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0.1 Dynamics of the Tyrrhenian subduction zone

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Several numerical and analytical models have been proposed to depict the dynamics of the Tyrrhenian subduction zone. The inference of the thermal structure is, instead, at an early stage. So far the temperature distribution within the Ionian slab was approach with conductive heating models. The thermal conditions of the subducting lithosphere and the surrounding mantle are key-information to understand the earthquake distribution and the magma generation in the back-arc area (Sicilian-Calabrian margin). In this paper, we improve previous thermal investigations by means of an analytical model that takes into account the effects of the dynamic interaction between the lithosphere slab and the surrounding mantle.

The proposed thermal model takes account of thickness, convergence rate, dip angle and seismogenetic zone of the slab. Moreover, it considers an appropriate adiabatic gradient in the mantle and the latent heat due to phase changes. The thermal field within the slab is such that the potentially seismogenetic portion tends to shift with depth. The mantle above the slab flows parallel to the subducting plate and no conduction occurs down the slab dip. The slab sinks at an angle of about 75˚ to 350-400 km and of 50˚ at greater depth, where earthquakes are less frequent and more scattered. Its geometry is based on the distribution of the intermediate and deep seismicity (between 60 and 600 km).

The thermal conditions at the boundaries were fixed on the basis of rheological considerations. Preliminarily, a reference geotherm was calculated for the undeformed part of the slab, by taking a thickness of 70 km for the mechanical boundary layer, a terrestrial heat-flow density of 42 mW/m^2, an asthenosphere potential temperature of 1300 ˚C, an adiabatic gradient of 0.6 mK/m and a mantle kinematic viscosity of 10^7

m^2/s. The calculated temperature-depth distribution compared to the mantle melting temperature indicates the decoupling between lithosphere and asthenosphere occurs at 105 km depth, corresponding to a temperature of 1260 ˚C.

The thermal-dependence of the lithosphere rheology was then expressed with the ratio γ of the critical temperature - above which no earthquake occurs - on the melting temperature. Considering that the maximum depth of earthquakes within an oceanic lithosphere remotely from the subduction zone is about 45 km, for the reference geotherm the corresponding critical temperature is 600 ˚C and γ = 0.56. This implies that the critical temperature at the lower boundary of the Ionian slab is estimated to be 990 ˚C. Consequently, by subtracting the temperature increase of 135 ˚C due to the latent heat of the olivine-spinel phase change at 400 km depth, a temperature value of 450 ˚C at upper surface of the plate as it enters the asthenosphere was inferred.

Once the lithosphere thickness and the temperature to its base are established, the subduction rate is the major unknown for calculating the thermal structure of the sinking slab. For a vertical temperature gradient in the mantle, the slab heating should depend mostly on the vertical component of the convergence rate. The subduction rate was determined using the “thermal parameter”, defined as the product of the age of subduction and the vertical component of the convergence rate, which for the Ionian slab is 4725 km. Since the assimilation time of the slab is 7 Myr, we obtained a cooling time of about 90 Myr and, for an average dip angle of the slab of 60˚, a subduction rate of 6 cm/yr.

As the model was performed for an isothermal mantle, the calculated thermal structure was performed in terms of potential temperature. The critical temperature at the depth of 600 km corresponds to a potential temperature of about 730 $\pm$ 70 ˚C. The results illustrate not only heating of the slab down dip, but also cooling in the mantle wedge. The minimum temperature within the slab tends to shift down dip away from the upper surface. At 600 km depth, the distance is about 23 km. The minimum temperature increases by 280 ˚C from 50 to 600 km and affects the seismic distribution in the deep region.

The difficulties arising in assessing the cooling time of the plate, defined as the time required for the ocean plate to move from the spreading centre to the trench, can be overcome by hypothesizing a subduction rate equal to spreading rate. If this is true, a direct proportionality of assimilation time to the cooling time is obtained. The error on the temperature in the slab can attain a maximum of 100 ˚C. The adopted model requires that the temperature in the asthenosphere wedge above the subduction slab (Tyrrhenian basin) is equal to the asthenosphere temperature beneath the stable part of the plate the lithosphere (Ionian basin). However, the thermal budget and the occurrence of extensional magmatism in the former basin would imply a moderately warmer asthenospheric wedge.