The subduction of continental lithosphere: insights from multiscale geophysical modelling of the Periadriatic region

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The subduction of continental lithosphere has been demonstrated in the Alps (Panza and Müller, 1979) and since this pioneering paper it has been recognized in several other collisional belts such as the Apennines (Panza et al., 2007), the Himalaya (Zhang et al., 2014) and Zagros chain (Motaghi et al., 2014) by means of seismological and geophysical investigations. We present a multiscale 3D model of the crust and upper mantle of the Periadriatic region showing that the Adriatic plate, the Northern indent of the African promontory, is involved in the Apennines, Alpine, and Dinarides subduction, respectively surrounding its western, northern, and eastern margins.

The superposition of different geodynamic mechanisms in the same area is coherent with the global asymmetry of plate tectonics (Doglioni et al., 2007; Panza et al., 2010) and supports a passive origin of plate boundaries, contrary to what is usually assumed.

Data and method

The 3D model is obtained through the ensemble of cellular models expressed in terms of shear waves velocity (V_S), thickness and density of the layers, to a depth of 350 km. These physical properties are obtained by means of advanced non-linear inversion techniques, such as the "hedgehog" inversion of group and phase velocity dispersion curves for the determination of V_S (Panza et al., 2007 and references therein) and the non-linear inversion of gravity data by means of the method GRAV3D (Li and Oldenburg, 1998).

The "hedgehog" method allows for the definition of a set of structural models without resorting to any a priori model, considering the V_S and the thickness of the layers as independent variables. Given the well-known non-uniqueness of the inverse problem, the representative solution of each cell is determined through the application of optimization algorithms (Boyadzhiev et al., 2008) and is also validated with the use of independent geological, geophysical and petrological data, e.g. the distribution of seismicity with depth.

The gravimetric inversion has been constrained to the geometry of the layers defined by the V_S absolute tomography model (Foulger et al., 2013) obtained from the inversion of surface wave dispersion data. To the gravimetric data input a Gaussian noise with an amplitude of 1.5 mGal has been applied and the density anomalies obtained by the inversion process are transformed into absolute values relative to a reference model consistent with the Nafe-Drake relation.

A temperature model of the mantle is finally obtained by means of an advanced conversion technique of V_S to temperature that takes in account variable chemical composition and bulk water content (Tumanian et al., 2012 and references therein).

Results

The 3D model thus obtained at the scale of 1°x1°, analysed along selected sections perpendicular to the orogenic complexes of the study area (Apennines, Alps, Dinarides) confirms the existence of deep structural asymmetries between E- and W-directed subduction zones. The asymmetry found between the almost vertical Apenninic subduction and the Alpine-Dinaric subduction, which is characterized by a low

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dip angle, can be ascribed to an eastward mantle flow taking place in the low velocity zone (LVZ) that characterizes the top of the very shallow asthenosphere beneath the Tyrrhenian basin.

The refined model obtained for the Alpine region at a scale of 0.5°x0.5°, enlightening the extreme variability of the crustal thickness as well the small scale heterogeneities in the upper mantle beneath the study area (fig. 1), shows the extreme importance of the best possible definition of the most superficial layers, which are fixed in the inversion, by means of reliable independent information.

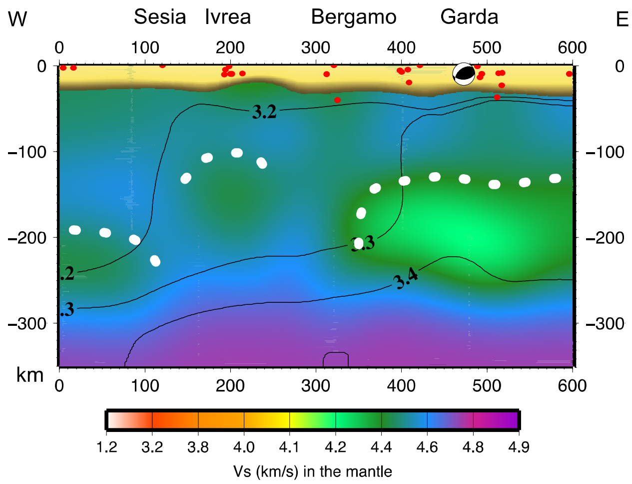

Figure 1. V_S and density (contour lines, g/cm^3) model along a W-E profile along latitude 45.75°N. Seismicity (red dots) and focal mechanisms of major events are shown as well. Dotted white lines delineate the lid-LVZ margin.

The density model clearly shows that the subducting lithosphere is less dense than the surrounding mantle (Brandmayr et al., 2011). This result opens the way to new interpretations in subduction dynamics, which in its common description relies on the "slab pull" phenomenon as a first order acting force. In the upper mantle of the whole study area temperatures are strongly variable and can reach 1500-1600°C at the top of the asthenosphere. This finding corroborates the condition of non adiabaticity of the mantle, i.e. a super adiabatic regime in the upper 200 km which would inhibit large scale upper mantle convention.

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References
Boyadzhiev, G., Brandmayr, E., Pinat, T. and Panza, G.F., 2008, Optimization for non linear inverse problem, Rendiconti Lincei: Sci. Fis. e Nat., 19, 17-43.
Brandmayr, E., Marson, I., Romanelli, F. and Panza, G.F., 2011, Lithosphere density model in Italy: no hint for slab pull, Terra Nova, 23, 292-299.
Doglioni, C., Carminati, E., Cuffaro, M. and Scrocca, D., 2007, Subduction kinematics and dynamic constraints, Earth Science Reviews, 83, 125-175.
Foulger, G.R., Panza, G.F., Artemieva, I.M., Bastow, I.D., Cammarano, F. et al., 2013, Caveats on tomographic images, Terra Nova, 25, 259-281.
Li, Y. and Oldenburg, D.W., 1998, 3D inversion of gravity data, Geophysics, 63/1, 109-119.
Motaghi, K., Tatar, M., Priestley, K., Romanelli, F., Doglioni, C. et al., 2014, The deep structure of the Iranian Plateau, Gondwana Research, http://dx.doi.org/10.1016/j.gr.2014.04.009.
Panza, G.F. and Mueller, S., 1979, The plate boundary between Eurasia and Africa in the Alpine area, Memorie di Scienze Geologiche, Università di Padova, 33, 43-50.
Panza, G.F., Doglioni, C. and Levshin, A., 2010, Asymmetric ocean basins, Geology, 38, 59-62.
Panza, G.F., Peccerillo, A., Aoudia, A. and Farina, B.M, 2007, Geophysical and petrological modelling of the structure and composition of the crust and upper mantle in complex geodynamic settings: The Tyrrhenian Sea and surroundings, Earth-Science Reviews, 80, 1–46.
Tumanian, M., Frezzotti, M.L., Peccerillo, A., Brandmayr, E. and Panza, G.F., 2012, Thermal structure of the shallow upper mantle beneath Italy and neighbouring areas: correlation with magmatic activity and geodynamic significance, Earth-Science Reviews, 114 , 369-385.
Zhang, Z., Teng, J., Romanelli, F., Braitenberg, C., Ding, Z. et al., 2014, Geophysical constraints on the link between cratonization and orogeny: Evidence from the Tibetan Plateau and the North China Craton, Earth-Science Reviews, 130, 1-48.