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Magnetic and gravimetric modeling of the central Adriatic region

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ABSTRACT

The high-amplitude wide magnetic anomaly that covers a large area of the north-eastern – central Adriatic Sea in the Croatian offshore is ~100 km wide and extends NW–SE for ~350 km. The anomaly is located between the Dinarides and Apennines chains, in an interesting geodynamic scenario. The presence of intruded gabbroid rocks in the Croatian archipelago also contributes to making this intriguing and still not extensively investigated anomaly potentially significant to the geologic and geophysical context in which it is located. In this work, we model the Bouguer and magnetic anomalies across the Adriatic Sea. The 2D geophysical modeling was produced across four cross sections considering surface heat flow data to calculate the Curie depth. The magnetic susceptibilities and densities used for the synthetic bodies are in agreement with the literature and with those derived by previous models. The results suggest the presence of an uplifted magnetized basement with high magnetic susceptibility (0.075 SI units) to be the main contributor to the observed magnetic anomaly. This magnetic susceptibility is interpreted as representative of a gabbroid-intruded basement. The high-susceptibility basement is in lateral continuity with a relatively low susceptibility basement (0.025–0.038 SI units). The results of the geophysical modeling are compared with a conceptual geological model realized from the integration of surface, well and geophysical data, the latter concerning seismic, tomographic, magnetic and gravimetric anomalies and heat flow data. These data have been merged in an integrated data-base using MOVE software, and the geophysical modeling was performed using GM-SYS. The comparison allowed to confirm the hypothesis that the magnetic anomaly is related to the basement and to its position in the complex geodynamic evolution of the Apennines–Adriatic–Dinarides system.

1. Introduction

The Adriatic region certainly represents an interesting and intriguing context, being localized in the complex geodynamic system of Apennines and Dinarides (Fig. 1). Geological and geophysical data for the Adriatic region, derived from oil exploration (i.e., wells and seismic), scientific seismic reflection campaigns for crustal information (e.g., CROP project), tectonic and geodynamic studies and derived models produced through time with increasing resolution and quality (e.g., Grandic et al., 1997, 1999, 2002; Tari, 2002; Scrocca et al., 2003; Finetti and Del Ben, 2005; Korbar, 2009), are abundant. Despite the large amount of scientific production regarding this region, there is still geological and geophysical evidence that is not clearly understood. Namely, a ~100-km-wide and ~350-km-long NW–SE-striking, high-amplitude (350 nT) magnetic anomaly covering a large area of the north-eastern central Adriatic Sea. This anomaly was first reported in the magnetic chart of Italy (AGIP, 1983) and was analyzed and integrated with data from Italian and Croatian national oil companies by Giori et al. (2007).

We present a magnetic and gravimetric model across four cross sections in the central Adriatic region to interpret the magnetic anomaly and constrain its origin in the Adriatic geodynamic evolution.

2. Geological setting and timing

The central and north-east Adriatic region (External Dinarides and Adriatic foreland) is located in a complex geological framework whose evolution and present-day deep-structural setting are still matters of debate. In a wide geodynamic context (Fig. 1), this area occupies an intermediate position between the north-eastern-verging Apennine thrust belt (toward the West) and the south-west-verging Dinaric thrust belt (toward the East).

The progressive, diachronous growth of these two thrust belts allowed the two superposed foreland basin systems to develop

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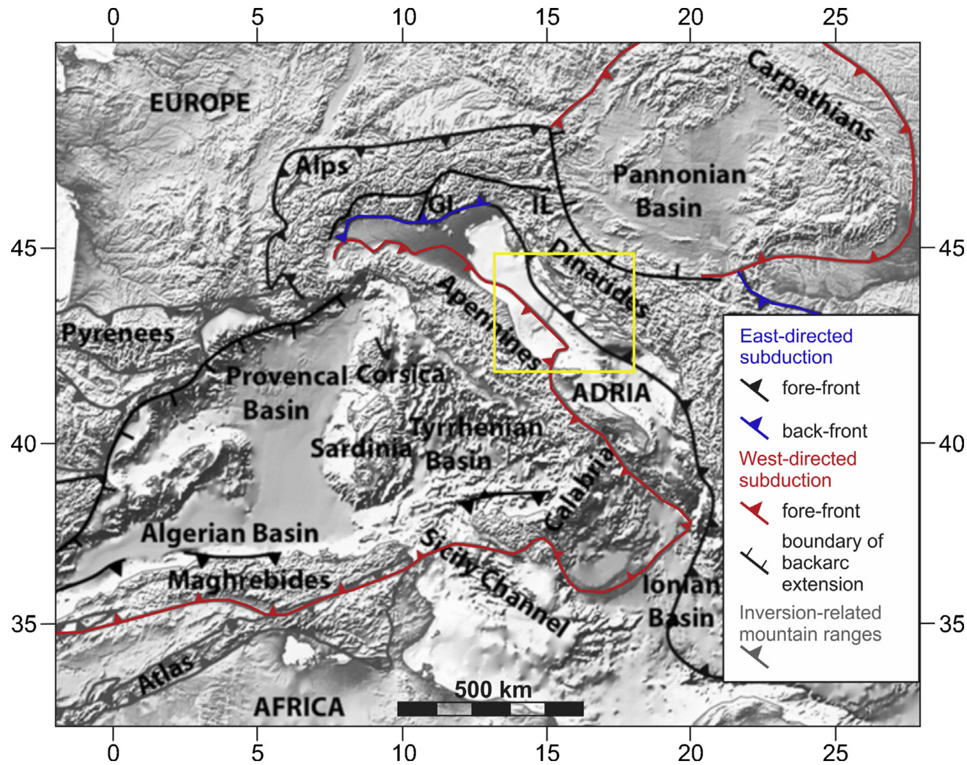

