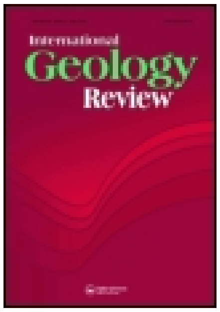

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An early first-century earthquake in the Dead Sea

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This article examines a report in the 27th chapter of the Gospel of Matthew in the New Testament that an earthquake was felt in Jerusalem on the day of the crucifixion of Jesus of Nazareth. We have tabulated a varved chronology from a core from Ein Gedi on the western shore of the Dead Sea between deformed sediments due to a widespread earthquake in 31 BC and deformed sediments due to an early first-century earthquake. The early first-century seismic event has been tentatively assigned a date of 31 AD with an accuracy of ±5 years. Plausible candidates include the earthquake reported in the Gospel of Matthew, an earthquake that occurred sometime before or after the crucifixion and was in effect 'borrowed' by the author of the Gospel of Matthew, and a local earthquake between 26 and 36 AD that was sufficiently energetic to deform the sediments at Ein Gedi but not energetic enough to produce a still extant and extra-biblical historical record. If the last possibility is true, this would mean that the report of an earthquake in the Gospel of Matthew is a type of allegory.

Keywords: Dead Sea; Holocene; varves; Earthquake; Crucifixion; New Testament

Introduction

The Ein Gedi core

The Dead Sea (31°30′N, 35°30′E) lies along the tectonically active Dead Sea Transform (DST), which separates the Arabian and Sinai plates (Garfunkel 1981). The DST is a mainly N–S-striking, left-lateral transform fault with normal faulting along its margins and at northwest bends and thrusting at northeast bends. A terminal lake, the Dead Sea, is situated in a pull-apart basin at the deepest location on land along the transform. Frequent seismic activity along the DST has been detected in the past century and recorded historically and archaeologically over the past 4000 years (Ben-Menahem 1991; Ambraseys *et al.* 1994; Salamon *et al.* 2003). Within the layered deposits of recent Dead Sea sediments lie subintervals which have been deformed, presumably due to earthquakes generated by fault movement along the DST (Marco and Agnon 1995; Enzel *et al.* 2000; Ken-Tor *et al.* 2001a; Migowski *et al.* 2004; Kagan *et al.* 2011).

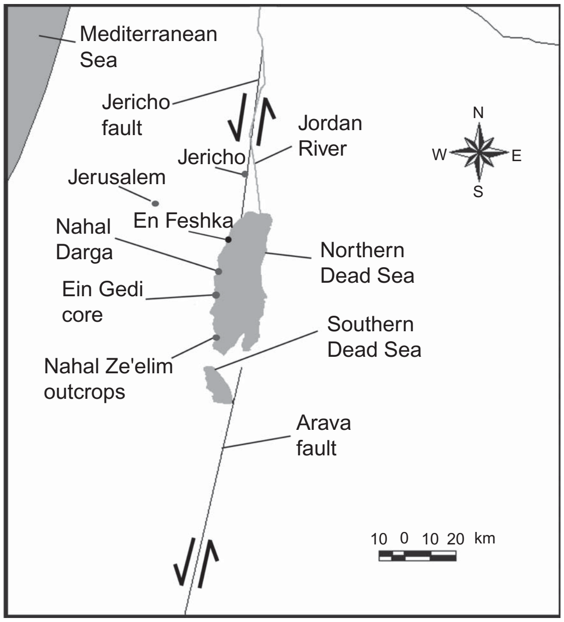

Figure 1. Map of the Dead Sea and surrounding area showing the core location in Ein Gedi and the outcrop location in Nahal Ze'elim.

In the fall of 1997, the GFZ German Research Centre for Geosciences in cooperation with the Geological Survey of Israel took three cores from the beach of the Ein Gedi Spa adjacent to the Dead Sea at a surface elevation of 415 m below sea level[1] (Figure 1). The cores sampled sediments that were originally deposited in a deep lacustrine environment (Migowski *et al.* 2004, 2006). A floating varve chronology was established (Migowski *et al.* 2004) after identifying and counting varves under the microscope and performing accelerator mass spectrometry (AMS) radiocarbon dating of wood fragments from the

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cores. Twenty-eight historically documented earthquakes were identified in a 1598-year interval between 140 BC and 1458 AD in Core Section A3 of the Ein Gedi core (Migowski *et al.* 2004).

While a previous study (Migowski *et al.* 2004) attempted to reconcile a varve-counted seismite date observed in the section to an earthquake date (33 AD) listed in the earthquake catalogues (e.g. Willis 1928; Amiran *et al.* 1994), this study makes no assumptions about the likely date of this early first-century seismite. A date was assigned to the seismite based on varve counting alone. Then, an attempt was made to determine the accuracy of that varve count and to compare this with an analysis of the historical sources which reveals a less well defined date assignment than the dominant 33 AD date that is present in most of the catalogues. By comparing the date from the varve count with the date range and date probabilities from the historical sources and conducting some geomechanical examination, we have come to some conclusions.

Varved sediments and seismites

The two fundamental assumptions that allow one to identify historically documented earthquakes in the Dead Sea sedimentary record of the Ein Gedi core are the following.

