Active tectonic and palaeoseismological features of the western section of Mustafakemalpaşa Fault; Bursa, NW Anatolia

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The Mustafakemalpaşa Fault (MF), located among Manyas, Ulubat and Orhaneli faults, is a right lateral strike-slip and 47 km in length. The MF begins with a pressure ridge and exhibits complex jog terminations at east ends in restraining left stepovers. The western section of the fault bounds Miocene and Quaternary units and continues towards İlyasçilar. The central segment of the fault, starts with approximately 750-m leftward stepover, exhibits a sinusoidal geometry between Kapaklıolu and Kabulbaba. In this section, MF traverses mountainous terrain and cuts Ophiolite, Jurassic limestones and Miocene detritals, forming dextral faulting features and gaining reverse component. The eastern section exhibits left stepping en-echelon pattern and consists 2.5-km offset on the Orhaneli River. In this study, palaeoseismological findings related to the Holocene activity and active tectonic properties of the MF are presented. The trenches exposed mismatched stratigraphy, demonstrating evidence of events across the fault. We identified three events (before BC 2190, later AD 1425 and 1850) that have occurred during the past 4000 years. We suggest a long non-characteristic recurrence interval and ~0.7 mm/y slip-rate for MF, based on trench data and offset of the Late Pliocene drainage of Orhaneli River.

Keywords: Mustafakemalpaşa Fault; palaeoseismology; active tectonic; strike-slip fault; NW Anatolia

1. Introduction

The neotectonic of Turkey is characterised by the deformations of the Anatolian microplate related to extrusion/tectonic escape motion resulting from the post-collisional intra-continental convergence (Armijo, Meyer, Hubert, & Barka, 1999; Jackson & McKenzie, 1984; Koçyiğit, 1984; Le Pichon, Chamot-Rooke, Lallemant, Noomen, & Veis, 1995; McKenzie, 1972, 1978; Şengör, 1979, 1980; Şengör, Görür, & Şaroglu, 1985; Taymaz, Jackson, & McKenzie, 1991). The North Anatolian Fault Zone (NAFZ) and the East Anatolian Fault Zone (EAFZ) accommodate the westward extrusion of the Anatolian microplate. The tectonic escape regime has resulted in distinct neotectonic provinces; (1) East Anatolian Compressional region, (2) North Anatolian region, (3) Central Anatolian ‘plain’ region and (4) West Anatolian extensional region (Bozkurt, 2001; Şengör et al., 1985) (Figure 1(a)).

The study area is located in southern Marmara region, at the transition zone between in neotectonic provinces, which is under the strike-slip and extensional processes (Figures 1(b) and 2). The NAFZ zone bifurcates into the strands extending up to 120-km broad deformation zone and the extensional tectonic structures represented by grabens observe the north and south of the transition zone, respectively.

The Mustafakemalpaşa Fault (MF) is one of the fault segments in the transition area. It is 47-km long, right-lateral strike-slip fault with general striking N50 W. Şaroğlu, Emre, and Boray (1987), Şaroğlu, Emre, and Kuşcu (1992) assessed the fault within the Manyas Fault zone and then, Emre, Doğan, Özalp, and Yıldırım (2011), Emre, Doğan, and Özalp (2011), Emre, Doğan, and Yıldırım (2012), Emre et al. (2013) first defined as a single fault segment and assigned as MF. The fault shows a slightly sinusoidal trend and terminates at both west and east ends in left stepover structures. It represents geological and morphological features indicating recent strike-slip faulting activity. The occurrence of units at different ages and lithologies side by side, the sudden cutoff of units and structures and morphological structures such as pressure ridges, linearly oriented slope debris and fans, elongated ridges, offset rivers, hanging valleys and fault scarp corresponding to earthquakes have been interpreted as significant data indicating that the Mustafakemalpaşa Fault is still active.

