ARCHAEOSEISMOLOGY

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Front cover: Fallen colums of the 5th century BC Temple of Zeus at Olympia (W. Peloponnese) with a characteristic domino-style arrangement of its drums. The temple was destroyed by an earthquake, probably in the Byzantine period. See article by S. Stiros. (Photo: I. K. Whitbread)

Back cover: The site of Susita (Lake of Galilee) is situated close to the surface trace of the Dead Sea Transform. Granite columns from a Roman palace complex have fallen parallel to each other and testify to an earthquake, probably that of AD 363, which caused destruction in the wider area. The direction in which the columns are lying is believed to indicate the direction of the strong seismic motion. See article by A. Nur and H. Ron. (Photo: A. Nur)

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Prehistoric Earthquakes and their Consequences, as Preserved in Holocene Sediments from Volos and Argos, Greece

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Examination of Holocene deposits in auger cores and construction trenches provides clues for tectonic movements in prehistory (Zangger, 1991). One auger core traverse between Neolithic Dimini and the present coast of **Volos** in Central Greece revealed, firstly, that the sea used to extend *c.* 2.5 km farther inland extending almost to the site of ancient Dimini. Secondly, the Holocene stratigraphy indicated a subsidence of the central plain of 3.1 m due to block tectonic movements. The Gulf of Volos has been notorious for earthquakes at least during the last few centuries (Schneider 1968, 72; Papazachos *et al.,* 1983). Most of these are attributable to offsets along a major E-W striking normal fault stretching from Volos to Velestinon. Another normal fault, however, runs parallel to the first one on the southern side of the Gulf of Volos from Pevkakia-Magoula to Paliouri (Ferrière, 1982); this fault was crossed by the auger core traverse shown in Fig. 1. The displacement of Holocene deposits occurred in two steps: the first one resulted in 1.7 m subsidence before 3000 BP; the second movement of 1.4 m must have occurred *c.* 1000 years ago (Fig. 2). The core stratigraphy provides no hints that would indicate whether these displacements happened suddenly, in which case they would have been accompanied by earthquakes, or whether they took place in the form of slow creep which is also known from Greece (Billiris *et al.*, 1991). Since Volos, however, constitutes one of the most earthquake-prone regions in Europe, these offsets as recorded in the Holocene sediments were most likely accompanied by strong earthquakes in prehistoric and historic times.

In the **Argive Plain** in southern Greece, earthquake damage has been recognized in archaeological excavations at Mycenae, Tiryns and Midea, but no quakes are reported in historic records. Once again, auger cores from the coastal plain provide evidence for active tectonic movement in the form of uplift of the Arcadian mountains on the western side of the Argolid. The main fault extends N-S from Argos to Lerna; its offshore continuation has been detected during a marine shallow-seismic survey of the Gulf of Argos (van Andel *et al.*, 1990). The fault displaced the Pleistocene red beds at the bottom of the stratigraphy as well as a superimposed Early Bronze Age alluvium (Fig. 3). Movement rates amounted to 2.5 m in 5000 years averaging 0.5 m per 1000 years (Finke 1988, 103). This observation was confirmed by a pipeline construction trench, 1.5 km long and 6 m deep. In this exposure, the displacement of the Early Bronze Age alluvium, sandwiched between two layers of lacustrine deposits from ancient Lake Lerna, turned out to be more complex than recognizable in auger cores. The offset, though very pronounced in the schematic core cross sections, is hardly discernible by just looking at an outcrop without using instruments. The steep angle of the faults in Figs 1–4 results from 40–50x vertical exaggeration.

Finally, on the opposite side of the Argive Plain, around Tiryns, an unusual ephemeral flood was found in the Holocene stratigraphy which accumulated up to 5 m of alluvium, especially E of Tiryns. This flood would

