



Bulletin of the Mineral Research and Exploration

<http://bulletin.mta.gov.tr>



An example study on re-evaluation of historical earthquakes: 1789 Palu (Elazığ) earthquake, Eastern Anatolia, Turkey

Mehmet KÖKÜM^{a*} and Fatih ÖZÇELİK^b

^aFirat University, Faculty of Engineering, Geological Engineering, Elazığ, Turkey

^bFirat University, Faculty of Humanities and Social Sciences, Department of History, Elazığ, Turkey

Research Article

Keywords:

East Anatolian Fault,
Palu-Elazığ, 1789
Earthquake.

ABSTRACT

The East Anatolian Fault (EAF) is an active left-lateral strike-slip fault extending between Karlıova (Bingöl) in the northeast and Iskenderun Bay in the southwest. The Palu, which is the subject of the study area, is located on the Palu segment of the EAF. The Palu segment starts from the northeast of Palu, and is approximately 77 km long, and reaches the Lake Hazar after passing the Baltaşlı Plain. Maximum shaking intensity in the earthquake listed in historical catalogs is estimated to have been Mercalli Intensity VIII, with conflicting accounts of as few as 8.000-10.000 to as many as 50.000 people killed. An examination of contemporary documents, books and administrative archives in the State Archives Head of Presidency Republic of Turkey for the district reveal that the extent of damage and the number of fatalities in the earthquake have been considerably inflated by these historical catalogs.

Received Date: 02.01.2019

Accepted Date: 28.05.2019

1. Introduction

The county of Palu near Elazığ in eastern Turkey is located on the Murat (Eastern Euphrates) River, and history of the Palu date backs to 5000 BC (Figure 1). Palu has been damaged by many major earthquakes in the historical and instrumental period, some of which have required relocation of the city as a consequence of being located on the East Anatolian Fault (EAF) (Şaroğlu et al., 2018) (Figures 1b and 2). Several historical earthquake catalogs record a major earthquake as having occurred between May 28 and June 2 1789 in Palu county (Pınar and Lahn, 1952; Soysal et al., 1981; Ambraseys and Finkel, 1995). Some of these accounts mention that 51.000 people lost their lives citing Abich (1878). Others cite the lower fatality count of 8.000-10.000 mentioned in *Tarih-i Lebîbâ* (Emecen, 1982) listed by the

contemporary historian Taylesanizâde with damage in Harput, Mazgirt (Tunceli), Çemişgezek (Tunceli), Peri (Tunceli), Palu (Elazığ), Keban Mine (Elazığ).

The purpose of his review is to question the credibility of the apparently inflated number of fatalities recorded for the 1789 earthquake (Ambraseys and Finkel, 1995). Because reported population of Palu is higher than the reasonable values. The population density of Palu region in 1789 was considerably lower than Istanbul in the 10 September 1509 Istanbul earthquake (population ~160.000), when 4.000-5.000 fatalities and 10.000 injured were reported (Ambraseys and Finkel, 1995), or in Erzincan when an earthquake on 23 July 1784 killed 5.000 people as a result of the collapse of 88-90% of its 8.000 dwellings (Soysal et al., 1981; Ambraseys and Finkel, 1995; Vogt, 2001). Palu was not a major city in 1789 and its population is uncertain. Kinneir (1818) cited by Ambraseys

Citation Info: Köküm, M., Özçelik, F. 2020. An example study on re-evaluation of historical earthquakes: 1789 Palu (Elazığ) earthquake, Eastern Anatolia, Turkey. Bulletin of the Mineral Research and Exploration. 161, 157-172. <https://doi.org/10.19111/bulletinofmre.603929>

* Corresponding author: Mehmet KÖKÜM, mkokum@firat.edu.tr

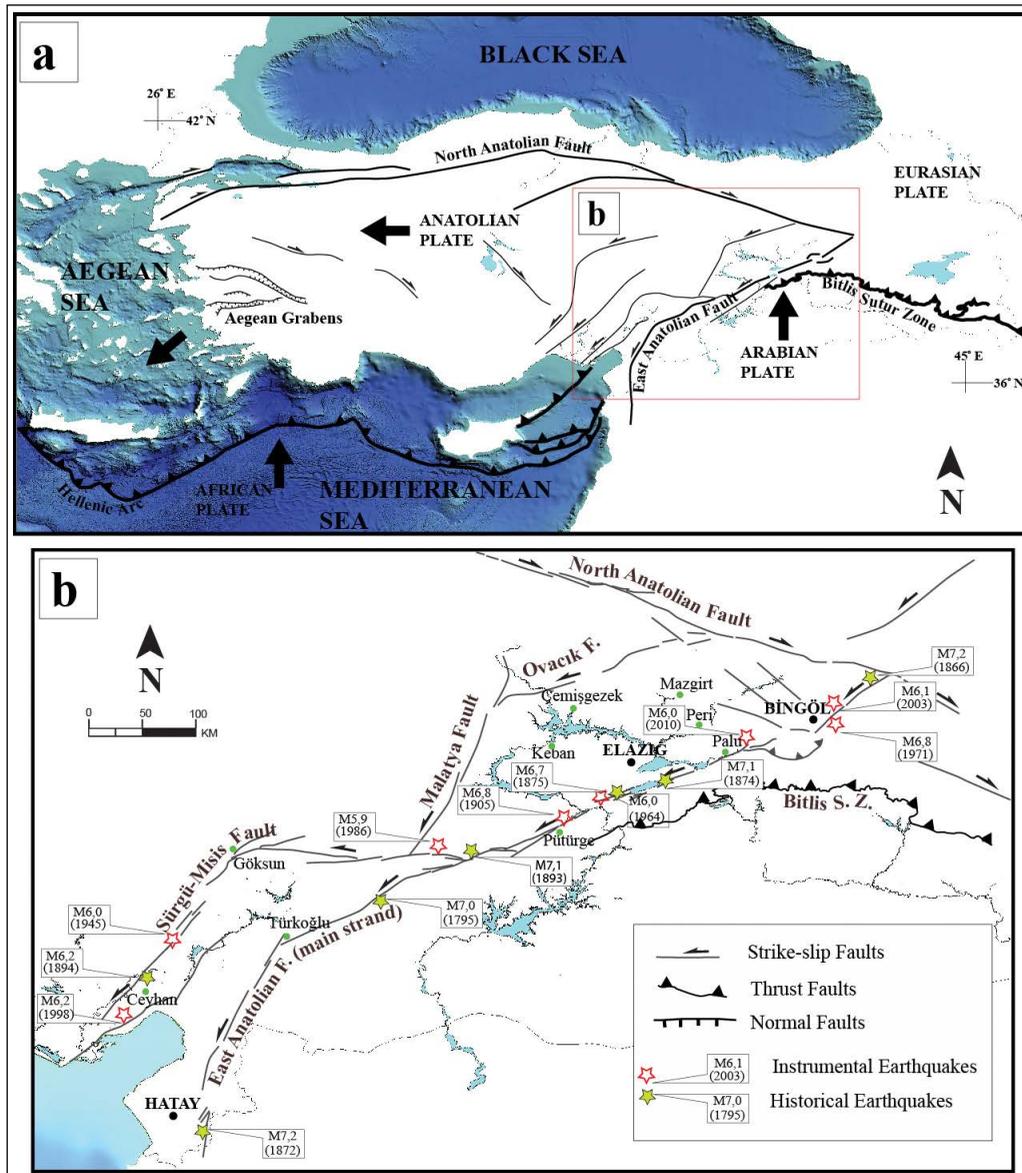


Figure 1- a) Simplified main tectonic features of Turkey and westward motion of Anatolian plate. Faults in Turkey (Emre et al., 2013) and faults located nearby of Turkey (Duman et al., 2016). Big black arrow indicates plate motion with respect to the Eurasian plate (Reilinger et al., 2006). b) Tectonic map of Eastern Anatolia, and historical and instrumental seismicity along the EAF. Historical earthquakes modified from Duman and Emre (2013) (Ambraseys, 1989; Ambraseys and Finkel, 1995; Ambraseys and Jackson, 1998; Tan et al., 2008; Palutoğlu and Şaşmaz, 2017). Instrumental seismicity (<http://www.koeri.boun.edu.tr/sismo/zeqdb>).

and Finkel, (1995) estimates the population of Palu 11 years after the earthquake (then in the province of present-day Diyarbakır) as approximately 8.000. Palu district was incorporated into Harput province after an administrative change in 1845-1846, and its 1845-1859 population is recorded as 35.436 people (Aksın, 1999). Thus, even 60 years after the earthquake, the population of Palu district is fewer than the number of people claimed to have died in the earthquake.

We summarize the geological and seismological setting of the 1789 earthquake, and provide contemporary information from hitherto unused sources (documents, books and related works) archived in Ankara in the State Archives Head of Presidency Republic of Turkey (henceforth referred to as the Ankara State Archives) and show that the actual death toll in the earthquake was much smaller than hitherto reported.

