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The 26th March 1993 (M5.4) Pyrgos earthquake on the western segment of the Movri causative fault of the 2008 event

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Abstract

This moderate sized **M**5.4 earthquake occurred on 26th March 1993, with epicentre in the Kyparissiakos Gulf, around 50 km to the east of the northwestern tip of the Hellenic Arc, near the city of Pyrgos. This area was notable for its historical paucity of large earthquakes (Fig. 1a) with the largest magnitude of the onshore seismicity being ML~5.2, until the occurrence of the **M**6.5 Movri earthquake on 8thJune 2008.The region is a transition zone, between NE-SW strike-slip tectonics and E-W normal faulting, whereas it is suggested to be situated above the tip of the Hellenic Subduction (Fig. 1b). The mainshock was widely felt,it was preceded by significant foreshock activity and was followed by numerous aftershocks. This event triggered several landslides along fault scarps and steep slopes, soil liquefaction and subsidence at the coastal area as well as several ground fractures.

The complexity of the local fault systems made it difficult to identify the causative fault, therefore vague and controversial interpretations were carried out. According to Papanastassiou et al. (1994), Stavrakakis (1996) and the GCMT Project, the main-shock displays a dextral strike-slip mechanism with a thrust component on a nodal plane striking NE-SW and dipping SE. On the contrary, Melis et al. (1994) interpret the 1993 event as occurring on a NW-SE trending, sinistral strike-slip fault-plane , due to its epicentral location falling to the south-east of the city of Pyrgos, where this orientation represents the dominant trend of faulting. These contrasting views result from the complexity of the deformation in the area (Fig. 1c-e). Nevertheless, the 2008 **M**6.5 Movri earthquake shed light to the controversies, revealing that the western segment of the ruptured NE-SW dextral strike-slip fault was most probably the causative fault of the 1993 Pyrgos earthquake.

Recorded ground motions and their resulting spectral accelerations were particularly high, in contrast with the moderate seismic coefficients with which the largest ratio of the building stock has been designed. Almost 50% of the masonry building stock was reported to be damaged; few Reinforced Concrete buildings to their bearing system, churches, neoclassical buildings of the 19th century, schools and the hospital were also impacted. The registered effects (Fig. 1f) led to intensity VIII at the town of Pyrgos (Fig. 1g). One death, few injuries and economic loss of the order of 170 M € allocated to financial aid to the affected population and rehabilitation of the town, was the aftermath of the moderate, yet damaging earthquake of 1993 in this historically active seismic area.

Study of the seismic ground response into different soil profiles by Karantoni & Bouckovalas (1997) and correlation with the spectral content of the ground motion allowed for the identification of site effects and resonance of buildings with soil sediments as possible factors influencing the spatial distribution of damage. Directivity effects are not explicitly documented, given the lack of waveform analysis; however, they are suspected because of the migration of aftershocks to the NE, the shape of the main shock intensity contours and the damage distribution.

While a debate has been recently initiated in Greece regarding the possible connection between the observed seismicity and hydrocarbon exploration and extraction in the already seismically active area of Pyrgos and western Greece, the lack of scientific publications to support it, the inherent high levels of tectonic seismicity in the area and the lack of reference to the 1993 earthquake within the Human-Induced Earthquake Database (2017) suggest that a natural origin is the most likely.

