were not contrary data. In general, there are fault systems in the Denizli Basin which are in the same opening period but rarely have NE-SW directions. However, the fault was in NNE-SSW direction opposite to the expectations. The position of this fault is $N10^0E/72^0NW$ (Figure 14). Slickensides are clearly observed on the fault plane. The faults are not entirely dip-slip, but there are some oblique slips. The Rake angle was measured as 65^0. Therefore, this fault can be called left-handed oblique fault. The fault does not cut the upper layer of marl and ends in this section. Thus, the fault is interpreted as a fracture formed earlier than NW-SE trending young faults across the basin. A detailed map of the study area was prepared based on these data (Figure 15).

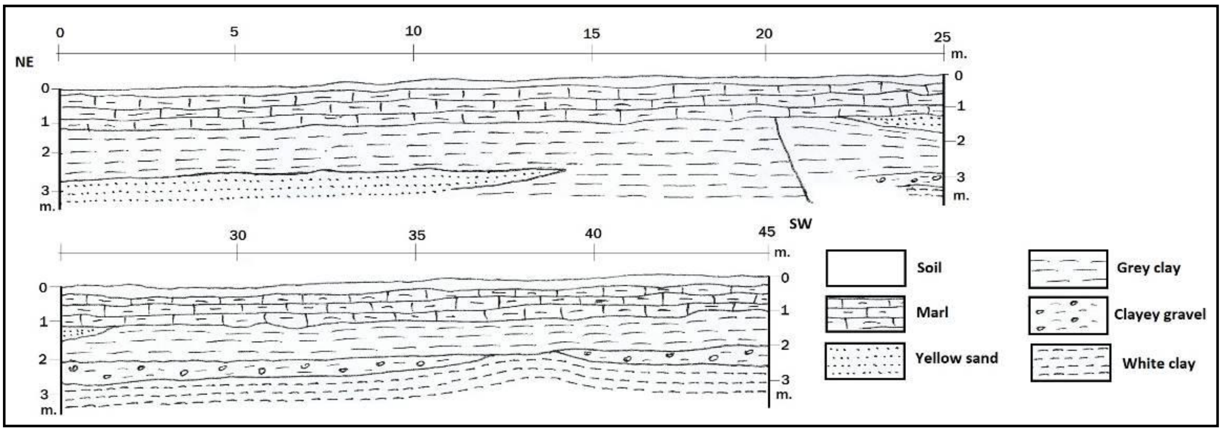

Figure 13. Lithological cross section of #2 trench

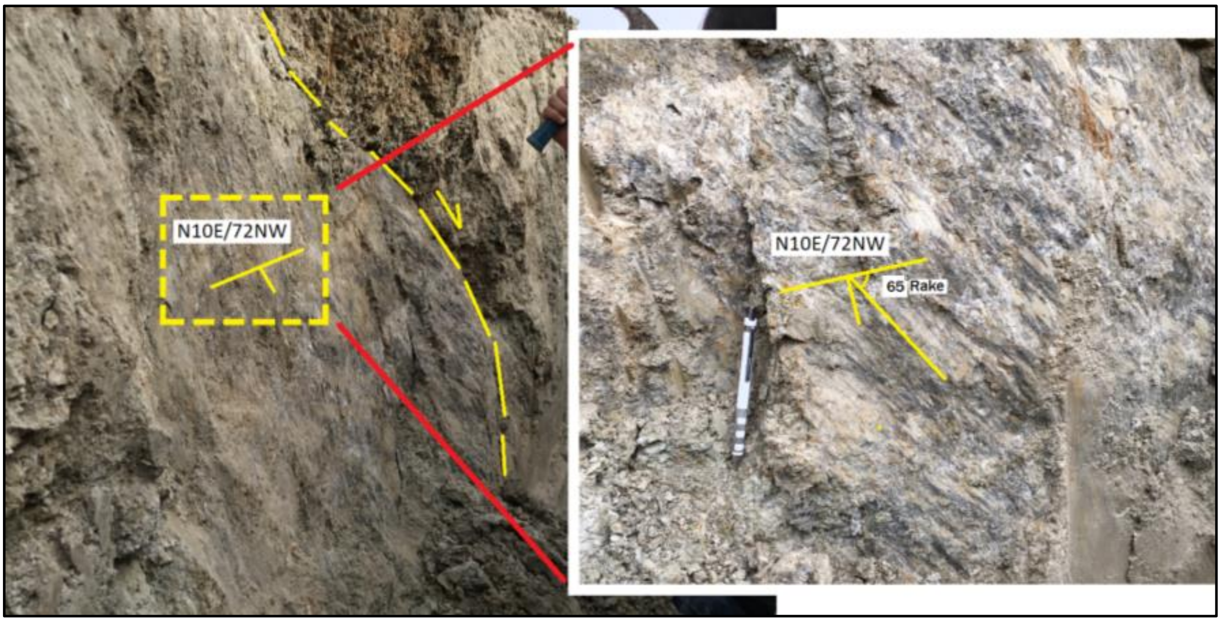

Figure 14. Fault line and slickensides traced 20 m away from #2 trench (look to S)