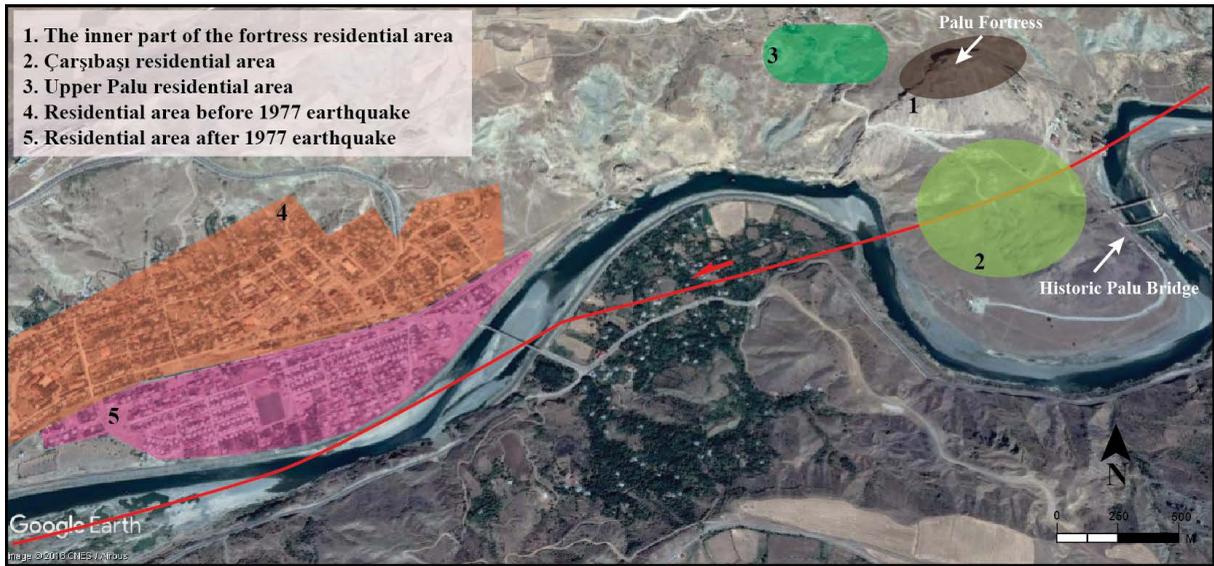


Figure 2- Google Earth image of Palu and changes in its location during history (modified after Şaroğlu vd., 2018). Each color and number represent relocated area.

2. Regional Geology

2.1. Geological Properties of Palu and its Surrounding Area

Various types of rock units ranging from Cretaceous to Holocene are exposed in the study area (Figure 3). The oldest units are the volcanic and granitic rocks of the late Cretaceous Elazığ Magmatites exposed in the northeastern part of the map. The upper Maastrichtian-lower Eocene Hazar Group consists of mainly sandstone-shale and marl intercalations is very common in the southern part of the map. The middle Eocene Maden Complex and middle Eocene-Oligocene Kırkgeçit formation are mostly composed of mudstone banded volcanic rocks, and basal conglomerate and reef limestones, respectively. The geological types of contacts of these two formations are tectonically controlled by East Anatolian Fault (Figure 3 and 4). The Quaternary Palu Formation consists of poorly sorted weakly cemented conglomerates and cross-bedded coarse-grained sandstones. The youngest and most widespread unit in the study area are Holocene alluviums, mostly composed of old river sediments dominated by free gravel and sand lithology. The present-day location of the town of Palu is located close to the river and the EAF and is sited on river alluvium, a seismically more hazardous location compared to its former locations on rock approximately 1 km to the east or to the north (Şaroğlu et al., 2018) (Figure 2 and 4).

2.2. Regional Tectonic Meaning of the East Anatolian Fault

Turkey lies between in the zone of convergence between the northward moving Arabian and African plates and the Eurasian plate (Figure 1a). The Anatolian plate moves to west westward with respect to Eurasian plate at approximately 2 cm/yr. The reason of the westward movement of the Anatolian plate is still controversial either the Anatolian plate is being pushed by the Arabian plate in the east, or the pulling of the Anatolian plate along the Hellenic arc in the west (McKenzie, 1972; Dewey and Şengör, 1979; Le Pichon and Angelier, 1979; Barka and Kadinsky-Cade, 1988; Taymaz et al., 1991; Reilinger et al., 1997; McClusky et al., 2000). The North and East Anatolian faults accommodate westward movement of the Anatolian plate with respect to the Eurasian plate (McKenzie, 1972).

The EAF has been studied by many researchers since the early 1960s. Altınlı (1963) mapped the fault between Karlıova and Bingöl on 1/500.000 scale maps prepared by MTA. The EAF was connected with North Anatolian Fault (NAF) in the north and Dead Sea Fault (DSF) in the south by Allen (1969). The Bingöl earthquake on 22 May 1971 attracted international attention to activity on the fault. In the studies after the earthquake accomplished by Seymen and Aydın (1972) and Arpat and Saroğlu (1972; 1975), EAF was mapped for the first time on a regional scale and some

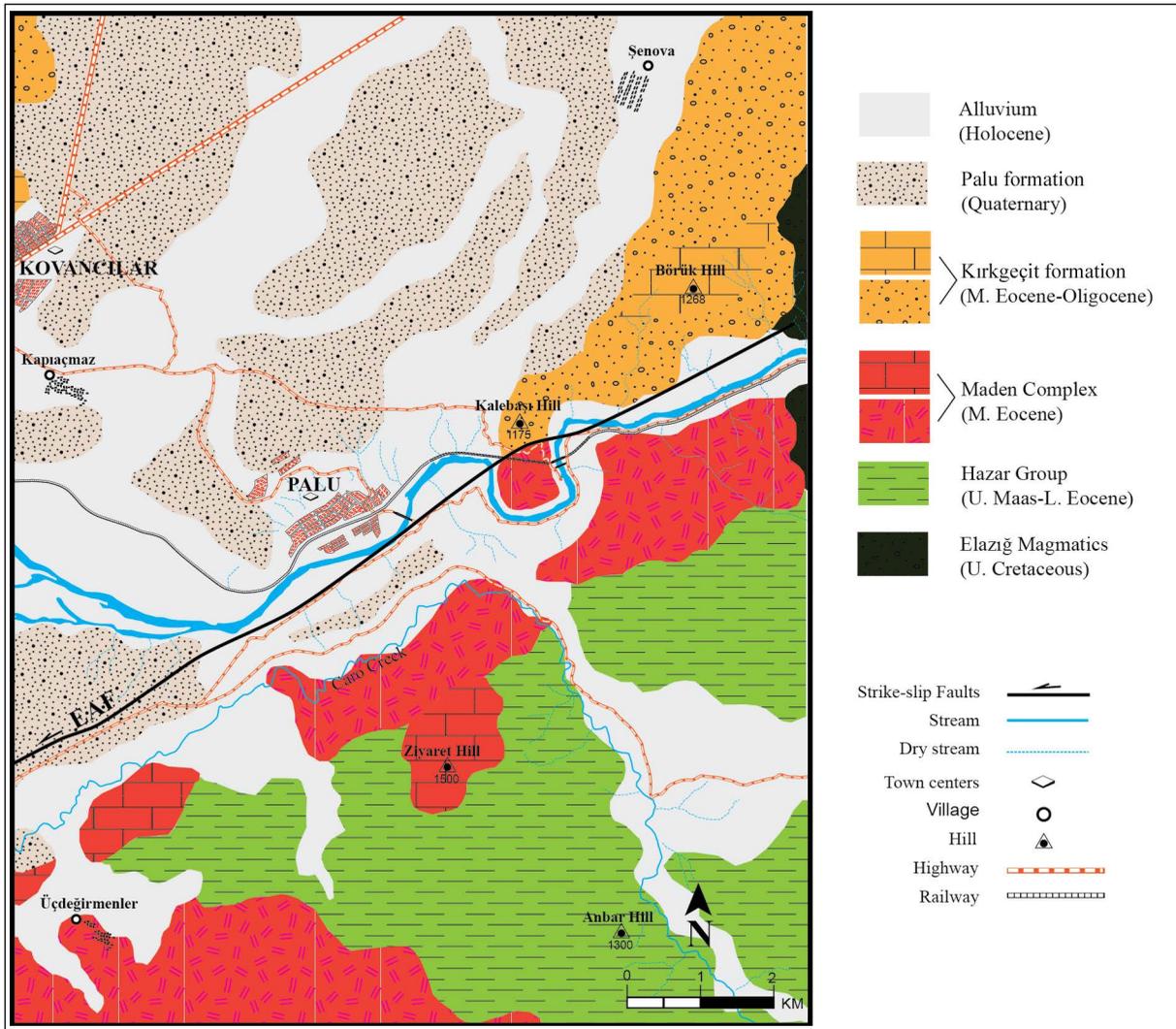


Figure 3- Geological map of Palu (modified from Herece, 2008).

