Determination of active faults by morphotectonic and geophysical data: Karsiyaka (Denizli-Western Anatolia) case

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Abstract

The graben faults of Aegean Graben system have produced many destructive earthquakes in historical and instrumental periods and the process is still going on. The surface traces of some of these faults, which have formed surface ruptures, may have been lost over time and/or the Holocene aged sediments have been caped. Therefore, difficulties may be encountered in determining the fault lines. This could be vital for microzoning studies in urban areas. In this study, a geological, morphotectonic and geophysical data ware used to identify a buried faulted line in Karsiyaka District of Denizli province. It cannot be observed because of the young sediments on the surface while it can be traced by morphological characteristics in some locations. The fault line has been identified using by geological data, geophysical (resistivity) tools. The results have been verified by trench studies.

Key words: *active fault, graben, morphotectonic, Denizli, Karsiyaka*

Introduction

As a result of the collision of the African-Arab and Eurasian plates, the Anatolian plate movement to the west forms a large deformation zone in Western Anatolia. The Aegean-Anatolian plate moves towards the Hellenic arch with a counterclockwise rotational movement and dips under the Aegean-Anatolian plate (Fig. 1). This speed of this rotational movement is about 23 mm/year according to the GPS data. Recent studies suggest that there are two main causes of this rotational movement: the first is the collision of the Arabian and Eurasian plates in the Eastern Anatolia and movement of the triangular shaped continental block of Anatolia from this region, and the second is extension of in Western Anatolia and Aegean regions into NNE-SSW direction due to sinking the oceanic crust in the Hellenic arc. There are a large number of detailed tectonic studies on the development of these structures (Arpat and Bingol, 1969; Koçyigit, 1984; Altunel and Barka, 1996; Hancock and Altunel, 1997; Seyitoglu and Scott, 1991, Yilmaz, 2000, Bozkurt and Sözbilir, 2004) and sismo-tectonic models have been proposed and discussed (McKenzie, 1978; Alptekin, 1978; Şengör, 1979) for this region. As a result, active extension in Western Anatolia is still continuing. The edge faults of these grabens formed by this process are active and have produced devastating earthquakes in Western Anatolia during the historical and instrumental periods. Active faults that cause earthquakes in the region are generally known. However, in some cases these faults, produced earthquakes in the past and formed a surface rupture, are not clearly the traced on the surface. The traces of ruptures on the surface may be lost over time and/or the young Holocene sediments may have been covered them. Tracing these buried active faults is crucial for microzoning studies of urban areas.

The active fault lines, produced earthquakes and formed surface rupture can be detected by using the geological and the morphotectonic data. Additionally the geophysical methods like ground penetrating radar (GPR) and resistivity are also be employed to support the studies. After that, the paleoseismological trench studies are required to verify the obtained data. In this study, a location was determined in the Denizli region where in the eastern part of the Western

Anatolia region. The geological and the morphotectonic traces on the surface were watched. Some geophysical cross-sections were taken at the critical locations. Finally, trench studies have been employed to verify the existence of fault line and to get the paleoseismological data.