(1) The sediments are varved (Heim *et al.* 1997; Migowski *et al.* 2004). Seasonal lamination patterns of white summertime precipitates (primarily aragonite, but also in a few cases gypsum and halite) and grey detritus from winter and spring time floods in the wadis (aka Nahal) can be counted as a varve, that is, 1 year of deposition.
(2) Brecciated layers, also known as intraclast breccias (Agnon *et al.* 2006), mixed layers, or seismites, were created by deformation of the varved layers due to seismic shaking (Marco and Agnon, 1995, Marco *et. al.*, 1996). An example containing annual varves and brecciated layers of Holocene Dead Sea sediments is shown in Figure 2.

Field observations of brecciated layers in cores and outcrops show that the upper contact is sharp whereas the basal contact can be sharp or gradual. Where the basal contact is gradual, folded and torn packets of laminae are abundant (Agnon *et al.* 2006).

There are several reasons that the brecciated layers are believed to have a seismic origin.

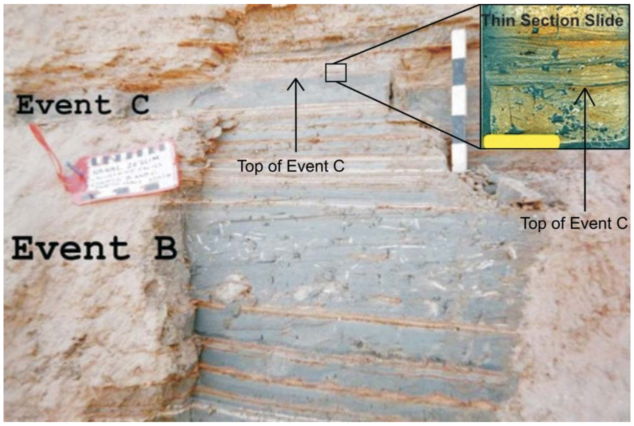

Figure 2. Photo of Events B and C in Nahal Ze'elim outcrop with a thin-section image from the same outcrop superimposed in the upper right. Events B and C are brecciated layers; believed to be deformed during earthquakes. Event B was correlated to the 31 BC earthquake (Ken-Tor *et al.* 2001a, 2001b; Williams 2004). Event C appears to be due to the same earthquake observed in the Ein Gedi core dated to 31 AD ±5 years in this article. Annual varves are present between Events B and C (note alternating white and grey or brown layers). Photo taken by Jefferson B. Williams in May 2000.

(1) *Field evidence*. In Nahal Ze'elim, where lateral relations of the brecciated layers were readily observed, it was noted that the topography was flat at the time of deposition. Thus, there is no field evidence for gravitational slides. In addition, none of the aragonite fragments in the brecciated layers showed lateral grading, imbrications, or other transport indicators such as would be expected from lateral flows or turbidity currents (Ken-Tor *et al.* 2001a).
(2) *Similar layers are found elsewhere in the world*. As noted by Ken-Tor *et al.* (2001a), similar soft sediment deformation structures have been documented in several other localities worldwide and interpreted as seismites (Sims 1973, 1975; Hempton and Dewey 1983; Allen 1986; Davenport and Ringrose 1987; Doig 1991).
(3) *Association with syndepositional faulting*. In nearby Nahal Perazim, brecciated layers with similar lithology occur in association with syndepositional faults presumed to be caused by earthquakes (Marco and Agnon 1995; Marco *et al.* 1996).
(4) *Correlation to documented earthquakes*. In the 1522-year varve-counting interval in the Ein Gedi core, brecciated layers were correlated to 28 historically documented earthquakes (Migowski *et al.* 2004). Seismites from other outcrops on the shores of the western Dead Sea have also been correlated to historically documented earthquakes (Enzel *et al.* 2000; Ken-Tor *et al.* 2001a, 2001b; Kagan *et al.* 2011).
(5) *Correlation to seismic intensity*. In the Ein Gedi core, a relationship was discovered between estimated local intensity due to an earthquake and the probability that a brecciated layer would correlate to a seismic event. At historically estimated modified Mercalli intensities (MMI) greater

> than VII (i.e. VIII and higher), all well-documented earthquakes were correlated, whereas at intensities smaller than VI, none were matching (Migowski *et al.* 2004). In the Nahal Ze'elim outcrops, Williams (2004) independently estimated that the threshold intensity for seismic deformation is VIII. Williams was further able to develop a quantitative relationship between the historically estimated intensity of local ground shaking (expressed as peak horizontal ground acceleration) and the thickness of the brecciated layers themselves.

In the thinnest brecciated layers (e.g. less than 1 cm thick), the entire interval appears to have been fluidized, brecciated, suspended, and then redeposited after the seismic shaking ended (Migowski *et al.* 2004). In larger brecciated layers (several tens of centimetres thick and larger), the brecciated layers appear to have been deformed in situ, avoiding suspension and resettlement. We suspect that the thinnest brecciated layers originally (preseismically) formed a thin veneer of uncompacted and possibly not fully grain-supported sediment that was mechanically closer to a suspension of water and detritus than the underlying sediment. When relatively lower intensity ground shaking occurred, these thin layers were then fully suspended into the water column and resettled. The thicker layers appear to have been formed by longer lasting and more intense levels of ground shaking.

