



*This volume is dedicated to Prof. Arthur Segal
who initiated and headed The Hippos-Sussita Excavation Project*



Published by

**The Zinman Institute of Archaeology
University of Haifa, Mount Carmel
Haifa 3498838
ISRAEL**

hippos@research.haifa.ac.il



Language Editor: Rebecca Toueg

Design and Layout: Anya Hayat and Anat Regev Gisis



This book was published with the support of the Israel Science Foundation.



Printed by Millenium Ayalon LTD

TABLE OF CONTENTS

LIST OF FIGURES.....	5
CHAPTER 1. INTRODUCTION..... <i>Michael Eisenberg</i>	10
CHAPTER 2. HISTORICAL EARTHQUAKES AROUND THE SEA OF GALILEE..... <i>Neta Wechsler, Shmuel Marco, Klaus-G. Hinzen and Hector Hinojosa-Prieto</i>	16
CHAPTER 3. THE NECROPOLEIS..... <i>Oren Zingboym</i>	24
CHAPTER 4. THE WATER SUPPLY SYSTEM..... <i>Tsvika Tsuk</i>	44
CHAPTER 5. THE HIPPOS WINERY COMPLEX..... <i>Rafael Frankel and Michael Eisenberg</i>	56
CHAPTER 6. HUMAN SKELETAL REMAINS..... <i>Emilia Jastrzębska</i>	74
CHAPTER 7. FINAL POTTERY REPORT OF THE 2010-2011 EXCAVATION SEASONS..... <i>Lev-Arie Kapitaikin</i>	88
CHAPTER 8. SUMMARY OF THE POTTERY FINDS..... <i>Mecheal Osband and Michael Eisenberg</i>	210
CHAPTER 9. THE GLASS VESSELS OF THE ROMAN, BYZANTINE AND EARLY ISLAMIC PERIODS..... <i>Mariusz Burdajewicz</i>	276
CHAPTER 10. STUCCO RELIEF DEPICTING MYTHOLOGICAL FIGURES..... <i>Adi Erlich</i>	320
CHAPTER 11. WALL PAINTING AND STUCCO FRAGMENTS..... <i>Silvia Rozenberg</i>	328
CHAPTER 12. POLLEN ANALYSIS..... <i>Patrick Scott-Geyer</i>	370
CHAPTER 13. THE PIG DEPOSIT IN EARLY ISLAMIC HIPPOS..... <i>Rachel Hesse</i>	378

HISTORICAL EARTHQUAKES AROUND THE SEA OF GALILEE

Neta Wechsler, Shmuel Marco

Department of Geosciences, Tel Aviv University

Klaus-G. Hinzen and Hector Hinojosa-Prieto

Cologne University



Geological Background

The archaeological remains of Hippos cover the hill of Sussita, located on the western flank of the Golan Heights, overlooking the Sea of Galilee. The geographical, geological and geomorphological settings of the Sussita region were summarized by Shtober-Zisu (2014). The aim of the summary here is to lay out the background for describing the earthquake effects at the site.

The Sea of Galilee occupies a tectonic depression (graben) that was formed between two branches of the Dead Sea Fault (DSF, Fig. 2.1a). The movement on the DSF commenced about 20 Myrs ago, during the Miocene epoch (Bartov et al., 1980). The interpretation of left-lateral shear along the DSF since the Middle Miocene is based on observations from four independent sources: regional plate tectonics, local geology, seismology, and geodesy. Plate tectonics shows that the opening of the Red Sea, where the Arabian plate breaks away from Africa, is transferred to the collision with Eurasia via a sinistral shear along the DSF (Freund, 1965; Garfunkel, 1981; Joffe and Garfunkel, 1987). Locally, a sinistral motion explains the systematic offset of numerous pre-Miocene geologic features by a total of ~105 km (Bartov et al., 1980; Freund et al., 1968; Quennell, 1956).

Paleoseismic studies show that historic and prehistoric seismicity was associated with sinistral offsets (e.g., Agnon, 2014; Marco and Klinger, 2014). Focal mechanisms of moderate-to-large earthquakes show left-lateral motion along the DSF (Baer et al., 1999; Hofstetter et al., 2007; Klinger et al., 1999; Salamon et al., 2003). Finally, geodetic measurements consistently confirm previous movement estimates of a 4–5 mm/yr left-lateral shear (Le Beon et al., 2008; Masson et al., 2015; Sadeh et al., 2012; Wdowinski et al., 2004). The short term as well as the long-term tectonic regime appears to be stable (Begin et al., 2005; Hamiel et al., 2009).

The hill on which Hippos is built is part of the fault-controlled eastern margin of the Sea of Galilee graben. This graben is one in a series of grabens that are associated with releasing bends along the DSF (Fig. 2.1). There is a striking dissimilarity between the faults to the south and to the north of the Sea of Galilee graben. Two parallel faults are recognized in the southern section, the eastern one bends toward the northeast and the western one bends toward the northwest near the town of Tiberias. Both faults exhibit a large vertical surface expression (Hurwitz et al., 2002). The exact location of the main strike-slip bearing fault south of the graben is unknown but is assumed to coincide with the eastern fault (Hamiel et al. 2016). However, there is no evidence of lateral motion on the current geomorphic expression of either fault. A single fault is recognized at the northern end of the lake—the Jordan Gorge Fault (JGF). There is evidence that this fault alone accommodates most of the lateral movement between the plates, at least during the Holocene epoch (Ellenblum et al., 2015; Wechsler et al., 2014).

The exposed rocks in the vicinity consist largely of pre-DSF Eocene marine carbonates, overlaid by the syn-tectonic basin fill of Miocene to Pleistocene lacustrine and fluvial sediments interspersed by sporadic layers of volcanic origin (basaltic lava flows and tuffs). The sediments lithology consists of clay, marl, chalk, limestone, sandstones and conglomerates. The sedimentary sequence is capped by the Plio-Pleistocene Cover Basalt (Mor, 1993), on top of which the major part of the ancient town of Hippos was built.

