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Rheological Transects Across the Aegean Region: a Contribution to the Seismotectonics of the Area

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Introduction

The Aegean Region is characterized by a dense pattern of seismogenic faults, whose terminations at depths are not always well defined. Rheological modelling, by means of strength profiles calibration and realization, is used to determine the depth of the brittle-ductile transition (hereinafter BDT) within the broader area. In the present paper we focus on the Hellenides fold and thrust belt and Hellenic subduction zone comparing our results (in terms of BDT depth) with the depth of the recorded seismicity. The primary aim is to constrain some of the principal seismotectonic parameters for better defining the seismogenic potential of the active faults.

Data and Methods

We realized eight transects in the Aegean Region (see Fig. 1a). The first three start offshore Corfu (western Greece) and terminate around Thessaloniki (northeastern Greece) thus entirely crossing a continental collision setting. A second group of three transects is almost parallel but it has been traced across the active western Hellenic subduction zone of oceanic Nubian/Ionian lithosphere below the Aegean microplate; it initiates offshore of southwestern Peloponnesus and ends in the Attica region. Two more transects have been designed parallel to the axis of the Hellenides fold and thrust belt in order to cross and link the other two groups; one runs in a distal offshore position and the other mainly onland. The crosscutting geometry of the transects array allows to use the two intersections both as control points and as 3D-view insights on the thermo-rheological characteristics of the western Hellenides region. Each transect (except for the NNW-SSE trending ones, which are longer) has a total length of ~430 km and results from the projection of well-calibrated 1D strength profiles onto the transect direction (mean inter-space between the 1D profiles along a transect is ~10 km). By interpolating the closely-spaced strength profiles we obtained BDT depth, strength and temperature distributions at depth (here we limit the analysis to the first 100 km) for the eight transects. In order to realize the rheological transects we collected literature data for the values of the input parameters of the constitutive rheological equations from different studies, methods and sources. The literature data were then integrated with our geological and tectonic considerations in order to select the proper values and obtain reliable profiles. For the purposes of thermo-rheological modelling we used the simplified approach first proposed by Brace and Kohlstedt (1980) and then widely used in the literature (e.g. Ranalli and Murphy, 1987; Ranalli, 1995). Such a method consists in taking into account only the frictional sliding (brittle) deformation mechanism and the dislocation creep one, for respectively, the brittle and the ductile behavior.

Results

As regards the BDT depth, in the western 180-200 km the southern group of profiles (profile EE’, see Fig. 1c) displays a deeper transition than the northern one, with values comprised between 35 and 40 km. This is probably due to the (cold and old) oceanic nature of the crust in those sectors. After the 200 km mark, the sudden shallowing of the BDT to depths comprised between 15 and 10 km in the Oichalia and Kalamata regions is related to the upward shift of the rheological transition from the downgoing Ionian plate to the overriding Aegean plate. In the northern group of profiles (profile BB’, Fig. 1b) a similar trend of rapid shallowing of the BDT after *ca* 170-180 km is also observed. In this case however, the BDT is no ever deeper than 33 km even in the low surface heat-flow region at the western end (Corfu area). Such a behaviour is related to the continental nature of the crust within the undergoing plate and the associated intermediate/felsic typical lithologies (we selected quartzite and granulite for the upper and the lower crust, respectively) which tend to yield at lower shear stresses (and therefore minor pressures and depths) with respect to mafic lithotypes. After the 200 km mark the BDT shallows to depths comprised between 15 and 20 km, being therefore deeper than the corresponding sectors of the southern profiles. This could be explained by the lower surface heat-flow characterizing Epirus and northern Hellenides area with respect to Attica and northeastern Peloponnesus regions. From a rheological point of view the comparison between continental collision (BB’) and oceanic subduction (EE’) settings emphasizes the following differences and peculiarities: i) the occurrence of a deeper brittle layer just below the uppermost one in the continental settings, which is instead absent in the oceanic crust; ii) a thinner brittle layer in the back-arc region for the oceanic subduction setting; iii) the presence in the continental settings of brittlely deforming layers occurring in the intermediate and lower crust even below considerably thick ductile layers, especially when geothermal gradient and surface heat-flow are particularly low.