Recent GPS studies reveal that the major strand of the NAFZ accommodates 24 ± 1 mm/y of dextral motion of Anatolian microplate (McClusky, Reilinger, Mahmoud, Ben Sari, & Tealeb, 2003; Reilinger et al., 2006). Additionally, some deformation in southern...
Marmara region where the NAF bifurcates fault segments in the broad zone are suggested ranging from 0.9 to 6.8 mm/y for dextral and from 0.8 to 5.5 mm/y for vertical movements (Aktuğ et al., 2009; Flerit, Armijo, King, & Meyer, 2004; Meade et al., 2002; Reilinger et al., 2006).

Destructive earthquakes in historical period (<1900) are documented by many researchers (e.g. Ambraseys & Finkel, 1991; Ambraseys & Jackson, 1998; Ergin, Güçlü, & Akşay, 1971; Soysal, Sipahiöğlu, Kolçak, & Altınok, 1981) as distributed over the study area and its near vicinity in southern Marmara. Besides, some moderate earthquakes have generated by the MF recorded in the instrumental period.

In this study, we present results of the palaeoseismological surveys on the MF. The surveys performed at two sites with two trenches, which exposed clear structural and stratigraphical evidences and provided recent activity. We identified three events that have occurred during the past 4000 years.

2. Geological features of Mustafakemalpaşa fault

The MF forms a wide bending facing southward together the Yenice-Gönen Fault, the Manyas Fault Zone and the Orhaneli Fault in southern Marmara. The MF, which is located between the Manyas Fault Zone and the Orhaneli Faults in the eastern part of this bend, extends in three main sections between Yumurcaklı and Ömeraltı villages. We use the terms of ‘fault section’ for convenience, without implying any particular geological or seismological significance.

The western section of the fault is 16-km-long trending N65 W and extends between Yumurcaklı and İlyasçılı (Figure 3(a)). The section begins at the E–W extending pressure ridge that has formed between the Manyas Fault Zone and MF (Figures 2 and 3(a)). It traverses along northern slopes of the ridge and cuts Miocene volcanics and Pliocene-aged Bayramiç formation. In this site, the MF deflects the boundary between these two units about 1 km, which can be considered as the minimal total offset of the fault (Figure 3). Selim, Tüysüz, and ve Barka
Figure 2. Simplified map showing active faults of the Northwest Anatolia (modified from Emre et al., 2013). White rectangle showing study area and geographic setting of MF. The shaded relief is from Shuttle Radar Topography Mission (SRTM).

Figure 3. (a) Geological map of the MF and its vicinity. (b) Google earth image showing the dextral offset of 2.5 km on the Orhaneli stream channel.
also reported that depending on the activity of the MF, Mustafakemalpasa river has changed direction to form 1125-m-long dextral offset together with alluvium narrowing at the Mustafakemalpasa city centre. The dextral slip character of the fault exposed in a quarry at Keltas with a ~100-m-wide shear zone (Figure 4b, c) (Emre, Dogan, Ozalp, & Yildirim, 2011; Emre et al., 2012). The western section then clearly transects Quaternary debris and fan deposits and juxtaposes Jurassic limestones with the Miocene deposits on the southern block. This western fault section trace is characterised by topographical steps and saddles on alluvial fan and Miocene lithologies surfaces, respectively (Figure 4(a)), and jog structure is represented by small bend and stepover.

The western and central sections are separated by a 750-m-wide left stepover in E–W direction at north of Ilyasclar. The 9-km-long central section between Kapaklioluk and Kabulbaba has reverse component resulting in geometry (Figure 3(a)). For this reason, instead of a significant dextral displacement at the boundary of the geological units, distinct uplifting along the north hanging wall of pre-Miocene rocks is observed (Figure 4(d)). For example, flexural scarps are systematically formed on the hanging wall ranging from several to decade metres between Guiller and Kabulbaba. The overall section traverses mountain terrains where it mostly cuts basement rocks but in some places juxtaposes basement rocks with Miocene units.