The Pleistocene tectonic activity near Sussita is manifested in several geological features. First, the ~3 ma cover basalt in the Sea of Galilee graben is found at about 2500 m depth, using seismic

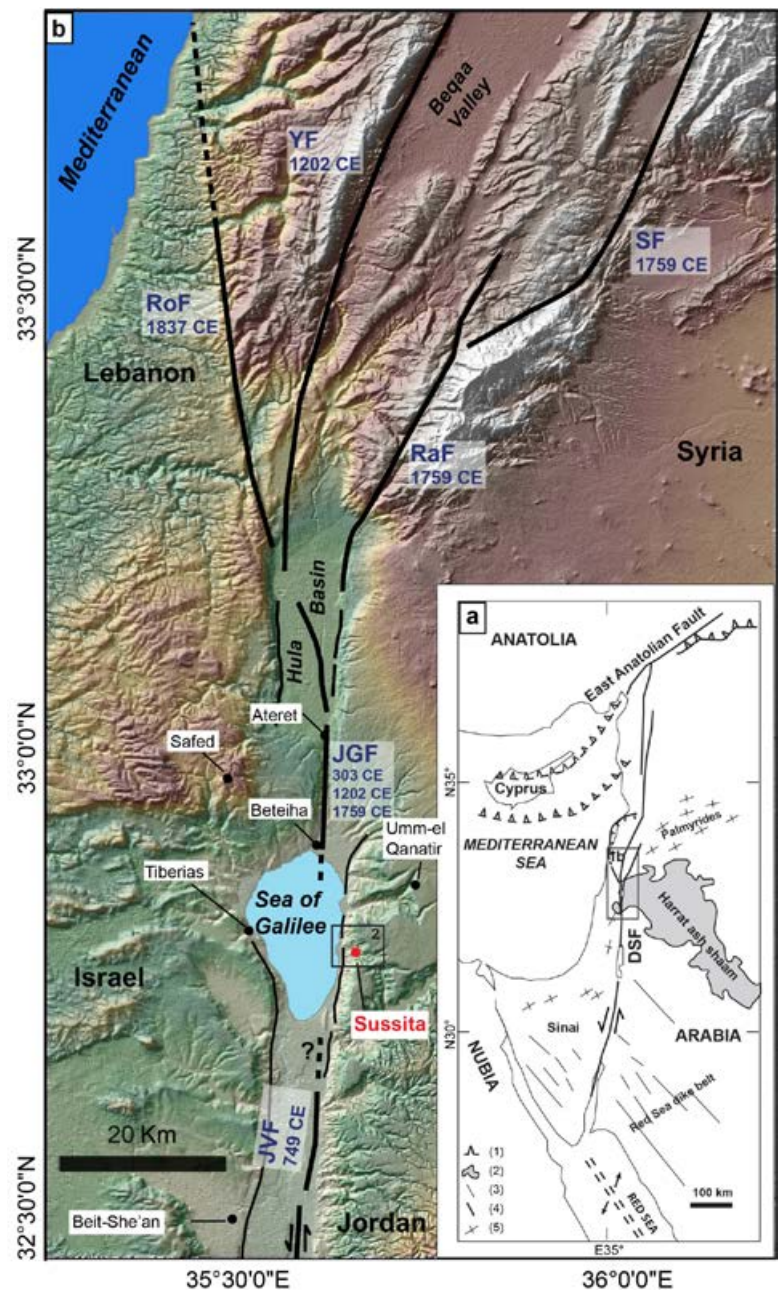


Fig. 2.1 a) Generalized tectonic framework of the Dead-Sea Fault (DSF) and other major structures in the area. The DSF is a left-lateral fault that accommodates the motion between the tectonic plates of Arabia and the Sinai. It transfers the opening at the Red Sea to the Taurus-Zagros collision zone (Freund, 1965; Quennell, 1956). Legend: (1) Collision zones. (2) Cenozoic volcanic. (3) Early Miocene dykes. (4) Plate boundary main faults. (5) Syrian arc folds (after Garfunkel, 1989). The black rectangle marks the extent of Fig. 2.1b. b) Location of major and minor faults of the DST in the vicinity of Hula Basin and the Sea of Galilee. JGF—Jordan Gorge Fault. JVF—Jordan Valley fault. RaF—Rachaya Fault. RoF—Roum Fault. SF—Serghaya Fault. YF—Yammounh fault. Below each fault name, the relevant earthquakes known to have ruptured it are mentioned. The black rectangle marks the extent of the map in Fig. 2.2.

reflection surveys (Ben-Gai, 2010), whereas in the Golan Heights near Sussita it is exposed at the surface at elevations of 200 m and above. Several normal faults that are part of the eastern flank of the Sea of Galilee graben offset the sediments in the vicinity (Fig. 2.2). Additionally, many landslides that are common on the cliffs that surround the Sea of Galilee were triggered by earthquakes (Wechsler et al., 2008; Yagoda-Biran et al., 2010).

