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Patterns of aftershock sequences along the Dead Sea Transform - Interpretation of historical seismicity

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Abstract

Many historical accounts describe the occurrence of series of earthquakes in the Levant which in terms of modern seismology resemble foreshock-mainshock-aftershock sequences. We classified and examined these series in order to identify its characteristic patterns.

First we constructed a list of significant earthquakes that affected the region of the Dead Sea Transform system and identified about a hundred damaging earthquakes during the last two millennia, a significant part of which were destructive. About a third of these affected the area comprising the State of Israel today. Overall, forty-eight of these events were reported as single earthquakes while the others were reported to have been associated with additional shocks. The single-event type is not known today and in our opinion results from incomplete reports. Among the multi-event series several modes could be distinguished: (i) Mainshocks: Most of the 'non-single' events included one predominant earthquake that caused most of the damage – the mainshock; (ii) Foreshocks: Five accounts report of earthquakes that preceded the main shock by minutes and hours and up to several weeks. In a few cases people reacted on time, evacuated their homes and saved their lives; (iii) Aftershocks: Thirty-eight of the reported historical earthquakes were followed by additional shocks, lasting for hours, days, weeks, months, and even more than a year. Some of these added to the damage; (iv) Series of earthquakes were also reported in 15 events, but the data is insufficient to specify further; (v) Swarms, although known in modern records, were not identified, possibly because the historical records are not detailed enough.

Interestingly enough, the duration and strength of shaking were also addressed by the reporters. Some events, mostly of recent centuries, were reported to have lasted several tens of seconds and this is comparable to the expected duration of large earthquakes. Other earlier events continued for a few hours – a duration which cannot be explained, unless it is assumed that the reports combined the main event together with the immediate strong aftershocks. In many cases the earthquake surprised the inhabitants for being "such as has not occurred before" and sometimes (e.g., 1796) even: "in Latakia [the earthquake was] so violent that almost everything collapsed with the first shock." Occasionally, such as in the 1822 earthquake, the violent shaking appeared in the later phase, allowing invaluable spare time for evacuation.

Past experience suggests that future destructive earthquakes along the Dead Sea Transform will most probably occur without foreshocks, and be followed by intensive aftershock series (hundreds and thousands) that may last for a year or so with tens of felt events. Strongly felt aftershocks will occur immediately within the first hours after the mainshock, and may last for a few months, decreasing in rate and size. No typical time was identified for the appearance of the largest aftershocks and they may appear sometimes during the first month, although several months delay will not be an exception. Singly felt foreshocks are less likely to appear, but if so they will most probably precede the mainshock by a few hours. Foreshock series of increasing magnitudes are also possible, with the main event occurring several days or weeks after they started.

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1 Introduction

Earthquakes appear in various temporal and spatial distributions, mostly in dense clusters consisting of one large event - the mainshock, which is usually followed by many smaller aftershocks. Sometimes the mainshock is preceded by a single or several foreshocks. A sequence in which there is no predominant single earthquake is called a swarm, and a successive occurrence of several mainshock-aftershock sequences is a second kind of a swarm or a seismic storm (e.g., Kisslinger, 1996; Utsu, 1961, 2002; and references therein). There is no universal definition or procedure for classifying seismic sequences or determining the exact nature of any single earthquake in a cluster. Most researchers refer to aftershocks as events immediately following a large earthquake within a distance of 1- 2 rupture lengths from it, and at a rate of occurrence that is higher than the background seismicity of that area prior to that mainshock. Practically, however, aftershocks are defined ad-hoc, according to the scope of the given study (Utsu, 1961, 2002).

The short-term relations between earthquakes and their aftershocks have traditionally been expressed by three empirical scaling laws, namely: (i) The empirical Gutenberg-Richter frequency-magnitude (power law) relation (Gutenberg and Richter, 1954); (ii) The magnitude relation between a mainshock and its largest aftershock (Bath, 1965); and (iii) The Omori law which states that a main earthquake is immediately followed by a sequence of aftershocks with a frequency of occurrence decaying at a rate proportional to t - p, where p~1 (Omori, 1894). A relation attempting to incorporate all three relations in one is the generalized Omori law (Shcherbakov et al., 2004) for aftershock decay rates.

In general, the larger the mainshock, the larger and more numerous are the aftershocks and the longer their period of occurrence, up to several years. Empirically, the average size of the largest aftershock in a mainshock-aftershock sequence, is ~1.2 magnitude units smaller than the mainshock (Bath, 1965), but this may vary widely from 0.3 to 3 or more, and cannot be predicted

The timing of the largest aftershocks cannot be predicted either. Many strong aftershocks appear within minutes and hours of the mainshock, but in many cases the strongest aftershock is delayed days, weeks and even months later (e.g., Hough and Jones, 1997). Moreover, often an earthquake sequence triggers a new sequence nearby

in which the mainshock is sometimes even stronger than the previous one (earthquake storm). This might be explained by a stress-triggering effect, but so far this is not predictable either.

The area affected by an aftershock occurrence is relative to the size of the manishock (e.g., Utsu, 2002) and this is also in accordance with the notion that the length of the seismogenic rupture scales with the magnitude of the mainshock.

Reports of past destructive earthquakes have been accumulating in the Levant for more than two millennia and contain a wealth of information. Although subjective, interpretative and incomplete, these descriptions allow a significant expansion of the seismological experience, almost 20 times the limited short time-span of modern, instrumental observations. Obviously, neither magnitudes nor epicenters were given for historical earthquakes, but the mere occurrence and the description of the damaged and felt areas constitute invaluable information. Thus studying historical events, especially with the given long repeat times of strong earthquakes in this region, would be more effective than waiting for the next strong one. The limitations of the historical chronicles are well recognized, nevertheless, ignoring partial and sometimes even vague information may result in overlooking important aspects of damaging earthquakes in this region.

There are many hidden, subtle aspects in past reports and a careful screening may reveal important descriptions which otherwise may have been ignored. The information which stretches over a period, paralleled only in a few other areas worldwide, may greatly improve our insight into the nature of the seismicity of the Dead Sea Transform (DST). For example, the historical 1837 strong earthquake in northern Israel was reported to have been associated with seismic tremors for four months (Ambraseys, 1997), and this can be interpreted as a typical sequence of mainshock and aftershocks. The event of April 30, 1212, can be interpreted as a foreshock to the large earthquake of May 1, 1212, in southern Israel (Ambraseys et al., 1994). The October 1759 large earthquake shortly followed by the November 1759 large event (Ambraseys and Barazangi, 1989) may resemble the destructive Izmit earthquake sequence of August and November 1999 in Turkey. This work focuses on historical accounts that report in detail the sequence of events that occurred along the DST, and examines the seismicity in light of modern seismology. It enables

characterizing the nature of strong earthquakes that appeared in the region and typify the sequence of events that preceded and followed it.

2 Analysis of historic seismicity

There are several sources reporting or indicating past earthquakes, each has advantages and limitations, and none lack uncertainties. Most common are historical documentations, paleoseismic evidence and archaeoseismic findings. Among these, the main body of information that details the pattern of the historical seismicity is reports of past earthquakes. They are written in various languages from many places and cultures and describe a wide spectrum of aspects and points of views. Bringing all the events together to a common denominator, in one language and in seismological terms is essential in order to build as unified and complete a catalogue as possible, but is not a trivial matter. This aim has already been targeted by several modern researchers (e.g., Ambraseys, Guidoboni), and we base our compilation upon their studies. We explain in detail how the list was compiled and discuss the patterns of seismicity that we were able to identify.

2.1 Method

a. List of historical earthquakes

The list was compiled from catalogues and seismological compilations that were based on original sources, in order to construct a dependable and comprehensive record of damaging earthquake that occurred along the DST system. The evaluated parameters include:

I. Origin time of occurrence of each of the events. This was adopted from the sources used for this work.

II. Location: Historical accounts provide information relating to the felt and damaged area and sometimes to natural effects. Therefore, the least interpretative approximation is to determine the center of the affected area as given by the historical sources. Determining the epicenter or the ruptured zone, however, requires alternative sources of information such as paleo- and archaeo-

seismology, as well as presumptions regarding the areal tectonics and active faulting.

III. Magnitude: Here too, the original 'recordings' are the felt and damage reports, therefore the first approximation of the size of the historic event can be in terms of seismic intensities. Transforming intensity to magnitudes needs further assessment.

IV. Type of events: The historical accounts describe the sequence of the earthquakes in many different ways and points of view, such as time and geographic spread, political and religious aspects, etc. We interpreted the sequence described in terms of which of the events was considered the main one and those that preceded and followed it.

b. Synthesis

The various sequences were classified in order to identify characteristic patterns.

c. Discussion

The various patterns were discussed in analogy with modern seismology. Historical patterns with no modern parallels were also discussed.

d. Conclusion

The typical behavior of past seismicity, both historic and modern, is summarized. It enables better understanding of the expected aftershock patterns along the DST and identifying the style of ongoing seismic events in its early stages.

2.2 Historical seismicity along the Dead Sea Transform

2.2.1 Sources of data

Most of the information regarding events around the Mediterranean until the 15th century A.D. has already been collected, compiled, analyzed and presented in catalogues by Guidoboni et al. (1994) and Guidoboni and Comastri (2005). Later events however, from the 16th century onwards, have not yet been catalogued in a similar systematic approach. Other invaluable reviews were published by Ambraseys (1989, 2004), Ambraseys et al. (1994), Ambraseys and Finkel (1995), Poirier and Taher (1980)

and others. Re-appraisals by Ambraseys (2005a,b), Ambraseys and White (1997), Karcz (2004), as well as focused investigations on specific events (e.g., Ambraseys and Barazangi, 1989; Ambraseys and Karcz, 1992; Ambraseys and Melville, 1988; Darawcheh et al., 2000; Guidoboni et al., 2004a,b) are also available. Many other lists draw from both primary and secondary sources (e.g., Amiran et al., 1994; Ben-Menahem, 1991; Khair et al., 2000; Plassard and Kogoj, 1968; Sbeinati et al., 2004) and we refer to them after cross correlating their data with the primary sources.

There have been far fewer direct field investigations of past earthquakes and these may provide a better estimate of the rupture zone, magnitude and mechanism (e.g., Akyuz et al., 2006; Amit et al., 1999; Daëron et al., 2005, 2007; Elias et al., 2007; Ellenblum et al., 1998; Gomez et al., 2001, 2003; Klinger et al., 2000; Marco et al., 1997, 2003, 2005; Meghraoui et al., 2003; Neimi et al., 2001; Reches and Hoexter, 1981; Zilberman et al., 2004, 2005). Attributing paleoseismic parameters to historical events, however, is not a straightforward process. In most cases, given field evidence is associated with the candidate from a known list of historical earthquakes that best fits it. Taking the paleoseismic data back to prove and support the existence of the selected historical event, should be done with care in order to avoid circular reasoning. For example, paleoseismic evidence may erroneously be used to support a historical earthquake while in fact the evidence may belong to an earthquake for which there is no historical report at all.

Other seismogenic effects, such as lacustrine seismites and deformed layers from the Dead Sea basin (Marco et al., 1996; Enzel et al., 2000; Ken-Tor et al., 2001; Migowski et al., 2004) may attest to the strength of shaking or to distance from the source of many of the historical events. These natural features may also record strong earthquakes that were possibly missed, ignored, lost or not reported in the course of history. Similarly, archaeoseismogical evidence also contains useful information. These sources are limited in pointing to the exact date, source area and strength of the event, yet they provide invaluable information that certainly should be addressed in future studies (Ambraseys, 2006; Karcz et al., 1977).

2.2.2 Reliability, uncertainties and limitations of the historical data

The notion that many of the earthquake catalogues contain erroneous entries has already been raised by several researchers (e.g., Ambraseys et al., 2002; Guidoboni and Comastri, 2005; Karcz, 2004) and this appears to be also the case with the Levant. They demonstrated that several of the events noted in the published literature originated from misprinting, misinterpretation, duplication, etc., and in fact are false. The critical studies were able to filter out the questionable events and present more reliable lists. Overall, it seems that sufficient information has already been accumulated, enabling reconstructing a dependable list of earthquakes that originated in the Levant area.

In our view, the main limitation of the historical reports is the subjective description which does not detail the source parameters. In contrast to modern instrumental recordings, where the threshold of detection is more or less known and completeness of the list can be evaluated, it is not possible to know which category or type of event is missing from the historical record. Hence, the reported earthquakes are probably a partial accounting of the actual occurrences.

Deriving quantitative source parameters from the historical descriptions is a subjective assessment involving considerable uncertainty. It is therefore important to mark out a clear line between the original story and the evaluated parameters. It is not even possible to quantify the uncertainty associated with the evaluation because it depends on personal judgment rather than on a measuring procedure. Therefore, one should be aware of the limitations and unknowns typical to the historical material, and realize how far interpretation may go.

2.2.3 The list of historic earthquakes

On the whole, we listed all the damaging events that were reported to have occurred in and around the DST system, regardless of their nature, whether schematic or detailed, small or large. Next, we correlated the data with the existing literature in order to validate or question each of the events. In most cases, studies that relied on primary sources and extracted the original description more accurately enabled distinguishing real events from questionable ones. This resulted in a compact, yet more reliable (in our opinion) list of earthquakes than if we had listed every possible event.

As we were focusing on the nature of seismicity along the DST, and given the limited resolution of the historical data, we listed all the events that affected the region belonging to the DST system and its associated structures. For example, Elias et al. (2007) suggested that the damage in the coastal cities of Lebanon caused by the earthquake of 551 A.D. was due to the rupture of the offshore Mount Lebanon thrust, and that this thrust belongs to the DST system. This implies that in addition to shear events that originated from the DST and its parallel and branching faults, the list also includes events from associated thrusts and normal faults.

The list is presented in Table 1 and, with a short description of each of the events, in Appendix 1. For each of the events we list the date of occurrence, locality and coordinates of the most severely affected area, the intensity in terms of Imax or I_0, and the estimated magnitude. For the seismic style we noted foreshocks that occurred and the time they preceded the mainshock, the number of mainshocks, and the length of aftershock series and specific aftershocks when reported. Below we explain in detail how these parameters were determined.

Origin time

This is a very important parameter and misinterpreting it may simply result in duplicating a given event and inflating the actual list. As trivial as the origin time maybe, determining it is not at all simple. For example, the exceptionally intense seismic sequences along the northern DST during the 12^{th} century were extensively studied by Ambraseys (2004) and Guidoboni et al. (2004a,b). Basically, the two researchers relied more or less on the same original contemporaneous sources, but each arrived at different origin times (by days) of what seems to be the same sequence of events.

Overall, origin times were adopted from studies that carefully examined this aspect and also related to errors in the published literature in relation to the questioned event. In cases still unresolved, we tried to avoid duplication and adopted the best estimate in our opinion. For each of the events selected, we cited its time of occurrence to the extent that it is known, by the year, month, day, part of the day, hour and minute.

Table 1 Pattern of seismicity of damaging historical earthquakes that occurred along the Dead Sea Transform

The following is a summary list of historical earthquakes that caused damage in the Levant, most of which possibly originated from the Dead Sea Transform system and nearby structures. The extended list is in Appendix 1. Also included are events with noted seismic effects or irregular sequence of events, and events that were felt in Israel up to the 18th century. Modern (20th century) events with noted aftershock activity are added for comparison. Earthquakes that hit (not necessarily originating in) Israel, are marked in blue.

Date: Events are marked by time of occurrence, as detailed as known, by year, month, day and part of the day or night.

Affected area: center of the **most severely affected area**, by locality and geographical coordinates. This is not necessarily the epicenter area.

Estimated size of the earthquake: by seismic intensity $\mathbf{I_0}$ - intensity at the area most severely damaged, in cases the data sufficiently cover all around the affected area, and **Imax** - intensity at the area most severely affected, in cases where there is only partial cover of the affected area. Estimated magnitude is given in the broad categories, as suggested by Ambraseys and Jackson (1998): **V**- very large event ($Ms \geq 7.8$), **L**- large ($7.8 > Ms \geq 7.0$), **M**- Moderate ($7.0 > Ms \geq 6.0$) and **S**- small ($Ms < 6.0$). Estimations were taken from historical, geological and paleoseismical studies, and if not available, made by personal judgment.

Pattern of seismicity: sequence of events as reported in the original sources. Preshocks are noted by number of events and period of time they preceded the main event; Main shocks, by number of events and length of time; Aftershocks, by number and length of time they lasted; and Noted aftershocks by number, date of occurrence and time lasted.

Date	Affected area			Estimated size			Pattern of seismicity			
	Locality	N	E	Imax	I_0	Mag.	Preshocks	Main	Aftershocks	Noted after.
760 - 750 B.C.	Jerusalem	31.8	35.3	?	?	?		1		
199 – 198 B.C.	Sidon	33.5	35.3	IX		M		several		
Mid 2nd cent. B.C.?	Nearby Sidon	33.5	35.3	≥V		M		1		
148 02 21 afternoon B.C. (or 130 B.C.)	Antioch	36.2	36.2	IX - X		M		1		
c. (69 –) 65 B.C.	Syria and Antioch	36.0	36.3	IX		M		1		
31 B.C. early spring	Judea	31.9	35.2	VIII		M		1		
A.D. 37 03 23 early in the morning	Antioch	36.2	36.1	VII		S (- M)		1		
c. 47	Antioch	36.2	36.2	VII		S (- M)		1		

Date	Affected area			Estimated size			Pattern of seismicity			
	Locality	N	E	Imax	I_0	Mag.	Preshocks	Main	Aftershocks	Noted after.
115 12 13 morning	Antioch	36.2	36.2	IX		M (- L)		1		
c. 127 – 130	Nicopolis, Caesarea	32.2	34.9	IX		M		1		
303 or 304	Tyre and Sidon	33.4	35.4	VIII - IX		M		1		
341	Antioch	36.2	36.2	VIII		(S -) M		1	1 year	3 days?
348 or 349	Berytus (Beirut)	33.9	35.3	VIII		S (- M)		1		
363 05 18 - 19 night	Judea and Samaria (and possibly Petra)	32.2	35.5		IX - X	M - L		1	Tremors	1, after 6 hr
419	Palestine, Jerusalem	32.2	35.5	VIII		M		Several		
450 - 457 night	Tripolis	34.4	35.8	VIII		S (- M)		1		
458 09 13 - 14 night	Antioch	36.2	36.2	VIII		S – M		1	Unknown length	
502 08 22 night	Ptolomais, Tyre, Sidon	33.0	35.0	IX - X		M		1		
526 05 20 or 29 mid-day	Antioch and Seleucia	36.1	36.1	IX		M		1	1 - 1.5 year	6 days
528 11 29	Antioch and Laodicea	35.9	36.0	IX		M		1 (lasted one hour?)	Unknown length	lasted one hour?
551 07 09 day	Beirut, off coast Lebanon	34.0	35.5	I_{max}/I_0 = X	I_{max}/I_0 = X	M - L		1 (or 2)		
c. 570	Around Antioch	36.5	36.5		IX	M		1		
580 or 581 noon	Daphne and Antioch	36.1	36.1	VIII - IX		S (- M)		1	Tremors?	
587 or 588 late October, night	Antioch	36.2	36.2	VIII - IX		S (- M)		1		
601 - 602 day	Syria, Rum (Cilicia)	36.5	35.5	VIII - IX		M		1		
634 09	Palestine, Jerusalem	31.8	35.3	VII		S - M		1	1 month	
659 06	Jerusalem	31.8	35.3	VII – VIII		M		1		
659 09 – 660 08	Jericho	31.8	35.5	IX		S - M		1		

Date	Affected area			Estimated size			Pattern of seismicity			
	Locality	N	E	Imax	I_0	Mag.	Preshocks	Main	Aftershocks	Noted after.
713 02 28 or 03 10, middle of the night	Antioch, Allepo, Qenneshrin	36.2	36.6		VIII - IX	M		1	40 days	
746 01 18 morning	Between Jerusalem and Tiberias	32.2	35.5		IX - X	M - L		1	40 days	
749 (or 750, or 757 03 09 midnight)	Around Mabbug: or in Mesopotamia:	36.5 35.0	38.0 41.0		IX	M	1?	1		
757 03 09, midnight (or 749, or 750)	Jerusalem	31.8	35.5	VII		S - M		1	3 events?	3 events?
835 01 05 – 12 25	Antioch	36.2	36.2	IX		S				
847 11 24 morning	a. Damascus: b. Antioch: c. Mawsil:	33.5 36.2 36.5	36.3 36.2 43.0	a, b, c.: VIII		a, b, c.: S - M		Several events, a: lasted 3 hrs		a: 3 hours?
853 06 12 – 854 06 01, night	Tiberias	32.8	35.6	VII		S		1		
859 12 30 – 860 01 29	Laodicea - Antioch	35.8	36.0		IX	M - L		1 (several?)		
881 05 16	Around the Mediterranean basin	?	?	?	?	?		Several		
972	Around Antioch	36.0	36.2	VII - VIII		S - M		1		
991 04 05 night	Damascus and Ba'albek	33.8	36.2	VIII		M		1	1 month	
1002 11 10 – 1003 10 29	Syria at the time	?	?	VIII		M		1		
1033 12 05 before sunset	Jericho–Nablus–Akko	32.0	35.2		IX	M - L		1	8 days	5-6/12; 6/12, 6-7/12, all 8 days?
1042 08 21 – 1043 08 09, (Tudmur, Palmyra)	Tudmur	34.5	38.3	IX		S - M		1		
1063 07 30 – 08 27	Tripoli	34.4	35.6	VII - VIII		M		Several		