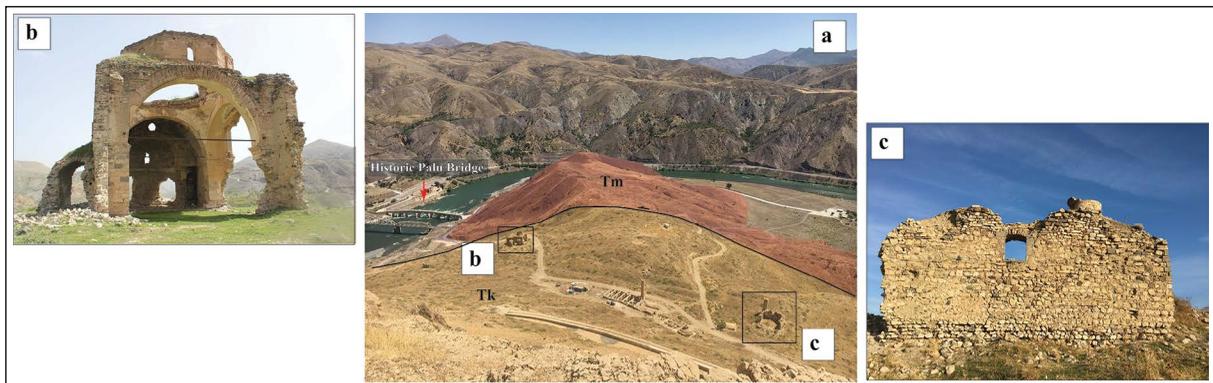


Figure 4- The settlement of historical Palu, where it is called Çarşıbaşı neighbourhood (for location see figure 2), a) the EAF looking south (black straight line) separates the Maden complex from the Kırkgeçit formation. EAF represent by, b) historic Surp Lusaroviç Church in Çarşıbaşı neighborhood and historical structures that survived recent historical earthquakes (looking northwest) and c) Historic Küçük Mosque (looking northwest).

fault-related morphological structures (compression and depression areas) were identified for the first time.

2.3. General Characteristics of the East Anatolian Fault

Several authors have proposed segmentation of the >900-km-long EAF into subsegments based on its geometry and seismic behaviour: five were proposed by Hempton and Dewey (1981) six by Şaroğlu et al., (1992), fourteen by Barka and Kadinsky-Cade (1988) and eleven by Herece (2008). A recent study (Duman and Emre, 2013) divides the EAF into three main sections with several subsegments: the southern (main) branch, the northern strand (Sürgü-Misis fault) and the Karasu trough (Figure 1b). The southern (main) strand includes the Karlıova Triple Junction in the northeast with the North Anatolian Fault and Varto Fault, and the Amik Triple Junction in the southwest where it joins the Dead Sea Fault and the Cyprus Arc. The southern (main) strand with a length about 580 km includes the Karlıova, Ilıca, Palu, Pütürge, Erkenek, Pazarcık and Amanos segments. The northern strand with length about 350 km includes the Sürgü, Çardak, Savrun, Çokak, Toprakkale, Yumurtalık, Karataş, Yakapınar, and Düziçi-İskenderun segments. The Karasu trough is defined as a releasing bend associated with the linkage of the EAF and Dead Sea Fault, and is subdivided into the Narlı, Yesemek, Reyhanlı and Antakya segments (Figure 1b).

Several researchers working in different parts of the EAF have proposed left-lateral offsets ranging from 9 to 30 km. Arpat and Şaroğlu (1972) defined 22 km offsets on the Maastrichtian mudstone in the Göynük valley, and 27 km offsets along the Palu-Lake Hazar area. İnceöz and İnce (1999) and Aksoy et al. (2007) suggest 9 km offset for the Palu-Lake Hazar region. Çelik (2008) proposed 30 km offset in the middle Eocene Maden Comp. for the same region. Gülen et al. (1987) suggest that the Maraş thrust fault is offset 25 km by the EAF in the south.

In many studies related to the age of the EAF (Herece and Akay, 1992; Şaroğlu et al., 1992; Çetin et al., 2003; Aksoy et al., 2007; Çolak et al., 2012; Köküm and İnceöz, 2018, Köküm, 2019), the initiation of slip on the EAF is believed to be no older than the late Pliocene (~ 3.6 my). The slip rate of the EAF using different methods has variously been reported as 4 to 35 mm/year. Considering the age of the EAF, and lithological and morphological offsets along the fault,

the long-term slip rate is calculated as 4-11 mm/year (Arpat and Şaroğlu, 1975; Öncel, 2000; Çetin et al., 2003; Aksoy et al., 2007; Çelik, 2008; Herece, 2008). From moment summations of significant earthquakes between 1955-1990 Taymaz et al. (1991) calculated the slip rate as 25-35 mm/year. Bulut (2017) summing moments of earthquakes with $M_w > 3$ derives a slip rate of 12.4 mm/year in the northeast and 4.3 mm/year in the southwest. The slip rate determined from GPS measurements in the past two decades is calculated as 9-11 mm/yr (Oral et al., 1995; McClusky et al., 2000; Reilinger et al., 2006; Aktuğ et al., 2016). InSAR and GPS data in the past decade between Lake Hazar-Palu on the EAF (~ 100 km) indicate a present day rate of 10 mm/year (Ergintav et al., 2019).

2.4. Seismicity of the East Anatolian Fault

Many destructive earthquakes have occurred on the EAF in historical and instrumental periods (Figure 1b). The only earthquake to have formed a surface rupture on the EAF in the last century is the 22 May 1971 Bingöl (M 6.8) earthquake (Arpat and Şaroğlu, 1972). Other damaging earthquakes occurred on 8 March 2010 $M_w=6.1$ at Okçular (Elazığ), 1 May 2003 $M_w=6.4$ at Bingöl, 27 June 1998 $M_w=6.2$ at Adana and 5 May 1986 M 6.0 at Malatya.

The historical earthquake catalog summarized most recently by Soysal et al., (1981) includes several severe earthquakes with uncertain magnitude but with estimated maximum Mercalli intensities as follows: 995 Palu-Sivrice (VI), 1114 Ceyhan-Antakya, Maraş (IX), 1268 Kozan-Ceyhan and its region (IX), 1737 Antakya (VII), 1789 Palu-Elazığ (VIII), 1855 Ceyhan-Adana (VI), 1872 Antakya-Samandağ (IX), 1874 Maden-Elazığ, Diyarbakır (VIII), 1875 Karlıova-Bingöl, Palu-Elazığ (VIII), 1889 Palu-Elazığ (VI).

A paleoseismological study at the northeast end of the Lake Hazar-Palu segment reports surface ruptures in earthquakes in 130, 400-450, 1513, 1874 and 1875 Çetin et al. (2003). No surface ruptures were found that could be associated with the historically recorded 995 and 1789 earthquakes.

2.4.1. Geometry and Seismic Activity of Palu Segment

In the study conducted by Duman and Emre (2013), the Palu segment with a length of 77 km is bounded by the Gökdere restraining bend and the Lake Hazar releasing bend (Figure 5). The Palu segment is

divided into three sub-sections (Duman and Emre, 2013). The eastern and central part are separated from each other by a left stepover south of Yamaçova near the epicenter of the 8 March 2010 Mw=6.1 Okçular (Elazığ) earthquake. The Palu segment, which passes east of Palu district, starts south of Yamaçova village in the northeast and continues to Örencik along the 22 km in a narrow zone with approximately N58°E strike. The surface fault is well exposed in the limestones of the Kırkgeçit Formation around Kalebaşı hill (Figure 6). The fault is obscured beneath reservoir of the Keban dam near Örencik, but it can be followed again in the north of the Orta Hill. The N65°E trending southern segment is nearly 30 km between Örencik and Lake Hazar. The southern segment observed in a narrow zone for 15 km between Örencik and Orta Hill, whereas it is divided into several strands with a wide deformation zone from the Kartaldere where it enters Lake Hazar (Figure 5). The length of the fault beneath Lake Hazar is approximately 20 km (Duman and Emre, 2013). There are significant earthquakes on the Palu segment according to historical and recent catalogs.

Çetin et al. (2003) defined the Palu segment with small faults parallel to the main fault in a 54 km long and 5 km wide zone. The Orta Hill Fault with N59°E strike is described as a left-oblique normal fault, and is defined as the main strand of this segment. The

surface trace of the Orta Hill Fault is obscured near Örencik, but can be followed on Orta Hill to a trough near Kartaldere with N65-70°E strike. It then divides into two branches: The Havri and Gezin Faults. The northern Havri Fault on which Çetin et al. (2003) infer a 10-11 mm/year slip rate continues into Lake Hazar (Eris et al., 2017). The southern Gezin Fault on which earthquakes occurred in 1874 and 1875 is a normal fault, with a negligible strike-slip component.

