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ORIGINAL PAPER

Exploiting the legacy of N.N. Ambraseys: known and unknown earthquakes in the Anatolian area

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Abstract

N.N. Ambraseys left us a wealth of papers and volumes on a number of topics; many of them concern the historical earthquake investigation. One of the last works is the 2009 volume (Ambraseys in Earthquakes in the Eastern Mediterranean and the Middle East: a multidisciplinary study of 2000 years of seismicity, Cambridge, Cambridge, UK, 2009), where he summarizes the results of more than thirty years of investigation through archives and libraries, covering earthquakes of a large area, from Albania to Caucasus. For each earthquake, a short summary of the main effects is supplied, together with the list of the sources used. Such information is intended as material for assessing location and size of the earthquakes, task that the author accomplished only in a very preliminary way for a few earthquakes, only. In addition to exhaustive descriptions of the most known earthquakes and the relevant historical sources, the volume contains information on a large number of earthquakes, so far unknown to the current earthquake catalogues. This paper intends to represent a homage to his immense work, partially showing the potential of his volume. We briefly present here some case histories, including the preliminary location and size of the earthquakes – known and unknown—around Anatolia. We add some examples of how he was able to prove that some alleged earthquakes are actually to be considered as fake or very doubtful. We also present the damage information supplied for some known and unknown earthquakes, and how they can be used for assessing location and size of them.

Keywords Earthquakes · Anatolia · Historical seismology

1 Introduction

There is no need to summarize, once again, the importance and the amplitude of Ambraseys' contribution to varied fields, including historical seismology. There is little which can be added to the obituaries published by Ansal (2013) and Bilham (2013) who describe in detail, among other aspects, the localities where he made archive and library investigation and the field work, which were essential for him. In this volume commemorating the late Assia Harbi it is also worth to mention some of the papers he wrote about North Africa,such as, among others: Ambraseys et al. (1991), Vogt and Ambraseys (1992). The same happened for a number of regions throughout the world; in some case his contribution was welcome and used while in some other not, because parametric catalogue compilers often limit their views to today national boundaries and national historical sources.

The volume "Earthquakes in the Eastern Mediterranean and the Middle East: A Multidisciplinary Study of 2000 Years of Seismicity" (Ambraseys 2009) is the last one of

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a series dedicated to varied areas of the globe and by far the most consistent. It provides a comprehensive body of information he was able to retrieve and summarize from a number of sources of varied origin. It summarizes many of his previous articles dedicated to single earthquakes or time-windows and, in addition, an outstanding number of descriptions (several thousands) of earthquakes he did not deal before. What is peculiar of this work is that, when one reads it, he brings him/her into a journey through time, space and historical sources without any barrier; the same he did during his life.

Figure 1, taken from his volume, shows the earthquakes, the description of which is contained in the volume, spanning from the presumed event of Jericho to 1900.

As it was typical from him, he presents the information in a very direct way, in the way he could interpret it: in some case he devotes many pages, in some case a few lines. The historical sources he was able to consult are given at the end of the account or inside it. Sometimes data allow his interpretation to be robust, sometimes not and he frankly admits it, like in this case (Fig. 2):

AD 1866 May 8 ***Çaldiran***

The facts about this event are not clear. A letter from Erzurum, dated Saturday 12 May, says that an earthquake in the region and its aftershocks were felt in the town, without damage, between Tuesday at 8 h and Wednesday at 4 h 30 m; some shocks were violent and others were light (PCH 1866, 5).

Fig. 2 Excerpt from Ambraseys (2009) for the earthquake of Çaldiran, 1866

In some cases, he is rather severe with previous compilers, mostly with those who committed chronological or geographical mistakes:

"The translators of Armenian texts have not perceived the chronological difficulties that occur in the manuscripts of Moses and Acogh'ig and have committed an anachronism of exactly 30 years"

He is also ready to admit mistakes by himself in previous works, such as the following case (earthquake of 1866 May 12 along the East Anatolian Fault, Fig. 3):

And, of course, some of his typical British humour is not missing. Talking of the 1843 earthquake near Khoy he says:

"Damage extended to the north of the town as far as Maku and to the south up to Taj al-Din ….The shock, which was allegedly predicted by a dervish [Wolff

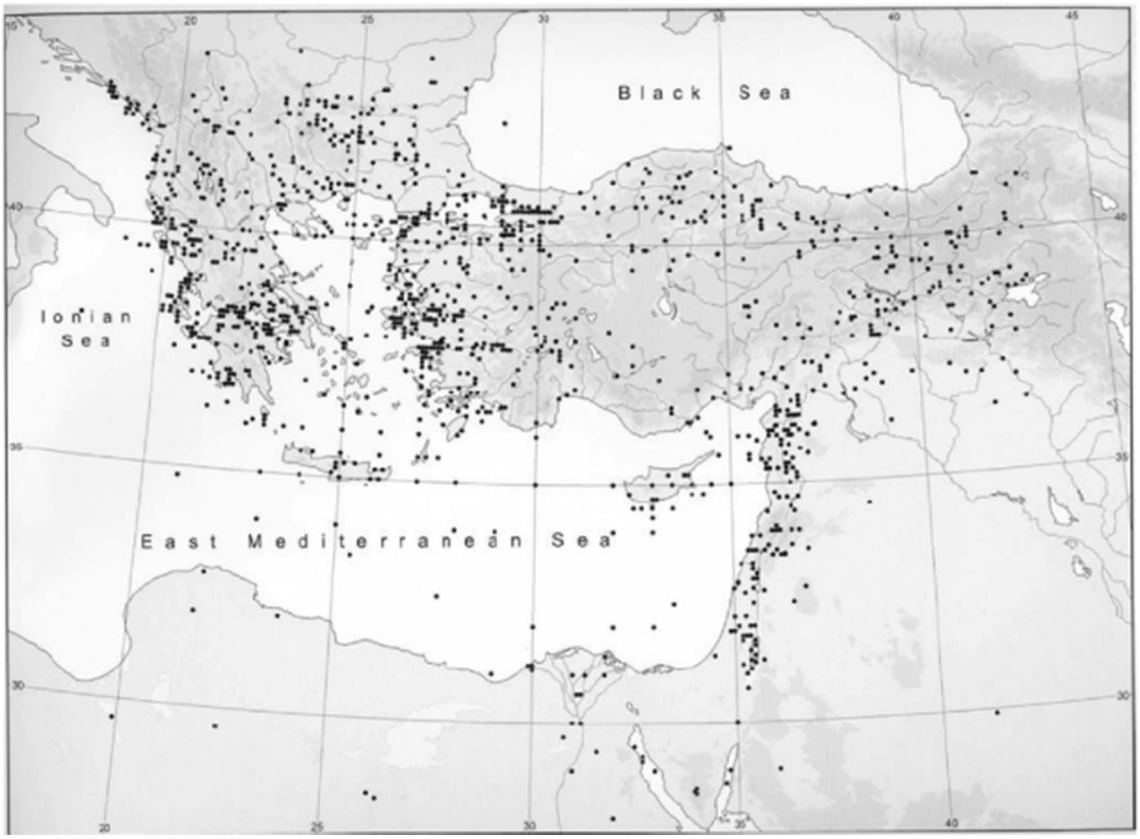


Fig. 1 Preliminary distribution of the earthquakes considered in the volume (from Ambraseys 2009)

a doublet on 22 July 1867. In turn, Perrey was copied by Pinar and Lahn (1952), who were then copied by Ergin *et al.* (1967), these authors adding no primary information. The far-field effects of the earthquake were also noticed by Firat (1961), who gives the wrong year, that is spring 1272 instead of 1282 a.H. (1866), while Ambraseys (1989), misled by the unpublished information in [4], identifies only one earthquake on 20 June in the region of Kulp and grossly mislocates it, dating the main event incorrectly and placing it in the Kulp area.

