ÄGYPTEN UND ALTES TESTAMENT 90

Tell it in Gath

Studies in the History and Archaeology of Israel

Essays in Honor of Aren M. Maeir on the Occasion of his Sixtieth Birthday

Edited by Itzhaq Shai, Jeffrey R. Chadwick, Louise Hitchcock, Amit Dagan, Chris McKinny, and Joe Uziel

Zaphon

ÄGYPTEN UND ALTES TESTAMENT

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Band 90

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EARTHQUAKES EAST AND WEST OF THE DEAD SEA TRANSFORM IN THE BRONZE AND IRON AGES

Kate Raphael and Amotz Agnon

INTRODUCTION

Among ancient Near Eastern societies, large-scale natural disasters were incorporated in oral mythologies, some of which were written down. It is surprising, therefore, that no earthquakes are cited in sources and correspondences found in the region's palatial archives. Sources for the Jordan plateau are almost entirely Pharaonic, prior to c. 1000 BCE, with limited contributions from the Biblical tradition (Kitchen 1992: 21); none mention earthquakes. A rare exception is the ~760 BCE earthquake described in Amos 1:1, Zechariah 14:3-5 and Ezekiel 38:19-22. The long list of cities struck by this earthquake and the well-dated destruction levels at archaeological sites has drawn considerable attention from archaeologists and geologists (Yadin 1961; Soggin 1970; Ben-Menahem 1979; Dever 1992; Austin et al. 2000; Guidoboni et al. 2005; Ambraseys 2009). However, the sole citation for this earthquake remains the exception.

The main difficulties in studying earthquakes that left no written record derive from the need to tie the events to secure dates. Because some sections in the chronology of the Bronze Age are still debated, and radiocarbon dates are not always available, fixing precise dates is not always possible.

These problems often deter researchers from undertaking studies on the subject. Nevertheless, progress has been made by Nur and Cline on Late Bronze Age seismic activity in the Aegean and the Eastern Mediterranean (2007). Ferry (2007) reviewed Bronze and early Iron Age earthquakes in Jordan in the context of a paleoseismological study. Thomsen and Zwickel (2011: 76-78) found evidence of an earthquake in Tell Kinrot (Table 1) and charted early Iron Age earthquakes in Israel. These may be related to ruptures of the Jordan Gorge segment documented by Marco et al. (2005) in paleoseismic trenches in fluvial beds north of the lake. Wechsler et al. (2014) have subsequently shown, by trenching in 1st millennium CE beds, that this segment can be active independently of the central Jordan Valley.

None of the Bronze and Iron Ages researchers examined or compared both sides of the Dead Sea Transform (DST herein). It is notable that earthquakes centered on the DST rarely leave their mark on only one side. In order to fully understand the force and extent of the damage of each earthquake, both sides of the fault must be surveyed. Evidence of earthquake damage east of the DST, or lack of it, strengthens or refutes the evidence collected west of the DST. Alternatively, lack of evidence can point to activity on a branch of the fault, as may be the case for the 363 CE earthquake (Kagan et al. 2011; Agnon 2014).

The archaeological evidence for earthquakes relies on the excavators' interpretation of destruction levels. In most cases, once the excavations end, it is difficult to return and reexamine the area. Many sites are partially destroyed by rain and animal burrowing. In some, debris is cleared, and conservation work conceals earthquake damage. Yet it is useful to revisit excavation reports in order to attempt to discover evidence of earthquake destruction (Alfonsi et al. 2012; Braun 2013).

The aim of this paper is to compile a preliminary database with maps of Bronze and Iron Age sites on both sides of the DST, where there is evidence of earthquake damage. This will be followed by examining the correlation between earthquake evidence from geological studies and evidence found at archaeological sites. Finally, the destructive capacity of contemporary armies to earthquake damage will be compared. Archaeologists have tended to attribute destruction levels east of the DST to earthquakes, while levels of destruction on the west are often attributed to military campaigns. In order to assess whether this variation reflects asymmetric destruction of earthquakes along the fault, the damage on both sides of the DST is compared using the only instrumentally recorded destructive earthquake of the 20th century CE.[1]

THE GEOLOGICAL AND GEOGRAPHICAL SETTING

The Dead Sea Transform (DST) forms a 1100 km long and narrow depression, running north-south along the plate boundary separating the Arabian sub-plate from the African Plate (Fig. 1a). The transform fault, together with the Red Sea and the East African Rift, comprise what has been referred to as "the Syrian-African Rift System," the largely continental rifting system that runs from Southern Africa to Southern Turkey. The various segments of the transform are capable of producing large destructive earthquakes. Each segment alternates in its seismic activity (Ben Menahem 1991: 20209; Klinger 2000; Agnon 2014). This study focuses on the Jordan Valley segment between the Sea of Galilee and the northern edge of the Dead Sea (Fig. 2). The entire segment is a left-lateral transform fault; measuring some 100 km (Reches and Hoexter 1981; Garfunkel 2006). A dense web of faults associated with the DST runs on the western block (Garfunkel 1981; Hofstetter et al. 1996; Horowitz 2001: 4-5, 67; Belitzky 2002; Gilat 2005). Of these, the most dominant is the Carmel Fault that branches off the DST (Fig. 1). On the east, parallel faults run close to the rift near Tell es-Sa'idiyeh and the Ghor Kabed south of Damya bridge (Macumber 1992a: 212).

While written sources are scarce and erratic, signs of local and regional earthquakes are recorded in three sedimentary sections exposed in outcrops along the Dead Sea: Ein Feshkha, Ze'elim Creek; and Ein Gedi (Fig. 1). In addition, a core drilled at Ein Gedi spans the entire Holocene period (11,000 years BCE). The core and outcrops reveal fine laminae of different thicknesses and patterns. Patterns formed in the well-bedded and laminated intervals are the key for reconstruction of earthquake chronology. Earthquake activities leave a clear mark, interrupting the neat sedimentary layering. Deformed structures, such as liquefied sands, folded laminae and small faults are detected (Fig. 3). Radiocarbon dates are retrieved from organic debris trapped in the sediment and counting laminae approaches annual precision for quiescent intervals. The laminae analysis shows 11 earthquakes that date to the Bronze and Iron Ages (Kagan et al. 2011: 1-4, Fig. 2; Migowski et al. 2006: 421-431).[2]

[1] The funding for this research was provided by The Helmholtz Association via the Virtual Institute "Dead Sea Research Venue – DESERVE". Prof. Bourke (Near Eastern Archaeology Foundation, University of Sidney, Australia) added valuable information on Pella. We would like to extend thanks to Erez Hassul, Benjamin Thormann, and the Neev Center for Geoinfomatics (Institute of Earth Sciences, The Hebrew University of Jerusalem, Israel) for help in drawing the maps. Eliot Braun helped to improve the writing of the manuscript.

[2] Epicenter - the point on the earth's surface directly above the focus of an earthquake (Bolt 1978).