The 1874 Maden-Elazığ/Diyarbakır (VIII) earthquake caused a surface rupture of the Palu segment and is one of the most important EAF earthquake sequences for which we have significant information. Ambraseys and Jackson (1998) state that the first earthquake of this sequence occurred on January 14 of 1874, and that the village of Sarıkamış (10 km northeast of Kartaldere village) was totally destroyed, with significant damage to nearby villages. The mines in Maden and the village of Örencik (Gülüşkür) were affected by this earthquake and it was felt in Diyarbakır. An aftershock occurred in Keban on April 29 of 1874, but no damage is reported for this event reported. The mainshock occurred in the morning on 3 May 1874 at 07.00 and lasted about 1 minute. The region north and south of the Lake Hazar was severely shaken. Habusu village was destroyed with damage to all villages in Uluova district. Ambraseys (1989) gave the epicenter of this earthquake as Gezin (Maden)

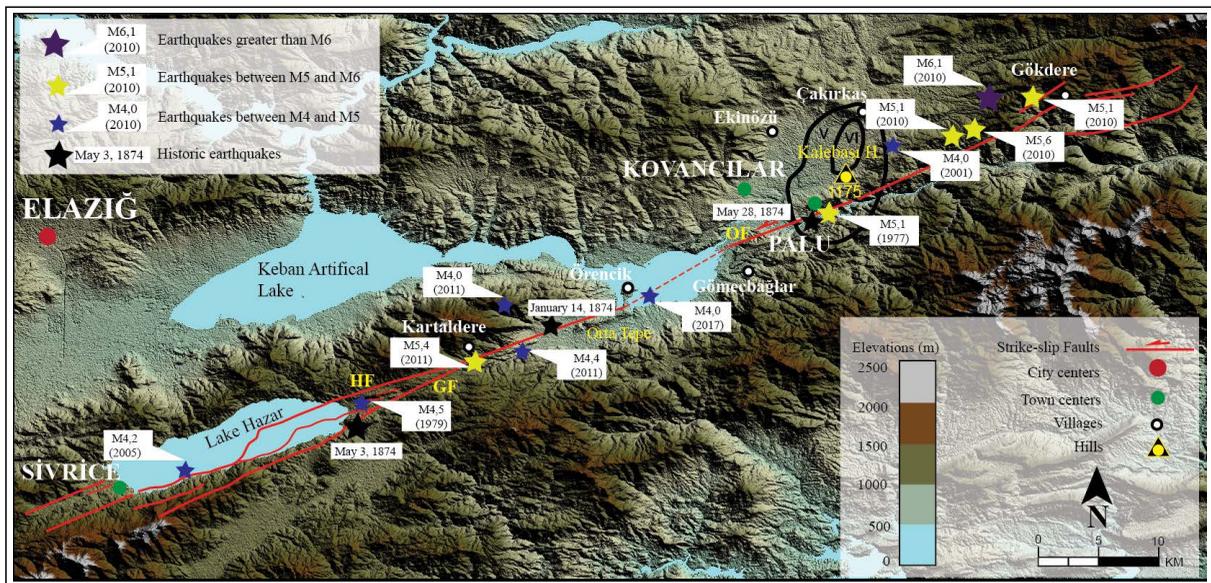


Figure 5- Tectonic map of the area with historical (Ambraseys, 1989; Ambraseys and Jackson, 1998) and instrumental seismicity on the Palu segment of EAF (<http://www.koeri.boun.edu.tr/sismo/zeqdb>) (modified after Çetin et al., 2003 and Emre et al., 2013). Fault geometry in Lake Hazar from (Eriş et al., 2017). Black closed curves show macrosismic map based on damage distribution from 1977 Mw=5.1 Palu earthquake (Şaroğlu et al., 1987).

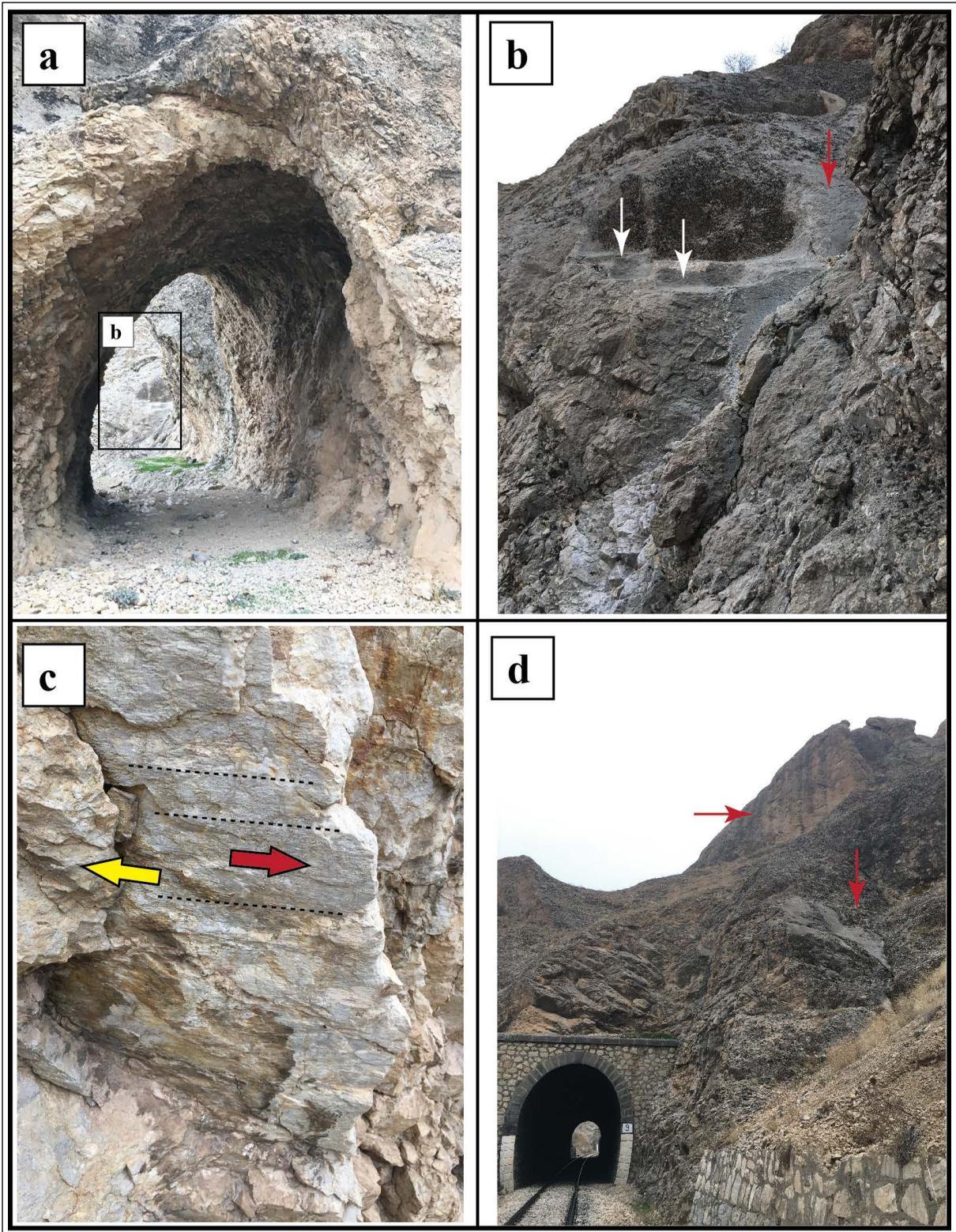


Figure 6- Slickensided fault surface within to limestones in Kırgeçit formation near Kalebaşı hill, a) historical hand excavated tunnel built to descend into the valley of the Murat River to supply water for the castle (looking north), b) stairs were offset by the EAF (looking north), c) faulted limestones near railway (looking northeast), d) fault surfaces near railway (looking northeast).

located in the northeast of the Lake Hazar. Çetin et al. (2003) described the surface rupture of this earthquake in their paleoseismological study on the Palu segment. Herece (2008) notes that a seasonal stream east of Yeşilova village may have been offset 2.6 m in a left-lateral sense in 1874. In the same region, Duman and Emre (2013) document 3.5 m displacement on a seasonal stream on the Orta Hill, with 2.6 m of left-lateral slip on the northeastern end around the Kayalık hill end of the Palu segment.