Date	Affected area			Estimated size			Pattern of seismicity			
	Locality	N	E	Imax	I_0	Mag.	Preshocks	Main	Aftershocks	Noted after.
1068 03 18 08 30	Ayla: or Hejaz:	29.5 28.5	35.0 36.7		X	L		1 lasted 2.5 hours		2 events in 2.5 hours?
1068 05 29	Ramla?	32.6	35.3	I_{max}/I_0 = X	I_{max}/I_0 = X	M		1		
1086 04 18 – 1087 04 07	Iraq, Mesopotamia, Syria, other provinces	?	?	VIII		?		Several	Unknown period	
1091 09 26 night	Antioch	36.2	36.1	VIII		M		1	Numerous	
1094 05 19 – 06 18	Syrian territories	?	?	VI		S		Many in one month		
1097 12 30	Antioch	36.2	36.1	V		S		1	Unknown	
1105 12 24	Around Jerusalem	31.8	35.2	V		S		1		
1117 06 26 night	Tyre	33.1	35.2	VIII		S		1		
Sequence from: 1138 10 11 afternoon, to 1139 06	Around Azrab, south of Triple Junction of east Anatolian fault	36.7	36.9		X	M - L		1 (3 sub-events?)	80 events in 8 months	11/10: 3 events, 14/10, 3 in 27/10, several on 29/10 and 31/10, terrifying 21/6
1140 08 17 – 1141 08 06	Sheizar	35.3	36.6	VI		S		1		
c. 1150	Jerusalem and Jericho	31.8	35.4	VIII		S - M		1		
1151 09 28 night	Busra	32.5	36.5	VII		S		3 shakes		
1152 02 01, shortly before dawn	Busra	32.5	36.5	III-V		S		3 shakes		
1156 09 27	Damascus?	?	?	V		S		1	1 day	
1156 10 13 night	Afamiyah (between Allepo and Hamat)	35.4	36.4	VII		S - M		Several		
1156 12 09 night	Allepo	36.2	37.2		VIII	S - M		1	Many	

Date	Affected area			Estimated size			Pattern of seismicity			
	Locality	N	E	Imax	I_0	Mag.	Preshocks	Main	Aftershocks	Noted after.
1157 04 02 night towards dawn	Afamiyah	35.4	36.6	VII		S - M		Several	Several	
1157 07 05 morning	Hamat	35.2	36.6		VII	M		Several	Several	
1157 08 09 – 09 07	Aleppo, Hamat, Hims	35.4	36.6		IX	L		Several	Several	
1163 08	Antioch	36.2	36.2		VIII - IX	M		1		
1170 06 29 0345 UT	Antioch, Tripoli Bekaa Valley, Allepo	34.6	36.2		IX - X	L		1-2	> 3-4 months	
1202 05 20 0240 UT	Lebanon, Syria, Israel: Akko, Tyre Baniyas Safad…	33.9	36.1		IX - X	L		2 shock or 2 sub-events	4 days	4 days?
1212 05 01 night/dawn	Ayla, Shubak-Karak	29.6	35.0	$I_{max}/I_0 \geq$ IX - X	$I_{max}/I_0 \geq$ IX - X	M (- L)	1, ~12 hr before	1	1 year	
1259 03 22 night	Damascus	33.5	36.3	VII		S		1	Numerous	
1287 02 2nd half	a. between Zafad and Hims b. Near Hims c: Near Zafad	a. 33.9 b. 34.7 c. 33.0	a. 36.1 b. 36.7 c. 35.5	VII		S		Series		
1287 03 08	near Hims:	34.7	36.7	VII		S		1		
1287 03 22	near Laodicea:	35.5	35.7	VII		S		1		
1293 01 11 – 02 08	Karak, Tafila	31.2	35.5	IX		M (-L)		1		
1339 01 13 – 02 11	Tripoli	34.4	35.9	VII		S		1		
1344 01 03	Aleppo	36.7	37.5		IX	M - L		2 closed	> 1 month	
1366 09 07 – 1367 08 27	Safad	33.0	35.5	V		S		1		
1404 02 20	Aleppo and Tripoli	35.3	36.5	VIII		M - L	1, on 1403 12 18	1	5 months	10 days?
1404 11 05 – 12 04	Aleppo	36.2	37.2	V		S		2		
1407 04 09 – 05 08	Antioch	36.2	36.1	VII - VII		S		1		

Date	Affected area			Estimated size			Pattern of seismicity			
	Locality	N	E	Imax	I_0	Mag.	Preshocks	Main	Aftershocks	Noted after.
1408 12 29	Shughr Bakas and Balatunus	35.7	36.2		IX	M		1		
1458 11 08 or 16	Karak	31.2	35.7	IX		M		1		
1484 03 29 – 04 28	Aleppo	36.2	37.2	V		S		6 or more		
1537 03 09	Antioch	36.2	36.1	VI		S		1		
1546 01 14 afternoon	Jordan Valley, Jerusalem to Nablus	32.0	35.5		IX	M		1	> 4 months	13/3, 13/5
1557 02	Jerusalem	31.8	35.3	VI		S		1		
1563 09 13 dawn	Damascus	33.5	36.6	VI		S		1		
1565 07 27 dawn	Damascus	33.5	36.6	V		S		1		
1588 01 04 13:00	Aila and Tabuk	29.0	36.0		VIII - IX	M		1		
1626 01 21	Gaziantep, Aleppo, Hama	36.2	37.2	VII - VIII		M		1		
1627 11 24 night	Damascus	33.5	36.3		IV - V	S		1		
1705 11 24 night	Yabrud, Al-Qastal, Damascus	34.0	36.6		VIII	M	1	1	1 month	
1738 09 25	Amanus	36.3	36.5		VII - VIII	M		1		
1759 10 30 03:45 LT	Zafad and Qunaitra	33.1	35.6		IX	M		1	Series	
1759 11 25 19:23 LT	Litani and Bakaa	33.7	35.9		X	L		1	> 9 months	26/11, 5/12, 12/12, 30/12
1795 12 ?? 14:10	Aleppo	36.2	37.2		VI	S		2		
1796 04 26 09:05	Latakia	35.7	36.0	IX - X		L		1, for 1 min.	2 months	
1822 08 13 20:40	Gaziantep, Aleppo, Han Shekhum	36.7	36.9		X	L	8 days slight shocks, 1 strong half hour before	1 in 3 phases in 40 sec	2.5 years	30 in 8 min
1834 05 26 04:00	Jerusalem and Bethlehem	31.7	35.2	VII		S - M		1	10 days	

Date	Affected area			Estimated size			Pattern of seismicity			
	Locality	N	E	Imax	I_0	Mag.	Preshocks	Main	Aftershocks	Noted after.
1837 01 01 14:34	Southern Lebanon	33.3	35.5		IX	M - L		2 in 5 min., 10-30 sec ea.	4 months	16/1, 22/1, 25/1, 20/5
1872 04 03 07:40	Antakya	36.4	36.5		X	L		1 in two phases	10 months	2 months
1927 07 11 13 04	Northern Dead Sea	31.6	35.4		IX	M, M_L=6.2		1	12 in 7 months, 2 more in next 29 months?	M_L4.5 on 17/7, M_L5.5 on 22/2/1928
1969 03 31 07 16 (Gulf of Suez)	Shadwan, Gulf of Suez	27.7	34.0		IX	M, M_L=6.6	35 in two weeks, 3 $M_L \geq 4$	1	> 2,000; 19 M_L ≥4 in half year; 4 in next 15 months	M_L≥5 on 8/4 and 26/9
1983 02 03 23 30	Gulf of Elat (Aqaba)	29.2	34.8		IV	S, M_L=5.3	Two weeks	1 in Swarm	8 months	
1993 08 03 12 43	Gulf of Elat (Aqaba)	28.6	34.6		V	S, M_L=5.8	2.5 hours	2, in a swarm?	420 of M_L>35 in 5 months	
1995 11 22 04 15	Gulf of Elat (Aqaba)	28.76	34.66		VIII	L, M_L=6.2 Mw=7.2		1	> 5,000, most in 100 days, all in two years	26/2/1996, Mw=5.6,
2004 02 11 08 15	Northern Dead Sea	31.7	35.55		VI	S, M_L=5.2		1	Few tens in half a year	M_L3.7 on 13/2

Intensities

The size of an earthquake, in terms of how severely it affected the population and manmade structures as well as the natural environment, is described by a seismic intensity scale. While the magnitude of an earthquake is a quantitative measure, seismic intensity is a subjective estimate of a suite of seismogenic effects, phenomena and damage.

Many scales evolved and in general they are typical to specific regions and building cultures. The common scales are: the Modified Mercalli Intensity (MMI), mostly used in the USA, the Mercalli Cancani Sieberg (MCS), the Medvedev Sponheuer Karnik (MSK), the European Macroseismic Scale (EMS), mostly in use in Europe, and the Japan Meteorological Agency seismic intensity scale (JMA). These are 12 degree scales, except the JMA, which has 7 degrees only.

Regarding the Levant, no specific macroseismic scale was developed and in fact researchers have used all the various scales: Amiran et al. (1994) used MMI, Sbeinati et al. (2005) used EMS 1992, Guidoboni and Comastri (2005) used MCS, Avni (1999) used MSK, and the empiric magnitude (M_L) – intensity relations for Israel were formulated in MSK (Feldman and Shapira, 1994). Correlation between the different scales is not simple. Panza (2004) for example, elaborated on the complex relation between intensity scales and acceleration, while Ferrari and Guidoboni (2000) arrived at a simple comparison. Michetti et al. (2004), who recently developed the INQUA scale which grades 12 degrees of environmental effects, approach this problem in a realistic way: "… *due to the level of uncertainty inherent in the structure itself of the macroseismic scales, and in case a conversion between scales is a step that cannot be absolutely avoided, the best we can do is to consider all the twelve degrees scales as equivalent*" - relating to MCS, MM, MSK EMS and the Chinese scale. Here we adopt the INQUA approach and regard all various intensity estimates assigned to damage in the Levant as if taken from the same scale. This of course is a preliminary evaluation that will certainly need to be re-examined in the future.

Assigning intensity degrees to macroseismic damage is the first important step in measuring the size of historical earthquakes. This is a subjective process which is based on both personal description of the seismic effects and personal evaluation of the damage (e.g., Cecic et al., 1996; Cecic and Musson, 2004). There are many other difficulties involved, for example, the level at which intensities saturate. Traditional

building practice in the Levant is not considered anti-seismic (Willis, 1928) and may not sustain high intensities. Regarding the 1837 earthquake in southern Lebanon, Ambraseys (1997) suggested that all local houses collapsed at VII-VIII MSK, and no indicators were left for higher degrees. Other studies, however, did assign higher maximal degrees, even for much earlier events (e.g., Guidoboni et al., 1994). Such difficulties increase uncertainty but are unavoidable and deserve further effort to overcome. Yet surprisingly, intensities do yield a relatively good idea of the size of historical earthquakes and the area affected. It also enables putting different earthquakes on a common scale and comparing events to each other.

Size of the historical earthquakes – maximal intensities

There is no consistent or systematic way to determine the strength of historical earthquakes, and this also holds for the DST, where descriptions, both full and partial, vary from place to place, time to time and event to event. Several empirical intensity-magnitude relations were suggested (e.g., felt area–magnitude, by Frankel 1994) and they usually relate to given regions and are associated with large uncertainties. Other quantitative estimates of the magnitude and epicenter location were developed in cases where a good set of data was available (e.g., Shebalin, 1973; Bakun and Wentworth, 1997; Gasperini et al., 1999; Sirovich and Pettenati, 2001). Seldom does complementary paleoseismic evidence enable a better magnitude determination. With the present understanding, where a magnitude of historical seismicity is mainly based on macroseismic data rather than on measurable parameters, it is impossible to assign a clear magnitude.

In this work we determined the maximal intensities and the center of damage, with the aim of evaluating the location and magnitude of the events in later stages. We identified the most severely affected or damaged places for each of the listed events and assigned intensity degrees to them. Generally, we followed the guidelines suggested by Ferrari and Guidoboni (2000) and estimates given in previous publications (e.g., Guidoboni et al., 1994; Guidoboni and Comastri, 2005). In cases where a full cover of the affected area was available and the most severely damaged zone was more or less at the center of it, we assigned the maximal intensity – $\mathbf{I_0}$. It is reasonable to assume that the $\mathbf{I_0}$ zone is a close approximation of the seismogenic focus area. In many other cases where only a partial cover of the affected area was available (e.g., where only a single

or a few localities were mentioned, along coasts, etc.), and the maximally damaged zone seemed to be clearly off center, we assigned **Imax** to the most severely damaged sites. These are possibly the closest to the epicenter sites, but the seismogenic epicenter could well be far away.

Based on the resulting maximal intensities, as well as on estimates in previous studies, we also evaluated the magnitudes of the historical events in terms of the broad categories suggested by Ambraseys and Jackson (1998) where: V- very large event (Ms $\geq$ 7.8), L- large (7.8 > Ms $\geq$ 7.0), M- Moderate (7.0 > Ms $\geq$ 6.0), and S- (6.0 $\geq$ Ms). Minimal magnitudes of historical earthquakes are also important, mainly for the study of small events such as foreshocks and aftershocks. Experience shows that the lowest magnitude of felt earthquakes is on the order of M 3.5-4, given that the observer is very near to the epicenter. As distance from the epicenter increases, the threshold of felt earthquakes increases as well.

Obviously, this is a subjective procedure because the original reports do not contain full coverage of the damage and effects and we have no simple calibrated damage-intensity relationship available. Therefore, some large events may be under-reported and listed as moderate. Similarly, inflated reports of moderate earthquakes, some closely-timed moderate events, a mainshock followed by an intensive aftershock sequence, an earthquake swarm with several strong events, and a sequence of strong events may all be described as one large earthquake. Moreover, factors such as site effects and directivity that increase damage are not considered either, and may bias interpretation of historical events.

Location of the historical earthquake – center of damage

Ideally, the center of the most severely damaged area should coincide with the epicenter or the rupture zone of the given earthquake. But this was proved to be too simplistic an assumption and in fact the relationship is much more complicated. For the populated area is not homogeneously scattered around the earthquake epicenter or in the area of interest, the spread of the seismic waves is not symmetric, site effects dramatically vary from place to place, and historical reports in most cases are biased and incomplete. Locating a historical event is therefore a dependent procedure and if not

carefully done, may result in duplicating an event, moving it to a different area or borrowing it from elsewhere (e.g., Karcz, 2004).

The original reports vary from referring generally to the affected area, pointing to one site only, and listing (all?) the affected localities and structures. Single sites might have been mentioned for being the most severely affected, those only known to be affected, most important or of special interest for the reporter, and in some cases, the site where the earthquake was felt by the reporter. In some cases it is possible to delineate the most severely affected area (I_0), while in others, where only a partial coverage of the affected zone was available, only the site of maximal damage (Imax) can be identified. Some localities, such as Antioch or Jerusalem, were mentioned to have been hit again and again, possibly due to being important cultural, political and religious centers. For the very same reason we may assume that other less important sites might have just been neglected.

Given the above constraints, the simplest and least biased interpretation would be to assume that the center of the most severely damaged zone (also termed macrocenter, intensity center, or barycenter) represents the seismic epicenter. Our estimates regarding the center of the affected area are presented in Table 1 and Appendix 1.

2.3 Synthesis – historical sequences

Altogether we count 97 significant earthquakes that have been reported to have caused damage in and around the DST area, since about the 8th century B.C. up to the end of the 19th century A.D. (Table 1 and Appendix 1). Also included are a few events noted for seismic effects or irregular sequence of earthquakes, and events that were felt in Israel up to the 18th century. Modern, 20th century events that were associated with noted foreshock and aftershock activity in the area studied are added for comparison. The thirty-three earthquakes that affected Israel, although not necessarily focused there, are marked in blue.

Looking at the spatial and temporal appearance of historical earthquakes, it is possible to distinguish patterns familiar in modern seismology. Most common are the mention of a single or a sequence of several noted events and the reporting of lighter shocks that followed the main event for some period of time. Rarely, but quite

interestingly, a few earthquakes that preceded the main event were also mentioned. Other unique aspects are the strength and length of the shaking of the main event.

We classified these patterns according to the time they appear in regard to what we interpreted as the main shock. Appendix 2 summarizes these classes and they are detailed and discussed below.

2.3.1 Single events

Many events were reported as single earthquakes with no mention of other shocks (e.g., fore- or aftershocks), these are listed in Table 2. Present-day single events in the region of the DST are mostly of small magnitude, and as the seismic network improves, aftershocks are recorded for even smaller events. On the other hand, almost all modern large earthquakes are associated with aftershocks (deep earthquakes are an exception), and this seems to be the nature of strong earthquakes. It is therefore reasonable to assume that large historical earthquakes were also associated with aftershocks, but these were not reported. Therefore, in our opinion, the appearance of large (damaging) historical earthquakes as single events is due to incomplete reporting. All together we count 48 single events, including 5 that occurred B.C. and 43 events A.D. Sixteen single events affected the area of Israel (blue color in Table 2).

Table 2 Historical events reported as single earthquakes

Single historical events
B.C.: 760-750, Mid 2nd century, 148 02 21 (or 130), c. (69 –) 65, 31.
A.D.: 37 03 23, c. 47, 115 12 13, c. 127-130, 303 or 304, 348 or 349, 450 - 457, 502 08 22, 551 07 09, c. 570, 580 or 581, 587 or 588, 601 - 602, 659 06, 659 09 – 660 08, 853 06 12 – 854 06 01, 972, 1002 11 10 – 1003 10 29, 1042 08 21 – 1043 08 09, 1068 05 29, 1097 12 30, 1105 12 24, 1117 06 26, 1140 08 17 – 1141 08 06, c. 1150, 1163 08, 1287 03 08, 1287 03 22, 1293 01 11 – 02 08, 1339 01 13 – 02 11, 1366 09 07 – 1367 08 27, 1404 11 05 – 12 04, 1407 04 09 – 05 08, 1408 12 29, 1458 11 08 or 16, 1537 03 09, 1557 02, 1563 09 13, 1565 07 27, 1588 01 04, 1626 01 21, 1627 11 24, 1738 09 25.

2.3.2 The mainshocks

Many descriptions relate to the strength and length of the shaking of the main event, whether reported as a single or part of a sequence.

Duration of the mainshock

Interestingly, ten descriptions tell how long the shaking lasted and even distinguish several phases within the given event. It was possible to arrange these reports according to the length of time the shaking lasted: by seconds, minute and even hours (Table 3).

Table 3 Mainshock durations of historical earthquakes

Duration	Historical earthquake	Comments
Seconds to a minute	**1588 01 04**: a strong shock of earthquake was felt in Cairo, where it was of long duration **1796 04 26**: lasted with intermissions for about one minute. **1822 08 13**: The main shock happened in three phases lasting altogether 40 s. After a short pause, the main shock was followed for about 8 min by successive shocks, about 30 in all, each of short duration but of damaging intensity. **1837 01 01**: The main shock lasted between 10 and 30 s, the earthquake consisted of two distinct shocks about 5 min apart.	Duration is correlative to magnitude
Minutes to hours	**528 11 29**: The earthquake … lasted for one hour **847 11 24** (one of the events): dreadful earthquake, lasted for three hours **1068 03 18**: an earthquake… lasted for two and a half hours **1822 08 13**: The main shock happened in three phases lasting altogether 40 s. After a short pause, the main shock was followed for about 8 min by successive shocks, about 30 in all, each of short duration but of damaging intensity; **1837 01 01**: The main shock lasted between 10 and 30 s, the earthquake consisted of two distinct shocks about 5 min apart.	Could be a succession of strong aftershocks immediately after the mainshock
Number of shocks	**1344 01 03:** Two shocks in close sequence **1404 11 05 – 12 04:** When the first shock ceased, another followed **1837 01 01**: The main shock lasted between 10 and 30 s, the earthquake consisted of two distinct shocks about 5 min apart. **1872 04 03**: Between the first shock and the latter part of destructive shaking many people managed to run out of their houses into the open.	Could be sub-events, triggered events or immediate strong aftershocks

The latter, such as that of 1068 03 18: "an earthquake… lasted for two and a half hours," is hard to interpret since we are not aware of such a long duration. Strong motion of earthquakes on the order of magnitude 7 near the epicenter may last several tens of seconds (rupture velocity of 2-3 km/sec for 100 km faults), and even the 9.2 2004 Sumatra earthquake lasted less than 10 minutes. A possible interpretation can be that these were intensive aftershock sequences that immediately followed the mainshock and gave the people at the time the impression that the earthquake lasted for hours.

Some reports describe a very close sequence of shocks, such as on 1404 11 05 – 12 04: "When the first shock ceased, another followed." The resolution we have is not sufficient to further classify these as, for example, a large aftershock that immediately followed a mainshock, or even speculate these as sub-events. Nevertheless, this is invaluable information since it tells us that some destructive earthquakes (e.g., 1872) started 'low' and intensified in later stages, thus giving the people short but precious time to evacuate into the open.

Strength of shaking

Eleven reports described earthquakes "such as has not occurred before" (31 B.C.), and the great impact of the shaking (Table 4). No tools are available to quantify terms such as "tremendous shaking" or "mighty earthquake" and we can only tell that this was the impression people got at the time. Even today, we know that a great earthquake is inevitable, but still its timing and shaking will probably be a complete surprise. Yet the reports tell that there was a strong motion and if "everything had been tossed" we may assume that this was a very strong motion. This of course, from our present point of view, may result from strong motion at the seismic origin, short distance from the earthquake source, and even from strong site effect.

The strongest shake may arrive right at the start of shaking: "In Latakia so violent that almost everything collapsed with the first shock" (1796 A.D.), or in later phases: "Between the first shock and the latter part of destructive shaking many people managed to run out of their houses into the open" (1872). Whenever the strong shaking appears and as trivial as it can be in our eyes, the historical reports clearly tell that the destruction was associated with the strong shakings, and this in fact is the essence of anti-seismic engineering.

