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Detailed crustal structure in the area of the southern Apennines–Calabrian Arc border from local earthquake tomography

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ABSTRACT

We present a new seismic velocity model for the southern Apennines–Calabrian Arc border region with the aim to better define the crustal structures at the northern edge of the Ionian subduction zone. This sector also includes the Pollino Mts. area, where a seismic sequence of thousands of small to moderate earthquakes has been recorded between spring 2010 and 2013. In this sector a seismic gap was previously hypothesized by paleoseismological evidences associated with the lack of major earthquakes in historical catalogs.

To perform the tomographic inversion we selected ca. 3600 earthquakes that have occurred in the last thirty years and recorded by permanent and temporary networks managed by INGV and Calabria University. Using for the first time the Local Tomography Software for passive tomography inversion (LOTOS hereinafter) to crustal analysis in southern Italy, we have computed the distribution of Vp, Vs, and the Vp/Vs ratio. The obtained velocity model, jointly evaluated with results of synthetic modeling, as well as with the hypocenter distribution and geological information, gives us new constraints on the geodynamical and structural knowledge of the study area.

The comparison between the shallow tomography sections and surface geology shows good correlation between velocity patterns and the main geological features of the study area. In the upper crust a low-velocity anomaly of P- and S-waves is detectable beneath the Pollino Mts. area and seems to separate the Calabrian and southern Apennines domains, characterized by higher velocities. The distributions of high Vp/Vs ratio, representing strongly fractured rocks with likely high fluid content, clearly correlate with areas of significant seismicity.

In the lower crust we detect a clear transition from high to low seismic velocities in correspondence with the Tyrrhenian coast of the study area, which may represent the transition from the thinner Tyrrhenian crust to the thicker one beneath Calabria. In this area, also characterized by a progressive detachment of a retreating lithospheric slab, the generation of a Subduction-Transform Edge Propagator (STEP) fault zone, that laterally decouples subducting lithosphere from non-subducting lithosphere in a scissor type of fashion, may have taken place. These conditions imply the existence of a kinematic decoupling which allows for differential movement between the Calabrian Arc and the southern Apennine chain. The low velocity anomaly separating the southern Apennines and the Calabrian Arc domain may be related to fluid upwelling occurring in correspondence with the northern edge of the Calabrian subducting slab.

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1. Introduction

The western Mediterranean area, located at the contact belt between the slowly convergent African and Eurasian plates (Calais et al., 2003; Nocquet and Calais, 2004; Serpelloni et al., 2007), has been the site of a continental-scale lithospheric subduction process, the evolution of which in the last 30 million years is marked by the eastward migration of the retreating subduction hinge (Fig. 1a; Wortel and Spakman, 2000). Most of the subduction system has already undergone detachment of the subducting lithosphere with the exception of the central, most arcuate portion of the system, the Calabrian Arc in southern Italy (Fig. 1b; Neri et al., 2009 and references therein). Different states of the subduction process can be related to the progressive change of lithospheric structure near the retreating trench zone and to strong lithospheric heterogeneity between the Calabrian Arc and the marginal tectonic units of Sicily

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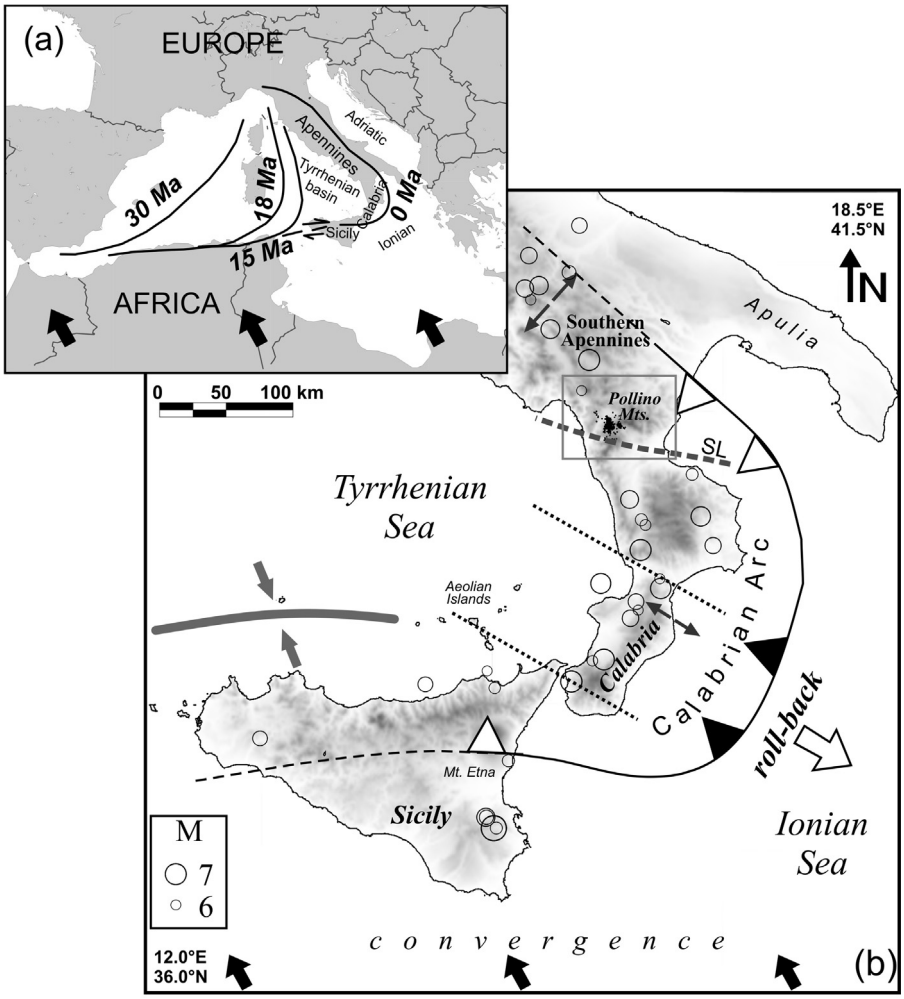