A strain softening type of liquefaction apparently played a significant role in the formation of the larger brecciated layers. This type of liquefaction has been observed in low-permeability sediments such as marine clays (e.g. see Vucetic and Dobry 1991) and is considered to have been operative in the Dead Sea sediments deposited from a deeper lacustrine environment such as was found in the Ein Gedi core. In strain softening liquefaction, increases in strain cause a reduction in the shear modulus of the soil, which reduces to such a point that the soil can no longer resist the deforming forces. More conventional pore pressure-induced liquefaction may be more operative in coarser grained, higher permeability Dead Sea sediments deposited in shore and near-shore environments (e.g. Enzel *et al.* 2000). Heifetz *et al.* (2005) proposed a model for soft sediment deformation that agrees well with field observations.

An important mechanical aspect to the deformation of Dead Sea sediments during earthquakes involves the sediment anisotropy. Cemented aragonite crusts provide lateral reinforcement. In fact, the sediments are significantly stronger in cyclic load tests when the load is applied laterally rather than vertically (Sam Frydman, personal communication 2000). In Holocene Dead Sea sediments, the aragonite crusts appear to undergo brittle rather than plastic failure during seismic shaking. Seismic loading away from the immediate epicentre of an earthquake is usually dominated by vertically propagating shear waves, which load the sediments horizontally. This appears to have been the case in most of the observed brecciated layers where the brittle aragonite crusts evidently fractured due to horizontal forces (Williams 2004).

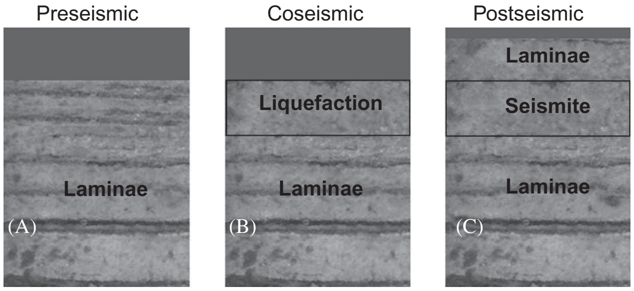

Figure 3. Interpretation of how brecciated layer seismites are formed. (A) Laminated sediments are deposited at the bottom of the Dead Sea. (B) Ground motion during an earthquake leads to liquefaction of the top layers of sediment on the Dead Sea floor. (C) Sedimentation continues depositing more laminated sediments on top of the brecciated layer. Modified from Marco and Agnon (1995). Reproduced/modified by permission of American Geophysical Union.

It appears that in the fine-grained lacustrine sediments present in the Ein Gedi core, brecciated layers were formed by either suspension of a thin veneer of uncompacted water and detritus or a strain softening type of liquefaction coupled with brittle failure of aragonite crusts. Whatever the specific mechanism of failure, brecciated layer formation can be visualized in a simplified form as shown in Figure 3. The important point is that the brecciated layers apparently formed at the sediment–water interface, and the timing of each event is constrained by dating the first undisturbed layer overlying the disturbed sequence (Marco and Agnon 1995; Migowski *et al.* 2004).

The 31 BC 'anchor' earthquake

Because of the ubiquity of sediment deformation due to the 31 BC earthquake throughout the Dead Sea (Reches and Hoexter 1981; Enzel *et al.* 2000; Ken-Tor *et al.* 2001a; Migowski *et al.* 2004; Kagan *et al.* 2011), once this event is identified in a given section, it can be treated as a chronological anchor (see Event B in Figure 2). Varve counting, for example, can proceed from the 31 BC event upward in the section towards more recent earthquake events. The primary historical source for the earthquake of the early spring of 31 BC is Josephus Flavius, who wrote in *The Jewish War* (Book 1, Chapter XIX, 370):

> But as he [King Herod] was avenging himself on his enemies, there fell upon him another providential calamity; for in the seventh year of his reign, when the war about Actium[2] was at the height, at the beginning of the spring the earth was shaken, and destroyed an immense number of cattle, with thirty thousand men; but the army received

> no harm, because it lay in the open air. (Josephus *et al.* 1981)

This was evidently a powerful earthquake. Amiran *et al.* (1994) believe that local intensities were as high as X in several places, whereas Arieh (1993) assigned a maximum local intensity value of IX and $M_L = 7.0$.[3] Ben-Menahem (1991) estimated $M_L = 6.7$ and places the approximate epicentre ~25 km north of where the Jordan River empties into the Dead Sea along the Jericho fault. Williams (2004) suggested that the fault break was most likely on the Jericho fault with a southern termination near Nahal Darga and a northern termination well up the Jordan Valley directly north of Gesher Adam (Jisr Damiya).