Table 4 Strength of shaking of the main event

Shaking	Historical earthquake
The shaking	**31 B.C**: such as has not occurred before **115 12 13:** unusually powerful, tremendous quaking **341**: most violent earthquake **363 05 18-19:** A mighty earthquake tore up the stones of the old foundation of the temple. **1097 12 30**: When the earthquake near Antioch began… I was so struck with terror… the earth continued to shake and the terror within me continued to increase. **1872 04 03**: Between the first shock and the latter part of destructive shaking many people managed to run out of their houses into the open.
Effects of the strong shaking	**363 05 18-19:** A mighty earthquake tore up the stones of the old foundation of the temple**.** **551 07 09:** Mountains were uprooted and violently split open. **1033 12 05**: "We have seen the mountains shake, leap like stags, their stones broken into pieces, the hillocks swaying to and fro, and the trees bending down". In some places the waters in the cisterns reached the brim…" ראינו ההרים רועשים כאילים רוקדים אבניהם מתפוצצות והגבעות מתנודדות והאילנות מתכופפים עד מימי הבורות במקומות עלו עד פיותיהם
Strong motion?	**458 09 13-14 :** Everything had been tossed and terribly shaken **526 05 20/29**: Foundations of buildings were struck by thunderbolts, thrown up, lifted and collapsed (liquefaction?) **1796 04 26**: in Latakia so violent that almost everything collapsed with the first shock**.**

2.3.3 Pre-shocks

Only five accounts report of earthquakes that preceded the main event by several minutes to a few months (Table 5). There could also be foreshocks that occurred a few minutes or seconds before the mainshock, but historical data does not enable resolving this from what happened during the main event (e.g., "When the first shock ceased, another followed," regarding the earthquake of 1404 11 05 – 12 04).

The reports do not tell if people did perceive in real time that a strong earthquake was to come, but clearly say that they felt worried: "… a strong shock was felt in the region: this caused considerable concern and warned the people of what was to follow. The main shock happened 30 min later…" (on 1822), or "The first caused general panic, the second was the strongest, causing the damage" (1705). In the case of 198-199 B.C., although there is no explicit mention of a preceding event, people realized the worst was to come and reacted: "… but the number of victims was limited,

because it did not happen in a single shock." Different instincts, unfortunately, were not proved to be so anti-seismic proof: "There was a tremor at night… and everyone had gone out of the city to pray at the temple… there was a sudden tremor and the temple collapsed on top of them…." (749).

Identifying foreshocks in real time is extremely important, because this is a true alarm, and it seems that somehow (intuitively, cumulative experience?) people at the time realized that, although they not always reacted right. Omitting the 48 reports of single events which we believe are incomplete, then about an eighth (5 out of 39) of the damaging earthquakes were associated with preshocks! Obviously, this is of great importance in seismic hazard evaluation and needs further examination.

Table 5 Historical foreshocks

Time before main event	Historical earthquake	Modern example
Minutes	**1822 08 13 20:40**: Slight shocks began on August 5 and continued intermittently until August 12. At 8 h 10 m pm on August 13 a strong shock was felt in the region: this caused considerable concern and warned the people of what was to follow. The main shock happened 30 min later.	
Hours	**749 (or 750, or 757 03 09):** There was a tremor at night… and everyone had gone out of the city to pray at the temple… there was a sudden tremor and the temple collapsed on top of them… **1212 05 01:** foreshock at sunset 30.4, main-shock at dawn 1.5. **1705 11 24:** Three main different sized shocks happened on Tuesday night: The first caused general panic, the second was the strongest, causing the damage.	**1993 08 03 12 43** (a swarm or a sequence): Largest event, M_L=5.8, was the third, 2.5 h after the first M_L=3.5, and 12 min after the second, M_L=4.8. Second largest event was M_L=5.6, 4.5 h after start.
Days, a few weeks	**1822 08 13 20:40**: Slight shocks, began on August 5 and continued intermittently until August 12. At 8 h 10 m pm on August 13 a strong shock was felt in the region: this caused considerable concern and warned the people of what was to follow. The main shock happened 30 min later.	**1969 03 31 07 16** (Suez Rift): Preceded two weeks before by 35 large preshocks, including 3 $M_L \geq 4$. **1983 02 03 23 30:** A swarm, largest event M_L=5.3 two weeks after start.
Months	**1404 02 20:** Before that, there had been an earthquake (1403 12 18), at midday.	

2.3.4 Aftershocks

The appearance of secondary shocks that closely followed the main shock is common in historical reports, mostly from the second millennium A.D., and refers to about a third (34 of 97) of the events. Some reports, mainly from the first millennium, are indirect and the occurrence of aftershocks is in fact a personal interpretation which is based on reactions of the people at the time: "Danger for three days" (341 A.D.), or "the inhabitants forced to take refuge in the desert, where they stayed for forty days" (746 A.D.).

Duration of aftershock sequence

The reported aftershocks were classified (Tables 6, 7) by hours, days, months, etc., according to the time they lasted after the main shock. We know today that large earthquakes produce intensive aftershock sequences which last several months and longer, including aftershocks of M3.5-4, which are considered as the lowest limit for felt quakes. The threshold limit for historical records is also of felt events, and it is therefore reasonable to accept aftershock sequences of historical events of similar length.

Short sequences, on the order of several days only, that follow destructive earthquakes are not common in modern seismology. Only when the observer is far away from the epicenter, the aftershock sequence seemingly 'becomes' shorter, simply because shaking decreases with distance. It can be assumed that short historical sequences related to the immediate strong aftershocks and neglected the tail of smaller, felt but non-damaging events. The notion of one month or 40 days could be a metaphoric symbol of a significant period of time derived from religious or cultural views, rather than what actually happened in real life.

In three reports it was possible to infer the occurrence of intensive activity after the main destructive event, but the time it lasted was not specified.

Total number of sequences per durations and number of noted aftershocks per time delay after the mainshock are presented in the summary at the end of Table 7. A simplified form of the summary is presented in Tables 8 and Figures 1 and 2, in order to emphasize the main trends.

Table 6 Duration of aftershock sequences of historical earthquakes

Duration	Historical earthquake
Several hours	**363**: event took place at the third hour, and partly at the ninth hour of the night **1068 03 18 08 30**: The earthquake was followed by two more shocks within the same period (two and a half hours?)
Several days	**1033 12 05:** For eight days the mind has not been satisfied and the soul is not at rest (שמונה ימים אין נחת רוח ואין נפש שוקטת**).** On that night (the earth) shook again – 5-6/12/1033; On Friday – 6/12/1033, as well as on the following night – 6-7/12/1033, the shocks recurred. **1202 05 20:** The major earthquake was followed by brief shocks towards noon on the same day, which were slightly felt in Cairo… earthquake at Hamat on 21 May was followed by another shock in the afternoon. Altogether, the shocks lasted for four days. **1834 05 26**: strong, many aftershocks during 10 days **Modern seismicity:** **1984 08 24 06 02**: 10 days, aftershocks were not felt.
A month	**634 09:** An earthquake with a series of tremors lasted for a month. **991 04 05**: The shocks went on repeatedly till …(5 May) in the same year. **1344 01 03:** two shocks in close sequence. In relation to the worst affected area, it is recorded that the places concerned were abandoned by their inhabitants for more than a month. **1705 11 24:** Light shocks continued to be felt till Ramadan (one month). **1759 10 30**: series of strong aftershocks (time not specified), some of which were felt as far as Aleppo, that added to the damage. Note that after a month this event was followed by the 1759 11 25 strong earthquake.
40 days	**713 02 28 / 03 10**: Earthquakes began throughout the world and lasted for forty days **746 01 18:** a strong earthquake in Syria … the inhabitants forced to take refuge in the desert, where they stayed for forty days…" This is an analogy or symbolic for something that took "considerable time." **835 01 05 – 12 25:** The earth shook for forty days. Possibly a duplication of 713?
Several months to a year	**341**: danger for three days, shocks for a whole year. **526 05 20 or 29:** lasted for six days (possibly the fire)… the earth shook for a year… The earthquake continued every day and night for a year and a half without ceasing. **1138 10 11 until 1139 06:** destructive seismic sequence until June, 1139. The main event was followed by three 3 large events in the first day. A total of 80 shocks were felt during the whole seismic sequence. **1170 06 29 0345:** The earthquake lasted for three or four months, or perhaps longer. There were times when three or four or even more shocks were felt by day or night. **1212 05 01:** aftershocks for a year **1404 02 20:** The most violent earthquake at Allepo was followed by a sequence of less powerful shocks which lasted until early July 1404 (Single + Earthquakes followed throughout the year, especially in the west; followed by a second series of lesser shocks; during the last ten days of 13 February – 12 March). **1546 01 14:** Then, on 13 March 1546 there was another alarm, the noise of which was greater before it died out. Then, on 13 May, there occurred another shock felt by some people more than others, apart from the continuous shocks of previous days, some of which occurred at night and some during the day. **1759 11 25**: aftershock sequence until 8/1760. Damaging shocks on 26/11, 5/12, 12/12, 30/12.

	1796 04 26: Aftershocks continued to be felt for two months. **1837 01 01**: Aftershocks continued to be felt for almost four months. Important are: 16 January widely felt and caused considerable damage in the south, 22 and 25 January reported from the north and caused panic in Damascus. 20 May was reported from the north and caused considerable damage at Hashbeya. **1872 04 03**: Aftershocks continued to be felt with decreasing severity throughout April and May, but did not cease altogether until February 1873. **Modern seismicity:** **1927 07 11 13 04**: Twelve 3.5 < M < 5 after-shocks until February 1928, and two such more until September 1930. Most powerful were on July 17, and February 22, 1928. **1956 03 16 19 32, 1956 03 16 19 43:** Thirty weak aftershocks until November 1956. **1969 03 31 07 16 (in Suez Rift):** Mainshock with more than 2,000 events. Preceded two weeks before by 35 large preshocks including 3 $M_L \geq 4$, followed by 19 $M_L \geq 4$ in half a year and four more in the next 15 months until December 1970. **1983 02 03 23 30:** Swarm, 8 months, largest event M_L=5.3 after two weeks, 28 events $M_L \geq 4$; 94 events $M_L > 3$**.** **1993 08 03 12 43:** Swarm or sequence? Two largest are ML 5.8 and 5.6, in the first hours. Strongest event preceded by a pre-shock. Overall, 420 events of ML>3. **1995 11 22 04 15:** Mainshock followed by >5,000 aftershocks, largest aftershock after three months on 1996 02 26, Mw=5.6, most Ml>4 occurred in first 100 days, a few Ml>4 continued for two years. **2004 02 11 08 15**: Mainshock with a few tens of aftershocks over half a year, the largest, M_L3.7, occurred two days later
Several years	**1822 08 13**: It was followed by an aftershock sequence that lasted almost 2.5 years.
Unknown period of time	**458 09 13-14 :** When the earthquake ceased, everyone of those who fled regained his confidence. **528 11 29:** The earthquake that now occurred lasted for one hour and was accompanied by a terrible sound. Than He appeared to a pious man, who told the survivors to write at the top of their doors 'Christ is with us. Stop'. When this was done, the wrath of God abated. **1091 09 26:** There was an earthquake and 86 towers in the walls of Antioch collapsed… there were numerous earthquakes in the Syrian territory. **1259 03 22**: there were numerous shocks in Syria at the time when the Tartars arrived.

Table 7 Duration of foreshock and aftershock sequences

Foreshocks				Main Event		Aftershocks																							
Wks	Dys	Hrs	Mnt	Mag.	Date	Hrs	Days						Weeks			Months													Unk
							1	2	3	4	5	6	1	2	3	1	40d	2	3	4	5	6	7	8	9	10	11	12	>12	
				M	341				+																			⊗		
				M-L	363	•, 6																								
				S-M	458																									?
				M	526							?																⊗	18?	
				M	528	1,⊗																								
				S-M	634											⊗														
				M	713												⊗													
				M-L	746												⊗													
		•		M	749																									
				S	835												⊗													
				S-M	847	3, ⊗																								
				M-L	859																									?
				M	991											⊗														
				M-L	1033	•, ~6	•	•					⊗																	
				L	1068 03	•, 2.5																								
				M	1091																									?
				S	1094											⊗														
				M-L	1138-9	•			•					•											•,⊗					
				S	1156 09	+	+							⊗																
				S-M	1156 10	+				+	+		+	+	+	+		⊗												
				S-M	1156 12	⊗																								
				S-M	1157 04		+	⊗																						
				M	1157 07	⊗																								
				L	1157 08	+				+			+		+			+	+	+	+				+			+	21, ⊗	
				L	1170															⊗										
				L	1202	+				⊗																				
		•		M	1212																							⊗		
				S	1259																									?
				M-L	1344											⊗														

9, •				M-L	1404									+							⊗								
				M	1546														•		•,⊗								
		•		M	1705	+										⊗													
				M	1759 10											?													
				L	1759 11	•						•		•	•										⊗				
				L	1796												⊗												
+	+		30,•	L	1822	+																						30, ⊗	
				S-M	1834							⊗																	
				M-L	1837								•	•							•,⊗								
				L	1872										+		+									⊗			
				M	1927		+					+	+	+	+	+				+	+	•		+				+	38? ⊗	
				S	1956																			⊗					
+	+			M	1969																	•							21, ⊗	
+	+	+		S	1983							•												⊗					
				S	1984								⊗																	
		+	12,•	S	1993																⊗								
				L	1995														•									24, ⊗	
				S	2004			•														⊗							

Summary of sequence duration (⊗)

Foreshocks				Area	Aftershocks																								
Wks	Dys	Hrs	Mnt		Hrs	Days						Weeks			Months														Unk
						1	2	3	4	5	6	1	2	3	1	40d	2	3	4	5	6	7	8	9	10	11	12	>12	
2	-	3	-	All DST	4	-	1	-	1	-	-	2	1	-	5	3	2	-	2	2	-	-	1	1	1	-	3	3	4
2	-	2	-	Northern DST	4	-	1	-	-	-	-	-	1	-	4	2	2	-	1	1	-	-	1	-	1	-	2	3	4
-	-	1	-	DST in Israel	-	-	-	-	1	-	-	2	-	-	1	1	-	-	1	1	-	-	-	1	-	-	1	-	-
Summary of time delay of significant aftershocks (•)																													
1	-	3	1	All DST	5	1	1	1	-	-	-	1	2	2	1	-	1	-	1	1	-	-	1	-	-	-	-	-	-
1	-	2	1	Northern DST	1	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
-	-	1	-	DST in Israel	4	1	1	-	-	-	-	1	1	2	1	-	1	-	1	1	-	-	-	-	-	-	-	-	-

Symbols and abbreviations: + Reported activity; • Noted event, possibly the largest fore- or aftershock; ⊗ Reported or inferred end of sequence; Wks- weeks; Dys- days; Hrs- hours; Mnt- minutes; Mag- magnitude, see Table 1 for explanation; Unk- unknown; 40d- 40 days; Blue: events that originated or caused damage in Israel; Red: earthquake storms, possibly triggered events. Information of the historical events relates to felt events (M>3.5-4), modern seismicity relates to recorded events of possibly M>2.

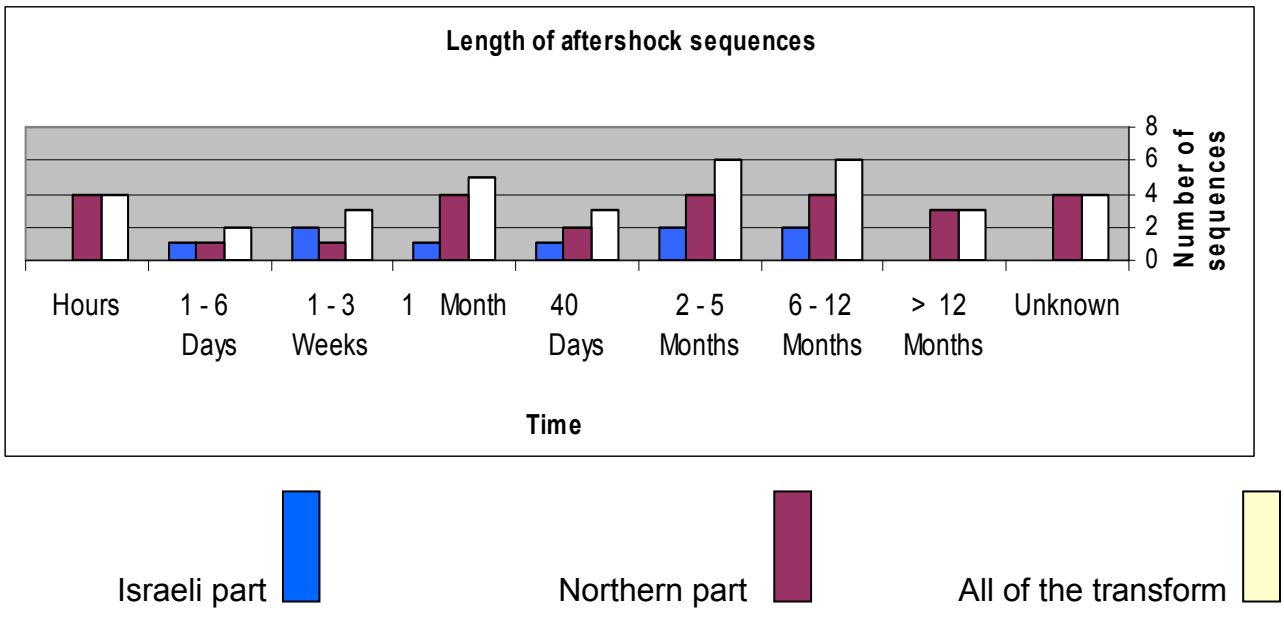
Although the data is incomplete, it is still possible to identify several trends in aftershock durations. Table 8 shows that about a half (17 of 36) of the sequences lasted a month or less, a sixth lasted 2-5 months and a quarter lasted almost a year and longer. Since short (less than a month) aftershock durations of damaging earthquakes (M > ~6) are not known in modern times from in and around the DST area, we assume that the historical record is not complete for these events. They might possibly relate to immediate aftershocks, ignoring later weaker stages of the sequence.

Felt foreshocks tend to appear several hours or a few weeks before the mainshock.

Table 8 Duration of the historical aftershock sequences in and around the DST (simplified from Table 7)

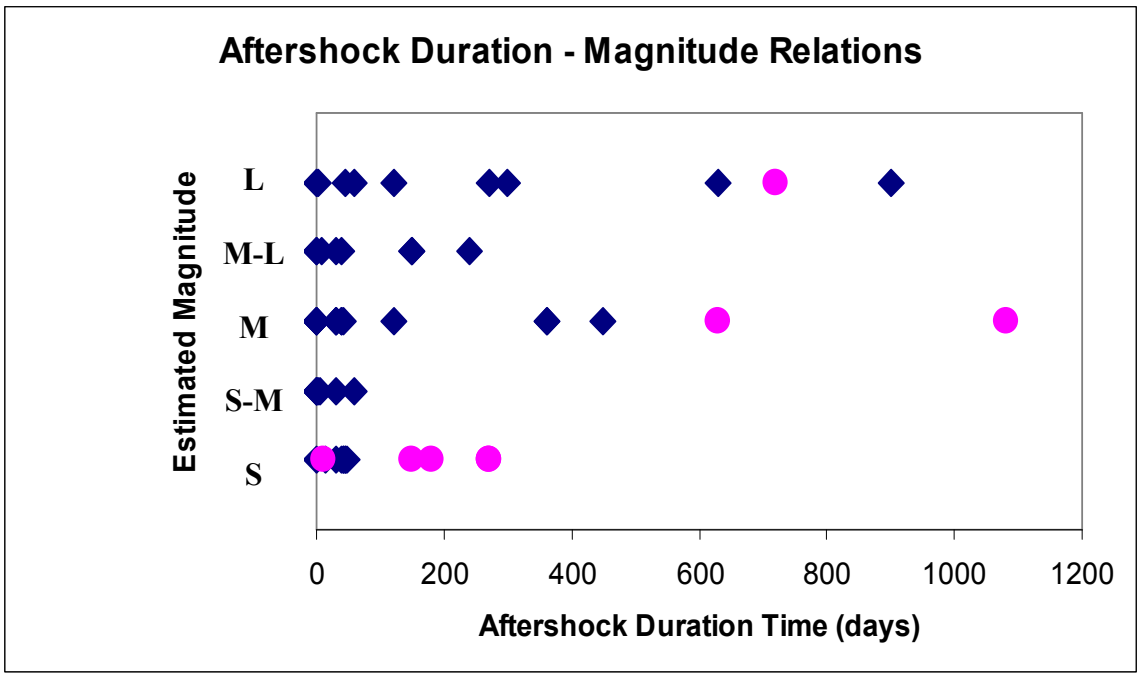
Foreshock sequences		Area	Aftershock sequences								
			Hours	Days	Weeks	Months					
Weeks	Hours-Minutes			1-6	1-3	1	2-5	6-7	8-12	>12	Un-known
2	3	All DST	4	2	3	8	6	-	6	3	4
2	2	Northern DST	4	1	1	6	4	-	4	3	4
-	1	DST in Israel	-	1	2	2	2	-	2	-	-

Figure 1 Histogram of the duration of historical aftershock sequences in and around the DST (simplified from Table 7)



Examining the correlation between the duration of the complete aftershock sequence and the estimated magnitude of the mainshock (Figure 2), it is possible to see that short duration (< ~50 days) is typical to the entire range of magnitudes and long duration appears with earthquakes of moderate magnitudes (M > ~6) and larger. Modern seismicity (pink circles) also show that the length of aftershock duration increases with magnitude, although durations are relatively longer. Short durations however, do not appear in nowadays records, suggesting that historic reports may possibly refer only to the immediate dense sequence of aftershocks and ignore the tail of the delayed and weaker shocks.