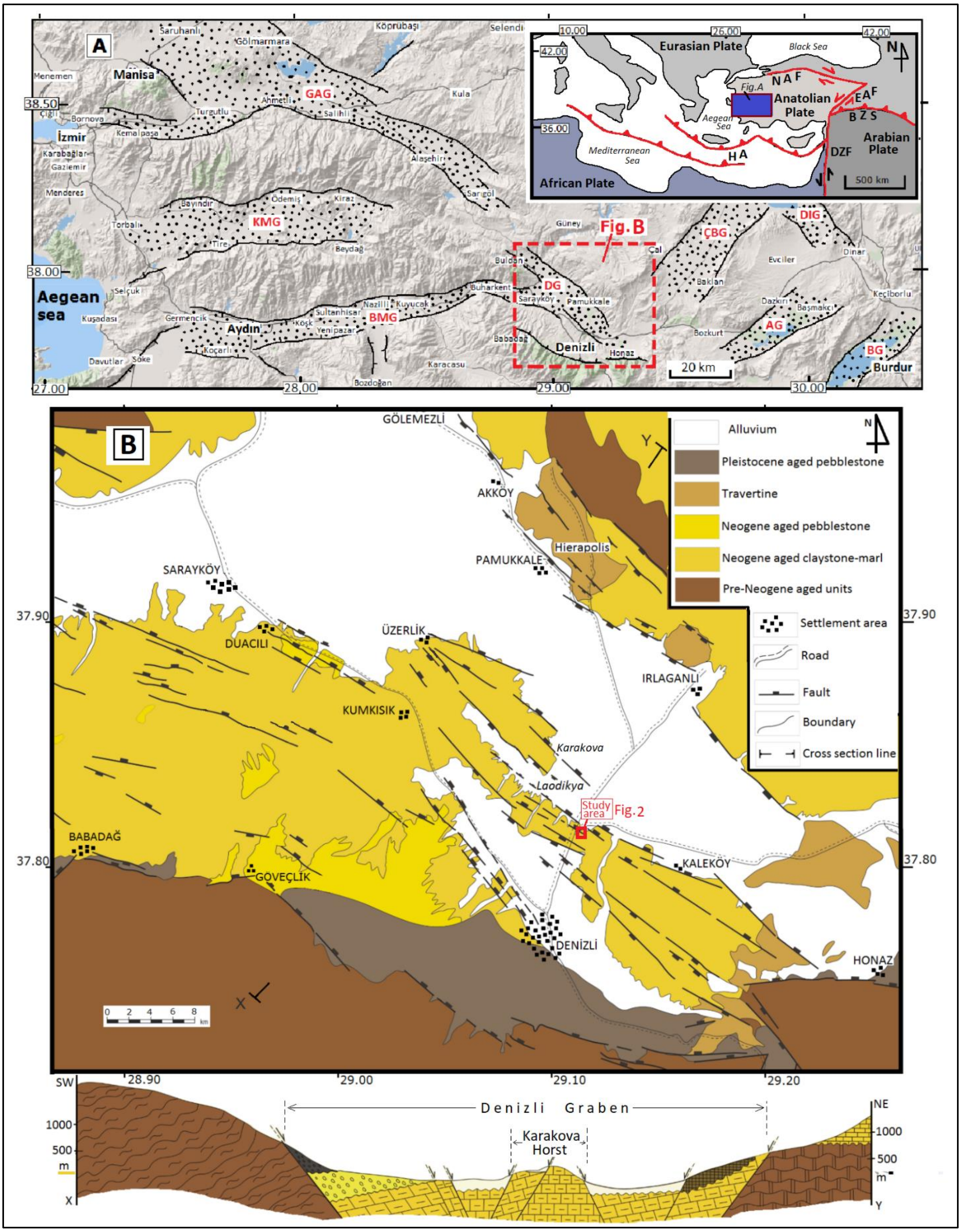

Figure 1. A: Graben map of Western Anatolia in 1/250 000 scale; (BMG: Büyük menderes Graben, KMG: Küçük Menderes Graben, GAG: Gediz (Alaşehir) Graben, DG: Denizli Graben, ÇBG: Civril-Baklan Graben, AG: Acıgöl graben, BG: Burdur Graben) (modified

from Emre et. al., 2011), B: Simplified geological map of the Denizli region and geological cross section (modified from Hancer, 2013; Kocyigit, 2005; Alcicek et al. 2007; Sun, 1990).

Geological Setting and Seismicity of the Denizli Region

Denizli Basin is NW-SE trending 7-28 km wide and 62 km. long (Koçyiğit, 2005). The faults that limit the basin are the Pamukkale faults in the northeast and the Babadağ - Honaz fault in the southwest. There are many faults developed in parallel between basin edge faults between Babadağ-Pamukkale region (Fig. 1). Karakova Horst is located between two edge faults of the graben. The fault zone in the Uzerlik-Karakova region, which forms the NE edge of this horst, is active and the epicenters of a large number of earthquakes occurred in the years 2000 and 2004 are in this region (Hançer, 2013). In particular, it can be said that the faults in K-KD section of the basin is seismically more active than the south. Many earthquakes occurred during the historical and instrumental periods in the region. The region is located where the grabens meet and crustal extension goes on that cause high seismic risk.