Ben-Menahem (1991) mentions damage in Jerusalem at the Second Temple, Masada, Qumran, and Jericho at Herod's Winter Palace. Guidoboni *et al.* (1994) believes this earthquake is mentioned by Iohannes Malalas in *Chronographia* (Malalas *et al.* 1986) when he reported that a city in Palestine named Salamine (possibly present-day Lod, near Tel Aviv) was destroyed and rebuilt by Augustus and re-named Diospolis. Rahmani (1964) reports that Jason's Tomb in Jerusalem was destroyed by this earthquake. Amiran *et al.* (1994) note that earthquake damage was severe in Galilee and Judea. Karcz (2004) and Ambraseys (2009), however, caution that there is limited textual evidence regarding the area affected by this earthquake and suggest that the extent of damage reported from archaeological sites in Israel (e.g. at Qumran, Masada, Jason's tomb, and/or Jericho) due to a 31 BC earthquake may be overstated. Karcz (2004) estimates a magnitude of 6.0–6.5.

The 31 BC earthquake appears to have ruptured the ground surface near Jericho and shows up in trenches excavated by Reches and Hoexter (1981). A seismite from the 31 BC earthquake also appears to be present in outcrops at Nahal Darga as a thick deformed layer labelled Stratigraphic Unit 11 by Enzel *et al.* (2000). At Nahal Ze'elim, a brecciated layer labelled Event B was assigned to the 31 BC earthquake (Ken-Tor *et al.* 2001a). This brecciated layer is ~17 cm thick and spatially continuous, appearing as shown in Figure 2. Kagan *et al.* (2011) assigned a 6 cm-thick brecciated layer in En Feshka to the 31 BC earthquake. Migowski *et al.* (2004) identified a 9 cm-thick brecciated layer with the 31 BC earthquake, and this layer is shown at the bottom of the thin-section log in Figures 4 and 6.

Methods and results

Counting varves from 31 BC to 31 AD

Thin-section images along with interpretive tracks of the Ein Gedi core from the 31 BC earthquake to the early first-century earthquake are shown in Figures 5 and 6.

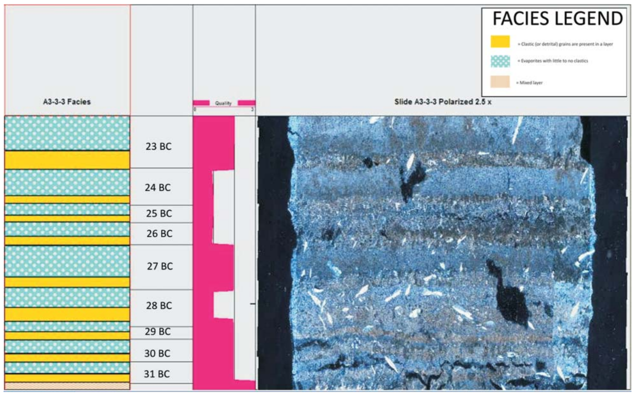

Figure 4. Close-up of deposition immediately following the 31 BC earthquake, when Josephus reported a drought.

It should be noted that the dark cracks present in the thin-section slides were created during the epoxy impregnation process in creating the thin sections. Fresh sediment slices (10 × 2 cm) were impregnated with resin after freeze-drying (Brauer and Casanova 2001). The impregnated sample blocks were cut along the long axis so that the cutting plane could be used for large-scale thin-section preparation.

Excluding the depth track (in millimetres) on the far left, there are nine tracks in these logs. On the far left and far right are images of the thin sections themselves (slides A3-3-2 and A3-3-3). Adjacent to each microscope image is a varve quality track.

A varve quality index is defined below.

1 = Discontinuous ambiguous clastic layer.
2 = Clearly identifiable clastic layer but thickness estimate is not very accurate.
3 = Well-preserved varve with good accurate estimate of thickness.

Every counted varve was assigned an index value of 1, 2, or 3. For the purpose of this study, where the goal is accurate chronological dating, a varve quality index value of 1 indicates that the varve is somewhat suspect and a varve quality index of 2 or higher indicates that the varve count is regarded as fairly certain.

In the 62 years counted from 31 BC to 31 AD, 36 (58%) had a varve quality rating of 1 and 26 (42%) had a varve quality rating of 2 or higher. In addition to the varve quality tracks, two more track types are present. They are the facies tracks and years tracks.

The facies tracks were developed for each individual slide (A3-3-2 or A3-3-3) and use simplified symbols geared towards the goal of counting varves and identifying earthquakes. Layers are defined, as shown in the facies legend of Figures 5 and 6, into one of three types of facies: clastic layers, evaporites, and brecciated layers. Evaporites

