Reappraised list of historical earthquakes that affected Israel and its close surroundings

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ORIGINAL ARTICLE

Reappraised list of historical earthquakes that affected Israel and its close surroundings

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Abstract Numerous historical reports of damaging earthquakes in the Levant have accumulated over the last 3000 years. Here, we screen that information and focus on the damaging earthquakes that affected Israel from the second millennia BCE to the 1927 CE Jericho earthquake and list the earthquakes by date, of major damage, type of sequence, and degree of size. The compilation results in three different lists: (i) 71 reliable earthquakes that in our opinion were most probably associated with the Dead Sea Transform (DST) and affected Israel and its close surroundings; (ii) 41 questionable earthquakes that should be re-evaluated or ignored; and (iii) 46 earthquakes that probably occurred but were erroneously associated with damage in Israel. What emerges from the list of the reliable earthquakes is that (i) Israel and its close surroundings suffered damage about 32 times during the last two millennia, that is, once in about 60 years, although not regularly; (ii) 21 of the earthquakes occurred during the last millennia, i.e., an event every ~45 years; and (iii) three intervals of increased reporting are noticed: between the fourth and the mid-eighth century, from the beginning of the eleventh to the end of the thirteenth century, and from the end of the eighteenth century up to the last entry in 1927, though this period may be extended until today. In-depth evaluation of the changing regimes over time within the study area, the historical reports of earthquake damage outside of Israel, and comparison with physical paleo- and archaeo-seismology evidence, such as the "137–206" and "165–236" paleoseismic earthquakes for which there is no historical match, indicates that the historical list is far from being complete. Thus, we argue that the apparent cycles of historical reporting do not necessarily reflect the actual rate of seismic activity and further investigation is needed to establish a compiled, multi-sourced list to decipher the true nature of cycles of strong earthquakes in this region during historical times.

Keywords Dead Sea Transform · Earthquake damage · Historical earthquakes · Israel · Seismic cycles

1 Introduction

Numerous accounts of past earthquakes, tsunamis, and the damage they caused in the Levant have been accumulating during the last three millennia. They include historical contemporary reports, chronicles, manuscripts, newspapers, drawings, maps, and in recent times even modern photographs. The majority of the historical share was already collected, translated, and organized within several catalogues and lists. However, up to the last three decades, many of these studies were not

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critical enough and, consequently, there are a considerable number of questionable, false, or duplicated entries in these lists. Moreover, several errors were copied from one catalogue to another, causing distortion of the information or even fabrication of new earthquakes (Ambraseys 2005a; Karcz 2004; Karcz and Lom 1987). The implications of this shortcoming are too important to ignore. For example, the ground acceleration maps of the current Israeli anti-seismic building code (IC 413) are based upon such a list (Geophysical Institute of Israel, unpublished dataset). Thus, it is essential to screen and construct a reliable list of historical earthquakes that hit or were felt in and around Israel during historical times.

The compilation suggested in this paper is based primarily on a systematical review of the historical share. As the historical archive is partial and inhomogeneous along time (Stucchi et al. 2004), we examine the extent to which it may have influenced the completeness of this archive. We thus compare the temporal spread of the earthquakes in light of their historical context as well as with the archaeoseismic (e.g., Marco 2008) and paleoseismic (e.g., Agnon 2014; Marco and Klinger 2014) inventories available nowadays and conclude with an updated list of historical earthquakes that affected Israel and discuss how complete it might be.

2 The available information of the historical earthquakes

The first attempt to systematically collect and organize the historical reports of earthquakes and construct a Mediterranean inventory was probably in the mid-fifteenth century by (Manetti 1457). Following, Ligorio (1574-77) organized the Mediterranean earthquakes and expanded the time frame, beginning with the first millennium BCE up to his times. During the nineteenth century, a few important catalogues were also published (Hoff 1840; Mallet 1852; Perrey 1850; Schmidt 1881). Although these works were more accurate than the pre-nineteenth century lists, they were still incomplete and contained several inaccuracies and confused items. Unfortunately, the early twentieth century lists of Arvanitakis (1903), de Ballore (1906), Willis (1928), and Sieberg (1932) partially adopted these catalogues along with the inaccuracies already existing, and thus, these ambiguities became rooted in the scientific literature in several of the following compilations (e.g., Karcz and Lom 1987). In the mid-twentieth century, Shalem (1951) made a pioneering attempt to assess the historical earthquakes and their damage consistently. The following compilations (e.g., Amiran 1952; Amiran et al. 1994; Ben-Menahem 1979; Turcotte and Arieh 1988) were more detailed and also listed damaged localities but still preserved several of the significant inaccuracies. For instance, the alleged 92 BCE earthquake in Jerusalem appears in Amiran (1952), Amiran et al. (1994), Ben-Menahem (1979), and elsewhere but was later strongly rejected by Karcz (2004). A second example is the amalgamation made by Amiran (1952) of the local 363 CE and the 365 CE Crete earthquakes, but this was subsequently corrected by the same author (Amiran et al. 1994). Recently, however, the importance of critical interpretation of the historical sources was strongly raised (e.g., Ambraseys 2005a; Guidoboni and Ebel 2009; Karcz 2004; Karcz and Lom 1987) and consequently more critical screenings were conducted. Perhaps, the first harbingers were the review made by Karcz (1987) and the catalogues of Ambraseys et al. (1994) and Guidoboni et al. (1994). Following, their critical approach was adopted in modern catalogues (e.g., Ambraseys 2009; Guidoboni and Comastri 2005), reappraisals (e.g., Ambraseys and White 1997; Salamon et al. 2011; Salamon et al. 2007), and reviews (e.g., Ambraseys 2004; Ambraseys and Finkel 1995; Salamon 2009). Additional sources of historical information can be found in focused investigations of specific earthquakes (e.g., Ambraseys 1997; Ambraseys 2005b; Ambraseys and Barazangi 1989; Ambraseys and Karcz 1992; Ambraseys and Melville 1988; Austin et al. 2000; Avni 1999; Hough and Avni 2010; Russell 1980).

Archaeoseismic and paleoseismic findings constitute evidence complementary to the historical reports. While the historical portion provides information only from the last 3000–4000 years, archaeological remains (e.g., Ambraseys 2006; Bikai 2002; Hayens et al. 2006; Karcz et al. 1977; Korjenkov and Mazor 1999; Marco 2008; Rucker and Niemi 2010; Russell 1985; Thomas et al. 2007; Tsafrir and Foester 1992) and paleoseismic findings (e.g., Agnon et al. 2006; Alsop and Marco 2011; Enzel et al. 2000; Kagan et al. 2005; Kagan et al. 2011; Ken-Tor et al. 2001; Ken-Tor et al. 2002; Marco et al. 1996; Migowski et al. 2004; Wechsler et al. 2014; Zilberman et al. 2005) provide evidence of several thousand years much earlier and up to the Pleistocene, respectively. Thus, they may support and

even augment the scope of the historical share. The recent archaeoseismic and paleoseismic reviews of Marco (2008), Agnon (2014), and Marco and Klinger (2014) reflect that modern tendency. In the last few decades, scientists become aware of the benefits in collaboration and a sharp increase in multidisciplinary efforts is evident (e.g., Ellenblum et al. 1998; Ferry et al. 2011; Marco et al. 1997; Marco et al. 2003; Meghraoui et al. 2003; Niemi 2011; Panza et al. 1997; Reinhardt et al. 2006; Shaked et al. 2004; Wechsler et al. 2009; Yagoda-Biran and Hatzor 2010).

3 Methodology—the compilation of the historical reports

3.1 General settings

Our investigation begins at the biblical event of Sodom and Gomorrah (Genesis 19: Bible 1989) which dates back approximately to the second millennium BCE (Ambraseys 2009) and ends with the first recording of the damaging event in 1927 (Avni 1999), which practically ends the pre-instrumental period. Within this time frame, we focused mainly on the earthquakes that caused damage or were felt in at least one locality in Israel and/or its close vicinity. Accordingly, and in light of the existing tectonic settings and the population distribution, we limited our search for damage to an area extending between the geographic latitude coordinates 28.5° and 33.5° and from the Mediterranean coast in the west to about 50 km east of the Jordan and the Arava valleys (Fig. 1). The most southern, northern, and eastern localities within this area are the St. Catherine monastery in Sinai, Egypt and the cities of Tyre (Lebanon) and Zarka (Jordan), respectively.

The main seismogenic unit that crosses the region is the Dead Sea Transform (DST), left lateral fault system extending from the Red Sea in the south to southeastern Turkey in the north, and borders the tectonic plate of Arabia on the east side and the Sinai sub-plate on the west (Freund et al. 1968; Garfunkel and Ben-Avraham 1996; Garfunkel et al. 1981).

For the purpose of review and compilation of the historical reports, we based our evaluation mainly on the critical catalogues, reappraisals, reviews, and focused investigations listed in the previous section. In general, we used the English translations of the raw materials, but in cases of unclear reports or disagreements between the interpretations of some of the scholars, we checked the original document. In addition, in order to substantiate some of the historical reports, we also consulted several paleoseismic (Agnon 2014) and archaeoseismic (Marco 2008) reviews and studies relevant to our work but refrained from circular reasoning (Ambraseys 2005a; Karcz and Kafri 1978) in cases which the historical studies rely on the archaeo- or paleoseismic information or vice versa.

3.2 Compilation of the data

An accurate compilation process depends on the completeness and reliability of the historical reports. Furthermore, the attempt to systematically review and characterize reports that span more than 2000 years encounters difficulties originating from the different languages, authors, places, and historical contexts. Nevertheless, as most of the sources can be evaluated and characterized in light of their contemporaneous settings, we thus classified the inspected reports into contemporary (or near contemporary) and secondary sources. Then, we tracked the "chain of transmitters" (e.g., Elad 1982; Elad 2002), i.e., "who transmitted the report to whom," and inquired whether the transmitter is considered reliable. In cases in which the credibility of a given transmitter was controversial, we referred to discussions concerning his reliability (e.g., Broshi 1982; Mazar 1982) so as to assess possible inaccuracies or exaggerations. Finally, we developed a five-level scale of reliability based upon the number and contemporaneousness of the reports of each event entry (see Table 1). It was then possible to formulate a unified method to determine and grade the degree of reliability of each of the historical earthquakes. Accordingly, an event reported by at least two independent contemporary sources that describe the same phenomena was attributed a "very high" reliability degree. On the other hand, an event reported by a single secondary source that draws its account from unknown sources was attributed a "poor" reliability degree. In cases of historical reports supported also by independent archaeoseismic or paleoseismic evidence, the reliability degree of the reported event was strengthened (see Fig. 2 for the flow diagram of the process). Whenever we were unable to determine the reliability of an event, we used critical, conservative judgment based on the analysis of the underlying historical reports.

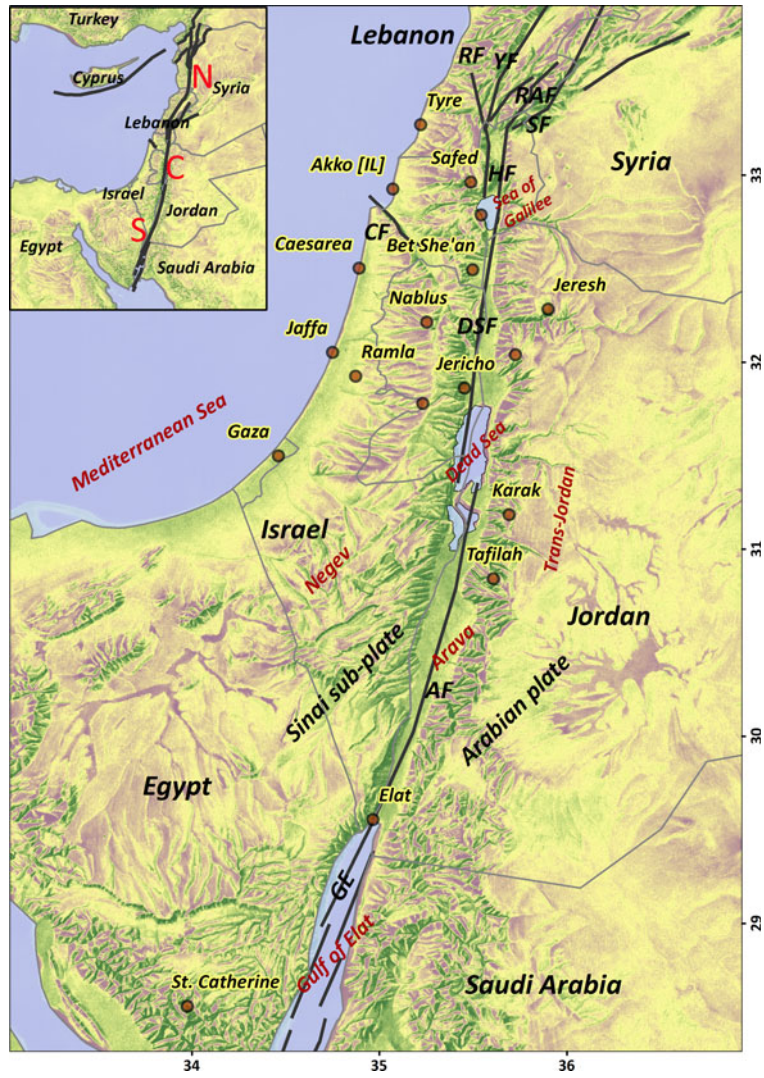

Fig. 1 Map of the study area which includes the central and southern parts of the Dead Sea Transform (DST) and its associated segments: *GE* the pull-apart structures in the Gulf of Elat and Aqaba, *AF* Arava fault, *DSF* Dead Sea fault, *HF* Hula fault, *RF* Roum splay, *YF* Yammouneh fault, *RAF* Rachaya splay, *SF* Serghaya splay, *CF* Carmel fault. A general overview of the DST is presented in the inset map; note the division of the transform into three geographic parts: South (*S*), Center (*C*), and North (*N*). Major ancient localities are marked and labeled

Date, degree of reliability, type (pre-, main, or aftershock) following (Salamon 2009), and zone of maximal damage were attributed to each of the compiled earthquakes. We also added a short description and noted the historical and scientific references we used for each of the entries. The reports of casualties required special attention as in many of the earthquakes the number of casualties seems to be extremely exaggerated. Furthermore, in several occasions, there are hardly any reports of damage but relatively large numbers of casualties. For instance, apart from the general term "Judea," there is no authenticated report of damage from the 31 BCE event, but Josephus (Josephus.AN. 15.121-4) still reports 30,000 casualties. This figure is strongly questioned by Ambraseys (2009). Broshi (1982) also claims that although the circumstances Josephus reports about probably did occur, the figures he notes in many cases are exaggerated.