The eastern section, has a general strike of N70 W, exhibits a pattern of left stepping en echelon of faults is separated by left-oversteps varying in length from 1 to 3 km. It traverses mountainous terrains for 10 km and forms linear features and offsets that can be easily recognised in recent morphology. It cuts basement rocks of the Karakaya group, which consist of Triassic detrital and carbonates and ophiolitic complex belonging to the

![Figure 4](image-url). Morphological and geological indicators of the MF. Red arrows indicate the fault trace on the morphology. Linear fault scarp to the north-east of Ocakil (a) and south-east of Mustafakemalpasa (looking south-east) (b), general view of the fault plane in a quarry located at the north-east of Keltas (looking south-east) Geologist 1.70 m for scale (c), general view of the fault trace at the north of Guiller (looking northwest) (d).
3. Historical and instrumental seismicity

Destructive earthquakes in the historical period (≤1900) are observed to be distributed over the study area and its near vicinity in southern Marmara. According to the historical earthquake catalogues (Ambraseys, 2002, 2009; Ambraseys & Finkel, 1991; Ambraseys & Jackson, 1998, 2000; Ergin, Güçlü, & Uz, 1967; Ergin et al., 1971; Kondorskaya & Ulomov, 1999; Soysal et al., 1981; Tan, Tapirdamaz, & Yörük, 2008), it can be said that destructive earthquakes showed orientation along the Mustafakemalpaşa, Ulubat and Edincik faults which are especially mapped as active faults (Table 1, Figure 5). Although some of these events may have been generated from the MF, which earthquake is related with MF is not clear from historical records due to the abundance of the seismic sources in the region and paucity of the reliable data. For example, the AD 368 event destroyed Germe city located in Mysia. Mysia is the name of the region located in north-west of Anatolia in ancient time almost corresponding recent Balıkesir city, although Germe was an ancient settlement area near Mustafakemalpaşa town (Ambraseys, 2009; Ambraseys & Finkel, 1991). However, the location for the 368 suggested between Mustafakemalpaşa and Manyas (Table 1, Figure 5). It is quite remarkable that another earthquake series, which is considered to have proceeded in the form of earthquakes triggering each other towards east started from the western part of MF in 1850 and ended with two earthquakes in 1855 on Ulubat Fault. From these, the epicentre of 1850 Earthquake is located in north of Yumurçaklı village in section where the MF ends at west. However, the epicentre of 1851 Earthquake is located in south-east of Mustafakemalpaşa town (Figure 5). Besides, instrumental earthquake records between 1900 and 2010 (Kadiрогlu et al., 2014; Kalafat et al., 2011) indicate recent activity including generally small and medium scale earthquakes (Ms. ≤ 4.9) along the MF. The 6 October 1964 Manyas earthquake
(Ms: 7.0) is the biggest earthquake that occurred in the near vicinity of the study area according to records of the instrumental period.

4. Site selection, trenching and dating methods

In the first stage, the geometry and geomorphological features of the Mustafakemalpaşa Fault were investigated through studies of aerial photos and satellite images. We analysed 1:35,000-scale aerial photos, high-resolution satellite images and digital terrain analysis produced from 10-m interval contours for proper palaeoseismological trenching surveys, coupled with detailed field studies. During both the aerial photos and field studies, we focused on the active fault related features such as fault scarplet, saddle structures, depression areas, river offsets and pressure ridges.
Figure 7. (a) Photo mosaic of Aralık Trench eastern wall without interpretation. (b) Log of Aralik Trench eastern wall.

Table 2. Radiocarbon dates on samples recovered from Aralık and Lalaşahin Trenches.

