Tectonophysics 657 (2015) 205–218

Contents lists available at ScienceDirect

Tectonophysics

journal homepage: www.elsevier.com/locate/tecto

Active upper crust deformation pattern along the southern edge of the Tyrrhenian subduction zone (NE Sicily): Insights from a multidisciplinary approach

Mimmo Palano [a,*], Domenico Schiavone [b], Mariano Loddo [b], Marco Neri [a], Debora Presti [c], Ruggiero Quarto [b], Cristina Totaro [c], Giancarlo Neri [c]

[a] Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo—Sezione di Catania, Catania, Italy
[b] Dipartimento di Scienze della Terra e Geoambientali, Università di Bari, Bari, Italy
[c] Dipartimento di Fisica e di Scienze della Terra, Università di Messina, Messina, Italy

ARTICLE INFO

Article history:
Received 22 July 2014
Received in revised form 1 July 2015
Accepted 3 July 2015
Available online 17 July 2015

Keywords:
Subduction edge
Seismic velocity structure
Density model
Ground deformation
Crustal shear zone
Calabro-Peloritan Arc

ABSTRACT

Using a multidisciplinary dataset based on gravimetric, seismic, geodetic and geological observations, we provide an improved picture of the shallow structure and dynamics of the southern edge of the Tyrrhenian subduction zone. With a local earthquake tomography we clearly identify two main crustal domains in the upper 15 km characterized by different P-wave velocity values: a high-velocity domain comprising southeasternmost Tyrrhenian Sea, NE Sicily and Messina Straits, and a low-velocity domain comprising Mt. Etna and eastern Sicily. The transition between the two domains shows a good spatial correspondence with a wider set of faults including the Taormina Fault System (TFS) and the Aeolian–Tindari–Letojanni Fault System (ATLFS), two nearly SE-striking fault systems crossing northeastern Sicily and ending on the Ionian shoreline of Sicily according to many investigators. Within this set of faults, most of the deformation/seismicity occurs along the northern and central segments of ATLFS, compared to low activity along TFS. A lack of seismicity (both recent and historical) is observed in the southern sector of ATLFS where, however, geodetic data reveal significant deformation. Our multidisciplinary dataset including offshore observations suggests the southeastward continuation of the ATLFS into the Ionian Sea until joining with the faults cutting the Ionian accretionary wedge described in the recent literature. Our findings imply the existence of a highly segmented crustal shear zone extending from the Aeolian Islands to the Ionian Abyssal plain, that we believe plays the role of accommodating differential motion between the Southern Tyrrhenian unit and the western compressional domain of Sicily. The ATLFS, which is a main part of the inferred shear zone, behaves similarly to what often observed at the edges of retreating subduction slabs, where the overriding plate drifts with a highly non-uniform transform motion along the lateral borders.

1. Introduction

At present, the Central Mediterranean basin is dominated by the geodynamic processes related to (i) the convergence between the African and the Eurasian plates (e.g. Malinverno and Ryan, 1986) and (ii) active back-arc spreading in the hanging-wall of the Apennines subduction zone (e.g. Cuffaro et al., 2011). Geological, seismological and geodetic observations collected in the past few decades in southern Italy have provided evidence that active crustal shortening is widely accommodated in southeastern Sicily at the front of the Apennine–Maghrebian orogen and along the northern-western offshore of Sicily (Fig. 1; Goes et al., 2004; Pondrelli et al., 2004; Palano et al., 2012; Presti et al., 2013). In southeastern Sicily the convergence process caused the segmentation of the Hyblean foreland by the reactivation of pre-existing structures (Musumeci et al., 2014), while along the northern-western offshore of Sicily the crustal shortening occurs along thrusts whose fronts are laterally offset by newly formed right-lateral crustal shear zones (Billi et al., 2007; Goes et al., 2004; Pondrelli et al., 2004). In northeastern Sicily and southern Calabria, crustal extension is controlled by subduction underneath the Calabro-Peloritan Arc of the Ionian oceanic crust and by southeast directed rollback of the subducting slab (see Neri et al., 2012 and references therein). The different deformation patterns of the two main geodynamic domains of the Western-Central Sicily and the Calabro-Peloritan Arc are accommodated in northeastern Sicily and several researchers (e.g. Billi et al., 2006; Cuffaro et al., 2011; Palano et al., 2012) have suggested that in this area a major role is played by the so called "Aeolian–Tindari–Letojanni" Fault System (hereinafter ATLFS), a complex and heterogeneous crustal discontinuity consisting of a broad NNW–SSE- to NW–SE-trending system of faults running from

* Corresponding author at: Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo—Sezione di Catania, P.zza Roma, 2, 95123 Catania, Italy. Tel.: +39 095 7165800.
E-mail address: mimmo.palano@ingv.it (M. Palano).

http://dx.doi.org/10.1016/j.tecto.2015.07.005
0040-1951/© 2015 Elsevier B.V. All rights reserved.