Fig. 3 Excerpt from Ambraseys (2009) for the earthquake of 1866 May 12

1845, 84, 219], was strongly felt in Tabriz but not beyond the Araxes river".

By the way, a similar warning by a Dervish is mentioned also for the 1500 July 24 earthquake in the Hellenic Arc.

2 The hunt for the "spurious" earthquakes

Part of the analysis contained in the volume is devoted to the identification of what historical seismologists use to call "fake quakes", that are events found in earthquake compilations and parametric catalogues which usually come from misinterpretation of the content of historical source. There is a number of papers on this topic: they can be really events which never took place, or true earthquakes which are simply misplaced in time or space, or even events which are of other origin than earthquake (such as landslides, storms, explosions, etc.). Ambraseys (2009) frequently uses the term "spurious" for them [*"Entries with bracketed date and place of occurrence refer, in my opinion, to spurious events"*]; he is never too assertive, leaving room for future improvements.

For instance, writing about the great 1170 Syrian earthquake, he says that:

"The earthquake was felt in most of the regions of Sham, Jazirah, as far as the borders of Mosul and in Iraq, while the area of maximum intensity was in Syria…., which, incidentally, was misspelled in some occidental sources as Styria…, thus placing a spurious earthquake in Steiermark, in what was then Hungary. This error passes on unnoticed to modern writers.

1752: In a similar way he deals of the AD 1752 July 21 in Tripoli, Lebanon event which, according to him, took place in Tivoli, Italy, near Rome instead:

"According to twentieth-century catalogues, an earthquake on the Syrian and Palestinian littorals on 21 July 1752 destroyed public buildings and houses, especially in the ports, where there were 20.000 victims (Sieberg 1932*; Amiran 1952;* Plassard and Kogoj 1968*)".*

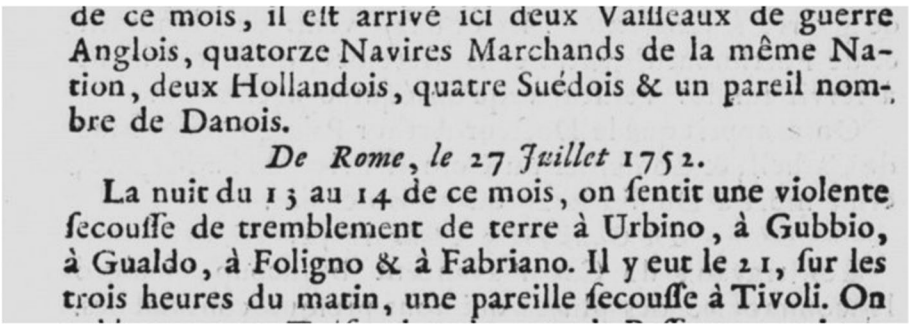
Actually, the earthquake is considered by:

- Ben Menhaem (1979), as located near the Syrian coast (with tsunami). with $I_o = 10$ and $M = 7.0$
- Soysal et al. (1981), as located in today Lattakia with $I_o = 9$.
- Sbeinati et al. (2005), with $I = 7$ in Lattakia.
- Sesetyan et al. (2013), with $I_o = 9$ and Mw = 6.77.

The sources for the Soysal et al. (1981) and for Sbeinati et al. (2005) are the ones quoted by Ambraseys (2009): in particular, Plassard and Kogoi (1968) quote Willis (1928) and Sieberg (1932) who reports *"Strong shocks in Laodicea [today Lattakya] and to South along the Syrian coast, with around 20,000 victims"*. Sesetyan et al. (2013) use Soysal et al. (1981) as a background.

Ambraseys (2009) was able to detect the primary source of the mistake by means of his knowledge of geography. Actually, he found that Seyfart (1756):

"Reports a felt earthquake in Tripoli, Lebanon, on 21 July 1752 (Seyfart 1756). *This is a misreading on his part of a report in the Gazette de France of 19 August 1752, which, on the basis of a report from Rome, records an earthquake in the similar-sounding Tivoli, in Italy, on 21 July 1752"* (Figs. 4 and 5).


de ce mois, il eſt arrivé ici deux Vaiſſeaux de guerre Anglois, quatorze Navires Marchands de la même Nation, deux Hollandois, quatre Suédois & un pareil nombre de Danois.

De Rome, le 27 Juillet 1752.

La nuit du 13 au 14 de ce mois, on ſentit une violente ſecouſſe de tremblement de terre à Urbino, à Gubbio, à Gualdo, à Foligno & à Fabriano. Il y eut le 21, ſur les trois heures du matin, une pareille ſecouſſe à Tivoli. On

Fig. 4 Excerpt from Gazette de France of 19 August 1752, dealing with some earthquakes in Central Italy

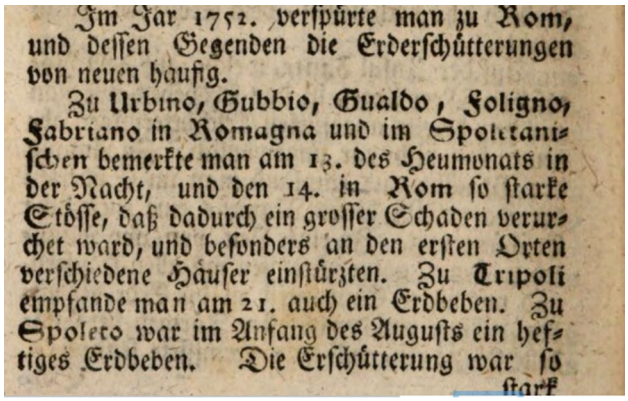

Im Jar 1752. verſpürte man zu Rom, und deſſen Gegenden die Erderſchütterungen von neuen häufig.
Zu Urbino, Gubbio, Gualdo, Foligno, Fabriano in Romagna und im Spoletaniſchen bemerkte man am 13. des Heumonats in der Nacht, und den 14. in Rom ſo ſtarke Stöſſe, daß dadurch ein groſſer Schaden verurſachet ward, und beſonders an den erſten Orten verſchiedene Häuſer einſtürzten. Zu Tripoli empfande man am 21. auch ein Erdbeben. Zu Spoleto war im Anfang des Auguſts ein heftiges Erdbeben. Die Erſchütterung war ſo ſtark

Fig. 5 Excerpt from Seyfart (1756) dealing with some earthquakes in Central Italy. Here Tivoli became Tripoli

Ambraseys (2009) then continues:

> "Later writers embroider the Tripoli story to produce a catastrophic earthquake in the eastern Mediterranean region (Arvanitakis 1903).

Actually, Arvanatakis (1903) reports an earthquake which hits

> "Cotes de Syrie et de la Palestine; Laodicée, etc.; 20,000 victimes, maisons, monuments et surtout les constructions des ports (Volney 1787)".

