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Temperature and density of the Tyrrhenian lithosphere and slab and new interpretation of gravity field in the Tyrrhenian Basin

F. Cella [a], S. de Lorenzo [b], M. Fedi [c], M. Loddo [b], F. Mongelli [b], A. Rapolla [c], G. Zito [b,*]

[a] *Department of Earth Sciences—University of Calabria, Italy*
[b] *Department of Geology and Geophysics—University of Bari, Italy*
[c] *Department of Earth Sciences—University "Federico II" of Naples, Italy*

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Abstract

The gravity anomaly field of the Tyrrhenian basin and surrounding regions reflects the complex series of geodynamic events active in this area since the Oligocene–Miocene. They can resume in lithospheric thinning and asthenospheric rising beneath the Tyrrhenian Basin, coexisting with the roll-back subduction of the African plate margin westward sinking beneath the Calabrian Arc. The geographic closeness between these processes implies an intense perturbation of the mantle thermal regime and an interference at regional scale between the related gravity effects.

A model of the litho-asthenospheric structure of this region is suggested, showing a reasonable agreement with both the evidences in terms of regional gravity anomaly pattern and the results concerning thermal state and petro-physical features of the mantle. The first phase of this study consisted of the computation of the isotherms in the crust–mantle system beneath the Tyrrhenian Basin and, afterwards, of the density distribution within the partially melted upwelling asthenosphere. The second phase consisted of a temperature/density modelling of the slab subducting beneath the Calabrian Arc. Finally, a $2^{1/2}$ interpretation of gravity data was carried out by including as constraints the results previously obtained. Thus, the final result depicts a model matching both gravity, thermal and petrographic data. They provide (a) a better definition of the thermal regime of the passive mantle rise beneath the Tyrrhenian basin by means of the estimation of the moderate asthenospheric heating and (b) a model of lithospheric slab subducting with rates that could be smaller than generally suggested in previous works.

Keywords: Tyrrhenian Basin; Central Mediterranean; Subduction; Lithosphere; Asthenosphere; Heat flow; Gravity anomalies; Thermal model; Density model

1. Introduction: the Tyrrhenian Sea–Calabrian Arc system: geophysical setting

The Tyrrhenian basin (Fig. 1) is a deep, asymmetric, depression representing one of the major structural elements of the central Mediterranean. Its Northern part, mostly composed of continental crust, has been interpreted as the western sector of an accretionary prism related to the westwards subduction below Corsica since the early Oligocene (Abbate et al., 1994). Along the western margin the continental basement results thinned by rotational normal faulting (Kastens et al., 1988).

The southern margin of the Tyrrhenian Basin shows a very composite volcanic activity whose products have large petrological differences, from the oldest terms (31–13 My) up to the Aeolian arc (active since 1 My ago) and the Lazio–Campania volcanic districts.

* Corresponding author.
E-mail address: gm.zito@geo.uniba.it (G. Zito).

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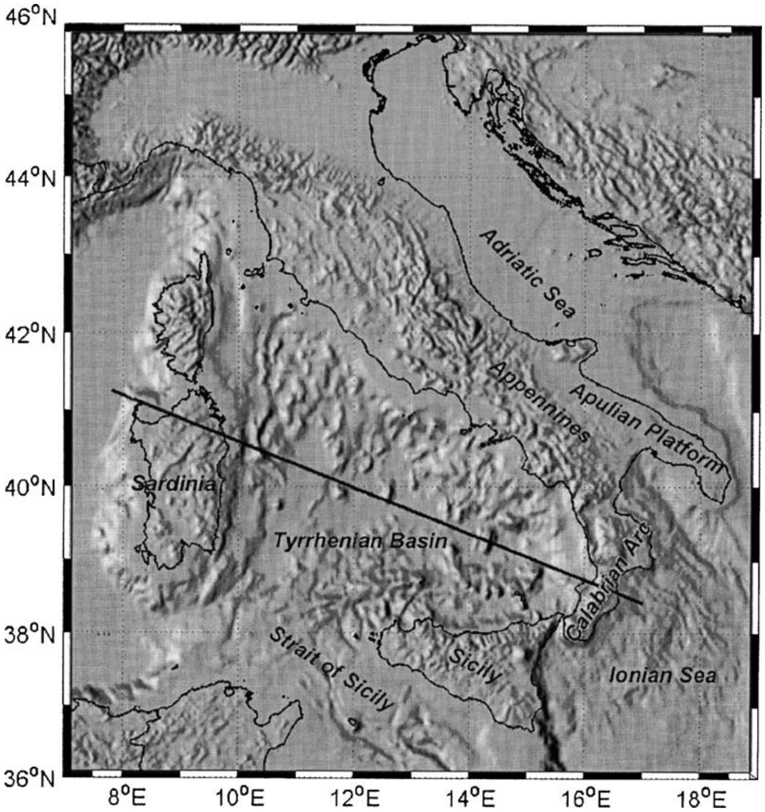

Fig. 1. Regional Sketch map of the main geological and structural features in the Central Mediterranean.

Within the central abyssal plain, a strongly stretched ancient continental crust underwent MORB magmatism (DSDP 373; ODP 650-651-655) and alkali-basaltic volcanic activity (Kastens et al., 1988). The Tyrrhenian Basin is described as an extensional Neogene–Quaternary back-arc basin formed by counterclockwise rotation of the Corsica–Sardinia and Adriatic microplates (Alvarez, 1972; Cherchi and Montadert, 1982; Rehault and Bethoux, 1984). The opening process migrated southeastward and was triggered by the passive westward dipping subduction (Malinverno and Ryan, 1986; Royden et al., 1987; Kastens et al., 1988) of Triassic oceanic lithosphere whose relicts should be present in the Ionian abyssal plain. Such a model agrees with the subduction-related processes like the Apenninic thrust-fold belt (Doglioni, 1991) and the shallower Moho inferred from seismic data (Steinmetz et al., 1983; Recq et al., 1984; Duschenes et al., 1986; Nicolich, 1989; Scarascia et al., 1994), from high heat flow (Della Vedova et al., 1984; Hutchison et al., 1985; Wang et al., 1989; Mongelli et al., 1991; Cataldi et al., 1995, Pasquale et al., 1999) and from the regional gravity field (Morelli, 1970; Corrado and Rapolla, 1981). Further quantitative elements supporting both the strong lithospheric thinning and a passive mantle rise beneath the Tyrrhenian basin came from the density model computed by Cella et al. (1998) not only by merely fitting the regional gravity field but basing also on constraints derived from geothermal information. They were directly inferred from a few available data (i.e. the potential temperature, the β factor and the pre-stretched lithospheric thickness) by means of the petrophysical model provided by McKenzie and Bickle (1988).

The hypothesis of the eastward migration of the rifting process has been recently supported by geophysical investigations (Pasquale et al., 1999; Zito et al., 2003) depicting the present heat flow in the southern Tyrrhenian Sea as a transient thermal wave migrating in time and space. Therefore, the eastward jumping of the spreading centers could be really explained as consequence of the break-up of the earlier Alpine orogen and of the roll-back of the slab that developed eastward (Spadini et al., 1995; Gueguen et al., 1997; Doglioni et al., 1998, 1999). Stretched continental block were dispersed by lithospheric boudinage within areas where the mantle melt rises at very shallow depths and solidifies by