The Mw=5.1 earthquake of March 26, 1977 occurred on this same segment, causing loss of life and property in and around Palu. Although no significant surface rupture was observed as a result of the 1977 earthquake, small cracks were observed in railway fill material. In addition, the maximum damage in the macro-seismic map used on spatial damage caused by the earthquake was not parallel to the EAF and occurred almost in the N-S direction (Şaroğlu et al., 1987) (Figure 5). Çetin et al. (2003) calculated a mean recurrence interval of 360 years for surface rupturing earthquakes this segment. Duman and Emre (2013) calculated the recurrence interval on the same segment as 350-400 years.

3. Information about the 1789 Earthquake

The entry on the 1789 earthquake listed by Ambraseys and Finkel (1995) is as follows:

“The earthquake occurred in the third hour of the night on Hijri 10-19 Ramadan 1203 (29 May-2 June 1789) and destroyed many places in the district of Tunceli. As a result of the earthquake, the villages of Harput, Mazgirt, Çemişgezek, Peri, Palu and Keban Mine were destroyed and ruined. In the earthquake during the tarawih prayer in Great Mosque in Peri all the worshippers died under the ruins. From all these places, 8.000-10.000 people lost their lives in the earthquake (Tarih-i Lebibâ). In a document sent to inform the authorities in İstanbul, 51.000 people died in a tract of land... 21 hours (of march) long and 21 hours (of march) wide (an area of a radius about 75 km) (Abich, 1878). The earthquake interrupted the operation of the mines in Palu and Çarsançak and the need to supply coal was coming up to the region from other places (M. 15 January 1790, DVN. MHM., 190). The earthquake destroyed many Armenian churches, the miners working in the Keban mine applied with a petition to repair their churches which were destroyed

in the earthquake in the middle of 1795. In another application dated September 1793, to the kadi and notables of Divriği, says that a petition submitted by the Armenian patriarch and by Armenians living in the village of Nikan, on the river Euphrates in the kaza of Divriği, requested permission to rebuild their churches as they had been before they were ruined in an earthquake (C. DRP., 32-1597). A European traveler passing through the region 11 years later comments that Palu (pop. 8.000) was subjected to ‘constant earthquakes’, perhaps an indication of continuing aftershocks.”

The information about the number of fatalities in the two source accounts “Tarih-i Lebibâ and Abich (1878)” are contradictory.

A hitherto unused source of information about the 1789 earthquake reported by Dikran S. Papazyan is “History of Palu’s Havav Village” by Housemadyan (2009). Havav village, also known as Ekinözü recently, is located 10 km north of Palu, and in Housemadyan (2009) its history is compiled from Papazyan, traditional information and from an oral history of the village handed down through generations. This narrative is mixed with the legend, in which the oral history of the village, passed from generation to generation and reached the author, is also included. In 1789, Havav (Ekinözü) was the largest Armenian village in the region. The village had two schools, two churches, a monastery and two fountains before 1915. There were 500 houses in the village during the Ottoman period.

The ruler of Havav at the end of the 18th century, Hacı Tihad exploited the wars and unstable situation of the Ottoman Empire, and was able to build large mansion within the village despite protests from the villager community. Shortly after its completion, a major earthquake occurred and nearly half of the village of Havav, including Hacı Tihad’s mansion, was destroyed. The people of Havav resisted reconstruction of the mansion, and Hacı Tihad was forced to settle in the village of Gömeçbağlar (Til), four hours from Havav (Housemadyan, 2009 from Papazyan) (Figure 5). In this account the date of the earthquake is not specified exactly, but it is written that it occurred in the late 18th century. During this period, the earthquake likely to affect Havav (Ekinözü) village was the 1789 Palu earthquake. Also, as a result of the earthquake, it is written that almost half of the village and the

mansion in the village were destroyed. The owner of the mansion moves to another village. In other words, as a result of the earthquake, the owner of the mansion did not lose his life. There is no information concerning loss of life in this account.

3.1. Examination of Official Documents of the Earthquake Period

The aim of this study is to determine the effects of the Palu earthquake in that period using documents, books and reports archived in the Presidency State Archives, Ankara and to investigate the accuracy of the information obtained from the historical earthquake catalogs as a source. Archive documents were first examined by us regarding the earthquake. As an archive document, the Sher'iyye Registers are one of the possible sources of data regarding the earthquake. The "Catalogs of the Religious Courts" include reports from Kadis, administrators who are responsible of the judicial, administrative and municipal affairs of the settlements where they are located. The books in which these officials record and official documents are also the Sher'iyye Registers. Because the "Catalogs of the Religious Courts" are contemporary sources of political, social and legal life for the period of the Ottoman Empire 472 years from the mid-15th century to the first quarter of the 20th century, it would be unexpected that the effects of the 1789 Palu earthquake, had it resulted in 51.000 fatalities, would have escaped notice (Soysal et al., 1981; Ambraseys and Finkel, 1995). Considering the conditions of the period, it must have caused a great destruction in and around the earthquake center. For this purpose, Diyarbakır and Keban (Elazığ) Sher'iyye Registers, which are present and compatible with the history and location of the earthquake, were examined.

Since the Palu district in 1789 was administratively linked to the province of Diyarbakır, the first source we investigated were the "Diyarbakır Catalogs of the Religious Courts No. 352 Öz (Öz, 2013). The registry dated "Hijri 1136-1264 / Gregorian 1724-1848" embraces the date of the earthquake. It was anticipated that had Diyarbakır been affected by a large earthquake this registry would mention its effects, however, there is no information regarding the reconstruction of the city, the registration of the inheritance of any person who died due to the earthquake, the appointment of successors to replace dead officials, and/or historical restoration of buildings, there are no requests for

assistance from the state of any one who suffered losses in the earthquake, and no record of any decision related to this earthquake. Nor is there information about any earthquake-related repairs in Diyarbakır for the first half of the 19th century (Yılmazçelik, 1990).

The Keban province of Elazığ is one of the areas likely to have felt the earthquake, and the Şer'iyye register for "Hijri 1190-1209, Gregorian 1776-1794" (Yüksel, 1987) includes information related to mines and their operations, extraction, processing, furnaces, coal transfers and transportation to and from the mines in Keban. This register is devoid of information concerning damage to any mine and mine furnace at the time of the earthquake. Concerned that the "Catalogs of the Religious Courts" might omit mention of earthquake matters we searched elsewhere in the catalogs, and found that a 1782 entry indeed contains a request from a plaintiff desirous of state assistance for the repair of earthquake damage in the preceding year.

It was mentioned above that there are mining areas in the area which is likely to be operational in the 1789 Palu Earthquake. Two different studies on mines in the region are among the sources examined (Tızlak, 1991; Yüksel, 1997). The information common to both works is expressed as follows:

"According to the information given by a western traveler who visited the region at the end of the 19th century, the people believe that the Keban mine started to be operated in 1812. However, according to the information provided by the archival documents, it was found out that the Keban mine started to be operated in about 1708. It is known that the production activity in Keban mine was continuously maintained until 1730. However, due to the damage and loss of life caused by the earthquake in the region at that time, the mine operations were interrupted for a period of 20 years as a result of the destruction of 70 smelter furnaces. In 1751, Spinach Mustafa was sent to Keban mine and as a result of 7 years of repair activities with his great efforts, the mine was put back into operation. Production has continued uninterruptedly since 1758".

In the above summary of Keban mine operations, there is no indication of damage by an earthquake in 1789. Nor did Aksın (1999) who examined the physical, administrative, demographic, social and economic life of Harput using similar archival documents mention evidence for earthquake damage in 1789.

An important source of earthquake information within the Ottoman Empire is the work by Vogt (2001) who compiled eyewitness accounts of earthquakes as related by foreign ecclesiastical sources. According to the author's own words, "foreign ecclesiastics do not only living in cities but also in remote regions". For example, the Armenian patriarch relates that the newly appointed Governor with his entourage were shaken by the 23 July 1784 earthquake while they were on way to Erzurum. Despite the presence of a large Armenian population in the area affected by 1789 Palu earthquake Vogt (2001) makes no mention of the 1789 Palu earthquake.

The existence of the 1789 earthquake is indeed mentioned in the Ankara State Archives (M. 15 January 1790). The "Ottoman Empire Council of

Ministers resolutions" (Book 190, January 15, 1790, MD 190) contains the following statement (Figure 7):

"...coal transport was interrupted because Palu and Çarsancak (Peri) were affected by earthquake..."