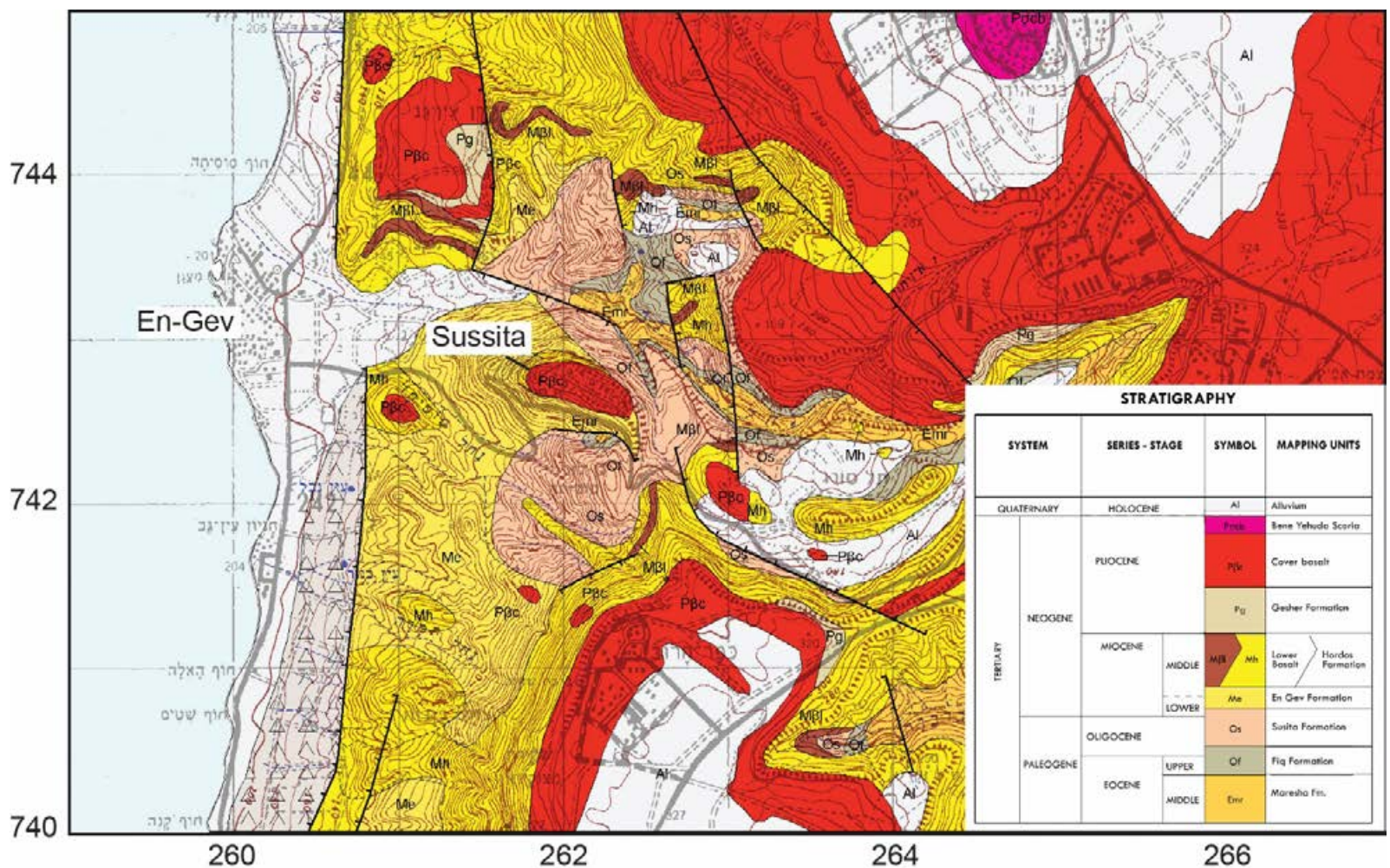


Fig. 2.2 Geological map of Sussita and vicinity, an excerpt from the geological map of Tiberias. The grid is in ITM coordinates.

Earthquake Activity

Several historically known large earthquakes reportedly affected the region around Sussita. Based on the historical, geological, and seismological records, the estimated recurrence interval of moment magnitude (M_w) 6 earthquake is in the order of 10^2 years, increasing to 10^3 years for M_w ~7 earthquakes (Begin et al., 2005). The national seismic building code (S.I.I., 2004) assigns horizontal peak ground acceleration (PGA) of 0.3 g in this region with a 10% probability of exceedance in 50 years.

Historical earthquake catalogues include records of strong earthquake damage in the vicinity of the Sea of Galilee (Ambraseys, 2009; Guidoboni and Comastri, 2005; Guidoboni et al., 1994; Sbeinati et al., 2005). The historically recorded earthquakes that might have affected Hippos occurred during the years 303, 363, 551, 749, 1202, 1759, and 1837 CE.

The 303 earthquake was strongly felt in the Lebanese coastal cities of Sidon and Tyre, causing building collapses and loss of life. The earthquake may have caused damage in Gush-Halav (in the Galilee) and a tsunami in Caesarea. Supporting evidence for this earthquake include an inscription from Byblos that records the name of an earthquake survivor on an altar dedication. Evidence for shaking was found in the Dead Sea sediment cores (Kagan et al., 2011; Migowski et al., 2004) and a contemporaneous surface rupture was mapped in paleoseismic trenches on the north shore of the Sea of Galilee (Wechsler et al., 2014).

The earthquake of 363 occurred during the night of May 18–19, and came in two separate shocks. The earthquake was widely felt and caused extensive damage, from Paneas (Banyas) in the north of Israel to Petra in the south of Jordan.

The earthquake of July 9, 551 was strongly felt along the coast of Lebanon, and triggered a tsunami. Most of the coastal cities of Phoenicia (modern-day Lebanon) were devastated. Tripoli is reported to have “drowned,” and Beirut was destroyed and did not recover for nearly 1300 years afterwards. Paleoseismic and geophysical studies in Lebanon and offshore indicate that the rupture was offshore, on the ~100–150-km-long active, east-dipping Mount Lebanon thrust. The moment magnitude (M_w) is estimated at 7.5 (Elias et al., 2007).

The earthquake of January 18, 749 was a strong event, with extensive damage reported to be centered along the northern part of the Jordan valley. Damage was also reported from Egypt to Turkey and from the Mediterranean coast to Iraq. Various earthquake catalogues list one or more earthquakes that caused severe damage in Egypt, Palestine, Jordan, Syria and Iraq. Several recent authors attributed the different years given in ancient texts to the inconsistent use of diverse calendars and errors in dating the same event of January 18, 749 CE. (Guidoboni et al., 1994; Tsafirir and Foerster, 1989). However, a closer examination of the historical texts shows that the authors relied on questionable sources and that the Byzantine and Arab chronicles and traditions



Fig. 2.3 Photo of the cathedral with the fallen columns, looking west.

clearly reported at least two, possibly three, discrete events up to three years apart and at a distance of hundreds of kilometers from each other (Ambraseys, 2005; Karcz, 2004).