The SW wing of Karakova horst continues towards the Kumkisik-Sevindik districts. The northern wing starts from Uzerlik village in NW, and extends towards SE along Celtikci, Karakova, Gonaali, Laodikya, Akhan and Kaleköy as different segments. Koçyiğit (2005) mapped this zone into five separate segments. Especially the earthquakes in April-October 2000 are concentrated on this line. The study area is located in the SE section of the fault forming the SW wing of Karakova Horst. The area is located in the region where the fault system parallel to the Karakova horst is very dense. The fault zone forming the SW wing of the horst starts from the east of Kumkısık in NW and extends to the Gökpınar dam site near the SE. This line was mapped as the NE wing of the Denizli half-graben by Koçyiğit (2005). This line extending between Kumkisik and Sevindik forms the SW boundary of the Denizli municipal area. From this line to the NE, there are developed fault groups within the Neogene aged units and the working area parallel to this line.

Since Denizli region is the meeting point of three different grabens, earthquake risk is extremely high. When the seismic activity of the historical period is examined, two violent earthquakes have been recorded in 65 BC and AC 60 in the region of Denizli. The latter has caused the destruction of the ancient city of Hierapolis. Additionally the earthquakes in 494, 700, 1358, 1651, 1717, 1887 and 1899 AC have caused loss of life and property in Denizli, Pamukkale, Honaz and Sarayköy region. Apart from these, the earthquakes occurred in Aydın, Nazilli and Burdur affected the region (Eravcı et al., 2007; Kumsar and Aydan, 2004; Kumsar at al, 2016).

There is not any earthquake greater than M=6.0 and only 12 events greater than M=5.0 during the instrumental period in Denizli region. They are concentrated in Buldan and Pamukkale regions. When the basin is taken into consideration, it is seen that earthquakes grouped in NE of the graben. Particularly the Pamukkale fault zone and NE section of Karakova horst are remarkable. The notable earthquakes in Denizli and surrounding area are 1963 Buldan (Ms=5.6), 1965 Honaz (Ms=5.6), 1976 Denizli (Ms=5.0), 21.04.2000 Denizli-Honaz (M=5.2) and 22-31.07.2003 Sarıgöl-Buldan-Yenicekent earthquakes (Md=5.3 on 23.06.2003 and Md=5.1 on 26.06.2003, Md=5.5 and Md=5.0). A total of 160 earthquakes ranging from 3.0 to 4.0 have been recorded during the six months just after the Denizli-Honaz earthquake (21.04.2000) earthquake (Eravcı et al., 2007).

Paleoseismological studies

The study area is under the control of the faults of the region, which is called Karakova horst in the Denizli basin and it was divided into small horst and grabens. These faults form small segments of the horst and grabens, start from Uzerlik and extend to the Laodicea and Kalekoy. There are synthetic and antithetic faults, mostly parallel to each other, developed within the Neogene aged sediments within this zone. The region is on active fault zone as shown on the active fault map of MTA (Emre et al., 2011).

A paleosismological study has been carried out on one of the faults in Karakova horst (Fig. 2). This fault is visible on the Ankara highway, in the Karsiyaka district where the position of the fault is N44^{0}W/60^{0}NE in this section. A yellow sand layer of 10-15 cm thickness is determined as a guide level and it suggests that the fault has an dip slip of 4.0-4.5 m. The fault was covered by the young Holocene sediments in this section the (Fig. 3). It is possible to trace the continuation of the same fault towards SE. There are small fractures which are antithetically developed 50 meters away from the first location (Fig. 4). The slip of the fault in the far SW section is slightly higher than others. The similar small cracks are visible at NE of this fault which has an slip of 2.5 m.

These cracks have small slip if the silt layer of 5 cm thickness is based on. The fault seen in the road cut is the continuation of the fault observed in the previous location. It has been investigated whether this fault continues towards SE.

Figure 2. Fault map of study area (based on Google Maps)