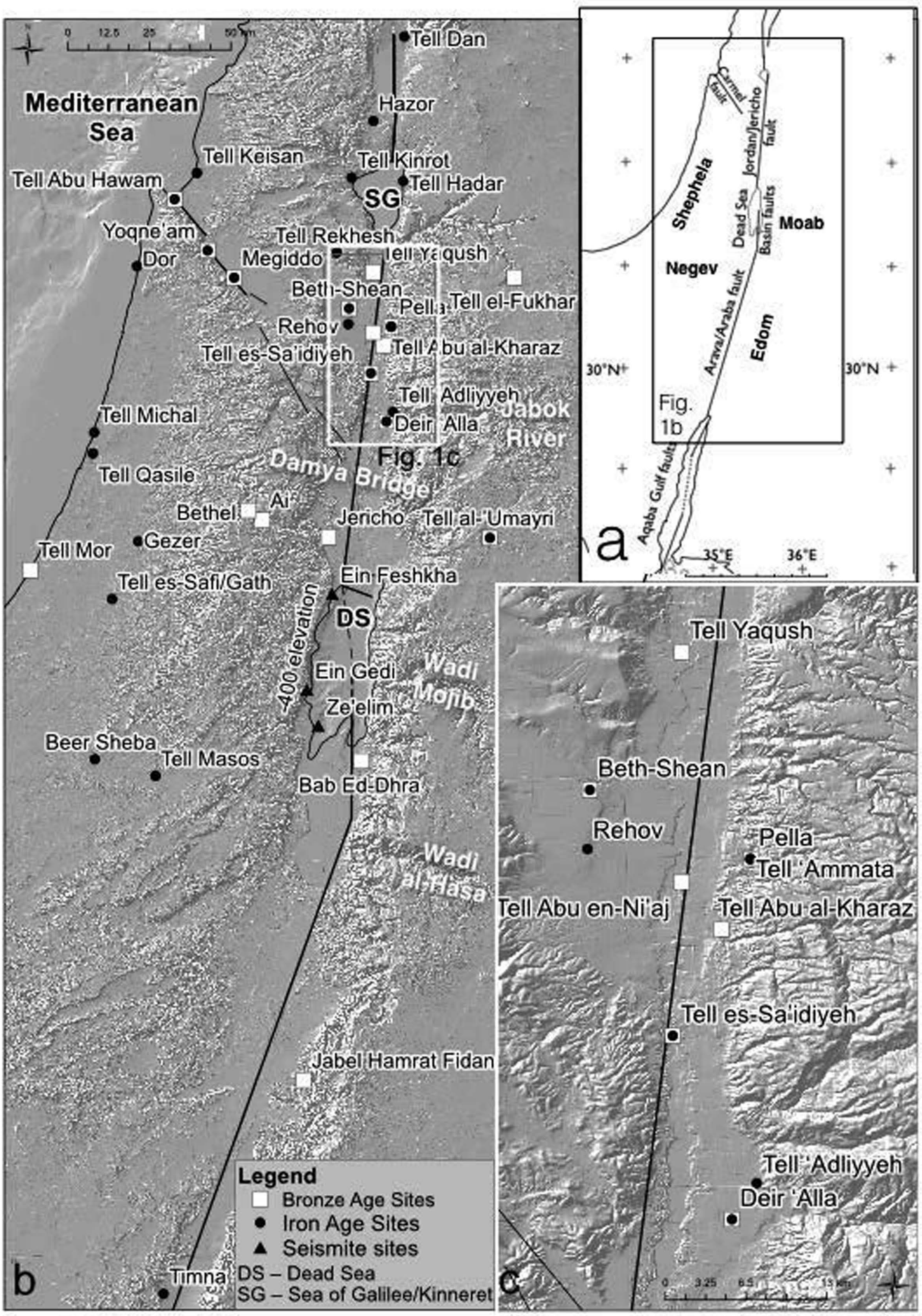

Fig. 1 Location maps. (a) The Dead Sea Transform. The frame shows the location of b. DB - Damya Bridge (b) Archaeological sites mentioned in the text, and locations of seismites in Dead Sea outcrops and core. Active fault segments are shown. (c) Detail of b as marked by a frame. Shaded relief from Hall 1996.

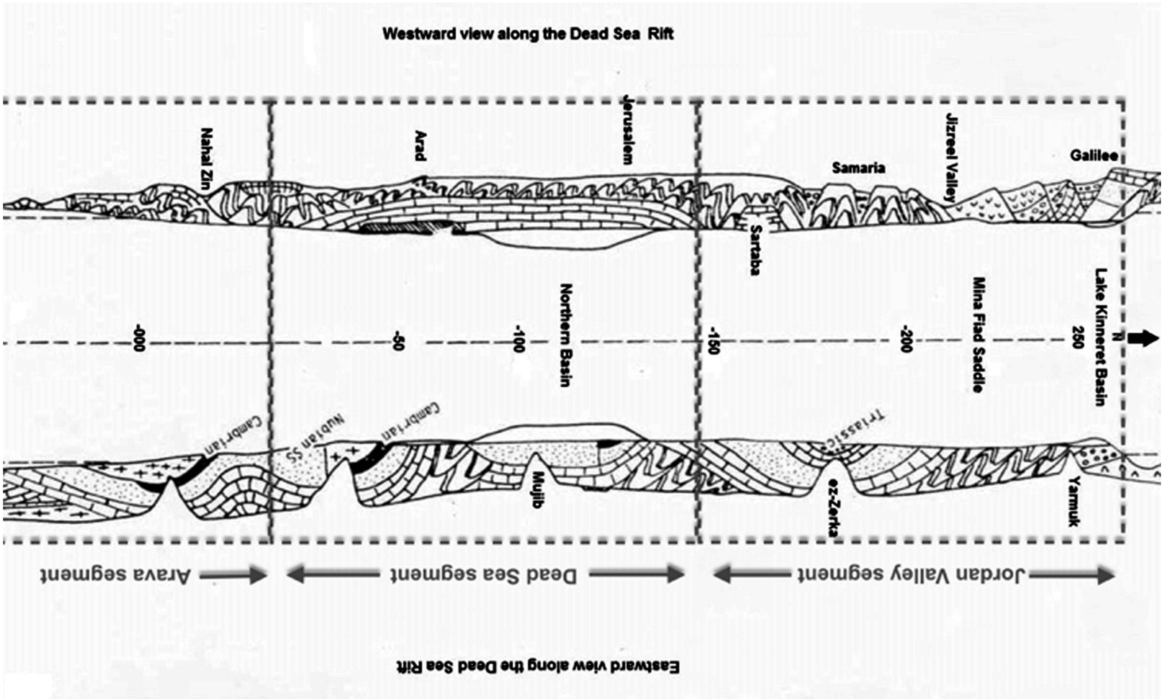

Fig. 2 Dead Sea Rift from the east bottom and the west top (After Freund and Garfunkel 1976)

PALEOSEISMIC EVIDENCE

Before discussing human-induced destruction, datable physical evidence for natural disruptions of the environment, interpreted by geologists as recording ground shaking is reviewed. Three types of phenomena have been used in recent decades to decipher the history of DST earthquakes:

1) Lake seismites: layers deposited at lake bottom, standing out as disruptions of the fine orderly bedding (Fig. 3). These include breccias (Marco et al. 1996; Agnon et al. 2006), soft sediment folding (Marco and Alsop 2011), and homogenites (Kagan et al. 2011).
2) Speleoseismites: cave deposits (chiefly stalagmites and stalactites) fractured and displaced during shaking (Kagan et al. 2005; Braun et al. 2011).
3) Rockfalls: massive boulders downhill from a seemingly stable bedrock position, showing synchronous displacement among different sites (Matmon et al. 2005; Rinat et al. 2014).

These types of evidence have been correlated to archaeological destruction layers by Migowski et al. (2004), Braun et al. (2011), and Agnon (2014). Agnon et al. (2006) have defined the resolution limit of lake seismites as the shortest recurrence interval detectable by this method. This interval is given by the ratio between thickness of a seismite bed and the sedimentation rate, and it varies between a century or two for typical Lisan seismites. For the late Holocene sequences, with high sedimentation rate and thin seismite beds, the resolution limit is typically only a fraction of a century.

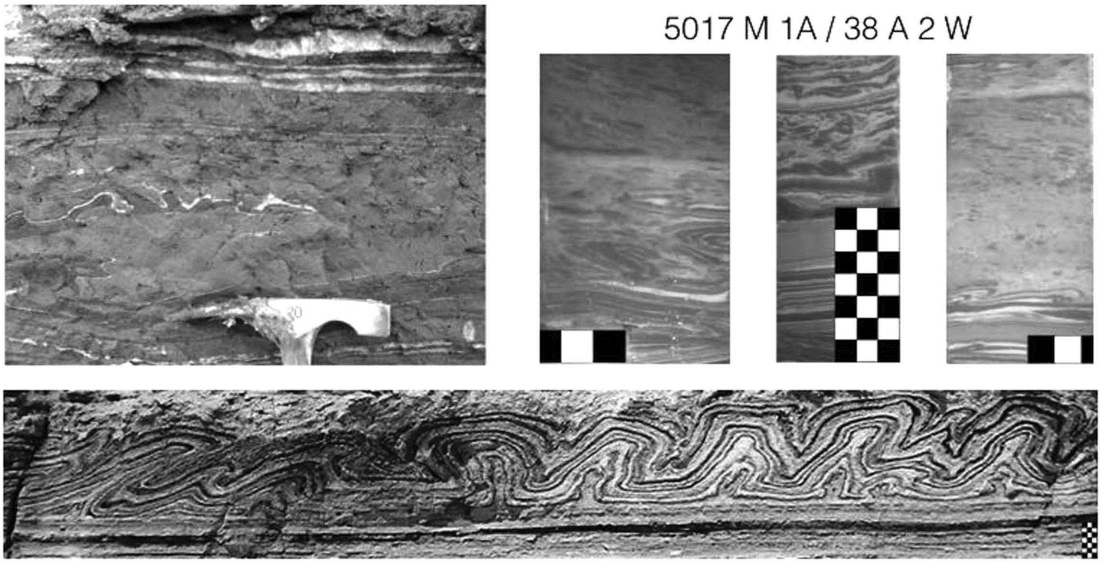

Fig. 3 Disturbed Dead Sea sediments indicating seismic activity. Scale - 1cm.