The main earthquake that affected Hippos and the region, that of 749 CE., caused widespread damage, including the destruction of Tiberias and Beit-She'an. There is evidence of surface rupture on the western shore of the Sea of Galilee (Marco et al., 2003) and near Jericho (Reches and Hoexter, 1981) that can be correlated with this earthquake. The synagogue at Umm-el-Qanatir (northeast of Hippos) collapsed and the village surrounding it was abandoned as a result of this earthquake (Wechsler et al., 2008). Hippos as well as other villages in the area were also abandoned at the same time.

The earthquake of May 20, 1202 is probably the strongest one that affected this region in historical times. It was felt at a radius of 500 km, from Egypt in the south to Lesser Armenia in the north, and from Syria in the east to Cyprus in the west. It caused damage in Syria, Lebanon, Jordan and Israel (Ambraseys and Melville, 1988). The surface rupture was recognized in archaeoseismic research at Ateret (Ellenblum et al., 1998; Ellenblum et al., 2015) and geological paleoseismic research at the Jordan Gorge Fault (Marco et al., 2005; Wechsler et al., 2014) and along the Yammouneh fault in Lebanon (Daeron et al., 2005).

During the year 1759, two earthquakes occurred in the region, a moderate one on October 30 and a strong one on November 25. The 0.5 m left-lateral surface rupture of the October event was found in Ateret (Marco et al., 1997) and in the Bet Saida Valley (Marco et al., 2005) north of the Sea of Galilee. The November event was stronger, causing damage in northern Israel, Syria and Lebanon. Some towns such as Tiberias and Quneitra, already suffering destruction from the October event, were obliterated. The extent of damage and reported aftershock locations were centered along the DSF (Ambraseys and Barazangi, 1989; Sieberg, 1932), and the surface rupture was identified in paleoseismic research on the Yammouneh section of the fault in Lebanon (Daeron et al., 2005). Nemer et al. (2008) raise the possibility that the Rachaya and Serghaya faults were the sources of the November 1759 earthquake.

The earthquake of January 1, 1837 was also strongly felt in northern Israel and southern Lebanon, causing severe damage in Tiberias and Safed, and a seiche in the Sea of Galilee. Damage and casualties reports were centered along the Roum fault, the western branch of the DSF in Lebanon, making it the likeliest source for the earthquake (Ambraseys, 1997; Nemer and Meghraoui, 2006).

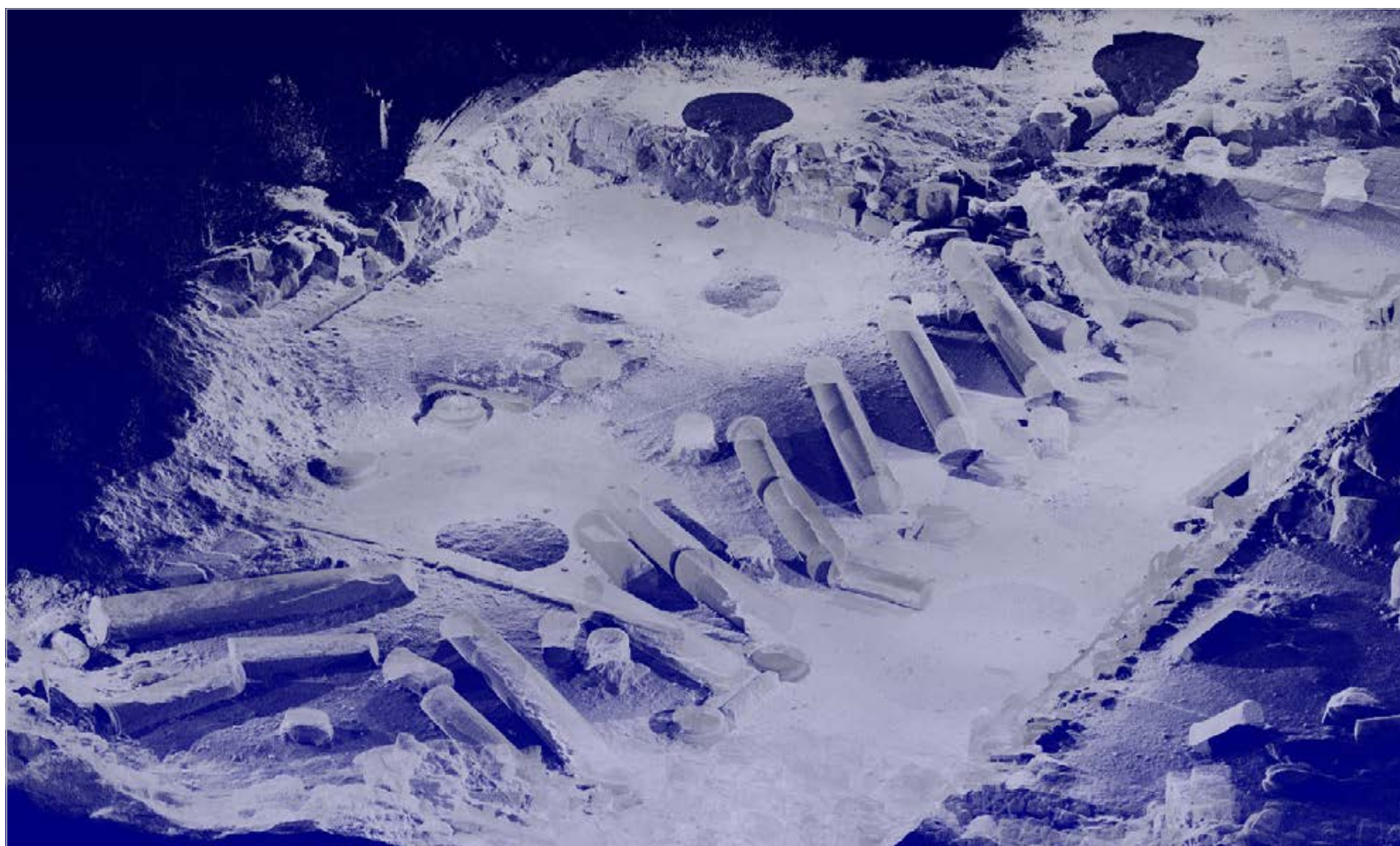


Fig. 2.4 Perspective clear view to a 3D laser scan model of the Cathedral of Hippus with a view from the northeast.

