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MODELING MACROSEISMIC INFORMATION FOR HISTORICAL EARTHQUAKES USING STOCHASTIC SIMULATION: THE CASE OF THE 1954 SOFADES (CENTRAL GREECE) EARTHQUAKE

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The Thessaly basin, the largest basin in central Greece, has a well-known history of large earthquakes, with mainshocks having typical magnitudes between 6.0 and 7.0. During the 20thcentury, eight major seismic sequences with mainshock magnitudes equal or larger than 6.0 occurred in the area (1905, 1911, 1930, 1941, 1954, 1955, 1957, 1980). The purpose of the present study is to simulate the seismic motions of the M=7.0 1954 Sofades earthquake, which had observed macroseismic intensities up to 9.5, resulting in heavy damages of the town and villages of the broader southern Thessaly area. This event marked the beginning of a series of earthquakes along the southern Thessaly rupture zone (Central Greece), that also involved the destructive events of 1955 and 1957 which mostly affected the city of Volos and the whole eastern part of the southern Thessaly basin (Papastamatiou and Mouyaris, 1986). The 1980 Almyros earthquake is another notable, recent seismic event with similar damaging consequences.

The stochastic simulation method was initially proposed by Boore (1983) and then applied by a large number of researchers, in order to simulate the ground motion from seismic sources (e.g. Boore and Atkinson, 1987). In the present study, a modified stochastic finite-fault method (EXSIM algorithm) was used in order to reproduce the damage distribution of the 1954 Sofades earthquake. The EXSIM algorithm can be employed for the estimation of Peak Ground Acceleration (PGA) and Peak Ground Velocity (PGV) from the synthetic time series generated for specified earthquake fault rupture scenarios. Its main advantage is that it can produce realistic strong motion measures, although the modelled ruptures are specified by a few simple metrics, such as earthquake magnitude and distance, with options to include more detailed information on fault geometry and slip.

For the purposes of this study, macroseismic data were collected from the published database of macroseismic information for the Aegean area (Papazachos et al., 1997) in order to constrain the source rupture information (e.g. possible positions for the Sofades fault) and reconstruct the observed intensities distribution among the settlements of the area (Fig.1). To assess the effect of local geology on seismic motions, geological formations within the broader Thessaly area were digitized using the available IGME maps (scale 1:50.000). The digitized formations were clustered into four groups according to their expected dynamic amplification behaviour, namely in: 1) Basement rocks, 2) Molassic type sediments, 3) Neogene sediments and, 4) Quaternary-Plio/Pleistocene sediments (Fig.1). Moreover, appropriate database corrections were performed regarding the actual settlement positions, using the more recently available cartographic data. For the 1954 event, observed intensities were available almost exclusively for sites on bedrock and Quaternary formation (groups 1 and 4), with a few additional observations reported for group 2.

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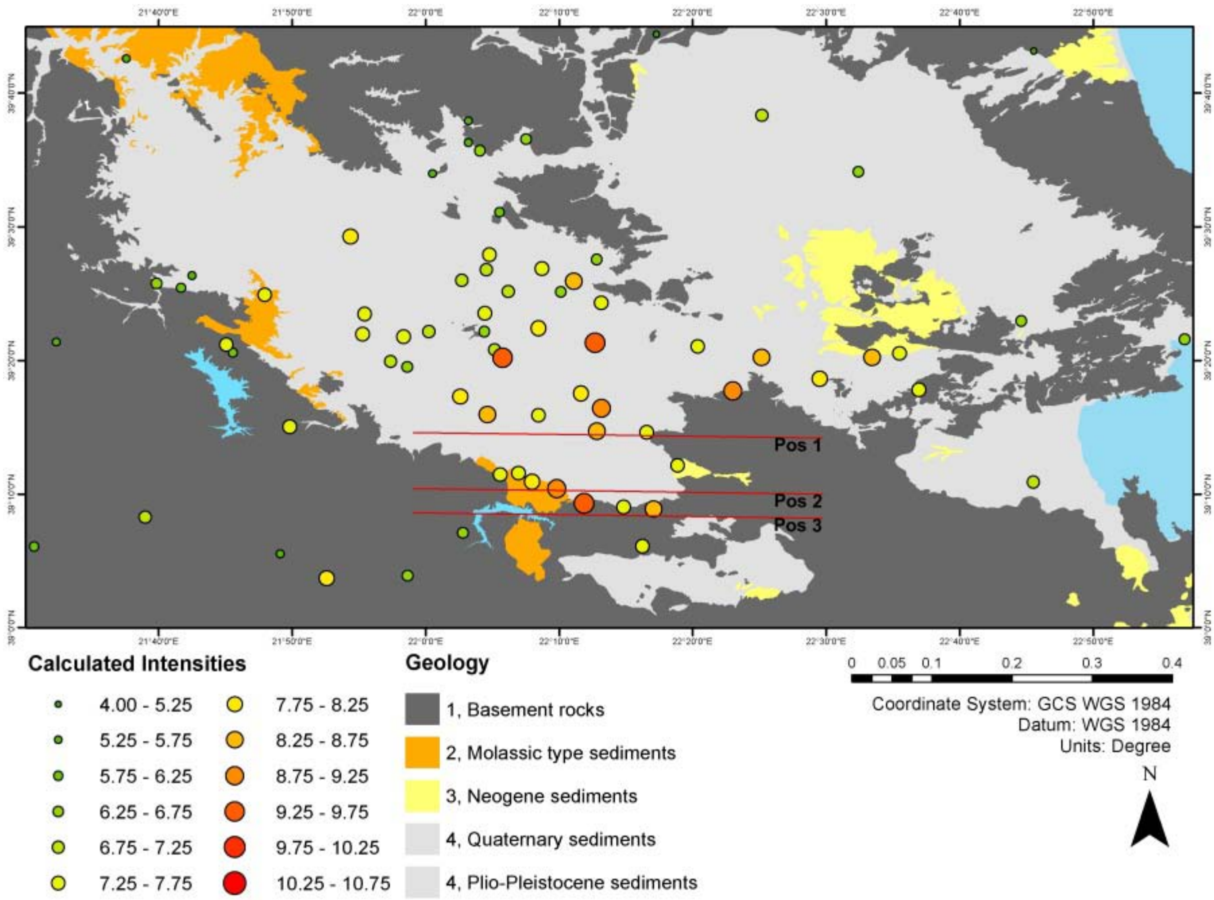