A short information included in the munitions book numbered 190 expressed that the transportation of oak coal that was provided for the mines was interrupted from the Palu and Çarsancak (Peri) settlements as a result of the earthquake that occurred in 1789. Also in the Cevdet/Darphane classification (C. DRP. 32–1597) the Palu administrator requests a tax amnesty from the central government as a result of damage in the earthquake, the central government responded by reducing the tax instead of eliminating it, and increased the amount of oak fuel that Palu would supply for the

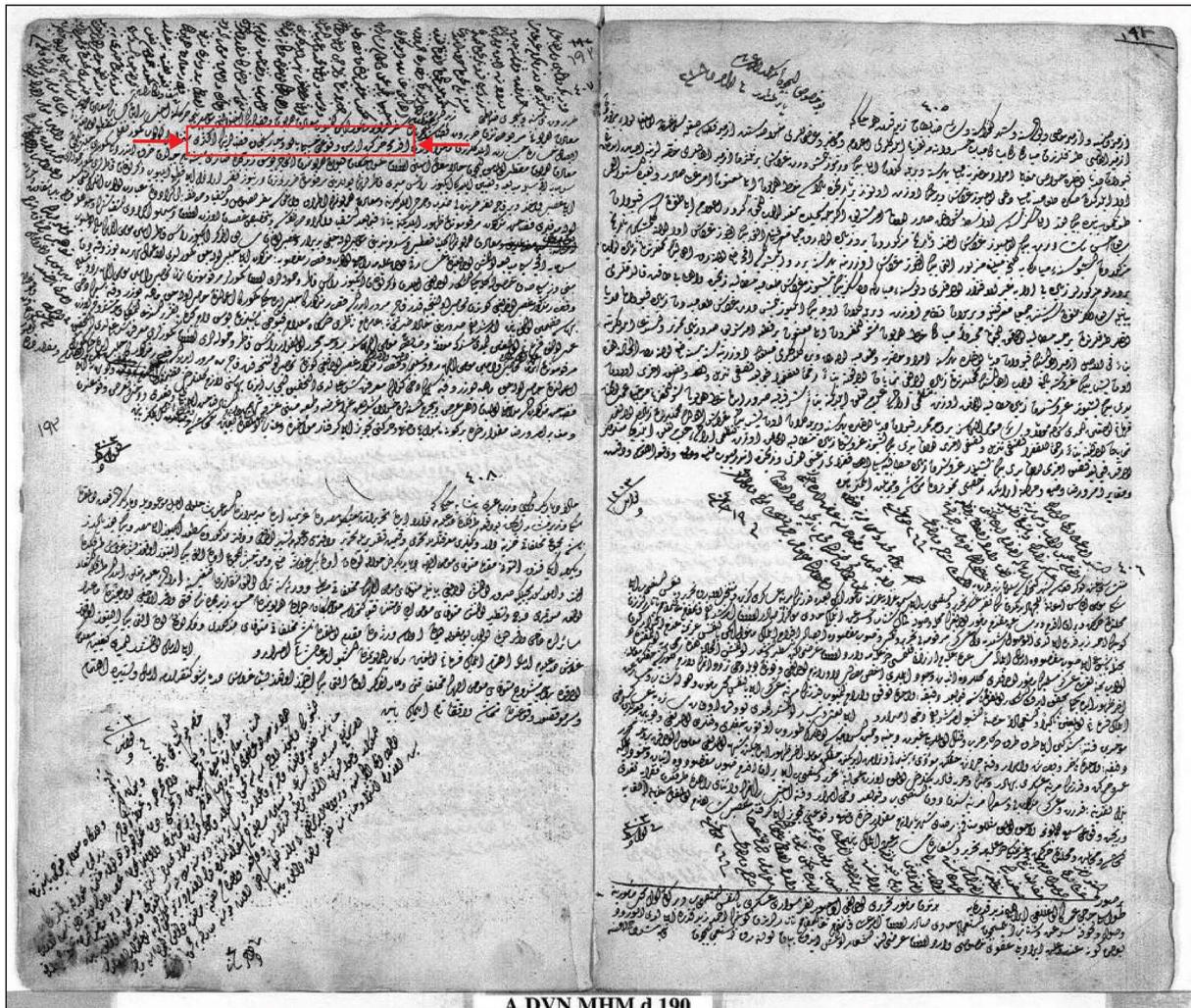


Figure 7- A page from the Ankara State Archives (Head of Presidency Republic of Turkey M. 15 January 1790) mentioning the 1789 earthquake. The relevant line is marked in red.

mines. As can be seen from this, there is no doubt that an earthquake occurred in Palu in 1789, but there is no information about the effects of earthquake.

3.2. The Assessment of the Earthquake

3.2.1. The Occurance Date and Center of the Earthquake

The earliest mention of the date of the earthquake is to be found in *Tarih-i Lebîbâ* written by Taylesanizâde Master Hafiz Abdullah. A major earthquake occurred in 1789, on a day between the 10th and 19th days of Ramadan (May 28-June 2, 1789) at three o'clock at night (9 in the evening), and Harput, Mazgirt, Çemişgezek, Palu, Keban and their villages were affected (Emecen, 1982). This work provides a five-day possible window for the earthquake- 28 May and 2 June 1789. In addition, the Ankara State archive (M. 15 January, 1790) states that Palu was the region worst affected by the earthquake.

3.2.2. Magnitude estimates for the 1789 Earthquake

If we assume that 1789 earthquake occurred on the Palu segment of the EAF, and that it ruptured the entire segment we may derive a maximum estimate for the earthquake (Figure 5). The length of the Palu segment is estimated as 54 km (Çetin et al., 2003) or 77 km Duman and Emre (2013). Depending on the length of the active strike-slip fault, the magnitude of the earthquake is expressed by Wells and Coppersmith (1994) with the following formula;

$$M = a + b \cdot \log(\text{SRL})$$

$$M_w = 5,16 + (1,12 \times \log(L)) \text{ (for strike-slip faults)}$$

where M_w is moment magnitude and L is the length of a strike slip fault

$$M_w = 5,16 + (1,12 \times \log(54))$$

$$M_w = 7,10$$

$$M_w = 5,16 + (1,12 \times \log(77))$$

$$M_w = 7,27 \text{ is calculated}$$

The magnitude calculation of the 1789 earthquake with the maximum displacement with the assumption that the last earthquake occurred on the Palu segment in 1513 is expressed by Wells and Coppersmith (1994) with the following formula;

$$M = a + b \cdot \log(\text{MD})$$

$$M_w = 6,81 + (0,78 \times \log(\text{MD}))$$

where MD is the amount of maximum displacement.

$$1789 - 1513 = 276 \text{ year}$$

Using a 10 mm/yr nominal slip rate the time interval yields a potential

$$276 \text{ year} \cdot 10 \text{ mm/year} = 2,76 \text{ m (MD)}$$

$$2,76 \text{ m slip deficit in 1789 for which slip}$$

scaling relations from Wells and Coppersmith (1994) indicate

$$M_w = 6,81 + 0,78 \log(2,76) = 7,15.$$

The findings of earthquakes forming surface ruptures in 130, 400-450, 1513, 1874 and 1875 were encountered in the Palu segment, while no surface fractures of 995 and 1789 earthquakes in the historical records were found (Çetin et al., 2003). Researchers claimed that these earthquakes may happen on the Karliova-Bingöl segment, or that traces of earthquakes may have been erased or they do not found these ruptures. Depending on the length of the active strike-slip fault proposed by Wells and Coppersmith (1994), the magnitude of the earthquake to be produced must be $M_w = 7.1$ and/or 7.2 for the Palu segment.

4. Discussion and Conclusions

Two conflicting death tolls are recorded for the 1789 earthquake that are unexpectedly high given the probable total population of settlements at the time. The first, for 8.000-10.000 deaths, comes from the contemporary source *Tarih-i Lebîbâ*, which was written in Istanbul using unknown primary accounts from the provinces, and the second, for 51.000, is recorded by the German geologist Otto Wilhelm Hermann von Abich (1878) in his travels at least 8 decades after the earthquake. Contemporary administrative documents in the Ankara State Archives and compiled from local traditions by Housemadyan (2009) suggest that both estimates are severely inflated.

These inflated numbers may be compared with the death toll in the 10 September 1509 Istanbul earthquake in which the death toll was no more than 3% of the population (4.500-5.000 in a population of 160.000) (Ambraseys and Finkel, 1995, or in the 23 July 1784 Erzincan earthquake where 5.000 people lost their lives (Soysal et al., 1981; Ambraseys and Finkel, 1995; Vogt, 2001). Abich (1878) includes questionable information for at least one other

earthquake. He states that 5.000 people fell into fissures caused by the 1582 Bitlis earthquake which is clearly an exaggeration.

Specifically, the following archival records contain no information substantiating severe loss of life or damage in 1789 in Palu, Diyarbakır, Keban-Ergani Mines or Harput: *Diyarbakır Catalogs of the Religious Courts No. 313 and 352, Catalogs of the Religious Courts dated 1776-1794, Diyarbakır in the First Half of the 19th Century (1790-1840), Mining in the Harput, Keban-Ergani Region in the 19th Century, Keban-Ergani Mines in the Ottoman Period the Mining Operating Book of 1776–1794, Seismicity Throughout History in the Ottoman Lands-Examples from Western Sources and Expressions of Witnesses.*

The Ankara archive (*M. 15 January 1790, Registers of Important Affairs (M. 15 January 1790, DVN. MHM., 190) and the Cevdet Darphanesi (C. DRP., 32–1597)*) includes mention of disruption of transport to local mines after the earthquake, adjustments to tax revenues, and severe damage in Palu, but provides no quantitative details concerning loss of life and damage to buildings. That damage was not excessive can be deduced from the absence of a request for reconstruction assistance to the central administration by the Çarsancak (Peri) administrator.

