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Pattern of deformation around the central Aeolian Islands: evidence from GPS data and multichannel seismics

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A lateral change in geodynamic regime, from soft-collision in Sicily to oceanic subduction underneath Calabria, characterizes the southern Tyrrhenian region. The contiguity of these two different geodynamic regimes along the same convergent boundary is due to the occurrence of a continent-to-ocean transition within the subducted plate (Africa), where the Ionian oceanic lithosphere passes to the west to the Hyblean-Pelagian continental lithosphere in Sicily. In the Aeolian Islands, representing the volcanic arc of the Tyrrhenian subduction, the effects of this lateral change along the subductive boundary is recorded in the distribution of seismicity with depth (Chiarabba et a., 2005), and in the time and space patterns of volcanic activity (De Astis et al., 2003), besides being well imaged by P wave seismic tomography (Wortel and Spakman, 2000; Piromallo and Morelli, 2003). Besides the abrupt lateral change of geodynamic regime, the Ionian lower plate appears to be passively sinking and torn apart from the buoyant Hyblean-Pelagian lithosphere during the final stage of the southern Tyrrhenian backarc opening (e.g., Gvirtzman and Nur, 1999; Argnani, 2000). In fact, the neotectonics of the eastern Sicily slope (Argnani and Bonazzi, 2005) can be interpreted as a surficial expression of an ongoing lithospheric tear or slab-transfer edge-propagator fault (STEP; Govers and Wortel, 2005) at its propagation tip.

Numerical modelling indicates that significative deformation and rotation of strain axes are expected along STEP faults (Govers and Wortel, 2005), particularly nearby the propagation tip, although such processes are currently undocumented in the geological record. The lateral tear or STEP fault possibly located along the eastern Sicily slope is supposed to continue northward in the central Aeolian Islands, being responsible for the NNW-SSE branch of the volcanic arc, composed by the islands of Vulcano, Lipari and Salina (Lanzafame and Bousquet, 1997; Argnani, 2000). The central Aeolian Islands, therefore, represent a candidate region where to test the STEP fault model against geological observation. Structural data of regional extent, however, are lacking because outcrops are restricted to the small volcanic islands, and, as a result, tectonic interpretations rely heavily on structural works carried out onshore (e.g., Mazzuoli et al., 1995), where the volcano-tectonic effects can interfere on regional tectonics. Marine geophysical data are required in order to outline the pattern of the main tectonic structures, but seismic profiles of good quality are scarse in the area around the central Aeolian Islands. In fact, existing seismic data consist mainly of single channel profiles acquired in the 70s, with poor resolution and unfavourable spacing (Barone et al., 1982), and the resulting structural maps presented in the literature appear in places tectonically unsound. To fulfil this gap of information a set of high-resolution multichannel seismic profiles have been purposedly acquired around the central Aeolian Islands.

A growing set of GPS data allows to contrain the instantaneous strain pattern of the Aeolian region (Hollenstein et al., 2003, Goes et al., 2004, D'Agostino and Selvaggi, 2004, Serpelloni et al., 2005). A roughly N-S-directed horizontal compression characterizes the whole western sector of the Aeolian Islands, where recently recorded focal mechanisms have shown the occurrence of a compressional belt that extends laterally for some 200 km in an E-W direction (Pondrelli et al., 2004). GPS data indicate that the convergence between Nubia and Eurasia is absorbed completely, or by a large extent, along this seismic belt (Hollenstein et al., 2003; Goes et al., 2004; D'Agostino and Selvaggi, 2004; Serpelloni et al., 2005). In the central-eastern sector of the Aeolian Islands the axes of maximun horizontal compression rotates clockwise, from west to east, from N-S to NE-SW, before leaving way, when approaching the Messina Strait and Calabria, to a dominant extension along a NW-SE direction. The strain pattern computed from GPS data highlights the first order inconsistency of structural maps presented in the literature, which shows only extensional and strike-slip faults, with poorly constrained direction, in the central Aeolian Islands (e.g., De Astis et al., 2003). Moreover, GPS velocities w.r.t. Eurasia at Cape Milazzo, Vulcano and Lipari are remakably larger than the velocities measured at Salina, Panarea and Stromboli, suggesting the occurrence of contractional structures in the western part of the Gioia basin.

Multichannel profiles offer a picture of the long-term geological strain and can be fruitfully combined with GPS data to unravel the history of deformation of a given region. The tectonic pattern outlined by our purposedly collected seismic data shows that no fault is present along the S-ward continuation of the Vulcano-Lipari-Salina allignment into the Gulf of Patti, and that faults do not occur underneath the Stromboli canyon, unlike previous interpretations. Moreover, a complex NW-SE-trending belt of compressional (or transpressional) structures connects the island of Vulcano with Capo Milazzo., showing a compatibility with GPS computed strain axes, as well as with seismic stress field (Neri et al., 2003).

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