Fig. 1. (a) Map of the Mediterranean region with the western Mediterranean plate boundary evolution in the last 30 Myrs (redrawn from Wortel and Spakman, 2000, with modifications according to Neri et al., 2009). The space–time evolution of the boundary marks the process of rollback of the subducting lithosphere and the related trench retreat until the present-day location near the Ionian shoreline of Calabria. Black arrows indicate the present motion of Africa relative to Europe (Calais et al., 2003; Nocquet and Calais, 2004; Nocquet, 2012). In (b) the solid curve with the sawtooth pattern, pointing in the direction of subduction, indicates the present-day location of the Calabrian Arc subducting system. According to the local earthquake tomography by Neri et al. (2009), black sawteeth indicate the continuous subducting slab while white sawteeth the plate boundary segments where slab detachment has already occurred. The white arrow shows the sense of the subducting slab rollback. The black arrows indicate the present motion of Africa relative to Europe (Calais et al., 2003; Nocquet and Calais, 2004). Gray dashed line is the locations of the surface projection of the northern STEP fault proposed by Rosenbaum et al. (2008) in correspondence with the Sangineto Line (SL in map). Black lines are the longitudinal limits of the continuous slab domain, according to Neri et al. (2009). West of the Aeolian Islands in the Tyrrhenian Sea, the location of the east–west trending compressive margin as proposed by several investigators (see e.g. Billi et al., 2007) is schematically reported. Circles show the locations of the earthquakes of magnitude 6.0 and larger that have occurred after 1000 A.D. according to the CPTI11 catalog (Rovida et al., 2011; http://emidius.mi.ingv.it/CPTI11); seismogenic stresses are from Montone et al. (2012). Gray box holds the Pollino Mts. area and the black dots inside represent the earthquake locations of the 2010–2013 seismic crisis.

and southern Apennines, where detachment has already occurred (Cimini and Marchetti, 2006; Faccenna et al., 2005; Lucente et al., 2006; Montuori et al., 2007; Neri et al., 2009; Spakman and Wortel, 2004). According to Govers and Wortel (2005) this scenario, characterized by a progressive detachment of a retreating lithospheric slab, may have led to the generation of a Subduction-Transform Edge Propagator (STEP) fault that laterally decouples subducting lithosphere from non-subducting lithosphere in a scissor type of fashion.

The lithosphere and mantle setting of the southern Apennines–Calabrian Arc border region has been deeply investigated in the last decades by means of regional and local seismic analyses reported in several previous papers (Barberi et al., 2004; Chiarabba et al., 2008; Chironi et al., 2000; Giacomuzzi et al., 2012; Montuori et al., 2007; Neri et al., 2002, 2009; Steckler et al., 2008). Different velocity patterns have been identified, providing evidences for first order crustal and sub-crustal heterogeneities and boundaries between the main crustal domains of Southern Apennines, Calabrian, and Tyrrhenian regions (Fig. 1b). High velocity pattern at crustal depth beneath the Tyrrhenian Sea is commonly interpreted with the thinning of the Tyrrhenian crust and incipient oceanization (Barberi et al., 2004; Chiarabba et al., 2008; Finetti, 2005a, 2005b; Orecchio et al., 2011; Pepe et al., 2000). At greater depths, tomographic analysis evidenced that the Ionian subducting slab is in-depth continuous only beneath the central part of the Arc in southern Calabria while detachment has already occurred at the northern and southwestern edges of the arc itself, e.g. northern Calabria and northeastern Sicily, respectively (Fig. 1b; Neri et al., 2009). Beneath the southern Apennines lack of subcrustal seismicity and of high-velocity anomalies down to 200 km depth, together with a southwestward dipping high-velocity body at greater depths have been detected (Cimini, 1999; Cimini and Marchetti, 2006; Wortel and Spakman, 2000). In this framework the Calabrian Arc, a curved structure characterized by very heterogeneous seismotectonic regimes along its length (Cristofolini et al., 1985; Montone et al., 2004), together with the adjacent southern Apennines

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