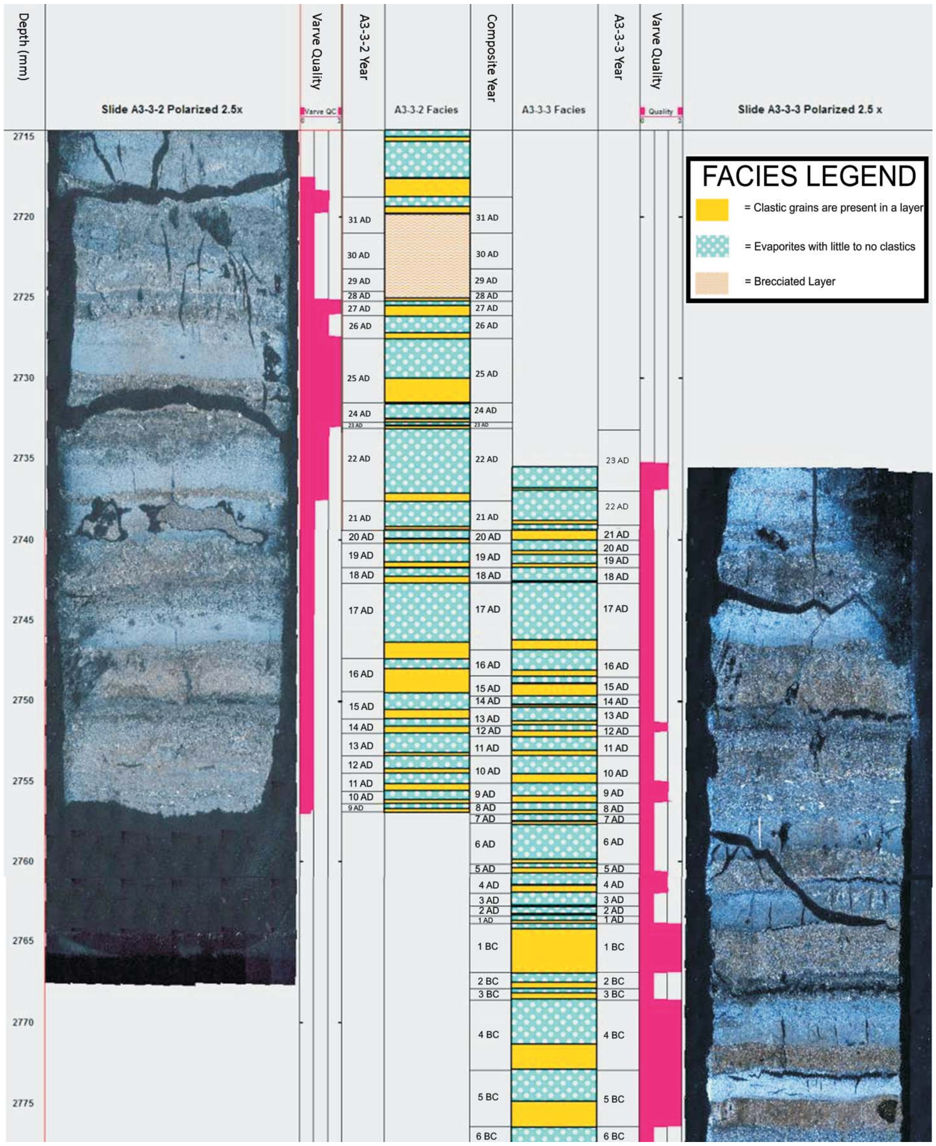

Figure 5. Interpreted log of Ein Gedi core thin-section A3-3-2 (composite core depth 2715–2755 mm) and overlapping thin-section A3-3-3 (composite core depth 2737–2833 mm). As a result of thin-section microstratigraphy and varve quality determination, a composite varve chronology is shown in the central column.

are primarily authigenic aragonite but gypsum and rare halite can also be present.

A brecciated layer has undergone deformation due to ground motion (usually due to earthquakes) in the predominantly undisturbed and finely laminated lacustrine Ein Gedi sediments. A combination of one clastic layer (deposited primarily during winter) and one evaporite layer (deposited primarily during summer) is assumed to represent one varve or 1 year of deposition (Migowski *et al.* 2004). Varves inside of brecciated layers were counted based on observed discontinuous laminations and maintaining congruence in varve thickness with the average thickness of adjacent undeformed varves. Years tracks were constructed adjacent to the facies tracks based on this assumption. One years track was created for each individual thin section (A3-3-2 and A3-3-3), and a composite years track was created combining what was regarded as the most accurate varve counts between the two thin sections. Varve quality index values were used to decide which chronology to use where the thin sections overlapped (see Figures 5 and 6).

Palaeoclimate information may be contained in the sediments deposited immediately after the 31 BC earthquake. In his book *Jewish Antiquities* (Book XV, Chapter 9), Josephus reported a drought in Judea in 28 BC or possibly 25 BC[4]:

