HOLIDAY GEOLOGY

Earthquakes, ancient and modern, in the region of the Dead Sea Rift

The Dead Sea Rift lies between the Sinai and Arabian plates on a transform fault about 1000 km long, linking the Red Sea spreading boundary with the continental collision zone of the Taurus-Zagros mountains. A family of faults was formed in the Cenozoic and there is about 105 km of sinistral displacement of the Arabian plate. Several pull-apart basins developed along the Rift, and the Dead Sea basin is one of the largest and deepest, bounded by the Jordan and Arava strike-slip faults.

Depressions within the trough are filled by Neogene and Quarternary sediments, mainly fluvial and lacustrine, overlying marine evaporites. The most extensive of the paleo-lakes, Lake Lisan, the precursor of the Dead Sea, reached about 220 km from the Sea of Galilee in the north to Arava in the south from about 60,000 years until 18,000 years BP. There was then almost complete desiccation (Begin et al, 1974), before the water level rose again to form the Dead Sea. During its highest stand, Lake Lisan reached about 200 m above the modern level of the Dead Sea and covered most of the marginal faults. Its deposits, the Lisan formation, consist of soft marls with alternating laminae, a few mm thick, of white aragonite and darker detrital material containing fine grained calcite, dolomite, aragonite, quartz and clays. These varve-like paired laminae are thought to be seasonal precipitates of aragonite in summer with darker detrital flood inputs in the winter.

The combination of a seismically active region with unconsolidated sediments, which can amplify the seismic effects, provides archaeological and geological evidence of historical and pre-historical earthquakes. The region has been populated for thousands of years and there are records throughout the period, of seismic events. These range from the mythical and religious writings of the early inhabitants to recent seismological records. A study of 4000 years of historical records concludes that the mean return period of strong earthquakes along the Arava, Dead Sea and Jordan River Valley section of the Rift is about 1500 years (Ben-Menahem, 1981).

The earthquake record

Modern earthquakes are well documented. Seismological observations in the area show that large events align with the traces of those transform faults with a predominantly sinistral movement. Micro-seismicity occurs over a wide area, with both normal and strike-slip faulting (Marco et al, 1996).The last major earthquake (M 6.2) struck the area in 1927, from an epicentre about 25 km south of Jericho, and caused many casualties with widespread damage in Nablus, Bethlehem and Jerusalem (Fig. 1).

Historical earthquakes are interpreted from biblical accounts, and seismic phenomena may underlie some of the well-known stories in the Bible. There is geological evidence that the destruction of Sodom and Gomorrah (Genesis 19: 24-28) resulted from an earthquake in the Dead Sea area (Neev & Emery, 1995). This involved the bituminous marls and limestones of the late Cretaceous that were buried within the rift, as well as overlying organic-rich, poorly consolidated sediments of the Dead Sea Group, producing seismic epiphenomena with an outburst of smoke and a rain of sulphurous fire. The structural geology and geotechnical properties of near-surface sediments may be related to seismicity, and it has been suggested that the cities of Sodom and Gomorrah were located near the Lisan Peninsula, and their destruction was due to earthquake-induced liquefaction in the poorly consolidated sediments (Harris & Beardow, 1995). The cities' disappearance beneath the waters of the north basin may be the first recorded liquefaction event in Judaeo-Christian history, and a tsunami-like wave stranding a block of salt on the newly formed shoreline may have given rise to the story of Lot`s wife!

***Figure 1**. Remains of the Winter Palace Hotel in Jericho, after the 1927 earthquake.*

Prehistoric earthquakes are interpreted from evidence within the Lisan Marls. In the area about 2 km east of Masada, deep canyons about 50 m deep give good exposures in the Lisan marls (Fig. 2), where earthquake deformations and sedimentary structures are well preserved. Decollements with separation of microfolds from undisturbed subjacent laminae are prominent though individually limited in areal extent (Fig. 3) and these have been ascribed to minor seismic events. Larger and more widespread mixed layers of pulverized and fragmented laminae occur in association with syndepositional faults of about 0.5 m vertical slip; they have been attributed to slip events on the faults, producing major earthquakes, of M > 5.5, with total disruption of beds at the sediment water interface (Marco & Agnon, 1996). The sedimentary record indicates a mean recurrence rate of ~1600 years for historical earthquakes of such magnitude, a figure comparable with that estimated for recent earthquakes.

Archaeological sites with earthquake impacts

For the interested geotourist, there is evidence of earthquakes during the historical period that may easily be viewed at the many archaeological sites along Highway 90, which lies along the Jordan Valley and the Dead Sea shore.