Archaeoseismological Aspects

From the archaeoseismological point of view, Hippus is an interesting and challenging site: (1) It spans more than 2000 years of building history; (2) It is in close proximity to an active plate boundary; (3) It was built at a unique location concerning both with regard to its topography and to the geologic layering of the subsurface; and (4) It includes buildings and structures of a large variety of size and construction techniques. Despite these conditions and the effects of several damaging earthquakes, little geoscientific and engineering seismological work has been done to answer open questions such as how earthquakes may be identified and dated based on the ruins of Hippus, how severe were the effects on the local site, how did they affect damage patterns, and how did the earthquakes influence the settlement history of the site?

In the context of the archaeological findings in Hippus, the fact that the site was partially abandoned during the first half of the 8th century CE points to the 749 CE earthquake as the major cause for its final abandonment. The dismantling of the Odeion during the 4th century CE (Segal, 2014b) may have been the result of it being irreparably damaged by an earthquake, perhaps by those of 303 or 363 CE. The destruction of the Roman Basilica built in the center of the city at the end of the 1st century CE is clear evidence for the 363 CE earthquake judging by the archaeological data (Eisenberg, 2016; Segal, 2014a). The latest coins found in-between the fallen architectural fragment and the basilica floor are dated to 362 CE while the floor built above its debris is dated to the 380s CE. It is possible that some of the later, strong, post-abandonment earthquakes caused some additional damage at the site.

The Cathedral, built in 590 CE (Łatjar, 2014), continued to function until the mid-8th century (Segal, 2007) making the 749 CE earthquake the causative one for the destruction of this basilica. The remaining columns of the Cathedral were unearthed in the 1950s lying on the floor of the building in subparallel directions. The original structure was a mono-apsidal basilica with an inscribed apse and two rows of nine columns with an average preserved height of 5 m, which separated the nave from the aisles. The columns were made of different types of colored marble and granite, which are not found locally in the region of Israel. Several column bases have a central hole and lead channel and others are without such holes. While the nine columns of the northern row are oriented $N220^{\circ}E (\pm 10^{\circ})$, the two remaining columns of the southern row are oriented $N295^{\circ}E (\pm 10^{\circ})$. This configuration was immediately interpreted as an indication of toppling by earthquake ground motions (Epstein, 1993). The spectacular setting (Fig. 2.3) even resulted in a display on the cover of the textbook 'Archaeoseismology' (Stiros and Jones, 1996). In the figure caption of this photo, the fallen columns of the Cathedral are wrongly linked to a "Roman structure" and to the 363 CE earthquake, and the column orientation was believed to indicate the direction of strong ground motion. Later, Nur and Burgess (2008) linked the columns to the 749 CE earthquake and remarked on the agreement between the toppling direction and the general movement of the Arabian Plate. Since the Cathedral was constructed only in 590 CE it cannot be assumed that it could have been destroyed during the 363 CE earthquake (Łatjar, 2014).

The Cathedral is, so far, the only structure that has been at the center of quantitative archaeoseismic studies. Yagoda-Biran et al. (2010) tried to estimate minimum levels of peak ground acceleration (PGA) during

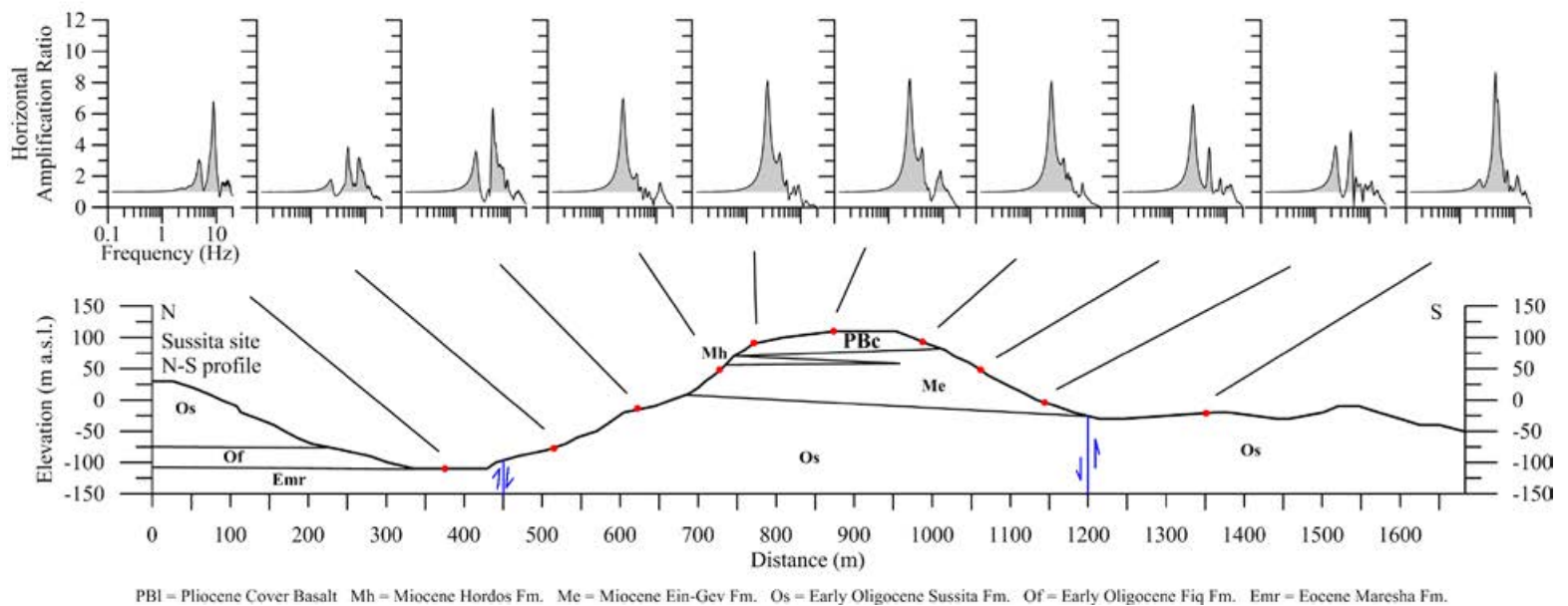


Fig. 2.5 Simplified north-south trending geological profile through the saddle-like structure of the Sussita hill. On top of the profile, a frequency-dependent seismic amplification is shown which was derived for ten one-dimensional linear elastic models of the subsurface. Abbreviations for the geologic units are given at the bottom of the figure.