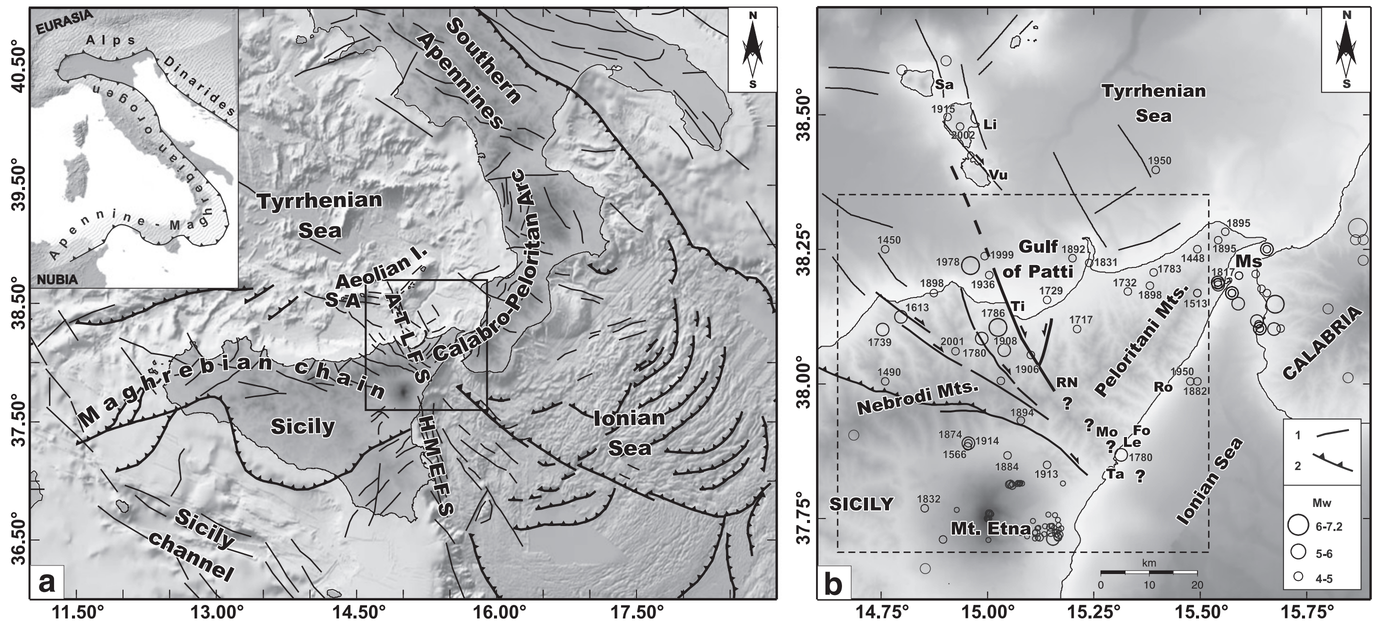

Fig. 1. a) Simplified tectonic map of Sicily and surrounding areas. Abbreviations are: ATLFS, Aeolian–Tindari–Letojanni Fault System; TFS, Tindari Fault System; HMEFS, Hyblean–Maltese Escarpment Fault System; SA, Sisifo–Alicudi shear zone. The Maghrebian Chain and the Calabro Peloritan Arc are parts of the Apennine–Maghrebian orogen (see inset). The black rectangle encloses the area reported in panel b). b) Circles show the locations of the earthquakes that have occurred in the investigated area after 1000 A.D. according to the CPTI11 catalogue (Rovida et al., 2011; http://emidius.mi.ingv.it/CPTI11). Labels indicate the year of occurrence. The completeness magnitude of the catalogue is 6.4, 5.9, 5.2 and 4.7 since 1300, 1530, 1700 and 1895, respectively (http://zonesismiche.mi.ingv.it). Epicentres falling in the Mt. Etna area and the Messina Straits are not labelled. Fo = Forza D'Agrò; Le = Letojanni; Li = Lipari; Ms = Messina Strait; Mo = Mongiuffi; RN = Rocca Novara; Ro = Roccalumera; Sa = Salina; Ta = Taormina; Ti = Tindari; Vu = Vulcano. Major oblique dip–slip (1) and reverse (2) faults are also reported. The dashed rectangle indicates the main study area of the present work.