Bet Shean was an important site of population for 6000 years, becoming a Roman city and the capital of the province of Palestina Secunda. A major earthquake in AD 363 destroyed the Roman city, though Byzantine builders reutilised the Roman stones and columns, and the city was destroyed again in AD 749 by another earthquake. The collapsed main street of Bet Shean remained untouched after this event, until recent excavations exposed fallen columns lying in a general northwesterly direction, which is interpreted as the orientation of seismic first motions (Fig. 4). Enthusiastic reconstruction of the old city by Israeli authorities will soon remove the splendid confusion of the seismic shock aftermath.

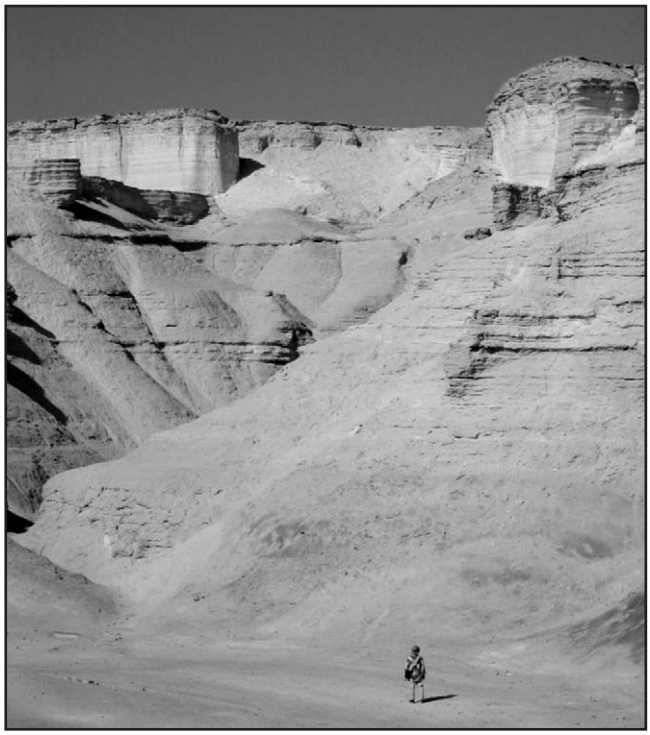

***Figure 2**. Deep canyons with walls up to 50 m high cut through the soft Lisan marls at Masada.*

***Figure 3**. The Lisan Marls show mm-thick banding of aragonite and detrital layers which have been folded and detached from subjacent laminae before being overlain by undeformed layers.*

Jericho has been inhabited for more than 10,000 years. The eastern edge of the ancient Tel is sited by the Spring of Elisha, which rises from its limestone aquifers through the fractured rocks of the East Jericho normal fault. Jericho offered major advantages for settlement and farming, but also a disadvantage for the fortifications that have collapsed several times through earthquakes. It is possible that the collapse of the walls during the siege by Joshua (Joshua 6: 1-16) followed an earthquake since it was associated with an earlier failure of flow in the Jordan River (Joshua 3: 13-16); this may have been due to primary seismic effects, in tilting or subsidence, or due to damming upstream by mudslides as occurred in 1927 (Nur & Ron, 1996). About 5 km north of Jericho, Hisham`s Palace was partially destroyed by an earthquake in AD748 while still under construction. This was probably the strongest seismic event in Palestine in the last 2500 years, with estimated magnitude of M>7 (Ben-Menahem, 1981). Distortion of the building structures from rectangular to rhomboidal shape was due to sinistral shearing stress between two faults with similar trends (Reches & Hoexter, 1981), and not as previously ascribed by archaeologists to shoddy builders and surveyors.

***Figure 4**. Fallen columns in the main street of the old city of Bet Shean, which was totally destroyed in AD 749 but is now being reconstructed.*

Qumran, on the northwest shore of the Dead Sea, was the home of the Essenes, an ascetic sect who paid great attention to ritual bathing and purity, and included the authors of the Dead Sea Scrolls. Clean living was, alas, no safeguard. In 31BC, an earthquake destroyed buildings and in particular ruptured the vital water system, forcing the inhabitants to abandon the site. Archaeologists have exposed faulted stairs in the cistern (Neev & Emery, 1995; Nur & Ron, 1996).

Masada is a fortress built on a horst of the rift margin halfway along the Dead Sea flank, and is the site of the alleged mass suicide of its defenders against the Romans. Tilted walls, disturbed floors and aligned fallen masonry are ascribed to earthquake damage of the first century (Karcz et al, 1977), but it is difficult to distinguish this from military action and the depredations of later occupants. Better evidence of seismic effect may be seen in the storehouse walls which have collapsed as a unit (Nur & Hagi, 1996).

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