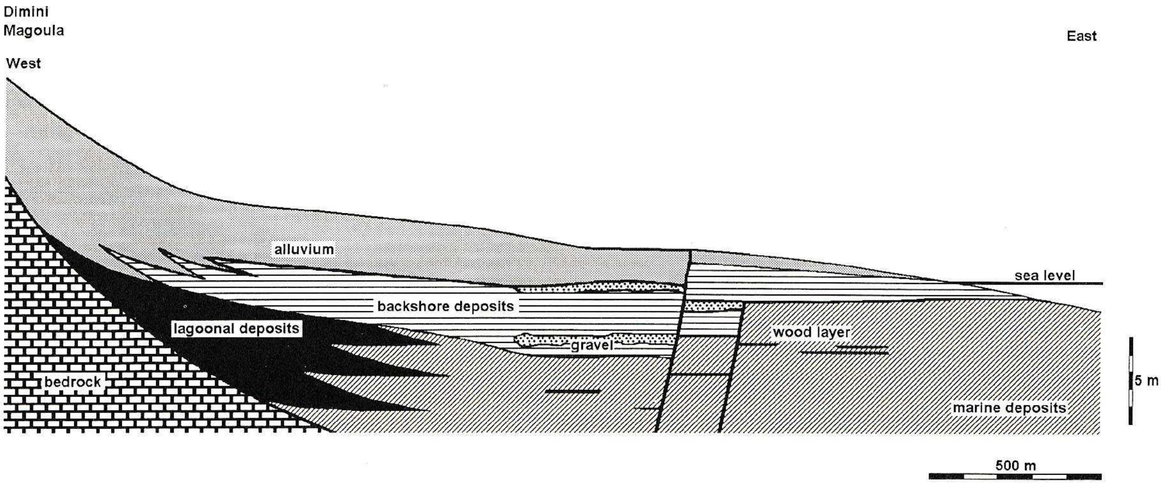

Figure 1. Auger core section across the floodplain of Volos. The bottom layer consists of fine-grained reduced marine deposits extending to the base of Dimini, where they develop a lagoonal character (clay-rich, grey color, abundant organic material). The marine mud is covered by silty backshore deposits and floodplain alluvium laid down by ephemeral stream floods. A normal fault can be seen in the profile, displacing the deposits, including a gravel layer and a wood layer.

have occurred 'simultaneously', that is given an error margin of *c.* 30 years for LH III pottery dating, with an earthquake around 1200 BC, as detected in archaeological excavations. But there are no indications for considerable tectonic displacement on this side of the Argive Plain. An Eu-Tyrrhenian beach-conglomerate including shells of *Strombus bubonius,* and thus dating to the last interglacial sea level maximum at *c.* 115,000 BP, is exposed on the northern side of Nauplion at 2 m above present sea level, precisely at the elevation where it must have been deposited. Similar results were obtained from power holes drilled on the eastern side of the Argive Plain. Thus, this area seems to have been tectonically stable at least for the last 100,000 years. Nevertheless, the Bronze Age sites could, of course, have been damaged during an earthquake which accompanied movement along the fault on the western side of the plain. Even in that case one would still need to determine how the earthquake could have caused an ephemeral flood. It may have triggered a landslide, rendering loose material for further downstream transport by a perennial river. On the other hand, the Mycenaean dam E of Tiryns, built in its present form after the flash flood, may have had a predecessor that collapsed during the earthquake at 1200 BC.

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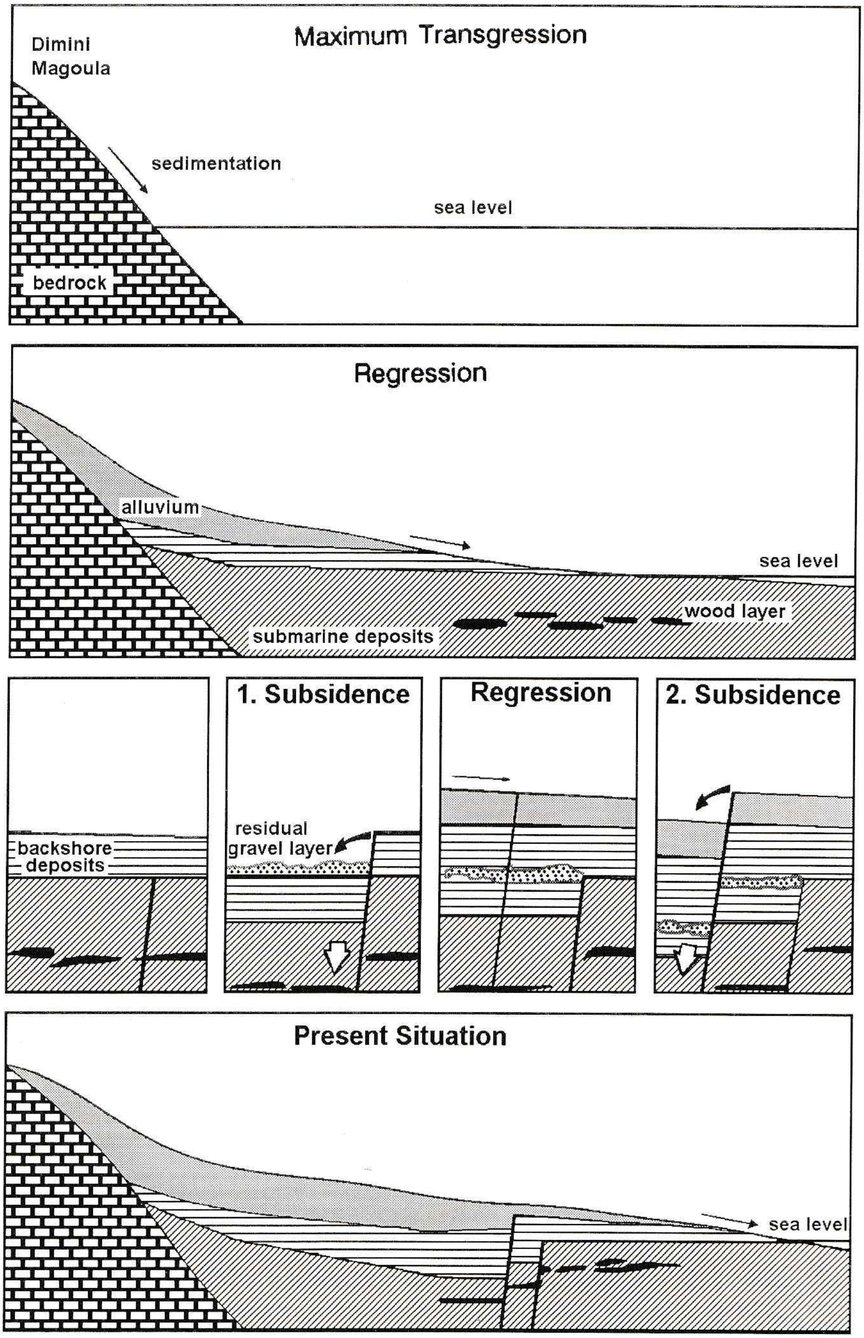