Ambraseys and Finkel (1995) equate Armenian labor being diverted in 1793 and 1795 from the Keban mine to repair destroyed churches, with damage in the 1789 earthquake. We counter that it is possible that earthquake damage may have been invoked as an arbitrary reason for church reconstruction. The reason for a 4-5 year delay between damage and repair remains unexplained.

Using scaling relations (Wells and Coppersmith, 1994) we calculate the maximum probable magnitude of an earthquake on the Palu segment as $7.1 < M_w < 7.2$. However, the absence of a 1789 surface rupture north of Lake Hazar (Çetin et al., 2003) remains problematic. Our investigations indicate that the locus of the 1789 earthquake was near Palu and therefore did not occur on the Karlıova-Bingöl segment as suggested by these authors. This result suggests that 1789 earthquake may have not created a surface rupture suggesting its magnitude may have been $M 6.5$ close to Palu.

Damaging earthquakes are common in the region of the Palu settlement as testified by its destruction and relocation several times in past millennia (Şaroğlu

et al., 2018) (Figures 1b and 2). In recent moderate earthquakes (1977 $M_w = 5.1$ Palu and 2010 $M_w = 6.1$ Okçular) loss of life and property was significant, and as a result of its current location and geological setting (Sunkar, 2011). Considering the factors, damages caused by earthquakes in the historical period cannot be measured with the magnitude of the earthquakes.

In conclusion, extant archival documents indicate that previous fatality estimates for the 1789 Palu earthquake have been grossly inflated. Our study shows much hitherto unused information is available in Ottoman archives and that these data have an important role in correcting our knowledge of historical earthquakes in Turkey.

References

- Abich, H. 1878. Geologische Forschungen in den kaukasischen Landern. 3. cilt. Viyana.
- Aksın, A. 1999. 19. Yüzyılda Harput, Elazığ, Ceren, 1999, 314, ISBN: 975-94229-0-5, 168.
- Aksoy, E., İnceöz, M., Koçyiğit, A. 2007. Lake Hazar Basin: A Negative Flower Structure on the East Anatolian Fault System (EAFS), SE Turkey. Turkish Journal of Earth Sciences 17, 319-338.
- Aktuğ, B., Özener, H., Doğru, A., Sabuncu, A., Turgut, B., Halıcıoğlu, Yılmaz, O., Havazlı, E. 2016. Slip rates and seismic potential on the East Anatolian Fault System using an improved GPS velocity field. Journal of Geodynamics 94-95, 1-12.
- Allen, C.R. 1969. Active Faulting in Northern Turkey. Contribution No:1577, Division of Geological Sciences, California. Institute. Technology, 32.
- Altınlı, İ.E. 1963. Explanatory text of the Geological Map of Turkey of 1:500 000 scale; Erzurum sheet. Publ. Bulletin of Mineral Research and Exploration Inst., Ankara.
- Ambraseys, N. N. 1989. Temporary seismic quiescence: SE Turkey. Geophysical Journal 96, 311–331.
- Ambraseys, N. N., Finkel, C. 1995. The Seismicity of Turkey earthquake of 19 December 1977 and the seismicity of the Adjacent Areas 1500–1800. Eren Yayıncılık ve Kitapçılık, İstanbul. 240.
- Ambraseys, N. N., Jackson, J. A. 1998. Faulting associated with historical and recent earthquakes in the Eastern Mediterranean region. Geophysical Journal International 133, 390–406.
- Arpat, E., Şaroğlu, F. 1972. The East Anatolian Fault System; Thoughts on its Development. Bulletin of Mineral Research and Exploration 78, 33-39.
- Arpat, E., Şaroğlu, F. 1975. Türkiye'deki bazı önemli genç tektonik olaylar, Türkiye Jeoloji Kurumu Bülteni 18, 1, 91-101.

- Barka, A.A., Kadinsky-Cade K. 1988. Strike-slip fault geometry in Turkey and influence on earthquake activity. *Tectonics* 7, 3, 663-684.
- Bulut, F. 2017. Doğu Anadolu Fayı boyunca Sismik ve A-sismik Tektonik Hareketler: Hazar Gölü Doğu'sunda Sismik Boşluk mu yoksa Krip mi? Afyon Kocatepe Üniversitesi, Fen ve Müh. Bil. Der. (FEMÜBİD) 015803, 257-263. DOI: 10.5578/fmbd.53986.
- Çelik, H. 2008. Doğu Anadolu Fay Sistemi'nde Sivrice Fay Zonu'nun Palu-Hazar Gölü (Elazığ) arasındaki bölümünde atımla ilgili yeni arazi bulgusu. *Fırat Üniv. Fen ve Müh. Bil. Dergisi* 20 (2), 305-314.
- Çetin, H., Güneşli, H., Mayer, L. 2003. Paleosismology of the Palu-Lake Hazar Segment of the East Anatolian Fault Zone, Turkey. *Tectonophysics* 374, 163-197.
- Çolak, S., Aksoy, E., Koçyiğit, A., İnceöz, M. 2012. The Palu-Uluova Strike-Slip Basin in the East Anatolian Fault System, Turkey: Its Transition from the Palaeotectonic to Neotectonic Stage. *Turkish Journal of Earth Sciences* 21,1-24.
- Dewey, J.F., Şengör, A.M.C. 1979. Aegean and surrounding regions: complex multiplate and continuum tectonics in a convergent zone. *Geological Society of America Bulletin* 90, 84-92.
- Duman, T.Y., Emre, Ö. 2013. The East Anatolian Fault: geometry, segmentation and jog characteristics. *Geological Society London, Special Publications*, 372.
- Duman, T.Y., Çan, T., Emre, Ö., Kadirioglu, F.T., Baştürk, N.B., Kılıç, T., Arslan, S., Özalp, S., Kartal, R.F., Kalafat, D., Karakaya, F., Azak, T.E., Özel, N.M., Ergintav, S., Akkar, S., Altınok, Y., Tekin, S., Cingöz, A., Kurt, A.İ. 2016. Seismotectonics database of Turkey. *Bulletin of Earthquake Engineering*, DOI 10.1007/s10518-016-9965-9
- Emecen, E. F., 1982. Tarih-i Lebiba'ya Dair. *Turkish Journal of History* 0 (33), 237.
- Emre, Ö., Duman, T.Y., Özalp, S., Elmacı, H., Olgun, Ş., Şaroğlu, F. 2013. Açıklamalı Türkiye Diri Fay Haritası Ölçek: 1/1.250.000. Maden Tetkik ve Arama Genel Müdürlüğü Özel Yayın serisi-30, Ankara.
- Ergintav, S., Çetin, S., Şentürk, S., Özdemir, A., Doğan, A., Çakır, Z., Karabulut, H., Şaroğlu, F. 2019. Doğu Anadolu Fayı, Hazar-Palu Segmenti Üzerinde Gerçekleşen Krip Davranışının Sorgulanması. *Uluslararası Katılımlı 72. Türkiye Jeoloji Kurultayı 28 Ocak-01 Şubat 2019*, Ankara, Türkiye, s. 33-34.
- Eris, K.K., Akçer, S., Çağatay, M.N., Ülgen, U.B., Ön, Z.B., Gürocak, Z., Arslan, T.N., Akkoca, D.B., Damcı, E., İnceöz, M., Okan, Ö.Ö. 2017. Late Pleistocene to Holocene paleoenvironmental evolution of Lake Hazar, Eastern Anatolia, Turkey. *Quaternary International* 486, 4-16. <https://doi.org/10.1016/j.quaint.2017.09.027>
- Gülen, L., Barka, A., Toksöz, M.N. 1987. Kıtaların çarpışması ile ilgili kompleks deformasyon: Maras üçlü eklemi ve çevre yapıları. *Hacettepe Üniversitesi Yerbilimleri Bülteni* 14, 319-336.
- Hempton, M.R., Dewey, J.F. 1981. Structure and tectonics of the Lake Hazar pull-apart basin, SE Turkey. *Transactions, American Geophysical Union EOS*, 62, 1033.
- Herece, E., Akay, E. 1992. Karlıova-Çelikhan arasında Doğu Anadolu fayı. *Türkiye 9. Petrol Kongresi Bildiriler*, 361-372, Ankara.
- Herece, E. 2008. Doğu Anadolu Fayı (DAF) Atlası. Maden Tetkik ve Arama Genel Müdürlüğü Özel Yayın serisi, Ankara, 13, 359.
- Housemadyan, 2009. Palu-Yerel Tarih. 1 Ocak 2019 tarihinde, <https://www.houshamadyan.org/tur/haritalar/diyarbakir-vilayeti/palu/yerlesim-birimi/yerel-tarih.html> adresinde erişildi.
- <http://www.koeri.boun.edu.tr/sismo/zeqdb> (2018, 30 Kasım)
- İnceöz, M., İnce, S. C. 1999. Doğu Anadolu Fay Zonu'nun (DAF) Palu çevresinde yapısal ve Morfotektonik özellikleri. *Aktif Tektonik Araştırma Grubu İkinci Toplantısı (ATAG-2) Ekim, 1999*, İstanbul Teknik Üniversitesi, İstanbul. *Bildiriler* 98-110.
- Köküm, M. 2019. Landsat TM Görüntüleri Üzerinden Doğu Anadolu Fay Sistemi'nin Palu (Elazığ)-Pütürge (Malatya) Arasındaki Bölümünün Çizgisellik Analizi. *Gümüşhane Üniversitesi Fen Bilimleri Enstitüsü Dergisi (GÜFBED/GUSTIJ)* (2019) 9 (1): 119-127. DOI: 10.17714/gumusfenbil.419865.
- Köküm, M., İnceöz, M. 2018. Structural analysis of the northern part of the East Anatolian Fault System. *Journal of Structural Geology* 114, 55-63. <https://doi.org/10.1016/j.jsg.2018.06.016>.
- Le Pichon, X., Angelier, J. 1979. The Hellenic arc and trench system: a key to the neotectonic evolution of the eastern Mediterranean area. *Tectonophysics* 60, 1-42.
- McClusky, S., Balassanian, S., Barka, A., Demir, C., Ergintav, S., Georgiev, I., Gürkan, O., Hamburger, M., Hurst, K., Kahle, H., Kastens, K., Kekelidze, G., King, R., Kotzev, V., Lenk, O., Mahmoud, S., Mishin, A., Nadrıya, M., Ouzounins, A., Paradissis, D., Peter, Y., Prilepin, M., Reilinger, R., Sanli, I., Seeger, H., Tealeb, A., Toksöz, M.N., Veis, G. 2000. Global Positioning System constraints on plate kinematics and dynamics in the eastern Mediterranean and Caucasus. *J. Geophys. Res.* 105, 5695-5720.