Figure 2 Aftershock Duration – Magnitude Relations
Correlation between the duration of aftershock sequence and the estimated magnitude of the mainshock. Blue squares - historic events; pink circles - modern events



Time delay of the largest aftershocks

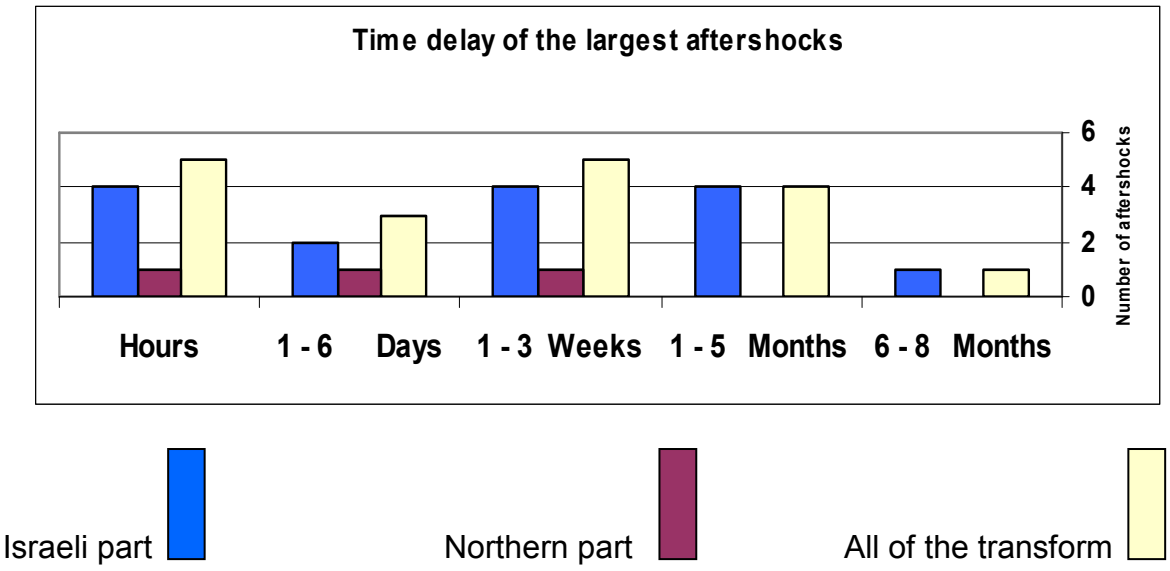
Several aftershocks are specifically mentioned for increasing the damage or panic, or being exceptionally strong. We may assume that these were the stronger in the sequence and possibly even the largest ones. Tables 7 and 9, and Figures 3 and 4, present the time delay of the most significant aftershocks from all the events, both historical and modern.

The time delay of the stronger aftershocks seems to resemble modern trends closer. Most of these aftershocks appear just after the main shock and in the following days and weeks, but several are delayed a few months and even as much as eight months (Table 9 and Figure 3).

Table 9 Delay time of the historical largest fore- and aftershocks in and around the DST (simplified)

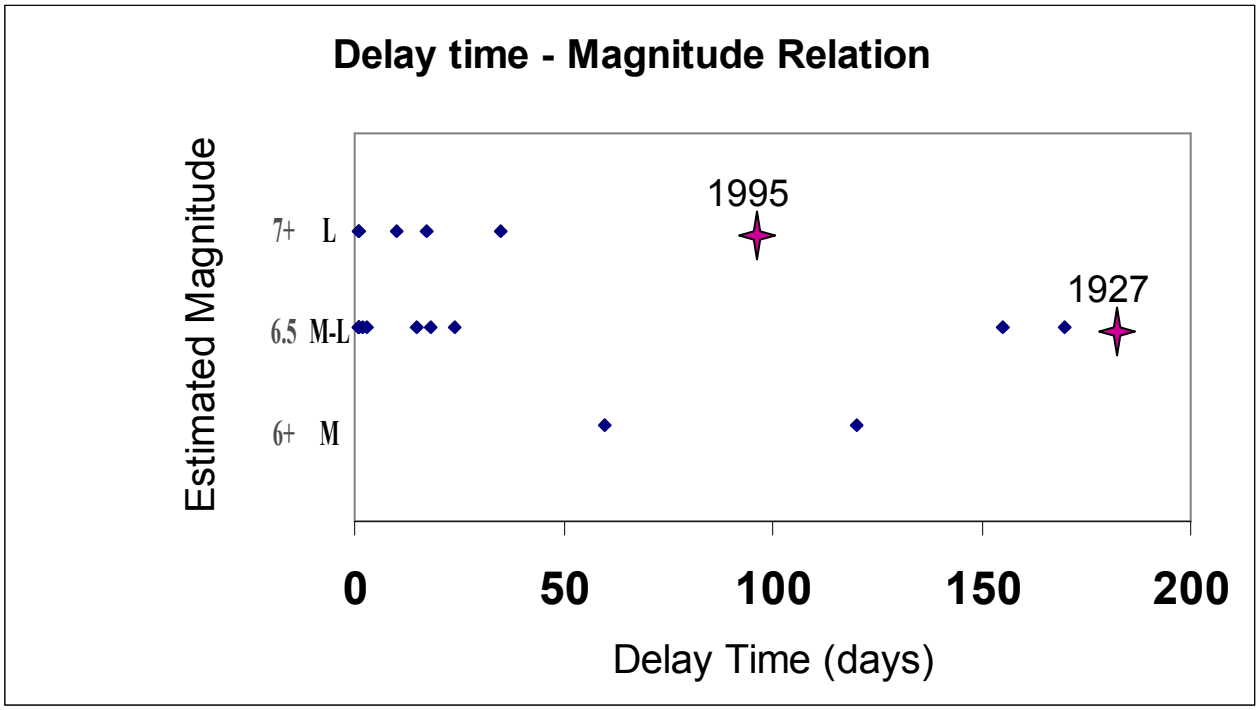
Noted foreshocks		Area	Noted aftershocks						
Weeks	Hours-Minutes		Hours	Days	Weeks	Months			
				1-6	1-3	1	2-5	6-8	> 8
1	4	All DST	5	3	5	1	3	1	-
1	4	Northern DST	1	1	1	-	-	1	-
-	1	DST in Israel	4	2	4	1	3	-	-

Figure 3 Histogram of the time delay of the largest historical aftershocks after the mainshock in and around the DST (simplified from Table 7)



Correlating the time delay with the magnitude of the mainshock, most of the aftershocks are clustered within the first days and weeks of the main event, but several others appear months later. There is no simple correlation, even with aftershocks of modern times, and no simple explanation is available for that. Knowing the limits of historic data, one should not rule out that this relation resulted from incomplete information and therefore is not indicative. Nevertheless, that significant aftershocks are delayed days, weeks and months after the mainshock, is a significant conclusion, even though it is not well correlated with the magnitude.

Figure 4 Delay time – magnitude relation
Correlation between the delay time of the largest aftershock and the estimated magnitude of the mainshock, in and around the DST. Blue squares are historic events and pink stars are modern ones.



2.3.5 Earthquake storms

Between September 1156 and May 1159 there was an intensive sequence of six destructive earthquakes in northwestern Syria, each followed by many smaller events, some of which were strongly felt. These may have been a series of several successive mainshock-aftershock sequences in a short time, sometimes called a seismic storm. The mainshocks of the major sequences were: 1156 09 27, 1156 10 13, 1156 12 09, 1157 04 02, 1157 07 05, 1157 08 09–09 07, the last being the largest one.

2.3.6 Unspecified clusters

There are 15 reports of "numerous earthquakes," "great earthquakes," "earth shook three times," or just "there were earthquakes," with no mention of a specifically noted event (Table 10). The information contained in these reports is insufficient to distinguish the various classes we used here, and they could be any type of a sequence, including a regular mainshock-aftershock sequence, swarms or seismic storms. Moreover, these could also be a compilation of several different earthquakes from remote locations into a one 'circum-Mediterranean' cosmic event, such as that of 881 A.D.**:** "there was a strong earthquake in Syria, Egypt, some parts of Mesopotamia, North Africa and Andalusia."

Table 10 Unspecified clusters of historical earthquakes

Type of event	Historical earthquake
Several unspecified noticeable earthquakes: ***Earthquake storms, swarms, clusters composite events***	**199-198 BC**: "but the number of victims was limited, because it did not happen in a single shock" **419**: great earthquakes in the East **757 03 09**: four events, or a single one followed by three significant aftershocks **847 11 24**: a dreadful earthquake at Damascus... The earthquake reached Antioch… Then it reached Mawsil… **859 12 30 – 860 01 29**: earthquakes which… **881 05 16**: There was a strong earthquake in Syria, Egypt, some parts of Mesopotamia, North Africa and Andalusia. **1063 07 30 – 08 27: t**here were earthquakes **1086 04 18 – 1087 04 07**: there were earthquakes … **1094 05 19 – 06 18**: In that month there was a series of many earthquakes in the Syrian territories lasting for a long time. **1151 09 28:** earth shook three times **1152 02 01:** earth shook three times **1259 03 22:** main shock and numerous shocks **1287 02 2nd half**: a series of earthquakes **1484 03 29 – 04 28:** a sequence of six or more shocks **1795 12**: two shocks

2.3.7 Missing sequences

We did not identify among the various events a sequence typical to a swarm, in which the magnitude slowly increases to a maximum that is not much stronger than the preceding or following events. This is not to say that swarms have not happened, because the resolution and magnitude determination of historical data are insufficient to recognize such clusters.

3 Discussion and conclusions

Historical and modern accounts report on about a hundred earthquakes that caused damage in the Levant during the last 22 centuries, a significant part of which were destructive (Table 1 and Appendix 1). About a third of these affected the area of present-day Israel. The list constructed enables re-assessment of the historical seismicity of the Levant, including for example, hazard evaluation and repeat time of strong events. Here we concentrated on studying the aftershock sequences that were described in the historical accounts.

Overall, forty-eight of the events were reported as single earthquakes while the others were reported to have been associated with additional shocks. Comparing the historical pattern of seismicity with that of today, it is possible to distinguish several modes:

a. Single events: Only one large event was reported. This type is not known today and in our opinion is a result of incomplete reports.

b. Mainshocks: Most of the 'non-single' events included one predominant earthquake that caused most of the damage. This was considered as the main shock.

c. Foreshocks: Earthquakes that preceded the main shock were reported in five events, ranging from minutes to several weeks before the mainshock. There were a few cases where people reacted on time to strong earthquakes which later were found to be foreshocks, evacuated and saved their lives. It may indicate a true fear, a good instinct and even educated experience, rather than a clear understanding of this natural phenomenon.

d. Aftershocks: Thirty-eight of the historic mainshocks were followed by additional earthquakes, lasting for hours, days, weeks, months, and sometimes more than a year. Some of the aftershocks added to the damage caused by the main event. Since large events produce more larger aftershocks (Bath and Omori lows) it is reasonable to assume that long and notable historical sequences reflect large mainshocks. Therefore, it can be assumed that historical events that were reported to have caused limited damage only but were associated with a long aftershock sequence, were in fact large events.

e. Clusters: Series of earthquakes were also reported in 15 events, but the data is insufficient to further specify them.

f. Swarms: This type was found only in the modern record, but cannot be excluded from historical seismic activity because the nature of the historical records does not enable distinguishing this style of seismicity.

Interestingly, several descriptions related to the duration and strength of the destructive shock. Some events, mostly of recent centuries, were reported to last for several tens of seconds, and this is reasonable. Other earlier events were said to have lasted a few hours – a duration which is not reasonable according to present day understanding. We may assume that these reports regarded the main event together with the immediate start of strong aftershocks. In many cases the earthquake surprised the inhabitants as "such as has not occurred before" and sometimes (e.g., 1796) even: [the earthquake] "in Latakia so violent that almost everything collapsed with the first shock." Occasionally, the violent shaking appeared in the later phase, allowing invaluable spare time for evacuation (1822).

Extrapolating from the past, we may assume the following characteristics of a future destructive earthquake:

a. It will most probably occur without foreshocks, and will be followed by a long sequence of aftershocks that may last a year or so with tens of felt events.

b. Strongly felt aftershocks will occur within hours immediately after the main event and may last for few months, with decreasing rate and size.

c. The largest aftershocks may appear sometimes during the first month, although several months delay will not be exceptional.

d. Single felt foreshocks are less likely to appear, but if so they will most probably precede the mainshock by few hours.

e. Foreshock series of increasing magnitudes are possible even with the main event occurring several days or weeks after they start.

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Appendix 1 Historical damaging earthquakes that possibly occurred along the Dead Sea Transform system

Historical earthquakes that caused damage in the Levant, most of which possibly originated from the Dead Sea Transform system and nearby structures. Also included are events with noted seismic effects or irregular sequence of events, and events that were felt in Israel up to the 18th century. Modern (20th century) events with noted aftershock activity are added for comparison. Earthquakes that hit (not necessarily focused in) Israel, are marked in blue color.

Date: Events are marked by time of occurrence, as detailed as known: year, month, day, part of the day or night.

Short description: information was taken from catalogues and seismologic compilations based on original reports.

Center of the affected area: **the most severely affected, felt or damaged area**, by locality and geographic coordinates. Note that this is not necessarily the epicenter.

Estimated size of the earthquake: Preliminary evaluation based on the estimates in the published literature. $\mathbf{I_0}$ - intensity at the area most severely damaged, in cases where the data sufficiently cover all around the affected area, and **Imax** - intensity at the area most severely affected, in cases where there is only partial coverage of the affected area. Estimated magnitude is given in the broad categories suggested by Ambraseys and Jackson (1998): **V**- very large event ($Ms \geq 7.8$), **L**- large ($7.8 > Ms \geq 7.0$), **M**- Moderate ($7.0 > Ms \geq 6.0$) and **S**- small ($Ms < 6.0$). Estimations were taken from historical, geological and paleoseismical studies, and if not available, made by personal judgment.

Pattern of seismicity: the sequence of events, whether a single or a series, as interpreted from the original reports. This is classified in Table 1 and Appendix 2 as preshocks, mainshocks and aftershock sequences.

Date	Short description, comments, references	Center of affected area Area, N / E	Est. Size Intensity, magnitude	Pattern of seismicity
760-750 B.C.	This is known as Amos's, Uzziah's or Zechariah's earthquake: **Amos** (1:1, The Holy Scriptures, 1942, Jewish Publ. Society, Philadelphia.): "*The words of Amos…which he saw concerning Israel in the days of Uzziah king of Judah…, two years before the earthquake*." **Zechariah** (14: 4-5, Ibid): "*And the mount of Olives shall be cleft in the midst thereof Toward the east and toward the west, So that there shall be a very great valley; And half of the mountain shall remove toward the north, And half of it toward the south … like as ye fled from before the earthquake In the days of Uzziah king of Judah…* " **GCT**: "In our opinion, this is the only earthquake in the Bible for which there is sound and direct historical evidence…"	Jerusalem: 31.8 / 35.3	?	Single

	Am7: "…the earthquake in Amos remains an event the date, location and magnitude of which cannot be assessed…" relating for example, to evaluations given by **AFF** (ML =8.2) and **BM** (759 10 11 B.C., evening, ML =7.3). "The description by Josephus, whether really on the earthquake mentioned by Amos, Josephus and Nathan or not, is at least evidence of the effects of an earthquake that had occurred before their time somewhere in Judea for which there are no means today of assessing its location and magnitude." Some archaeological evidence, such as from Hazor (**Ya**) and Gezer (**D**e), were suggested to have been damaged by this event. **FW**. **ZAB**: Possible surface rupture at Bet Shean Valley.			
199 – 198 B.C.	**GCT,** after Posedonius: "As a result of an earthquake in Phoenicia, a city above Sidon was swallowed up, and almost two thirds of Sidon itself collapsed, but the number of victims was limited, because it did not happen in a single shock. The same disaster struck the whole Syria, but with moderate intensity". **Ka2**: This was described together with the famed emergence of the island of Hiera in 198 B.C., although Strabo's text is a discourse of unusual natural phenomena rather than a report of interrelated contemporaneous events". **AW**: 198 B.C.	Sidon: 33.5 / 35.3	Imax: IX M	"… but the number of victims was limited, because it did not happen in a single shock": i.e., several shocks?
Mid 2nd century B.C. ?	**Ka2:** raises the possibility that the report about the earthquake and submergence at nearby Sidon could be associated with the mid 2nd century B.C. tidal wave between Ptolemais and Sidon. 143/2 B.C.? The same report was interpreted by **AW** and **GCT** as the 199-198 B.C earthquake in Phoenicia and Syria. **GMDH:** paleoseismic event on 170 B.C – A.D. 20 on the Serghaya fault, Syria (~2 m left lateral slip, MW 7 - 7.2.), but no direct evidence to associate it with this earthquake	Southern Lebanon, nearby Sidon, 33.5 / 35.3	Imax: ≥V M	Single
148 02 21 afternoon B.C. (or 130 B.C.)	**GCT,** after Malalas after Domnius: "… at the tenth hour of the day, Antioch suffered from the wrath of God. It was completely rebuilt and improved…". Theoretically, there could possibly have been two events. **AW. Ka2:** 146 B.C. or 140 B.C.	Around Antioch 36.2 / 36.2	Imax:IX-X M	Single
c. (69 –) 65 B.C.	**GCT,** after Pompeus Trogus: "… Syria…, it was devastated by an earthquake, which killed one hundred and seventy thousand people and destroyed many cities…"; and after Malalas: Pompey was generous to Antioch, "and rebuilt the bouleuterion, for it had fallen down". **AW:** 69 –	Syria, around and south of Antioch 36.0 / 36.3	Imax: IX M	Single

	66 BC. **Ka2:** This event occurred in Antioch and later "imported into the Israeli catalogues" and placed at 64 BC in Jerusalem (e.g., by **AAT, BM**)			
31 B.C. early spring	**GCT,** after Josephus in *The Jewish Antiquities* and *The Jewish War*: "… there was an earthquake in Judea, such as has not occurred before, which killed many cattle throughout the country. And about thirty thousand persons also perished in the ruins of their houses, but the army, which lived in the open, was not at all harmed by this calamity." It is very likely that this is the same earthquake as the one recorded by Malalas: "… a city in Palestine named Salamine suffered from the wrath of God. Augustus rebuilt the city and called it Diospolis." **Ka2** suggests that this was a moderate (6-6.5) event rather than a strong one, as previously suggested (e.g., **AAT, BM:** for the event on 31 09 02). **Ka1:** Archaeoseismic damage (e.g., Qumran) is based on extrapolation of Josephus's description. **RH**: A vertical throw of about 3.5 m on the Jericho segment.	Around Judea 31.9 / 35.2	Imax =VIII M	Single
A.D. 37 03 23 early in the morning	**GCT,** after Malalas: An earthquake at Antioch, "... Daphne area (6 km to the west) was also damaged, and Gaius (Caligula) gave a great deal of money to the city and its surviving inhabitants."	Around (and west of?) Antioch 36.2 / 36.1	Imax =VII S (- M)	Single
c. 47	**GCT,** after Philostratus, Malalas: "The great city of Antioch was also shaken by an earthquake..... cracks appeared in the temple of Artemis, Ares and Heracles, and famous palaces collapsed as well."	Around Antioch 36.2 / 36.2	Imax = VII S (- M)	Single
115 12 13 morning	**GCT,** after Dio Casius: "While he [Trojan] was visiting Antioch, there was an unusually powerful earthquake. Many cities were badly damaged, but Antioch suffered the worst destruction. …a sudden blowing roar … followed by a tremendous quaking … whole earth heaved up … even buildings were thrown into the air. Some were crashing back down in pieces… others were tossed… fearful dim of splitting and breaking timbers and tiles… vast quantities of dust arose… Many people were hurt, even though some were outside their houses: they were snatched up, tossed violently about, and then dashed to the ground as though they had fallen from a cliff. …trees with all their roots were thrown into the air. It was impossible to calculate the number of those who were trapped in their houses and killed …Mt. Casius was so badly shaken that its peak seemed to lean over and break off, and to be falling right into the city."	Around Antioch 36.2 / 36.2	Imax = IX M (– L)	Single, tremendous quaking … whole earth heaved up … buildings were thrown into the air… trees with all their roots were thrown into the air

	MGS associate this event with a left lateral surface rupture of 4 - 4.5 m (M_W=7.3 - 7.5) at Missyaf segment, Syria (which is more than 100 km south of Antioch!) **AJ**: Ms=Large. **Ka1:** "Talmudic references are not specific neither in time nor location, but Yavne may have been affected."			
c. 127-130	**GCT,** after Eusebius: "Nicopolis (Emmaus) and Caesarea were destroyed in an earthquake." **Ka1:** It has been suggested in the literature that the primary documentation referred to Nicopolis and Neocaesarea in Pontus.	Between Nicopolis and Caesarea 32.2 / 34.9	Imax = IX M	Single
303 or 304	**GCT,** after Eusebius: "A terrible earthquake caused many buildings to collapse at Tyre and Sidon, and a large number of people were killed"; after Orosius: "An earthquake followed in Syria, as a result of which buildings collapsed everywhere, and many thousands of people were crushed in Tyre and Sidon."	Southern Lebanon, inland, between Tyre and Sidon 33.4 / 35.4	Imax= VIII-IX M	Single
341	**GCT,** after Socrates: "… most violent earthquakes in the East, but especially at Antioch, which continued to suffer shocks for a whole year"; after Michael the Syrian: "Collapse of Arian church at Antioch"; after Theophanes and Cedrenus: "… Antioch was shaken by violent earthquake, and was in danger for three days."	In the "East", but especially around and south of Antioch: 36.2 / 36.2	Imax =VIII (S -) M	Single with "Antioch was in danger for three days" and "shocks for a whole year"
348 or 349	**GCT,** after Theophanes and Cedrenus: "… a powerful earthquake struck Berytus in Phoenicia, and much of the city was destroyed."	Around Berytus 33.9 / 35.3	Imax=VIII S (- M)	Single
363 05 18-19, night	**GCT,** after Gregory of Nazianzus: "Immediately fleeing before both the furious storm and the earthquake…"; after Socrates: "A mighty earthquake tore up the stones of the old foundation of the temple, and dispersed them all together with the adjacent edifices."; and after Cyril, Bishop of Jerusalem: " 3. …Jerusalem… the land shook considerably, and there were great tremors in the towns round about. …5. For many Christians living in these regions, as well as the majority of the Jews, also perished in that scourge – and not just in the earthquake, but also as a result of fire and in the heavy rain…6. …there were strong winds and storms. 11. … towns which were destroyed: More than half of Bet Gubrin; part of Beishan; the whole of Sebastia and its territory, the whole of Nicopolis and its territory, more than half of Lydda and its territory, about half of Asclon, the whole	Around Judea and Samaria, and possibly as far as Petra 32.2 / 35.5	I_0 = IX - X M - L	Single shock: event took place on Monday at the third hour, and partly at the ninth hour of the night (an aftershock?); tremors in the towns round about: i.e., aftershocks?