In addition, we also determined the average of the magnitude values given by early researchers for the damaging earthquakes (e.g., Ambraseys 1997; Ambraseys and Barazangi 1989; Ambraseys and Jackson 1998; Ben-Menahem 1979; Ben-Menahem 1981; Ellenblum et al. 1998; Hough and Avni 2010; Marco et al. 1997; Marco et al. 2003). Although some of these scholars were not aware of the limitations of the historical data, they are all professional geologists and seismologists, well experienced in earthquake studies from all around the world. We therefore think that the earthquake magnitudes, as an opinion given by those

Table 1 Degrees of reliability that characterize a report of an event

Symbol	Reliability	Transmitters
V_R	Very high	Based upon at least 2 contemporary or near contemporary independent sources with no confusion or contradiction regarding date, location, and details of event
H_R	High	Based on at least one contemporary or near contemporary source with no confusion or contradiction regarding date, location, and details of occurrence
M_R	Moderate	Based on at least one secondary source that draws from at least one reliable contemporary or near contemporary source that is not available to us today
P_R	Poor	Based on secondary sources that rely upon other secondary or unknown sources
D_R	Doubtful	False, duplicated, or misinterpreted sources

In case of supporting, independent (dating not relying on historical information) archaeoseismic, or paleoseismic evidence, the reliability of the given event is raised by a degree. For example, an event based on secondary sources that rely upon other secondary or unknown sources but is recorded in supporting archaeoseismic or paleoseismic evidence is graded "moderate" degree instead of "poor"

researchers as an expert group (e.g., Dalkey 1969; Linstone and Turoff 2011), are well worth consulting. Accordingly, we also assigned each of the damaging earthquakes a size degree (see definitions in Table 2).

The compilation described above resulted in three separate lists: (i) reliable earthquakes that in our opinion were most probably associated with the DST and affected Israel and its close surroundings; (ii) questionable earthquakes that should be re-evaluated or ignored; and (iii) earthquakes that probably occurred elsewhere but were erroneously associated with damage in Israel. The complete compilation process is presented in Fig. 3, and the resulting lists appear in Appendices 1–3.

4 Classifying the earthquakes

The compiled list of reliable earthquakes we refer to as "probably occurred" contains 71 earthquakes (electronic supplement, Appendix 1) that were attributed to moderate degree of reliability (symbol M_R) or higher (see definitions in Table 1 and Fig. 2). This threshold reflects the significance we ascribe to the use of contemporary or near contemporary sources in determining the reliability of a report. Of the 71 earthquakes, 32 caused damage to at least one locality within the inspected area (Table 3). The other 39 are all mainshocks that were only felt within the study area, although some of them did cause destruction beyond it.

Although the books of Genesis and Joshua give several descriptions of environmental effects that might be associated with earthquakes (Bentor 1989), the first reliable description that seems to cite a specific earthquake appears at the beginning of the book of Amos (Amos 1.1). It does not specify any destruction or damage but clearly refers to the prophecy of Amos in relation to the rule of kings Uziah of Judea and Yerova'm of Israel, a time frame that we are able nowadays to reconstruct reliably as c. 760 BCE (Ambraseys 2009; Guidoboni et al. 1994). After this event and up to the 31 BCE event, no meaningful quakes are mentioned although further questionable reports do appear (e.g., Zechariah, 14.4-5; Isaiah, 2.19, 21), but to date, we are unable to authenticate any of them. This means nearly 700 years of "silence," although it is reasonable to assume that earthquakes did occur but somehow were not documented. Thus, in order to better assess the recurrence interval of the damaging earthquakes, we focus on the time frame between the 31 BCE and the 1927 AC earthquakes. This leaves us with 31 reliable damaging earthquakes in about 1960 years, that is, one event per ~60 years on average, but not regularly with time. This figure well coincides with Agnon (2014) estimating an event every 65–70 years. Considering only the 20 earthquakes reported also causing casualties (Table 3), indicates a single event per century, again irregularly. Inspecting the last millennium only, we count 21 damaging earthquakes and 14 earthquakes with casualties, i.e., one event per ~45 and ~70 years, respectively. Being aware of the possible incompleteness of the reports, these intervals might be even shorter.

We also identify 41 questionable entries (electronic supplement, Appendix 2) that appear in the existing literature. These are classified into (1) doubtful earthquakes, most probably originating from duplicated records, amalgamations, and erroneous entries, and (2) earthquakes that appear in the literature without indication of their historical sources or that are reported by doubtful sources. Finally, we recognize 46 earthquakes that, in our opinion, are reliable and did occur but were interpreted erroneously as causing damage in Israel (electronic supplement, Appendix 3). This list contains earthquakes that originated along the DST away from

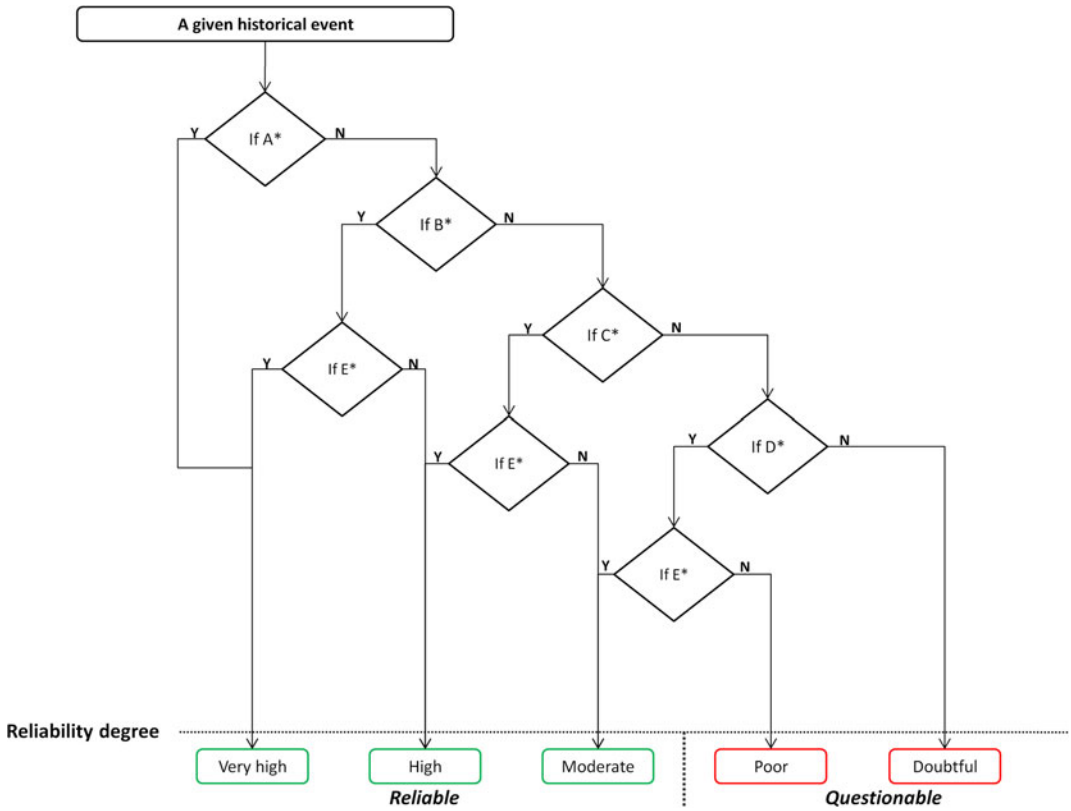

Fig. 2 Decision flow chart for determining the reliability of a given earthquake according to the following criteria: (*A*) At least two contemporary or near contemporary independent sources; (*B*) at least one contemporary or near contemporary source; (*C*) at least one secondary source that draws from at least one reliable contemporary or near contemporary source; (*D*) secondary sources that rely upon other secondary or unknown sources; (*E*) supporting independent (dating not relying on historical information) archaeoseismic or paleoseismic evidence. For full description of the reliability degrees, see Table 1

Israel as well as earthquakes associated with neighboring tectonic sources off the DST system.

Although much effort has been made in screening the historical data, the compiled lists are far from being complete. In case other original historical, archaeological, or paleoseismological evidence is discovered or new interpretations of existing sources are raised, earthquakes should accordingly be added, removed, or shifted between the three lists.

5 Temporal distribution of the earthquakes

Inspecting the documentation of the earthquakes over the past history, we should bear in mind that the Levant is located at the crossroads of Asia, Europe, and Africa, and as such, it has been under several political regimes during the last two millennia. Figure 4 presents the number of reported earthquakes per 100 years along these periods, classified into reliable and doubtful

Table 2 Size of earthquakes classified by degrees, from light (Lht) to great (Grt)

Degree	Size	Symbol	Description	Estimated magnitude
1	Light	Lht	Felt only	$4 \le M < 4.9$
2	Moderate	Mod	Slight damage to buildings and other structures	$5 \le M < 5.9$
3	Strong	Str	May cause a lot of damage in very populated areas	$6 \le M < 6.9$
4	Major	Maj	Major earthquake. Serious damage	$7 \le M < 7.9$
5	Great	Grt	Great earthquake. Can totally destroy communities near the epicenter	$M \ge 8$

Each degree represents a possible range of magnitudes (adapted from Ambraseys and Jackson 1998)

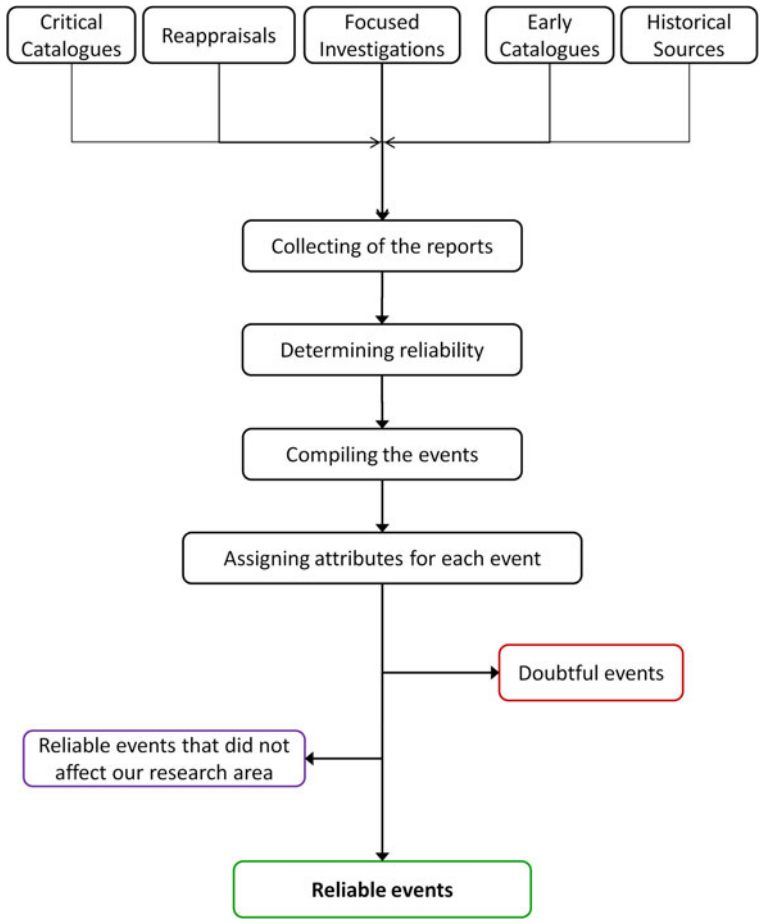

Fig. 3 The complete compilation process. Note the separation of the results into three lists: (1) reliable earthquakes (see also Appendix 1); (2) doubtful earthquakes (Appendix 2); and (3) reliable earthquakes that occur but did not damage any locality within the research area (Appendix 3)

entries. Accordingly, up to the Roman period, the number of doubtful earthquakes is greater than that of the reliable ones. Starting from the Byzantine period, from the fourth century and onwards, the reliable earthquakes constitute ~60 to 80 % of the total reported number. Exceptional is the Mamluk period in which the number of the reliable and the doubtful earthquakes is equal. This period also breaks the expected trend in growth in the total number of reports as we get closer to our present times—it has much fewer reports relative to the preceding Crusader or the following Ottoman periods.

Considering the temporal distribution of the damaging earthquakes (Table 3), we detected three intervals of increased reporting along with a rise in the strength of the earthquakes (Fig. 5): (1) between the fourth and mid-eighth centuries; (2) between the beginning of the eleventh and the end of the thirteenth centuries; and (3) from mid-eighteenth century up to our last inspected historical earthquake of 1927 CE, but this period may not have faded out yet. The first interval includes the earthquakes of 363 and 749 that affected Palestine and the 303, 502, and 551 quakes that affected mainly the southern Lebanese coast. The second period includes the destructive earthquakes of 1033, 1063, 1068, 1157, 1170, 1202, 1212, and 1293, while the third phase that consists of five destructive earthquakes (1759 October and November, 1834, 1837, and 1927) and many other felt ones begins approximately at the first half of the eighteenth century.

