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Geodynamic evolution of the central and western Mediterranean: Tectonics vs. igneous petrology constraints

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ABSTRACT

We present a geodynamic reconstruction of the Central–Western Mediterranean and neighboring areas during the last 50 Myr, including magmatological and tectonic observations. This area was interested by different styles of evolution and polarity of subduction zones influenced by the fragmented Mesozoic and Early Cenozoic paleogeography between Africa and Eurasia. Both oceanic and continental lithospheric plates were diachronously consumed along plate boundaries. The hinge of subducting slabs converged toward the upper plate in the double-vergent thick-skinned Alps–Betics and Dinarides, characterized by two slowly-subsiding foredeeps. The hinge diverged from the upper plate in the single-vergent thin-skinned Apennines–Maghrebides and Carpathians orogens, characterized by a single fast-subsiding foredeep. The retreating lithosphere deficit was compensated by asthenosphere upwelling and by the opening of several back-arc basins (the Ligurian–Provençal, Valencia Trough, Northern Algerian, Tyrrhenian and Pannonian basins). In our reconstruction, the W-directed Apennines–Maghrebides and Carpathians subductions nucleated along the retro-belt of the Alps and the Dinarides, respectively. The wide chemical composition of the igneous rocks emplaced during this tectonic evolution confirms a strong heterogeneity of the Mediterranean upper mantle and of the subducting plates. In the Apennine–Maghrebide and Carpathian systems the subduction-related igneous activity (mostly medium- to high-K calcalkaline melts) is commonly followed in time by mildly sodic alkaline and tholeiitic melts. The magmatic evolution of the Mediterranean area cannot be easily reconciled with simple magmatological models proposed for the Pacific subductions. This is most probably due to synchronous occurrence of several subduction zones that strongly perturbed the chemical composition of the upper mantle in the Mediterranean region and, above all, to the presence of ancient modifications related to past orogeneses. The classical approach of using the geochemical composition of igneous rocks to infer the coeval tectonic setting characteristics cannot be used in geologically complex systems like the Mediterranean area.

1. Introduction

A vast scientific literature is available for the Cenozoic geological and magmatological evolution of the Central–Western Mediterranean (Figs. 1 and 2), with nearly all the most important geological formations, structures, igneous and metamorphic rocks having been described in detail. Also the crustal and the upper mantle structure have been investigated using seismic and seismological data, showing a complex scenario, governed by several subduction zones and rifting environments (e.g., Amato et al., 1993; Giacomuzzi et al., 2011; Piromallo and Morelli, 2003; Wortel and Spakman, 2000). The present-day and the past stress state has been investigated via in-situ measurements, seismological and classical structural geology analyses. The past and present plate kinematics of the region has been constrained by reconstructions based mostly on paleomagnetism and, in recent years, on space geodesy (mainly GPS). This huge amount of knowledge, together with field geology, and the presence of igneous activity with peculiar geochemical and petrographic characteristics, have been condensed in a wealth of geodynamic evolutionary models (e.g., Boccaletti and Guazzone, 1974; Carminati et al., 1998a, 1998b; Chalouan et al., 2008; Channel and Mareschal, 1989; Csontos and Voros, 2004; Doglioni, 1991; Faccenna et al., 1997; Gueguen et al., 1998; Malinverno and Ryan, 1986; Mauffret, 2007; Rosenbaum et al., 2002a, 2002b; Schmid et al., 2008; Tari, 2002; Wortel and Spakman, 2000). Why, thus, another study on the Central–Western Mediterranean geology?

One of the major problems for a full understanding of Mediterranean geodynamics is that, with few exceptions, the available scientific literature represents the results of single discipline investigations rather than multidisciplinary approaches. The result is that the various geochemical, petrological, structural and tomographic models do not fully take into consideration the constraints evidenced by the other disciplines. In this work we integrate all the available pieces of information in a geodynamic reconstruction focussing on