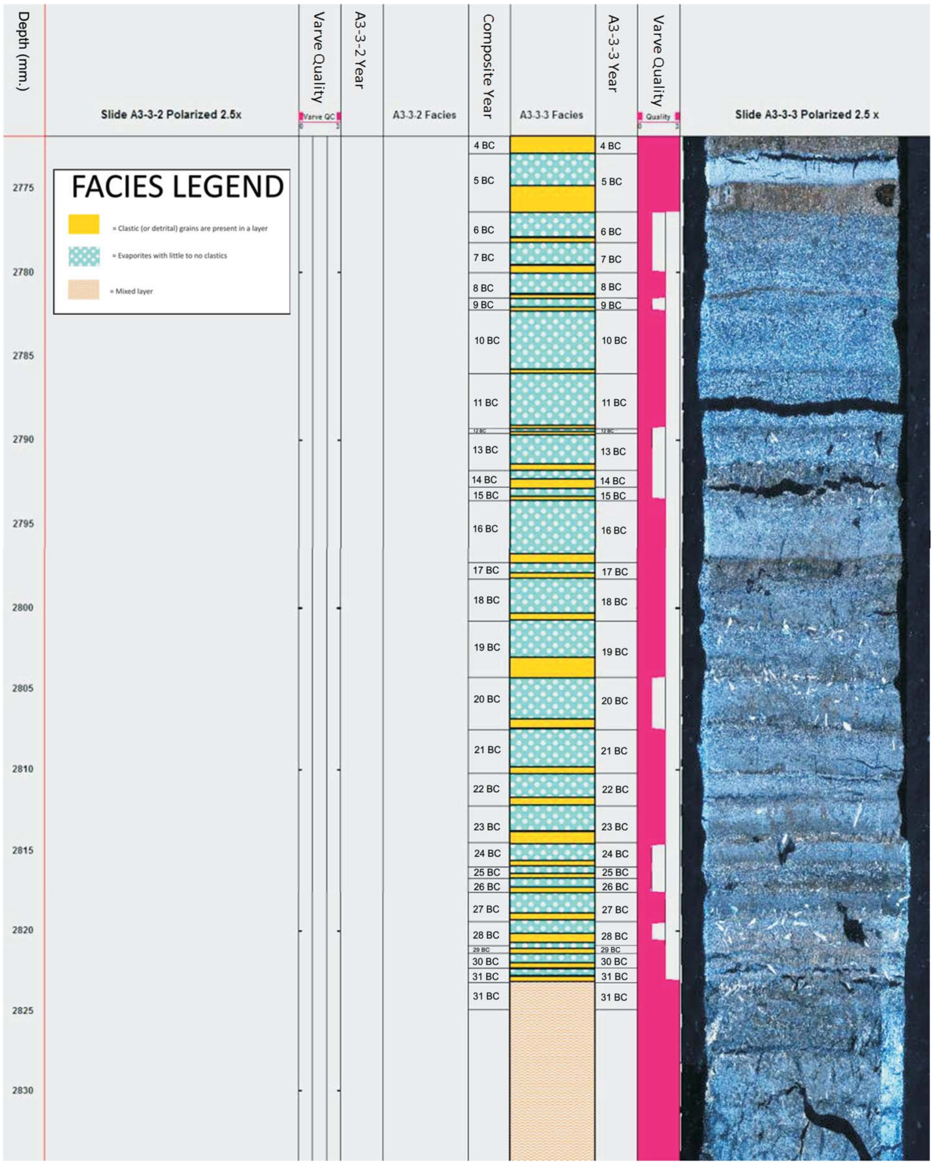

Figure 6. Interpreted log of Ein Gedi core (for explanation see Figure 5).

> Now on this very year, which was the thirteenth year of the reign of Herod, very great calamities came upon the country; whether they were derived from the anger of God, or whether this misery returns again naturally in certain periods of time (14) for, in the first place, there were perpetual droughts, and for that reason the ground was barren, and did not bring forth the same quantity of fruits that it used to produce. (Josephus 1930)

From 31 BC to 28 BC in Figure 4, we note that the aragonite layers are relatively thin and that there are a fairly large number of gypsum rhombs.[5] If these were years of drought, this would tend to support the thesis of Stein *et al.* (1997) and Barkan *et al.* (2001) that enhanced aragonite production requires a continuous supply of freshwater loaded with bicarbonate (Migowski *et al.* 2006), leading to the conclusion that thick aragonite layers were precipitated in the summers after years of heavier rainfall and abundant runoff into the Dead Sea, whereas thinner aragonite layers correspond to summer time precipitation following years of less rainfall and less runoff. In addition, the extra gypsum in these years may represent drier years, when the upper water mass of the Dead Sea was diminished due to lower water input and enhanced evaporation (Migowski *et al.* 2004). Leroy *et al.* (2010) noted a decrease in cultivated pollen (*Olea*, *Pistacia*, *Juglans*, and *Vitis*) in the Nahal Ze'elim outcrop in the ~5 years after the 31 BC earthquake, which could indicate drought conditions and/or a decrease in agricultural productivity due to destruction caused by the 31 BC earthquake.

The date of the crucifixion

Migowski *et al.* (2004) assigned the brecciated layer in Figure 5 to an earthquake listed as occurring in 33 AD in the earthquake catalogues. Ken-Tor *et al.* (2001a), using the outcrops at Nahal Ze'elim, assigned a correlative seismite (labelled Event C) to the 33 AD earthquake. Kagan *et al.* (2011) also assigned 33 AD to an earthquake event identified in outcrops at En Feshka. All of these assignments could refer to an earthquake reported to have occurred immediately after the crucifixion of Jesus of Nazareth. The primary source document for the earthquake of the crucifixion is the 27th chapter of the Gospel of Matthew in the New Testament. It describes an earthquake occurring when Jesus of Nazareth died on the cross:

> [50]But Jesus, again crying out in a loud voice, yielded up his spirit.[51] At that moment the curtain in the Temple was ripped in two from top to bottom; and there was an earthquake[6] with rocks splitting apart.

The curtain referred to comes from the Aramaic word parokhet, which was a 1 ft-thick piece of fabric covering the entrance to the holy of the holies in the Second Temple. The Gospels of Mark and Luke also mention the tearing of the temple curtain in the moments surrounding Jesus' death, but do not cite an earthquake as the cause of destruction.[7] In Chapter 28, the Gospel of Matthew goes on to describe another earthquake roughly 36 hours after the one described above:

> [1]After the Sabbath, toward dawn on Sunday, Mary of Magdala and the other Mary went to see the grave. [2]Suddenly there was a violent earthquake, for an angel of God came down from heaven, rolled away the stone and sat on it.