ARCHAEOLOGICAL EVIDENCE

Table 1 compiles archaeological destruction layers from the Bronze and Iron Ages. Up to 22 destruction layers at various sites were documented in sites east of the rift valley, while west of it 26 layers for the same duration. Table 2 summarizes the count and highlights the non-uniform rate of recurrence along this duration.

Table 1 Earthquake damage around the DST during Bronze and Iron Ages.

Period	Site and Description of Damage
EB II (3000-2700 BCE)	**Pella:** earthquake destruction of domestic architecture, public buildings and defense wall (the latter remained in use since the EB I), c. 2800 BCE (Bourke 2000: 235; Bourke 2009).
	Tell es-Sa'idiyeh: faults and slips, as great as 0.5 m. Floors turned into ledges and steps (Area B). Lines of slippage and faulting detected in Area DD in the mudbrick houses. Collapse of houses in the lower tell and signs of a strong fire (Tubb et al. 1997: 58, 62).
	Tell Abu Kharaz: a large settlement (Phase II), approximately four hectares. Thick level of debris, very likely from an earthquake, sealed the entire settlement, preserving the architecture, dating to 2900 BCE (Fischer 2000: 201, 224; 2006: 67-68).
	Tell el-Fukhar: c. 25 km north of Irbid, at the entrance to Wadi Shallala. The settlement was built on fill retained by terrace walls. The latter were damaged, presumably by earthquakes (Savage et al. 2003: 462).
	Tell Yaqush: located between Wadi Tabor and the Jordan River. A house, sealed by collapsed mudbrick walls. Four courses of stone foundations remained intact. Bricks remained coursed indicating a sudden and complete collapse. Destruction layer 0.75 m thick. ^{14}C date of 2745 BCE (Esse 1989/1990: 113; 1993: 1502-4).

	Ai: “total destruction of everything standing seems to have been caused by an earthquake.” At the Acropolis (Area D, Phase V), a rift in the bedrock of the temple room extends through the north wall and stones tilt into the break. The curved wall in the west side of the temple shifted and when it was later rebuilt, the angle of the tilt was preserved (Callaway 1972: 191). Roof and walls collapsed (Building B, Area A). Debris 0.5-1 m thick covered houses in Area C. Fierce signs of fire. The earthquake put an end to the Early Bronze city. ^{14}C dates the destruction to 2720 BCE (Callaway 1993: 41-42).
	Jericho: defense walls (wall 1; stage XXXIV trench 1) collapsed down the slope as a whole, leaving the core of the wall standing (Kenyon 1957: 175-176).
	Megiddo: earthquake shock probably led to the partial destruction and abandonment of Level J-4 temple (Stratum XVIII), dated to c. 3000 BCE (Marco et al. 2006: 572; Braun 2013: 51; Ussishkin 2015: 85-86).
EB III (2700-2200 BCE)	**Jabal Hamrat Fidan:** major earthquake knocked down roofs and brick walls (Savage et al. 2001: 443).
	Bab Ed-Dhra: mudbrick walls tilting at 45° probably caused by an earthquake (Field XIV). Defensive wall built in sections with transverse faces at 7-15 m intervals, a possible earthquake protection device (Schaub 1993: 134).
EB IV (2300-2000 BCE)	**Tell Abu en-Ni’aj:** village southwest of the modern town of Meshara, northern Jordan Valley. A 26 m long stratigraphic cross-section along the west revealed an earthquake slip fault (Savage et al. 2001: 438-39).
MB IIB (1750-1550 BCE)	**Bethel:** Temple destroyed in a fire or earthquake, mid-16th century BCE (Albright and Kelso 1968: 14, 23).
	Pella: ca. 1700 BCE or slightly earlier. The archaeologists have some reservations (S. Bourke, pers. comm.).
	Jericho: According to Kenyon (1992: 738), the burnt buildings at the bottom of the tell were destroyed due to upheavals after the Hiksos were expelled. In contrast, Ben Menahem (1991: 20205) interprets an earlier report by Kenyon, and attributes the damage to an earthquake, but does not give data or a clear convincing argument.
	Tell al-’Umayri: “An earthquake distorted many of the north south walls…including some of those in the palace” (Savage et al 2003: 463).
LB I (1550-1400 BCE)	**Beth-Shean:** temple badly damaged, walls cracked and slanted (Phase R2). Temple found empty and went out of use due to an earthquake (Mazar 1997: 151-152).
LB II (1400-1200 BCE)	**Bethel:** houses, destroyed in an earthquake (Albright and Kelso 1968: 28-31, pl. 14a, b).
	Tell Mor: the governor’s house (Building B, Strata VIII-VII), a mudbrick building, (22.5x22.5 m) with walls 2.6 m thick, probably carried a second story. A layer of 90 cm separated Stratum VII from Stratum VI. No evidence of burning, which led the excavators to suspect that an earthquake had caused the partial collapse of Building B in Stratum VII (Barako 2007: 20-25).
	Tell Abu Hawam: destruction of the Late Bronze-Early Iron Age (Stratum V) fortifications may have been due to an earthquake (Balensi et al. 1993: 12).
	Megiddo: cracks and fractures in the Level J-4 gate and temple (Marco 2006: 569).

	Yoqne'am: houses (Area A4, XIXa) found under 1 m of collapsed mudbrick and stone, intense burning (Ben-Ami 2005: 141-156).
	Pella: major change in the design of the temple, around 1350-1300 BCE, probably as a result of a severe earthquake. Western wall of the temple revealed stress-twisting and shattering (Bourke 2012).
	Deir 'Alla: massive earthquake destruction followed by fire in the temple and surrounding buildings (Phase E), at the end of the Late Bronze AGE. A wide crack through Room E1 was noted, where the floor sunk. Collapsed roofs, broken floors were also distinguished, along with debris over 1 m high. Straw and reeds mixed with clay formed the roof, which led to fires at high temperatures. Roof found directly on the floor. Cracks running east-west. Subsequent earthquakes followed during the end of the period (Franken 1992: 6-9).
	Tell al-'Umayri: a wall in the western defense leaned 10° off plumb (Field B, Phase 6), suggested it was an earthquake, but other reasons were also given (Clark 1989: 247, 256). In the Late Bronze Age-early Iron I (Field B, Stratum 13), "The inhabitants of 'Umayri built their settlement, but before they could live there very long an earthquake seriously jolted the settlement around…very few architectural remains from this stratum" (Herr and Clark 2009: 81).
Iron I (1200-1000 BCE)	**Tell 'Ammata:** end of Late Bronze-early Iron Age I. Burnt mudbrick debris, cracks and shifts in the floor, probably the result of an earthquake (Phase E). It is possible that the earthquake came at a later date (Petit 2009: 38).
	Pella: c. 1150, the entire site suffered destruction, possibly due to an earthquake though human activity remains an option (Bourke 2004: 9).
	Tell es-Sa'idiyeh: late 12th century BCE. Thick debris from city walls, public and private buildings and signs of fire (Stratum XII) were noted at the site. The excavators' impression was that people had time to escape (Tubb 1988: 41). Building in Area AA suffered severe faulting; five intersecting cracks, the largest responsible for a stratigraphic downshift of nearly 50 cm (Tubb and Dorrell 1993: 58-59).
	Deir 'Alla: buildings, pits and courtyards (phase C) were destroyed by an earthquake (Petit 2009: 26).
	Tell al-'Umayri: temple or palace (Field B, Stratum 14) was destroyed by an earthquake. Collapse of the upper floor filled ground rooms with mudbricks, second-story flooring and roofing debris. Walls of the ground floor stand 3 m high due to this debris (Herr and Clark 2009: 76, 78; Savage et al. 2003: 463).
	Tell Masos: damage in Storage House 2102 (Area C, Level II). In House 480 (Area C1), debris thickness of 1.50 m (Level III), dating to the end of the 13th-second half of the 12th century BCE. House 2004 (Area A, Level II) of the second half of 12th-end of the 11th century BCE had walls preserved to 1.30 m due to the debris of the upper floor that covered the entire house. No ash or weapons (apart from a dagger) were discovoered. "The house was probably destroyed in an earthquake" (Givon 1996: 9-10). House 167 had debris 0.80 m thick (Fritz and Kempinski 1983: 22-23). Houses were built very closely, with outer walls often touching those of the neighboring house. Site abandoned and resettled only in the mid-7th century BCE.
	Tell Abu Hawam: fortifications, temple and domestic structures, c. 1125-c.1050 BCE, Stratum IV A (Balensi 1980: 586-587; Warren and Hankey 1989: 160-161).
	Yoqne'am: Stratum XVII exhibited limited evidence (Ben-Tor 2005: 13).
	Tell Qasile: large buildings (Area A, Stratum XI), late 12th-early 11th century BCE, were destroyed by an earthquake (Dothan and Dunayevsky 1993: 1204). Earthquake destruction of domestic buildings (Stratum X), late 11th-early 10th century BCE is also noted, although military destruction is also possible (Mazar 1977: 342; 1980: 10; 1985: 123; 1993, 4: 1212).

