Proceedings of the 18th Iranian Geophysical Conference, May 2018, pages 471-473

Tethyansubducted slab and seismic anisotropy in the upper mantle beneath the north Zagros collisionusing S teleseismic tomography

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ABSTRACT

First, primary results in the inversion of teleseismicS-waves traveltime residuals along a dense 520-km long temporary dense seismic profile across the north Zagros and west Alborzmountains to investigate its upper mantle structure were presented.Existence of tworealative high velocity one under Zagros Iran beneath Zagros to 70 km over MRF suture zone up to depth of 200 km and second in depth of 400-600km beneath central Iran using of ?S-waves show a probable rest of remnant of subducted Arabian plate under central Iran that maybe rest in transition zone.

Second, computing of anisotropy from inversion of data from difference between relative residuals of S_Radial and S-Transverse for common events and seismic stations was done. So that Presence of higher velocity beneath Zagros up to depth of 200 km from 200 km before MRF and 50 km after it shows lithospheric anisotropy with fast axes parallel to Zagros orogeny belt in Zagros and on the contrary presence of a large volume beneathcentral Iran up to 300 km show asthenospheric anisotropy with fast axes perpendicular to Zagros orogeny belt.

Keywords: Anisotropy, teleseismic,traveltime, relative residual,transition zone

INTRODUCTION

The Zagros mountain belt of Iran is the region of present-day collision between the Arabian plate and the continental blocks of Central Iran. It belongs to the Alpine–Himalayan orogenic system that resulted from the closure of the Neotethys Ocean during the Cenozoic (Stampfli and Borel, 2002).In order to study the crust and upper mantle structure and its anisotropy across the northern portion of the Zagros collision Central Iran and west Alborz, we used data from a dense temporary network of 63 broad band seismic stations positioned along a linear profile from SW edge of the Zagros collision, at the political border between Iran and Iraq, toward northeast across Sanandaj–Sirjan metamorphic zone (SSZ – e.g., Hassanzadeh and Wernicke, 2016), the Urumieh–Dokhtar magmatic arc (UDMA – the volcanic arc of past Neotethyansubduction), Central Iran (a relatively less deformed block surrounded by active margins), the western Alborz Mountains, to the southern shoreline of the South Caspian Basin (SCB, Fig. 1a). Also, Not only being aware of the relationship between the surface deformation and the velocity fields with the underlying mantle flows, but also knowledge about the presence of high and low velocity zones like existence of subducted slab and likely delamination place can help us to present a better geodynamic model for the region.

Methodology & Data

A temporary seismic array comprising 63 seismic stations was used since 2013 August to 2014 October from the western Iran (the city of Ilam) to the western shoreline of the Caspian Sea (the city of Guilan). This array was employed along a linear profile with 520-km-long, 47 seismic stations with average interstation spacing almost 11km as the main line plus bilateral 17 seismographs off the main line, trending N37°E across to the Zagros (perpendicular to the trend of Zagros collisional zone), Central Iran and west Alborz. The network was installed and coordinated by the Institute for Advanced Studies in Basic Sciences (IASBS), Geological Survey of Iran(GSI) and Chinese Academy of Sciences (CAS) (fig1a).

Firstly, for achieve Tele seismic tomography of S-wave Selection of 70 Teleseismic earthquakes for residual radial and transverse arrival-time reading was done. The selected seismograms were filtered before to the phase picking and then were rotated to radial and tangential components. As the majority of the events from the east, we imposed different selection of the east and west events so that we increased number of rays from the west to achieve a reasonable tomographic results. So the events had a magnitude of 5.5 or greater, and their back-azimuth was within ±20° of the average azimuth of the profile for the east and events with magnitude of 5.0 or greater and their back-azimuth within ±30° of the average azimuth of the profile for the west (Fig.1b). To increase rays from the west many of phases (1658 S, 1075 SkSac, 384 ScS, 239 Sdiff, 117 SKSdf)were picked. Blue and red circles are Teleseismic data arrived from transverse and radial components, respectively.