the earthquake ground motion which was necessary to topple the Cathedral columns. However, they used the model of a freestanding column of the same size as the ones found in the Cathedral, but with no capital, architrave or other superstructure. Since 2D models were used and forces were applied to the center of gravity of the columns and pedestals, the reported 0.2–0.4 m/s² PGA threshold at frequencies between 0.2 and 4.4 Hz can only be regarded as a rough estimate and are not necessarily representative for the complete structure of the Cathedral which has a significantly different response to earthquake ground motions than a solitary column.

Hinzen (2009) used 3D discrete element models conforming to the size of the toppled columns of the Cathedral and showed that the toppling direction during a realistic earthquake ground motion in three dimensions is a matter of chance. A column that is being rocked by earthquake ground motions is in a nonlinear dynamic system and its behavior tends to be of a chaotic character. Small changes to the initial conditions can have a strong influence on the general dynamic reaction and significantly alter the toppling direction. The same paper shows that the parallel orientation is probably an effect of the superstructure connecting the columns mechanically and not a consequence of the ground motion character. This interpretation is also strongly supported

by the fact that the two remaining columns of the southern row rest at angles of ~90° compared with the columns from the northern row, as shown in a 3D laser scan model of the site (Fig. 2.4). A similar analysis of the Hippos columns was performed by Hinzen (2010).

The saddle-like structure of the Sussita hill is prone to topographic amplification of strong ground motion during earthquakes, especially at the hilltop. The focusing effects of seismic waves in similar situations have been reported to lead to significant ground motion amplification (e.g., Massa et al., 2010). In the case of Hippos, the special geometry of the hill is combined with the unusual situation of high impedance material in the form of a basalt flow on top of weaker conglomerates. Figure 2.5 shows a simplified north-south trending profile through the site and the neighboring valleys of Ein-Gev and Sussita. Estimates of ground motion amplification of vertically traveling shear waves from 1D model calculations indicate amplification factors at the hilltop in the range of 8 at frequencies of 2–3 Hz, a frequency range at which constructions such as colonnades show high vulnerability. In any further archaeoseismic studies of the damaged structures in Hippos, the exceptional location of the site and the local conditions must be taken into account.

Bibliography

- Agnon, A.
2014 Pre-Instrumental Earthquakes Along the Dead Sea Rift, in Garfunkel, Z., Ben-Avraham, Z., and Kagan, E., eds., *Dead Sea Transform Fault System: Reviews*, V. 6, p. 207–261.
- Ambraseys, N.
1997 The earthquake of 1 January 1837 in southern Lebanon and northern Israel: *Annali di Geofisica*, v. 40, p. 923–935.
- Ambraseys, N. N.
2005 The seismic activity in Syria and Palestine during the Middle of the 8th century; an amalgamation of historical earthquakes: *Journal of Seismology*, v. 9, no. 1, p. 115–125.
- 2009 *Earthquakes in the Mediterranean and Middle East: A Multidisciplinary Study of Seismicity up to 1900*, Cambridge, Cambridge University Press.
- Ambraseys, N. N. and Barazangi, M.
1989 The 1759 earthquake in the Bekaa valley: Implications for earthquake hazard assessment in the eastern Mediterranean region: *J. Geophys. Res.*, v. 94, no. B4, p. 4007–4013.
- Ambraseys, N. N., and Melville, C. P.
1988 An analysis of the eastern Mediterranean earthquake of 20 May 1202, in Lee, W. K. H., Meyers, H., and Shimazaki, K., eds., *Historical Seismograms and Earthquakes of the World*: San Diego, California, Academic Press, p. 181–200.