| Sample no | Laboratory no | Stratigraphic unit | Sample material | Measured radiocarbon age (BP) | $\delta^{13}C$ (%) | Conventional radiocarbon age (BP) | Calibrated age range (2σ) |
|-----------|---------------|--------------------|-----------------|-------------------------------|-------------------|----------------------------------|--------------------------|
| Lalaşahin trench | | | | | | | |
| MKL-C-W01 | 390687 | Unit 6 | Organic sediment | 3450 ± 30 | −26.2 | 3430 ± 30 | BC 1775–1660 |
| MKL-S-W02 | 390688 | Unit 6 | Shell | 3490 ± 30 | −10.7 | 3720 ± 30 | BC 2200–2030 |
| MKL-C-E01 | 390686 | Unit 7 | Charred material | 3690 ± 30 | −25.8 | 3680 ± 30 | BC 2140–1975 |
| MKL-S-W04 | 390689 | Unit 8 | Shell | 320 ± 30 | −10.2 | 560 ± 30 | AD 1385–1425 |
| Aralık trench | | | | | | | |
| MKA-C-W01 | 390684 | Unit 3 | Charred material | 3260 ± 30 | −25.8 | 3250 ± 30 | BC 1610–1450 |
| MKA-C-W02 | 390685 | Unit 4 | Organic sediment | 2610 ± 30 | −25.1 | 2610 ± 30 | BC 815–780 |
In the trenches, which were opened at nearly perpendicular directions to the fault, the walls were first cleaned. Later, we set up grid as 1 × 1 m on the trench walls and take photographs of the gridded trench walls, then, produced photomosaics for all trench walls. The photomosaics of 1:20 scale are used for logging of the walls. Earthquake event horizons were defined on logs based on the structural and stratigraphical data. Available charcoal and organic materials analysed by AMS-14C (radiocarbon) method at the laboratories for developing a numerical age chronology of the trench stratigraphy and event horizons. The collected samples were dated in BETA Analytic Laboratory in Miami (Florida, USA) using AMS\(^{14}C\) (radiocarbon) method. Radiocarbon dates can be obtained on a range of biogenic materials. Two approaches are employed to measure residual \(^{14}C\) activity in samples of these materials relative to modern standards: beta counting, which involves the detection and counting of \(\beta\) emissions from \(^{14}C\) atoms over a period of time, working on the principle that the rate of emissions will reflect the residual level of \(^{14}C\) activity within the sample, and accelerator mass spectrometry (AMS), which employs particle accelerators as mass spectrometers to count the relative number of \(^{14}C\) atoms in a sample, as opposed to the decay products (Walker, 2005).

5. Trenching and dating
The areas which had seen Holocene deposits along the MF were exposed to urbanisation heavily. For this

![Figure 8. (a) Photo mosaic of Aralik Trench western wall without interpretation. (b) Log of Aralik Trench western wall.](image-url)
reason, suitable site for palaeoseismological trenching are very limited. By evaluating all candidates in the study area, we excavated for two cross trenches in two different sites, which have right bending with mall track structure and a fault scarplet that considered as related with the Holocene events on the MF.

5.1. *Aralık* trench site

The trench site is located 3.5 km south-east of Mustafakemalpaşa and 1.5 km south-west of Aralık (UTM Coordinate: 623541E, 4431828N). The trench was about 20-m long, 4-m wide, 2.3-m deep (Figure 6). It was excavated where topographical slope breaks, which have been considered as Holocene surface rupture.

The trench exposed well- and simple-stratified section sediments of Holocene. The lowermost stratum, unit 1, is greenish-black clayey with rare well-rounded pebbles derived from the various lithologies of the bedrocks, which we infer to be associated with marshy environment of lake flat (Figures 7, 8). This unit is overlain with an erosive bottom by fine pebbly, pale grey lacustrine sandstone unit 2 of which its thickness varies in between 30 and 70 cm. In the central part of the unit, which consists of poorly carbonate cemented and badly sorted grains, there is a 5–10 cm thick, grey coloured clay band. Unit 2 is overlain by a massive, grey coloured clay layer (unit 3) containing of pebbles rarely derived from the bedrocks in the SW part of the trench. However, unit 2 is overlain by a charcoal-bearing massive clay unit 4 within pale grey, fine pebble and pebbles in the NE section of the trench. According to a coal sample taken from the west wall of the trench (MKA–C-W01) 3250 ± 30 BP and (MKA-CW02) 2610 ± 30 BP 14C ages were obtained for units 3 and 4, respectively (Table 2, Figures 7 and 8). These units are then overlain by brownish-pale grey clay (unit 5) lithology, and the age of the unit could not be determined because of paucity of material for dating. All units in the trench are covered by a recent soil unit 6.

The deformation structures that have exposed in the trench walls are folds and faults, affecting the whole or one part of stratigraphical units. The faults are characteristics by dextral slip with reverse component trending N05–15 W with dip amounts ranging from 40° to 65°SW. The faulted zones also affected by folding deformation with asymmetrical, SW verging folding.