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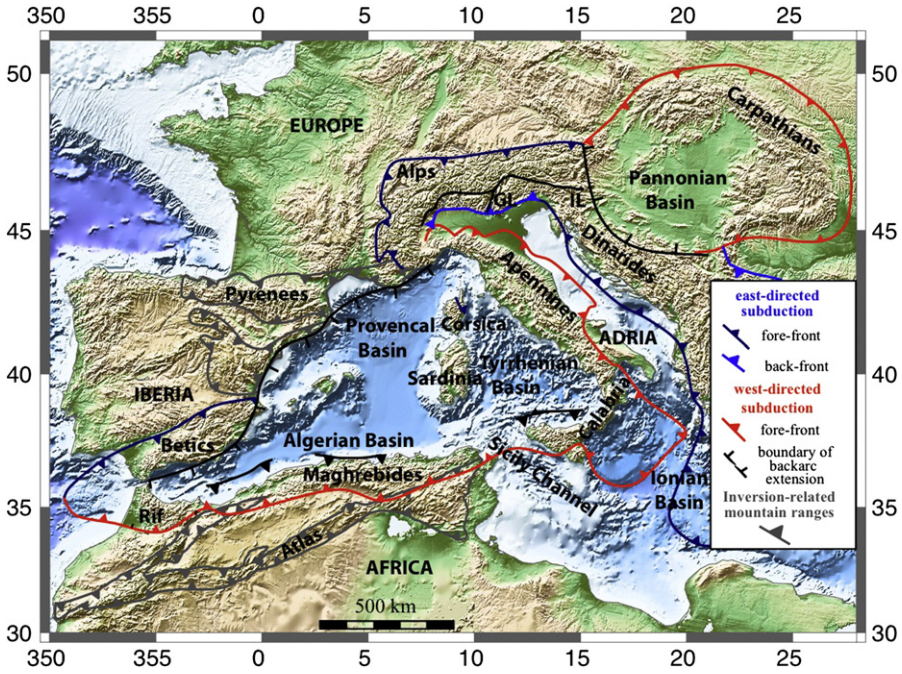

Fig. 1. Simplified present-day geodynamic scenario of the Central–Western Mediterranean region superimposed on the topography and bathymetry. GL: Giudicarie Lineament; IL: Insubric Line.

the Central–Western Mediterranean area, from the Gibraltar Straits to Western Greece, comprising Maghrebian Africa and Central–Eastern European domains (Rhine Graben to Pannonian–Carpathians). Carminati et al. (2010) presented fifty plane-section views of the post-50 Myr evolution of the Central–Western Mediterranean, highlighting the most important structural constraints and all the main igneous rock districts. Starting from this model, we present two evolutionary cross section views, one roughly NW–SE directed, passing through NE Spain to the Ionian Sea, and another from Southern France to the Carpathians, passing through the Adriatic Sea (see the movie associated with this manuscript, downloadable from the journal website). The cross sections presented here at 1 Myr interval are the first that take into consideration the full geological, metamorphic and igneous petrology of the investigated area and have a temporal continuity sufficient to evaluate their feasibility. A brief description of the main tectonic and magmatic features of the area is also provided, with special reference to the geology of the Central–Western Mediterranean area. For further details on tectonics

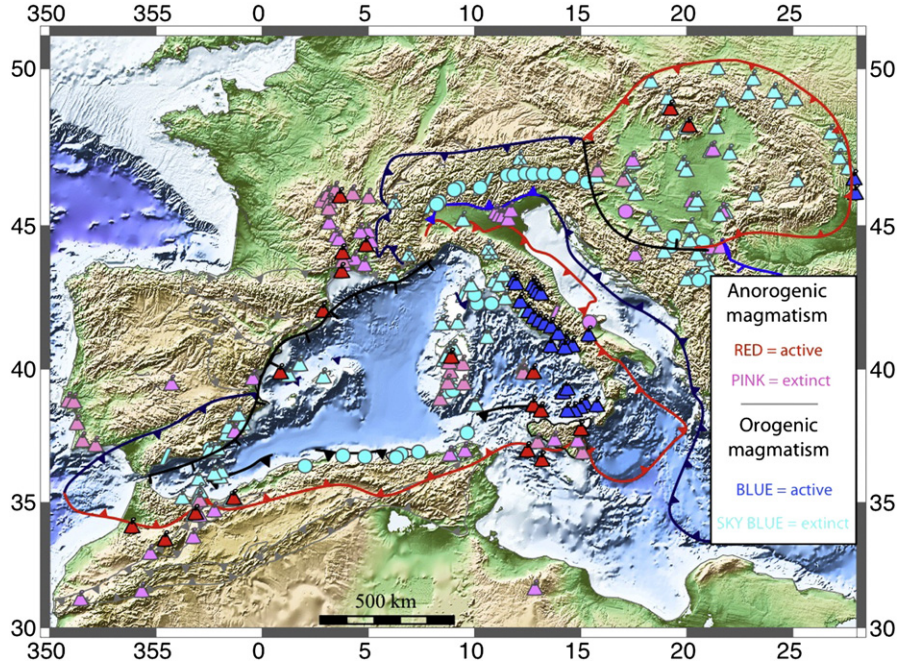

Fig. 2. Distribution of Tertiary magmatism in the Central–Western Mediterranean region. Triangles: volcanics and pyroclastics; Triangles with crosses: volcaniclastics; Circles: plutons; Slashes: dykes. Red symbols: active "anorogenic" igneous rocks; Pink symbols: extinct "anorogenic" igneous rocks; Blue symbols: active "subduction-related" igneous rocks; Sky Blue symbols: fossil "subduction-related" igneous rocks.