We used adaptive stacking method (Rawlinson & Kennet2004) for the procedure of the picking to estimate the residual pattern across the profile. The method is very fast and capable in the presence of noisy waveforms. A filter (0.03-0.3)was applied before the phase picking. Residual pattern were initially achieved by first approximately alignment of the traces of an event based on deletion of moveout-corrections by an initial propagation model and then stacking to a reference trace. In continue Each of moveout-corrected traces moves directly until a best fit to the reference stack were achieved and then each of the traces were stacked again and the procedure were repeated until the most accessible and stable alignment is achieved. So the estimation of traveltime residuals from initial model were created that is basically due to the lateral anomaly in the target volume. In continue the associated means for each event were then removed to achieve relative arrival-time residuals to minimize the influence of error in source location and anomalies in deeper mantle. With this procedure only the upper parts of the incoming rays are inverted, and velocity perturbations relative to an unknown Earth model are achieved (Aki et al. 1977).We used a weighted damped least-squares approach (e.g. Menke, 1989) so that the weights for the data were counted from the errors assigned to each phase based on the accuracy of traveltime residuals during the phase picking method and for weights of model parameters, a squared roughness matrix (Menke, 1989) was took into account. This matrix is the square of a matrix whose rows are [. . .0 1 -2 1 0. . .] and was used to smooth each model parameter with twice of its horizontal neighbor cells.To achieve the best groups of eigenvalues based on a trial-and-error test, different amounts of eigenvalues upon a synthetic data generated from some checkerboard models were considered.

In the next stepwe present seismic anisotropy across the profile based on a new method that has been used for the first time. When the relative residuals of S-Waves on both radial and transverse components were picked and plotted with different colors (Fig 3a), we found a very interesting result that residuals of them followed from a specific trend so that in some areas transverse waves arrived before radial ones (e.g. up to 1.5 Sec for the Zagros) and vice versa. So we selected each of Teleseismic events that were recorded on both radial and transverse components in each of the seismic stations and time difference in the same station and event on components were considered as existence of seismic anisotropy because the seismic station, seismic event, and the path of two components should have the exact arrivals without any seismic anisotropy. Finding similar phases recorded on similar seismic stations on both components of radial and transverse were tricky task, especially for SW (south of the profile) because there are no more strong earthquakes there.

CONCLUSIONS

An important higher velocity zone is positioned up to depth of 200 km and latitude between 200 under Zagros before MRF to 70 km after MRF suture zone, beneath x= 0 km, where located in reliable area for our tomogram and we interpret it the lithosphere of Arabian plate.

Another two important higher velocity feature are positioned in 50 km < X < 150 km and depth range of 400-500 km and also in 200 km < X < 300 km and depth range of 450-600 km. These anomalies located where there is good enough ray crossing and resolution values and they were returned back in synthetic tests. Although, accept of deepest anomaly (450-600 km) is controversial but this anomaly were presented by whole mantle tomography studies(e. g . Douwe G. van der Meer et al. 2017 across Zagros proposed a slab was subducted beneath Central Iran and rest in transition zone). So we propose that these two higher velocity anomaly are the remnant of subducting slab that entered into transition zone but we cannot find out these to deepest higher anomaly are jointed to that of 200 km < Z < 300 km and 0 < X < 100 km or not because of vertical smearing.

Fig.4aShows the averages of residuals on each of the seismic stations so that red and black circles are for radial and transverse, respectively.By use of raw data we proclaim that seismic anisotropy across Zagros parallel to mountain range (NW – SE) and it rotates 90 degrees (NE – SW) across Alborzmountains and coastal Caspian. The seismic anisotropy changes twice to NE – SW first, and to NW – SE second in Central Iran. In the following the residuals of the radial component were subtracted from the transverse one and then the resulted residuals with another data (e.g.Seismic events, ray parameters, stations were exactly the same between two components of them during phase picking) were inverted to attain a tomogram for seismic anisotropy. If there is no relative high or low velocity in a region so there is no anisotropy there and if a region would be blue means that the fast axes anisotropy is perpendicular to the plane of seismic tomogram (transverse waves are perpendicular to the plane of seismic tomogram) and finally the red zones mean that the fast axes is in the plane of seismic tomogram.