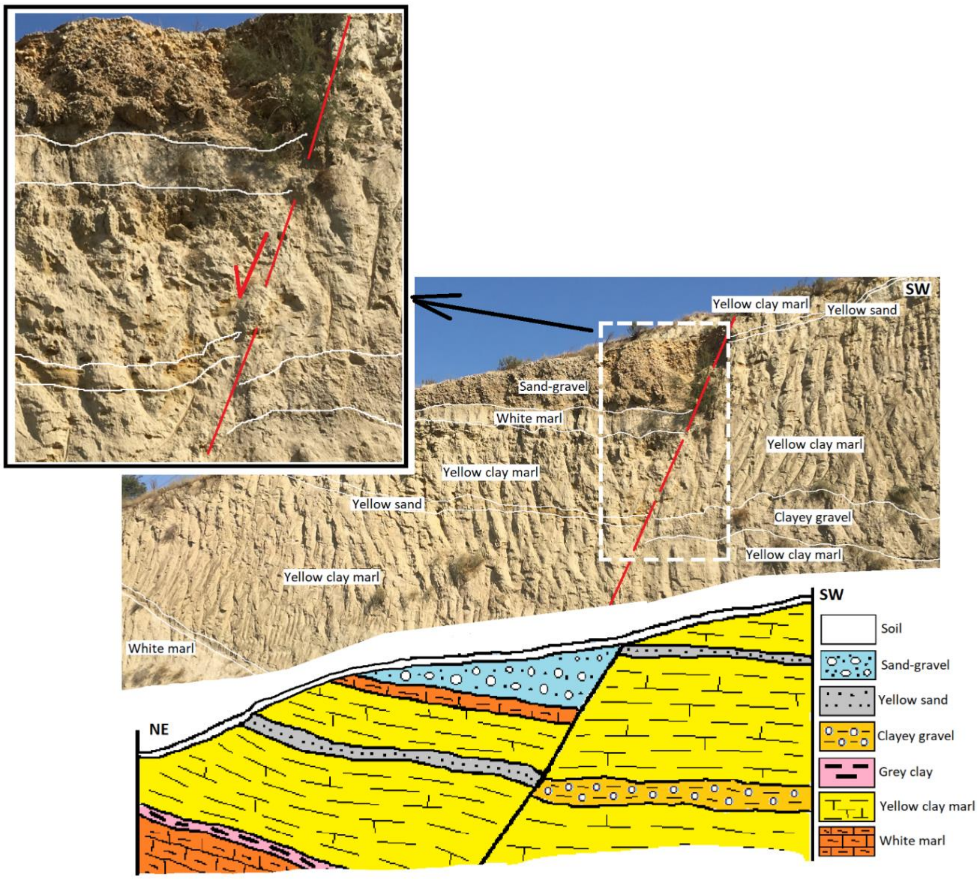

Figure 3. General and detailed view of the fault and geological units on the east of Denizli-Ankara highway road cut (look from NW to SE) and its geological cross section of it (section # 1).

