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The Ionian and Alfeo–Etna fault zones: New segments of an evolving plate boundary in the central Mediterranean Sea?

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ABSTRACT

The Calabrian Arc is a narrow subduction–rollback system resulting from Africa/Eurasia plate convergence. While crustal shortening is taken up in the accretionary wedge, transtensive deformation accounts for margin segmentation along transverse lithospheric faults. One of these structures is the NNW–SSE transtensive fault system connecting the Alfeo seamount and the Etna volcano (Alfeo–Etna Fault, AEF). A second, NW–SE crustal discontinuity, the Ionian Fault (IF), separates two lobes of the CA subduction complex (Western and Eastern Lobes) and impinges on the Sicilian coasts south of the Messina Straits.

Analysis of multichannel seismic reflection profiles shows that: 1) the IF and the AEF are transfer crustal tectonic features bounding a complex deformation zone, which produces the downthrown of the Western lobe along a set of transtensive fault strands; 2) during Pleistocene times, transtensive faulting reactivated structural boundaries inherited from the Mesozoic Tethyan domain which acted as thrust faults during the Messinian and Pliocene; and 3) the IF and the AEF, and locally the Malta escarpment, accommodate a recent tectonic event coeval and possibly linked to the Mt. Etna formation.

Regional geodynamic models show that, whereas AEF and IF are neighboring fault systems, their individual roles are different. Faulting primarily resulting from the ESE retreat of the Ionian slab is expressed in the northwestern part of the IF. The AEF, on the other hand, is part of the overall dextral shear deformation, resulting from differences in Africa–Eurasia motion between the western and eastern sectors of the Tyrrhenian margin of northern Sicily, and accommodating diverging motions in the adjacent compartments, which results in rifting processes within the Western Lobe of the Calabrian Arc accretionary wedge. As such, it is primarily associated with Africa–Eurasia relative motion.

1. Introduction

The Calabrian Arc (CA) (Fig. 1) is a narrow and arcuate subduction–rollback system related to the Africa/Eurasia plate convergence and the southeastward retreat of the Tethyan slab (Rehault et al., 1984; Malinverno and Ryan, 1986; Gueguen et al., 1998; Jolivet and Faccenna, 2000; Faccenna et al., 2001a, 2004; Rosenbaum and Lister, 2004). Back-arc extension in the Liguro–Provençal Basin since ~30 Ma, and in the Tyrrhenian Sea since ~10 Ma (Malinverno and Ryan, 1986; Patacca et al., 1990; Gueguen et al., 1998; Faccenna et al., 2001b; Rosenbaum et al., 2002; Nicolosi et al., 2006) accommodated 1200 km of displacement of Calabria to its present position (Bonardi et al., 2001; Faccenna et al., 2001a; Barberi et al., 2004; Rosenbaum and Lister, 2004).

Tomographic images in the central CA show a continuous slab penetrating into the mantle (Bijwaard and Spakman, 2000; Wortel and Spakman, 2000; Faccenna et al., 2007; Neri et al., 2009, 2012) and a well defined Wadati–Benioff zone (Wortel and Spakman, 2000) is marked by earthquakes down to nearly 500 km depth (Selvaggi and Chiarabba, 1995). In this area, geodetic measurements suggest the outward motion of Calabria relative to Apulia (GPS rate of 2 mm/yr, D'Agostino et al., 2008) with shortening accommodated in the accretionary wedge (Polonia et al., 2011). Furthermore, tomographic imaging has shown that the deep (lithosphere–upper mantle) structure in the Calabrian-Sicily region has the characteristics of a STEP setting, similar to that of the northern Tonga subduction zone (Carminati et al., 1998;

