INQUA Focus Group Earthquake Geology and Seismic Hazards

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# Active faults as Seismogenic sources in the Aegean region

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***Abstract:*** *In this article review we emphasize the key-role of active faulting in the geodynamic setting of the broader Aegean region. We also describe briefly the transition from active faults to seismogenic sources through the Greek Database of Seismiogenic Sources (GreDaSS), an ambitious project that aims at the homogenization of seismic hazard in this region. This transition relies on various philosophical aspects and criteria in order to fulfil the practical needs of Seismic Hazard Assessment and give answers to scientific questions about the seismotectonic setting of the Aegean. In this context we show some characteristic cases of different types of morphometric features and coseismic surface rupture patterns that occurred in this area of interest.*

***Keywords****: Active faults, seismogenic sources, seismotectonics, surface faulting, Aegean.*

## GEOTECTONIC SETTING

The broader Aegean Region is among the most tectonically active areas of the Mediterranean realm. Its geotectonic evolution started during the Mesozoic, when the discontinuous southwestward migration of the Alpidic orogenic process, characterized by intense collisional tectonics, caused successive subductions of the Tethyan oceanic basins producing a complete stack of several nappes. Today, the Aegean geodynamic setting is controlled by the relative lithospheric plate motions. Either continental collision (Apulia vs Aegean) or convergence (Africa vs Eurasia), along with quasi-oceanic subduction (Mediterranean beneath Eurasia), the Aegean crust undergoes an inner strong deformation which is expressed by intense faulting. Active faults try to overprint their morphological marks on the older Alpidic relief, although sometimes they just follow the older inherited structures. Whether the Alpidic orogenic process has stopped or still goes on in northwestern Greece (where the Apulian continental plate is subducted under the Aegean), the Hellenic Arc keeps its southward retreat and roll-back movement, which started since the Priabonian stage, leaving plenty of space in the back-arc region for crustal extension. As a consequence, all the active procedures above produce intense seismicity in both terms of magnitude and frequency.

The neotectonic period in the Aegean started since the Late Pliocene-Early Pleistocene and continues until Today. During this period, the roughly N-S crustal stretching develops, due to the Hellenic Arc southward migration. The geodynamic regime is rather complex forming a large variety of faults which in turn produce earthquakes of different P/T-axes orientations. It is noteworthy to mention that Greece, like other modern industrialized countries with high concentration of population in large and constructionally complex urban areas, has suffered many human losses and economic damages. The Athens 1999 earthquake alone, caused 143 deaths and $3.0-4.2 million in damage.

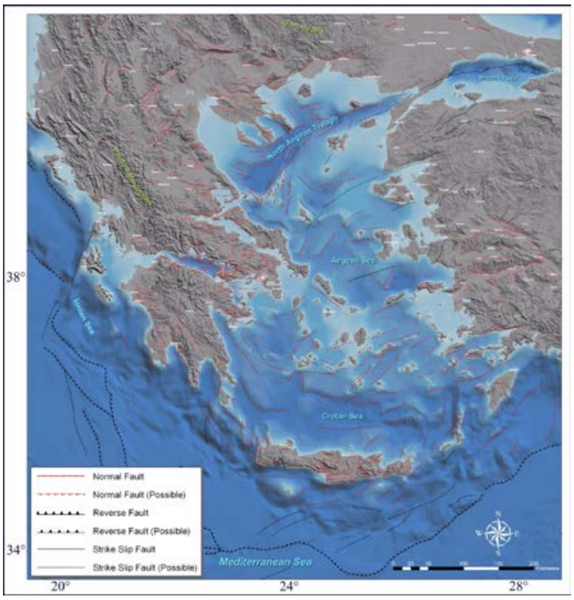


*Figure 1: The map of capable faults in Greece, as proposed by Pavlides et al. (2007).*

## THE GREEK DATABASE OF SEISMOGENIC SOURCES (GreDaSS)

Aiming at a better, reliable and realistic contribution towards seismic hazard assessment, GreDaSS was developed (Sboras et al. 2011; Caputo et al. 2012; http://gredass.unife.it) using the structure and informatics of DISS, a well-tested, time-proven and worldwide acknowledged geodatabase developed by the Working Group of INGV (e.g. Valensise and Pantosti, 2001; Basili et al., 2008). GreDaSS is a continuously updatable open-file built in GIS environment. Only shallow (crustal) tectonic structures are initially included. Shallow structures are more important in terms of SHA since they are scattered all over the Aegean Region, close to and sometimes even directly affecting inhabited areas. Not only GreDaSS does analyse and combine all kind of information that is hidden in numerous publications, but it also represents a multi-level tool of interconnected data addressing to all kinds of end-users, expertized or not. As a result, the second target of GreDaSS is to help comprehend the complex geodynamic regime of the Aegean.