	of Antipatris and its territory; part of Ceasarea, more than half of Samaria, part of NSL'; a third of Paneas, half of Azotus, part of Gophna, more than half of Petra (RQM'); more than half of Hada, a suburb of the city (Jerusalem); more than half of Jerusalem. And fire came forth and consumed the teachers of the Jews. Part of Tiberias too, and its territory, more than half of Areopolis (RDQLY'), the whole of Sepphoris (SWPRYN') and its territory, 'Aina d-Gader; Haifa (HLP') flowed with blood for three days; the whole of Japho (YWPY') perished, (and) part of 'D'NWS. 12. This event took place on Monday at the third hour, and partly at the ninth hour of the night. There were great loss of life here." **Am9**: Ms=7.4. **Shal**: 363 05 24, tsunami in southern Dead Sea.			
419	**GCT,** after Augustine: "Great earthquakes are reported from the East. Some great cities suddenly collapsed in ruins…"; after Marcellinus: "Many towns and villages in Palestine were reduced to ruins in an earthquake."; after Hydatius: "… the Holy Places of Jerusalem and other areas were shaken by a very severe earthquake." **Ka1:** It is not clear whether it could be the same event as reported in 417?	In Palestine, around Jerusalem or north of it 32.2 / 35.5	Imax =VIII M	Great earthquakes in the East
450 - 457, night	**GCT,** after Malalas: "… the city known as Tripolis in Phoenicia maritima suffered from the wrath of God, at night… He restored the summer bath… He also reconstructed the Phacidion and several other buildings in the city, as well as the aqueduct"	Around Tripolis 34.4 / 35.8	Imax =VIII S (– M)	Single
458 09 13-14 night	**GCT,** after Severus of Antioch: much damage, deaths and wounded: "… for everyone ran towards the mountain tops and towards the distance places of the country…For there was no place, wall or roof where you could be sure of being secure… everything had been tossed and terribly shaken […] When the earthquake ceased, everyone of those who fled regained his confidence…. For many were burned by lightening flashes, many were swallowed up by chasms of the ground, others were engulfed by the waters of the sea or of the clouds"; after Evagrius: "… This earthquake destroyed nearly all the buildings in the new city…. In the old city the porticoes and the houses were completely untouched, but… Some buildings collapsed in the Ostracine district… "	Around Antioch 36.2 / 36.2	Imax =VIII S – M	Single, and a sequence with unknown length of time: "When the earthquake ceased, everyone of those who fled regained his confidence…"
502 08 22 night	**GCT,** after Pseudo-Joshua the Stylite: "… a great fire appeared to us blazing in the northern quarter the whole night…… the city of Ptolomais or Akko was overturned, and nothing in it left standing. … the half of their cities fell, namely of Tyre and Sidon. In Berytus only the synagogue of the	Ptolomais, Tyre, Sidon, off coast S. Lebanon?	Imax= IX-X M	Single

	Jews fell down on the day Akko was overturned."	33.0 / 35.0		
526 05 20 or 29 mid-day	**GCT**, after several sources: a disastrous earthquake at Antioch, which was followed by a great fire and caused thousands of deaths; after Malalas: "The surface of the earth boiled and foundation of buildings were struck by thunderbolts thrown up by the earthquake and were burnt to ashes by fire… For nothing remained apart from some buildings beside the mountain… Everything had been utterly destroyed. … In this terror up to 250,000 people perished"; after Pseudo-Dionysius: "… Seleucia in Syria and the coast above Antioch over an area twenty thousand paces square were shaken and destroyed, and those that saw them were struck not so much by the fire as by the tremor itself"; after Theophanes: "The earth was shaken by tremors for a whole year"; after Cedrenus: "… wrath of God began to be felt in the city in the form of an earthquake and fire. It struck the center of the city and lasted for six days. … And the earth shook for a year"; after John of Ephesusu: "… and so the foundations of the buildings, with all the stories above them, were thrown up; they were lifted and collapsed back down again… … a few houses which survived at the foot of the mountain above the city, but they too split open and were in danger of collapse… Moist dust bubbled up from the depth of the earth, and the sea gave off a great stench; and the dust could be seen bubbling up in the water as it threw up sea shells… The earthquake continued every day and night for a year and a half without ceasing".	Around Antioch and Seleucia 36.1 / 36.1	Imax = IX M	Single + Lasted for six days: possibly aftershocks, or fire? The earth was shaken by tremors for a whole year The earthquake continued every day and night for a year and a half without ceasing
528 11 29	**GCT,** after Malalas: "… Antioch suffered its sixth calamity…The earthquake that now occurred lasted for one hour and was accompanied by a terrible sound, so that the buildings that had been reconstructed after the former shock collapsed;… Part of areas around the city also suffered… Up to 5,000 lives were lost in this earthquake. … Laodicea suffered its first earthquake disaster. Half the city was brought down by the shock, including the Jewish synagogue, and 7,500 people perished…"; Seleucia is also mentioned for tax exemption after the earthquake, but was not specifically mentioned for being damaged; after Theophanes: "All those who had remained in the city prayed… weeping and throwing themselves down…Than He appeared to a pious man, who told the survivors to write at the top of their doors 'Christ is with us. Stop'. When this was done, the wrath of God abated"	Between Antioch and Laodicea 35.9 / 36.0	Imax = IX M	Single, lasted for one hour ? "When this was done, the wrath of God abated": Possibly Aftershocks?
551 07 09, day	**GCT**, after Antoninus of Piacenza: "This (island of Antharidus near Syria	**A**round	Imax = X	Single

	and Tripolis in Syria) and other cities were reduced to ruins by an earthquake… Byblos, which was also destroyed with its inhabitants… Trieris, which was also reduced to ruins in the same way… That city (Berytus) was also destroyed. …thirty thousand known people had been killed…"; after Malalas: "…a severe and tremendous earthquake occurred throughout the land of Palestine, in Arabia and in the land of Mesopotamia, Antioch, Phoenice Maritima and Phoenice Libanensis. In this terror the following cities suffered: Tyre, Sidon, Berytus, Tripolis, Byblos, Botrys and parts of the other cities. …In the city of Botrys part of the mountain called Lithoprosopon, which is close to the sea, broke off and fell into the sea. …At the time of the earthquake the sea retreated for a mile and many ships were destroyed. Then at the God's command the sea was restored to its original bed."; after John of Ephesus: "… Beirut collapsed, as did many coastal cities and villages in Galilee, Arabia, Palestine and Samaria. … Along the whole Phoenician coast, too, the sea withdrew and retreated nearly two miles…. But after they had escaped (from the returning sea) … a violent earthquake took place, which overturned houses in the cities…"; after Symeon the Stylite the Younger: "… and the mountains were uprooted and violently split open, and chasms opened up in the earth in various places. … However, the region to the north, from Laodicea to Antioch, remained standing, and only a few towers and church walls were damaged… and the area to south from Tyre to Jerusalem was also preserved…" **AJ:** m; **AMA**, **Am3**: "Many writers place… offshore from Lebanon. … us, however, suggest an epicenter in the Jordan Valley". **Am9**: Ms=7.3. **DEK, ETSK**: Mw7.5 on Mount Lebanon thrust. **DSMP:** Roum Fault.	Beirut and off coast Lebanese coast: 34.0 / 35.5	M - L	(or two events?)
c. 570	**GCT**, after Elias of Nisibis: "… a severe earthquake… and a deep rumbling sound; and a soot came down through the air like leaves from the trees"; after ***Chronicle of 724*****:** "Almost the whole Antioch collapsed in ruins, as did Seleucia and the two Cilicias as well"; after Theophanes: "A great disaster took place in Cilicia, earthquake at Anzarabus and Antioch the Great"	Around Antioch and northwards 36.5 / 36.5	I_0 = IX M	Single
580 or 581, noon	**GCT**, after Evagrius: "… a violent earthquake struck Theopolis (Antioch) and the suburb of Daphne, precisely at noon. The tremors caused the total destruction of Daphne, whereas public and private buildings in Theopolis, though badly damaged, were not totally destroyed".	Around Daphne and Antioch 36.1 / 36.1	Imax = VIII-IX S (- M)	Single, and the tremors?

587 or 588 late October, night	**GCT**, after Evagrius: "…the entire city was shaken by violent tremors… This earthquake razed most buildings to the ground and even disturbed their foundations… Almost the whole Ostracine district was reduced to ruins, as was Psephium… the whole of Brysia… About sixty thousand lost their lives"	Around Antioch 36.2 / 36.2	Imax = VIII-IX S (- M)	Single
601-602, day	**GCT**, after Ibn Batriq: "… violent earthquake in the territory of Rum (Cilicia) and in Syria… Many cities were destroyed in Syria and in the territory of Rum, and the earthquake caused the death of many people."; after Michael the Syrian: "…for the earth boiled and split open". Location unclear: very large area on two sides of the Iskendrun Bay. Could be in Asia Minor.	Syria, Rum (Cilicia): general location only 36.5 / 35.5	Imax = VIII-IX M	Single
634 09	**GCT**, after Theophanes: "…an earthquake struck Palestine… meteor… It (the meteor?) lasted for thirty days…"; after Michael the Syrian: "There was a severe earthquake… the sun grew dark. The church of Resurrection and that of the Golgotha and many places collapsed in the earthquake…"; after Al-Makin: "… Palestine was struck by a series of tremors which lasted for a month… there was an earthquake followed by an epidemic"	Palestine, around Jerusalem 31.8 / 35.3	Imax = VII S – M	An earthquake, a series of tremors lasted for a month
659 06	**GCT**, after Maronite Chronicle: "… there was a violent earthquake in the region of Palestine… Many places collapsed"; after Theophanes: "… a violent earthquake which caused destruction in Syria and Palestine"; after Elias of Nisibis: "many places collapsed, including most of Palestine". No mention of specific sites or casualties, only that "many places collapsed".	Around Jerusalem (northern Dead Sea???) 31.8 / 35.3	Imax = VII-VIII M	Single
659 09 – 660 08	**GCT**, after Maronite Chronicle: "… there was a tremor and a violent earthquake, and most of Jericho collapsed with all its churches. The church of St. John at the Jordan of the Baptism of our Redeemer was razed to the ground, and the entire monastery as well. And not only the monastery of St. Euthymius collapsed, with many residences of monks and hermits, but many other places as well"	Around Jericho 31.8 / 35.5	Imax = IX S - M	Single
713 02 28 or 03 10, middle of the night	**GCT**, after Theophanes: "… a violent earthquake struck Syria…"; after Notitia annorum: "… there was a tremor and a severe earthquake, with the result that village houses and churches and many great cities collapsed on top of their inhabitants… Some houses, villages and cities were swallowed up. … that is to say the region now called the western region, by which I mean the city of Antioch and the district of Sidqa and Ksyut, and the whole coast and the islands"; after Al-Isfahani: "… earthquakes began throughout the world and lasted for forty days, causing collapses	Around Antioch, Allepo, Qenneshrin 36.2 / 36.6	I_0 =VIII-IX M	Single, tremors lasted for forty days

	among high buildings, and the house of the city of Antioch also collapsed"; after Ibn al-Athir: "There were earthquakes in Syria which lasted for forty days, and the whole province was destroyed … The strongest shock took place at Antioch"; after Michael the Syrian: "… many places collapsed in the region of Antioch, Allepo and Qenneshrin. Churches and temples in particular collapsed".			
746 01 18 morning	**GCT**, 749 01 18; after Theophanes: "… there was a powerful earthquake in Palestine, along the river Jordan and throughout Syria, and countless thousands of people were killed, and churches and monasteries also collapsed, especially in the desert near the Holy City (Jerusalem)."; after Al-Dhahabi: "… there was a strong earthquake in Syria… the strongest shocks occurred in Jerusalem, causing the death of many conquering troops and others"; after Ibn Tagri Birdi: "…there was a strong earthquake in Syria which destroyed Jerusalem… the inhabitants were forced to take refuge in the desert, where they stayed for forty days…"; after Elias of Nisibis: "In that year there were many earthquakes, and many places were reduced to ruins. A village near Mt. Tabor moved 4 miles (c. 6 km) from its original position…" He seems to make a report combined out of the two events after Michael the Syrian: "Meanwhile, there was a tremor at Damascus and it lasted for days shaking the city like… at Beit Qubayeh there was a fortress … It collapsed in ruins. …many… perished in Gautah and Dareya, while Bosrah, Nawa, Dar'at and Ba'albek were completely swallowed up. The water in the springs of the city turned into blood… In the sea … the water rose up to the sky… The sea boiled and overflowed, and it destroyed most of the cities and villages along the coast. In the land of Balqa – that is Moab – there was a fortress situated on the coast…. When the flood of the sea struck, it was uprooted…. The tremor caused the collapse of the city of Tiberias … A village near Mt. Tabor was moved… The spring of water near Jericho was moved… At Mabbug the collapse took place at the time of the mess …. In Constantinople…", here too, he seems to combine three earthquakes in one report. **AAT**: 749 01 18. **Am8:** 746 01 18. **Am9**: Ms=7.0. **Ka2. MHH:** Surface rupture in Tiberias (western coast of the Sea of Galilee). **RH**: A seismic event on the Jericho segment.	Between and around Jerusalem and Tiberias 32.2 / 35.5	I_0 = IX-X M – L	Single with aftershocks: inhabitants forced to take refuge in the desert, stayed for forty days, tremor in Damascus lasted for days.
749 (or 750, or 757	**Am7:** This affected only Mesopotamia and presumably the adjacent part of northern Syria, where a number of towns, which are not named, were	Around Mabbug:	I_0 = IX M	Not clear if there were one or two events,

03 09, midnight)	destroyed or half demolished. Also three villages near Khabura on the Euphrates River collapsed. **GCT**, after Pseudo-Dionysius: "there was a severe and powerful earthquake in the west…There was a tremor at night… and everyone had gone out of the city to pray at the temple… I mean at Mabbug, in the west… there was a sudden tremor and the temple collapsed on top of them, and crushed them all … there was a great, violent and terrible earthquake at midnight in the land of Mesopotamia and three villages near Habura collapsed." Several cataloguers merged this event with that of 746.	36.5 / 38.0 Or in Mesopotamia, Around Habura 35 / 41		possibly pre-shock and main-shock?
757 03 09, midnight (or 749, or 750)	**GCT**, after Theophanes: "a powerful earthquake struck Syria and Palestine…" **Am7:** "… it is described as of *some size,* affecting Palestine and Syria and the second earthquake to occur in Jerusalem where it destroyed the repairs that had just been made to the Aksa mosque after the first earthquake. It was said that at the time of the third earthquake the platform of the mosque opened, allowing the sky to be seen; another earthquake following after this last one closed the gap up again". **AAT:** 756 03 18.	Around Jerusalem: 31.8 / 35.5	Imax ≥ VII S – M	Single + three significant aftershocks?
835 01 05 – 12 25	**GCT,** after al-Suyuti: "The earth shook for forty days at Antioch, and the city was destroyed". Might be a duplication of 713?	Around Antioch 36.2 / 36.2	Imax =VIII S	earth shook for forty days
847 11 24, morning	**GCT**, after al-Dhahabi: "… there was a dreadful earthquake at Damascus. It lasted for three hours, causing the walls to collapse. People ran to the mosques to invoke God's mercy, and many of them died in the ruins. The earthquake reached Antioch, and it was said that 20,000 people died there. Than it reached Mawsil; it was claimed that 50,000 people died in the ruins"; after Al-Suyuti: "The earth shook in Damascus… A quarter of the mosque was broken off… The minaret fell down; and bridges and houses collapsed. The earthquake reached al-Ghuta and it destroyed Daraya, al-Mazzah, Bayt Lahya and other…"	Three sites?: a. Damascus 33.5 / 36.3 b. Antioch 36.2 / 36.2 c. Mawsil 36.5 / 43.0	Imax (in three sites): = VIII S – M	Several single events? In Damascus: lasted for three hours
853 06 12 – 854 06 01, night	**GCT**, after Ibn al-Imad al-Hanbali: "During the night, the earth shook at Tiberias. The mountains shook, and than a big rock – eighty cubits by fifty – split open and so … Many people died"	Around Tiberias 32.8 / 35.6	Imax = VII S	Single
859 12 30 – 860 01 29	**GCT**, after al-Tabari: "…there was an earthquake at Antioch which killed a large number of people, as well as causing the collapse of 1,500 houses	Around Laodicea -	I_0 = IX M - L	Syria was struck by earthquakes, the

	and about 90 towers in the walls of the city. Dreadful and indescribable rumbling noises were heard and people fled into the desert. Mt. Casius split open and rock fell into the sea which was stormy that day. Then, a black and stinking pall of smoke rose from the sea, obscuring the sunlight. A river sank into the ground over a distance of about a parasang (5.6 km) and disappeared. The people of Tinnis, in Egypt, … There was another earthquake in the cities of Balis, Raqqa, Harran, Ra's al- Ayn, Hims, Damascus, al-Ruha, Trsus, al-Messisa, Adhana and along the Syrian coast. The earthquake reached Laodicea where no home remained standing. Only a small number of people managed to escape"; after Ya'qubi: "Syria was struck by earthquakes which destroyed Laodicea and Jablah. Many people were killed, and the inhabitants finally decided to abandon their homes and seek refuge in the desert". **AAT**: 859 04 08. **AAKY:** ~M7 at Hacipasa segment, northern DST. **Am9**: Ms=7.0. **An4**: "a large number of earthquakes prevailed in the east**".** **AMA** 860 01.	Antioch 35.8 / 36.0		inhabitants finally decided to abandon their homes and seek refuge in the desert
881 05 16	**GCT:** "… a violent earthquake affecting many parts of the Mediterranean basin… This may be a case of two separate events…"; after Ibn al-Athir: "… there was a strong earthquake in Syria, Egypt, some parts of Mesopotamia, North Africa and Andalusia. The earthquake was preceded by a powerful rumbling noise"; after Ibn Abi Zar: "… there was an earthquake unlike any that had been before. It destroyed strongholds and removed rocks and mountains. …people fled… Houses and walls collapsed, and birds fled from their nests, vanishing into the air until the earthquake ended. The shock struck the enemy's land, from Tanga to Tilimsan, and the whole of Andalus, from the coast to the mountains". **AMA**: Hellenic Arc. **EM**: South Spain and north Morocco.	A single location cannot be determined, possibly several events	?	Several events?
972	**GCT**, after al-Antaki: "There was an earthquake in Antioch, and a large part of its walls collapsed"; after al-Maqrizi: "A strong earthquake suddenly occurred in Damascus and the surrounding area. It caused many towers to collapse in Antioch".	Antioch, towards Damascus 36.0 / 36.2	Imax = VII-VIII S - M	Single
991 04 05 night	**GCT**, after al-Antaki: "There was an earthquake at Damascus. More than 1,000 houses collapsed, and a huge number of people died…. a village near Ba'albek swallowed by the earth. Other tremors occurred in Damascus and the surrounding area and Ba'albek… The shocks went on repeatedly till … (5 May) in the same year."	Around Damascus and Ba'albek: 33.8 / 36.2	Imax =VIII M	Single, and more shocks went on repeatedly till …(5 May) in the same year (one month)

