Earth and Planetary Science Letters 484 (2018) 229–240

Contents lists available at ScienceDirect

Earth and Planetary Science Letters

www.elsevier.com/locate/epsl

Lithospheric thickness under the Dinarides

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ARTICLE INFO

Article history:
Received 21 September 2017
Received in revised form 11 December 2017
Accepted 14 December 2017
Available online 27 December 2017
Editor: P. Shearer

Keywords:
lithoshpere–asthenosphere boundary
receiver functions
Dinarides

ABSTRACT

The nature of the interaction between Adriatic and Euroasian lithospheric plates in the Dinarides is important for understanding the complex tectonic history of the central Mediterranean. Using the data from permanent and temporary seismic stations in the wider Dinaric region, we imaged the lithospheric and upper mantle structure under this area. Specifically, we focused on mapping the lithosphere asthenosphere boundary (LAB) using the S receiver functions in order to establish boundaries between different tectonic domains present in this region. The lithospheric thickness in the investigated area varies between ∼50 and ∼160 km with high degree of variability between adjacent tectonic realms. Below northwestern Dinarides the LAB depth varies between 100 and 120 km thinning towards Adriatic sea and Pannonian basin, to 90 and 70 km respectively. In the central Dinaric region (Lika region) we find anomalously thin lithosphere with thickness varying between 50 and 70 km and weak velocity gradient defining the LAB. Further south the signal from the LAB is more pronounced with lithosphere getting thicker again with average depths around 90 km. The intriguing observation of thinned lithosphere under central part of the Dinarides coincides with the zone of lower seismicity and with the tomographic images showing the slab gap in this area.

1. Introduction

Interaction between the Adriatic microplate (Adria) and stable Europe played the vital role in the shaping of the Central Mediterranean. Although many papers have been written about Adria, most of them deal with the northern and western margins of Adria (i.e. Alps and Apennines) with relatively few exploring the northeastern boundary zone in the Dinarides. The Dinarides are the trust and fold belt located roughly between the Adriatic Sea and the Pannonian basin (Fig. 1). Their formation started in the Middle-Late Jurassic with the progressive closure of the Neotethyan ocean (Pamić et al., 1998; Schmid et al., 2008; Handy et al., 2015). Northward movement of Adria, then still part of the African plate, initiated the subduction along the Dinaric margin which probably lasted until Late Cretaceous–early Paleogene time when it was replaced by the collision (Pamić, 2002; Schmid et al., 2008; Ustaszewski et al., 2010). Collisional shortening in the Dinarides, where Adria is the compliant lower plate, was accompanied by the nappe stacking and folding of the Adria's carbonate platform. This produced a thick carbonate sedimentary cover at places reaching thickness in excess of 10 km (Aljinović, 1983). Shaping of the Dinarides was also influenced by the neighbouring tectonic processes like the extension in the Pannonian basin and the extrusion in the Eastern Alps (Ratschbacher et al., 1991b, 1991a; Schmid et al., 2008; Ustaszewski et al., 2008; Neubauer, 2014).

The long history of the interaction between Adria and Europe can be pieced together from the teleseismic tomographic images by tracing positive velocity anomalies under the mountain chains surrounding the Adriatic Sea. Beneath the Western and the Central Alps tomography maps south-easterly dipping slab consistent with the south-southeast directed subduction of the Alpine Tethys (Bijwaard and Spakman, 2000; Wortel, 2000; Piromallo and Morelli, 2003) while the orientation of the slab below the Eastern Alps is more controversial with results pointing either to the southward (Piromallo and Morelli, 2003) or northward (Lippitsch, 2003) directed subduction. The question of the slab orientation under the Eastern Alps is especially important in the scope of Dinaric research as each distinct orientation draws different conclusions about the geodynamical processes under the Dinarides. Southward oriented subduction fits well with the overall image of the Alpine–Carpathian orogenesis where the European continental lower lithosphere was subducted below the Adria along the whole Europe–Adria boundary. In this scenario Alpine and Dinaric subduction–collision systems are two distinct entities and interaction between them and the Pannonian Basin is regulated

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https://doi.org/10.1016/j.epsl.2017.12.030