It is to be noted that one line below Arvanatakis (1903) reports the earthquake of 1759 in the Baalbeck region with similar wordings. As a matter of fact, Volney (1787) only mentions the 1759 earthquake in Baalbek, with 20,000 victims.

In conclusion, a small earthquake was first moved from Tivoli to Tripoli, then associated to large damage and even to a tsunami, both of which never took place. The small earthquake in Tivoli is not in the Italian catalogues, because of its low size.

By the way, it seems that misunderstanding Tripoli for Tivoli was not infrequent in the past. For instance, William Johnson Neale in his book *"Cavendish, or the Patrician at Sea [anon.], 3 vols., London, 1831*", writes the following dialogue (courtesy of Viviana Castelli):

> "Why to go to Tivoli, to be sure"
> "Oh go to Tripoli yourself"
> " I'm not going to Tripoli"
> " Tripoli, man! Not Tripoli, but Tivoli!"

1509–1513/14: A more complicated case is represented by earthquakes to have happened in Çorum, Anatolia in 1509, the same year of the large Istanbul earthquake, and in 1513/1514 as suggested by Calvi (1941), Arıncı (1945), Pınar and Lahn (1952) and later adopted by Soysal et al. (1981).

For the 1509 event in Çorum, Soysal et al. (1981) give Io = 8, Tan et al. (2008) give $M = 7.5$ while Stucchi et al. (2013) do not list the event. For the 1513 one, Soysal et al. (1981) give Io = 6 with epicentral area in Amasya, further to the East near the North Anatolian Fault; Sesetyan et al. (2013) list the event without assigning any Mw value. Ambraseys (2009) says:

"Although many of the details of the 1509 earthquake are quite clear, an Ottoman source, introduces a complication. A near contemporary Ottoman chronicle, the Vekayi-i Sultan Bayezit ve Selim Han, adds that in the town of Çorum the 1509 earthquake caused the destruction of two quarters, where mescids and minarets were razed to the ground….]. The anonymous author of this chronicle otherwise follows Ruhi's account closely, but does not mention Çorum among the towns affected. This suggests either a copyist's error or the conflation of two separate events. By the end of the sixteenth century, Ali, in his account of the earthquake, describes Çorum as being in the district of Rum in Anatolia [1], and subsequent authors follow him. The extension of the damaging effects of the 1509 earthquake to Çorum which is about 500 km east of Istanbul, must be rejected until further conclusive evidence becomes available.

……Arinci (1945) dates the earthquake in Çorum a.H. 920 (26 February 1514 to 29 March 1514), five years after the earthquake in Istanbul, and says that it had its centre in Istanbul (sic.) and that the main damage in Çorum was to the Great Mosque and the collapse of the Çakirli mosque, with one in three dwellings becoming uninhabitable. He adds that as a result of the earthquake the people were obliged to migrate to Egypt and other places [18]. No Çakirli mosque in Çorum has been traced…….The only earthquake known about in Anatolia in 1514 occurred before July and affected the region of Malatya, about 400 km southeast of Çorum; this event is not mentioned in Ottoman sources.

Actually, Sakin (2002) analysed the contemporary Ottoman sources for the 1509 Marmara Sea earthquake (e.g. the accounts of Edirneli Ruhi, Kemal Paşazade, Anonim Tevarih-i Al-I Osman). He particularly provides the following information on the supposed 1509 Çorum event: the town of Çorlu which is located west of Istanbul is one of the localities heavily damaged by the 1509 Marmara Sea earthquake and the damage is mentioned by most of the contemporary accounts. On the other hand, the name of Çorum as a damaged locality in 1509 is mentioned only in the account of Gelibolu'lu Mustafa Ali. That account does not include Çorlu among the damaged localities. Therefore, the interpretation of Sakin (2002) is that Çorum was wrongly included in that account instead of Çorlu. This information was later transformed to an independent earthquake in Çorum. In addition, the information given by Pınar and Lahn (1952)

on an earthquake in Amasya in the year 1513 was not supported by any other account.

In conclusion, both Sakin (2002) and Ambraseys (2009) independently agree in that the information given by later sources most probably arise from a misreading of Çorlu, located in Thrace and damaged by the 1509 earthquake.

3 Earthquakes in Anatolia

A large part of Ambraseys (2009) is dedicated to the Anatolian region, for either geographical, historical or seismological regions. Anatolia has a long history, as attested by very early settlements like Çatalhöyük, Göbekli Tepe, etc., and complicated by the several changes of populations, ruling systems, languages and so on.

The seismicity of the Anatolian region is mostly concentrated around the two main transform faults, North Anatolian (NAF) and Eastern Anatolian (EAF) and around the graben systems of western Anatolia; the relevant twentieth century seismicity (Fig. 6) is rather well known.

On the other hand, historical earthquakes are not very well known, in comparison with other countries of Europe, where historical seismology developed in the last tens of years due to a number of reasons mostly deriving from the complicated history of the region.

For the time-window before 1900 we list three compilations: Calvi (1941); Pınar and Lahn (1952) and Soysal et al. (1981), with the addition of Ergin et al. (1967). The first two are descriptive, while the last two are parametric. The common point among these four items is that, similarly to what happened in most countries, they mainly rely on previous compilations, not on original sources, and without critical review. The result is that a fake event erroneously copied from one source to another may finally become an earthquake with presumed "good quality information" because it is mentioned by several sources in Soysal et al. (1981). Among several sources of Calvi (1941) we can cite the works of von Hoff (1840), Schmidt (1879), Arvanitakis (1903) and Sieberg (1932). Pınar and Lahn (1952) rely on the same, as well as on local newspapers for the post-1850 period, however without indicating them earthquake-specifically. Ergin et al. (1967) take the data of Pınar and Lahn (1952) for the pre-1900 period and assign epicentral coordinates and intensity to each event. Soysal et al. (1981) use all these previous catalogues and more recent ones such as Karnik (1971), Shebalin et al. (1974), Ambraseys (1965) and a number of historical works. The catalogue gives epicentral coordinates and intensity if they are available in the original source, and a quality code.

The catalogue by Soysal et al. (1981) contains about 850 events, half of which unfortunately have no Io; M has later