5.1 Were there strong earthquakes missed by historians?

We witness cycles of reporting and it raises the question whether these periods reflect the actual seismic activity or they are just an artifact due to incomplete reporting. Figure 6 demonstrates the cumulative number of the reliable felt and damaging earthquakes against the changing regimes in Palestine at the time, and they seem to be in accord, more or less, with each other. This is not

Table 3 List of reliable damaging earthquakes that occurred between c. 760 BCE and 1927 CE and hit Israel and its close surroundings in at least one locality (see Fig. 1)

Date	Reported damaged localities	Estimated magnitude in previous studies	Average magnitude	Size degree	Casualties
c. 760–750 BCE	Jerusalem, Judea	7.8–8.2 (AUS); 8.2 (BM5); 7.3 (BM)	–	–	–
31 early spring BCE	Judea	6–6.5 (KA2); 6.7 (MIG); 6.7 (BM); 7 (BM5); 7 (TUAR)	6.7	Str	M
303 April 2	Tyre	7.1 (BM); 7.1 (MIG after BM)	7.1	Maj	M
363 May 18–19 (night)	Antipatris, Caesarea, Gophna, Hada (unknown), Areopolis, Ashdod, Zippori, A-Salt, Haifa, Jaffa, Baniyas [Israel], Palestine, Tiberias, Bet-Guvrin, Petra, Sebastia, Samaria, Zoar, Bet-She'an, Jerusalem, Nicopolis [Israel], Ashqelon, Lod	6.7 (BM); 6.4 (BM5); 7 (TUAR); 6.7 (MIG after BM)	6.7	Str	M
418	Palestine	6.2 (TUAR); 6.9 (MIG)	6.5	Str	–
502 August 22 night	Akko, Tyre	7 (TUAR); 7 (MIG after BM); 7 (BM)	7.0	Maj	–
551 July 9	Sarafand, Tyre	7.8 (TUAR); Ms 7.2 (DAR); 7.5 (MIG); 7.5 (BM)	7.5	Maj	M
634 September	Jerusalem, Palestine	5.5 (light damage, personal judgment)	5.5	Mod	–
659 June 7	Jericho, St. John, Palestine	6.6 and 6.6 (BM; BM5)	6.6	Str	M
749/Early 750	Jordan River, Palestine, Tabor Mt., Tiberias, Bet-She'an, Khirbet al Karak	$M > 7$ (MAR); 7–7.5 (MIG); 7.3 (BM); 7.3, 7.3 (BM5, BM3); less than 7 (KA2, BEG)	7.2	Maj	M
~~756~~ 757 March 9	Jerusalem, Palestine	6 (moderate damage, personal judgment)	6.0	Str	–
1033 December 05 (night)	Jericho, Ramla, Palestine, Baniyas [Israel], Ashqelon, Jerusalem, Akko, Gaza, Nablus, Hebron, el-Badan	7.1 (MIG); 6.7 (BM); 6.7 (BM5)	6.8	Str	M
1063 August	Akko, Tyre	6.5–7 (MIG);	6.7	Str	F
1068 March 18	Palestine, Elat	6.9 (MIG); 6.6–7 (ZIL); $7.0 \leq MS \leq 7.8$ (AMJA); 7 (BM); Me = 8.1 (GC)	7.3	Maj	M
1068 May 29	Ramla	6 (GC)	6.0	Str	M
1117 June 26	Jerusalem	5.5 (Light damage, personal judgment)	5.5	Mod	–
1157 August 12 (night)	Jerusalem	7–7.5 (MIG); $M > 7$ (AMBR); 7.3 (BM)	7.2	Maj	M
1170 June 29 (0345)	Baniyas [Israel]	7 (MIG); $M > 7$ (AMBR); 6.6 (HOAV); 7.9 (TUAR); $7.0 \leq MS \geq 7.8$ (AMJA); 7.5 (BM)	7.3	Maj	M
1202 May 20 (0240)	Akko, Samaria, Tebnine, Vadum-Jakub, Baniyas [Israel], Hunin Castle, Nablus, Tyre, Jerusalem	7.5 (MIG); 7.5 (AMME); 7.6 (HOAV); 6.8 (BM); 6.8 (BM4); $M > 7$ (EMARB); $7.0 \leq MS \geq 7.8$ (AMJA)	7.2	Maj	M
1212 May 01	Karak, Elat, St. Catherine, el-Shaubak	6.7 (MIG)	6.7	Str	F
1293 January 11–February 08	Karak, Ramla, Lod, Gaza, Tafilah, Qaqun	6.6 (MIG)	6.6	Str	–
1458 November 16	Ramla, Lod, Hebron, Jerusalem, Karak	6.5 (MIG)	6.5	Str	M
1546 January 14 (afternoon)	Hebron, Maa'yan Elisha, Jericho, St. John, Bethany, Jerusalem, Jordan River, Nablus, Beit-Jala, Bet-Lehem, Batir	$M \sim 6$ (KA2); 7 (TUAR); 6.1 (MIG); 7 (BM); 7.7 (BM5, BM3)	6.6	Str	M
1588 January 04 (13:00)	Elat, St. Catherine	6.7 (MIG)	6.7	Str	–
1643 March 23	Jerusalem	5.5 (light damage, personal judgment)	5.5	Mod	–
1759 October 30 (03:45)	Akko, Quneitra, Benot Ya'aqov Bridge, Sassa, Nazareth, Safed, Tiberias, Nablus	Ms ~ 6.6 (AMBR); 6.5 (BM)	6.5	Str	M

Table 3 (continued)

Date	Reported damaged localities	Estimated magnitude in previous studies	Average magnitude	Size degree	Casualties
1759 November 25 (19:23)	Hula, Deir Hanna, Safed, Nabatiya, Nablus, Sassa, Hermon Mt., Akko, Beit-Jann, Hasbaya, Deir Hanna, Quneitra, Caesarea, Marjuyun, Tiberias, Haifa, el-Rama	7.4 (MIG); MS ~ 7.4 (AMBR, 1989); Ms = 7.4 (AMJA; WECO); 7 ≤ M ≤ 7.2 (GOM); 7.4 (BM)	7.3	Maj	M
1817 March	Jerusalem	5.5 (light damage, personal judgment)	5.5	Mod	–
1834 May 26 (13:00)	Dead Sea Southwest, Caesarea, Jerusalem, Jaffa, Umm al-Rassas, Deir Mar-Saba, Bet-Lehem, Medaba	6.4 (MIG); 6.3 (BM)	6.3	Str	–
1837 January 01 (16:35)	Nabatiya, Qana, el-Fara, el-Salha, Jish, Marun Al-Ras, Bint-Jbeil, Malkiyya, Qadas, Ya'tar, Tebnine, Hunin Castle, Baniyas [Israel], Metula, Zeqqieh, Deir Mimas, el-Khiam, el-Tahta, Deir Mar-Elias, Qaddita, Jibshit, Gaza, Arraba, Attil, Qaqun, Tubas, Ajloon, Nablus, Zeita, Harithiya, Jerusalem, Kfar Bir'im, Lake Tiberias, Hasbaya, Kafr Aqab, Jeresh., Areopolis, Hula, Tarshiha, Dallata, Jaffa, Mrar, Ein-Zeitun, Tyre, Atlit, Meron, Eilabun, Akko, Migdal, Irbid, Reina, Safed, Tiberias, Hadatha, Haifa, Zemah, Kafr Kanna, Kafr, Sabt, Lubiya, Nazereth	7.4 (MIG); *M* > 7 (AM3); MS = 7.4 (WECO); Ms 7.1 (NEM after AM3); 6.7 (BM)	7.1	Maj	M
1839	St. Catherine	5.5 (light damage, personal judgment)	5.5	Mod	–
1927 July 11 (15:04)	Salfit, Soreq River, Nabi-Musa, Abadia, Ajloon, Gaza, Atara,, Meslovia, Lod, Ein-el-Qilt, Ein-Dok, Azraa', Deir, Mar-Saba, Merhavya, Masada, Mrar, Maa'yan Elisha, Moza, Medaba, Migdal, Karak, Kafaringi, En, Harod, Ramat Yishai, Migdal Yava, Qiryat Anavim, Dead, Sea North 1, Tel Aviv, Nablus, Shunam, Refidie, Ramat, Rahel, Dara'a, Ramla, Shiloah Village, Rehovot, Amman, Reina, Rammala, *En-Kerem*, Qalqilya, Kabab, Zora, Safed, Zemah, Petah Tiqwa, Eqron, Afula, Akko, Ein-Fara', Ein Qinya, Ein-Musa, Rosh ha-'Ayin, Be'er-Sheva, Jiftlik, Gimzoo, Gedera, Batir, Beit-Surik, Bet-She'an, Beit-Liqya, Bet-Lehem, Bet-haKerem, Beit-Jimal, Bet-Guvrin, Toov, Mt., Bira, Jisr Magmi, a-Ram, Irbid, A-Salt, el-Hama, Abu Tlul, Nazereth, Jaffa, Yarmouk Fall, Jordan River, Abu-Dis, Abu-Ghosh, Beit-Jala, Zarka Maein, Amman-Jordan Road, Jerusalem-Jericho Road 2, Jerusalem-Jericho Road, Jericho, Holly Mt., Armon ha-Naziv (Jerusalem), Jerusalem, Yalo, Tulkarm, Tiberias, Tabgha, Jaljulya, Hebron, Jenin, Zikhron Yaa'qov, Zarka, Wadi al-Shueib, Mt. Scopus, Olives, Mt., Deir A-Sheikh, Daharia, Bnot-Ya'akov Bridge, Allenby Bridge, Gesher, Jeresh, Michmach Village, Haifa	6.25 (AVN; AVN2); 6.2 (BM2); 6.3 (MIG) = 6.25	6.25	Str	M

Date year of occurrence and whenever possible—also month, day, and hour; *Reported damaged localities* localities damaged within the research area (Fig. 1) that we consider as of moderate (M_R) or higher degree reliability (Table 1; localities that were affected by the listed earthquakes outside our study area are not mentioned); *Estimated magnitude in previous studies* list of studies that estimated the magnitude of the given event. See Appendix 4 for abbreviation reference; *Average magnitude* averaged value of previous magnitude estimations; *Size degree* following categorization made by Ambraseys and Jackson (1998); *Casualties* estimated according to historical reports: *F* few (ten or less), *M* many (more than ten)

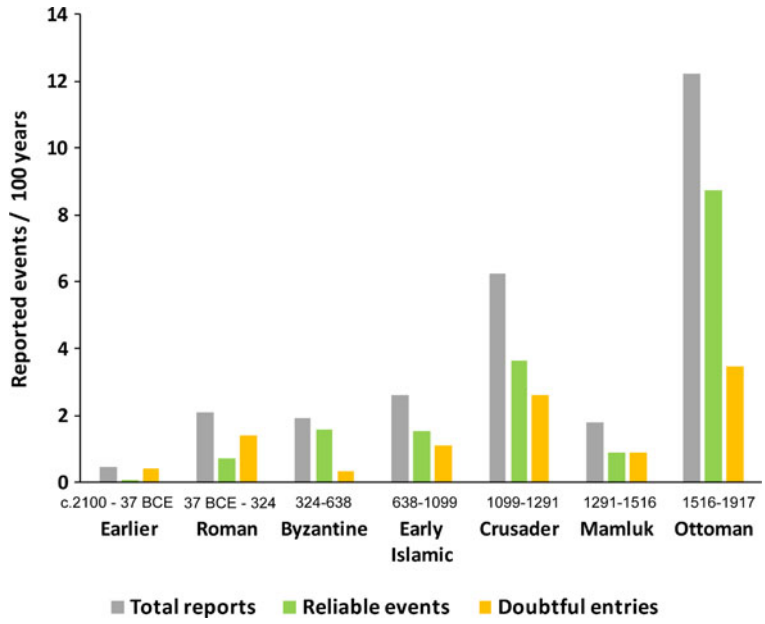

Fig. 4 Average number of reports of felt and damaging earthquakes normalized per 100 years and classified into historical periods and regimes. Note the division into the total number of reports, the reliable (Appendix 1) and the doubtful (Appendix 2) earthquakes

surprising since each of the ruling regimes paid different attention to the land of Palestine.