- Baer, G., Sandwell, D., Williams, S., Bock, Y. and Shamir, G.
1999 Coseismic deformation associated with the November 1995, Mw = 7.1 Nuweiba earthquake, Gulf of Elat (Aqaba), detected by synthetic aperture radar interferometry: *J. Geophys. Res.*, v. 104, no. B11, p. 25, 221–225, 232.
- Bartov, Y., Steinitz, G., Eyal, M. and Eyal, Y.
1980 Sinistral movement along the Gulf of Aqaba—its age and relation to the opening of the Red Sea: *Nature*, v. 285, p. 220–221.
- Begin, B. Z., Steinberg, D. M., Ichinose, G. A. and Marco, S.
2005 A 40,000 years unchanging of the seismic regime in the Dead Sea rift: *Geology*, v. 33, no. 4, p. 257–260.
- Ben-Gai, Y.
2010 Subsurface geology of the southern Lake Kinneret (Sea of Galilee), Dead Sea Transform—Evidence from seismic reflection data: *Isr. J. Earth Sci.*, v. 58, p. 163–175.
- Daeron, M., Klinger, Y., Tapponnier, P., Elias, A., Jacques, E. and Surssock, A.
2005 Sources of the large AD1202 and 1759 Near East earthquakes: *Geology*, v. 33, no. 7, p. 529–532.
- Eisenberg, M.
2016 Hippos-Sussita: From a Polis in the Decapolis to a Declining Town: *Qadmoniot* v. 151, p. 2–17 (Heb.).
- Elias, A., Tapponnier, P., Singh, S. C., King, G. C. P., Briais, A., Daëron, M., Carton, H., Surssock, A., Jacques, E., Jomaa, R. and Klinger, Y.
2007 Active thrusting offshore Mount Lebanon: Source of the tsunamigenic A.D. 551 Beirut-Tripoli earthquake: *Geology*, v. 35, no. 8, p. 755–758.
- Ellenblum, R., Marco, S., Agnon, A., Rockwell, T. and Boas, A.
1998 Crusader castle torn apart by earthquake at dawn, 20 May 1202: *Geology*, v. 26, no. 4, p. 303–306.
- Ellenblum, R., Marco, S., Kool, R., Davidovitch, U., Porat, R. and Agnon, A.
2015 Archaeological reconstruction of earthquake ruptures in Tell Ateret, the Dead Sea Fault: *Tectonics*, v. 34, no. 10, p. 2105–2117.
- Epstein, C.
1993 Hippos (Sussita), in Stern, E., Lewinson-Gilboa, A. and Aviram, J., eds., *Encyclopedia of archaeological excavations in the Holy Land*: Jerusalem, The Israel Exploration Society, p. 634–636.
- Freund, R.
1965 A model of the structural development of Israel and adjacent areas since Upper Cretaceous times: *Geol. Mag.*, v. 102, p. 189–205.
- Freund, R., Zak, I. and Garfunkel, Z.
1968 Age and rate of the sinistral movement along the Dead Sea Rift: *Nature*, v. 220, p. 253–255.
- Garfunkel, Z.
1981 Internal structure of the Dead Sea leaky transform (rift) in relation to plate kinematics: *Tectonophysics*, v. 80, p. 81–108.
- Guidoboni, E. and Comastri, A.
2005 *Catalogue of Earthquakes and Tsunamis in the Mediterranean Area from the 11th to the 15th Century*, Bologna, Istituto Nazionale di Geofisica.
- Guidoboni, E., Comastri, A. and Traina, G.
1994 *Catalogue of Ancient Earthquakes in the Mediterranean Area up to the 10th Century*, Bologna, Istituto Nazionale di Geofisica.
- Hamiel, Y., Amit, R., Begin, Z. B., Marco, S., Katz, O., Salamon, A., Zilberman, E. and Porat, N.
2009 The seismicity along the Dead Sea Fault during the last 60,000 years: *Seismological Society of America*, v. 99, no. p. 2020–2026.
- Hinzen, K.-G.
2009 Simulation of toppling columns in archaeoseismology: *Bulletin of the Seismological Society of America*, v. 99, no. 5, p. 2855–2875.
2010 Sensitivity of earthquake toppled columns to small changes in ground motion and geometry. *Israel Journal of Earth Sciences*, v. 58, p. 309–326.
- Hofstetter, R., Klinger, Y., Amrat, A. Q., Rivera, L. and Dorbath, L.
2007 Stress tensor and focal mechanisms along the Dead Sea fault and related structural elements based on seismological data: *Tectonophysics*, v. 429, no. 3–4, p. 165–181.
- Hurwitz, S., Garfunkel, Z., Ben-Gai, Y., Reznikov, M., Rotstein, Y. and Gvirtzman, H.
2002 The tectonic framework of a complex pull-apart basin: seismic reflection observations in the Sea of Galilee, Dead Sea transform: *Tectonophysics*, v. 359, no. 3–4, p. 289–306.
- Joffe, S. and Garfunkel, Z.
1987 Plate kinematics of the circum Red Sea- a re-evaluation: *Tectonophysics*, v. 141, p. 5–22.
- Kagan, E., Stein, M., Agnon, A. and Neumann, F.
2011 Intrabasin paleoearthquake and quiescence correlation of the late Holocene Dead Sea: *J. Geophys. Res.*, v. 116, no. B4, p. B04311.
- Karcz, I.
2004 Implications of some early Jewish sources for estimates of earthquake hazard in the Holy Land: *Annals of Geophysics*, v. 47, no. 2–3, p. 759–792.
- Klinger, Y., Rivera, L., Haessler, H. and Maurin, J. C.
1999 Active faulting in the Gulf of Aqaba: New knowledge from the Mw7.3 earthquake of 22 November 1995: *Bull. Seism. Soc. Am.*, v. 89, no. 4, p. 1025–1036.
- Le Beon, M., Klinger, Y., Amrat, A. Q., Agnon, A., Dorbath, L., Baer, G., Ruegg, J. C., Charade, O. and Mayyas, O.
2008 Slip rate and locking depth from GPS profiles across the southern Dead Sea Transform: *Journal of Geophysical Research-Solid Earth*, v. 113, no. B11.
- Marco, S., Agnon, A., Ellenblum, R., Eidelman, A., Basson, U. and Boas, A.
1997 817-year-old walls offset sinistrally 2.1 m by the Dead Sea Transform, Israel: *Journal of Geodynamics*, v. 24, no. 1–4, p. 11–20.
- Marco, S., Hartal, M., Hazan, N., Lev, L. and Stein, M.
2003 Archaeology, history, and geology of the A.D. 749 earthquake, Dead Sea transform: *Geology*, v. 31, no. 8, p. 665–668.
- Marco, S. and Klinger, Y.
2014 Review of On-fault Palaeoseismic Studies Along the Dead Sea Fault, in Garfunkel, Z., Ben-Avraham, Z. and Kagan, E.