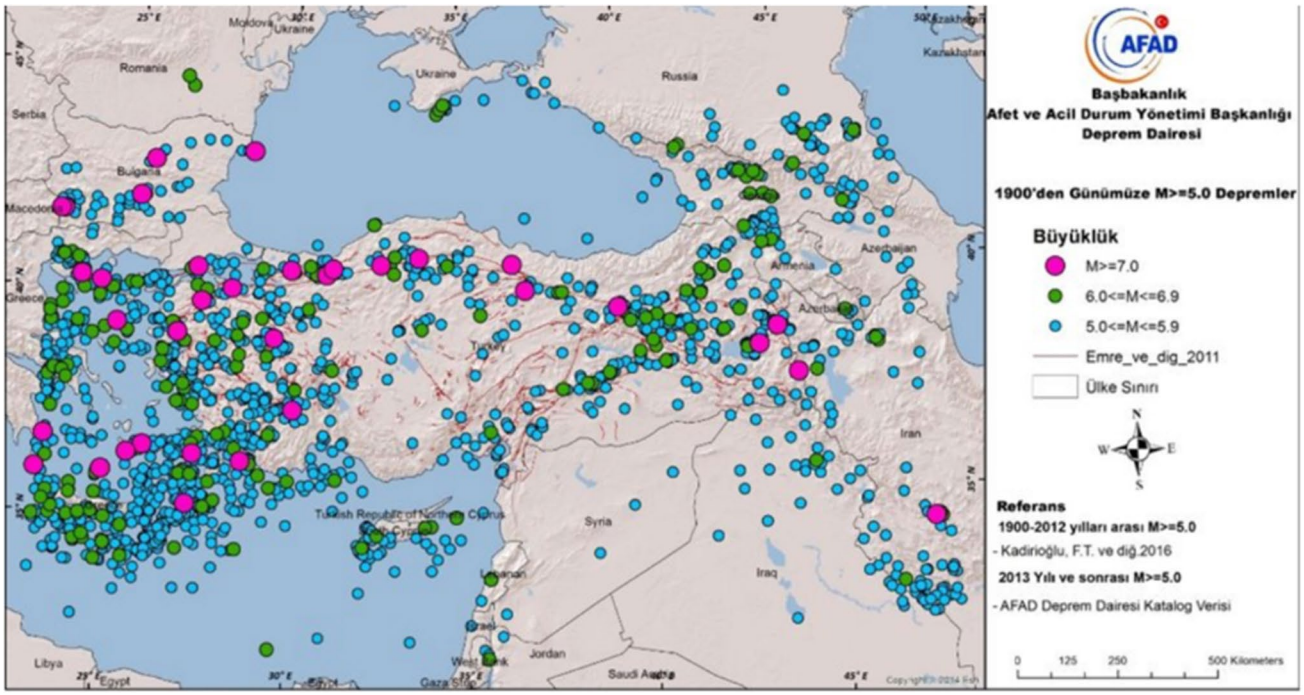


Fig. 6 twentieth century seismicity as described by AFAD (Disaster and Emergency Management Presidency of Turkey), on the basis of Kadirioğlu et al. (2018)

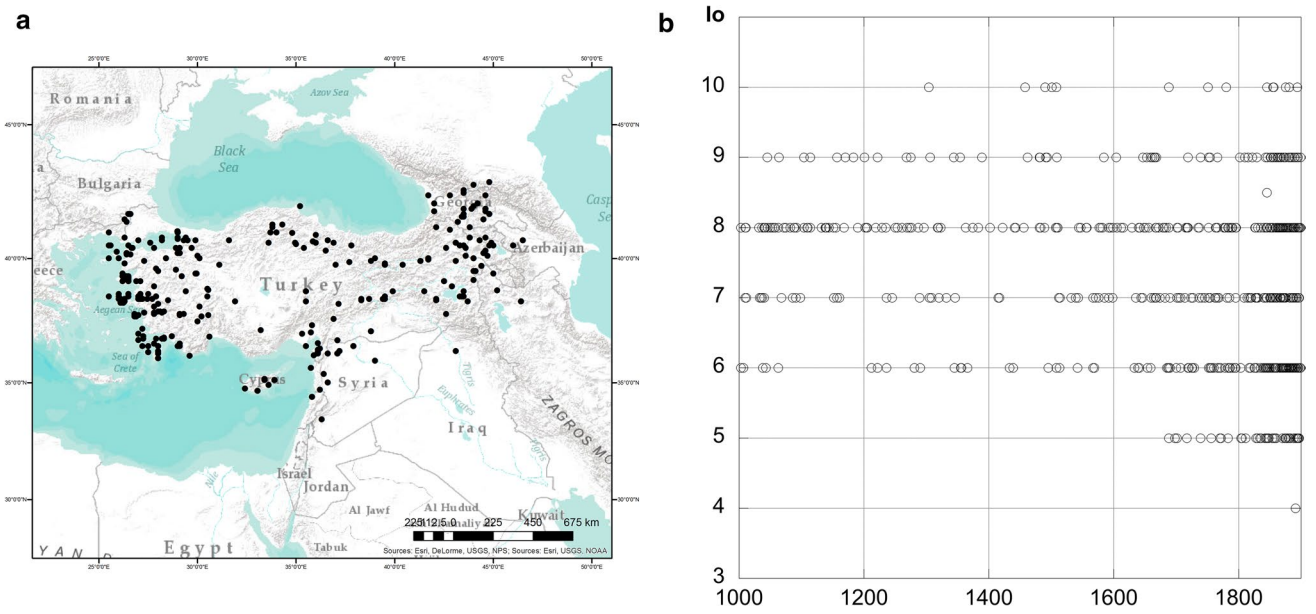


Fig. 7 From Soysal et al. (1981): **a** epicentres 1000–1900; **b** I_o distribution through time

been derived from I_o by Kalafat et al. (2011), then by Stucchi et al. (2013) and Sesetyan et al (2013).

Considering the seismicity in the time-window 1000–1900 we get the following description (Fig. 7):

More recently, Tan et al. (2008) proposed a parametric earthquake catalogue for Turkey covering the period 2100 BC – 1963. It relies only on previous parametric catalogues and it contains 656 events for the period 1000–1899. For the events without magnitude estimations in the original sources, M^* (estimated magnitude) is calculated from I_o using the equation of İpek et al. (1965).

Similar to Fig. 7, plotting the data from the two catalogues of the SHARE project, Stucchi et al. (2013) and Sesetyan et al. (2013) we get the following description (Fig. 8). Gaps of information are evident.

4 Towards a macroseismic database for the Anatolian area

As the most recent parametric catalogues do not make use of the information supplied by Ambraseys (2009), we decided to start and exploit it. According to the most recent standard, such as for instance AHEAD (Locati et al. 2014; https://www.emidius.eu/AHEAD/), we started compiling macroseismic intensity data for the Anatolian earthquakes.

The work we are performing is to consider the about 1150 events contained in the volume in the time-window 1000–1900 and the Anatolian region; to compare them with the most important current catalogues; to assess macroseismic intensities (EMS scale) for each event, with the perspective of establish a macroseismic intensity database for the area and to derive the earthquake parameters from intensity distributions according to modern, repeatable methods (such as Bakun and Wentworth 1997; Gasperini et al. 1999;). Such a database does not exist for this region yet, intensity data are available for only a few historical earthquakes, including those from Syria (Sbeinati et al. 2005) and those included in the above mentioned AHEAD portal come from studies performed in Greece (Papazachos and Papazachou 2003; Kouskouna and Sakkas 2013). More recently, a prototype of a macroseismic intensity database for the Anatolian region has been developed by Şeşetyan et al. (2020) through funding of Boğaziçi University Research Fund.

4.1 Intensity assessment

Intensity assessment from the material contained in the volume is not always an easy task, mostly for earthquakes for which available effect descriptions are poor. It is worth to remember that N.N. Ambraseys did assess intensity in the first part of his career (see for instance Zatopek and Ambraseys 1969); then, he abandoned it for varied reasons and decided to use other methods for assessing earthquake magnitude.