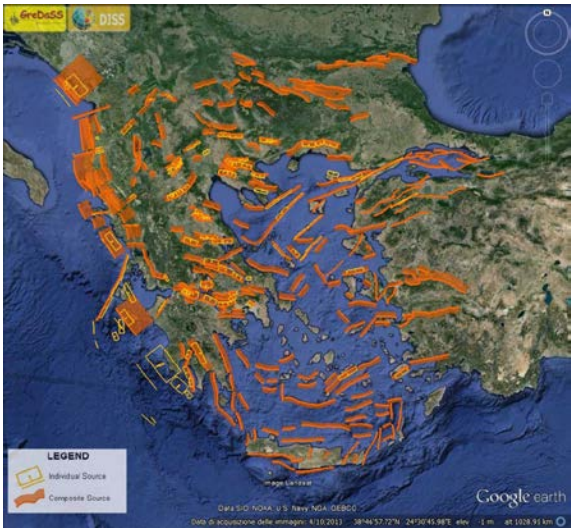


*Figure 2: GreDaSS in Google Earth environment.*

Terminology varies in literature as long as the definition of active, capable and inactive (?) faults concerns. These terms usually deal with the time window used to describe the latest activity. Herein, the term "active fault" is preferred instead of "capable fault", of producing a future earthquake.

Defining an active fault: Faults have different derivatives, while "fault zone" is either a band of finite width across which the displacement is partitioned among many smaller faults, or the zone of rock bordering the fault that has fractured during faulting". However, a shear zone is defined as the zone of finite width along which displacement is attributed to major shear forces. Thus, the term of active fault is applied when a fault shows evidence of recent reactivation and/or is capable of being reactivated in the future. The definition of recent is quite relative and can be very subjective, but it is always comparable to the seismotectonic regime of the Aegean Region. When an active fault can be safely associated with a specific seismic event, the term "seismic fault" is preferred. Some criteria can be assigned to the active faults, all adapted suitably for the faulting character of the Aegean. These criteria are described by Pavlides et al. (2007).

Active faults in Greece show a large variety at all scales. However, small individual faults are insignificant for the aims of Seismic Hazard Assessment (SHA). For this reason, GreDaSS basically contains seismogenic sources. Based on the definition of Kastelic et al. (2008) for DISS, seismogenic sources are active faults capable of generating $M_w$ > 5.5 earthquakes. The latter definition is also suitable for the case of the Aegean region, given that Pavlides and Caputo (2004) suggest that a magnitude larger than 5.5 is needed in order to have linear morphogenic earthquakes (sensu Caputo, 2005) in the Aegean.

**CHARACTERISTIC FAULT RUPTURES IN GREECE**

A few cases of active faulting in Greece showing various coseismic ground rupturing patterns and morphotectonic features are listed below:

The Samothraki fault, a segment of the North Aegean Trough, uplifts and hangs the Giali drainage basin also forming triangular facets (Figure 3).

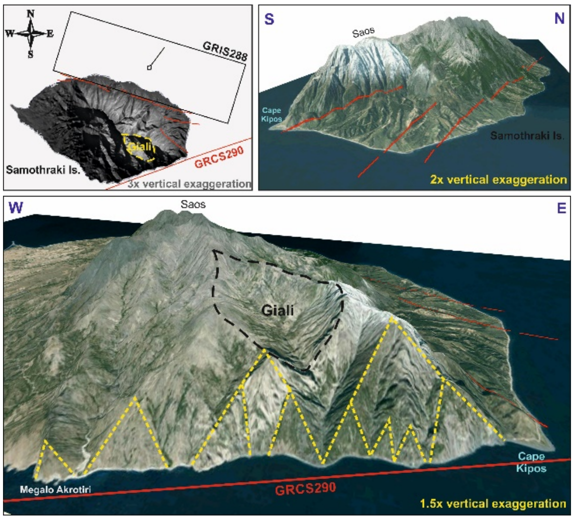


*Figure 3: Morphotectonic features on Samothraki Island (uplifted valleys and triangular facets). The seismogenic sources at the North (GRIS288) and South of the island (GRCS290) are also shown. The onshore fault traces (red lines) are the surficial expression of ISS288 source. From Sboras et al. (2017).*