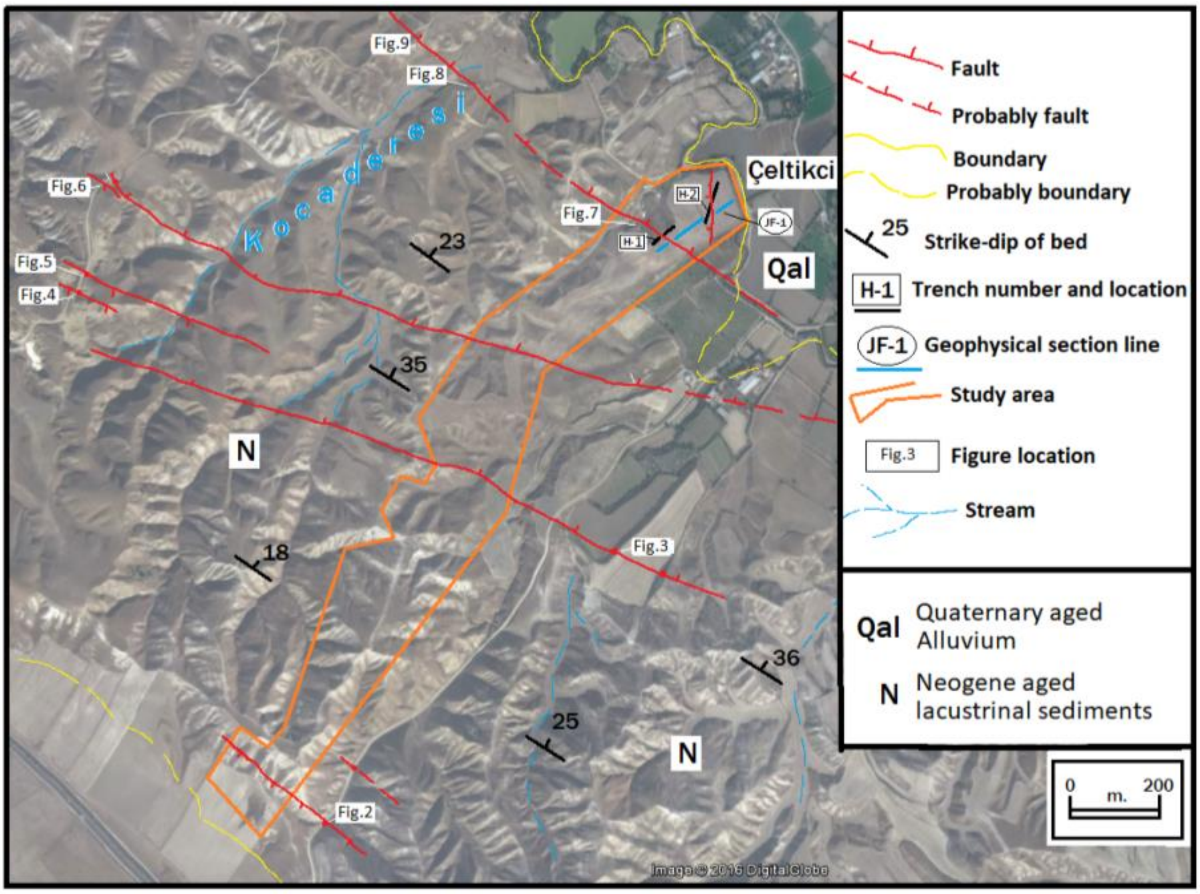

Figure 15. Faults and trench locations, geophysical section lines and geological units based on Google Maps (modified from Hancer, 2013)

Results

The study area is located in central part of Denizli graben. The SW and NE wings of the graben are formed by Babadag by the Pamukkale faults respectively. The young faults, parallel to those faults, are intensified in central parts of the graben. Karakova host is positioned just in the middle of the graben. The fault zone which forms the NE wing of the Karakova horst extends along the Kaleköy and Uzerlik. The fault that forms the SW wing extends between the Kumkisik village and the Sevindik district. The study area is a narrow part extends between the two fault zones. These faults were defined as active based on active map of Turkey of MTA.

The Kaleköy-Uzerlik fault line is at far end of northeastern part of the study area. It does not cross the study area based on the field observations, the active fault map of MTA and the aerial photographs. However, detailed studies have proved presence of the fault. However, a geophysical study was employed in order to find out whether this fault is a part of Kaleköy-Uzerlik fault line or a synthetic-antithetic fracture of this fault.

Two fault anomalies were identified in the multi-electrode geophysical study and two trenches were dug. The graben faults, active lines and dominant fault systems in the Denizli basin are NW-SE directions. Therefore, the fracture line passing near an active fault system with NW direction was expected to be in the same direction. There are NE-SW trending fractures but they are not active in the basin. The recent extension in the basin is NE-SW oriented. The faults that are active and dominant are therefore NW-SE directed faults.

All these active faults are located in urban areas and they may cause catastrophic consequences. Thus the mitigation measures have to be taken in these zones.

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