In modern terms, this might be described as an aftershock event.

The day and date of the crucifixion are fairly well known. The year is not so well known. According to the four canonical gospel accounts (Matthew, Mark, Luke, and John), the crucifixion occurred on a Friday on either 14 or 15 Nisan, a month in the Jewish lunar calendar. The year, however, is not specified. One clue to the year is that the crucifixion occurred during the reign of Pontius Pilate who was the Procurator of Judea from 26 to 36 AD. This is agreed upon by all four gospels as well as Tacitus in Annals (Book XV, 44) (Tacitus *et al.* 1942).

Humphrey and Waddington (1983) tabulated the days between 26 and 36 AD when 14 or 15 Nisan fell on a Friday and came up with four possible years: 27, 30, 33, and 34 AD. Humphrey and Waddington (1983) further pointed out that 27 and 34 AD were unlikely dates when one tried to match the crucifixion with the time of Jesus' ministry and the estimated date of Paul of Tarsus' conversion on the road to Damascus.[8] Thus, they listed two dates as the most likely dates for the crucifixion: Friday 7 April 30 AD (14 Nisan) or Friday 3 April 33 AD (14 Nisan). They proposed that Friday 3 April 33 AD was the more probable of the two dates.

Conclusions

Plausible earthquake candidates

Obviously, based on the discussion of the previous section, it is not likely that an earthquake of the crucifixion could have occurred in 31 AD. However, as mentioned earlier, over half of the counted varves between 31 BC and 31 AD were characterized as being discontinuous or ambiguous. The 31 AD date is an estimate, the accuracy of which needs to be determined.

One way to determine the accuracy of this estimate is to compare the varve-counting accuracy of this study with that of Migowski (2001), who counted varves in the same core. Since both investigations independently came up with similar dates for the early first-century earthquake (31 AD vs. ∼ 33 AD in Migowski (2001)), this is considered to be a valid comparison. Between two well-defined 'anchor' earthquakes of 31 BC and 1293 AD, Migowski (2001) counted 1324 varves. Of these, 94 years were masked by earthquake deformation. Inasmuch as Migowski (2001) used varve counts in the masked intervals to match her varve-counted year to historically documented earthquakes, the number of masked years in the 1324-year interval represents a combination of deformed layers and adjustments in the varve count to account for errors in varve counting; 94 years out of 1324 years amounts to 7.1%. Assuming a worst case scenario that the entire masked varve count is due to varve-counting errors, 7.1% of the 62-year interval between 31 BC and 31 AD amounts to 4.4 years. Rounding up, this means that for any given earthquake between 31 BC and 31 AD, the dating possesses an accuracy of at least ±5 years. This places the above-postulated 31 AD earthquake within the 26–36 AD window (31 ± 5 years) when Pontius Pilate was Procurator of Judea and the earthquake of the crucifixion is historically constrained.

In addition to this statistical approach, one can also use a geomechanical approach to assess the likelihood that the earthquake dated at 31 AD was caused by another historically reported earthquake. Several other historical earthquakes occurred in the vicinity of the age range of ±20 years (11–51 AD). These earthquakes are[9]:

1. a presumed submarine earthquake with an epicentre off the coast of modern-day Lebanon near the port city of Sidon in 19 AD (Turcotte and Arieh 1993);
2. a 37 AD earthquake with an epicentre close to Antioch, Syria (Guidoboni *et al.* 1994);

(3) a 47 AD earthquake with an epicentre close to Antioch, Syria (Guidoboni *et al.* 1994); and
(4) a 48 AD earthquake that is reported by Turcotte and Arieh (1993) to have been caused by a rupture along the Arava fault south of the Dead Sea.

Some doubt exists about the validity of the 48 AD rupture on the Arava fault. Whereas Ben-Menahem (1979) noted that there was archaeological evidence[10] that indicated an earthquake occurred in the Arava between 9 BC and 50 AD, the source for this date in many of the earthquake catalogues appears to be based on an erroneous interpretation of an earthquake reported in the Act of the Apostles in the New Testament. Willis (1928), whose earthquake catalogue forms a reference for many of the more recent earthquake catalogues, noted that an earthquake in 48 AD was felt in Palestine and Jerusalem and that damage was light. Willis (1928) lists Arvanitakis (1903) as his only reference for this earthquake. Arvanitakis (1903) reports that a 48 AD earthquake was felt in Jerusalem and Palestine, where damage was also characterized as light. The source for Arvanitakis (1903) is the Acts of the Apostles (8:24) in the New Testament. Although an earthquake is mentioned in the Acts of the Apostles around 47–48 AD in Philippi, Macedonia, while Paul and Silas were imprisoned, this account is not in 8:24.[11]

In Chapter 16 of the Acts of the Apostles, the following passage (16:25–26) can be found.