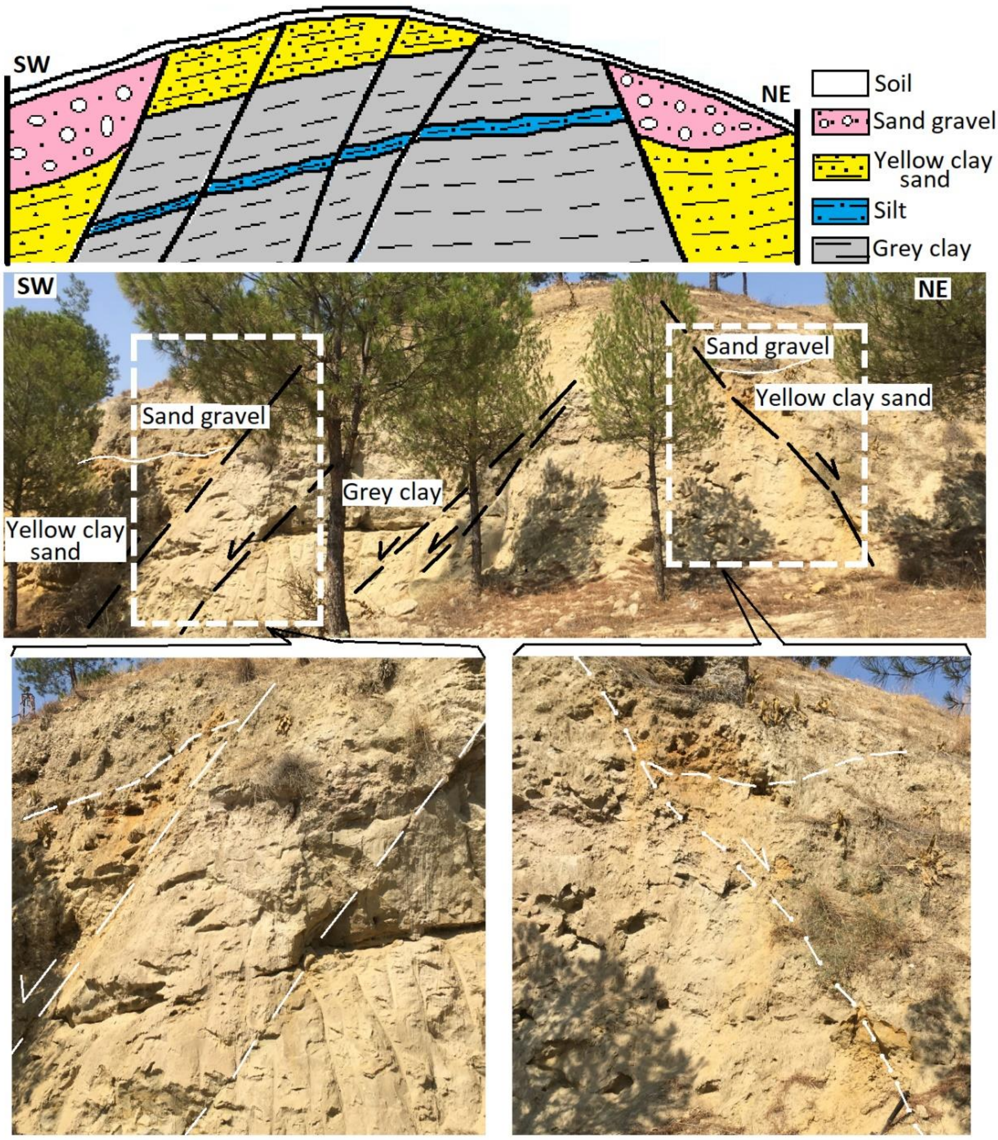

Figure 4. General and detailed views of the fault zone and geological units on the south of 1 numbered section (look from SE to NW) and geological cross section of it (section #2).

The fault was observed again in the excavation number 3, which was opened 100 m away from this cut (Fig. 5). The position of the fault is N43^{0}W/51^{0}NE. The fault slip is about 1 meter if the pebble unit at the upper levels is based on.

From this point, the location of the fault towards the SE cannot be traced due to the artificial fill in the field. The trench (#4) in 3 m deep has been opened in this region and it is of artificial filling material. A deeper trench was impossible with available equipment to pass the fill depth. Than two geophysical methods namely electric resistivity and multi array electrode were employed to visualize the underground. The obtained data suggest that the fill thickness is getting higher towards SW. It reaches up to 10-15 meters and a fault data were obtained beneath the fill (Fig. 6).

Morphotectonic data was employed to determine the continuation of the fault even further towards the SE and a trench was dug in a location where the fill has minimum thickness. The faults with N65^{0}W/70^{0}NE position ware observed again in this trench (Fig. 7). It can be said that there is 2 about meters slip relative to the gravel and clay contact cut by the fault in the trench.