the Aeolian Islands down to the Ionian coast of Sicily (Fig. 1). Notwithstanding that the ATLFS is characterized by the lack of tectonic and morphological faulting expressions at its southern termination (Fig. 1; e.g. Billi et al., 2006; De Guidi et al., 2013), several authors extend it down to the Ionian coast of Sicily, linking it with major tectonic structures located close to the Ionian offshore. Several investigators connect the ATLFS with the Hyblean–Maltese Escarpment fault system (e.g. Govers and Wortel, 2005; Lanzafame and Bousquet, 1997; Rosenbaum et al., 2008), a right lateral transtensional Mesozoic lithospheric boundary separating the Sicilian continental crust from the Ionian oceanic basin (Fig. 1a). Other investigators suggest that ATLFS simply connects the northern-western Sicilian contractional belt to the Ionian accretionary wedge, accommodating differential movements within the contractional belt itself (Fig. 1a; e.g. Goes et al., 2004; Neri et al., 2004; Billi et al., 2006). A number of authors (e.g. Govers and Wortel, 2005; Neri et al., 2009; Rosenbaum et al., 2008 and references therein) suggest the ATLFS is the current shallow expression of a sub-vertical lithospheric-scale tear-fault, bordering the southern edge of the Tyrrhenian subduction zone at depth. Other investigators advocate that ATLFS developed during the Plio-Pleistocene as part of a complex synthetic and antithetic grid of high-angle strike–slip faults and is no longer active (e.g. Catalano et al., 2009; Giunta et al., 2009).

This study focuses on the ATLFS and surrounding zones. We adopted a multidisciplinary approach based on gravimetric, seismic, geodetic and geological observations collected in the last two decades. In particular, we have investigated a broad deformation zone that include the ATLFS and attempted to establish whether such a deformation zone really play the role of accommodating the differential motion between the eastern extensional domain of the Calabro-Peloritan Arc and the western compressional one of Western-Central Sicily.

2. Background setting

The convergence between the African and Eurasian plates has dominated the evolution of the central Mediterranean basin since the Cretaceous, controlling the generation, spatial distribution and shape of all mountain chains and of the intervening basins (Anderson and Jackson, 1987; Dewey et al., 1973; Doglioni, 1993; Jolivet et al., 1998). Despite the convergence process occurring at a rate of 1–2 cm/yr during the last 8–10 Myr, the Calabro-Peloritan Arc (part of the Apennine–Maghrebian orogen accreted since the Miocene; Fig. 1a, Malinverno and Ryan, 1986; Patacca et al., 1990), experienced rapid E to SE motion at a rate of 5–8 cm/yr up to Early Pleistocene, driven by rollback of the Ionian subducting slab. Moreover, during the Middle–Late Pleistocene, when the Calabro-Peloritan Arc almost reached its present location, subduction trench retreat slowed to less than 1 cm/yr, probably because of a tectonic reorganization on this sector of the Mediterranean basin (Faccenna et al., 2001; Goes et al., 2004; Westaway, 1990; Wortel and Spakman, 2000). Regional tectonic evolution and lithospheric structures were strongly influenced by rollback and back-arc extension, with the formation of new oceanic crust in the Tyrrhenian Sea basin (Faccenna et al., 2004; Gueguen et al., 1998; Rosenbaum and Lister, 2004). The progressive southeastward rollback of the subducting slab was accommodated by the development of some right-lateral shear zones which, bordering the forearc–backarc system, have migrated eastward over time (e.g. Billi et al., 2010; Finetti et al., 1996; Rosenbaum and Lister, 2004). The NNW–SSE striking Aeolian–Tindari–Letojanni Fault System (ATLFS), consisting of a set of mainly right-lateral and extensional faults (Fig. 1b), is believed to represent the easternmost and youngest of these tectonic accommodation structures (Finetti et al., 1996; Guarnieri, 2006).

The ATLFS can be divided into three sectors (northern, central and southern) characterized by different kinematic, geological and geomorphological features. The northern sector extends from the central Aeolian Islands up to the Gulf of Patti. The central sector develops in northeastern Sicily onshore, between Tindari and the watershed of the Peloritani Mts. (close to Rocca Novara; RN in Fig. 1b), while the southern sector extends from the watershed of the Peloritani Mts. down to the Ionian coast, close to Letojanni (Le in Fig. 1b). The ATLFS is rather well defined by geological and geophysical evidences only in its northern and central sectors, while in the southern sector it is characterized by less evident tectonic and morphological faulting expressions (Billi