- J., eds., *Dead Sea Transform Fault System: Reviews*, Volume 6: Dordrecht, Springer, p. 183–206.
- Marco, S., Rockwell, T., Heimann, A., Frieslander, U. and Agnon, A.
2005 Late Holocene activity of the Dead Sea Transform revealed in 3D palaeoseismic trenches on the Jordan Gorge segment: *Earth and Planetary Science Letters*, v. 234, no. 1–2, p. 189–205.
- Massa, M., Lovati, S., D’Alema, E., Ferretti, G. and Bakavoli, M.
2010 An Experimental Approach for Estimating Seismic Amplification Effects at the Top of a Ridge, and the Implication for Ground-Motion Predictions: The Case of Narni, Central Italy: *Bulletin of the Seismological Society of America*, v. 100, no. 6, p. 3020–3034.
- Masson, F., Hamiel, Y., Agnon, A., Klinger, Y. and Deprez, A.
2015 Variable behavior of the Dead Sea Fault along the southern Arava segment from GPS measurements: *Comptes Rendus Geoscience*, v. 347, no. 4, p. 161–169.
- Migowski, C., Agnon, A., Bookman, R., Negendank, J. F. W. and Stein, M.
2004 Recurrence pattern of Holocene earthquakes along the Dead Sea transform revealed by varve-counting and radiocarbon dating of lacustrine sediments: *Earth and Planetary Science Letters*, v. 222, no. 1, p. 301–314.
- Mor, D.
1993 A time-table for the levant volcanic province, according to K-Ar dating in the golan heights, Israel: *Journal of African Earth Sciences (and the Middle East)*, v. 16, no. 3, p. 223–234.
- Nemer, T. and Meghraoui, M.
2006 Evidence of coseismic ruptures along the Roum fault (Lebanon): a possible source for the AD1837 earthquake: *Journal of Structural Geology*, v. 28, no. 8, p. 1483–1495.
- Nemer, T., Meghraoui, M. and Khair, K.
2008 The Rachaya-Serghaya fault system (Lebanon): Evidence of coseismic ruptures, and the AD1759 earthquake sequence: *J. Geophys. Res.*, v. 113, no. B5, p. B05312.
- Nur, A. and Burgess, D.
2008 *Apocalypse: earthquakes, archaeology and the wrath of god*, Princeton University Press.
- Quennell, A. M.,
Tectonics of the Dead Sea rift, in *Proceedings Congreso Geológico Internacional*, 20th session, Asociación de Servicios Geológicos Africanos, Mexico City, 1956, p. 385–405.
- Reches, Z. and Hoexter, D. F.
1981 Holocene seismic and tectonic activity in the Dead Sea area: *Tectonophysics*, v. 80, p. 235–254.
- Sadeh, M., Hamiel, Y., Ziv, A., Bock, Y., Fang, P. and Wdowinski, S.
2012 Crustal deformation along the Dead Sea Transform and the Carmel Fault inferred from 12 years of GPS measurements: *Journal of Geophysical Research: Solid Earth*, v. 117, no. B8, p. B08410.
- Salamon, A., Hofstetter, A., Garfunkel, Z. and Ron, H.
2003 Seismotectonics of the Sinai subplate—the eastern Mediterranean region: *Geophysical Journal International*, v. 155, no. 1, p. 149–173.
- Sbeinati, M. R., Darawcheh, R. and Mouty, M.
2005 The historical earthquakes of Syria: an analysis of large and moderate earthquakes from 1365 B.C. to 1900 A.D.: *Annals of Geophysics*, v. 48, no. 3, p. 347–435.
- Segal, A.
2007 The Churches of Sussita: Interim Report at the End of Seven Excavation Seasons (2000–2006), <http://hippos.haifa.ac.il/hipposchurches.htm>.
- 2014a Basilica, in Segal, A., Eisenberg, M., Mlynarczyk, J., Burdajewicz, M. and Schuler, M., *Hippos—Sussita of the Decapolis: The First Twelve Seasons of Excavations (2000–2011), Volume I*: Haifa: The Zinman Institute of Archaeology, University of Haifa, p. 164–181.
- 2014b Odeion, in Segal, A., Eisenberg, M., Mlynarczyk, J., Burdajewicz, M. and Schuler, M., *Hippos—Sussita of the Decapolis: The First Twelve Seasons of Excavations (2000–2011), Volume I*: Haifa: The Zinman Institute of Archaeology, University of Haifa, p. 182–193.
- Shtober-Zisu, N.
2014 The Geographical, Geological and Geomorphological Settings of the Sussita Region, in Segal, A., Eisenberg, M., Mlynarczyk, J., Burdajewicz, M. and Schuler, M., *Hippos—Sussita of the Decapolis: The First Twelve Seasons of Excavations (2000–2011), Volume I*: Haifa: The Zinman Institute of Archaeology, University of Haifa, p. 35–39.
- Sieberg, A.
1932 *Erdbebengeographie, Handbuch der Geophysik*, Band IV: Berlin, Borntraeger, p. 527–1005.
- Stiros, S. and Jones, R. E.
1996 *Archaeoseismology*, in Whitbread, I. K., ed.: Athens, Institute of Geology & Mineral Exploration, and The British School at Athens, p. 268.
- Tsafir, Y. and Foerster, G.
1989 The date of the earthquake of the ‘Seventh Year’: *Tarbiz*, v. 58, p. 357–362.
- Wdowinski, S., Bock, Y., Baer, G., Prawirodirdjo, L., Bechor, N., Naaman, S., Knafo, R., Forrai, Y. and Melzer, Y.
2004 GPS Measurements of current crustal movements along the Dead Sea Fault: *J. Geophys. Res.*, v. 109, no. B05403, p. 1–16.
- Wechsler, N., Katz, O., Dray, Y., Gonen, I. and Marco, S.
2008 Estimating location and size of historical earthquake by combining archaeology and geology in Umm-El-Qanatir, Dead Sea Transform: *Natural Hazards*, v. 50, p. 27–43.
- Wechsler, N., Rockwell, T. K., Klinger, Y., Štěpančíková, P., Kanari, M., Marco, S. and Agnon, A.
2014 A Paleoseismic Record of Earthquakes for the Dead Sea Transform Fault between the First and Seventh Centuries C. E.: Nonperiodic Behavior of a Plate Boundary Fault: *Bulletin of the Seismological Society of America*, v. 104, no. 3, p. 1329–1347.
- Yagoda-Biran, G., Hatzor, Y. H., Amit, R. and Katz, O.
2010 Constraining regional paleo peak ground acceleration from back analysis of prehistoric landslides: Example from Sea of Galilee, Dead Sea transform: *Tectonophysics*, v. 490, no. 1–2, p. 81–92.