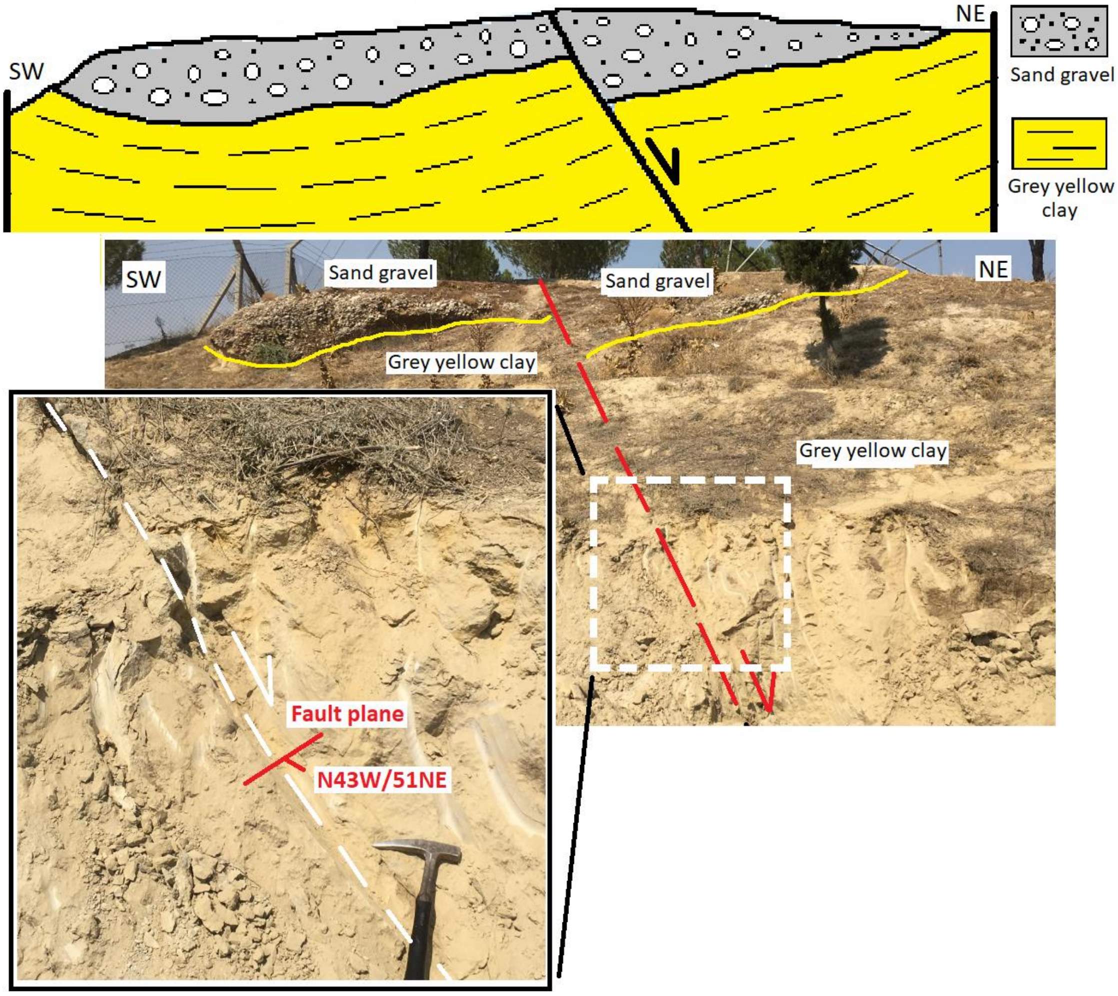

Figure 5. General and detailed views of the fault zone and geological units on the southeast of the factory (look from SE to NW) and geological cross section of it (section #3).

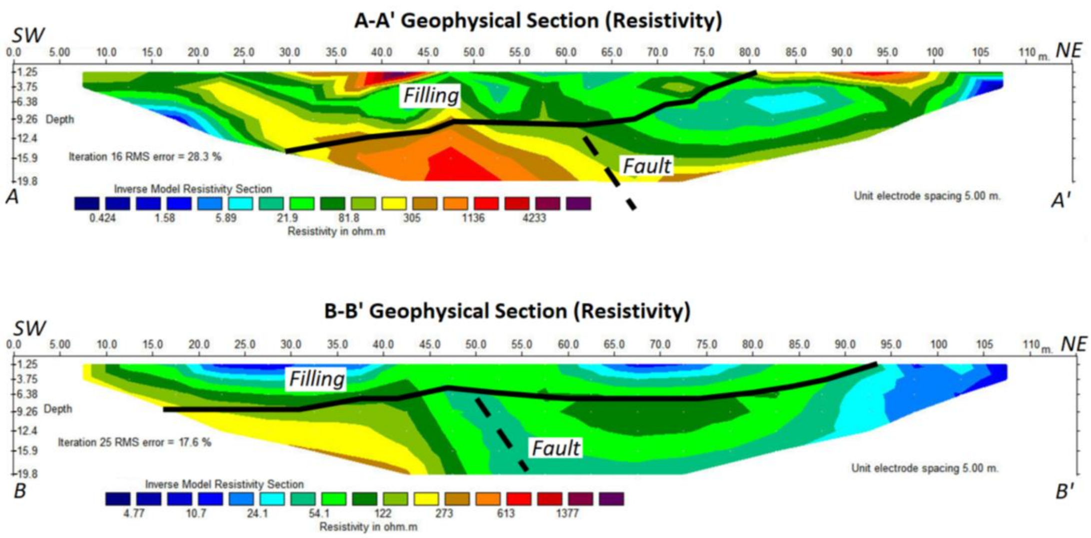

Figure 6. Geophysical multi electrode (Resistivity) sections during to A-A' and B-B' lines