Prior to the second poorly documented period in the mid-eighteenth century, the Byzantines and their successors, the Umayyads, had a lot of interest in Palestine. However, after the Abassid conquest (750 CE), the political, cultural, and economic center moved eastward to Bagdad (Iraq) and the focus on Palestine significantly decreased (Elad 1978). Towards the end of the eleventh century, the Crusaders defeated the Abbasids and the attention to Palestine rapidly increased again (Praver 1984). The tendency of rising interests again alternated during the Mamluk and the first half of the Ottoman periods. At that time, the land of Palestine was mostly abandoned and thus fewer reports exist. From the mid-eighteenth century, European attention towards the Levant increased, in particular after the journey of Napoleon in 1799 (Ben-Arieh 1970). Then and with greater intensity from the nineteenth century onward with the expansion of media and modernization, the

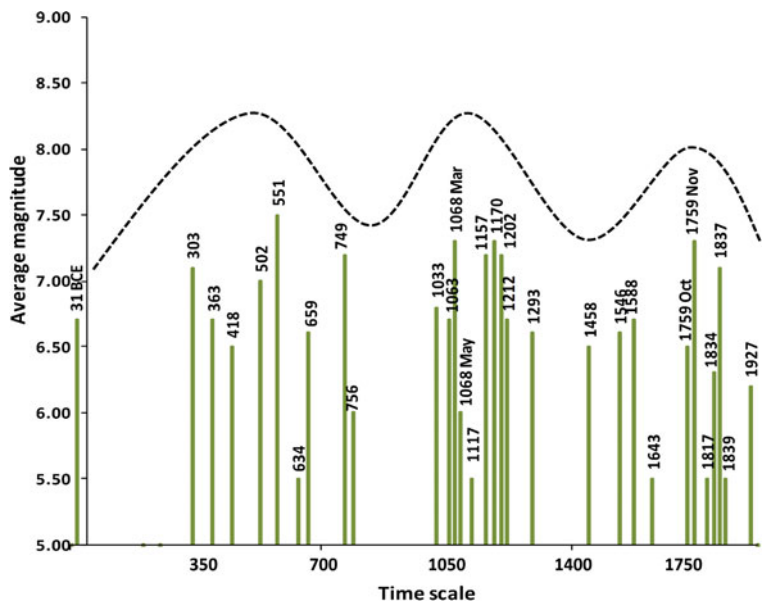

Fig. 5 Temporal distribution of the reliable damaging earthquakes along with the average value of the magnitudes attributed to it in previous studies (Table 3). Note the three alleged cycles of earthquakes in time and size (*dashed line*). The *labels above the bars* denote the year the earthquake occurred

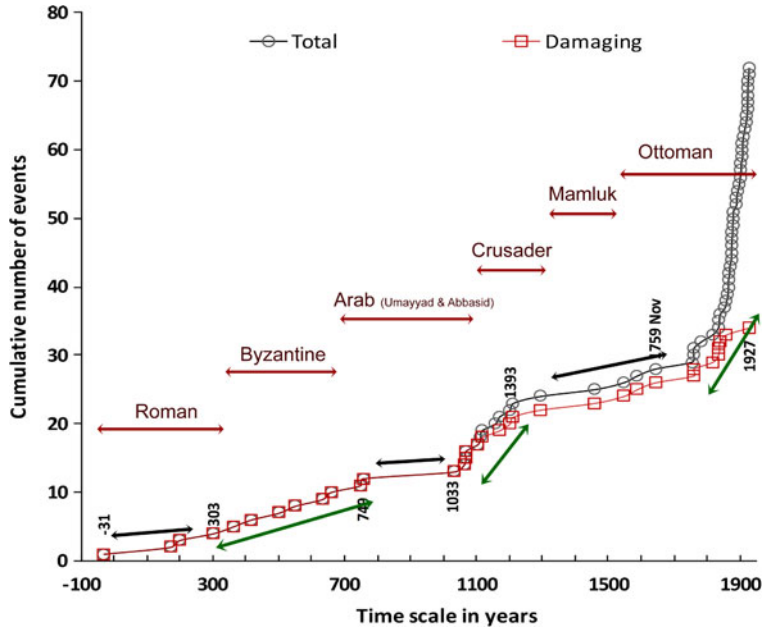

Fig. 6 Cumulative number of the reliable earthquakes that hit Israel and its close surroundings in the last two millennia (foreshocks and aftershocks are excluded). *Red squares and black circles* mark the damaging earthquakes (Table 3) and the cumulative number of damaging and felt earthquakes (Appendix 1) together, respectively. Destructive earthquakes that initiate or end sequences of reporting are labeled. The three cycles of low and increased reporting are demarcated by *black and blue arrows*, respectively, whereas the changing regimes are noted by *brown labels and arrows*

number and quality of the reports rise steeply (Fig. 6). Thus, it is reasonable to assume that when Palestine attracted less attention, the number of reports decreased as well.

Indeed, the modern historical catalogues (Ambraseys 2009; Ambraseys et al. 1994; Guidoboni and Comastri 2005; Guidoboni et al. 1994) do contain reports of considerable seismic activity during the three poorly documented periods. However, the reported damage was not in Palestine but rather in its bordering neighboring countries at the time and thus is not considered in our analysis. During the first period for example, earthquakes occurred in c. 20 BCE in Egypt, 17–15 BCE and 76 CE in Cyprus, and 37 CE, c. 41–54 CE, and 115 CE in northern Syria. The second period, between mid-eighth and mid-eleventh century, includes earthquakes that affected mainly southern Syria (e.g., 813–820 CE, 847 CE, 973 CE, and 991 CE in Syria, 835 CE, 850 CE, and 860 CE in Antioch, and 956 CE in the eastern Mediterranean). The third period, during the Mamluk and the first half of the Ottoman periods, includes earthquakes that damaged Tripoli (1339 CE and c. 1706 CE), Damascus (1399 CE, 1563 CE, 1565 CE, 1618 CE, 1627 CE, and 1712 CE), Baa'lbek (1604 CE, 1606 CE, and 1715 CE), Hama (Syria) in 1626, and Yabrud (Lebanon) in 1705. Since several strong remote earthquakes such as in 1157 and 1170 CE caused damage also in Israel, it is possible that at least some of the earthquakes mentioned above did cause some damage in Palestine but was not documented.

Yet the hiatus or lack of reporting we attribute to the historical share may also, at the same time, support the assertion that there were no damaging earthquakes in Israel during these periods and thus there was nothing to write about. To cope further with this issue, we resort to physical evidence coming from alternative disciplines outside the historical archive, namely, paleo- and archaeo-seismology in our case.

5.2 Complementary sources of information: paleo- and archaeo-seismology

Concentrating on the physical evidence for strong earthquakes that may have affected our research area during the historical period and in particular the "silent" time windows, we find a wealth of evidence. Ken-Tor et al. (2001) examined and correlated eight disturbed sediment layers in the fan deposits of the Ze'elim terrace along the Dead Sea shorelines with historically documented earthquakes (Fig. 1). Migowski et al. (2004) extended the research and inspected the disturbances in the lacustrine sediments of the En-Gedi core and found records of seismic activity, some dated to the poorly documented historical periods. Agnon et al. (2006) followed their study and identified the 1202 CE event. Kagan et al. (2011) compared the former studies

with two additional sites in Ze'elim and Ein-Feshkha and pointed towards a quiescent period between the end of the second century and the beginning of the fourth century CE, as well as a high rate of activity in between the ninth and the eleventh centuries. Nonperiodic behavior between the first and seventh centuries CE was also suggested by Wechsler et al. (2014), who trenched the Jordan gorge fault in northern Israel. Outside of Israel and along the northern segments of the DST, Gomez et al. (2001) elaborated on the 1705 CE event, whereas Akyuz et al. (2006) inspected the 859 CE and 1408 CE earthquakes.

The archeoseismic studies of Russell (1985) concluded damage to Avedat and Shivta in the Negev in c. 110–114 CE, whereas Bikai (2002) pointed to a mid-eighth century event and Hayens et al. (2006) concluded damage to Qasr Tilah, south of the Dead Sea, during the earthquake of 873 CE.

5.3 Filling the "historical hiatus?"

Integrating the evidence coming from paleo- and archaeo-seismology as well as historical reports of Palestine does show significant seismic activity during the poorly documented periods in our research area (Table 4). The case of the "137–206" and "165–236" paleoseismic earthquakes suggested by Wechsler et al. (2014) is a good example of the lack of historical reports that could be matched to this physical evidence. Having ruptured the surface, these earthquakes could have been of M6 at least and therefore comparable in size to other historical earthquakes. Thus, these earthquakes do exemplify the incompleteness of the historical share in Palestine during the historically poorly documented periods. We do not reject the possibility of seismic cycles during the last 2000 years, for there still appears to be a quiescent period between the second and fourth centuries and some implications of cycles afterwards. The target of future historically based studies is to further elaborate on these "holes" of reporting, construct an integrated, multi-sourced list of earthquakes, and figure out the form of seismic cycles in Israel during the historical period.

6 Summary and conclusions

This study presents a critical compilation of historical accounts with the aim of constructing a dependable and accurate list of historical earthquakes that damaged or were felt in Israel and its close vicinity. Much effort was made in the systematic collection and organization of the data as well as scrutinizing the authenticity and credibility of each of the historical earthquakes. Overall, we were able to construct a list of 71 reliable earthquakes that caused damage or were felt in Israel

Table 4 Possible seismic activity in Palestine not documented during the "historical hiatus" periods, as well as seismic activity reported outside Israel during these periods

Hiatus during historical periods	Paleoseismic/archaeoseismic evidence for activity during the "historical hiatus"	Historical documentation of earthquakes outside the study area during the "historical hiatus"
31 BCE–303 CE	**KEN**, 33 (5–50) **MIG**, 33; 76; 90; 112; 115; 175 **KAG**, 33; 115 **WEC2**, 33 (392 BCE–91 CE), 130? (137–206), undocumented (165–236) **RUS**, c. 110–114 CE	**AM; GC; GCC:** 20 BCE (Egypt); 19 BCE (Syria); 17–15 BCE and 76 (Cyprus); 37, c. 41–54, 115 (northern Syria)
756 CE–1033 CE	**MIG**, 859; 991; 1032 (?) **KAG**, 847; 859; 873; 956; 991 **HNA**, 873 **AAK**, 859 **BIK**, mid-eighth century	**AM; GC; GCC:** 813–820, 847, 973, and 991 (Syria); 835 and 850, 860 (Antioch); and 956 (eastern Mediterranean)
1293 CE–1759 CE	**MIG**, 1408 (?); 1656; 1712 **KAG**, 1312 **GMD**, 1705 **AAK**, 1408	**AM; GC; GCC:** 1339 and c. 1706 (Tripoli); 1399, 1563, 1565; 1618, 1627, and 1712 (Damascus); 1604, 1606, and 1715 (Baa'lbek); 1626 (Hama); 1705 (Yabrud)

Abbreviations of the data presented in bold: KEN Ken-Tor et al. (2001), *MIG* Migowski et al. (2004), *KAG* Kagan et al. (2011), *WEC2* Wechsler et al. (2014), *HNA* Hayens et al. (2006), *RUS* Russell (1985), *GMD* Gomez et al. (2001), *AAK* Akyuz et al. (2006), *BIK* Bikai (2002), *AM* Ambraseys (2009), *GCC* Guidoboni et al. (1994), *GC* Guidoboni and Comastri (2005)

and its close surroundings (Appendix 1). Parallely, we compiled lists of 41 doubtful earthquakes (Appendix 2) as well as 46 earthquakes that did occur elsewhere but were erroneously associated with damage in Israel (Appendix 3). We are aware that these lists might be incomplete and should more original evidence be discovered or a new interpretation of existing sources be raised, earthquakes should be added, removed, or shifted between the lists accordingly.

Of the 71 reliable earthquakes, 31 are considered to have caused damage to at least one locality in Israel between 31 BCE and 1927 CE, that is, a damaging event every ~60 years on average, but not regular with time. An earthquake causing casualties is reported to occur every ~100 years, although not evenly in time. Examining only the last millennium, we count 21 damaging and 14 deadly earthquakes, i.e., one event per ~45 and ~70 years, respectively.

Since the first century CE, we identify three periods of increased reporting: (1) between the fourth and the mid-eighth century; (2) from the beginning of the eleventh to the end of the thirteenth century; and (3) from the end of the eighteenth century to the last entry in 1927, though this period might be extended until today. We find that these peak and low sequences alternate, more or less, in accordance with the changing regimes in Palestine at the time. Nevertheless, paleo- and archaeo-seismological evidence of strong earthquakes, such as the paleoseismic findings of the "137–206" and "165–236" earthquakes for which there is no match during the periods of low historical reporting ("historical hiatus"), suggest the incompleteness of the historical share. Thus, we argue that the apparent cycles of historical reporting do not necessarily reflect the actual pattern of seismicity and further investigation is needed to establish the true nature of the cyclicity of strong earthquakes in this region.

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Supplement material to reappraised list of historical earthquakes that affected Israel and its close surroundings

Dataset · April 2016

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Appendix A: The list of reliable historical earthquakes most probably associated with the DST activity that affected Israel and its close surroundings

Following is the list of reliable historical earthquakes that in our opinion are most probably associated with the activity of the Dead Sea Transform (DST) and were felt or caused damage in Israel and its close surroundings. The list covers the period between c.760-750 BCE and 1927 CE. Each entry contains the following information: **Date**: time of occurrence in year and whenever possible - also the month, day and hour. Asterisk (*) denote earthquake that caused damage in Israel; **U:** uncertainty of the origin time (in years); **Type**: the type of event (following Salamon 2009): S - Single, C - Cluster, F - Foreshock, A - Aftershock, FM - Foreshock and Main, MA - Main and Aftershock; FMA - Foreshock, Main and Aftershock, and U - Undefined; **Rel.**: degree of reliability: V_R - Very high, H_R – High and M_R – Moderate (further details in Table 1); **Zone**: association of the event with a geographic region of the DST (see Fig. 1): N – North (northern Lebanon and Syria), C – central (Israel and southern Lebanon), S – South (southern Israel, Sinai and Gulf of Aqaba); **Most damaged or felt locations**: localities reported to have been most severely affected or felt; **Description**: a short description and comments with some selected references and citations; **Modern References**: abbreviated catalogues, articles and reappraisals that were used during the compilation process of the event's entry (see Appendix 4 for abbreviations).