> Around midnight Paul and Silas were praying and singing hymns to God, while the other prisoners listened attentively. Suddenly there was a violent earthquake which shook the prison to its foundations. All the doors flew open, and everyone's chains came loose.

It is very unlikely that an earthquake in Macedonia would cause damage in Jerusalem. Karcz and Lom (1987) concur that the 48 AD earthquake may be a misrepresentation of a Judean earthquake based on Paul and Silas' release from prison in Macedonia.

Nonetheless, all four earthquakes can be examined on a magnitude–distance plot (Figure 7) which was used by Migowski *et al.* (2004) to determine which earthquakes caused sufficiently energetic local ground shaking to deform the sediments in the section. Earthquakes which plot above the upper line on the chart did not deform the section. We note that the earthquakes of 19 AD, 37 AD, and 47 AD did not create sufficient localized ground shaking at Ein Gedi to deform the sediments. Those that plot well below the lower line in the chart did deform the sediments. The 48 AD earthquake is plotted as it represents a rupture in the Arava. It appears unlikely that such an earthquake could have deformed the sediments in Ein Gedi. This leaves the 26–36 AD earthquake as the only historically reported candidate likely to have caused local ground deformation.

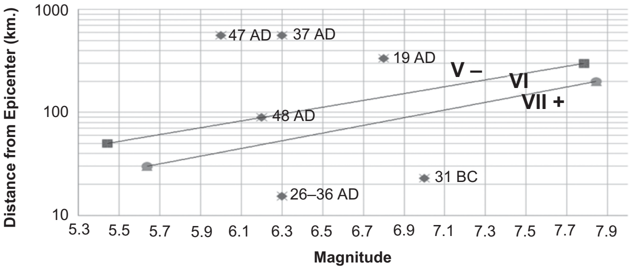

Figure 7. Magnitude–distance plot with lines of equal intensity based on Agnon *et al.* (2006). Magnitude and distance for the 26–36 AD earthquake are based on Williams (2004). All other magnitudes and distances are based on published earthquake catalogues.

However, it is possible that a non-historically reported earthquake created the 26–36 AD seismite. It has been surmised that an earthquake of magnitude (M) of 5.5 or larger is capable of deforming the ground surface in the immediate vicinity of the epicentre (Avi Shapira, personal communication 2000). A slightly more energetic version of such an earthquake (e.g. $M_L = 5.7$) could be capable of deforming lacustrine sediments in Nahal Ze'elim, Ein Gedi, and En Feshka, but might not cause sufficient structural damage in nearby populated areas to be reported in the currently extant historical record.

This leaves three possibilities for the cause of the 26–36 AD earthquake observed in the Ein Gedi section:

(1) the earthquake described in the Gospel of Matthew occurred more or less as reported;
(2) the earthquake described in the Gospel of Mathew was in effect 'borrowed' from an earthquake that occurred sometime before or after the crucifixion, but during the reign of Pontius Pilate;
(3) the earthquake described in the Gospel of Matthew is allegorical fiction and the 26–36 AD seismite was caused by an earthquake that is not reported in the currently extant historical record.

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Notes

1. 31°25.176′N 35°23.136″E.
2. Actium was the site of a naval battle in Greece between the forces of Mark Anthony and Caesar Octavianus, who was later known as Augustus Caesar. King Herod of Israel allied himself with Anthony and fought a series of land battles with the Arabians at the same time. Herod's army is believed to have camped in the plains of Jericho at the time of the earthquake (de Vaux 1973).
3. M_L = local magnitude.
4. Josephus refers to a drought in the 13th year of Herod's reign. In one reckoning, Herod's reign starts in 40 BC, when he was appointed King by Rome (Finegan 1998, Section 227). In another reckoning, Herod's reign begins in 37 BC (or possibly 36 BC), when he conquered Jerusalem (Finegan 1998, Section 503). Thus, by the first reckoning, 28 BC corresponds to the 13th year of Herod's reign and in the second reckoning, 25 BC (or possibly 24 BC) corresponds to the 13th year of Herod's reign. Finegan (1998, Section 227) notes that Josephus could be inconsistent in the way he reckoned time in his books.
5. At 2.5× magnification, the aragonite crystals are not visible, but some of the larger white rhomboid-shaped gypsum crystals are visible. Gypsum rhombs have a flattened diamond shape.
6. Earthquake is translated from the word seismos (σεισμός) in the original Greek text. Seismos unambiguously refers to an earthquake.
7. The curtain-tearing incident described in Matthew, Mark, and Luke can also be interpreted allegorically.
8. This is described in Chapter 9 of the Acts of the Apostles in the New Testament.
9. Besides earthquakes 1–4, there are no other historically reported earthquakes in the vicinity of Judea between 11 and 51 AD.
10. The description in the catalogue reads as follows: 'Structures at the Nabatian Temple at Aram (Gebel-E-Ram, 40 km. East of Akaba, built ca 31–16 AD), fortified to withstand earthquakes. Same at Tel-El Haleife, near Eilat, and at Petra.'
11. This part of the Acts takes place in Samaria and depicts a conversation between the apostles Peter and John and a man named Simon. Acts 8:24 reads ' 'and having answered, Simon said, you pray for me to the lord that nothing may come upon me of which you have spoken'. There is no mention of an earthquake.

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