In the Mygdonia Basin, where the 1978 ($M_w$ 6.3) Thessaloniki earthquake epicentre is located, the major marginal faults have formed a distinctive curvilinear escarpment, but the co-seismic ground ruptures formed three main bifurcating antithetic lineaments (Figure 4a). Similar complexity also demonstrated the co-seismic ground ruptures of the 1995 ($M_w$ 6.4) Kozani-Grevena earthquake (Figure 4b). The main fault was expressed by discontinuous and scattered surface ruptures, while an older antithetic inherited structure was partially reactivated (Chromio Fault). The most prominent fault escarpment next to the seismic fault (to the east) did not slip at all. Rupture was also complicated at depth, showing moderate dipping angle at deeper depths and steeper at shallower depths. The 1954 strong earthquake ($M_w$ 6.6) near Sophades left ground ruptures that were parallel or sometimes diagonal to the segmented main fault escarpment (Figure 4c). The fault segments had to be breached in order to produce an earthquake of such magnitude. The Kaparelli seismic fault was reactivated during the third strongest shock ($M_w$ 6.2) of the 1981 Alkyonides sequence on March 4. Surface rupture did not prefer the prominent fault escarpment towards the west, but jumped parallelly to the SW forming a relay-ramp in between (Figure 4d). More recently, a hidden or blind seismic fault produced the NW Peloponnesus 2008 earthquake.

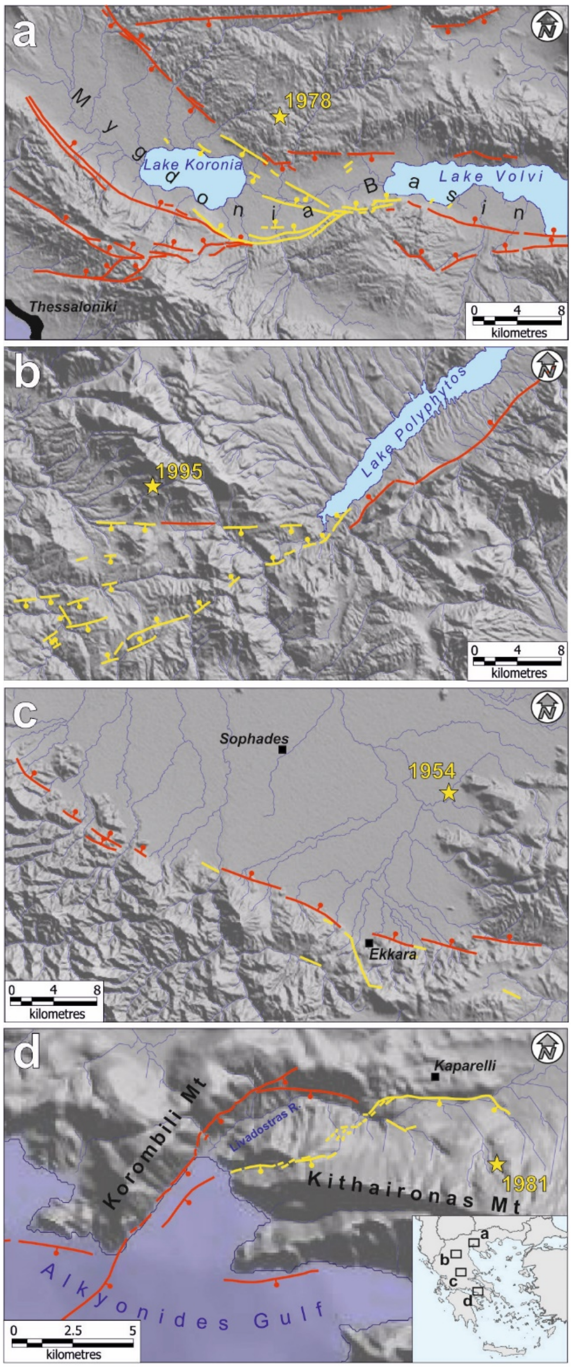


*Figure 4: Active fault traces (red lines) and coseismic ground ruptures (yellow lines) for four cases in Greece: a) 1978 Thessaloniki earthquake, b) 1995 Kozani-Grevena earthquake, c) 1954 Sophades earthquake, and d) 1981 Alkyonides Gulf sequence (3rd strongest shock).*

**Acknowledgements:** Brief words given thanks to Projects and supporters. Font style: Calibri 8 pts. One line from the final conclusions and two lines before the references.

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