	Tell Kinrot: warped and displaced walls, considerable evidence of fire found in domestic dwellings (Stratum V) of the 11th century BCE. Destruction was also revealed in Stratum VI (Thomsen and Zwickel 2011: 76).
	Tell Hadar: public buildings (Stratum II, later described as IV) filled with debris, signs of severe fire, c. 1000 BCE. In one building, stone pillars were preserved almost to their original height (2 m) due to the depth of the rubble (Kochavi 1993: 551-552; 2009: 1756-1757).
	Beth-Shean: debris in domestic architecture and two skeletons (Stratum S-4) support destruction by an earthquake c. 1140-1130 BCE (Mazar 2009: 17).
	Tell Dan: walls dating to 1050-950 BCE collapsed *en masse*, with an earthquake suspected (Area B, Phase B8, Stratum IVB). Few signs of fire were noted (Ilan 1999: 56).
Iron IIA (1000-900 BCE)	**Rehov:** thick mudbrick debris, intact fallen brick walls (Area C, Stratum VI) suggest an earthquake (Mazar 2008: 2015). Based on a preliminary paleomagnetic fold test, Ben-Yosef and Ron (2016: 4-7) suggested that the tilted wall (Area C, Stratum V) was the result of an earthquake.
	Tell Rekhesh: domestic building destroyed by fire (Area D6, Phase 2), stone tumbles and collapsed mudbrick walls (Paz et al 2010: 36; Cline 2011: 67).
	Deir 'Alla: Iron Age or later (no details). Landslides (Franken 1969: 31-32).
	Tel al-'Umayri: layer of debris (Phase 9), early Iron II 1000-900 BCE. Destruction and ash above Phase 10 (Herr 1999: 100-103, 106).
	Megiddo destruction of domestic and cultic buildings, late 10th century BCE (Stratum VIA, Levels K4, M4, F4, H4, L4). Signs of fierce fire with evidence of a hurried evacuation. Skeletons of people trapped covered by debris (Guy 1935: 203-204). Guy's date was later corrected to the 10th century BCE (Lamon and Shipton 1939: 7; Kempinski 1993: 89-90; Marco et al. 2006: 572, Cline 2011; Harrison 2003: 32, 60; 2004: figs. 30-32, 72-73, 82-83).
	Tell Keisan: destruction of domestic building c. 1000 BCE (Phase 9A), with severe fire and outer brick walls collapsed while courses remained attached to one another (Humbert 1993: 865-6; Cline 2011: 67).
	Tell Michal: remains of a cultic building dating to the second half of the 10th century BCE. Complete vessels and traces of burning suggest a sudden catastrophe, perhaps an earthquake (Strata XIV-XIII). No weapons were found (Moshkovitz 1989: 67-72; Herzog 1989: 73-75).
	Dor: in a domestic area, a skeleton of a young woman trapped under 1 m of debris suggested earthquake destruction, around 1000 BCE or just after (Stewart 1993: 31-36). Stern (1994: 104-110) attributed this destruction to human violence.
Iron IIB (900-700 BCE)	**Tell 'Adliyyeh:** a house (Phase 3) dating to the 9th century BCE was possibly destroyed by an earthquake (Petit 2009: 70). Phase 9 included collapsed walls and smashed pottery; occupation ended suddenly, leaving the inhabitants no time to clear their houses.
	Pella: entire settlement destroyed (Phase 5) c. 950-850/800 BCE, probably by an earthquake. Arrowheads and scale armor were found (Bourke 2012: 190-191).
	Tell es-Sa'idiyeh: houses (Stratum VI) from the mid-8th century BCE may have been destroyed by an earthquake, and were leveled in order to prepare the ground for new buildings (Ferry et al. 2011: 56; Tubb 1988: 26).
	Deir 'Alla: domestic area, walls the width of a brick (Phase IX) were damaged in 760 BCE earthquake. ^{14}C dates attributed to 800 BCE (van der Kooij 1993: 340-341). Second earthquake struck the walled village (Phase VII), at the end of the 8th century BCE. Site abandoned after this earthquake (Petit 2009: 28-29).

	Hazor: houses (Area A, stratum IV) with tilting walls and a street and drain that were split down the center are indicative of an earthquake (Yadin 1975: 150-151; Dever 1992: 28).
	Megiddo: northern stables (Level L-2, Stratum VA-IVB), 835-800 BCE or later (Marco et al. 2006: 572).
	Gezer: offset along defense wall in Field VI, Area 32, showing a crack that splits three courses (Dever 1992: 28-31).
	Tell es-Safi/ Gath: in Area F on top of the abandoned level, a 20 m long brick wall was revealed, collapsed in a uniform direction and manner. Before it collapsed it shifted about a meter north of the wall's foundation. It collapsed in a wavy haphazard manner that is often found in earthquakes. "This collapse can be closely dated… quite securely, to somewhere between the early 8th and the third quarter of the 8th century BCE (Maeir 2012: 245). At the time of this earthquake, the site had already been deserted (Maeir 2012: 247).
	Beer Sheba: enormous rebuilding projects, solid fortification razed to the ground (Level IV-III), replaced by a thinner wall. Outer gate destroyed and never rebuilt again. Destruction attributed to the mid-8th century BCE earthquake. If the city had been destroyed by an army, the fortifications in the following level would have been stronger, not weaker (Herzog and Singer-Avitz 2004: 230). In Level III, partial destruction of casemate defense wall and storage houses is noted, with damage repaired almost immediately (Aharoni 1973: 107-108).

Table 2 Earthquake damage east (+) and west (•) of the DST, Early Bronze II-Iron Age IIB (Gray shading indicates a period of relative quiescence).

Period/ Site	EB II (3000 -2700 BCE)	EB III (2700 -2200 BCE)	MB (1750 -1550 BCE)	LBI (1550 -1400 BCE)	LBII (1300 -1200 BCE)	IAI (1200 -1100 BCE)	IAIIA (1000 -900 BCE)	IAIIB (900 -700 BCE)
Keisan							•	
Abu Hawam					? •	•		
Dor							•	
T. Michal							•	
T. Qasila						•		
T. Mor					•			
Dan						•		
Hazor								•
Hadar						•		
Kinrot						•		
Rekhesh							•	
Yaqush	•							
Megiddo					•		•	•
Rehov							•	
Yoqne'am					? •			

Beth Shean				•				
Jericho	•							
Bethel			•		•			
Gezer								•
Beer Sheva								•
T. es-Safi								•
T. Masos						•		
Pella	+		?+		+	+		+
T. Sa‘idiyeh	+					+		+
Deir ‘Alla					+	+	+	+
T. ‘Umayri			+		+	+	+	
T. ‘Ammata						+		
T. Fukhar	+							
T. Abu el-Kharaz								
B. edh-Dhra’		+						
T. en-Ni’aj			+					
Hamrat Fidan		+						+
T. ‘Adliyyeh								+

EARTHQUAKE DAMAGE, MILITARY CAMPAIGNS AND PALEOSEISMIC RESULTS

The Early Bronze Age

Excavations at many Early Bronze sites have not yielded clear answers as to what led to their ruin or abandonment (Ben-Tor 1992: 97; Strange 2004: 427-432). However, archaeologists on both sides of the DST rarely attributed their destruction to military campaigns. Marco et al. (2006) documented seismogenic damage to a number of layers at Megiddo, where the earliest damage is recorded in the massive stone walls of the Great Temple (~3000 BCE). Adams (2013) challenged the earthquake source for this destruction. Subsequently Braun (2013) corroborated the seismogenic hypothesis by analysis of excavation reports of the Chicago expedition to Megiddo.