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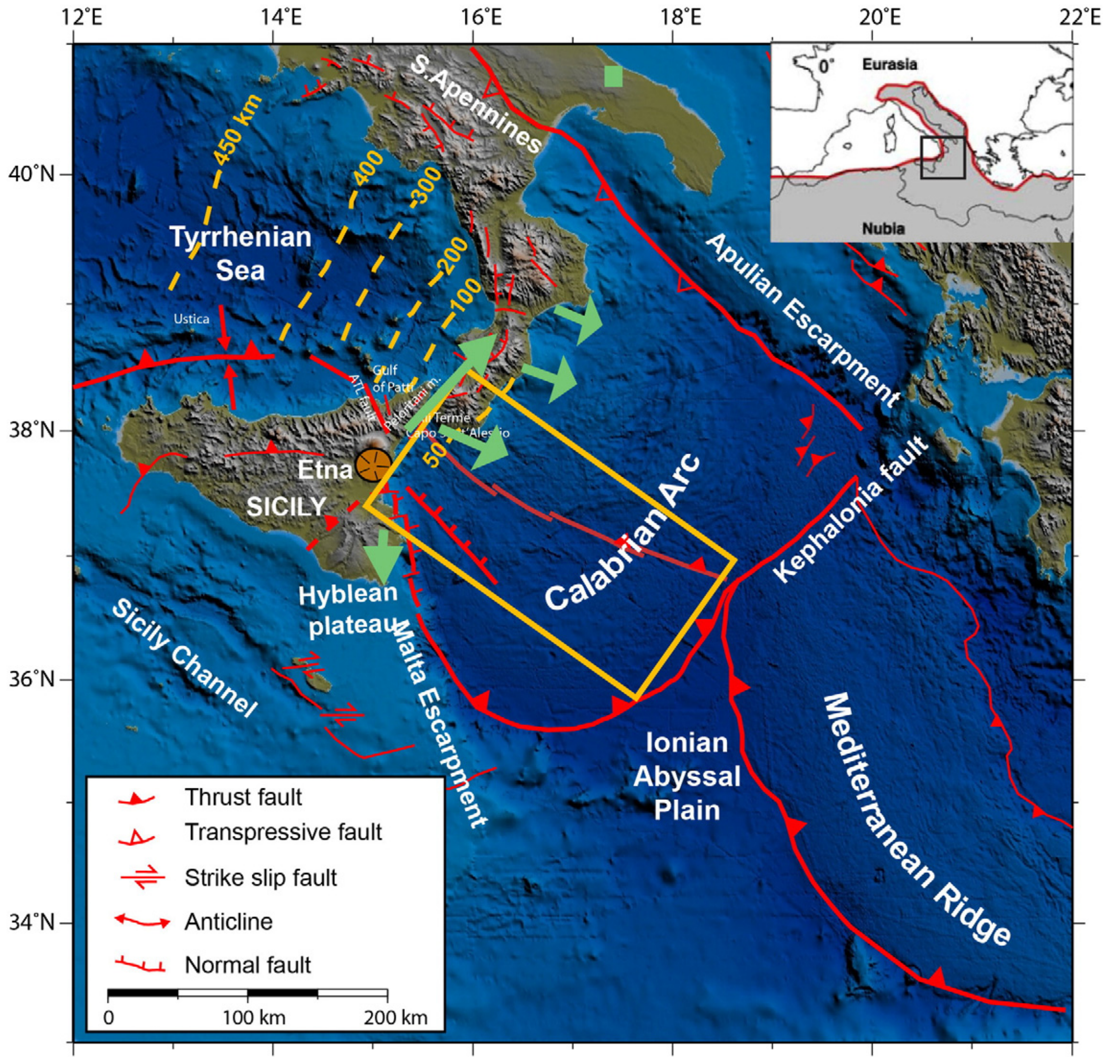

Fig. 1. Geodynamic setting of the study area represented by the yellow box. The geological model is modified from Morelli and Barrier (2004) and Polonia et al. (2011). In green GPS vectors in the Apulia fixed reference frame in which the motion of Calabria is parallel to the slip vector suggesting the existence of active crustal compression as a result of subduction of the Ionian lithosphere beneath the Calabrian Arc (D'Agostino et al., 2008). The NW ward dipping subducting slab of the African plate is represented by the yellow isodepth lines in the Tyrrhenian Sea spacing from 100 to 450 km depth (Selvaggi and Chiarabba, 1995). ATL: Aeolian–Tindari–Letojanni fault.

Wortel et al., 2009). The Calabria slab has distinct edges and a Subduction-Transform Edge Propagator (STEP, Govers and Wortel, 2005) laterally bounds the narrow CA in both the northeast and southwest. These are loci of lithospheric tearing that result from the subduction of the (retreating) Calabria slab while adjacent parts (Apulia, Sicily) remain at the earth surface. The plate boundary between the overriding plate and the surface plate that develops in the wake of the STEP is referred to as the “STEP fault” (Baes et al., 2011). The geometry and kinematics of a STEP fault (or fault zone Özbakır et al., 2013) are still poorly constrained, on the one hand because of their dependence on the regional situation, presumably resulting in a great variety of expressions and, on the other hand, owing to the lack of direct, diagnostic observations, as exemplified by incomplete (too short) records of earthquake activity accompanying STEP action.

Geodetic data highlight the presence of distinct deformation belts separating the Tyrrhenian Sea, and the Sicily and Calabria blocks, which interfere in NE Sicily and the Messina Straits area (Palano et al., 2012; Doglioni et al., 2012; D'Agostino and Selvaggi, 2004; Serpelloni et al., 2005). Several regional-scale active structures were proposed in this region: the southern Tyrrhenian contractional belt, along which tectonic inversion occurred since the middle Pleistocene (see also Pepe et al., 2005; Billi et al., 2007, 2011); the Aeolian–Tindari fault system, whose southward continuation into the Ionian offshore is controversial (Billi et al., 2006); the Messina fault, whose strike and pitch are also not completely agreed upon (Amoruso et al., 2002; Aloisi et al., 2012; Doglioni et al., 2012), and the Cefalù–Etna tectonic boundary (Billi et al., 2010). This complex setting was commonly related to a Middle Pleistocene tectonic reorganization in the southern-central Mediterranean driven by the stalling of the Calabrian roll-back/subduction and related Tyrrhenian back-arc extension (Wortel and Spakman, 2000; Goes et al., 2004; Faccenna et al., 2011). This process probably resulted in several crustal expressions, including the partial jump of the Sicilian thrusting towards the southern Tyrrhenian contractional belt, the increased extension and uplift rates in W Calabria and NE Sicily, the variation in chemical composition of magmas in the eastern Aeolian arc (De Astis et al., 2000), and the triggering of Mt. Etna volcanism (Gvirtzman and Nur, 1999; Doglioni et al., 2001; Faccenna et al., 2011).

GPS and seismicity observations suggest that the subducting African plate may contain several active fault/shear zones (Oldow et al., 2002; D'Agostino et al., 2008). Apulia may be moving with the Ionian Sea and the Hyblean Plateau, while Adria has a distinctly different motion (D'Agostino et al., 2008). In this framework, a key question is the role played by the submerged CA and the Ionian domain, which is described either as part of the Hyblean–Malta block or as part of the diverging