Anisotropy derived from difference of common radial of transverse phases in Fig4brepresent two important higher velocity anomalies with good ray tracing as well as resolution (0.7) with fast axes vertical to the tomogram one in initial of profile (X = - 200) to 50 km front of suture with depth range of 0 – 200 km where we interpreted for underplating Arabian lithosphere beneath Central Iran. In fact anisotropy beneath Zagros shows theunderplated Arabian lithosphere well and this lithosphere is thick enough to produce anisotropy here. This is a tipic feature of collision zones and has been observed in many of the world's orogeny belts (Silver, 1996; Meissner et al., 2002; Li and Chen, 2006; Barruol et al., 2011; Bokelmann et al., 2013).

A strong big area with lower velocity anomaly positioned beneath Central Iran between 50 < X < 250 km and 0 < Z < 300 km were resolved. On the other hand Central Iran has shallow moho related to its high elevation so its elevation is supported physically by mantle flows so we interpret the large lower velocity area in our tomogram (Fig4b) with asthenosphere source for implying anisotropy.

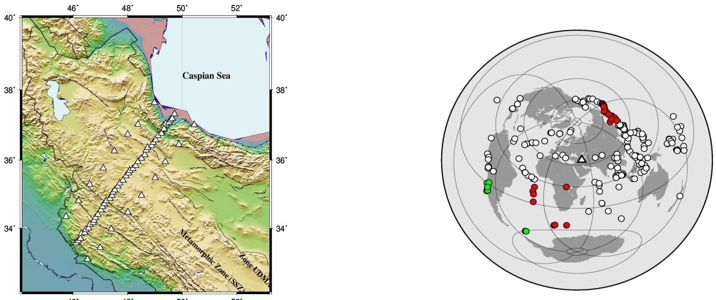

Figure 1. topographic map of NW Iran with profile(a). (b)epicentral distribution of events)

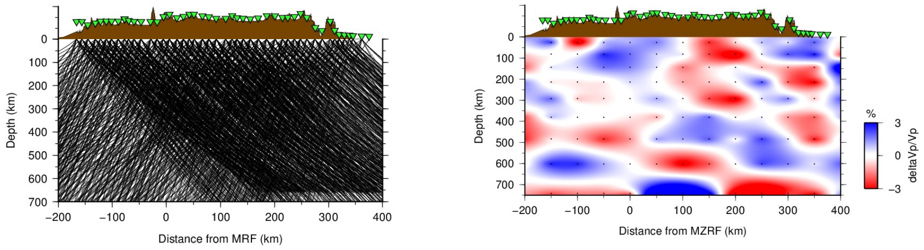

Fig2. Deep sections of ray paths of S-Radialphases(a) and seismic tomogram of S-Radial(b)

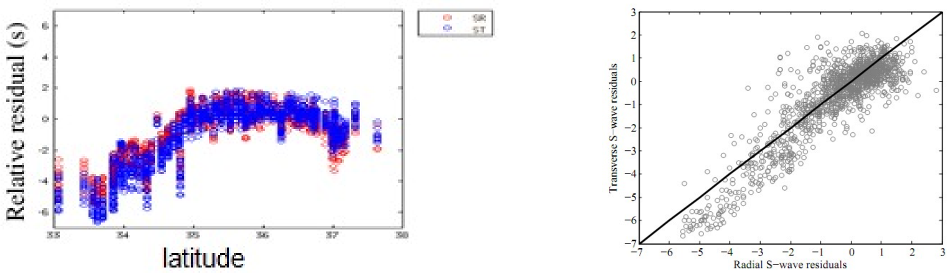

Fig3.Relative residuals of S-Radial (red circles) and S-Transverse (blue circles) (a) and Vs (b)

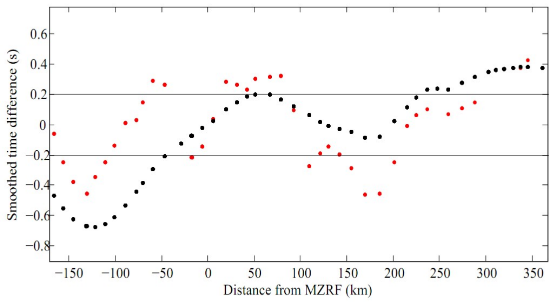

Fig4. Mean of Relative residuals of S-Radial (red circles) and S-Transverse (black circles)(a)and seismic tomogram of difference of common S-Radial and S-Transverse

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