The cluster of Early Bronze II sites on the north-east side of the Jordan Valley exhibits higher local intensities of earthquakes (Fig. 4). At both Tell es-Sa’idiyeh and Pella, slippage lines and displaced stratigraphy favor severe earthquake activity as the explanation, rather than a more common ‘invader from the north’ scenario (Bourke 2000: 252). The Ein Gedi core provided one signal, dating to c. 2700 BCE, that matches the Early Bronze II cluster (Migowski et al. 2004: Table 2; Agnon 2014: Table 1). Braun et al. (2011) dated damaged cave deposits in Haifa and inspected implications for the broader scale. They noted a date correlation of damage in geological and archaeological materials in northern and central Israel. Rinat et al. (2014) extend the correlation suggested by Braun at al. (2011) for northern and central

Israel to dated rockfalls around Timna (southern Israel), about 300 km south of Pella (Fig. 1b). Yet the rockfalls were dated by cosmogenic isotopes to times similar to nearby Timna rockfalls dated by Matmon et al. (2005), with uncertainties larger than the recurrence intervals concerned in this study (Table 2). So, while a damaging event seems to have affected the entire plate boundary from Galilee to the southern Arava Valley during the late Holocene, the uncertainty in age is ±1kyr.

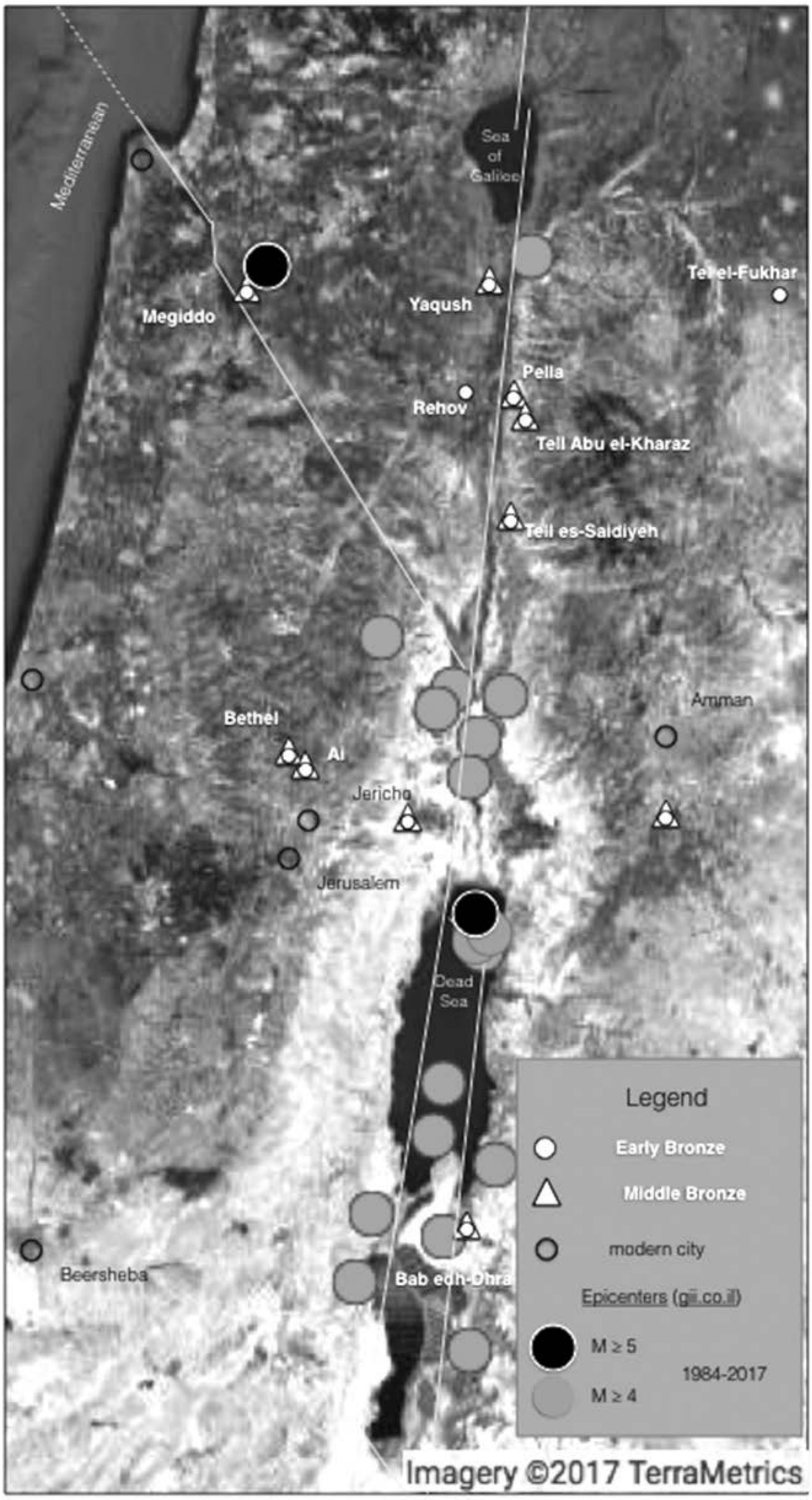

Fig. 4 Early Bronze and Middle Bronze Age Earthquakes.

The average recurrence interval of prehistoric (7th to 1st millennia BCE) Dead Sea seismites dated by Migowski et al. (2004) is 300 years, yet the two Early Bronze seismites 3600-3300 and (~2800 BCE) occur during a period of low recurrence rate (~600 yr). Therefore, the correlation between the damage at the end of the Early Bronze II in the Jordan Valley and a seismite from ~2700 BCE at the Ein Gedi core seems to reflect causative relations: perhaps the same earthquake that ruptured Tell es-Sa'idiyeh, and shook the entire Jordan Valley, also disrupted sedimentation at the bottom of the Dead Sea. Alternatively, a large earthquake on one segment triggered rupture on its neighbor. Such a large rupture is associated with a mid-8th century CE earthquake, for which Agnon (2014) inferred a triggering relationships with the rupture of the entire Arava Valley. This was corroborated by paleoseismic trenching (Klinger et al. 2015). The entire seismic sequence likely lasted a decade, between the years 747, 749 and 757 CE (Ambraseys 2009). Another sequence ruptured the plate boundary in the 11th century BCE (Ambraseys 2009). This lasted 35 years, between 1033 CE in the north, and 1068 CE in the Arava Valley. For the latter, a debated shock is also reported in Ramla in central Israel (Ambraseys 2009).

The correlation of shaking around the Jordan Valley and its Carmel branch at about 5ka pointed out by Braun et al. (2011) inspired them to consider coupling of the plate boundary and its Carmel branch. An historic event of a similar pattern has been suggested by Kagan et al. (2011) and Agnon (2014) for the 363 CE sequence. These authors inferred a rupture that skipped over the northern Arava Valley, as corroborated by a paleoseismic trench (Klinger et al. 2015). The event at the end of the Early Bronze II shows a magnitude larger than any historic event, as the former was the last to leave remarkable damage in both speleothem caves (in Haifa and near Jerusalem). Hence it is possible that this event involved a sequence of ruptures along the entire Jordan-Arava-Carmel system. While geochronological dating is unable to rule out a multitude of independent ruptures, such a "mega-event" would readily trigger rockfalls in the caves and around the Arava Valley, which have not been noted in later periods. Higher dating accuracy for rockfalls is required for testing the hypothesis that the three segments of the transform, namely the Jordan Valley, the Dead Sea, and the Arava, ruptured in a coupled manner

The Middle Bronze Age

A significant number of Middle Bronze sites have been excavated in Israel, some revealing substantial destruction (Broshi and Gofna 1986: 73-90; Kempinski 1992: map 6). Na'aman (1982: 174-175) and Kochavi (2009: 595) tied the destruction levels to the Egyptian conquest during the early years of the 18th dynasty. Although relatively few sites have been excavated in Transjordan, none of the destruction levels were attributed to the Egyptian campaign (Strange 2004: 427-432; van der Kooij 2006: 202-209).