1002 11 10 – 1003 10 29	**GC**, after Ibn Taghribirdi: "… the earth shook in the Syrian territories, in the principal towns and along the coast; and there were many victims in the ruins".	Syria at that time ? / ?	Imax =VIII M	Single
1033 12 05 before sunset	**GCT**, after Salomon ben Zemah: **"…**This event took place on Thursday, 12 Tevet, suddenly before sunset, affecting not only Ramla but the whole of Filastin, from fortified vity to open village, all the fortresses of Egypt [i.e. subject of Fatimid rule] from the sea to Fort Dan [Baniyas], all the cities of the south (Negev) and from the Mount to Jerusalem (and its surroundings) to Shehem (Nablus) and its villages, Tiberias and its villages, the Galilean mountains and the whole of Palestine. Those that traveled on high roads relate the mighty acts of the living God. They say "We have seen the mountains shake, leap like stages, their stones broken into pieces, the hillocks swaying to and fro, and the trees banding down". In some places the waters in the cisterns reached the brim… He, moreover, in his goodness brought out thick clouds and heavy raindrops fell. Two great rainbows appeared. One of them split into two and fire was visible from the south west. Thereupon the earthquake took place, the like of which there had not been since early times. On that night (the earth) shook again. All were in the streets, men, women and children, imploring God, the Lord of the spirits, to quiet the earth and set it at rest and save both man and animal. On Friday as well as on the following night, the shocks recurred. All were terrified and fear-stricken… For eight days the mind has not been satisfied and the soul is not at rest. "... והיה הדבר הזה ביום חמישי בשנים עשר יום לחודש טבת טרם בוא השמש פתע פתאום ברמלה כן בכל ארץ פלישתים כן מעיר מבצר עד כופר הפריזי כן בכל מבצרי חוף הים עד מבצר ח[יפ]ה ובכל ערי הנגב עד ירושלים וכל עריה עד שכם וכל כפריה [ועד ט]בריה וכל בנות[י]ה הר הגליל וכל ארץ הצבי ואשר היו מתהלכים בדרכים יגידו גבורות אל חיים יאמרו ראינו ההרים רועשים כאילים רוקדים אבניהם מתפוצצות והגבעות מתנודדות והאילנות מתכופפים עד מימי הבורות במקומות עלו עד פיותיהם ... גם טובו אשר הגדיל כי לפני היות הרעש ה[ע]לה עבים מוחשכים והגשימו טיפים עבים ונראו שתי קשתות גדולות ונראה כי האחת נחצת ונראתה אש ממערב נגבה בשעה ההיא היה הרעש אשר לא נראה כמוהו מימים קדומים ובלילה ההוא שוב נדדה והכל בחוצות אנשים ונשים וטף צועקים אל אלוהי הרוחות להשקיט הארץ ולהרגיעה להושיע אדם ובהמה עוד בערב שבת נדדה עוד בלילי שבת והכל נבהלים אחוזי רעד... ...נעים נודדים זה שמונה ימים אין נחת רוח ואין נפש שוקטת..." After Al-Antaki: "… a terrible earthquake struck the area… Half the	**GC**: Around Jericho – Nablus – Akko 32.0 / 35.2	I_0 = IX M - L	Single: פתע פתאום Suddenly. On that night (the earth) shook again – 5-6/12/1033; On Friday – 6/12/1033, as well as on the following night – 6-7/12/1033, the shocks recurred. Aftershocks שמונה ימים אין נחת רוח eight days the mind has not been satisfied

	houses in Ramla collapsed as well as various parts of the walls. There were many victims. Riha (Jericho) and its inhabitants were swallowed up and the same thing happened at Nablus and nearby villages. Part of the great mosque of Jerusalem collapsed, as well as convents and churches in its province. Houses collapsed at Acre as well. .. The sea water receded from the port for an hour and than returned to its place"; after Ibn al-Jawsi: "There was an earthquake in Ramla. … the earthquake destroyed a third of the town… and killed a large proportion of the populace… Nablus, where it destroyed half of the houses, killing three hundred people. A nearby village was swallowed up by the earth… and other villages suffered the same fate. Part of the city walls of Jerusalem collapsed, "… the minaret collapsed at the congregational mosque in Asclon, and the same thing happened to the top of the minaret in Gaza."; after Bar Hebraeus: "… there was an earthquake in Egypt and Palestine… one half of the city of Balash fell down. And the earth swallowed up many villages in Syria with their inhabitants… and half of the city of Akko…"; after Al-Suyuti: "… Half the buildings in Nablus were razed to the ground, and at the village of Badan, subsidence swallowed up the inhabitants with their herds of cows"; Al-Ulaimi: "… the same thing happened to the mosque of Abraham (at Hebrin)"; Sawirus ibn al-Muqaffa': "… two mountains in the province of Banyas struck against each other, and their clash produced flames which burned many trees…" **AJ**. **AMA**.			
1042 08 21 – 1043 08 09	**GC**, after Al-Suyuti: "The earth shook at Palmyra [Tudmur] and Ba'albek. Most of the inhabitants of Palmyra died in ruins".	Around Tudmur: 34.5 / 38.3	Imax = IX S - M	Single
1063 07 30 – 08 27	**GC**, after Ibn al-Jawsi: "… there were earthquakes at Antioch, Laodicea, in part of Byzantine territory, at Tripoli, at Sur, and at various places in the Syrian territories. The walls of Tripoli collapsed"	Around Tripoli: 34.4 / 35.6	Imax = VII-VIII M	There were earthquakes
1068 03 18 08 30	**GC**, after Ibn al-Banna who was in Baghdad at that time and felt this earthquake, in regard to the first event: "there was a terrible earthquake in the city of the prophet (Medina) … which brought down two merlons from the minaret of the mosque of the prophet… The earthquake then continued its course, overwhelming Wadi al-Safra', Al-Marwa, Khaybar, Wadi al-Qura, Taima, Tabuk and Aila. As for Aila, its inhabitants all perished except for 12 persons who had gone fishing at sea, thus escaping death. As for Taima, it used to have one source of water, God then produced another	**GC**: Around Ayla and southwards: 29.5 / 35.0 **AMA:** In Hejaz: 28.5 / 36.7	I_0 = X L (-)	Single: an earthquake in Palestine which lasted for two and a half hours, followed by two more shocks within the same period

	source… And the earth was laid open disclosing a large place yielding pure gold and golden jewels. …Tabuk… in a place known as Al-Qur, three more springs of water, improving their condition. The earthquake then ploughed through ar-Ramla, 15,000 persons perished and nothing was left in it according to reports, except two houses. The sacred Rock of Jerusalem moved… it had passed through Surair, in the Hejaz, and most of Syrian territories until it arrived at ar-Ramla. The sea … the distance of one day's march… there have occurred in Palestine and ar-Ramla… a terrible earthquake…"; after Ibn al-Jawzi: "… Its effects were also felt at Ruhba and Kufa… the town of Ramla had completely collapsed"; after Ibn al-Qalanisi: "… (in Ramla) water came out of wells. At Baniyas about a hundred people perished in the ruins; and the same thing happened at Jerusalem"; after Sibt Ibn al-Jawzi: "… an earthquake in Palestine which lasted for two and a half hours… and loud thunder-claps were heard in the sky, and violent sounds which caused people to faint. The earthquake reached Euphrates, whose water overflowed its banks…. And the earthquake struck Wadi al-Safra', Yunbu', Badr, Khybar, and Wadi al-Qura and spread throughout Hejaz…"; after Sawirus ibn al-Muqaffa': "… various places were destroyed at Ramla, Tinnis and elsewhere, and at Alexandria… One corner of the congregational mosque in Cairo moved. The earthquake was followed by two more shocks within the same period." **AJ:** L. **AZP. ZAP**.			
1068 05 29	**GC** note that there were two events at that time, but it is rather difficult to distinguish between the two; after Ibn al-Banna, in regard with the second event: "…the effect that there have occurred in Palestine and ar-Ramla, on … (29 May, 1068)… a terrible earthquake that destroyed all the dwellings except two. Approximately 15,000 persons perished. The rock of Jerusalem clove in two, then drew back together… …. The sea sank into the earth…"	Around Ramla?: 32.6 / 35.3	Imax = X M	Single
1086 04 18 – 1087 04 07	**GC**, after Al-Athir: "… there were earthquakes in Iraq, Mesopotamia, the Syrian territory and many other provinces. People abandoned their homes and fled into the desert, returning when calm returned"; after Al- Suyuti: "… there were earthquakes in Iraq, the Arabian peninsula and the Syrian territories, and numerous buildings were destroyed. Most inhabitants in Iraq fled into the desert, returning to their homes later".	In: Iraq, Mesopotamia, Syria, other provinces: **Location can not be determined**	Imax =VIII M	There were earthquakes, inhabitants in Iraq fled into the desert, returning to their homes when calm: possibly aftershocks?

1091 09 26 night	**GC**, after Michael the Syrian: "…there was an earthquake and 86 towers in the walls of Antioch collapsed"; after Matthew of Edessa: "…Much destruction occurred in the city of Antioch… and many men and women perished in the ruins of their homes"; after Ibn al-Athir: "… there were numerous earthquakes in the Syrian territory…"; after Sambat Sparapet after ?Matthew of Edessa who mentions that the earthquake affected "Mcbin", the Armenian name for Nisibis."	Around Antioch (and eastwards?): 36.2 / 36.1	Imax =VIII M	Single, and numerous earthquakes
1094 05 19 – 06 18	**GC**, after Inb al-Qalanisi: "… there were earthquakes night and day, such as had never been before. Each shock lasted longer than usual"; after Ibn al-Athir: "In that month there was a series of many earthquakes in the Syrian territories lasting for a long time, but they did not cause great destruction".	Syrian territories ? / ?	Imax = VI S	Earthquakes night and day; a series of many earthquakes in that month
1097 12 30	**GC**, after Raymond of Aguilers: "there was a great earthquake … For shortly after nightfall, the sky in the north became so red that it almost seemed that the dawn of a new day had come". […] when the earthquake near Antioch began… I was so struck with terror… the earth continued to shake and the terror within me continue to increase…"; after Fulk of Chartres, while being in the upper Euphrates Valley: "At that time we saw the sky grew red in an amazing fashion, whereupon we felt a great earthquake…	Around Antioch and eastwards? 36.2 / 36.1	Imax = V S	When the earthquake near Antioch began… I was so struck with terror… the earth continued to shake and the terror within me continue to increase
1105 12 24	**GC**, after Fulk of Chartres: "… all we who were in Jerusalem felt great earthquake, which severely frightened us, on Christmas Eve"; after Bartolf of Nangis: "… felt by all those who lived in Jerusalem". **Ka1:** "The cited catalogues include felt reports from Jerusalem and mention considerable damage but give no details of extent of damage, nor of casualties…"	Around Jerusalem 31.8 / 35.2	Imax = V S	Single
1117 06 26 night	**GC**, after Folk of Chartres: "… God caused the earth to shake and then calms it again… Then the king built a fortified place about five miles outside the city of Tyre and called it Scandelion,… and he repaired the damage…"; after Lisiard of Tours: "… Buildings were so shaken that they collapsed…"	Around Tyre: 33.1 / 35.2	Imax =VIII S	single
Sequence from: 1138 10 11 afternoon, until 1139 06	**GC, Am6**, **GBC**: Destructive seismic sequence from 1138 10 until 1039 06, main event on 1138 10 11. **GC**: "There was a destructive seismic sequence in the present day border territories between Turkey and Syria. The most seriously damaged area was in the region of Aleppo (Halab)… Edessa (Urfa). Explicitly	South of the East Anatolian Fault, near Azrab	I_0 = X M - L	In the first day,11/10: single event and 3 more large (felt in Damascus), or 3 large sub-events;

	mentioned are: Atharib, Azrab, Tall Ahmar, Zaradna, Shaykh al Hadid, Tall Hadid, and some others. Many of the shocks, especially in October were felt as far as Damascus, with no damage. In particular, three separate shocks were clearly felt in Damascus on 11 October 1138, the day on which the sequence began. It was also felt in Mesopotamia, but not in Jerusalem. Near Callinicus (Ar-Raqqah), in the Syrian desert, the earthquake caused cracks and fissures in the ground. After Ibn Al-Qalanisi: regarding the sequence of events: "During the afternoon of [11 October] there was a terrible earthquake in Damascus causing the earth to shake three times… further shocks the following Friday [14 October] at the hour of sunset… during the first third of the night of [27 October] … the earth shook three times… There were more shocks during Wednesday night [29 October] and yet more in the last quarter of Friday night [31 October] … the number of shocks was eighty… In the early hours of the morning of [21 June 1139] there were some terrifying shocks."	**GC**: 36.7 / 36.9 **Am6:** 36.1 / 36.8		14/10 further shocks, 27-31/10 many shocks 21/6 some shocks; **Am6**: Altogether 80 aftershocks
1140 08 17 – 1141 08 06	**SDM**, after Al Dawadri: "in this year there was an earthquake in Sheizar, causing damaging its citadel"	Sheizar area: 35.3 / 36.6	Imax = VI S	Single
c. 1150	**GC**, after John Phocas: "The monastery of the Prodromos (Precursor, St. John the Baptist, Qasr al-Yahud) was completely destroyed in an earthquake. … (Mar Elias monastery) … was later totally destroyed in an earthquake".	Between Jerusalem and Jericho 31.8 / 35.4	Imax = VIII S – M	Single
1151 09 28 night	**GC,** after Ibn al-Qalanisi, on 1151 09 28: "News arrived of an earthquake … which caused the earth to shake three times in the province of Busra and Hawran and the surrounding areas. House walls collapsed in Busra and elsewhere..."; **Am6:** 1151 09 27	Around Busra 32.5 / 36.5	Imax = VII S	earth shook three times
1152 02 01 shortly before dawn	**GC,** after Ibn al-Qalanisi, on 1152 02 01: "… There was an earthquake which caused the earth to shake three times…" **Am6:** 1151 09 27	Around Busra 32.5 / 36.5	Imax= III-V S	earth shook three times
1156 09 27	**GC, Am6:** This is the first significant event that started the long and destructive seismic sequence that struck the area of present-day northwest Syria, northern Lebanon and the region of Antioch, until May 1159. **Am6:** A strong earthquake caused considerable concern in Damascus… Shock continued until the end of the day.	Around Damascus? ? / ?	Imax = V S	A start of an earthquake storm shocks continued until the end of the day
1156 10 13 night	**GC: "**The earthquake… struck fear into the inhabitants of Damascus and	Around	Imax ≥ VII	Several shocks

	vague news reached the city of disasters in many areas of the provinces of Allepo (Halab) and Hamat (Hamah). Furthermore, one of the towers of Afamiyah had also collapsed." **Am6:** 1156 10 10	Afamiyah (between Allepo and Hamat): 35.4 / 36.4	S – M	
1156 12 09 night	**GC:** "… strongly felt at Damascus but caused no damage (there). At Allepo many houses collapsed, causing many deaths; serious damage also probably affected Shayzar (no detailed information)… The inhabitants of Kafar Tab and Hamat fled panic-sticken from their towns."	Around Allepo: 36.2 / 37.2	I_0 = VIII S – M	Single, and other earthquakes followed, too frequent to number
1157 04 02 during the night towards dawn	**GC:** "The earthquake … caused a great scare in Damascus. Allepo, Shayzar, Hamat, Kafar Tab and Afamiyah were probably damaged, although Ibn al-Qalanisi does not record any details of effects".	Around Afamiyah: 35.4 / 36.6	Imax = VII S – M	Several shocks
1157 07 05 morning	**GC**: "… four shocks were felt in Damascus, the third of which caused outbreaks of panic and confusion…At Hamat, Kafar Tab and Afamiyah there was unspecified damage, but reconstruction work undertaken in previous months was destroyed. There was probably damage at Aleppo as well and perhaps at Hims". **Am6** dates this event to 1157 07 13 whereas the July 05 was considered as a smaller event.	Around Hamat: 35.2 / 36.6	I_0 = VII M	Several shocks
1157 08 09–09 07	**GC**: The most destructive shocks occurred at that time period, on 9/8 and 7/9, with the strongest felt at Damascus on 12/8, 17/8 and 6/9. Most serious destruction occurred in the Muslim regions of Aleppo, Hamat and Hims. Much damage was also in many other places. Cumulative effect due to long sequence does not allow for magnitude and epicenter determination. **Am6**: 1157 08 12	Aleppo, Hamat, Hims **GC**: 35.4 / 36.6 **Am6**: 35.1 / 36.5	I_0 = IX L	Several shocks
1163 08	**GC**, after Bertrand of Blanquefort: "…after fortifications were thrown down in the earthquake, and many castles were destroyed, and huge numbers of us were crushed under the debris of walls…"; after King Amalric I of Jerusalem: "An earthquake such as had never been seen before razed castles, towers and towns to the ground … both in the mountains and the plains, both in Antioch and in all neighboring places in the plains or the mountains…"	Around Antioch 36.2 / 36.2	I_0 =VIII-IX M	Single
1170 06 29 0345 UT	**GC, GBCB**: One of the largest events. The whole territory belonging to the cities of Antioch to the north and Tripoli to the south, both along the Mediterranean Sea, and in the hinterland, along the Bekaa Valley and the River Orontes up to the area of Allepo was seriously affected, with	**Am6**: 34.5 / 36.4 **GC**:	I_0 = IX-X L	One or two main shocks, aftershocks lasted for 3 or 4 months, or longer.

	widespread destruction. Enormous propagation zone: Al-Mawsil, Sinjir, Nisinin, Al-Ruha, Harran, Ar-Raqqah, and Mardin, as far as Baghdad, Basra and other cities in Iraq. Felt with no damage in Palestine (neither in Caesarea). The earthquake lasted for three or four months, or perhaps longer. There were times when three or four or even more shocks were felt by day or night. Me=7.7. **Am6:** M >> 7. **MGS** associate this event with a left lateral surface rupture of 4 - 4.5 m (M_W=7.3 - 7.5) at Missyaf segment, Syria.	34.6 / 36.2		There were times when three or four or even more shocks were felt by day or night.
1202 05 20 0240 UT	**AM1, GC:** There was a very destructive earthquake affecting the oriental Mediterranean coast and hinterland of what are now Lebanon, Syria and Israel. Akko and Tyre were severely damaged, as well as Baniyas and Safad, Bayt Jinn, etc… The major earthquake was followed by other brief shocks towards noon on the same day which were slightly felt in Cairo…. earthquake at Hamat occurred at midday on 21 May and was followed by another shock in the afternoon. Altogether, the shocks lasted for four days. We may conjecture that the event nucleated in the south, near Nablus, and that it was completed by a second rupture that originated in the Tyre-Baalbek segment of the meizoseismal area. **AB**: Syria-Baalbek, Ms=7.5. **AJ**: L. **AM2**. **Am9**: Ms=7.2. **AMA**. **DKT1, DKT2**: Yammouneh fault. **EMA**. **GC:** Me=7.6. **MAE.**	**Am6:** 33.9 / 36.1 **GC**: 33.4 / 35.7	I_0 = IX-X L	**Am4**: possibly two shocks?, was followed by brief shocks towards noon on the same day which were slightly felt in Cairo… earthquake at Hamat on 21 May was followed by another shock in the afternoon. Altogether, shocks lasted for four days
1212 05 01 night-dawn	**GC**, after Abu Shama: "During the night, there was a tremendous earthquake which destroyed many parts of old and new Cairo; it also destroyed towers and houses al Al Karak and Shubak. Many women and children died in the ruins. The most violent shock was at Aylat, on the coast. It was said that the earthquake was preceded by a black wind and many falling stars"; after Al-Maqrizi: " … and smoke was seen coming down from heaven to earth in Damascus between dusk and evening." **Am9**: Ms=7.0. **AMA:** severe damage to the monastery of St. Catherine. **KAD**: Possible surface rupture in the northern Arava Valley, Mw~7.	Around Ayla or between Ayla and Shubak-Karak **GC**: 29.6 / 35.0 **AMA**: 30.0 / 35.2	I_{max}/I_0 = IX-X M (- L)	**AMA**: Foreshock at sunset 30.4, mainshock at dawn 1.5, aftershocks for a year
1259 03 22 night	**GC**, after Al-Maqrizi: "… God sent rain, cold, wind, thunder and lightning, and an earthquake which caused collapses in many places…"; after Ibn Duqmaq: "… and there were numerous shocks in Syria at the time when the Tartars arrived…."	Around Damascus: 33.5 / 36.3	Imax = VII S	Main shock and numerous shocks
1287 02 2nd half	**GC**, after Ibn 'Abd al-Zahir: "… there was a series of earthquakes which damaged some fortresses, including that of Safad. Half way through Muharram, our sultan set about repairing the damage."	a. between Hims and Safad	Imax = VII S	Series of earthquakes

	Could be a composite of two separate events, one near Safad and the other near Hims	33.9 / 36.1 or b. near Hims 34.7 / 36.7 or near Zafad 33.0 / 35.5		
1287 03 08	**GC**, after Ibn ‘Abd al-Zahir: The fortress at Hims was also being repaired, when it was again struck by another shock on [8 March].	near Hims 34.7 / 36.7	Imax = VI S	Single
1287 03 22	**GC**, after Ibn ‘Abd al-Zahir: During the night of [22 March], there was an earthquake in the direction of Laodicea which almost completely destroyed its tower in the sea…”	near Laodicea 35.5 / 35.7	Imax = VII S	Single
1293 01 11 – 02 08	**GC**, after Al-Jazari: “… there was a violent earthquake in the towns of Gaza, Ramla, Ludd (Lydda), Qaqun and Karak. The worst damage was at Karak, to the extent that three of the citadel’s towers were destroyed, as were a number of buildings”; after Ibn Kathir: “… there was an earthquake in Karak and many buildings were destroyed at Tafila”.	Around Karak, possibly toward Tafila: 31.2 / 35.5	Imax = IX M (-L)	Single
1339 01 13 – 02 11	**GC**, after Al-Yafii: “… sixty people died in an earthquake at Tripoli in Syria”.	Around Tripoli: 34.4 / 35.9	Imax = VII S	Single
1344 01 03	**GC: “**At the citadel of Manjib in Syria, almost all buildings collapsed and there were a great many victims. There was similar damage at other localities in its district: the fortress of Bayra (present day Birecik), ‘Ayntab (Gaziantep) and Rawandan… in Turkey, and that of Muslimini-ya, in Syria, were largely reduced to ruins. Farther north… massive destruction and widespread collapse at the fortress of Bahasana (Besni). Allepo (Halab) also suffered very serious damage: 32 towers collapsed at the citadel and many houses, mosques and shrines were destroyed. The town walls were also badly damaged. In relation to the worst affected area, it is recorded that the places concerned were abandoned by their inhabitants for more than a month.”;' after Al-Wardi: “… there was a tremendous earthquake which caused a great deal of destruction in Aleppo and its province, especially at Manjib where the fine fortress of Rawandan was damaged.”	Around Aleppo and to the northeast: 36.7 / 37.5	I_0 = IX M – L	Two shocks in close sequence. In relation to the worst affected area, it is recorded that the places concerned were abandoned by their inhabitants for more than a month.
1366 09 07 – 1367 08 27	**GC**, after Ibn al-Imad al-Hanbali: “… there was a dreadful earthquake at Safad”	Around Safad: 33.0 / 35.5	Imax = V S	Single