Figure 2. Depositional history of Dimini Bay. During the maximum transgression in the Neolithic, the sea stretched landward to Dimini. Soil erosion and redeposition caused a swift regression. When the first subsidence took place, the marine mud was already covered by back-shore deposits. The regression continued after the faulting. During the second subsidence a residual gravel layer originating from the first off-set and the floodplain alluvium was displaced (after Finke, 1984).

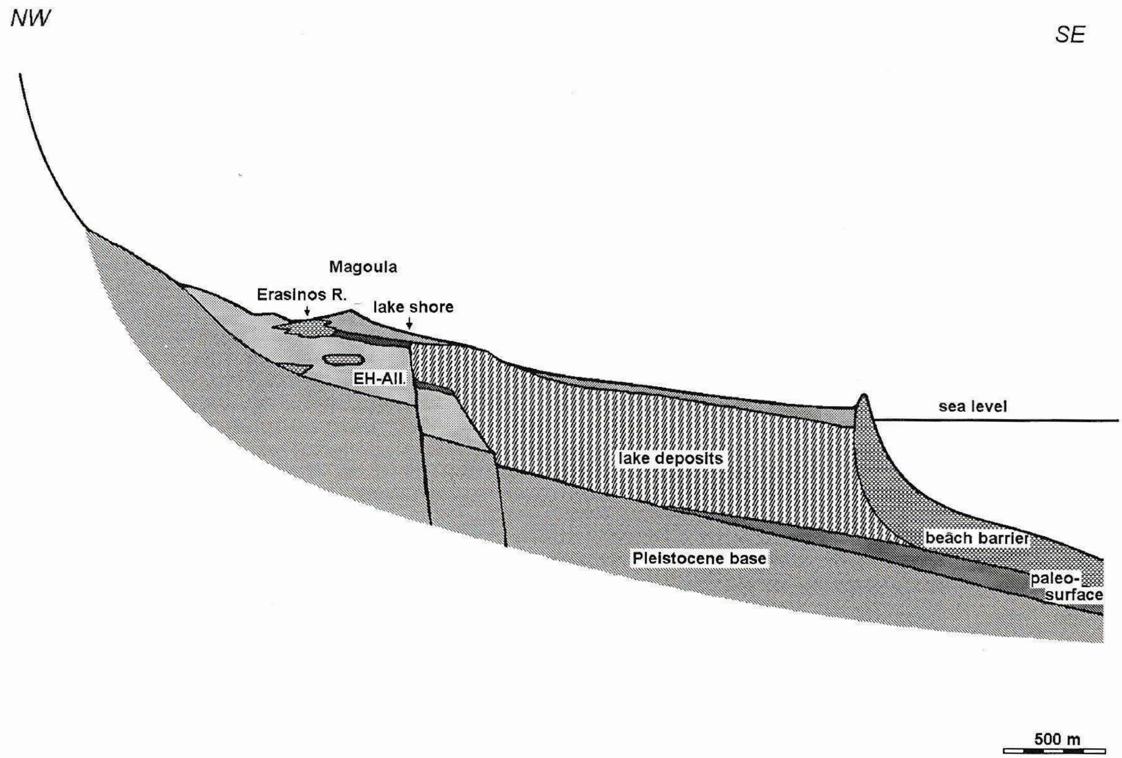

Figure 3. Section through Holocene and Pleistocene sediments between Magoula and the sea in the Argive plain. A Pleistocene paleosol occurs at the bottom of all cores and at the surface west of the section. On the seaward side of the profile a paleo-surface (A horizon) is preserved on top of the Pleistocene base. The existence of Lake Lerna is represented by thick and extensive lacustrine deposits. The lake was separated from the open sea by a beach barrier. Only limited alluviations occurring in the Early Bronze Age were found in this traverse (EH–All.). Paleo-A-horizon (dark layer on top of EH–All.) indicates landscape stability.