For the Middle Bronze Age sites, Bethel, Jericho, Pella, and Tell al-'Umayri revealed earthquake damage (Table 1, Fig. 4); in some, the excavators had reservations. It is notable that out of Na'aman's long list of Middle Bronze Age sites, only four revealed earthquake damage in the latter part of the period. At Beth-Shean, "the events that brought about the end of the Middle Bronze town remain unclear" (Mazar and Mullins 2007:17). Beth-Zur and Shiloh were destroyed by violent fires, but the excavators could not determine the cause (Funk 1993: 152-157; Campbell 1993: 1351-1352; Finkelstein 1993: 1367). At Ashkelon and Aphek, destruction was attributed to the conquest of Ahmose I in c. 1550 BCE (Stager 1993: 107; Kochavi 2009: 595).

The seismite archive in the Dead Sea sediments provides an independent series of shaking events for comparison (Table 3). A seismite from the Ein Gedi core (Migowski et al. 2004: Tables 1 and 2) yielded an organic sample with a calibrated radiocarbon date of 1570-1365 BCE (IntCal 98, Stuiver et al. 1998). The authors have correlated that seismite to destruction layers of ~1560 purported by Ben-Menahem (1991). Considering the scarce archaeological evidence, it seems that much of the Middle Bronze Age was free of earthquake destruction.

Table 3 Dates of Ein-Gedi seismites (Migowski et al. 2004) and earthquake destruction layers at Pella with the differences between successive dates (durations of quiescence). For both time series, the durations of quiescence are highly variable. The right column gives the gaps between the paleoseismic and the archaeoseismic date.

Ein Gedi Core (BCE)	Preceding quiescence (centuries)	Pella (BCE)	Preceding quiescence (centuries)	Date gap between Pella and Ein-Gedi seismites (centuries)
~700	0.6	~800	3-3.5	0.4-1
-760	~3			
c. 1050	0.5	1150-1100	2.5-3	0.5
~1100	2.5			
~1350	2	~1350	3.5	0
~1550	2.5			
~1800	2	~1700	11	-1
~2000	0.5			
c. 2050	0.5			
c. 2100	0.5			
c. 2700	6	~2800		1

The Late Bronze Age

The transition into the Late Bronze saw the region fall under Egyptian rule. Within the international arena, the main threat to Egyptian rule in Canaan came from the kingdoms of Mitanni and Hatti. These power struggles provide the context for regional rebellions and Egyptian military campaigns (Gonen 1992: 211-216; Spalinger 2005: 235-237). Levels of destruction in excavations throughout Israel have been attributed to these conflicts.

Destruction at Yoqneʿam (Stratum XXa), Megiddo (Stratum IX) and the temple of Tell Kitan were ascribed to Thutmosis III in 1457 or 1483 BCE (Ben-Tor and Ben-Ami 2005: 242; Redford 2003: 206-209; Eisenberg 1976: 105-109). At Rehov, the cause of destruction (Phase D-8) could not be determined due to the poor state of preservation (Mazar 1993: 2014). Inland, destruction at Shechem/Nablus (Stratum XIII) was dated to 1350 BCE, but the cause could not be established (Campbell 1993: 1352). The Egyptian governor's residence at Aphek was discovered under 2 m of debris mixed with ash in which arrows were found, indicating it was destroyed in battle. The enemy's identity remains an enigma (Beck and Kochavi 1993: 68).

Fig. 5 Late Bronze Earthquakes.

In northeastern Jordan, stelae erected by Seti I and Ramesses II (Wimmer 2002; Brand 2000:123), suggest that only the main routes were safeguarded by Egyptians.[3] The region south of Wadi al-Hasa (Fig. 1b) was almost ignored by them. Although Pella rebelled against Egypt as early as 1800 BCE, and was defeated by Tuthmosis III, and possibly Amenhotep III, was also conquered by Seti I and probably conquered once again by Ramesses II, levels of destruction were not related to the Egyptian campaigns (Kitchen 1992: 25; Strange 2004: 428-429; Smith 1973: 23-31).

[3] The stela of Seti I was found near at-Turra in northern Jordan. The stela of Ramesses II was found in southern Syria.

Signs of earthquakes west of the DST were revealed at Bethel, Tell Mor, Megiddo, possibly at Yoqne'am, and Tell Abu-Hawam. The last three are located along the Carmel Fault. East of the DST, strong evidence of earthquake damage was found at Tell al-'Umayri, Deir 'Alla and Pella (Fig. 5) The Ein Gedi core gives a date of c. 1365 BCE, which corresponds with most of the archaeological evidence (Migowski et al. 2004).

The Iron Age

The migration of the Sea Peoples and the Israelites into the region during Iron Age I partially destabilized the region. Many settlements were destroyed and rebuilt within a relatively short period. New villages were established in the hills and mountainous regions of Israel and Transjordan (Warburton 2001: 233). The destruction is sometimes ascribed to newcomers. Others have suggested new methods of warfare, or environmental changes which led to severe droughts. In many sites the cause of destruction remains unknown (Mazar 1992; Drews 1993). Large-scale military campaigns are not recorded along the Jordan Valley during this period.

The number of Iron Age I sites with earthquake damage is the highest recorded in this study (Table 2). Almost all the sites east of the DST are very close to the fault (Fig. 1). Damage at Abu Hawam, Yoqneʿam and Beth-Shean show that the earthquake struck along the Carmel Fault, indicating it was a fairly strong event. Kagan et al. (2011) modeled radiocarbon ages assuming a uniform sedimentation rate and bracketed the event at 1136–846 BCE. They correlated this with the Ein Gedi core seismite of c.1050 BCE (Migowski et al. 2004). The latter was based on Ben-Menahem (1991), who cited destruction at the Timna copper mines, perhaps based on Rothenberg and Lapu (1966). Destruction levels dating to Iron Age IIA are much debated, due to the campaigns of Shishaq I (c. 925 BCE), and conflicts among local rulers and groups of foreign settlers. East of the Jordan Valley, there was only a brief expedition (Kitchen 1992: 29), described as "a feeble demonstration of force" (Strange 2004: 429). Otherwise, Transjordan was free from direct Egyptian interference.

It seems Shishaq did not aim to reestablish Egyptian rule in Canaan. He raided the coast, the Shephelah (piedmont), the hill country north of Jerusalem, the Negev, the northern plains, the central Jordan Valley, and the area of the Jabok River in Transjordan (Na'aman 1992: 80-81, 88; Finkelstein 2013: 41-42). Along the DST, the destruction of the double temple complex at Beth-Shean (Level V) was attributed to Shishaq/Sheshonq (Mazar 2006: 29, 34). The destruction of Tell el-Hammah is also ascribed to Shishaq or slightly earlier, perhaps to the Israelites. The site's name was not identified in Shishaq's topographic list (Cahill and Tarler 1993: 562; Cahill et al. 1989: 38). At Tell Keisan, damage was ascribed to local clashes (Humbert 1993: 866). At Rehov, Mazar (2008: 2018; 2015) suggested the conflagration was due to Shishaq's conquest, but thick debris and intact fallen walls also imply earthquake activity. Destruction at Megiddo was attributed to the armies of the Philistines (Albright 1936: 28; and Aharoni 1971: 57), Shishaq (Finkelstein 2002), the Israelites (Finkelstein 2013: 32-36) or King David's campaigns (Harrison 2003: 62; 2004: 108). The possibility of an earthquake was first suggested by Guy (1935: 203), and then by Lamon and Shipton (1939). Kempinski suggested that the earthquake, which destroyed many cities, helped the Israelites conquer the region (1993: 89-94). Geological studies at Megiddo found sufficient evidence to support earthquake destruction (Marco et al. 2006; Cline 2011). At many of these sites the severe conflagration led excavators to reject earthquake evidence, and choose warfare as the cause of destruction. The latter is the only case where the coast, usually perceived as an area of low seismic risk (Sneh 2000), is represented by three damaged sites (Tell Keisan, Dor and Tell Michal). This suggests the earthquake was fairly strong, as these sites are relatively far from the main fault. East of the DST, only two sites reveal earthquake damage (Fig. 1), neither of which appears to be very strong. The

Ze'elim outcrop provides clear signals of seismic activity during the 10th century BCE (Kagan et al. 2011: Table 2).