No.	Date (y/m/d/h)	U	Type	Rel.	Zone	Most damaged or felt locations	Description	Modern References
1	**c.760-750 BCE***	±10	S	H_R	C	Judea	Damaging event during mid-8th century BCE. Amos references his prophecy according to an earthquake occurred two years before in a time frame that can be reconstructed today, during the reign of Uziah and Jerova'm, kings of Judea and Israel, respectively. Consequently, we assume the event had indeed occurred and was significant enough to be remembered and documented. However, apart from Amos, there are only a few late secondary sources (**AM**; **GCT** and references therein) that imply of a possible damage in Jerusalem but they cannot be authenticated. Other archaeological evidence cannot be unequivocally associated with this event (**AM**)	AM; GCT; AM2; SAL; SAL2; WALE; BEN; ZIL2

No.	Date (y/m/d/h)	U	Type	Rel.	Zone	Most damaged or felt locations	Description	Modern References
2	**31 early spring BCE***	±1	S	H_R	C	Judea	Destructive event occurred in the Judea area of that time. Josephus notes that during the Actium war a devastating earthquake occurred killing 30,000 people (Josephus Ant. 15, 121-124; Josephus Bel. 1, 369-379). Generally, Josephus is considered reliable but tends to exaggerate (**BR**; **MZ**) and thus 30,000 deaths seems to be overestimated. Since Judea of that time extended up to Syria and Hawran and the reports are related to Herod's battle with the Nabataeans, the epicentral region might be north of what we reckon today as Judea. The supposed damage to Jerusalem (**AAT**) and the Galilee (**SI**) are contradicted by **AM**. Paleoseismic evidence near Deir-Hajla (**RH**) and Qumran (**NURO**) were questioned by **AM** and **KA3,** respectively, although **KEN** dated possible seismic activity at that time in a Ze'elim gully. **KA2** notes that this was probably a moderate event. **WEC2** found evidence for a possible event between 392 B.C.E. and 91 C.E. Indeed, this evidence can be related with the 31 BCE event, but also with another, undocumented one. **KEN** dated an event between 50 BCE – 230 CE and associated it with this event.	AM; GCT; KA; KA2; SAL; BR; MZ; AAT; SI; RH; NURO; KA3; KEN; AMM; WEC2
3	**303 Apr 2***	-	S	H_R	C-N	Sidon, Tyre	Damaged mainly the south Lebanese littoral. Eusebius and Orosius date the event to 303 and describe damage in Syria, Sidon and Tyre (**AM; GCT**). They describe large numbers of people (Eusebius) or thousands (Orosius) who were killed. The numbers however, seems to be exaggerated. The fact that the affected cities are located along the Lebanese littoral may suggest that the event	AM; GCT; SAL; SAL2; RUS; SDM; WEC2

No.	Date (y/m/d/h)	U	Type	Rel.	Zone	Most damaged or felt locations	Description	Modern References
							may have been generated somewhere offshore. **WEC2** found an evidence for a possible event between 250–310 C.E or 269–329 C.E. or 294–369 C.E.	
4	**363 May 18-19 (night)***	-	MA	V_R	C	Palestine	Two earthquakes, on Sunday, 18/05 at the 3rd and 9th hours after sunset (i.e., Monday, 19/05 at around 03:00). The latter seems to have been less damaging and affected the northern parts of Palestine (**AM**; **GCT; KA**). The damage in Antioch (modern Antakya) as reported by Libanius seems to have resulted from the 365 earthquake (see Appendix 3). The earthquake extent is described in a contemporary Syrian letter attributed to Cyril, the Bishop of Jerusalem (Brock 1977). The record of damage in Petra is supported by three inscriptions found in Zoar of 4 people who perished during the earthquake (**MEI**). Additional questionable records of the earthquake are also found in archaeological excavations (**RUS**; **RUS2**) and paleoseismic findings (**KEN**). **WEC2** found an evidence for a possible event between 294–369 C.E. **KEN** dated an event between 358 and 580 and associated it with this event. **MIG** suggest it was recorded in lacustrine sediments along the Dead Sea shores.	AM; GCT; KA; SAL; RUS; RUS2; SDM; KEN; AMM; WEC2; MIG
5	**418/419***	±1	U	M_R	C	Palestine	Affected Palestine at that time. The event was reported by two contemporary writers, Augine and Idatius. **AM** suggests that Augine, claiming that "great cities collapsed", could be interpreted as a theological poet while Idatius, reporting that "Jerusalem as well as others were shaken" was writing when in fact he was living far away in the Roman province. Archaeological remains	AM; GCT; KA; SAL; RUS; MIG

No.	Date (y/m/d/h)	U	Type	Rel.	Zone	Most damaged or felt locations	Description	Modern References
							(**RUS**) need further authentication. **MIG** suggest it was recorded in lacustrine sediments at the Dead Sea shorelines.	
6	**502 Aug 22 night***	-	S	H_R	C-N	Akko	Damage reported along the northern coastline of Palestine at that time. The absence of damage inland may suggest an offshore epicenter (**AM**). **WEC2** found an evidence for a possible event between 505 and 593. **MIG** suggest it was recorded in lacustrine sediments along the Dead Sea shores.	AM; GCT; KA; SAL; RUS; SDM; WEC2; MIG
7	**551 Jul 9***	-	MA	V_R	C-N	Lebanon, Syria	Damaged mainly the south Lebanese littoral. John of Ephesus describes a tsunami and two events, about 1 hour apart from each other. According to **AM**, Agathias mentions this event in reference to Alexandria, where he was that year. However, **GCT** places this report in 554 as an event felt in Egypt and adds an event, also reported by Agathias that occurred during 554-558 in the island of Cos. This and the facts that only the coastal cities in Lebanon were damaged and that there was a tsunami, leads to an assumption that Agathias might have duplicated a remote event. The other alternative is that the epicenter was in the sea or inland, very close to the shore (**AM**). Caesarea and Gush-Halav could have been also affected (**RUS**). Jerusalem was not reported as damaged. **WEC2** found an evidence for a possible event between 505–593 C.E. **MIG** suggest it was recorded in lacustrine sediments along the Dead Sea shores	AM; GCT; KA; SAL; SAL2; RUS; SDM; DAR; AMA; ELI; WEC2; MIG
8	**634 Sep***	±2	MA	M_R	C	Palestine, Jerusalem	Affected Palestine at the time. The event is based upon the evidence of Theophanes (ca. 778-845), credited as reliable (**AM**; **GCT**). Byzantine sources (Michael the	AM;GCT;KA;SAL;RUS; SDM; WEC2;

No.	Date (y/m/d/h)	U	Type	Rel.	Zone	Most damaged or felt locations	Description	Modern References
							Syrian, 12th century) and Arabic sources (al-Makin, Abu'l Fara) seem to copy Theophanes. **AM** proved that the testimony of Michael the Syrian is somehow vague, stressing that contemporary source remains silent. **WEC2** found an evidence for a possible event between 619–684 C.E.	
9	**659 Jun 7 (659 Sep-660 Aug)***	-	MA	M_R	C	Palestine, Jericho	Probably caused damage to central Palestine at the time. The date of event is confused in the Maronite chronicles and also by Theophanes though their implication of damaged localities seems to be correct (**AM**; **GCT**). Archaeological evidence (**RUSS**) is not decisive. The 659 Jun 9th is probably an aftershock of this event (**AM**). **WEC2** found an evidence for a possible event between 619 and 684. **MIG** suggest it was recorded in lacustrine sediments along the Dead Sea shores	AM; GCT; KA; SAL; RUS; BM; BM4; WEC2; MIG

No.	Date (y/m/d/h)	U	Type	Rel.	Zone	Most damaged or felt locations	Description	Modern References
10	**749/early* 750**	±1	FM	H_R	C	Palestine	An event that occurred in 749 which can be reliably dated according to numismatic evidence found in the ruins of Bet-She'an (Schitopolis) by **TSFO**. The historical sources partly support this claim but add 1 or 2 additional possible earthquakes. The near-contemporary Byzantine chronicler Theophanes reports on 3 earthquakes: (1) in 745/6 (6238, Alexandrian system) in Palestine, Syria and along the Jordan River (Theophanes); (2) 748/9 (6241) in Syria and Mesopotamia (Theophanes); and (3) 755/6 (6248) in Palestine and Syria (Theophanes). Theophanes was most likely using primary sources but may have also been confused, replacing damage that resulted in the first event with that of the second. The claim of 3 earthquakes is also supported by other two groups of sources (see **GCT; AM; KA; KA2**): (1) Syrian sources (e.g., Pseudo Dionysius that relies on contemporary accounts); (2) 4 Arabic writers (al-Dhahabi, al-Suyuti, Mujir al-Din and al-Ulaimi) who also add damage to Al-Aqsa in 757. Other studies referencing a single event, such as **MARG,** ignore most of the mid-8th century reports, describing at least two destructive earthquakes. **KA2** reinforces 3 earthquakes and notes that: (1) all single-event reports do not supply full date, i.e., day, month, year; (2) they neglect the dating according to the 'Feast of the Mary for the seeds' holyday; and (3) they mention in Palestine only Tiberias, Mt. Tabor and Jericho but not Jerusalem (in contradiction to the Arab sources). **AM**: The extent of damage, when referring to	AM; GCT; KA2; MAR; MAR2; TSFO; WE; AM4; BEG; AMA; MIG
11	**756(757) Mar 9***	±1	U	M_R	C	Palestine		AM;GCT;KA;KA 2;SAL; SDM;

No.	Date (y/m/d/h)	U	Type	Rel.	Zone	Most damaged or felt locations	Description	Modern References
							a single event (Cairo-Tiberias-Nicea-Khabura) is enormous and implies an earthquake that could hardly be generated by a geological strike-slip fault structure (as demonstrated in **WECO).** Thus, it is more likely that 3 separate earthquakes had occurred. **MIG** suggest the 749 earthquake was recorded in lacustrine sediments along the Dead Sea shores	
12	**1033 Dec 05 (night)***	-	MA	V_R	C	Ramla, Palestine, Syria (?)	Large earthquake heavily damaging Ramla and other cities in the center of Palestine. The main source is the letter of Salomon ben-Zemah (Ya'ari 1943, 70-73). **GC** places the epicenter in Palestine while **AM** claims the earthquake occurred in Syria. There are also reports of an associated tsunami (**SAL2** and references therein). The 1034 Feb 17th is probably a belated aftershock. **MIG** suggest it was recorded in lacustrine sediments along the Dead Sea shores	AM; GC; SAL; SAL2; AMJA; AMA; MIG
13	**1063 Aug***	-	MA	M_R	U	Syrian littoral	**AM**: The earthquake struck the Lebanese coast from Antakya to Tyre. The source was probably offshore between the Lebanese coast and Cyprus. **MIG** suggest it was recorded in lacustrine sediments along the Dead Sea shores	AM; GC; SAL; SDM; MIG
14	**1068 Mar 18***	-	MA	H_R	S	Gulf of Elat	Destructive earthquake reported in several independent Arabic sources (**AM; GC; KA**). **GC** places the epicenter at 34.95° / 29.55° with I_0 =IX and Me=8.1. Based on paleoseismic study, **ZIL** attributes a magnitude of 6.6 – 7 according to a vertical displacement of 1 m.	AM; GC; KA; SAL; SAL2; AMJA; AMA
15	**1068 May 29***	-	S	M_R	C	Ramla	Close in time to the 1068 March earthquake (see previous entry) but probably not related to it (**AM**). The primary source for both the earthquakes is Ibn al-Banna	AM; GC; SAL; MIG

No.	Date (y/m/d/h)	U	Type	Rel.	Zone	Most damaged or felt locations	Description	Modern References
							who mentions two dates: March 18th and May 29th. All other sources are secondary and cite each other (**GC; AM**). **MIG** suggest it was recorded in lacustrine sediments along the Dead Sea shores	
16	**1105 Dec 24 evening**	-	S	H_R	C	Jerusalem	Felt earthquake that was recorded by an eye witness (Fulcher of Chartres), accounted as reliable, and several creditable secondary sources. (**AM**). The earthquake did not result in damage but was felt in Jerusalem (**GC)**	AM;GC;KA;
17	**1113 Jul 18**	-	MA	H_R	C	Jerusalem	**AM**: Based upon the testimony of Fulcher of Chartres, probably an eye witness. **MIG** suggest it was recorded in lacustrine sediments along the Dead Sea shores	AM; MIG
18	**1117 Jun 26***	-	S	H_R	C	Jerusalem		AM; KA; SAL
19	**1157 Aug 12 (night)***	-	FMA	V_R	N	Apamea	Very destructive earthquake occurred in the northern part of the DST. **AM**: It ends a period of over a year of foreshocks. Probably occurred at the collision of the DST with the East Anatolian Fault with an epicenter near Apamea, Shaizar and Hama (**AM**). **GC** (relies on Ibn al-Jawzi) dates the earthquake to have occurred between August 9th and September 7th. **MIG** suggest it was recorded in lacustrine sediments along the Dead Sea shores	AM; GC; SAL; SAL2; AMJA; SDM; RAP; MIG
20	**1170 Jun 29 (0345)***	-	FM	V_R	C-N	Shaizar	Relatively large earthquake (**HOAV; AMJA; KA; AM; GC**) in northern Syria that was felt in what is present-day Iraq. Many of the localities that were hit by previous earthquakes were not completely repaired when the earthquake struck. **MIG** suggest it was recorded in lacustrine sediments along the Dead Sea shores	AM; GC; KA; SAL; SAL2; AMJA; SDM; RAP; HOAV; AMA; MIG
21	**1202 May 20 (0240)***	-	MA	V_R	C-N	Baalbek	Destructive earthquake in Lebanon, ground breakage north of the Hula pull-apart basin (**EMARB; MABBEE**).	AM; GC; KA; SAL; SAL2;

No.	Date (y/m/d/h)	U	Type	Rel.	Zone	Most damaged or felt locations	Description	Modern References
							Wide extent, casualties and many affected localities (**AM; GC**). **MIG** suggest it was recorded in lacustrine sediments along the Dead Sea shores	AMME; AMJA; SDM; HOAV; DAKL2; AMM; AMA; MIG
22	**1212 May 01***	-	FMA	H_R	S	Gulf of Aqaba	Moderate earthquake that affected southern Palestine at the time. The main evidence is that of the contemporary Arabic scholar Abu-Shama. **GC** and **AM** estimate the origin to be in the Gulf of Aqaba region. **KEN** dated an earthquake between 1220 and 1390 and associated it to this earthquake. **MIG** suggest it was recorded in lacustrine sediments along the Dead Sea shores	AM; GC; KA; SAL; AMM; AMA; MIG
23	**1293 Jan 11–Feb 08***	±1	S	H_R	C	Palestine.	Was felt in the center-south of Palestine (Ramla, Lud, Gaza, Qaqun, Tafilah), destroying many houses (**AM, GC**). **KEN** dated an earthquake between 1270 and 1400 and associated it to this earthquake. **MIG** suggest it was recorded in lacustrine sediments along the Dead Sea shores	AM; GC; KA; SAL; KEN; AMM; AMA; MIG
24	**1458 Nov 16***	-	S	H_R	C	Karak	Probably occurred in the Dead Sea area and reported by several contemporary writers (**AM; GC** and references therein). **GC** placed the epicenter near Karak (Jordan). **MIG** suggest it was recorded in lacustrine sediments along the Dead Sea shores	AM; GC; KA; SAL; AMA; MIG
25	**1546 Jan 14 (Afternoon)***	-	MA	V_R	C	Palestine	Moderate earthquake that affected central Palestine at the time and reported to topple down the bell tower of the Church of the Holy Sepulchre (**AMKA**). Occurred only 30 years after the Ottoman conquest which probably explains the absence of Arabic sources mainly from Egypt and Syria (**AM**). The primary source is a	AM; KA; AM2; SAL; SAL2; AMKA; BM; SDM; SHAL; AMA; MIG