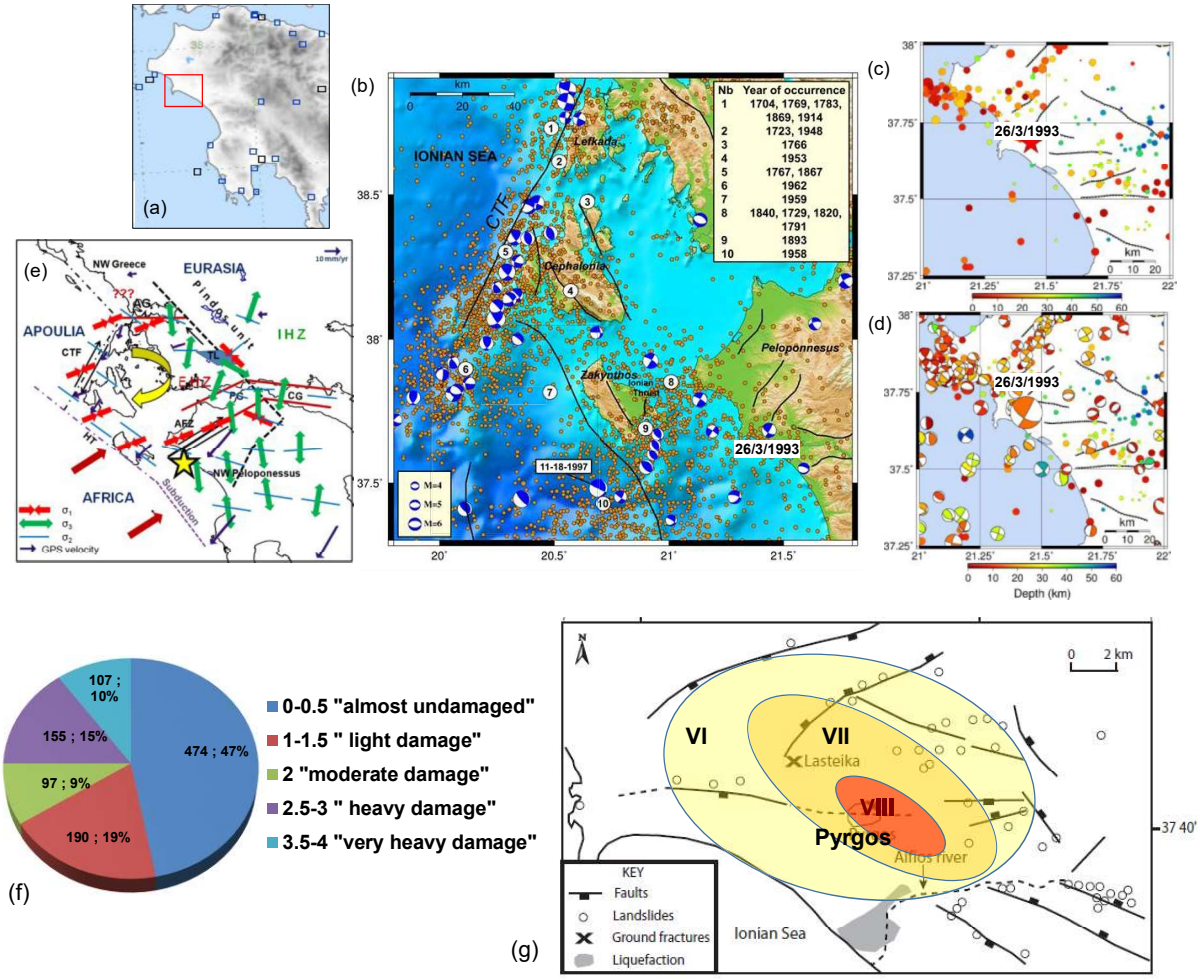

Figure 1. (a) Historical earthquakes in the broader region (AHEAD platform), (b) Seismotectonic map presenting relocated seismicity and focal mechanisms. White circles denote the most important earthquakes in the area prior to 1964 (Papadimitriou et al., 2012), (c) hypocentral locations from manually picked P- and S-wave phases (DGGSL-NKUA) (d) earthquakes as in panel c and focal mechanisms available for the area. (e) Sketch map which summarizes seismological and CGPS data: AFZ-Andravida Fault Zone; AG-Amvrakikos Gulf; CFT-Cephalonia Transform Fault; CG-Corinth Gulf; EHZ-External Hellenides Zone; HT-Hellenic Trench; IHZ-Internal Hellenides Zone; PG-Patras Gulf; TL-Trichonis Lake. The yellow star denotes the location of the 1993 earthquake, (f) Number and percentage of damaged masonry buildings per damage grade (data from Karantoni & Bouckovalas, 1997), (g) Intensity distribution in EMS-1992 scale in the broad area (modified from Lekkas et al. 2000)

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