CONTEMPORARY ARMIES AND THEIR CAPABILITY OF MASS DESTRUCTION

Much of the information on the Pharaonic campaigns derives from geographical lists describing their victories. The cities of the northern Jordan Valley had come under Egyptian control by the time of Tuthmosis III. The Egyptian goal, in this particular region, was to collect tribute (Knapp 1992: 41-42; Redford 1990: 76-77). Later, Egyptian contingents were stationed at Beth-Shean, Pella and Yeno'am. When rebellions broke out, forces were sent to suppress the uprisings. It is during this period, from roughly 1479-1425 BCE to Shishaq I (r. 943-922 BCE) that earthquakes and military campaigns occur in close proximity. Northern Transjordan was at the periphery of direct Egyptian concern and southern Transjordan was outside of it altogether. Nevertheless, Tuthmosis III sent forces into Transjordan in his 29th year; Seti I (r. 1304-1318 BCE) and Ramesses II campaigned in Transjordan more than once. According to Hasel (1998: 124), Seti I only dealt with Pella (see also Routledge 2004: 62-63). Ramesses II campaigned in Beth-Shean, Moab (between Wadi Mojib and Wadi al-Hasa) and raided the Negev. Warburton suggests that Egyptian military interest in Transjordan was restricted to the reigns of Seti I and Ramesses II, when the Hittite empire was attempting to expand and find regional allies. Regional stability was restored after a treaty between Egypt and the Hittites was signed. The Egyptians eventually retreated from the region at the end of the Late Bronze Age (Kitchen 1964: 65-60; Higginbotham 2000: 1-2, 28-34; Warburton 2001: 233).

While several researchers have tried to match destruction levels in excavations to the cities mentioned in different lists (Hasel 1998; Hoffmeier 1989; Wilson 2005; Junkkaala 2006), few studies have tried to evaluate the force of the Egyptian armies. This is a critical question, when comparing the destructiveness of armies to that of earthquakes. In general, there appears to be a substantial gap between the complexity of engineering displayed in urban defenses and the level displayed in siege warfare. The Egyptian army, in this period, was capable only of laying siege in hope of starving out the defenders (Redford 2003: 49). Modest battering rams were used, archers fought from siege towers, torches were thrown and soldiers scaled walls with ladders (Wiseman1989: 48-49; Tallis 2008: 57; King 2000: 266-276). There is no archaeological evidence, nor written or pictorial sources, that indicate siege machinery capable of hurling large stone projectiles (Kern 1999: 9-21). Nor is there any evidence of tunnels having been dug under walls (McDermott 2004: 44, 114). The Egyptians preferred open battlefields and resorted to sieges only to draw the enemy into the open. Textual records show massive conflagration was not employed in Egyptian campaigns of the 19th and 20th dynasties (Hasel 1998: 150).

There is some disagreement as to the length of the campaigns; some argue six days while others claim they lasted five months (Knapp 1992: 48). According to textual evidence, the campaign of Seti I against Pella, Hamath, Beth-Shean and Yenoʿam lasted one or two days. The campaigns of Ramesses II were mere skirmishes. His first full-scale military expedition in southern Canaan was conducted after the battle of Kadesh (Higginbotham 2000: 22-24, 28). These short campaigns did not allow prolonged destructive sieges. The scarcity of sources limits our ability to obtain a detailed picture of Shishaq's military capacities. His army was composed of infantry and chariotry with a greater emphasis on non-Egyptian troops; his siege warfare was similar to that of his predecessors (Sagrillo 2012: 425-450). The evidence suggests that the Egyptian forces were sent to threaten or punish the rebelling towns, but not to destroy them.

The Israelites clashed with the population of Edom, Moab, the Amorite kingdom and Beth-Shean. However, their resources and ability to conduct siege warfare were limited (Knapp 1992: 48; Kern 1999: 29-33). In short, the best-trained and equipped Bronze and Iron Age armies could ransack property, kill and capture civilians, but they could not match the destructive forces of a strong earthquake. Military technology did not change significantly, even towards the end of the Iron Age. Dever is one of the few archaeologists who, when he studied the damaged wall at Gezer, wrote without hesitation: "Certainly a battering ram or the work of sappers could not have produced such a phenomenon as this whole stretch of wall tipped outward" (Dever 1992: 28-31).

COMPARING BRONZE AND IRON AGE EARTHQUAKES TO THE 1927 EARTHQUAKE: SCALE OF DAMAGE AND DISTRIBUTION

The advantage of examining and comparing the Bronze and Iron Age earthquakes to the 1927 earthquake derives from the contemporary British reports evaluating damage in 133 settlements on both sides of the Jordan Valley. The 1927 earthquake was the strongest to be measured by instruments thus far. Its epicenter was in the northern edge of the Dead Sea (Fig. 6) with a magnitude ML 6.2 (Avni 1999).[4] The casualties and damage to property along the western side of the Jordan Valley is considerably lower than on the eastern side (Table 4). The number of towns and villages recorded is by far higher on the west side, reflecting the higher settlement density. West of the DST, high death tolls and severe damage to property occurred in Lydda, Jerusalem, Nablus and Hebron, which are relatively far from the Jordan Valley (Fig. 6).

Table 4 Samples of damage distribution due to the 1927 earthquake (Avni 1999; Hough and Avni 2011).

West of the DST	East of the DST
Jericho: 3 killed, hotel, monastery of St John and police station destroyed. (7-8 / 33)	al-Salt: 32 killed, 34 wounded, 742 houses destroyed. (8.5-8.5 / 36)
Jiftlik: 1 house destroyed. (7-7 / 65)	Madaba: 3 killed, 6 injured, 36 houses destroyed. Many badly damaged. (7.5-7 / 39 km)
Beth-Shean: 2 houses and railway station destroyed. (6.5-6 / 102)	Irbid: 15 killed, 20 injured, 351 houses destroyed. 466 badly damaged. (7.5-7.5 / 116)
Jenin: severe cracks. No casualties. (6-6 / 99)	Jarash: 8 killed, 5 houses destroyed, 35 houses badly damaged. (7-7 / 90)
Batir (7-7 / 32)	Kafaringhi: Severe damage; no details. (8-8 / 84)
Nabi Musa (4 km west of monastry): Road to Jerusalem loaded with debris. (8-8 / 24)	Wadi Shueib: Jordan River - Amman road rendered impassible due to breaks in the road (8-8 / 35).
West Jerusalem (7-7 / 30) East Jerusalem (8.5-7.5 / 26)	Amman: most houses rendered dangerous. (8.5-8.5 / 64)
Abu Ghosh (6.5-6.5 / 40)	Zarka: Q. al-Hajj tower destroyed. (7-7 / 84)

Note: Figures in brackets denote mode-mean Mercali intensity/epicentral distance km.[5]

[4] ML is a unit of magnitude used to measure shallow earthquakes, based on the maximum amplitude (A) in micrometers recorded on a standard short period (1 second) seismometer (Ambraseys 1988: 309-310).