Application to seismotectonics

We used the depth of the BDT as a tool for constraining the geometrical (width and hence expected maximum magnitude) characteristics of some selected seismogenic sources taken from the GreDaSS database (Caputo *et al*., 2012). The selected sources crosscut either the transect BB’ or the EE’ and correspond to the South Kourveleshi Thrust (composite source, BB’), Paleochori Fault (individual source, BB’), Pamisos Fault (composite source, EE’) and the Fili Fault (individual source, EE’). The South Kourveleshi Thrust lies in the central-western sector of the BB’ transect, where on average the BDT is ~21-22 km deep; assuming a dip angle of 45° for this reverse fault and using empirical relationships a maximum expected magnitude of 7.1-7.2 is obtained which is consistent with the estimate of the GreDaSS database. The Paleochori Fault lies instead in the central-eastern portion of the BB’ transect. Here aftershocks of the 1995 Kozani-Grevena earthquake are distributed down to depths of ca 15-16 km (Rigo *et al*., 2004; Resor *et al*., 2005), being consistent with the BDT depth from our rheological modelling equal to ca 16 km. The maximum expected magnitude is in the order of 6.8, which is slightly higher than the value of Mw=6.5 of the 1995 earthquake. However, the estimate is considered to be acceptable, also considering that the 1995 earthquake did not produce surface ruptures and aftershocks did not occur any shallower than 4 km (Resor *et al*., 2005), indicating that probably the seismogenic rupture did not propagate for the entire thickness of the seismogenic layer (while our estimate are always conservative meaning that all the seismogenic thickness is ruptured coseismically). As regards the Pamisos Fault, this lies on the central sector of the EE’ transect; also in this case the seismological data are in agreement with the BDT depth obtained from the rheological modelling, which is around 16 km. The calculated maximum expected magnitude corresponds to values around 6.8, which is consistent with the estimate given in the GreDaSS database equal to 6.7. The last selected source, corresponding to the Fili Fault is located close to the eastern termination of the EE’ transect. The BDT in this region is quite shallow, with depth of *ca* 9-10 km, consistent with the focal depth of the 1999 Athens earthquake being on average ~10-11 km and most of the aftershocks occurring above 11-12 km (e.g. Louvari and Kiratzi, 2001; Papadimitriou *et al*., 2002; Papadopoulos *et al*, 2004). We obtained a maximum expected magnitude of 6.3-6.4, which is slightly greater than the value of the 1999 mainshock. Also in this case however, it must be taken into account that the rupture only propagated upwards to depths as shallow as 3-5 km, and therefore the maximum magnitude associated to the Fili Fault could be greater and comparable to our estimate in the case of a rupture fully propagating throughout the entire seismogenic layer.

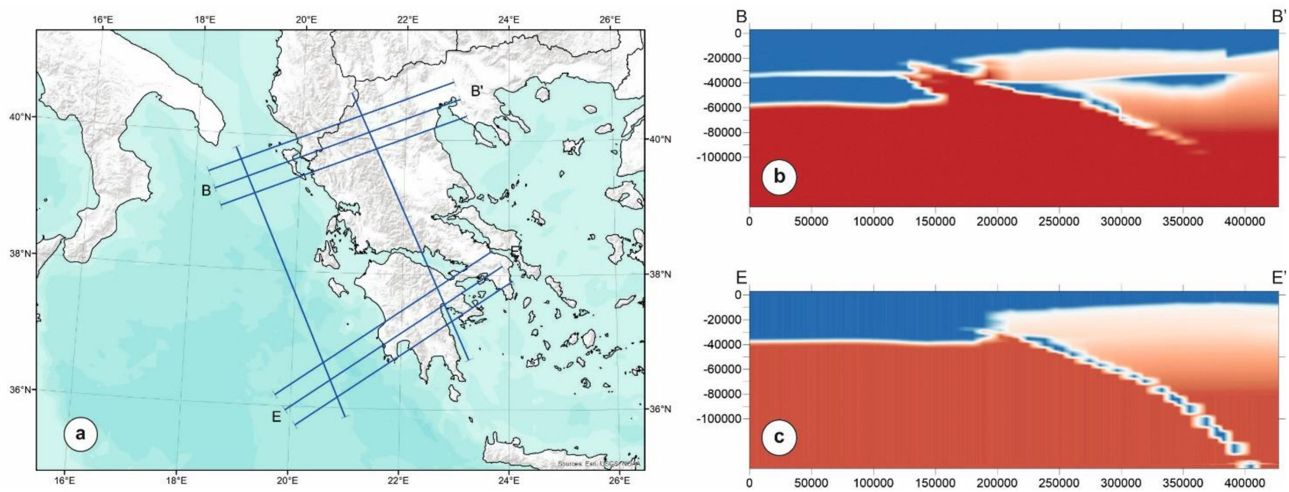

Figure 1. a) Terrain map of the Central-Eastern. Mediterranean Region showing the position of the investigated profiles; b) section of the difference between brittle (blue) and ductile (red) strength for the BB’ profile. The whitish colors indicate the brittle-ductile transition zones; c) same as b) but for the EE’ profile.

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