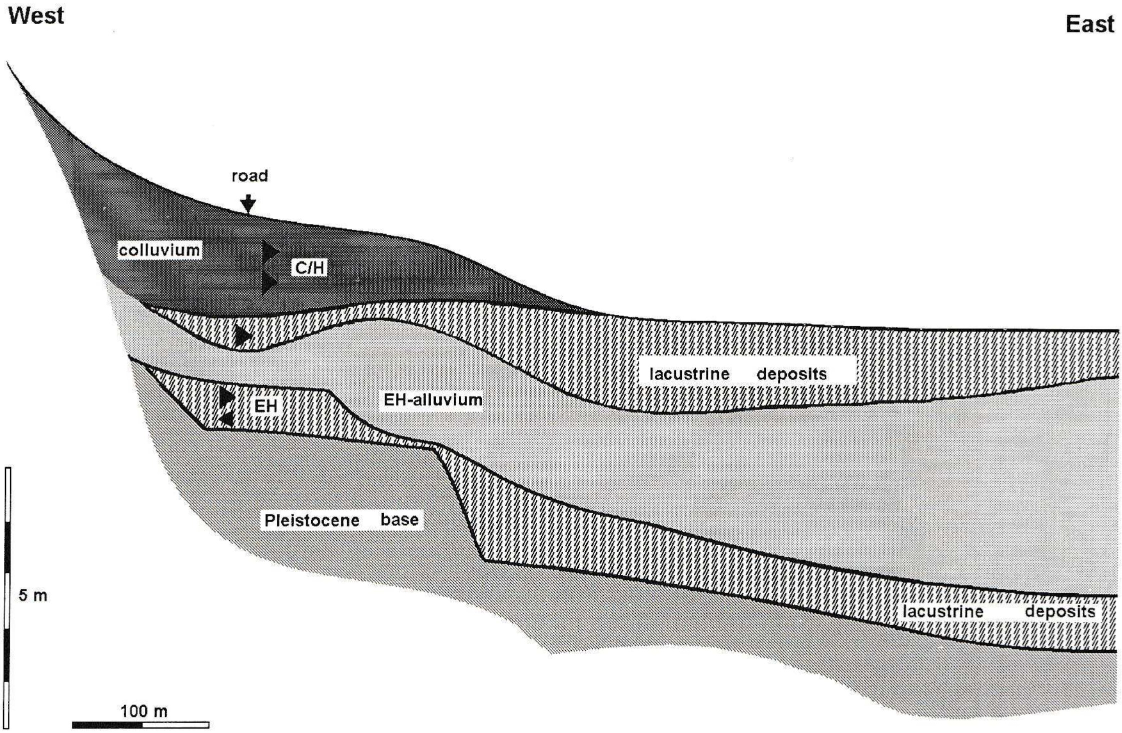

Figure 4. An exceptionally large trench (1.5 km long, 6 m deep) provided the opportunity to verify the auger core data in the Argive plain. At the base is a Pleistocene paleosol covered by dark gray lacustrine deposits belonging to the Lernaean Lake and containing Early Helladic I sherds. Subsequently, alluvium dated by the presence of many Early Helladic II sherds filled the lake. It is covered in turn with another lacustrine layer indicating a second lake stage. The final layer is a colluvial deposit containing many dispersed Classical and Hellenistic sherds. A Classical house (C/H) was found in this colluvium about 1 m under the main road to Argos. The complex stratigraphy in this trench is assumed to represent an uplift of the mountain ranges in the west relative to the coastal plain. It should be noted, however, that the vertical scale is *c.* 40x exaggerated; the displacement of the Pleistocene base is, in reality, much shallower.

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