Figure 9. Micro topographic map showing the fault trace (red thick line) and locations of the trenches (blue rectangles) on the Lalaşahin site (contour interval is 20 cm). Map produced from measurements made with Total Station instrument.
We interpreted these deformations to have been formed at the left restraining stepover. The faults cut all units between the 10th and 12th metres on the east wall of the trench, but terminate below recent soil (unit 6) (Figure 7). According to these data, the bottom of the recent soil unit was defined as the youngest event horizon in the trench. In addition, three faults observed between the 4th and 10th metres on the same wall are covered by brownish-pale grey coloured clay (unit 5), and the bottom of unit 5 is an event horizon related to a previous earthquake as well. Four faults, between the 11th and 16th metres on the west wall of the trench, cut all units in the trench and reached to the bottom of the recent soil (unit 6). This layer was interpreted as the event horizon related to the last event (Figure 8). The fault and folds exposed east and west walls of the Aralik trench do not appear to match well each other’s. In particular, the faults that are covered by unit 5 and observed between 4th and 10th metres on east wall, do not have any continuations on west wall. However, a fault appears in the second trench wall, which could be a left stepped of ~6 m continuation of the fault that have terminated in the trench. We therefore interpret these to be a structure of en-echelon pattern formed at the local restraining stepover. According to the stratigraphical and structural investigation, we recognised two event horizons related earthquakes have ruptured in Holocene period.

5.2. Lalaşahn trench site

The trench excavated on the topographical slope break, which is considered to correspond to the Holocene fault scarp, was named as Lalaşahn Trench (UTM Coordinate: 622486E, 4432146N). This fault scarp is located 2.8 km south-east of Mustafakemalpaşa town (Figure 3). Before performing trench excavations, the micro-topography map of the excavation area with 20-cm contour interval was produced using a ‘Total Station’ device (Figure 9). The detail topographical map have provided trench excavation on a slope break observed on a piedmont plain section in NE of the very small hill on the map (Figure 10). The trench is 4-m wide, 2.6-m deep and 50-m long trending N22E.

The trench exposed both pre-Quaternary basement rocks and recent deposits. Late Miocene-aged Mudamköy volcanic member was observed at the bottom (unit 1) and the basement composed of rocks belonging to middle-late Miocene-aged Göbel formation (unit 2) (Figures 11 and 12). The Mudamköy volcanic member represented by yellowish-brown andesites is located in and on the Göbel formation, which is represented by fine to medium bedded, beige to yellowish white coloured clayey limestones and greenish, pale grey coloured, conglomerate–siltstone–claystone lithologies intercalating with each other, and is lensoidal. Over these rocks, there are observed caliched, yellowish to pale grey coloured, pebble-bearing layer derived from the basement (unit 3),
and black coloured mud and sand (unit 4) lithologies. A deposit packet is observed above the defined units, which presents a channel geometry between 1st and 11th metres of the trench. Within these deposits, there brownish-dark grey coloured mud are observed with fine sand layers (unit 5), dark brown-black coloured mollusc and charcoal-bearing sand and mud (unit 6), blackish-dark grey coloured fine to medium grained and occasionally charcoal-bearing pebble (unit 7), dark brown-black coloured charcoal-bearing mud (unit 8) and pale brown mud (unit 9) lithologies. All units defined at the uppermost part of the trench are overlain by brown coloured sandy paleosol (unit 10) and recent soil (unit 11). On the west wall of the trench charcoal (MKL-C-W01) and mollusc samples (MKL-C-W02) collected from the bottom layers of unit 6, were dated as 3430 ± 30 BP and 3490 ± 30 BP 14C, respectively. Charcoal samples collected from the bottom layers of unit (8) on the same wall (MKL-C-W04) and of unit 7 from the east wall of the trench (MKL-C-E01), yielded ages of 560 ± 30 BP
and 3680 ± 30 BP, respectively, (Table 2, Figures 11 and 12).