[5] The intensity scale gives the severity according the direct effect on the population, damage to property, disturbance to the surface of the ground, and the extent of human and animal reaction to the shaking. The highest value is XII

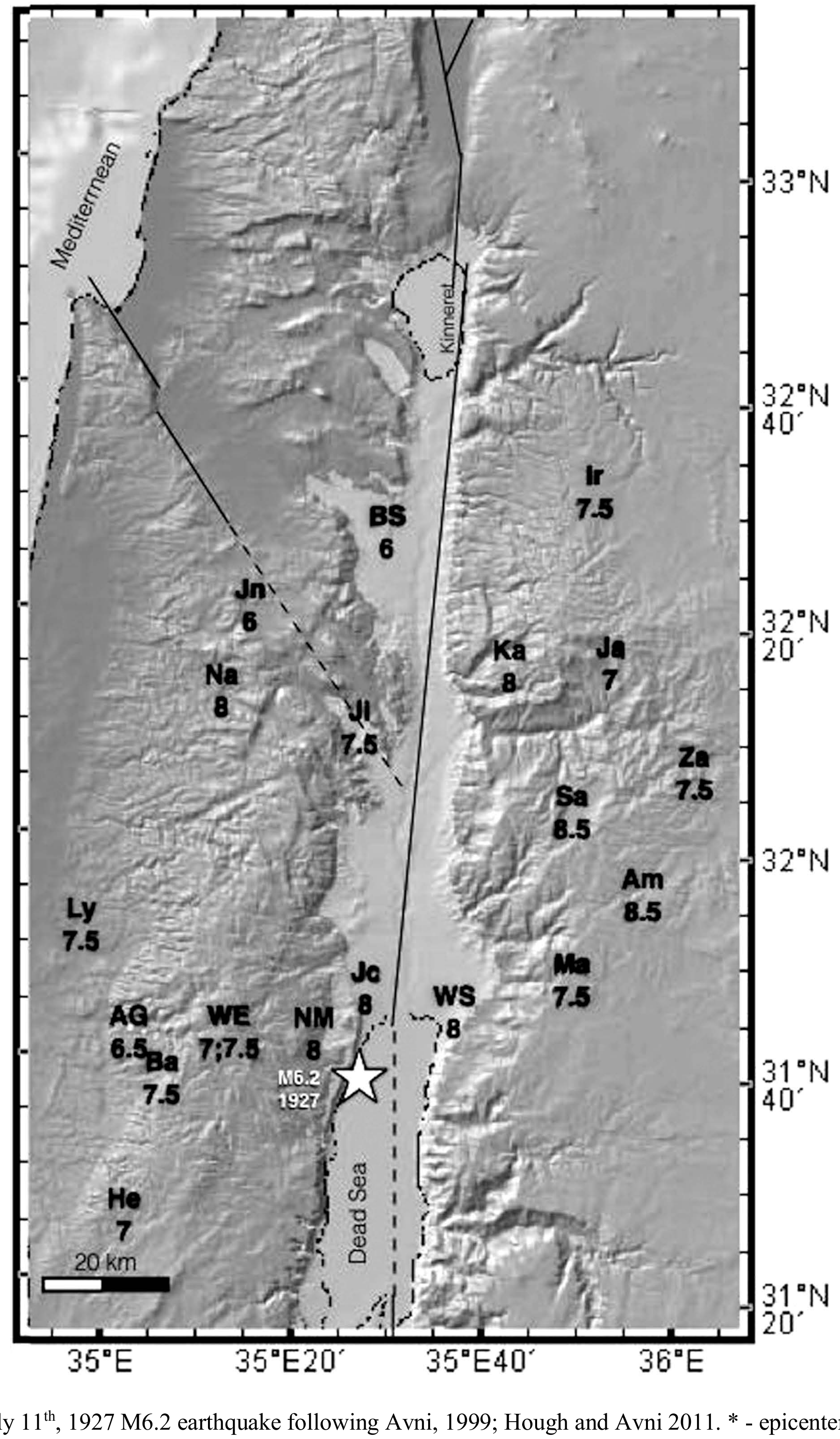

Fig. 6 The July 11th, 1927 M6.2 earthquake following Avni, 1999; Hough and Avni 2011. * - epicenter. Locations of damaged sites and intensities (see Table 4 and text): AG - Abu Ghosh; Am - Amman; Ba-Barir; BS Beith Sha'an; He - Hebron; I - Irbid; Ja - Jarash; Jc - Jericho; Ji - Jiftlik; Jl - Jerusalem; Jn - Jenin; K - Kafaringhi; Ly - Lydda; M - Madaba; Na - Nablus; NM - Nabi Musa; Sa - al-Salt; WS - Wadi Shueib (Shaibe); Z - Zarka. Background topography - ASTER by http://www.geomapapp.org (Ryan et al. 2009).

(Ferrari and Guidoboni 2000). We tabulate the mode and the mean values, along with epicentral distance according to Hough and Avni (2011).

According to Al-Homoud (1998: fig. 5), Pella, Tell Abu Kharaz, Tell es-Sa'idiyeh and Tell Umayri all fall within the highest earthquake intensity zone grade. Rehov and Beth-Shean fall within a slightly lower grade. Only Bethel, Ai and Jericho match the high intensity grade of the eastern sites. The distribution of damage reflects the characteristics of the fault. Ben-Menahem (1991: 202-09) was the first to describe the asymmetric distribution of damage. The asymmetrical behavior is possibly only true in some periods, and each period and segment of the DST must be examined carefully. Explaining this asymmetry is a more difficult task. The scale of damage depends on many different variables. The distance from the source fault is the leading factor. However, for historic events, the location and depth of the epicenter is another unknown.

Other essential factors are the lithological infrastructure upon which settlements are built. Steep topography, especially if associated with soft soil, will tend to increase damage. Sites located on hilltops suffer worse than sites built on a plain (Tiedemann 1992: 62-63, 140). The eastern flank of the DST is higher and wider, its width decreasing towards the north. On the west, from Beth-Shean to the Dead Sea, the terrain is relatively flat. Another critical factor is the proximity of sites to the rift, which may act as a wave guide (Wust Bloch, 2002). This may explain some of the destruction layers at Pella, which lies at the intersection of an 18 km-long fault running sub-parallel to the DST (Figs. 5-6, Table 3). A short fault (~1 km) bisects Tell al-'Umayri, striking southeast-northwest (Bender, 1968; Schnurrenberger 1997: 316).

Pella is described as "a large buttress-like plateau," that rises 125 m above the floor of the Rift Valley (60 m bsl). The stratigraphic sequences consist predominantly of Tufa limestones which are 100 m thick, fluvial conglomerates and dense travertine limestone. Towards the edge of the Rift, there is a layer of dense limestone (Macumber 1992b: 32-33). On the west side, the basalt formation (Cover Basalt) stretches north of Beth-Shean (Belitzky 1996: 8) and is thicker towards the east.[6] The basalt is underlain by conglomerates, siltstones and limestone. The limestone layer is considerably thinner, some 30-50 m of porous Tufa (Rozenbaum 2009: 21-32). The local geotechnical characteristics between Pella are compounded by the overall amplification of longer waves within the rift (Wust-Bloch et al. 2002).

SUMMARY

The comparison of the distribution of earthquake damage in the Bronze and Iron Ages versus 1927 shows that west of the DST and close to the fault, at Beth-Shean, Rehov and Jericho, earthquake evidence is infrequent and damage generally modest. There are no thick layers of debris across the entire site; the death tolls and damage to houses in 1927 was considerably low. This is due to the moderate magnitude of the 1927 earthquake (M6.2) despite possibly higher vulnerability of some of the ancient edifices. The high population density in the west, throughout history, often distorts the picture. The number of sites struck in the west is sometimes higher, but the scale of damage in the east appears clearer in Bronze and Iron Age sites, and is considerably greater in the 1927 earthquake.

Fault branches require special attention; damage at sites along the Carmel Fault at Megiddo and Yoqneʿam is significantly greater than at Beth-Shean, Rehov, and Jericho, although they are much farther from the main fault. The smaller faults running near Pella and Tell al-'Umayri may have been active throughout the period under discussion. Of all the sites examined, Pella figures as a key site; each of its five earthquakes has a clear paleoseismic reading. None of the sites west of the DST provided such a continuous record. Concerning the frequency of earthquakes, there is sufficient evidence for five

[6] Crust, the outermost rocky shell of the earth (Bolt 1978).

distinguishable seismic events: Early Bronze II, Late Bronze II, Iron Age I, II and IIB. In most cases, the paleoseismic and archaeological evidence correlate. Concerning the Middle Bronze Age, archaeological evidence is insufficient to support the geological reading. It thus seems that the Middle Bronze Age was free of earthquakes destructive to masonry edifices. This earthquake database will change as more information is revealed through excavations and geological research and as dating methods become more accurate.

Although little is known about military assaults on each town, long sieges were rare and weapons of mass destruction unknown. The absence of weapons in the destruction levels in most sites remains a real riddle. Leveling cities and leaving a thick homogeneous destruction level appears to be beyond the capabilities of contemporary armies. Perhaps in some cases, earthquakes should be considered as the source of destruction. Few sites were permanently abandoned after an earthquake. In cases of mass destruction, debris was leveled and new buildings constructed. Public buildings, such as urban defenses and temples, were repaired. In some cases, new building techniques or plans were tried out in order to combat future events. The temple at Pella was damaged five times and rebuilt on a smaller scale on the same spot. It seems no one dared to rebuild it elsewhere, as in many cases, sacred buildings were seldom moved.

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