His criticism towards intensity is summarised in the introduction (2.5.1), where he underlines that

"Most of the existing intensity scale have been designed chiefly for twentieth-century European-type

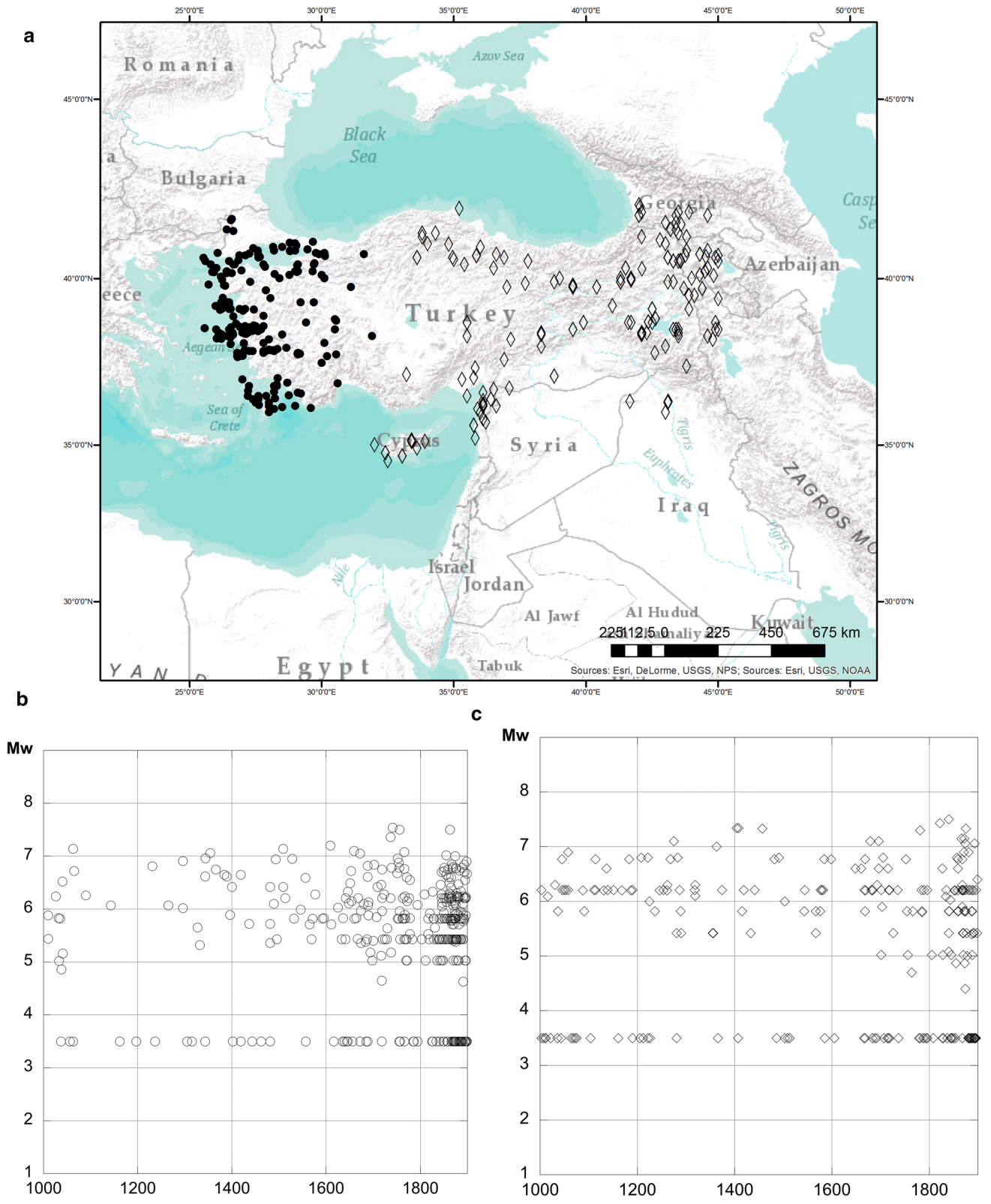


Fig. 8 From Stucchi et al. (2013), circles, and Sesetyan et al. (2013), diamonds: **a** epicentres 1000-1900: **b** and **c** Mw time distribution

constructions, the vulnerability of which differs enormously from that of historical dwellings and from that types of construction used today in the rural Middle East….."

and stresses the problem of "saturation of intensity" related to the highly vulnerable building stock. He also states that

"Unfortunately there has been more emphasis on development of methodology to analyse intensity data than on the intensity data themselves".

Nevertheless, he did assess intensity for a few earthquakes in the volume (see for instance an earthquake in 1114); then he took the road of designing the felt area, trying avoiding subjectivity in contouring intensity as much as possible with the introduction of the "kriging" technique, and then assessing magnitude from it.

On the other hand, we are convinced that the use of above mentioned, repeatable methods represent a step forward; therefore, we started assessing intensity directly from Ambraseys (2009) accounts, checking his primary sources when possible and in a limited number of cases introducing new sources.

Beside the problems that Ambraseys noted, we found that poor descriptions also contribute to intensity saturation, a problem which is frequently met in historical seismology, not only in Middle East.

As an example, for the 1779 March 14 in the Malatya area (EAF) we have the following description:

In Agn (Agin) and particularly in Arapgir many houses and a church fell, but the area most affected was that of Kizik and Khopik (Hopik) in the Ovacik valley in the vicinity of the Keban dam, where many people were killed….."

In this case we assigned range intensities ($I = 8$–10) to Kizik and Hopik, leaving the task of adopting sharper values to the users, if needed.

4.2 Location and place-names

Identification of correct locations corresponding to macroseismic data points for our region of interest necessitates dealing with many problems. First, under the influence of different inhabiting populations and changes in ruling powers throughout history, place names in Anatolia have undergone several changes. In some case these changes are smoother and more easily traceable, while in some others they are not. In several cases the accounts refer to historical village names, which either do not exist today, or are displaced due to natural or political reasons, or have completely different names. A period of such abrupt change is after the foundation of the Turkish Republic, when the locality names of Greek, Armenian, Kurdish or of other origins have been changed. In some case Ambraseys gives hints to where the mentioned place would be; sometimes he adds the present day name or provides maps although he mostly refers – inevitably – to the place-names in the historical accounts. To deal with this problem, we try to find the new names of the mentioned localities through a variety of sources and associate them with the official gazetteer, but this is not always possible. Another problem is that transliteration of the name from the original source, which usually uses an alphabet different than Latin (e.g. the Arabic alphabet used in the Ottoman documents) introduces further difficulties in the identification of the localities. For instance, we have found that the village Nikan mentioned in connection with the 1789 Keban Dam earthquake was in fact Pingan, today's Adatepe. We identified Hopik, Danzig and Zernig damaged by the 1856 Ovacık Valley earthquake as today's Havuzlu, Dereboyu and Yeşilyazı respectively. But we could not identify, yet, Kizocan/Kozlican nor Segruk, which were mentioned in 1784 Erzincan earthquake.

5 Case histories

1776: The earthquake of 29 December 1776 in Central Anatolia is not known to any current parametric catalogue for Turkey.

Ambraseys (2009) says that *"little is known about this seemingly large earthquake in Central Anatolia",* which caused damage in a region extending for about 130 km along the North Anatolian Fault, from Vezirkopru to Tokat.