Several faults expressed in the trench walls a 2-m wide shear zone within the bedrocks composed of rocks of the Mudamköy volcanic member and Göbel formation. After the 12th metre of the trench, these faults, which were seen at depths very close to surface within units of the bedrocks in further south, berried by pale brown coloured mud (unit 9), sandy soil (paleosol) (unit 10) and recent soil (unit 11). There are younger faults cutting channel-fill type deposits covering the basement rock mainly in two areas between the 1st and 12th metres of the trench. The first area covers the section between the 5th and 7th metres on east wall and the section between the 4th and 6th metres on west wall of the trench. There is also a fault which cut units 3 and 4 with basement rocks in this section. However, it has not been determined whether this fault cuts units 5 and 6 that overlie unit 4 due to erosion, but is covered by unit 7 (Figures 11 and 12).

Another area, where faults are observed in the trench, is between the 10th and 13th metres on east wall and the

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**Figure 12.** (a) Photo mosaic of Lalaşahin Trench western wall without interpretation. (b) Log of Lalaşahin Trench western wall.
10th and 12th metres on the west wall. In this area, faults cut dark brown-black coloured, charcoal-bearing mud (unit 8). This unit is located in the depositional packet which represents the Holocene and overlies the basement of the Mudamköy volcanic member and Göbel formation (Figures 11 and 12). These faults divided into several branches trending N50°–55° W and dipping 70°–75° to SW at the surface. Based on the geometry expressed in the walls, these are interpreted to be combined and became one major fault in the shallow deep. This fault has the character of dextral strike-slip fault having a shallow positive flower structure developed among branches separating from the main fault. For faults, which are covered by pale brown mud lithology (unit 9), the bottom contact of this unit is in the position of a second event horizon in the trench.

As a result of stratigraphical and structural investigations performed, it was determined that there were two different event horizons and earthquakes which developed in two different periods in the Lalaşahin Trench. Faults in the trench are dextral strike-slip with reverse component. In Aralık Trenches, folded deformation structures were also observed in addition to faults with reverse component. However, in Lalaşahin Trench, strike-slip faults with reverse component observed forming a shallow positive flower structure. Stratigraphical relationships detected in trenches and age data taken were obtained using OxCal 3.10 software (Bronk Ramsey, 1998). In doing so, the probability distribution of calibrated 14C ages was determined and the assessments related to events are, respectively, given below (Table 2, Figure 13).

The trace of Event 1 (last event) can clearly be observed on both walls of the Aralık and Lalaşahin trenches. All faults on the west wall of the Aralık trench and the fault observed between the 10th and 12th metres on the east wall cut all units of the trench, and is covered by the recent soil (unit 6) formed on top (Figures 7 and 8). Unfortunately, no material was found to make age determination in the youngest unit 5 which the faults cut, but 815–780 BC age was taken from unit 4 which underlies unit 5. So, it can be assumed that faults in the Aralık Trench produced earthquakes forming a surface rupture in a time later than this period. More distinct and clear age data related to this event were obtained in the Lalaşahin Trench. The fault zone, which is observed between the 10th and 13th metres on the east wall and between the 10th and 12th metres on the west wall of Lalaşahin Trench, was divided into several branches and extends as one branch at the trench bottom. It then cuts unit 8 and extends until the bottom of unit 9 (Figures 11 and 12). There was not found any material to perform age determination in unit 9 which overlies faults. When 560 ± 30 BP 14C age value from the youngest unit 8 which is cut by faults and located below unit 9 is considered, it is reasonable to say that faults in this section of the trench produced an earthquake in such a way that it formed a surface break in a period later than AD 1425. Thus, these represent the active branch of the MF (Table 1, Figure 13).

Event 2 (penultimate event) is solely observed on the east wall of the Aralık trench, between the 4th and 10th metres in the form of three fault branches. The faults cut unit 4 starting from the trench bottom but are buried by unit 5 (Figure 7). From the bottom levels of the youngest unit 4, which is cut by these faults, the age of 815–780 BC was obtained. But there was not any information obtained on the age from the overlying unit 5 because it does not have datable material. Accordingly, there has been another event between 815 BC and the last event.