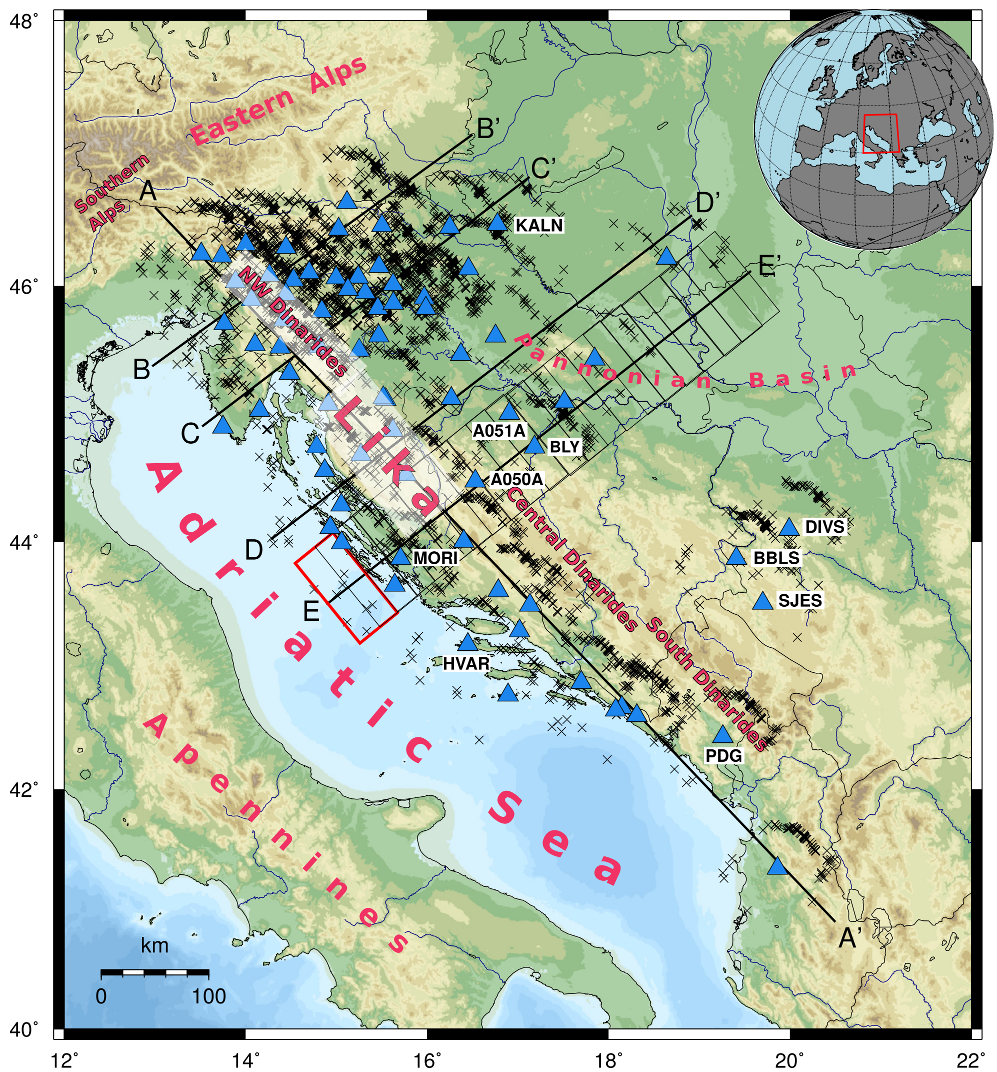

Fig. 1. Map of the wider Dinarides area with seismological stations (blue triangles) used in this study. Names of the several stations mentioned in the main text are marked. The inset shows the study area location in the central Mediterranean. Black lines indicate the location of the cross sections used in the research along with the SRF piercing points at 90 km depth (black crosses). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

through a triple junction point mechanism (Brückl et al., 2007, 2010). On the other hand, northward oriented subduction is compatible with the images of a northeast dipping slab along the active Hellenic arc-trench system which extends to the Central and Southern Dinarides (Bijwaard and Spakman, 2000; Piromallo and Morelli, 2003). Recently, Handy et al. (2015) proposed a hypothesis in which the southward dipping subduction under the Eastern Alps was replaced by the north oriented subduction of the Adriatic lithosphere following the slab brake-off. In this context it is important to highlight an even more unusual anomaly that keeps appearing on regional tomographic images: a large negative velocity anomaly beneath the central part of the Dinarides (Bijwaard and Spakman, 2000; Wortel, 2000; Lippitsch, 2003; Piromallo and Morelli, 2003; Koulakov et al., 2009; Mitterbauer et al., 2011). This anomaly separates the aforementioned lithosphere slab anomaly in the Eastern Alps from the positive anomaly mapped beneath the southern portion the Dinarides, and it is somewhat unexpected due to significant thrust shortening. Ustaszewski et al. (2008) proposed an explanation for this slab gap: thermal erosion of the Adriatic lithospheric slab due to the opening of the Panonnian basin and an influx of the hot asthenospheric material. On the other hand, in the model of Handy et al. (2015) the slab gap evolved on the foundation of the former transfer fault (Alps–Dinarides Transfer Fault or ADT2 in Handy et al. 2015) linking the opposing Alpine and Dinaric subduction systems. The Alps–Dinarides Transfer Fault was active until around 20–23 Ma and was later overprinted by the subsequent tectonic activity (e.g. Miocene clockwise rotation and strike-slip faulting in the Pannonian basin). This model combines slab tearing beneath the Alps and the Dinarides, northward movement and subduction of Adria beneath the Eastern Alps (for details we refer the reader to the paper of Handy et al., 2015). In addition, there are suggestions that part of the extension in Pannonian basin can be attributed to the delamination and slab rollback under the Dinarides (Schefer et al., 2011; Matenco and Radivojević, 2012). This hypothesis is interesting as it means that the slab gap could have developed due to the strong asthenospheric corner flow around the northern edge of the sinking slab.

Another important question arising from the teleseismic tomographic images is the nature of the interaction between Adria and European mainland beneath the Central and the Southern Dinarides. Observations show a shallow high velocity anomaly under this area reaching up to 200 km depth (Bijwaard and Spakman, 2000; Wortel, 2000; Piromallo and Morelli, 2003; Koulakov et al., 2009). Most interpretations agree that this anomaly represent underthrusting of the continental Adria lithosphere beneath the Dinarides (Ustaszewski et al., 2008, 2010; Schmid et al., 2008;