Journal of Geodynamics 82 (2014) 125–137

Contents lists available at ScienceDirect

Journal of Geodynamics

journal homepage: http://www.elsevier.com/locate/jog

Apulian crust: Top to bottom

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ARTICLE INFO

Article history:
Received 14 March 2014
Received in revised form 9 September 2014
Accepted 11 September 2014
Available online 28 September 2014

Keywords:
Crustal structure
Receiver functions
Moho
Adria
Apulia
Foreland
Apennines
Crust

ABSTRACT

We investigate the crustal seismic structure of the Adria plate using teleseismic receiver functions (RF) recorded at 12 broadband seismic stations in the Apulia region. Detailed models of the Apulian crust, e.g. the structure of the Apulian Multi-layer Platform (AMP), are crucial for assessing the presence of potential décollements at different depth levels that may play a role in the evolution of the Apenninic orogen. We reconstruct S-wave velocity profiles applying a trans-dimensional Monte Carlo method for the inversion of RF data. Using this method, the resolution at the different depth level is completely dictated by the data and we avoid introducing artifacts in the crustal structure. We focus our study on three different key-elements: the Moho depth, the lower crust S-velocity, and the fine-structure of the AMP. We find a well defined and relatively flat Moho discontinuity below the region at 28–32 km depth, possibly indicating that the original Moho is still preserved in the area. The lower crust appears as a generally low velocity layer (average Vs = 3.7 km/s in the 15–26 km depth interval), likely suggestive of a felsic composition, with no significant velocity discontinuities except for its upper and lower boundaries where we find layering. Finally, for the shallow structure, the comparison of RF results with deep well stratigraphic and sonic log data allowed us to constrain the structure of the AMP and the presence of underlying Permo–Triassic (P–T) sediments. We find that the AMP structure displays small-scale heterogeneities in the region, with a thickness of the carbonates layers varying between 4 and 12 km, and is underlain by a thin, discontinuous layer of P–T terrigenous sediments, that are lacking in some areas. This fact may be due to the roughness in the original topography of the continental margins or to heterogeneities in its shallow structure due to the rifting process.

1. Introduction

The Adria microplate is a key element in the present-day evolution of the Mediterranean region, belonging to the Alpine-Hymalayan macro-orogenic process (Fig. 1). Such global-scale phenomenon is widely supposed to follow the closure of the Thetys ocean. The final stage of the closure of an ocean should be characterized by the interplay between the subduction of oceanic fragments and the collision/delamination of its continental margins. While the oceanic fragments are thought to sink in the upper mantle, due to their negative buoyancy, the fate of the continental lithosphere is controversial. The deformation of the continental margins leads to its disruption, possibly focused along inherited weak-zones, so that slices of different origin and lithologies are piled up to form the crustal wedge, i.e. the actual mountain chains. It is straightforward that the knowledge of the structure of the involved continental margins is fundamental to model the present-day deformation across the orogens. The Adria microplate represents one of the continental paleo-margins, now fragmented across the Mediterranean region. Unraveling Adria's fine structure and its lateral variations is, thus, a crucial issue to understand what happens when it is subducted/delaminated below the Apennines and the Dinarides.

Many regions of Adria, particularly the foredeeps surrounding it, have been extensively investigated for oil and gas extraction (Mostardini and Merlini, 1986; Nicolai and Gambini, 2007) with seismic lines and deep wells. However, only the upper 7 km (often less) are well known from drillings. Many of these deep wells reached the top of the so-called Apulian Multi-layer Platform (AMP), a thick shallow-water carbonate sequence that developed on the rifted margin in Meso-Cenozoic times. Only rarely boreholes have reached the bottom of the AMP, penetrating Permo–Triassic continental clastic deposits (Patacca et al., 2008; Improta et al., 2000). The top of the AMP below the Apennines and the Adriatic region has been mapped by Nicolai and Gambini (2007). Mariotti

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http://dx.doi.org/10.1016/j.jog.2014.09.007
0264-3707/