The available information is rather poor: a dispatch of the British Ambassador in Istanbul, dated 4 February 1778 [may be 1777?] mentions damage in Tokat and Amasya, which is also attested by another document dated 22 Zilkade 1190 (2 January 1777). The precise earthquake date is established by Cevdet Pasha (wrongly given as 1953, the correct date of the reference is given as 1891 in Ambraseys and Finkel 1995) who also mentions damage in Merzifon and Köprü (today Vezirköprü), where about 100 persons lost their lives.

Table 1 Macroseismic data points of 29 December 1776 Central Anatolia earthquake

Locality	Lattitude (°N)	Longitude (°E)	Intensity
Tokat	40.314	36.552	7–8
Amasya	40.651	35.826	7–8
Vezirkopru	41.144	35.459	8–9
Merzifon	40.875	35.458	7–8

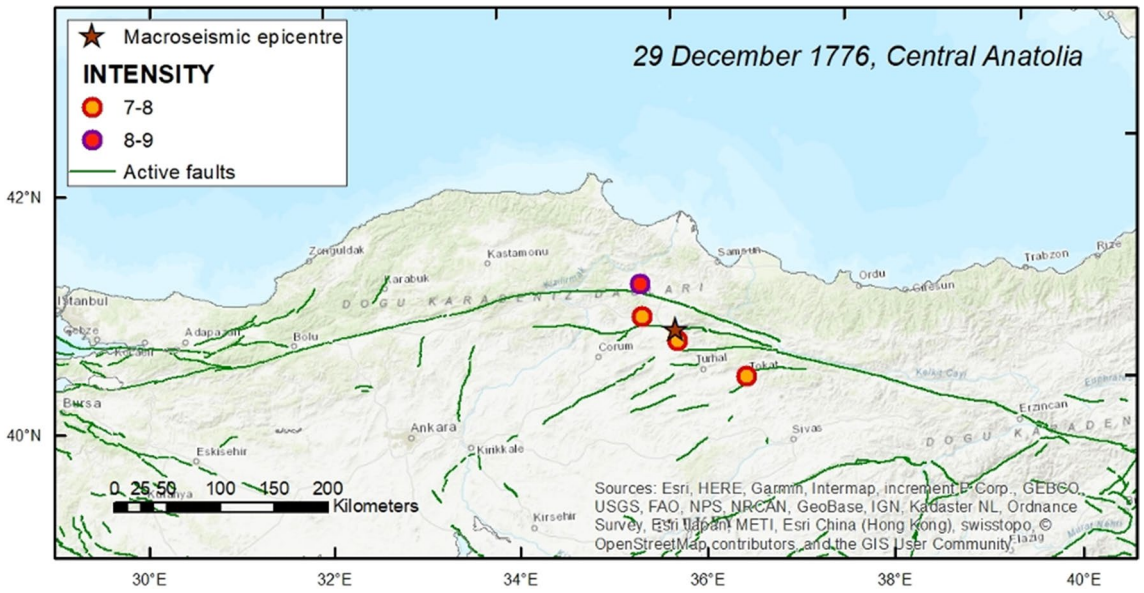


Fig. 9 Macroseismic data points for the 1776 Central Anatolia earthquake

Based on the account of Ambraseys (2009) we have extracted macroseismic data points as given in Table 1 and plotted in Fig. 9.

A preliminary assessment of Mw gives 6.3 ± 0.3, while the epicentre is located slightly north of Amasya.

1856: Another strong earthquake which is unknown to current parametric catalogues is the one which happened in the Ovacik Valley on 16 January 1856. The most damaged area is not located in the NAF nor EAF zones, but probably on the northeastern end of the so-called Malatya-Ovacık fault zone, which runs parallel to EAF to the west of it. The sources of information for this event are Allgemeine Zeitung (Riggs 1909) and two documents from the Ottoman Archives. According to the available information, several villages were destroyed in the districts of Dersim and Harput, and the Ovacık valley, however the names of only four villages are known. Place names mentioned follow the old nomination, the present-day name of only one was provided by Ambraseys, and we were able to identify the others through the procedure described in "Location and place-names". Later Şeşetyan et al. (2020) added a new data point (Divriği) to this event based on a new document from the Ottoman Archives. Descriptions of the effects are rather poor, so that we had to assign range-intensities. The location of Agin is a question mark: there are two Agin/Egin in the epicentral region, 40 away from each other; one is today's Kemaliye (historically Agn) and the other is Ağın. Here the location of Ağın is adopted. Macroseismic data points are given in Table 2 and plotted in Fig. 10.

A preliminary Mw estimate give 7.5+/0.3.

Table 2 Macroseismic data points of 16 January 1856 Ovacık Valley earthquake

Locality	Lattitude (°N)	Longitude (°E)	Intensity
Ağın	38.938	38.712	7–9
Danzig (Dereboyu)	39.455	39.798	8–10
Dersim (Tunceli)	39.099	39.544	7–8
Divriği	39.367	38.106	7
Harput	38.705	39.251	6–7
Hasanova	39.550	38.593	7–9
Hopik (Havuzlu)	39.401	39.269	8–10
Zernig (Yesilyazi)	39.335	39.081	8–10

1851 02 28, Fethiye area

1851 02 28, Fethiye area: This is a different case, that is an earthquake known to current parametric catalogues for which Ambraseys (2009) adds new data. The earthquake is known to:

- Soysal et al. (1981) with $I_o = 9$ (sources: Calvi 1941; Ergin et al. 1967; Karnik 1971 and Shebalin et al. 1974, who also mentions a tsunami; epicentral coordinates, mainly the longitude, vary in different sources)
- Ergin et al. 1967 with $I_o = 6$
- Papazachos and Papazachou (1997) and Stucchi et al. (2013). For the last two catalogues Mw is around 6.8; the epicentre is somewhere between Rhodes and the Turkish coast for the first one, on land for the second one. The