Evidence for the event 3 (antepenultimate event) is expressed between the 5th and 7th metres on the east
wall and the 4th and 6th metres on the west wall of the Lalaşahin Trench (Figure 11 and 12). The units 3 and 4 cutting by the fault on the trench walls is covered by unit 7 (Figures 11 and 12). Samples were taken for age determinations from the bottom of unit 6 on unit 4, where there is not observed any crosscutting relationship due to erosion. Other samples were also collected from the unit 7 deposited with an erosive bottom on unit 4 which is cut by fault. Thus, it is assumed that the earthquake occurred in a period earlier than 2190 BC (Table 2, Figure 13).

6. Conclusion and discussion
The MF is one of the significant structures in the South Marmara region in terms of its geometry, length and capable of destructive earthquakes. We performed palaeoseismological investigation, along the MF to understand recurrence behaviour. So, we excavated two cross trenches at the two best sites, exposed mismatched stratigraphy across the fault demonstrating distinct evidence of events. Preliminary palaeoseismological data obtained from trenches clearly reveal the Holocene activity of the MF.

On the walls of the Aralik and Lalaşahin trenches, the faults cut the whole or some parts of stratigraphical units and deformation structures developed in the form of folds. Strike and dip direction amount of faults generally range between N05–55 W and 40–70°SW, respectively. These are dextral strike-slip faults with reverse component which are compatible with recent deformation style. Fold structures on the walls of the Aralik trench were formed within the deformation zone, in which faults are observed. They also gained an asymmetrical structure in such a way that it overlaps towards the north-east especially in sections where they are cut by faults. It was also observed that the fault became younger towards the south by making very small en-echelon stepovers in this trench. The faults separate into several branches at the surface and combine in the trench bottom to become one main fault in the section, which characterises the last-term deformations in the Lalaşahin trench. There is also a shallow flower structure that developed among branches separating from the main branch.

Based on both structural and stratigraphic data, we identified at three events that have accompanied with surface during the past 4000 years. According to age data obtained from trenches, the oldest event (event 3, antepenultimate event) has occurred at a time earlier than 2190 BC. The event 2 (penultimate event) occurred at a time between 815 BC and 1310 AD. According to historical records, the Germe city (ancient settlement area around Mustafake- malpaşa town) in Mysia region, which is located in northwest of Anatolia; today it coincides with the provincial boundaries of Balskeir which was destroyed by an earthquake in AD 368. Taking all these into consideration, the earthquake which occurred in AD 368 is related with the MF. In this case, the earthquake, which occurred in AD 368, should be the equivalent of the earthquake detected between 815 BC and AD 1310 (Figure 13).

The last earthquake on the MF occurred at a time later than AD 1425. Looking at historical earthquakes, it is seen as a series, which is considered to have proceeded in the form of earthquakes triggering each other towards east started from the western part of the MF in 1850 and ended with two earthquakes in 1855 in the Ulubat Fault (Table 1, Figure 13). In this case, either there was an earthquake unrecorded in the region or the deposits which were carrying traces of 1850 and 1851 earthquakes might be eroded on trench wall. Considering the time of occurrence together with magnitudes and epicentres it can be said that 1850 and 1851 Earthquakes more correspond with age data obtained from trenches. Besides, the 1850 Earthquake should be the main earthquake related with the MF, and 1851 earthquake should be the aftershock. According to the number of events and radiocarbon ages detected, the MF is active and continuously produces earthquake. We suggest a long non-characteristic recurrence interval and ~0.7 mm/y slip-rate for the MF based on trench data and offset of the Late Pliocene drainage of the Orhaneli River. According to this limited data, it can be said that there has been a strain accumulation which equals to 1.15-m displacement within 165 years after the 1850 Earthquake, the last event that occurred on the MF.

The total length of the MF, which is formed by three main segments with different lengths, is 47 km. If this fault will be broken as one segment then the magnitude of a probable earthquake will be Mw: 7.04 (Wells & Coppersmith, 1994). If the longest segment, which is located in NW, will be broken then the magnitude of the probable earthquake will be Mw: 6.47. Although the data are limited, a strain value of 1.15 m, which has accumulated since the last earthquake and the probable earthquake magnitudes (Mw) varying between 6.47 and 7.04, contribute significantly in assessing the earthquake risk in areas from which the MF passes and of which its Holocene activity was definitely set forth.

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