Figure 1. Main geologic formations of the Thessaly plain, observed macroseismic intensities of the 1954 Sofades M=7.0 earthquake and the examined candidate Sofades fault positions.

Initially, the fault position was constrained following the parameters (position, azimuth, dip, faulting type) provided by Papazachos et al. (2001). The fault's dimensions (length, width) were constrained using equations relating seismic fault dimensions to moment magnitude for continental dip-slip faults (Papazachos et al. 2004, Papazachos et al. 2006). Initially, expected synthetic seismograms were simulated without considering local site effects (all formations were considered as basement rocks, group 1). Following this step, the calculated PGA and PGV values were corrected for site-effects using the constant amplification factors proposed by Skarlatoudis et al. (2003). For this estimation we assumed that bedrock, Molassic and Quaternary sediments corresponded to UBC and EC8 soil categories B, C and D considered by Skarlatoudis et al. (2003). Moreover, an additional simulation was performed assuming the spectral amplifications proposed for the same site classes by Klimis et al.(1999). Finally, the PGA and PGV values were converted to macroseismic intensities (MM scale) and averaged using the conversion relations proposed by Tselentis and Danciu (2008).

The results from this initial simulation showed significant deviations between observed and synthetic intensities when the Skarlatoudis et al. (2003) constant site-amplification corrections were used, while similar results were found for the Klimis et al. (1999) spectral amplification factors. In order to explain this discrepancy, two additional possible fault positions were considered (also presented in Fig.1), with the southernmost one (position 3) constrained by the observed surface ruptures and neotectonic faulting of the southern Thessaly basin (Papastamatiou and Mouyaris, 1986, Mountrakis et al, 1993). As is shown in Figure 2, simulations using this southernmost position Sofades fault (position 3) led to the best results. It should be noticed that simulations using the amplification factors proposed by Klimis et al. (1999) led to overestimation of macroseismic intensities for Quaternary formation sites, especially for the central basin part. Selected HVSR measurements performed in the southern Thessaly basin showed that the recovered resonance frequencies for the central section of the basin (Karditsa area) showed a different pattern, as much lower resonant frequencies were found in comparison to the results of Klimis et al. (1999) for class D formations, which can be considered as the main reason for the observed overestimation.

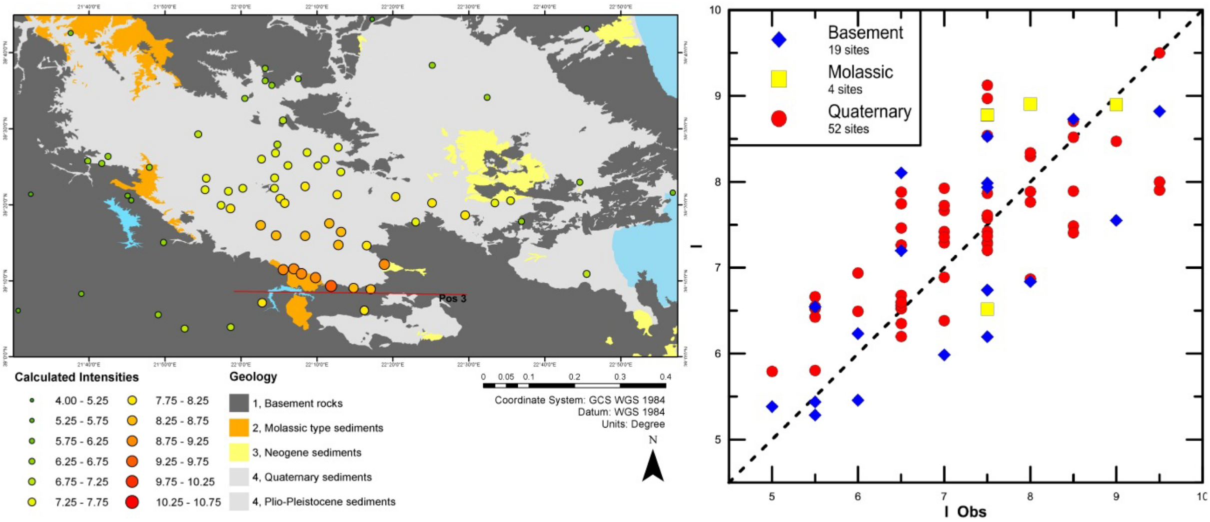

Figure 2. (Left) Estimated intensities of the Sofades M=7.0 1954 event for the optimal fault position 3 (see Fig.1). (Right) Comparison of modeled, I, against observed, I Obs, macroseismic intensities for the same model.

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