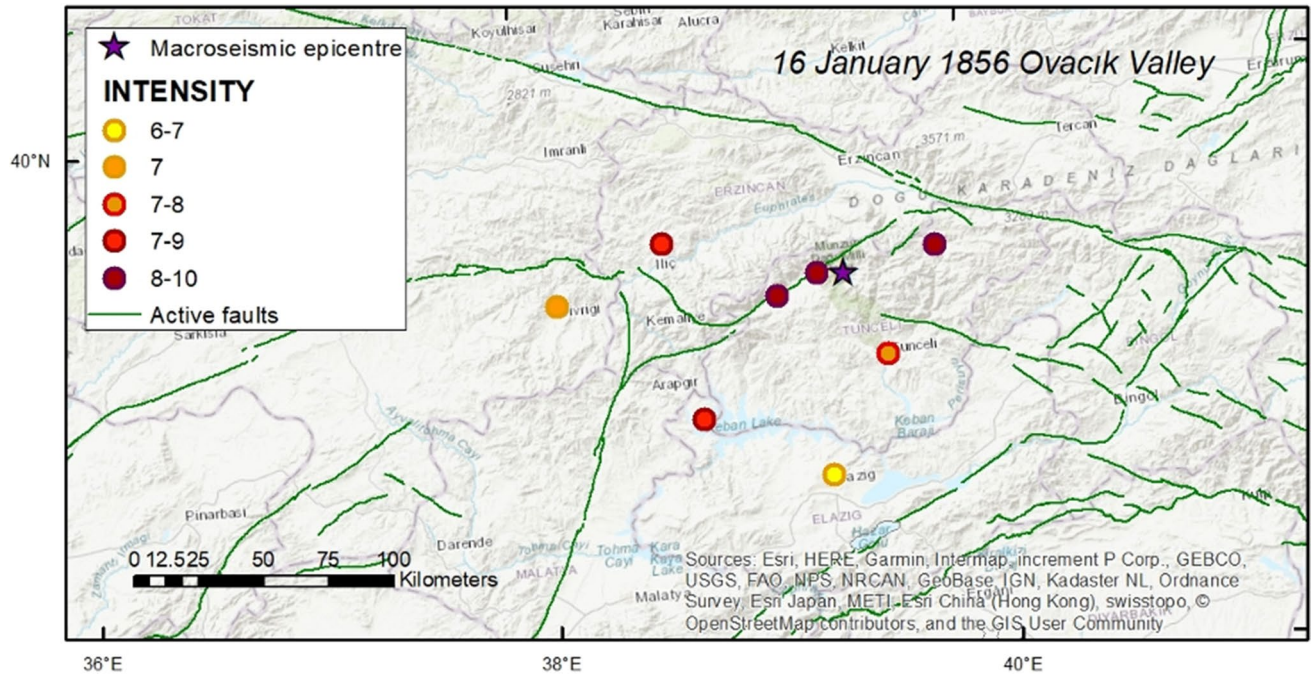


Fig. 10 Macroseismic data points for the 1856 Ovacık Valley earthquake

background information for this event in Stucchi et al. (2013) are five macroseismic data points from Papazachos and Papazachou (1997): $I_{max} = 10$ in Leivesio, today Kayakoy, a deserted settlement not far from Fethiye. Macroseismic data points are given in Table 3 and plotted in Figure 11

Ambraseys (2009) adds a number of information from several sources, allowing to assess intensity for 27 localities, four of which we were not able to retrieve, yet. Heavy destruction ($I = 9$–10) is reported for five localities.

Table 3 Macroseismic data points of 28 February 1851 Fethiye earthquake (from Papazachos and Papazachou 1997)

Locality	Lattitude (°N)	Longitude (°E)	Intensity
Muğla	37.214	28.364	6
Chalki	36.220	27.620	6
Rhodos	36.446	28.224	7
Fethiye	36.623	29.112	9
Leivesio (Kayaköy)	36.570	29.180	10

The most damaged localities are located in Turkey in a small area, while Rhodes city suffered limited damage: this allows Ambraseys to state that the earthquake was locally destructive.

Macroseismic data points are given in Table 4 and plotted in Fig. 12.

The preliminary Mw assessment gives 6.5 ± 0.5. The epicentre is on land.

6 Conclusion

At this stage of the work we can say that the contribution of Ambraseys (2009) to the knowledge of Anatolian historical earthquakes is considerable, for earthquakes both known and unknown to current parametric catalogues. Out of the about 1150 events above mentioned, about 50 are to be considered as "spurious", while about 500 events are not known to the current catalogues; among them, some tens potentially have a magnitude ≥ 6 (Fig. 13).

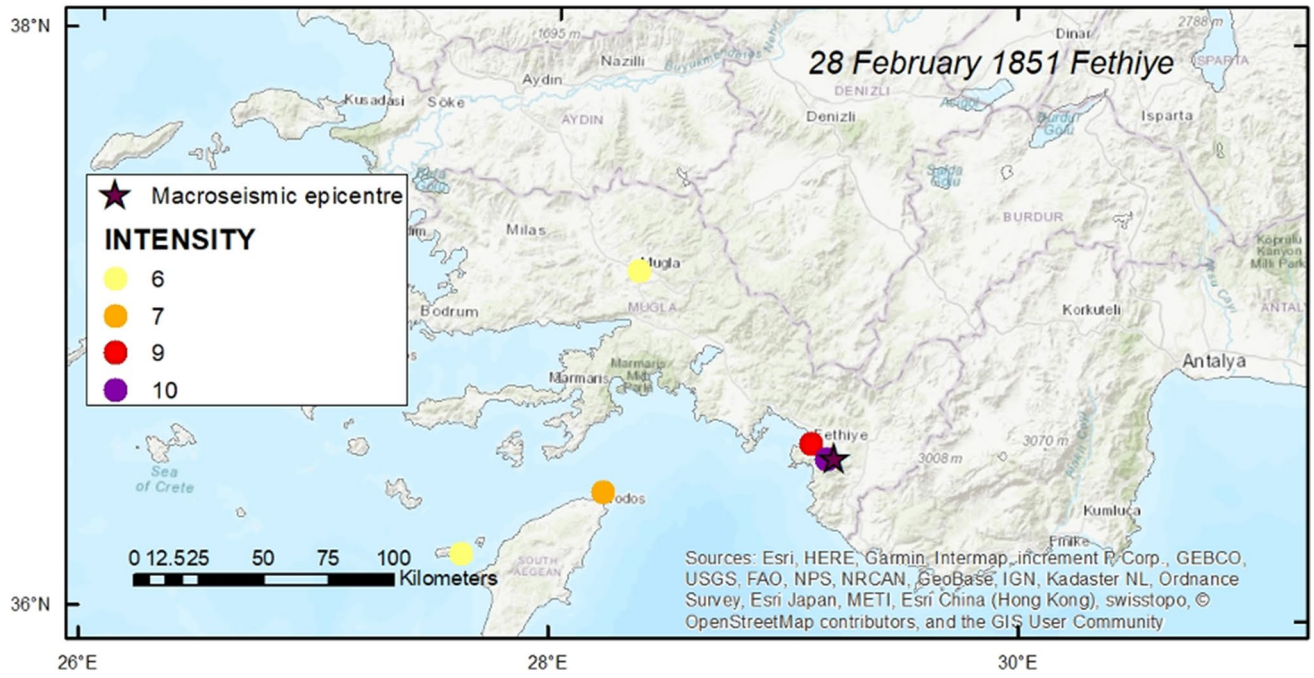


Fig. 11. 1851 Fethiye earthquake, data points from Papazachos and Papazachou (1997)

Table 4 Macroseismic data points of 28 February 1851 Fethiye earthquake, as assessed from Ambraseys 2009

Locality	Lattitude (°N)	Longitude (°E)	Intensity
Izmir	38.456	27.155	F
Isparta	37.766	30.554	4
Muğla	37.214	28.364	5
Chalki	36.220	27.620	5
Rhodos	36.446	28.224	6–7
Patlangic	36.620	29.154	7
Esenkoy	36.628	29.218	8–9
Karaçulha	36.641	29.172	8–9
Fethiye	36.623	29.112	8–9
Keçiler	36.587	29.098	8–9
Belan	36.594	29.081	8–9
Firincikla	Could not be identified, yet		8–9
Manastir	Could not be identified, yet		8–9
Yakabag	36.476	29.275	9
Dontkoy	36.621	29.219	9
Dudurga	36.401	29.206	9
Eldrek	36.677	29.197	9
Ovacik	36.580	29.154	9
Uzumlu	36.665	29.153	9
Çatallar	36.590	29.146	9
Culce	Could not be identified, yet		9
Hastahane	Could not be identified, yet		9
Düğer	36.555	29.394	9–10
Gokben	36.585	29.252	9–10
Leivesio (Kayaköy)	36.570	29.180	9–10
Çeditkoy	36.575	29.130	9–10
Sarıagaç / Yanıklar	36.705	29.054	9–10