No.	Date (y/m/d/h)	U	Type	Rel.	Zone	Most damaged or felt locations	Description	Modern References
							Venetian letter, probably copied from the account published in Beinart (1955) which resembles the Venetian letter and might be merely a copy of it (**SHAL; BRA**). **BM** assigns a magnitude of 7.0 and epicentral intensity of X-XI. Alternatively, **AMKA** analyzed the spread of damage and suggest that this was a magnitude 6 event, similar to the 1927 Jericho earthquake. **MIG** suggest it was recorded in lacustrine sediments along the Dead Sea shores	
26	**1588 Jan 04 (13:00) ***	-	S	M_R	S	Elat	**AM**: Destructive earthquake in northern Saudi Arabia and southern Palestine at the time. The earthquake was felt also in Cairo and east of the DST (mostly by pilgrims to Mecca and Medina). **MIG** suggest it was recorded in lacustrine sediments along the Dead Sea shores	AM; KA; SAL; AMA; MIG
27	**1643 Mar 23***	-	S	H_R	C	Jerusalem	Light earthquake felt in Jerusalem, according to the contemporary source of Paisios, future bishop of Jerusalem (**AM**).	AM
28	**1753 Dec 16**	-	S	M_R	C	Jerusalem	Light earthquake felt in Jerusalem. The source of al-Budayyri that **AM** is based upon, needs further verification. However, **AM** also bases on Tobler who, although born almost 100 years later, is known for his reliability. Thus, moderate reliability was attributed to the earthquake.	AM;
29	**1759 Oct 30 (03:45) ***	-	F (S?)	V_R	C-N	Safed	Strong shock in northern Israel-Southern Lebanon in the area confined to Safed-Tiberias-Benot Ya'akov bridge and Quneitra. **AM**: Probably a foreshock of the Nov 25 earthquake. DAKL2 claim that this is not a foreshock but rather separate earthquake acting on the Rachaya segment.	AM;KA;SAL;SAL 2;AMBR;TMK; MAR2; SDM; EMARB; DAKL; DAKL2

No.	Date (y/m/d/h)	U	Type	Rel.	Zone	Most damaged or felt locations	Description	Modern References
30	**1759 Nov 25 (19:23) ***	-	FMA	V_R	C-N	Litany, Northern Palestine	A most destructive earthquake that (**AM**) generated landslides, changes in water course and ground breakage in south Lebanon and northern Galilee (**AM)**. Many reporting sources. **MIG** suggest it was recorded in lacustrine sediments along the Dead Sea shores	AM;SAL;SAL2;AMBR;AMJA;TMK; SDM; DAKL; ODON; KA; AMBR; MAR2; EMARB; DAKL; DAKL2; GOM; MIG
31	**1783 Jul 20**	-	C	H_R	C-N	Tripoli	**AM**: Earthquake felt in the region of Tripoli, Lebanon and also report of damage from rock fall near Nablus, not necessarily from or due to an earthquake.	AM
32	**1817 Mar***	-	S	H_R	C	Jerusalem	**AM**: Some damage in Jerusalem (a Greek and an Armenian Church as well as part of the Church of the Holy Sepulchre)	AM;
33	**1834 May 26 (13:00) ***	-	S	V_R	C	Palestine	Damaging earthquake in central Palestine at the time. Occurred during the Fellahin siege of Jerusalem (**AM**). The main source is Neofitus, a contemporary monk from Mar Saba who witnessed the earthquake and described in detail the earthquake and its effects (Spyridon 1938). **KEN** dated an earthquake in the 19th and associated it to this earthquake. Confirmed also by **MIG**	AM; SAL; KEN; AMM; MIG
34	**1837 Jan 01 (16:35) ***	-	MA	V_R	C-N	Palestine, Syria	Damaging earthquake in southern Lebanon and northern Palestine at the time. The earthquake was felt also in central Israel and the Nile Delta, Egypt. Most of the information comprises reports of survivors and aid delegations (e.g., Calman 1837; Thomson 1837; Ya'ari 1943). This earthquake is probably followed by two aftershocks on the 16th Jan and 20th of May (**AM**). Confirmed also by geological evidence (**MIG**)	AM; SAL; AM3; NEM; AMJA; SDM; ODON; MIG

No.	Date (y/m/d/h)	U	Type	Rel.	Zone	Most damaged or felt locations	Description	Modern References
35	**1839***	±1	S	M_R	S	St. Catherine	**AM**: light earthquake mentioned by Grigoriadis, a near contemporary writer. However, the source of the earthquake is questionable; there are no other supportive reports of damage in the southern DST area (Elat or Aqaba).	AM; AMA
35	**1854 Nov 3**	-	S	M_R	C	Dead Sea, Jerusalem	**AM**: Felt only. The only source is the **PER** catalogue.	AM; PER
37	**1859 Oct 24 (05:15)**	-	S	H_R	C	Jerusalem	**AM**: A strong earthquake but without reported damage.	AM; GII
38	**1863 Sep 24 (20:15)**	-	S	H_R	C	Jerusalem	**AM**: Felt only.	AM;
39	**1864 Feb 19 (midnight)**	-	S	H_R	C	Jerusalem	**AM**: Felt only.	AM;
40	**1864 Mar 24 (02:30)**	-	S	H_R	C	Jerusalem	**AM**: Felt only.	AM;
41	**1868 Jan 24 (15:50)**	-	S	H_R	C	Jerusalem	**AM**: Felt only.	AM;
42	**1868 Oct 7 (19:30)**	-	S	H_R	C	Jerusalem	**AM**: Felt only.	AM;
43	**1873 Feb 14**	-	S	M_R	C	Jerusalem, Akko, Sur	**AM**: Felt only. This earthquake may have combined either with the one reported on 9.2.1873 that affected the Antakya region or with the one of 29.6.1873 that affected Jerusalem and Jaffa.	AM; SDM; GII
44	**1873 Jun 29 (02:30)**	-	S	H_R	C	Jerusalem, Jaffa	**AM**: Felt only.	AM;
45	**1874 Mar 03 (01:40)**	-	S	H_R	C	Jerusalem	**AM**: Felt only.	AM;
46	**1875 Mar 28 (02:48)**	-	S	H_R	C	Jerusalem	**AM**: Felt only.	AM;

No.	Date (y/m/d/h)	U	Type	Rel.	Zone	Most damaged or felt locations	Description	Modern References
47	**1877 Feb 15 (07:15)**	-	S	H_R	C	Jerusalem	**AM**: Felt only.	AM;
48	**1877 Mar 14 (06:15)**	-	S	H_R	C	Jerusalem	**AM**: Felt only.	AM;
49	**1879 May 19 (06:00)**	-	S	H_R	C	Haifa	**AM**: Strong earthquake at 06:00 lasted for only a few seconds.	AM;
50	**1879 Dec 31 (09:00)**	-	S	H_R	C	Jerusalem	**AM**: Felt only.	AM;
51	**1889 Aug 23 (19:00)**	-	S	H_R	C	Safed	**AM**: Felt only. According to newspaper report from 13.09.1889.	AM;
52	**1889 Dec 11 (00:25)**	-	S	M_R	C	Jerusalem	**AM** after **AAT**: Felt only.	AM; AAT
53	**1893 Jan 12 (04:00)**	-	S	M_R	C	Jerusalem	**AM** after **AAT**: Felt only.	AM; AAT
54	**1898 Mar 19**	-	S	M_R	C	Carmel, Haifa	Felt only. Occurred at 11:20 and lasted about 3 seconds (**AAT**).	AM; AAT
55	**1900 Jan 5**	±1	S	M_R	C	Palestine	Slight shock felt in the Galilee, Jerusalem and Hebron. The earthquake is listed by **AAT** who use **SI**, **WI**, **BL**, **AB** and some extracts written by the Meteorological Service of Israel.	AAT;
56	**1903 Mar 29**	-	C	H_R	C	Palestine	Felt only. The earthquake is listed by **AAT** who use **SI**, **WI**, **BL**, **AB** and some extracts from the meteorological station notebooks of the Meteorological Service of Israel.	AAT; SAL3
57	**1903 Dec 19 (00:20-00:44(?)**	-	C	M_R	C	Jerusalem, Jaffa, Hebron	Felt only. **AAT** use some extracts from the meteorological station notebooks of the Meteorological Service of Israel.	AAT
58	**1907 Feb 1 (01:00)**	-	S	M_R	C	Hebron	Felt only. **AAT** use some extracts from the meteorological station notebooks of the Meteorological	AAT

No.	Date (y/m/d/h)	U	Type	Rel.	Zone	Most damaged or felt locations	Description	Modern References
							Service of Israel.	
59	**1907 Jun 22 (15:32)**	-	S	H_R	C-N		Felt only. According to **SAL3** based upon **BM3.**	SAL3; BM3
60	**1907 Jul 22 (17:40)**	-	U	H_R	C-N		Felt only. According to **SAL3** based upon **SHA2.**	SAL3; SHA2
61	**1910 Jul 10 (19:54)-**	-	S	H_R	C-N		Felt only. According to **SAL3** based upon **SHA2.**	SAL3; SHA2
62	**1914 Jun 24 (16:40)**	-	S	M_R	C	Tabgha	**AAT**: Felt only.	AAT
63	**1918 Sep 29 (20:17)**	-	S	H_R	C-N	Syria	Damaging earthquake in northern Syria (**SAL3)**. **AM5** places the source origin near Cyprus. The event was probably slightly felt in Haifa and maybe at Qalqiliya (**AAT**). Although it might not be related to DST activity, we include it in this list for being felt in Israel.	SAL3; AAT; AM5;
64	**1921 Apr-Jun**	-	C	M_R	C	Galilee	Felt only. According to **AAT**, 15 slight earthquakes during April-June felt in the Galilee.	AAT
65	**1922 May 5,8 and 9**	-	C	M_R	C	Galilee	Felt in northern Mandatory Palestine (**AAT**).	AAT
66	**1922 May 21, 22 and 23**	-	C	M_R	C	Galilee	Felt in northern Mandatory Palestine (**AAT).**	AAT
67	**1923 Feb 27 (18:15)**	-	S	V_R	C	Allone-Abba (Waldheim)	Felt only. **SAL3** based upon **IRPG.**	AAT; SAL3; IRPG
68	**1923 Dec 21 (14:11)**	-	S	H_R	N		Felt only. **SAL3** based upon **RIME.**	SAL3; RIME
69	**1924 Feb 27 (20:04)**	-	S	H_R	C	Palestine	Felt only. **AAT** based upon **BM** and **SI**. However, **BM** draws from **SI** whereas the latter does not mention his sources. Yet, in light of contemporaneous **SI**, the earthquake is ascribed with high reliability	AAT; SAL3; BM;SI
70	**1926 Jun 26**	-	S	H_R	C	Jerusalem	Felt only. **AAT** base upon **BM** and **SI**. However, **BM**	AAT; BM; SI

No.	Date (y/m/d/h)	U	Type	Rel.	Zone	Most damaged or felt locations	Description	Modern References
	(19:46)						draws from **SI** whereas the latter does not mention his sources. Yet, in light of contemporaneous **SI**, the earthquake is ascribed -high reliability	
71	**1927 Jul 11 (15:04)***	-	MA	V_R	C	Nablus, Ramla	Moderate destructive earthquake with a series of aftershocks (**SAL**). About 300 hundred casualties. Magnitude estimated as ML = 6.2 with the epicenter at the north of the Dead Sea (**AVN; AVN2; ZOMA**). **KEN** dated an earthquake to the 20th century and associated it to this event. Confirmed also by **MIG**	AVN; AVN2; SAL; ZOMA; AAT; BM2; AMA; VEST; SHA; KEN; AMM; MIG

Appendix B: Questionable earthquakes that were allegedly affected Israel and its surrounding

Following is the list of questionable earthquakes, duplicated records, erroneous entries or reported earthquakes that appear in the literature without any support of historical, archaeological or paleoseismic references. This list summarizes our present state of knowledge and understandings and may be changed or updated if new information emerges. Each entry contains the following information: **Date**: time of occurrence in years and whenever possible – also the month, day and hour; **U:** uncertainty of the time origin (in years); **Type**: the type of occurrence (following Salamon 2009): S - Single, C - Cluster, F - Foreshock, A - Aftershock, FM - Foreshock and Main, MA - Main and Aftershock; FMA - Foreshock, Main and Aftershock and U - Undefined; **Rel.**: degree of reliability: P_R - Poor and D_R – Doubtful and (see further details in Table 1); **Most allegedly damaged locations**: reported localities of maximal damage; **Why doubtful**: a short explanation for doubtfulness, description, comments, references and citations of the relevant historical sources ; **Modern References**: abbreviated catalogues, articles and reappraisals that were used during the compilation process of this list (see Appendix 4 for abbreviations).

