Deep structure of the Sistan continental collision zone from nonlinear teleseismic tomography

Meysam Mahmoodabadi[1],Farnaz Yaminifard[1],Ali Hashemi Gazar[1],Mohammad Tatar[1]

[1]*International Institute of Earthquake Engineering and Seismology, faryam@iiees.ac.ir*

ABSTRACT

In this study, we used the records of teleseismic earthquakes from a dense passive array of 36 seismometers to investigate the lithospheric and uppermost mantle structures beneath the Sistan suture zone. Teleseismic data from 240 events with high signal-to-noise ratios were recorded during the nine-month deployment period of the array, from which 3992 relative arrival time residuals were picked. We used a nonlinear teleseismic tomography method to map the relative arrival time residuals as 3D perturbations in *P*-wave velocity beneath the suture zone down to depths of 370 km. The solution model indicates a number of features that have important ramifications for the interpretation of the tectonic history in the region. The most prominent feature is the presence of a low-velocity anomaly beneath the high elevations in the region. The low-velocity anomaly extends to depths as much as 120 km, beneath which a high-velocity anomaly is observed. This feature may indicate the presence of melts due to the delamination of the base of the lithosphere and asthenospheric upwelling as a response to continental collision.

Keywords: Continental collision; Lithosphere; Sistan suture zone; Teleseismic tomography.

INTRODUCTION

The mountains of eastern Iran record the tectonic history of the Sistan suture zone. Subduction and destruction of a narrow portion of the Neotethyan oceanic crust between the Afghan and Lut blocks resulted in continental collision and further folding and faulting in eastern Iran since the Paleocene (Tirrul et al. 1983). In order to better understand the tectonic evolution of this region, superficial observations are not sufficient, and we need to investigate the lithospheric and upper mantle structure variations. A recent study by Namvaran et al. (2020) indicates a lithospheric thickness of ~120 km beneath the region. They suggest that the lower portion of the lithosphere has been delaminated.

With the help of local and regional seismic arrays, we can get more precise images from the subsurface structures. To image the crustal and upper mantle structure of the Sistan suture zone, a temporary array of 36 seismic stations was deployed across the eastern Iranian mountains in 2017 (Fig. 1). The array provides a good opportunity to investigate the collision processes through the study of the crustal and upper mantle structures in this collision zone. In this study, we investigate the geodynamical evolution of the upper mantle in the collision zone. Teleseismic relative arrival time residuals can lead us to upper mantle velocity perturbations beneath a network of seismic stations. Thus we used a nonlinear teleseismic tomography approach (Rawlinson et al. 2006) to constrain the upper mantle velocity structure and to better understand the upper mantle processes in the collision zone.