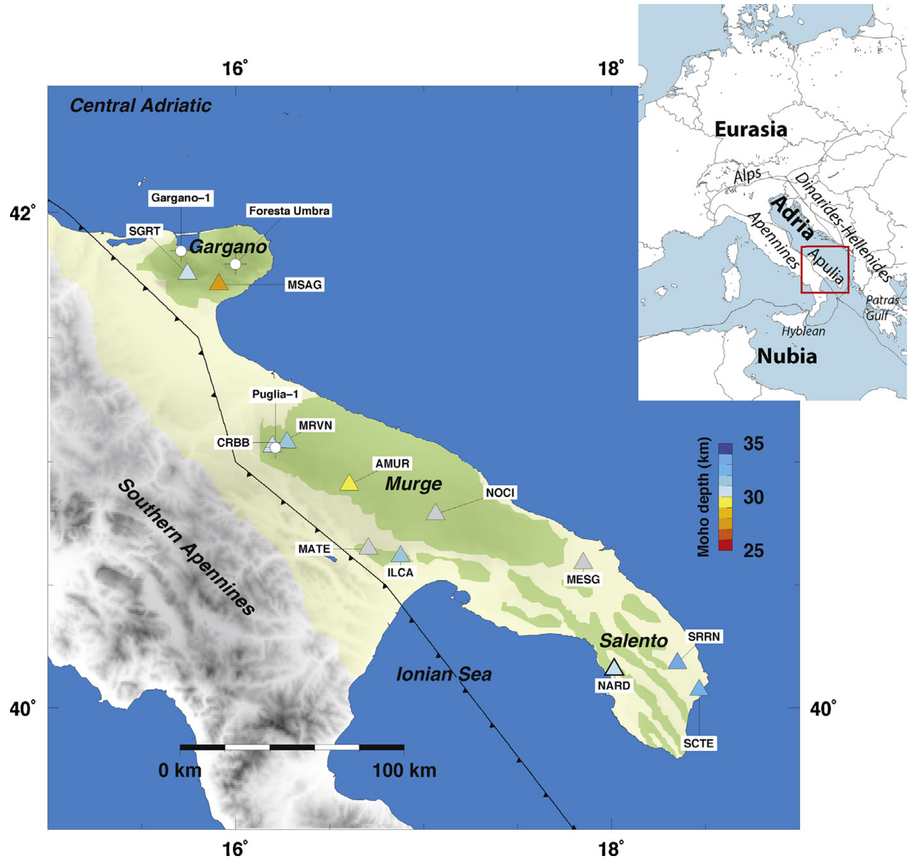

Fig. 1. Location of seismic stations used in this study. Symbols' colors are indicative of previously published Moho depth estimates (from Piana Agostinetti and Amato, 2009), gray for stations not previously analyzed. White-filled circles show the position of the deep wells cited in the study. Background colors schematize simply the geology of Apulia; yellow for foredeep and Quaternary sediments, and green for carbonate units. Inset: map of the Italian region showing the Adria plate surrounded by the Apennines, Alps and Dinarides, and outcropping in the Apulia region. The box around Apulia includes the study area. (For interpretation of the references to color in figure legend, the reader is referred to the web version of the article.)

and Doglioni (2000) have reconstructed the geometry of the Adria top showing that it dips gently below the belt, with different angles along the foredeep. However, all this information about the Adria structure and geometry did not answer to the question of which part of the AMP has been involved in the tectonic evolution of the belt (Patella et al., 2005; Patacca et al., 2008; Speranza and Chiappini, 2002; Scrocca et al., 2005; Steckler et al., 2008; Chiarabba et al., 2014). Moreover, it is not clear whether the documented lateral heterogenities of the sedimentary cover (Puglia-1, Gargano-1 and Foresta Umbra well-log for the AMP, Improta et al., 2000; Patacca et al., 2008) could reflect lateral variations in the deep structure. In this situation, uncertainties in the Adria structure lead to very different modeling scenarios for the involvement of the Adria microplate in the orogenic process.

Aim of this study is to reconstruct the Adria crustal structure computing S-velocity profiles retrieved from receiver functions (RF) inversions, in the Apulia foreland region, where the Adria microplate is widely exposed in the Murge and Salento (Fig. 1). RF are a widely used tool to investigate the crustal S-wave velocity structure through the analysis of P-to-s converted waves contained in the P-coda of teleseismic events. In this area, the continental margin has not been already affected by significant deformation (i.e. subduction/delamination), and therefore we can retrieve its original seismic structure. Studying the undeformed continental margin allows us to catch both the general features of the Adria Microplate and the small-scale heterogenities, inherited from geodynamic processes that occurred before the closure of the Thetys ocean. In this study, RF are computed from teleseismic data recorded at 12 permanent and temporary seismic stations, with recording period spanning more than 2 years for each station. We focus our analysis on three main issues, namely, the Moho depth, the lower crust structure, and the shallow AMP thickness throughout the study region.

2. Geological/geophysical background

Besides the wide portion submerged below the Adriatic Sea, the Adria microplate includes the Po Plain and Apulia and corresponds to a reduced foreland–foredeep area nearly consumed by the complex orogenic processes occurring along its borders (Patacca and Scandone, 1989; Doglioni et al., 1994; Di Stefano et al., 2009; Piccardi et al., 2011, and references therein). Both the offshore sector and the outcropping area of Adria belong to a foreland basin formed on a lithospheric plate that is flexured between the Apennines, the Alps and the Dinarides-Hellenides chains (Moretti and Royden, 1988; Patacca and Scandone, 1989; Royden et al., 1987; Mariotti and Doglioni, 2000; Billi and Salvini, 2003). This foreland basin is covered by sedimentary successions that accumulated on the continental margins of Adria since the early Mesozoic (Channell et al., 1979; D'Argenio and Horvath, 1984; Anderson and Jackson, 1987).

Although there are still different views about its role in the long history of Eurasia-Nubia plate convergence, it is generally accepted that Adria played an important role in the frame of the subduction/collision process of the region, acting as a sort of African promontory (Argand, 1924). Its position, separated from the main