No.	Date (y/m/d/h)	U	Type	Rel.	Most damaged locations	Why doubtful	Modern References
1	**2100-1700 BCE**	±400	S	P_R	Sodom, Judea	The claim that the destruction of Sodom, Gomorrah, Admah, Zebo'im and Zoar (Genesis, 19.24-28; 29.23: Bible 1989) was a result of an earthquake is not decisive. Strabo, a 1st century BCE writer, mentions earthquakes as a possible cause for ruins near Masada but also cites an alternative physical explanation suggested by the 3rd BCE writer Eratosthenes (Strabo 16.2 42, 44). No other supportive source or evidence is found and thus the alleged event needs further authentication.	AM; BEN;
2	**c.1400 BCE**	±100	S	P_R	Jericho	The tumbling down of Jericho's walls (Joshua, 6.20-21: Bible 1989) as an outcome of an earthquake is not significantly supported by other literary sources. Some archaeoseismic evidence implies possible earthquake damage in the middle of the 2nd millennium BCE (**AM** and references therein) but its relation to the conquest of Jericho by Joshua needs further authentication.	AM; BEN;
3	**c.1225-1175 BCE**	±50	C	D_R	Eastern Mediterranean	A storm of quakes might have occurred and damaged several archaeological sites in the Eastern Mediterranean including Palestine. This is bases only on archaeology with no decisive evidence of damage that could be unequivocally associated	NUCL

No.	Date (y/m/d/h)	U	Type	Rel.	Most damaged locations	Why doubtful	Modern References
						with an earthquake (**NUCL**)	
4	**c.1070 BCE**	±50	S	P_R	Mizpeh, Judaea	Josephus describes a battle taken place in Mizpeh, north of Jerusalem, but the other details seem to be incidental (Josephus 6.2). Furthermore, Josephus' sources of the event remain anonymous.	AM;
5	**590 BCE**	-	-	D_R	Tyre	**KA2** pointed out the entry citation by **PLKO**, **BM** and **SI** with no specific reference of occurrence.	BM; PLKO; SI; SDM; KA2
6	**525 BCE**	-	-	D_R	Sidon		
7	**148 Feb 21 (or 130) BCE**	±20	S	P_R	Antakya	The only source is Malalas, living in the 6th century, who cites Domnianus, 5th century writer (**AM, GCT**). He does not mention an earthquake but rather the phrase "wrath of god" and apparently confuses the date and the details implying that perhaps there was more than one event or the damage was resulted by an outer invasion. **WEC2** found an evidence of event between 392 BCE and 91 CE and imply of possible association.	AM; GCT; SAL; AW; WEC2
8	**139 BCE**	±1	S	P_R	Akko	No reference of earthquake but rather a record of sea waves that flooded the shore between Tyre and Akko (**SAL2** and references therein). Had there been an earthquake, it may have occurred offshore, west of the DST (**AM**).	AM; SAL2
9	**92 Feb 28 BCE**	-	S	D_R		**KA2**: **BM** places earthquake of M7.1, relying on **PLKO** who do not quote a reference but probably use **SI** and **WI**. **WI** uses **MA** who uses **VH**. The latter author does not mention any of his sources and is probably responsible for the confusion. **WEC2** found an evidence of event between 392 BCE and 91 CE and imply of possible association.	AM;KA2;SAL2; BM; PLKO; SI; WI; MA; VH; WEC2
10	**44-32 BCE**	±6	S	D_R	Salamis	No contemporary sources (including the near contemporaneous Josephus that remains silent). **AM**: This is probably a duplication of the 15 BCE Cyprus earthquake in which the convention Salamis/Diospolis (nowadays Lod) was confused with Salamis in Cyprus.	AM;
11	**19**	-	S	D_R	Sidon, Syria	The reference in SDM relies upon **BM**, **PLKO** and **SI** who in turn	SDM; PLKO; SI;

No.	Date (y/m/d/h)	U	Type	Rel.	Most damaged locations	Why doubtful	Modern References
						do not cite their historical sources.	BM
12	**33**	±1	S	P_R	Jerusalem	Matthew reports of two earthquakes during the crucifixion and resurrection of Jesus. Though contemporaneous, his testimony is strongly doubted as being associated with theological interests. The secondary sources, Eusebius and Orosius, use Matthew and mix his report with sun eclipse and an earthquake that occurred in Bithynia (**KA**). Paleoseismic findings (**MIG**; **WILL**) suggest that an earthquake occurred close to this date. However, it could have been a rather small earthquake (M >= 5.5) that left sedimentary evidence but no meaningful damage to inhabited sites. **WEC2** found an evidence of event between 392 B.C.E.–91 C.E. and imply of possible association. **KEN** dated an event between 5 and 50 CE and associated it to this event	AM;KA;AM2; KEN; AMM; WEC2
13	**2nd century (c.110-114?)**	±5	S	P_R	Petra, Masada, Avdat	**AM** questionably refers to an event between c.110-114. Other scholars (e.g., **KOMA; NEG**) imply of possible damage to structures in the ancient Negev cities. However they rely only on archaeological excavations that imply possible damage but not necessarily from an earthquake.	AM; KOMA; NEG; AMA
14	**<597**	?	S	P_R	Areopolis	According to an inscription found in Areopolis which implies restoration of the city but not necessarily damage from an earthquake (**AM**).	AM;
15	**835**	±1	C	D_R		Al-Suyuti probably duplicated the 713 event with this entry (**AM**; **GCT**).	AM;GCT;SAL; SDM; GII
16	**853 Jun 12 - 854 Jun1**	±1	S	P_R	Tiberias	Only a single secondary source which uses unknown sources (**AM; GCT**).	AM;GCT;KA;SAL; SDM;
17	**873**	?	?	P_R	Qasr Tilah	Based on archaeological remain (**HNA**). No supportive historical sources	HNA
18	**1016 Aug 27**	-	S	P_R	Jerusalem	**AM**: The Dome of the Rock in Jerusalem was allegedly damaged. The only reports are secondary sources that do not mention an earthquake occurrence.	AM;KA;

No.	Date (y/m/d/h)	U	Type	Rel.	Most damaged locations	Why doubtful	Modern References
19	**1047**	-	S	P_R	Ramla	**AM**: The only reporting source is the secondary al-Fariqi.	AM;
20	**1091 Feb 12**	-	C	P_R	St. Catherine	Only one anonymous source dating this event based on Archbishop John the Athenian's death. The interpretation of this source yields two possible dates of occurrence: 1091 or March 1068 (**AM**)	AM;SAL; AMA
21	**1114 Apr-May**	-	C	P_R	Jerusalem? Sea of Galilee	Although Jerusalem is mentioned in the chronicle of 'Historia Hierosolymitanae' to have been hit, it is not mentioned by Fulcher (**AM**). Thus, had the earthquake occurred, it was probably felt north of Jerusalem (perhaps near the Sea of Galilee)	AM;
22	**1119 CE**	±1	S	P_R	Hebron	Cave collapse in Hebron (Khalil). The cause is not mentioned.	AM;
23	**c.1150**	?	S	P_R	Mar Elias, St. John	**GC**: Date of occurrence, according to the pilgrim John Phocas, is not clear. **AM** doubts the event on the basis that Mar Elias was already ruined on June 7, 659.	AM;GC;SAL;
24	**1261**	±1	S	P_R	Acre	Seven islets sank off the coast of Akko but without specifically mentioning an earthquake (**AM**).	AM;SAL2;
25	**1267 Dec 8**	-	S	P_R	Jordan River	**AM** following **WAT**: alleged evidence of landslide that dammed the Jordan River. The event is also mentioned by al-Maqziri, secondary source.	AM;
26	**1366 Oct**	-	S	P_R	Safed	**AM, GC**: According to a vague report of the secondary al-Imad.	AM;GC;
27	**1504**	±1	C	P_R	Jerusalem	**AM**: Based upon al-Umari. Needs further examination.	AM;
28	**1532**	±1	S	D_R	Bet Lehem	**AM**: Based upon unknown source. Further verification is needed.	AM;
29	**1557 Feb**	-	S	P_R	Jerusalem	**AM**: Vague report of an earthquake in Jerusalem.	AM;SAL;
30	**1605 Jan 08**	-	C	D_R	Saba	Questionable report (**AM**; **KA**).	AM;KA; GII
31	**1644**	±1	S	P_R	Jerusalem	**AM**: Probably duplicated from the 1643, March 23 event.	AM;
32	**1762**	±1	S	P_R	Akko	**AM**: Sole report with no other supportive evidence.	AM;
33	**1769**		S	D_R	Palestine	**AM**: Probably wrong entry of **ARV.**	AM; ARV
34	**1802**	±1	S	P_R	Aleppo	The claim that this event was felt also in Palestine at that time is rejected by **AM**. Suggests that these reports are associated with the 1822 earthquake (Appendix 3).	AM;KA; SDM;

No.	Date (y/m/d/h)	U	Type	Rel.	Most damaged locations	Why doubtful	Modern References
35	**1838**		S	D_R	Judea	Wrong entry in **ARV** has led to duplication of the 1838 Cyprus earthquake.	AM; ARV
36	**1843 May 12**	-	S	P_R	Jerusalem	**AM**: Appears in **TOB** but needs further authentication.	AM; TOB
37	**1844-1845**	±1	C	P_R	Jerusalem	**AM**: Cited in **AMI** without supporting source.	AM; AMI
38	**1848 Apr 26**	-	S	P_R	Dead Sea	Reports only in the Dead Sea onboard a boat. The reporter also mentions rock fall from cliffs 9 hours later. No other reports and the fact that he was on a boat might cause some confusion (**AM**).	AM;
39	**1857 Sep 21**	-	S	P_R	Jerusalem	**AM**: Cited in **AMI** without supporting source.	AM; AMI
40	**1876 Nov 21 (01:00)**	-	S	P_R	Nazareth	**AM**: Cited in **AMI** without supporting source.	AM; AMI
41	**1885 Mar 13 (11:00)**	-	S	P_R	Jerusalem	**AM**: Cited in **AMI** without supporting source.	AM; AMI

Appendix C: Reliable earthquakes originated either along or off the DST that reported erroneously to cause damage in Israel

Reliable earthquakes originated either along or off the DST that were erroneously related in the literature to cause damage in Israel. Each entry contains the following information: **Date**: time of occurrence in years and wherever possible - also month, day and hour; **U:** uncertainty of the time of origin (in years); **Type**: the type of occurrence (following Salamon 2009): S - Single, C - Cluster, F - Foreshock, A - Aftershock, FM - Foreshock and Main, MA - Main and Aftershock; FMA - Foreshock, Main and Aftershock and U - Undefined; **Rel**: degree of reliability: V_R - Very high, H_R - High, M_R – Moderate and U – Undefined (see further details in Table 1); **Zone**: association of the event with a geographic region: CA – Cypriot arc, EAF – East Anatolian fault, HA – Hellenic arc, SG – Suez Gulf and regions of the DST (Fig. 1): N – North (northern Lebanon and Syria), C – central (Israel and southern Lebanon), S – South (southern Israel, Sinai and Gulf of Aqaba); **Most damaged locations**: reported localities of maximal damage; **Description**: a short description, comments and citations of the relevant historical sources; **Modern References**: abbreviated catalogues, articles and reappraisals that were used during the compilation process of this list (see Appendix 4 for abbreviations).

No	Date (y/m/d/h)	U	Type	Rel.	Zone	Most damaged locations	Description	Modern References
1	**c.198 BCE**	±1	S	H_R	C-N	Sidon	The earthquake is reported by Posidoinus, near contemporary and a highly reliable source that was born 60 years later (**GCT**). The shocks were felt in Phoenicia and with less intense in Syria. The earthquake seems to be accurate but the reported damage is probably exaggerated.	AM;GCT;SAL;SAL 2; SDM; AW
2	**c.65 BCE**	±5	S	M_R	N	Northern Syria	According to Justin, the earthquake happened during Tigranes's occupation of Syria (83-69 BCE) and hit several unspecified cities, probably in northern Syria. The earthquake was mistakenly imported to pre 90's catalogues (e.g., **AAT**, **BM**) as occurred in Jerusalem (see **KA2** and references therein). **KEN** dated an earthquake between 200 and 40 BCE and associated it to this earthquake.	AM; GCT; KA2; SAL; SDM; AAT; BM; GII; KEN; AMM
3	**c.20 BCE**	±5	S	M_R	CA (?)	Egypt	This earthquake is based upon the evidence of the	AM; KA; SAL;

No	Date (y/m/d/h)	U	Type	Rel.	Zone	Most damaged locations	Description	Modern References
							contemporary Strabo and the 3rd – 4th century Eusebius, both referring to a phenomenon that was not necessarily the result of an earthquake in Egypt. It could have been duplicated from the 15-17 BCE earthquake that allegedly occurred in Cyprus (**AM**). For further details see **SAL; SAL2; KA**. **GII** refers to 26 BCE	SAL2; GII
4	**17-15 BCE**	±2	S	M_R	CA	Cyprus	The earthquake is recorded by Dio Cassius who, though a 3rd century writer, is considered reliable (**AM**) and this is also supported by Eusebius. The earthquake affected Cyprus and there is no evidence of damage in Israel, Lebanon or Syria.	AM; GCT; KA
5	**76**	±1	S	M_R	CA	Cyprus	**AM**: This earthquake is recorded by secondary but reliable sources of Eusebius and Orosius. The question whether there was a tsunami remains unresolved.	AM;
6	**115 Dec 13**	-	MA	H_R	N	Antioch (modern Antakya)	Large earthquake that almost totally ruined Antioch (modern Antakya) and its surrounding cities (**AM**; **GCT**; **KA**). The alleged tsunami (**SAL2** and references therein) in Caesarea (**REI**) and along the coast down to Yavne is questionable as there are no supporting contemporary indications for this claim. Yet, the earthquake is mentioned in several catalogues (e.g., **AAT**) as hitting or at least affecting Israel.	AM;GCT;KA;SAL; SAL2;AMJA; SDM;REI; AAT
7	**127-130**	±3	S	H_R	EAF (?)	Nicopolis, Neocaesarea (Asia Minor)	This earthquake is likely to have occurred in Asia Minor and not in the DST area. The confusion is the interpretation of Eusebius's report replacing NeoCaesarea and Nicopolis in Greece (Asia Minor) with Caesarea and Nicopolis (Emmaus) in Palestine (**AM**; **KA**). **WEC2** match this earthquake to seismic activity in northern Israel between 137 and 206 CE. In light of the confusion in the sources, it is most likely that these are	AM;GCT;KA;SAL; WEC2