1404 02 20	**GC**: The most violent earthquake at Allepo was followed by a sequence of less powerful shocks which lasted until early July 1404. After Ibn Hajar: "… the earth shook violently at Aleppo and in its province, causing much destruction. Before that, there had been an earthquake on [18 December], at midday. Earthquakes followed throughout the year, especially in the west"; after Ibn al-Shihina: "… a great many places were destroyed; the earthquake was followed by a second series of lesser shocks."; after Al-Ayni: "Chronicles record a violent earthquake in the province of Tripoli during the last ten days of [13 February – 12 March], causing the destruction of many buildings"; after Al-Maqrizi: "… an earthquake which had struck Tripoli of the Lebanon and its province; many buildings were destroyed, including one side of the citadel of Marqab". 1403 12 18, midday: possibly a preshock. **AB**: 1404 02 22, Ms Large.	<u>1403 12 18:</u> Around Aleppo: 36.2 / 37.2 <u>1404 02 20:</u> Between Aleppo and Tripoli: 35.3 / 36.5	Imax =VIII M - L	<u>14031218</u>: pre-shock? <u>14040220</u>: Single, violent earthquake, earthquakes followed during the last ten days of Sha'ban [13 February – 12 March]; more followed throughout the year (lasted until early July 1404?), especially in the west.
1404 11 05 – 12 04	**GC**, after Ibn Hajar: "there was a strong earthquake at Aleppo which struck panic into the local people. … When the first shock ceased, another followed, but there was no damage, thanks to God".	Around Aleppo: 36.2 / 37.2	Imax = V S	When the first shock ceased, another followed
1407 04 09 – 05 08	**GC**, after Al-Suyuti: "… the earth shook at Antioch. Many people died in the ruins".	Around Antioch: 36.2 / 36.1	Imax = VII-VIII S	Single
1408 12 29	**GC**, after Ibn Hajar: "… there was a tremendous earthquake in the region of Allepo and Tripoli; the shock caused destruction in Laodicea and Balatunus, the citadel of the latter town collapsed… 15 people were killed… 15 people were also killed in Jabala. The whole of Shugur Bakas was destroyed… The earth split open for a distance of about a mile, from Qusayr to Saltuhum – the latter is a mountain village – and it moved for a mile, including trees, streams and inhabitants, without anyone realizing what was happening. The earthquake also struck Cyprus, causing a great deal of damage there. It also struck the coastal and mountain areas; snow in the summit of Mt. Cassius was seen to come down to the sea. A high tide stretched over 10 parasangs [64 km]. Sailors said that boats at sea were pushed on to the land by the tide; when the sea fell back, nothing proved to have been damaged"; after Al-Maqrizi: "The earthquake also affected Laodicea, Jabala, the citadel of Balatunus, Shugur Bakas, and a great many villages in the mountains and along the coast; many people died in the ruins". **AAKY:** ~M7 at Hacipasa and Amik Basin segments,	Around Shughr Bakas and Balatunus: 35.7 / 36.2	I_0 = X M – L	Single

	northern DST. **AB**: Ms=7			
1458 11 08 or 16	**GC**, after Ibn Taghribirdi: "… there was a minor earthquake at new Cairo, but it was sufficiently strong in Syria to cause the collapse of most of the town walls, the government building and many dwellings in the town of Karak. Furthermore, the minaret collapsed in the town of Ramla, as well as another minaret at Khalil, part of a minaret in Jerusalem and the great dome which was close to the Qumama [church of the Holy Sepulchre]"; after Al-Suyuti: "… A hundred people were killed."; After Al-Ulaimi, in Jerusalem: "… a minaret… part of which destroyed…"; after Ibn Iyas: "… causing the collapse of a great number of houses in Jerusalem and Khalil"; after Al-Suyuti, in Karak: "…A hundred people killed". **Am9**: Ms=7.1. **AMA**: 1458 11 12. **KAD**: Possible surface rupture in the northern Arava Valley, Mw~7.	Around Karak and northwards: 31.2 / 35.7	Imax = IX M	Single
1484 03 29 – 04 28	**GC**, after Al-Suyuti: "… the earth shook at Aleppo six times or more, giving rise to panic."	Around Aleppo: 36.2 / 37.2	Imax = V S	Six or more
1537 03 09	**AK**, after al-Ghuzzi and al-Umari: Slight shock was felt in Damascus. In Antioch the shock caused walls to collapse.	Around Antioch: 36.2 / 36.1	Imax = VI S	Single
1546 01 14 afternoon	**AK:** a medium magnitude event of M_S about 6.0, in many respects similar to that of the earthquake of 1927. …The area strongly affected by the 1546 earthquake was confined between Nablus, Ar-Ramla and some points north of Jerusalem… Nablus suffered more than other sites, 500 lives were lost under the ruins… Jaffa, except the sea wave, is difficult to assess… Damage Jerusalem, chiefly to tall structures, was widespread but repairable…Bell tower of the Holy Sepulchre is missing, south part of madrasa of Qayitbay, top of the minaret above the Bab as-Silsila destroyed… Bethlehem – the bell tower of the basilica, the church of St Jeronymous and a few appended structures destroyed or damaged beyond repair… Hebron damage to tall buildings, a collapse of a few houses with casualties (no widespread destruction)… Gaza serious damage to the madrasa of Qayitbay… As-Salt and Al-Karak strong shaking… Nazareth no clear indication of damage… Tiberias no evidence for collapse of the walls… Safed no report of damage… Damascus some concern… Lebanon, Egypt, Cyprus no evidence it was felt there… Seismic sea wave flooded the coast between Gaza and Jaffa, allegedly causing additional loss of life.	Jordan Valley, between Jerusalem and Nablus: 32.0 / 35.5	I_0 = IX M	Single + aftershocks, + on 13/3, 13/5: then, on 13 March 1546 there was another alarm, the noise of which was greater before it died out. Then, on 13 May, there occurred another shock felt by some people more than others, apart from the continuous shocks of previous days, some of which occurred at night and some during the day.

	The discoloration of water and change in the yield of springs, as well as temporary damming of the river Jordan and of streams around Jaffa…			
1557 02	**AK**, after Cohen (1990): **"**an earthquake caused the collapse of a gun foundry, the forging house and ovens in Jerusalem**".**	Around Jerusalem: 31.8 / 35.3	Imax = VI S	Single
1563 09 13 dawn	**AK, SDM**, after Badr al-Din al Ghuzzi: An earthquake, accompanied by a sound from the earth, destroyed a number of houses and cracked walls in Damascus".	Around Damascus 33.5 / 36.6	Imax ≥ VI S	Single
1565 07 27 dawn	**AK**, after Badr al-Din al Ghuzzi: Earthquake was felt in Damascus**. SDM**, after al-Ghazi: It was accompanied by a sound from the earth.	Around Damascus 33.5 / 36.6	Imax = V S	Single
1588 01 04 13:00	**AMA: "**A little after midday, a strong shock of earthquake was felt in Cairo, where it was of long duration… The earthquake was destructive at the pass of Aila and caused rockfalls on the Egyptian pilgrim route to Mecca. At Tabuk, on the Syrian pilgrim route, the shock was very strong and the castle collapsed on the pilgrims there. Medina was also affected… In Sinai, the mosque in the monastery of St. Catherine collapsed and, together with other structures, was later rebuilt. These details are consistent with an epicenter in the northern Red Sea area, to the east of the Gulf of Aqaba".	Between Aila and Tabuk: 29.0 / 36.0	I_0 =VIII-IX M	Single, in Cairo: long duration
1626 01 21	**AF**: There was a great earthquake in the Middle East as a result of which many places in the region of Aleppo and Gaziantep were ruined with great loss of life. **SDM**, after al-Nablsi: A slight earthquake was felt in Damascus on Wednesday… In the meantime an earthquake hit Hama, causing the Souk Al-Dahsheh to collapse and killing many people under the debris.	Around Gaziantep, Aleppo, Hama 36.2 / 37.2	Imax = VII-VIII M	Single
1627 11 24 night	**SDM**, after al-Nablsi: A strong shock hit Damascus on Wednesday night, but without any damage	Around Damascus 33.5 / 36.3	I_0 = IV-V S	Single
1705 11 24 night	**SDM**, after al-Nablsi: "… three main different sized shocks happened on Tuesday night… in Damascus. The first one caused general panic while the second was the strongest, causing houses to fall, walls to be destroyed in and around Damascus…., to the extent that large number?s of people in the villages were killed under the debris. In Al-Qastal village, its fortress collapsed as well as a monastery in Yabrud village. Light shocks continued to be felt till Ramadan (one month)".	Around Yabrud, Al-Qastal, Damascus: 34.0 / 36.6	I_0 = VIII M	Three main different sized shocks happened on Tuesday night: the first caused general panic, the second was the strongest, causing the damage, light

	AF1 adds that in Tripoli roofs and walls of the city, some of the walls of the towers of the coastal fort and some of the quarters of the gar were destroyed. **GMDS**: Serghaya Fault?			shocks continued to be felt till Ramadan (one month).
1738 09 25	**AF2, SDM**: This earthquake caused considerable damage in the region of Amanus, ruining a number of villages on the east side of Belen Bass (Riggs). Part of Antioch's walls and some houses collapsed according to European traveler. A part of castle between Bayas and Iskendrun has been demolished. Probably it was demolished by this earthquake. The shock, according to an eyewitness, was strongly felt in Aleppo without damage. This is certainly the same event that was also felt in Kilis (Kilisli Kadri) and in other parts of the region of Bereket.	Amanus region: 36.3 / 36.5	I_0 = VII-VIII M	Single
1759 10 30 03:45 LT	**AB: "…** It affected the region of Safad and a mountain area to the northeast where many villages were destroyed with the loss of about 2000 lives… Safad and Qunaitra were almost totally ruined, and many of the inhabitants were killed, while others left the town. Damage extended to Saida, where a few houses collapsed, as well as to Sassa, Nazareth, and Acre, where private and public buildings were ruined, but without casualties. In Damascus … and in the surrounding plain of Ghutah, the shock caused considerable concern and widespread minor damage. … the water supply of the city was affected by rock falls that blocked the Qanawat water supply channel. Further away, the damage was widespread, in Tiberias… mainly because of foundation failure of houses built on soft ground and elsewhere because of landslides, but without loss of life. The shock was rather strongly felt as far as Antioch, Allepo, Jerusalem, and Gaza, and it was reported by sailing boats between Cyprus and Beirut. This earthquake was followed by a series of strong aftershocks, some of which were felt as far as Aleppo, that added to the damage." Ms=6.6. **DKT1**: Rachaiya fault. **Ka1:** "The origin of felt report from Jaffa is not clear. Damage in Tiberias may have been rather slight." **MRH**: Surface rupture at Jordan Gorge segment.	Between Zafad and Qunaitra 33.1 / 35.6	I_0= IX M	Single, and a series of strong aftershocks, some of which were felt as far as Aleppo, that added to the damage.
1759 11 25 19:23LT	**AB:** "The main shock occurred on November 25, 1759, at 1923 LT. It was of long duration, about 50 s, and almost totally destroyed all villages in a narrow zone extending to the northeast for about 120 km along the Litani and Bakaa valley into the upper reaches of the Orontes river in northwest Syria… faulting, at least 100 km long,… Contemporary sources mention over 100 places from which an assessment of damage can be made…	**AB**: 33.7 / 35.9	I_0 = X L	Single, and aftershock sequence until 8/1760. Damaging shocks on 26/11, 5/12, 12/12, 30/12.

	Safad: rebuilt after the first shock but with a much reduced population, was almost totally destroyed with loss of life. Metwali, Bshara, Shouf region: razed to the ground, many monasteries and cloisters were destroyed. Near Mukhatra and Djordjos: rock falls and landslides. Upper reaches of Barada river, Serghaya, Hasbaya, Baalbek: totally destroyed with great loss of life. A series of ground ruptures many yards wide were formed… along the Bekaa Valley, from Baalbek to opposite Tripoli to the plain of Satern… a total distance of about 100 km. Most probably however, the displacement occurred along the Yammouneh fault,… District of Damascus: great panic, several casualties, considerable but repairable damage. Villages around Damascus in Ghutah and Marj suffered from foundation failure, collapse of well shafts and more…. Antioch, Ladhikiya: strongly felt, panic, collapse of a number of old houses. Allepo, Tarba, Gaza, Al Arish: few walls were fissured. The shock was felt throughout of Anatolia as far as Nakhichevan, 1100 km away, and in Egypt. Estimates of casualties vary between 10,000 and 40,000. A seismic sea wave was noted as far as the Nile Delta. In Acre, ships were thrown onto the shore, and there were some casualties. Aftershocks continued to be felt till August 1760. Of which the shocks of November 26 and December 5, 12 and 30 caused additional damage and loss of life, mainly in the region of Baalbek, Tripoli, and Homs and slight damage as far as Aleppo". Ms=7.4. **Am9**: Ms=7.5. **AJ:** L. **DKT1**: Serghaya fault. **GMDS**: Serghaya Fault? **Ka1:** "Reports of shock continue to 1760. The cited sources do not provide felt reports for Central and Southern Palestine."			
1795 12 ?? 14:10	**AF2, SDM:** two shocks in Aleppo. The second being strong enough to damage many houses.	Around Aleppo: 36.2 / 37.2	I_0 = VI S	Two shocks
1796 04 26 09:05	**AF2, Am4, SDM:** This was a destructive shock in the Sahel region of Latakia on the Syrian littoral… without foreshocks and lasted with intermissions for about one minute. In Latakia so violent that almost everything collapsed with the first shock. In the port area the old fort at the entrance of the harbor and the tobacco store of the customs house and the han,[?] solidly built structure, collapsed instantly killing the Aga, his officers, 400 people and many animals. Out of a population of about 5,000, 1,500 – 2,000 people were killed and many injured. One third of the	Lattakia **AB**: 35.7 / 36.0 **SDM**: 35.3 / 36.2	Imax = IX-X L	Without foreshocks, lasted with intermissions for about one minute. In Latakia so violent that almost everything collapsed with the first

	houses were destroyed and the reminder more or less ruined. Damage was equally heavy in Jableh where most of the houses were destroyed… farmers lost their lives in surrounding villages; the castle of Markab and Qadmus were completely ruined. There was also loss of life in the Bucak area north of Latakia and settlements along the Nahr Al-Kebir River suffered in particular. The shock was felt between Aleppo and Tripoli and in Saida. It is said that as a result of the earthquake the surface of the ground around Latakia rose but this may be an exaggeration. Aftershocks continued to be felt for two months. Ms=6.8. **AB**: Ms=6.6. **AF1**. **AJ**: Ms=6.6, Syria-Ladhikiya (Latakia).			shock. Aftershocks continued to be felt for two months.
1822 08 13 20:40	**Am4:** The earthquake was the largest in the border zone in the last five centuries… The earthquake was felt from the coast of the Black Sea to Gaza and it was followed by an aftershock sequence that lasted almost 2.5 years. The shock almost entirely destroyed the region between Gaziantep and Antakya in Turkey and Aleppo and Han Shekhum in NW Syria, killing a very large number of people. Slight shocks, reported mainly from Aleppo and Antakya, began on August 5 and continued intermittently until August 12, but since they were like many others which had been experienced in the past, they caused no alarm to the inhabitants. At 8 h 10 m pm on August 13 a strong shock was felt in the region between Latakia, Aleppo and Antakya: this caused considerable concern and warned the people of what was to follow. The main shock happened 30 min later in three phases lasting altogether 40 s. A flash of light was seen in the sky over Aleppo, Antakya, Suaidiya and Iskenderun. After a short pause, the main shock was followed for about 8 min by successive shocks, about 30 in all, each of short duration but of damaging intensity; in Aleppo, Antakya and Aintab these were as strong as the main shock and completed the destruction and caused the bulk of the loss of life…. The main shock was felt by ships sailing between Cyprus and Latakia and halfway between Alexandria and Cyprus. There is no evidence … an abnormal fluctuation of sea-level. The total number of people killed… 30,000 – 60,000… sober estimates …20,000. **AB**: Ms=7.4. Aafrine, Turkey-Syria region, the East Anatolian Fault where it joins the Dead Sea system. **AJ**: Ms=7.5. **SDM**: Ms=7	**AB**: 36.7 / 36.9 **SDM**: 36.1 / 36.75	I_0 = X L	Slight shocks, began on August 5 and continued inter-mittently until August 12. At 8 h 10 m pm on August 13 a strong shock caused considerable concern and warned the people of what was to follow. The main shock happened 30 min later in three phases lasting altogether 40 s. After a short pause, the main shock was followed for about 8 min by successive shocks, about 30 in all, each of short duration but of damaging intensity; Aftershock sequence that lasted almost 2.5 years.
1834 05 26 04:00	**AAT:** "Strong, many aftershocks during 10 days. Tiberias, Akko, Nablus, Jerusalem, Bethlehem, Ashkelon, Gaza. Jerusalem: several churches	Around Jerusalem	Imax = VII S-M	Single + aftershocks for 10 days

	damaged, including the cupola of the Holy Sepulchre. Damage to the city walls, many houses and cisterns, which were emptied as a result of the earthquake. A minaret in the city and one on the Mount of Olives collapsed, as did the cupola of the ascension. Bethlehem: much damage to the Latin, Armenian and Greek Orthodox monasteries. Many people were killed (in Bethlehem?). Deir Mar Saba: a tower cracked. Large blocks of asphalt floated on Dead Sea…" **Shal.** **BM**: M_L = 6.3.	and Bethlehem 31.7 / 35.2		
1837 01 01 14:34	**Am5:** "The main shock occurred on 1 January 1837 … at 10 min before sunset. The earthquake was reported from Beirut and other places at different local times between 16 h 35 min and 16 h 45 min. The main shock lasted between 10 and 30 s and eyewitness reports imply that the earthquake consisted of two distinct shocks about 5 min apart. It was probably a multiple event, the second shock occurring about five minutes after the main shock. Destruction or heavy damage was done along a relatively narrow zone which extended from the coastal area of Saida (Sidon) through the inland iklimi (regions) of al-Touiffa, Marjuyun, Bshara to Lake Tiberias, for a total length of about 120 km. Damage in the epicentral region was widespread and varied from place to place over short distance. Loss of life – the reported figure is 6-7,000 killed. Aftershocks continued to be felt for almost four months, three of which are particularly important: 16 January was widely felt and caused considerable damage in the district of Jaffa and Nablus. 22 and 25 January were reported from the north part and caused panic in Damascus. 20 May was reported from the north and caused considerable damage at Hashbeya. **AJ**: Ms=7.4. **Am9**: Ms=7.0. Ms = 7.0+.	Possibly the Roum fault: 33.3 / 35.5	I_0 = IX M - L	The main shock lasted between 10 and 30 s, earthquake consisted of two distinct shocks about 5 min apart. Aftershocks continued to be felt for almost four months. Important are: 16 January widely felt and caused considerable damage in the south, 22 and 25 January reported from the north and caused panic in Damascus. 20 May was reported from the north and caused considerable damage at Hashbeya
1872 04 03 07:40	**Am4:** This was a large earthquake. It occurred at 7 h 40 m am and affected the lower reaches of the Orontes where the river empties into the Mediterranean. The shock almost totally destroyed Antakya as well as its seaport of Suaidiya and it was felt throughout the Eastern Mediterranean, from Rhodes to Diyarbakir and from Konya to Gaza. The sea rose after the earthquake, allegedly to a great height, flooding the coast. The relatively small number of fatalities was due to the fact that between the first shock and the latter part of destructive shaking many people managed to run out of their houses into the open.	**Am4, AB:** 36.4 / 36.5 **SDM**: 36.2 / 36.5	I_0 = X L	Between the first shock and the latter part of destructive shaking many people managed to run out of their houses into the open. Aftershocks continued to be felt with

	Aftershocks continued to be felt with decreasing severity throughout April and May, but did not cease altogether until 1873 February. **AB**: Ms=7.2, Amik Gulu,.the East Anatolian Fault where it joins the Dead Sea system. **AJ, Am9**: Ms=7.2. **Am4**. **Am9**: Ms=7.0. **AAKY:** ~M7 at Hacipasa segment, northern DST.			decreasing severity throughout April and May, but did not cease altogether until 1873 February.
Modern activity				
1927 07 11 13 04	**Av:** 285 people were killed and 940 injured on both sides of the Jordan River. Intensities were assessed at 133 sites. Maximal seismic intensities were IX on the MSK, along the River Jordan, from Allenby Bridge to the north coast of the Dead Sea. Aftershocks: 20 recognized, 12 of which were 3.5 < M < 5, until February 1928. Four more possible aftershocks appeared until September 1930, 2 of which were 3.5 < M < 5. Most powerful aftershocks took place on July 17, and February 22, 1928. **SAN**: M_L= 6.2	**ABSN:** 31.6 / 35.4 **SAN**: 31.8 / 35.5	I_0 = IX M M_L=6.2	Twelve 3.5 < M < 5 after-shocks until February 1928, and two such more until September 1930. Most powerful were on July 17, and February 22, 1928.
1956 03 16 19 32 **1956 03 16 19 43**	**ISS, PK:** Two earthquakes, Chouf in Southern Lebanon, 136 killed, 6,000, houses destroyed, 30 weak aftershocks until November.	**ISS:** 33.8 / 35.6	I_0 = IX S M_L=5.2,5.5	30 weak aftershocks until November
1969 03 31 07 16 **(Gulf of Suez)**	**BMA:** The event itself (M_B=6¾) was preceded and followed by a swarm of shocks. Two thousand of these were recorded at Elat with 2½ ≤ M_B ≤ 5½ during March – May 1969. The shock was felt up to 600 km from the source, the damage was reported as far as 300 km from there. **Sa1:** At least three $M_L \geq 4$ preshocks occurred during the week before the main shock, 19 events of $M_L \geq 4$ in the next 6 months and 4 more $M_L \geq 4$ until December 1970. **Ke**: The earthquake was preceded by 35 large foreshocks during the last half of March 1969. Maximum intensity of IX on MSK, in a small area of Shadwan islend, Suez Gulf.	**BMA**: 27.7 / 34.0	I_0 = IX M M_L=6.6	More than 2,000 aftershocks. Preceded two weeks before by 35 large preshocks, including 3 $M_L \geq 4$, followed by 19 $M_L \geq 4$ in half a year and four more in the next 15 months, lasted until December 1970.
1983 02 03 23 30	**Sa1:** A swarm in the Gulf of Elat, lasted from January to October. Largest event of M_L=5.3 occurred after two weeks. No damage. 28 events with $M_L \geq 4$. **Ho**: 94 events with M_L>3.	**ISC:** 29.2 / 34.8	I_0 = III-IV S M_L=5.3	Swarm, 8 months, largest event M_L=5.3 after two weeks, 28 events $M_L \geq 4$; 94 events M_L>3
1984 08 24 06 02	**HvES:** M_L=5.3 in Yizra'el Valley, slight damage. At least seven 1<M_L<2.8 aftershocks during the first week. **GII**: Five 2.1<M_L<2.8 aftershock within 10 days.	**HvES** 32.66 / 35.18	I_0 = VI S M_L=5.3	Five 2<M_L<3 aftershock within 10 days