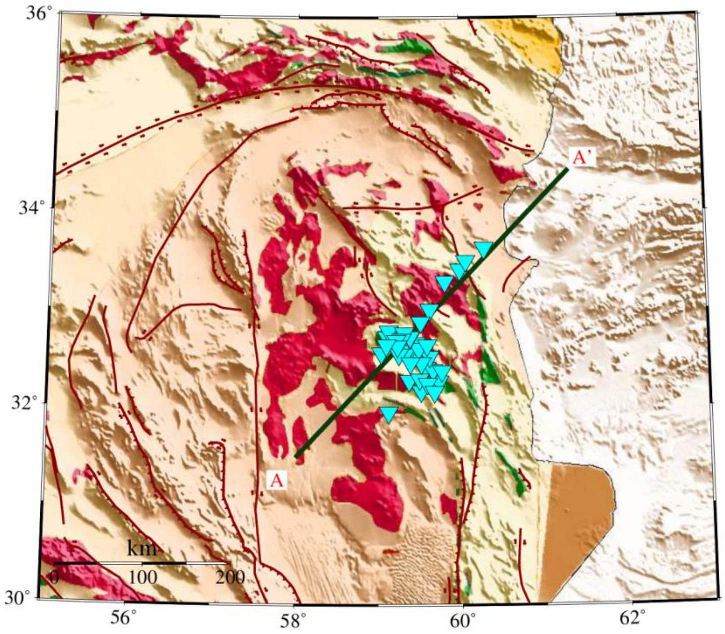

Figure 1. **Seismic stations of the array used in this study.**

Methodology and Results

The data-set used in this study is derived from teleseismic waveforms recorded in the temporary stations. In order to obtain relative arrival time residuals, a variety of global body wave types including *P*, *PcP*, *Pdiff*, *PKPdf*, and *PP* were picked with the adaptive stacking method (Rawlinson and Kennet 2004) from events with magnitudes Mw>5.5 to produce sub-vertical ray paths beneath the receivers. A number of 3992 relative arrival time residuals are obtained, and 4 iterations of the tomographic scheme are used to map these residuals to the tomographic image of the upper mantle.

The solution model (Fig. 2) shows a high-velocity anomaly in the lithospheric depths beneath the Afghan block indicating a stronger or colder lithosphere in the northeastern part of the profile. A prominent feature of our model is the transition from the high-velocity anomaly in the northeast to a low-velocity anomaly beneath the high-elevated mountainous regions in the southwest. The base of this low-velocity anomaly is bounded to an underlain high-velocity anomaly at depths between 100 km-200 km.

We assume that the edge of the Afghan block has been less deformed relative to the Lut block during the continental collision and subduction of the underlying plate. The collision between the two plates has resulted in thickening and delamination of the lower parts of the lithosphere. These processes and asthenospheric upwelling may justify the low-velocity in the lithospheric depths and high-elevated mountains in the region. Deep high-velocity anomalies may indicate the delaminated continental lithosphere and/or subducted Neotethys lithosphere down to depths of ~300 km.

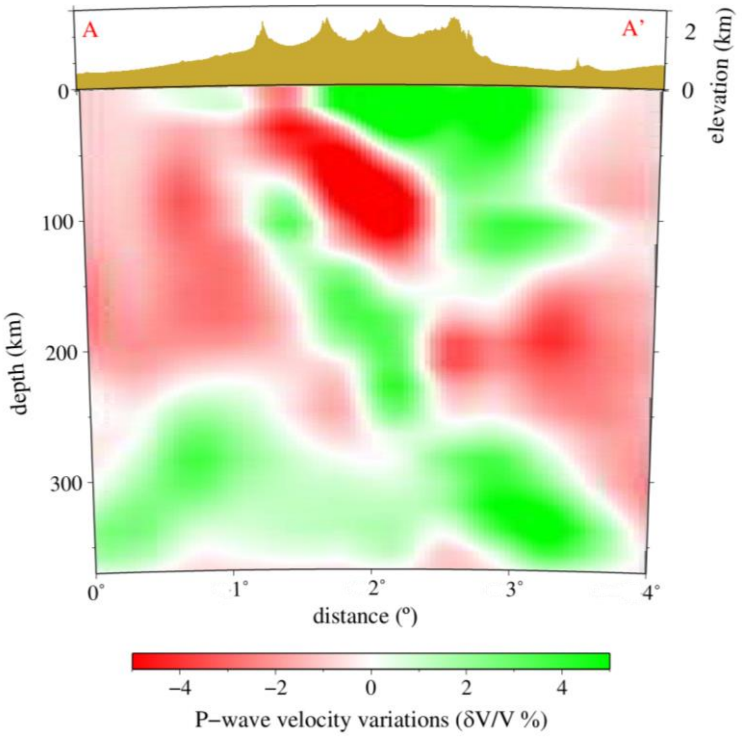

Figure 2. **The solution model from nonlinear teleseismic tomography.**

Conclusions

We investigate the upper mantle structure beneath eastern Iran using a nonlinear teleseismic tomography method. A number of 3992 relative arrival time residuals were picked from distant earthquakes to constrain the upper mantle structure. The Afghan block to the east of the region of study is distinguishable with its relatively higher velocities relative to eastern Iran (beneath the high elevations), where a prominent low-velocity anomaly prevails. A process of lithospheric delamination may explain this transition of high to low velocities from northeast to southwest of the profile.

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