No	Date (y/m/d/h)	U	Type	Rel.	Zone	Most damaged locations	Description	Modern References
							two separate earthquakes.	
8	**341**	±1	MA	H_R	CA	Salamis (Cyprus)	**AM**, **GCT**: Occurred in Cyprus.	AM;GCT;SAL;SAL 2; SDM;
9	**347 Sep (348/349)**	±1	S	M_R	C-N	Beirut	Based upon the two Secondary but reliable sources of Theophanes and Cedrenus. **WEC2** found evidence for a possible earthquake between 269 and 329 CE or 294–369 CE but they point it might be associated with the 303 or 363 CE earthquakes (appendix A).	AM;GCT;SAL;SAL 2; SDM; GII; WEC2
10	**365 Jul 21**	-	S	V_R	HA	Crete-Peloponnese	Was probably generated in the Hellenic Arc (**AM**; **GCT**; **SAL2**) and was mistakenly adopted by early catalogues as having occurred in Palestine.	AM;GCT;SAL2; AMA
11	**c.388**	±10	S	P_R	EAF	Constantinople	**AM**: There are 3 references of John Chrysostom for the occurrence of an earthquake. Two of them are not decisive and the third implies an earthquake that lasted for 3 days. Orosius (contemporary) and Marcelinus Comes (5^{th}-6^{th} centuries) report of an earthquake that struck the vicinity of Constantinople in c.395. Since the nature of Chrysostom's writing is preaching along with the fact that he was living in Constantinople, he might have used this earthquake for his own interests and apply damage also to Antioch (modern Antakya). Thus, the evidence of Orosius is more acceptable (this is also supported by **GCT**).	AM; GCT
12	**395**	±1	MA	H_R	EAF	Constantinople	See the previous entry.	AM; GCT; KA; SDM;
13	**455 Sep**	-	S	H_R	U	Tripoli	The main source for this earthquake is the near-contemporary Malalas who allegedly is counted as using reliable primary sources. The fact that he was close to the earthquake (491-578) attributes reliability to that earthquake. However, Malalas does not mention any	AM;GCT; SDM;

No	Date (y/m/d/h)	U	Type	Rel.	Zone	Most damaged locations	Description	Modern References
							other damaged location (in particular Antakya). Moreover, no other source reports damage in major cities (e.g., Damascus, Beirut). This leads to the option that the earthquake did actually occur but rather offshore (**AM**; **GCT**). Note that Michael the Syrian attributes effects to 'all the entire inhabited world' – maybe an earthquake that happened far away and affected the Mediterranean.	
14	**601 Apr 2**	-	S	M_R	U		**AM**: Might have occurred somewhere in northern Syria or Iraq. Most of the reported damage was in Turkey.	AM;GCT;SAL; SDM;
15	**c.746 Jan**	±3	MA	M_R	N	Syria	See discussion in appendix 1, entry 10	AM;KA;KA2;SAL;SAL2;MAR; SDM; AM4
16	**796 Apr**	-	S	M_R	HA		**AM**: Probably the Hellenic Arc.	AM;GCT;
17	**813-820**	±7	S	P_R	EAF	Constantinople	Two incomplete sources imply a possible earthquake somewhere between 813 and 820 (**GCT**). **AM** claims the earthquake occurred in Constantinople in 815 CE	AM;GCT;
18	**860 Jan 29**	±1	MA	M_R	HA	Gulf of Antakya	**AM**: The earthquake could have been related to the Hellenic Arc or, though less probable, to the north of the DST. **GII** refers to 859 CE.	AM;GCT;KA;SAL; SAL2; SDM;
19	**952**	±1	MA	U	EAF	Maras	Occurred in southern Anatolia (**AM**; **GCT**).	AM;GCT;SAL; SDM;
20	**956 Jan 5**	-	S	M_R	SG	Egypt	Reports of damage in Egypt, the report of al-Masudi about a report in Syria has no other authentication (AM; AMA)	AM; AMA; GII;
21	**991 Apr 5**	-	MA	M_R	C-N	Damascus	According to several independent secondary sources (**AM**; **GCT**; **KA**). **MIG** suggest it was recorded in lacustrine sediments alond the Dead Sea shores	AM; GCT; KA; SAL; SAL2; SDM; GII; MIG
22	**1002 Nov 10-**	±1	S	M_R	EAF	Northern Syria	**AM** refers to an earthquake in northern Syria affecting	AM; GC; SDM;

No	Date (y/m/d/h)	U	Type	Rel.	Zone	Most damaged locations	Description	Modern References
	1003 Oct 29						the regions of al-Wasim and al-Thughur based on al-Istakhri and Thagri Birdi. **GC** use the report of Matthew of Edessa to imply an additional earthquake in the Edessa region.	SAL
23	**1032/3 Mar 6**	±1	S	P_R	EAF	Constantinople	**AM** interprets this earthquake as occurred on Mar 6, 1033 in Constantinople.	AM; GII
24	**1063 Aug**	-	MA	M_R	U	Syrian littoral	**AM**: The earthquake struck the Lebanese coast from Antakya to Tyre. The source was probably offshore between the Lebanese coast and Cyprus.	AM;GC;SAL; SDM;
25	**1114 Nov 29**	-	FM	V_R	EAF	Antakya, Maras	**AM**: Large earthquake close to the East Anatolian Fault. The 1114 Aug 10th and Nov 13th are probably foreshocks of the 1114 Nov 29 earthquake	AM;SDM; GC
26	**1120 Jan 1**	-	S	M_R	EAF	Probably Edessa	**AM**: Based upon the testimony of Michael the Syrian.	AM;
27	**1127 Feb**	-	S	M_R	EAF	Probably Edessa		
28	**1127 Nov**	-	C	M_R	EAF	Probably Edessa		
29	**1287 Feb 16**	-	F	H_R	N	Safitha (in Syria	The earthquakes in Feb 1287 contain three entries, all by one contemporary source (Ibn Zahir). **AM** imply of two foreshocks in northern Syria but **SAL** and **GC** refer to it as 3 separate earthquakes.	AM;GC;SAL; SDM;
30	**1303 Aug 8 (03:30)**	-	S	V_R	HA	Crete, Nile River	Large earthquake originating on the Hellenic Arc and generating damage and tsunami in the eastern Mediterranean (**AM; GC**). The littoral extending between Palestine and Syria suffered a tsunami (**SAL2**). **MIG** suggest it was recorded in lacustrine sediments along the Dead Sea shores.	AM; GC; KA; SAL2; AMA; MIG

No	Date (y/m/d/h)	U	Type	Rel.	Zone	Most damaged locations	Description	Modern References
31	**1344 Jan 3**	-	S	H_R	EAF	Aintab	Occurred in southern Turkey (**AM; GCT**).	AM;GC;SAL; SDM;
32	**1425 Jun 23**	-	S	M_R	SG	Gulf of Suez	Affected the Gulf of Suez (**AM**)	AM; GC ; AMA
33	**1457 Apr 23**	-	S	H_R	EAF	Eastern Anatolia	**AM**: Occurred in Eastern Anatolia.	AM; GII
34	**1481 Mar 18**	-	C	H_R	HA		Series of earthquakes originating in the eastern Mediterranean (**AM; GC**).	AM;GC; AMA
35	**1568 Oct 10**	-	FM	H_R	CA	Cyprus	Affected Cyprus and the Syrian coast (**AM**).	AM; SDM
36	**1801 Oct 10**	-	S	M_R	SG	Gulf of Suez	**AM**: Felt in Cairo. There is no other evidence of an earthquake; had it occurred, it probably originated in the Gulf of Suez	AM;
37	**1814 Jun 27**	-	FM	H_R	SG	Cairo, Suez	**AM**: This is probably an earthquake that affected Cairo and implies that the source was not in one of the DST southern segments.	AM;KA; AMA; GII
38	**1822 Aug 13 (20:40)**	-	FMA	V_R	EAF	Southeastern Anatolia	Destructive earthquake that seems to have occurred at the junction between the northern section of the DST and the East Anatolian fault (EAF). The earthquake was felt from Gaza to the Black Sea and was accompanied by ground fissures, landslides and liquefaction. Aftershocks continued probably until March 1824 (**AM**). **MIG** suggest it was recorded in lacustrine sediments along the Dead Sea shores	AM;SAL;SAL2; SDM; MIG
39	**1846 Mar 28**	-	S	V_R	HA		**AM**: Offshore epicenter, probably around the Hellenic Arc.	AM;
40	**1847 Aug 7**	-	S	V_R	SG	Egypt	Damaged Cairo and it vicinity **(AM; AMA)**	AM; AMA

No	Date (y/m/d/h)	U	Type	Rel.	Zone	Most damaged locations	Description	Modern References
41	**1856 Oct 12**		S	V_R	HA	Crete	**AM**: Large earthquake with an epicentral region offshore from Crete.	AM;SAL2;
42	**1863 Apr 22**		S	V_R	HA	Rhodes	**AM**: Occurred in the eastern part of the Hellenic Arc near Rhodes.	AM; AMA
43	**1868 Feb 20 (03:15)**	-	C	H_R	SG	Alexandria	Probably originated in the Gulf of Suez.	AM; AMA
44	**1870 Jun 24 (17:00)**	-	S	V_R	HA	Eastern Mediterranean	Affected Eastern Mediterranean (**AM**)	AM;SAL2; AMA
44	**1872 Apr 3**	-	S	V_R	EAF	Southern Anatolia	**AM**: Occurred in southern Anatolia.	AM; GII
46	**1896 Jun 29**	-	FMA	H_R	CA	Cyprus	**AM**: Damaging earthquake in Cyprus at 20:48 was preceded by many foreshocks and followed by aftershocks.	AM; GII

Appendix D: List of abbreviations

Critical catalogues and reappraisals

AG: Agnon (2014)
AM: Ambraseys (2009)
AM2: Ambraseys (2005a)
AM4: Ambraseys (2005b)
AM5: Ambraseys (1992)
AMA: Ambraseys et al. (1994)
AW: Ambraseys and White (1997)
BR: Broshi (1982)
GCT: Guidoboni et al. (1994)
GC: Guidoboni and Comastri (2005)
KA: Karcz (1987)
KA2: Karcz (2004)
SAL: Salamon (2009)
MZ: Mazar (1982)
SAL2: Salamon et al. (2011)

Catalogues and lists

AAT: Amiran et al. (1994)
AMI: Amiran (1952)
ARV: Arvanitakis (1903)
AB: Abel (1931)
BL: Blanckenhorn (1905)
BM: Ben-Menahem (1991)

BRA: Braslavsky (1956)
GII: GII ()
IRPG: IPRG (1982-1993)
MA: Mallet (1852)
PER: Perrey (1850)
PLKO: Plassard and Kogoj (1968)
SDM: Sbeinati et al. (2005)
SHAL: Shalem (1955)
SI: Sieberg (1932)
TUAR: Turcotte and Arieh (1988)
VH: von Hoff (1840)
WI: Willis (1928)

Focused investigations

AM3: Ambraseys (1997)
AMBR: Ambraseys and Barazangi (1989)
AMJA: Ambraseys and Jackson (1998)
AMKA: Ambraseys and Karcz (1992)
AMME: Ambraseys and Melville (1988)
AUS: Austin et al. (2000)
AVN: Avni (1999)
AVN2: Avni et al. (2002)
BEG: Begin (2005)
BEN: Bentor (1989)
BM2: Ben-Menahem et al. (1976)
BM3: Ben-Menahem and Aboodi (1981)
BM4: Ben-Menahem (1981)

BM5: Ben-Menahem (1979)
DAR: Darawcheh et al. (2000)
GOM: Gomez et al. (2003)
HOAV: Hough and Avni (2010)
MARG: Margalioth (1960)
ODON: Katz and Crouvi (2007)
RAP: Raphael (2010)
RIME: Riad and Meyers (1985)
RUS: Russell (1985)
RUS2: Russell (1980)
SAL3: Salamon et al. (1996)
SHA: Shapira et al. (1993)
SHA2: Shapira (1979)
VEST: Vered and Striem (1977)
WECO: Wells and Coppersmith (1994)
ZOMA: Zohar and Marco (2012)

Archaeoseismic remains and paleoseismic evidence

AAK: Akyuz et al. (2006)
AMM: Agnon et al. (2006)
DAKL: Daëron et al. (2007)
DAKL2: Daëron et al. (2005)
ELI: Elias et al. (2007)
EMARB: Ellenblum et al. (1998)
GMD: Gomez et al. (2001)
HNA: Hayens et al. (2006)
KA3: Karcz and Kafri (1978)

KAG: Kagan et al. (2011)
KEN: Ken-Tor et al. (2001)
KOMA: Korjenkov and Mazor (1999)
MABBEE: Marco et al. (1997)
MAR: Marco et al. (2003)
MAR2: Marco (2008)
MEI: Meimaris and Kritikakou (2005)
MIG: Migowski et al. (2004)
NEG: Negev (1974)
NEM: Nemer and Meghraoui (2006)
NUCL: Nur and Cline (2000)
NURO: Nur and Ron (1996)
RH: Reches and Hoexter (1981)
REI: Reinhardt et al. (2006)
TMK: Nemer et al. (2008)
TSFO: Tsafrir and Foester (1992)
WALE: Wachs and Levitte (1984)
WE: Wechsler et al. (2009)
WEC2: Wechsler et al. (2014)
WILL: Williams et al. (2011)
ZIL: Zilberman et al. (2005)
ZIL2: Zilberman et al. (2004)

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