1993 08 03 12 43	**Ho, GII:** The 1993 sequence (swarm?) in Gulf of Eilat, started on August 3 and lasted about 5 months. Largest event, M_L=5.8, was the third, 2.5 h after the first M_L=3.5, and 12 min after the second, M_L=4.8. Second largest event was M_L=5.6, 4.5 h after start. Overall, over 420 events of magnitude M_L>3.	**ISC:** 28.6 / 34.6	I_0 = V S M_L=5.8	Swarm? Sequence? Two largest are M_L 5.8 and 5.6, in the first hours. Strongest event preceded by a pre-shock. Overall 420 events of M_L>3.
1995 11 22 04 15	**Ho:** Nuweiba earthquake, Over 5,000 recorded aftershocks, largest aftershock Mw=5.6 on 1996 02 26, large portion of the moderate and strong aftershocks (M_L>4) occurred in the first 100 days after the main shock,. The seismic activity decayed relatively fast, in less than a year. M_L=6.2, Mw=7.2. **AT:** The maximum observed intensity was VIII on MMI scale around Nuweiba. At least 11 people killed and 47 injured. A few more sporadic M_L>4 aftershocks continued for two years after the main shock.	**Ho**: 28.76 / 34.66	I_0 = VIII L M_L=6.2 Mw=7.2	Mainshock followed by >5,000 aftershocks, largest aftershock on 1996 02 26, Mw=5.6, most M_L>4 occurred in first 100 days, a few M_L>4 continued for two years.
2004 02 11 08 15	**Sa2:** Moderate earthquake in the northern Dead Sea, many natural effects, slight damage. The main shock was followed by few tens of smaller events that lasted about half a year, the strongest of which occurred a couple of days later with M_L=3.7. **GII:** M_L=5.2.	**GII:** 31.7 / 35.55	I_0 = VI S M_L=5.2	Mainshock with few tens of aftershocks in half a year, the largest occurred two days later with M_L3.7.

Appendix 2 Patterns of earthquake sequences

Interpreted from the original historical sources. Blue color denotes earthquakes that affected Israel, not necessarily focused in Israel.

History		
Type of event		**Events** (origin time and short description)
Before the main earthquake: ***pre-shocks***		**749 (or 750, or 757 03 09):** There was a tremor at night… and everyone had gone out of the city to pray at the temple… there was a sudden tremor and the temple collapsed on top of them, and crushed them all … **1212 05 01:** Foreshock at sunset 30.4 and main-shock at dawn 1.5. **1404 02 20:** Before that, there had been an earthquake (1403 12 18), at midday **1705 11 24:** Three main different sized shocks happened on Tuesday night: The first caused general panic, the second was the strongest, causing the damage. **1822 08 13 20:40**: Slight shocks, began on August 5 and continued intermittently until August 12. At 8 h 10 m pm on August 13 a strong shock was felt in the region: this caused considerable concern and warned the people of what was to follow. The main shock happened 30 min later in three phases lasting altogether 40 s. **Modern seismicity:** **1969 03 31 07 16 (in Suez Rift):** Preceded two weeks before by 35 large preshocks including 3 $M_L \geq 4$. **1983 02 03 23 30:** A swarm, largest event M_L=5.3 two weeks after start. **1993 08 03 12 43:** Swarm or sequence? Two largest are ML 5.8 and 5.6, in the first hours. Strongest event preceded by a pre-shock.
The main earthquake: ***Main shock***	**Single events**	Many of the earthquakes are reported without any associated events (fore- or aftershocks), but it is reasonable to assume that they also occurred but were not reported: **B.C.: 760-750, Mid 2nd century, 148 02 21 (or 130), c. (69 –) 65, 31,** **AD: 37 03 23, c. 47, 115 12 13, c. 127-130, 303 or 304, 348 or 349, 450-457, 502 08 22, 551 07 09, c. 570, 580 or 581, 587 or 588, 601-602, 659 06, 659 09 – 660 08, 853 06 12 – 854 06 01, 972, 1002 11 10 – 1003 10 29, 1042 08 21 – 1043 08 09, 1068 05 29, 1097 12 30, 1105 12 24, 1117 06 26, 1140 08 17 – 1141 08 06, c. 1150, 1163 08, 1287 03 08, 1287 03 22, 1293 01 11 – 02 08, 1339 01 13 – 02 11, 1366 09 07 – 1367 08 27, 1404 11 05 – 12 04, 1407 04 09 – 05 08, 1408 12 29, 1458 11 08 or 16, 1537 03 09, 1557 02, 1563 09 13, 1565 07 27, 1588 01 04, 1626 01 21, 1627 11 24, 1738 09 25.**
	Length and number of shocks of the main event	**528 11 29**: The earthquake … lasted for one hour **847 11 24** (one of the events): dreadful earthquake, lasted for three hours **1068 03 18**: An earthquake… lasted for two and a half hours **1344 01 03:** Two shocks in close sequence. **1404 11 05 – 12 04:** When the first shock ceased, another followed **1588 01 04**: A strong shock of an earthquake was felt in Cairo, where it was of long duration **1796 04 26**: Lasted with intermissions for about one minute.

		1822 08 13: The main shock happened 30 min later in three phases lasting altogether 40 s. After a short pause, the main shock was followed for about 8 min by successive shocks, about 30 in all, each of short duration but of damaging intensity; **1837 01 01**: The main shock lasted between 10 and 30 s; the earthquake consisted of two distinct shocks ~5 min apart. **1872 04 03**: Between the first shock and the latter part of destructive shaking many people managed to run out of their houses into the open.
	Strength of the shaking	**31 B.C**: Such as has not occurred before **115 12 13:** Unusually powerful, tremendous quaking **341**: most violent earthquake **363 05 18-19:** A mighty earthquake tore up the stones of the old foundation of the temple **458 09 13-14 :** Everything had been tossed and terribly shaken **526 05 20 or 29**: Foundations of buildings were struck by thunderbolts thrown up, lifted and collapsed (liquefaction?) **528 11 29**: The earthquake that now occurred lasted for one hour **551 07 09:** Mountains were uprooted and violently split open **1033 12 05**: ראינו ההרים רועשים כאילים רוקדים אבניהם מתפוצצות והגבעות מתנודדות והאילנות מתכופפים עד מימי הבורות במקומות עלו עד פיותיהם "We have seen the mountains shake, leap like stages, their stones broken into pieces, the hillocks swaying to and fro, and the trees bending down". In some places the waters in the cisterns reached the brim…" **1097 12 30**: When the earthquake near Antioch began… I was so struck with terror… the earth continued to shake and the terror within me continue to increase. **1796 04 26**: In Latakia, so violent that almost everything collapsed with the first shock.
Seismic activity after the main earthquake: ***Aftershocks***	**Several Hours**	**363**: Event took place at the third hour, and partly at the ninth hour of the night **1068 03 18 08 30**: The earthquake was followed by two more shocks within the same period (two and a half hours?)
	Several Days	**1033 12 05:** For eight days the mind has not been satisfied and the soul is not at rest (שמונה ימים אין נחת רוח ואין נפש שוקטת**).** , On that night (the earth) shook again – 5-6/12/1033; On Friday – 6/12/1033, as well as on the following night – 6-7/12/1033, the shocks recurred. **1202 05 20:** The major earthquake was followed by brief shocks towards noon on the same day which were slightly felt in Cairo… earthquake at Hamat on 21 May was followed by another shock in the afternoon. Altogether, the shocks lasted for four days. **1834 05 26**: Strong, many aftershocks during 10 days. **Modern seismicity:** **1984 08 24 06 02**: 10 days, aftershocks were not felt.
	A month	**634 09:** An earthquake with a series of tremors lasted for a month

		991 04 05: The shocks went on repeatedly till …(5 May) in the same year **1344 01 03:** Two shocks in close sequence. In relation to the worst affected area, it is recorded that the places concerned were abandoned by their inhabitants for more than a month. **1705 11 24:** Light shocks continued to be felt till Ramadan (one month). **1759 10 30**: Series of strong aftershocks (time not specified), some of which were felt as far as Aleppo, that added to the damage. Note that after a month this event was followed by the 1759 11 25 strong earthquake
	40 days	**713 02 28 or 03 10**: Earthquakes began throughout the world and lasted for forty days **746 01 18:** A strong earthquake in Syria … the inhabitants forced to take refuge in the desert, where they stayed for forty days…" **835 01 05 – 12 25:** The earth shook for forty days. Possibly a duplication of 713?
	Several months to a year	**341**: Danger for three days, shocks for a whole year **526 05 20 or 29:** Lasted for six days (possibly the fire)… the earth shook for a year… The earthquake continued every day and night for a year and a half without ceasing **1138 10 11 until 1139 06:** Destructive seismic sequence until June, 1139. The main event was followed by three large events in the first day. A total of 80 shocks were felt during the whole seismic sequence. **1170 06 29 0345:** The earthquake lasted for three or four months, or perhaps longer. There were times when three or four or even more shocks were felt by day or night. **1212 05 01:** Aftershocks for a year **1404 02 20:** The most violent earthquake at Allepo was followed by a sequence of less powerful shocks which lasted until early July 1404 (Single + Earthquakes followed throughout the year, especially in the west; followed by a second series of lesser shocks; during the last ten days of Sha'ban [13 February – 12 March]). **1546 01 14:** Then, on 13 March 1546 there was another alarm, the noise of which was greater before it died out. Then, on 13 May, another shock occurred felt by some people more than others, apart from the continuous shocks of previous days, some of which occurred at night and some during the day. **1759 11 25**: Aftershock sequence until 8/1760. Damaging shocks on 26/11, 5/12, 12/12, 30/12. **1796 04 26**: Aftershocks continued to be felt for two months. **1837 01 01**: Aftershocks continued to be felt for almost four months. Important are: 16 January widely felt and caused considerable damage in the south, 22 and 25 January reported from the north and caused panic in Damascus. 20 May was reported from the north and caused considerable damage at Hashbeya. **1872 04 03**: Aftershocks continued to be felt with decreasing severity throughout April and May, but did not cease altogether until 1873 February. **Modern seismicity:** **1927 07 11 13 04**: Twelve $3.5 < M < 5$ after-shocks until February 1928, and two such more until September 1930. Most powerful were on July 17, and February 22, 1928. **1969 03 31 07 16 (in Suez Rift):** Mainshock with more than 2,000 events. Preceded two weeks before by 35 large preshocks including 3 $M_L \geq 4$, followed by 19 $M_L \geq 4$ in half a year and four more in the next 15 months

		until December 1970. **1983 02 03 23 30:** Swarm, 8 months, largest event M_L=5.3 after two weeks, 28 events $M_L \geq 4$; 94 events M_L>3**.** **1993 08 03 12 43:** Swarm or sequence? Two largest are ML 5.8 and 5.6, in the first hours. Strongest event preceded by a pre-shock. Overall, 420 events of ML>3. **1995 11 22 04 15:** Mainshock followed by >5,000 aftershocks, largest aftershock after three months on 1996 02 26, Mw=5.6, most Ml>4 occurred in first 100 days, a few Ml>4 continued for two years. **2004 02 11 08 15**: Mainshock with a few tens of aftershocks in half a year, the largest, M_L3.7, occurred two days later.
	Several Years	**1822 08 13**: It was followed by an aftershock sequence that lasted almost 2.5 years.
	Unknown period of time	**458 09 13-14 :** When the earthquake ceased, everyone who fled regained his confidence **528 11 29:** Then He appeared to a pious man, who told the survivors to write at the top of their doors 'Christ is with us. Stop'. When this was done, the wrath of God abated. **1091 09 26:** There was an earthquake and 86 towers in the walls of Antioch collapsed… there were numerous earthquakes in the Syrian territory. **1259 03 22**: there were numerous shocks in Syria at the time when the Tartars arrived.
Earthquake storms		**1156 05 19 – 1159 06 06:** Several main events followed by tens of aftershocks**.** Strongest event on 15/7/1157.
Several unspecified noticeable earthquakes: ***Storms, Swarms, Clusters, Composite Events, etc.***		**199-198 BC**: "but the number of victims was limited, because it did not happen in a single shock" **419**: Great earthquakes in the East **757 03 09**: Four events, or a single one followed by three significant aftershocks **847 11 24**: A dreadful earthquake at Damascus... The earthquake reached Antioch… Then it reached Mawsil… **859 12 30 – 860 01 29**: Earthquakes which… **881 05 16**: There was a strong earthquake in Syria, Egypt, some parts of Mesopotamia, North Africa and Andalusia. **1063 07 30 – 08 27:** There were earthquakes **1086 04 18 – 1087 04 07**: There were earthquakes … **1094 05 19 – 06 18**: In that month there was a series of many earthquakes in the Syrian territories lasting for a long time. **1151 09 28:** Earth shook three times **1152 02 01:** Earth shook three times **1259 03 22:** Main shock and numerous shocks **1287 02 2nd half:** A series of earthquakes **1484 03 29 – 04 28:** A sequence of six or more shocks **1795 12**: Two shocks

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Reference Abbreviations

AAKY: Akyuz et al., 2006.
AAT: Amiran, Arieh and Turcotte, 1994.
AB: Ambraseys and Barazangi, 1989.
ABSN: Avni et al., 2002.
AF1: Ambraseys and Finkel, 1993.
AF2: Ambraseys and Finkel, 1995.
AFF: Austin, Franz and Frost, 2000.
AJ: Ambraseys and Jackson, 1998.
AK: Ambraseys and Karcz, 1992.
AM1: Ambraseys and Melville, 1988.
AM2: Ambraseys and Melville, 1995.
AMA: Ambraseys, Melville and Adams, 1994.
Am3: Ambraseys, 1962b.
Am4: Ambraseys, 1989.
Am5: Ambraseys, 1997.
Am6: Ambraseys, 2004.
Am7: Ambraseys, 2005a.
Am8: Ambraseys, 2005b.
Am9: Ambraseys, 2006.
An4: Antonopoulos, 1980c.
AT: Al-Tarazi, 2000.
Av: Avni, 1999.
AW: Ambraseys and White, 1997.
AZP: Amit et al., 1999
BM: Ben-Menahem, 1991.
BMA: Ben-Menahem and Aboodi, 1971.
De: Dever, 1992.
DEK: Daëron et al., 2004.
DKT1: Daëron et al., 2005.
DKT2: Daëron et al., 2007.
DSM: Darawcheh et al., 2000.
EM: El Mrabat, 2005.
EMA: Ellenblum et al., 1998.
ETSK: Elias et al., 2007.
FW: Freedman and Welch, 1994.
GBC: Guidoboni, Bernardini and Comastri, 2004a.
GBCB: Guidoboni et al., 2004b.
GC: Guidoboni and Comastri, 2005.
GCT: Guidoboni, Comastri and Traina, 1994.
GMDH: Gomez et al., 2003.
GMDS: Gomez et al., 2001.
Ho: Hofstetter, 2003.
ISC: International Seismological Center, 2007.
Ka1: Karcz, 1987
Ka2: Karcz, 2004.
KAD: Klinger et al., 2000.
Ke: Kebeasy, 1990.
MAE: Marco et al., 1997**.**
MGS: Meghraoui et al., 2003.
MHH: Marco et al., 2003**.**
MRH: Marco et al., 2005**.**
PK: Plassard and Kogoj, 1968.
RH: Reches and Hoexter, 1981.
Sal: Salamon, 1993.
Sa2: Salamon, 2005.
SAN: Shapira, Avni and Nur, 1993.
Shal: Shalem, 1956.
SDM: Sbeinati, Darawcheh and Mouty, 2004.
Ya: Yadin, 1975.
ZAB: Zilberman et al., 2004.
ZAP: Zilberman et al., 2005.

תקציר

רבים מהתיאורים ההיסטוריים של רעידות אדמה במזרח התיכון מדווחים על סדרת אירועים חריגה שלוותה את האירוע המרכזי וההרסני. הסדרות הללו דומות למקבצים של רעידות מקדימות ומאוחרות לאירוע העיקרי כפי שמוכר לנו בעת החדשה. בעבודה הנוכחית סווגו הסדרות הללו לקבוצות אופייניות ונערך דיון במשמעותן. בשלב הראשון נבנתה רשימה של רעידות האדמה המשמעותיות שאירעו באזור המערכת הטקטונית של טרנספורם ים המלח, וזוהו כמאה רעידות שגרמו לנזק באלפיים השנים האחרונות, חלקן אף הרסניות. כשליש מהרעידות הללו פגעו באזור שכיום נמצא בשטח מדינת ישראל. ארבעים ושמונה מהאירועים דווחו כבודדים והשאר לוו ברעשים נוספים. סגנון הופעה של אירועים חזקים יחידים אינו מוכר כיום בעולם (להוציא רעידות עמוקות) וניתן להניח שבמקרים אלה הדיווח ההיסטורי חסר.

מבין סדרות האירועים ניתן להבחין במופעים הבאים: א. אירוע עיקרי (mainshock): בדרך כלל דווח על אירוע אחד בולט שגרם את מרבית הנזק; ב. רעידות מקדימות (foreshocks): בחמישה דיווחים צוינה רעידה חזקה שהקדימה את האירוע העיקרי בדקות ספורות, שעות ולעיתים אף בכמה שבועות. בחלק מהמקרים התושבים הגיבו בזמן, נמלטו מהבתים וניצלו; ג. רעידות מאוחרות (aftershocks): נמצאו דיווחים על שלושים ושמונה אירועים אשר לוו ברעידות עוקבות אשר נמשכו כמה שעות, ימים, חודשים ולעיתים אף שנה ויותר. כמה מהרעידות הללו הוסיפו על הנזק שנגרם באירוע העיקרי; ד. בחמישה עשר מקרים דווח על מקבץ של רעידות (cluster), אולם המידע אינו מספיק להגדרה מפורטת יותר; ה. נחיל (swarm): סגנון זה מוכר בימנו, אולם המידע ההיסטורי אינו מפורט דיו כדי לזהות מופע דומה לזה בעבר.

מעניין לציין שהתיאורים ההיסטוריים מתייחסים גם לגבי משך הזעזוע העיקרי ועוצמתו. לגבי כמה אירועים, בפרט מהמאות האחרונות, דווח שנמשכו כמה עשרות שניות, בהתאמה לצפוי ברעידות אדמה חזקות. מאידך, צוין בכמה אירועים מוקדמים יותר שהם נמשכו כמה שעות וזהו משך זמן ארוך מאד שאינו מוכר כיום, אלא אם כן מניחים שהדיווח ההיסטורי כולל גם את רעידות המשנה החזקות שהופיעו מיד לאחר האירוע העיקרי. הרבה אירועים היו בעוצמה שלא הייתה מוכרת באותו דור והפתיעו את התושבים, כך למשל באירוע בשנת 1796 בלטקיה שם הרוב נהרס כבר בזעזוע הראשון. לעיתים נדירות, כמו למשל באירוע משנת 1822, התנודות ההרסניות הופיעו רק בשלב מאוחר יותר של הרעידה והתושבים נמלטו מבעוד מועד.

מניסיון העבר אפשר להניח שרעידת אדמה חזקה בסביבת המערכת הטקטונית של העתק ים המלח תתרחש ככל הנראה ללא רעידות מקדימות, תלווה בסדרה של מאות ואף אלפי רעידות עוקבות במשך כשנה, ועשרות רבות מהן תורגשנה. מרבית רעידות המשנה החזקות יופיעו בשעות הראשונות שלאחר האירוע וימשיכו אף מספר חודשים לאחר מכן בקצב ובעוצמה פוחתים והולכים. לא נמצא זמן אופייני להופעת רעידת המשנה החזקה ביותר וזו ככל הנראה תופיע בחודשים הראשונים שלאחר האירוע, אם כי היא עלולה להתעכב עוד יותר. רעידות מקדימות, אם ייקרו, יופיעו דקות עד שעות בודדות לפני האירוע העיקרי. אפשר גם שתופיע סדרה של רעידות מקדימות בעוצמה הולכת וגוברת, אשר תלך ותתפתח בימים או בשבועות שלפני האירוע העיקרי.

משרד התשתיות הלאומיות
המכון הגיאולוגי

דפוסים של רעשי משנה לאורך טרנספורם ים המלח - ניתוח אירועים היסטוריים

עמוס סלמון

מוגש לועדת ההיגוי להיערכות לרעידות אדמה

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