- McKenzie, D.P. 1972. Active tectonics of the Mediterranean region. *Geophysical Journal of the Royal Astronomical Society* 30, 109–185.
- Oral, M.B., Reilinger, R.E., Toksöz, M.N., King, R.W., Barka, A., Kınık, İ., Lenk O. 1995. Global Positioning System Offers Evidence of Plate Motions in Eastern Mediterranean. *EOS Transac.* 76 (9).
- Öncel, A.O. 2000. Fraktal Analiz İle Türkiye'deki Doğrultu Atımlı Fayların Yapısal Ve Sismolojik özelliklerinin Belirlenmesi. *Deprem Araştırma Bülteni* 84, 5–109.
- Öz, D. 2013. 352 Nolu Diyarbakır Şer'iyeye Sicilinin Transkripsiyon ve Değerlendirilmesi (H. 1136-1264/M. 1724-1848). Dicle Üniversitesi Sosyal Bilimler Ens. Yüksek Lisans Tezi, Diyarbakır (unpublished).
- Palutoğlu, M., Şaşmaz, A. 2017. 29 November 1795 Kahramanmaraş Earthquake, Southern Turkey. *Bulletin of the Mineral Research and Exploration* (155):10-10. DOI: 10.19111/bulletinofmre.314211
- Pınar, N., Lahn, E. 1952. Türkiye Depremleri İzahlı Kataloğu. Bayındırlık Bakanlığı Yapı ve İmar İşleri Reisliği Yayınlarından 6, 36, 1952.
- Reilinger, R.E., McClusky, S.C., Oral, M.B., King, R.W., Toksoz, M.N. 1997. Global Positioning System measurements of present-day crustal movements in the Arabia–Africa–Eurasia plate collision zone. *Journal of Geophysical Research* 102, 9983–9999.
- Reilinger, R., McClusky, S., Vernant, P., Lawrence, S., Ergintav, S., Çakmak, R., Özener, H., Kadirov, F., Guliev, I., Stepanyan, R., Nadariya, M., Hahubia, G., Mahmoud, S., Sakr, K., ArRajehi, A., Paradissis, D., Al-Aydrus, A., Prilepin, M., Guseva, T., Evren, E., Dmitrova, 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. *J. Geophys. Res.* 111, B05411.
- Seymen, İ., Aydın, A. 1972. The Bingöl Earthquake Fault and its Relation to the North Anatolian Fault Zone. *Bulletin of the Mineral Research and Exploration* 79, 1-8.
- Soysal H, Sipahioğlu S, Kolçak D, Altınok Y. 1981. A catalogue of earthquakes for Turkey and surrounding area (BC 2100-AD 1900). Final report, Project number Tbag 341, The Scientific and Technical Research Council of Turkey (TUBİTAK), Ankara.
- Sunkar, M. 2011. 8 Mart 2010 Kovancılar-Okçular (Elazığ) Depremi; Yapı Malzemesi ve Yapı Tarzının Can ve Mal Kayıpları Üzerindeki Etkisi. *Türk Coğrafya Dergisi* 56, 23-37.
- Şaroğlu, F., Emre, Ö., Boray, A. 1987. Türkiye'nin Diri Fayları ve Depremsellikleri Maden Tetkik ve Arama Genel Müdürlüğü Rapor no: 8174, Ankara (unpublished).
- Şaroğlu, F., Emre, O., Kuşçu, I. 1992. The East Anatolian Fault Zone of Turkey. *Annalae Tectonicae* 6, 99–125.
- Şaroğlu, F., Ardahanlıoğlu, A., Demirci, E. 2018. Yer Değiştir(mey)en Kent: PALU/ELAZIĞ. *Mavi Gezegen Popüler Yerbilim Dergisi* 25, 18-34.
- Tan, O., Tapırdamaz, M. C., Yörük, A. 2008. The earthquake catalogues for Turkey. *Turkish Journal of Earth Sciences* 17, 405–418.
- Taymaz, T., Eyidoğan, H., Jackson, J. 1991. Source parameters of large earthquakes in the east Anatolian fault zone (Turkey). *Geophysical Journal International* 106, 537–550.
- T.C. Cumhurbaşkanlığı Devlet Arşivleri Başkanlığı (M. 15 Ocak 1790) DVN. MHM. d.190.
- T.C. Cumhurbaşkanlığı Devlet Arşivleri Başkanlığı Cevdet Darphanesi (C. DRP) 32–1597 (H. 28 Rebiülahir 1204).
- Tızlak, F. 1991. Keban-Ergani Yöresinde Madencilik (1780-1850). Fırat Üniversitesi Sosyal Bilimler Enstitüsü Doktora Tezi, Elazığ (unpublished).
- Vogt, J. 2001. Osmanlı Topraklarında Tarih Boyunca Depremsellik: Batılı Kaynaklardan ve Tanıkların İfadelerinden Örnekler, Osmanlı İmparatorluğu'nda Doğal Afetler. Ed. Elizabeth Zachariadou, Çev. Gül Çağalı Güven–Saadet Öztürk, Tarih Vakfı Yurt Yayınları, İstanbul, 13-58.
- Wells, D.L., Coppersmith, K.J. 1994. New Empirical Relationships among Magnitude, Rupture Length, Rupture width, Rupture Area and Surface Displacement. *Bulletin of Seismological Society of America* 84, 4, 974-1002.
- Yıldız, A. 1994. 135/313 No' lu Şer'iyeye Siciline Göre (1135/1722-1213/1798) Yıllarında Amid (Diyarbakır) Sancağında Sosyal ve Ekonomik Durum, Uludağ Üniversitesi Sosyal Bilimler Enstitüsü Yüksek Lisans Tezi, Bursa (unpublished).
- Yılmazçelik, İ. 1990. 19. Yüzyılın İlk Yarısında Diyarbakır (1790-1840). TTK Yayınları, Ankara.
- Yüksel, H. 1987. Hicri 1190 (M.1776)–Hicri 1209 (M. 1794) Tarihli Keban Şer'iyeye Sicilinin Transkripsiyon ve Değerlendirilmesi. Ankara Üniversitesi Sosyal Bilimler Enstitüsü, Yüksek Lisans Tezi, Ankara.
- Yüksel, H. 1997. Osmanlı Döneminde Keban–Ergani Madenleri–1776–1794 Tarihli Maden Emni Deferi. Dilek Matbaası, Sivas.