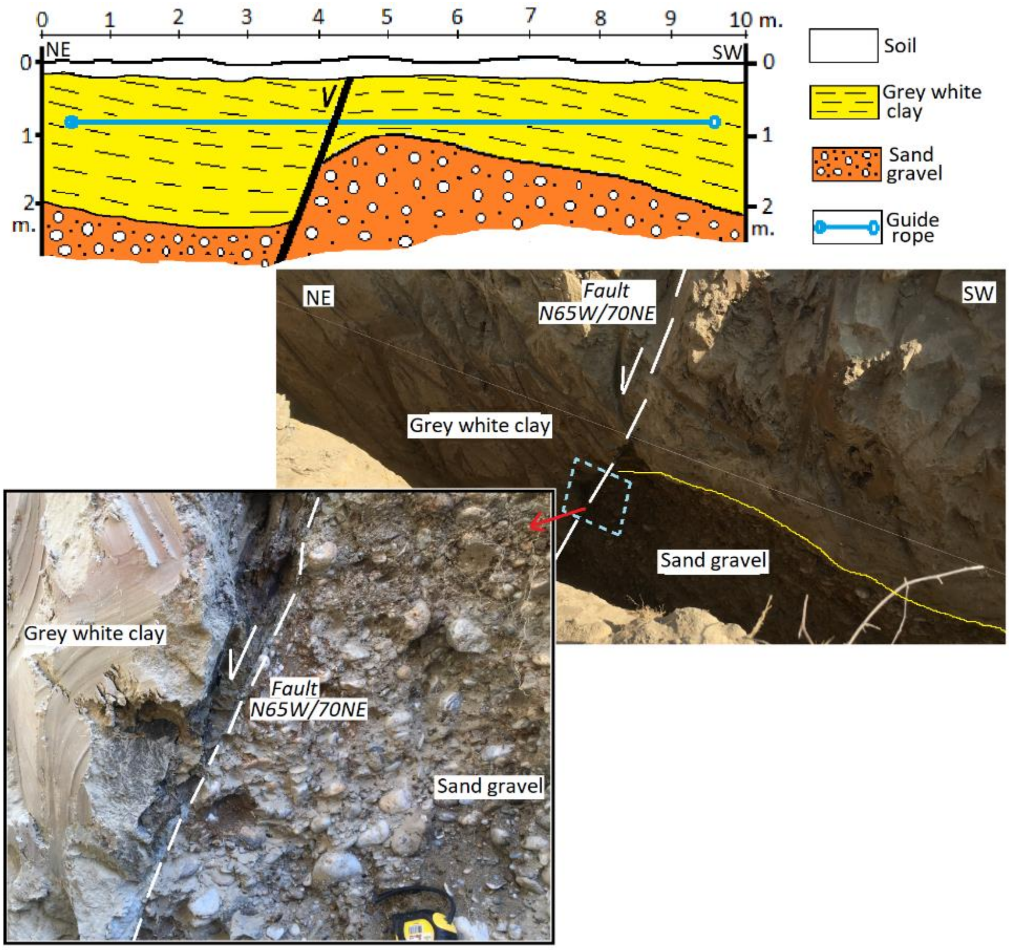

Figure 7. General and detailed views of the fault zone and geological units in trench on the southeast of the region (look from W to E) and geological cross section of it (5 numbered section).

Results and discussion

Karakova Horstu is located in the central part of the Denizli Graben. There are syntetic and antithetic fractures developed parallel to this horst. One of the regions where these fractures are intense is the area between Kalekoy and Laodikeia. Some of these faults in this region are clearly observed in the outcrops. Some of the fault traces are not clearly observed due to the cover, fill and alteration. The geological, geomorphological and geophysical studies play an essential role for determining the faults-fractures which are not visible on the surface. The location of these fault zones is significant in the land use and urban planning. For this purpose, the goal of this study is to determine the routes of the faults which cross the Karşıyaka district between Kaleköy and Laodikeia.

First of all, the fault was examined and mapped where it was observed on the surface located just on the eastern edge of the Denizli Highway. In the continuation of the fault towards SW, any fault trace could not be observed due to the artificial fill in the region. Two geophysical studies were performed in the areas where the fault is likely to pass. The geophysical suggest that the upper artificial fill thickness was increased towards SW and some fault anomalies were detected under the fill. A trench was opened to verify the geophysical data and a fault was obtained at a location where the fill has minimum thickness. The fault was covered by Holocene aged sediments. The obtained data suggest that this fault is a potential active fault.

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