Fig. 1. Simplified present-day geodynamic scenario of the Mediterranean region on topography and bathymetry data (mod. from Carminati et al., 2012). The yellow square indicates the study area (Figs. 2 and 3). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

with opposite polarity and ages, having in the Adriatic Sea a common peripheral bulge zone. Both the present-day north-eastern and central Adriatic region and the External Dinarides developed following the long and complex evolution of a major lithospheric unit of African affinity known as the Adriatic Sub plate or the Apulian plate (Lort, 1971; Channel and Horvath, 1976; Channel et al., 1979; Bosellini, 2002). Carbonate platform-type deposition in these areas started in the Triassic and persisted up to the Eocene, punctuated by episodes of drowning or emersion (Ciarapica and Passeri, 2002). Extensional tectonics affected the Adriatic region since the Middle Triassic, with extensive normal faulting also accompanied by gabbroid intrusions found at the Jabuka islet (Fig. 2) and dated 262–200 My (Pamic and Balen, 2005; Juracic et al., 2004). Even if in the Croatian offshore there is no evidence of oceanic crust-derived rocks, the presence of those gabbroid intrusions suggests that a strong crustal thinning could have occurred at that time. As a result of the motion of the African and European plates, the latter overthrusted the Adriatic microplate, causing the formation of the Dinaric orogen. The main tectonic deformation occurred since the Paleogene, following a compression in the north-eastern direction whose consequence is the present-day Dinaric thrust-belt (Tari, 2002; Korbar, 2009). The upper portion of the sedimentary cover was affected by progressive thin-skinned deformation, while the Adriatic foreland remained out of the deformation. During the period from the Oligocene to Miocene, a late orogenic thick-skinned compressional uplift occurred, masking primary thin-skinned deformations. Along the present-day coast of Croatia, the Adriatic microplate is underthrusting the Dinarides (Herak, 1986; Moretti and Royden, 1988; Korbar, 2009) along a north-eastern oriented subduction (Bennett et al., 2008) suggested by the analysis of seismicity data (Kuk et al., 2000) and tomographic data (Piromallo and Morelli, 2003). The subduction continues laterally into the Adriatic Sea, extending toward and away from the island of Vis in the southern Adriatic (Sumanovac, 2010; Carminati et al., 2012) (Figs. 1 and 2).

3. Geophysical data

In the studied area, tomographic data (Venisti et al., 2005) suggest the presence of a high velocity volume beneath the Adriatic sea and Dinaric chain from west to east; the Bouguer anomaly ranges from $-60 \times 10^{-5}\,\mathrm{m\,s^{-2}}$ to $30 \times 10^{-5}\,\mathrm{m\,s^{-2}}$ (Tesauro et al., 2007; Tassis et al., 2013), with the minimum values observed beneath the Dinaric chain (Fig. 3a). The Moho depth ranges between 30 km in the central Adriatic and 40 km beneath the Dinaric chain (Nicolich and Dal Piaz, 1992; Nicolich, 2001) (Fig. 3d). Heat flows range between 30 and 40 $\mathrm{mW\,m^{-2}}$ (Della Vedova et al., 2001; Scrocca et al., 2003) (Fig. 3c), with maximum values observed in the northern portion of the investigated area. The significant magnetic anomaly in the Adriatic region was first reported in the "*Carta Magnetica d'Italia*" (AGIP, 1983) and, a few years later, in the "*Long wavelength anomalies*" chart (Pinna, 1987). The Adriatic anomaly is also reported in the aeromagnetic chart produced in 1994 by AGIP and Servizio Geologico Nazionale and in the magnetic anomaly map of Italy at sea level (Chiappini et al., 2000a, 2000b). New data acquired by Eni SpA Exploration & Production in 2001 and 2002 led to a new aeromagnetic map of Italy (Caratori Tontini et al., 2003). Finally, Giori et al. (2007) integrated data from Italian and Croatian national oil companies to enlarge the coverage on the Adriatic anomaly. Due to its detail and extension, we used this map in our work (Fig. 3b). In this map, the Adriatic magnetic anomaly shows two local and relative maximum points where the amplitude increases to a value of 360 nT and also covers areas of the Croatian onshore and offshore not reported in previous maps. In these regions, the observed anomaly closes onshore Croatia and, still NW–SE striking, clearly presents a weak plunging trend toward SE in contrast with the net cut observed NW.

This anomaly is ~100 km wide and strikes for approximately 350 km along the Adriatic Sea with NW–SE direction, covering all of the eastern central Adriatic and reaching maximum values above 350 nT.