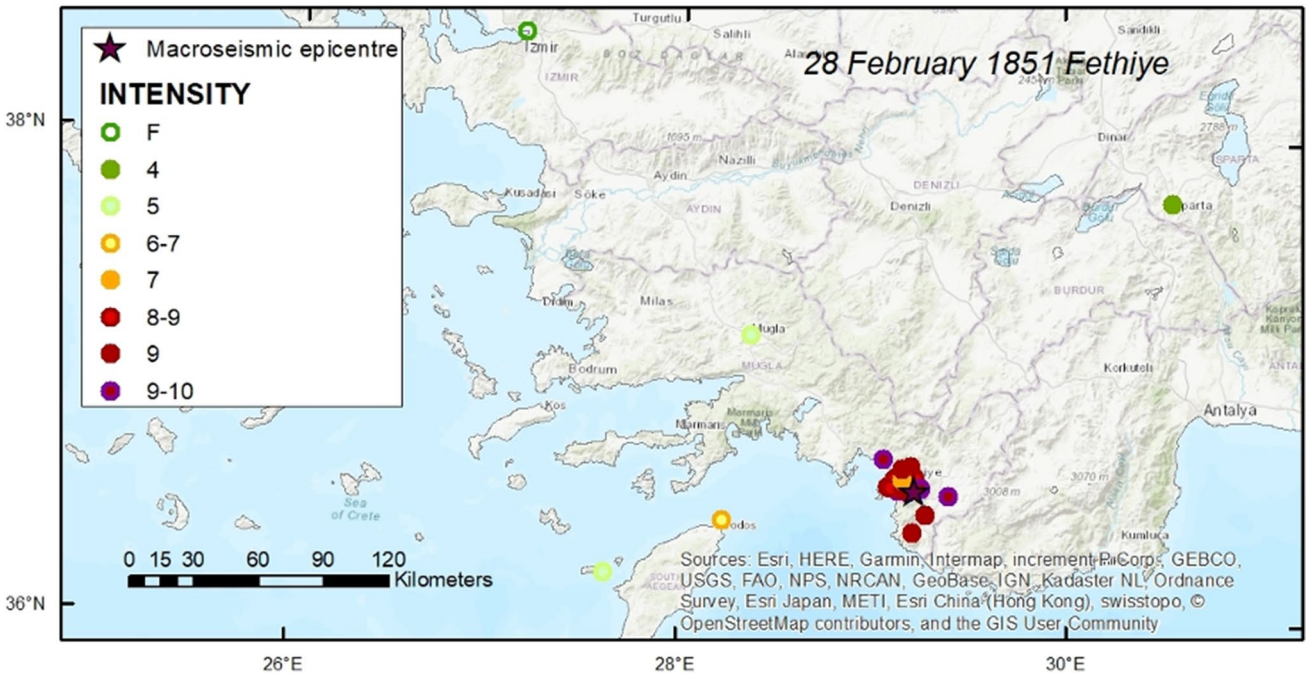


Fig. 12. 1851 Fethiye earthquake, data points retrieved from Ambraseys (2009)

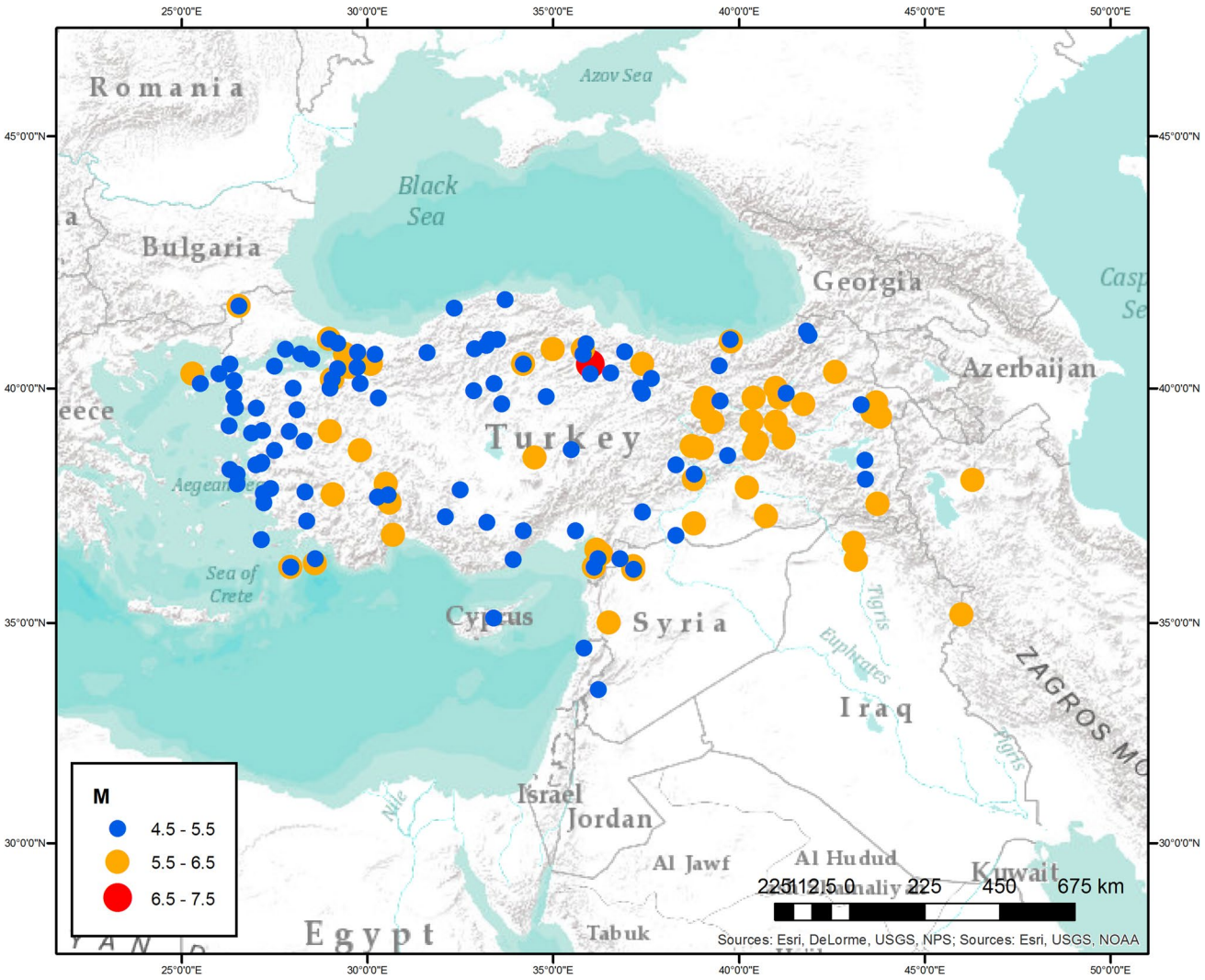


Fig. 13 Earthquakes unknown to current parametric catalogues, supplied by Ambraseys (2009). Magnitude has been assessed in a preliminary way

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