Analyzing Crustal Velocity Structure of the Central Zagros (Ghir-Karzin region) Using Local Earthquake Tomography

Amin Aghaee Naeini[1], Saeed SoltaniMoghadam[2], Mohammad Tatar[3]

[1]*M.Sc., IIEES, Tehran, Iran, aminaghaee76@gmail.com*
[2] *PhD., IIEES, Tehran, Iran, saeed.sltm@gmail.com*
[3] *Professor of Seismology, IIEES, Iran, mtatar@iiees.ac.ir*

ABSTRACT

The purpose of this study is to analyze the crustal velocity structure of the Ghir-Karzin region, which is located in Central Zagros. It has always been a challenging illustration of the deep subsurface structures for this region due to the thick (roughly ~10 km) sedimentary cover. Generally, Local Earthquake Tomography (LET), by presenting different anomalies, has the potential of imaging velocity structures in 3 dimensions that can provide valuable information about different subsurface structures. In this paper, we used a unique dataset of 309 local earthquakes recorded by a dense local temporary network consisting of 30 seismic stations alongside by using SimulPS14 (a well-known and powerful code for retrieving seismic 3D velocity) to calculate crustal structure of the study area. Many parameters, especially a wide variety of grid configurations were checked to obtain the most accurate velocity model. Near the surface of our tomography image, we found a good correlation between the elongation of velocity masses and the topographic trend in the area, which may suggest that the velocity is more affected by surface geology. In deeper parts, this relationship is likely to be substituted by underlying layers (upper crystalline crust), which may be more affected by blind faults.

Keywords: Central Zagros, LET, Configuration, Surface geology, Blind faults

INTRODUCTION

The Central Zagros as a part of the Zagros Fold-Thrust Belt (Fig. 1) is one of the most active continental collision zones (Stoneley, 1990; Tatar et al., 2002; Hessami et al., 2006), which contains a large number of complex subsurface structures. Presence of a very thick (~10-12 km) sedimentary cover (Hatzfeld et al., 2003; Najafi et al., 2014), begins with the Aghajari and the Bakhtiari formations and ends with a thin low-density salt layer known as the Hormuz, makes it more complicated as there is no surface rupture for even large earthquakes (Berberian & King, 1981). The Hormuz salt layer is the most important detachment horizon across the Belt and has a strong impact on seismicity, folding and hidden faults' mechanism (Sherkati et al., 2006; Najafi et al., 2014). Hence, knowing the subsurface structures located beneath this layer is too challenging to achieve by shallower data (like explosion). Here we used local earthquakes data recorded on a densely distributed network of 30 temporary stations (Hatzfel et al., 2003; Tatar et al., 2004) to obtain a 3-D crustal velocity structure in the region using SimulPS14 code (Haslinger, 1999). We believe earthquake data generally have the potential of imaging subsurface structures especially in the deep parts (in their seismic zones), which finally will end in highlighting our perception of subsurface structures within the Ghir region like the geometry of the basement hidden faults.

Table 1. Conditions of the high-quality data selection

Max. Azimuthal Gap	Min. P phase	Min S phase	Max. RMS	Max. Epicenter Err	Max. Depth Err
260˚	4	2	0.5 (s)	5 (km)	8 (km)

METHOD AND DATA

Firstly, after analyzing recorded data, there is a need for removing lower quality data from higher ones, before doing anything. To do this, we used the conditions identified in Table 1. Although

the limitation introduced for azimuthal gap seems relatively large compared with usual tomography studies (generally less than 200˚), we confirm from our selected data, the ones that have gap greater than 200˚ are also trustworthy as mostly have at least one station with minimum distance of 18 km or smaller, which is close enough based on our study scale. Finally, after using Table 1, the number of data was reduced from ~500 to 309 (Fig. 1).

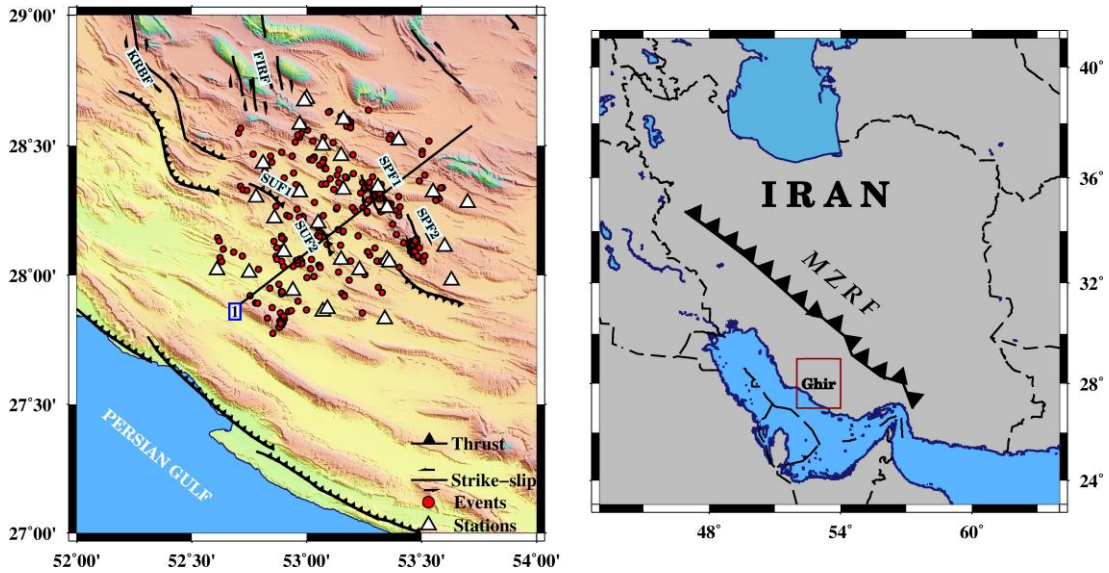

Figure 1. Position of the study area and Main Zagros Reverse Fault (right). Map of faults' location, the analyzed profile (see Fig. 3) and seismicity along with the local network used in the Ghir – Karzin region (left). KRBF, FIRF, SUF1&2 and SPF1&2 are the abbreviation forms of Karebass, FiroozAbad, Surmeh and Sabz-Poushan faults.

Secondly, we used a new statistical method called Fuzzy Self-Tuning Particle Swarm Optimization or FST-PSO (see SoltaniMoghadam et al., 2019) to calculate 1-D velocity model of the region. The obtained 1-D velocity model (Fig. 2) is in good agreement with the initial geological information from the Central Zagros zone in which a thick sedimentary cover, Vp around 5 km/s (Hatzfeld et al., 2003), is already expected. Consequently, our 1-D model, which also passed several stability tests successfully, seems to be accurate enough to be used as an input parameter for the 3-D model.

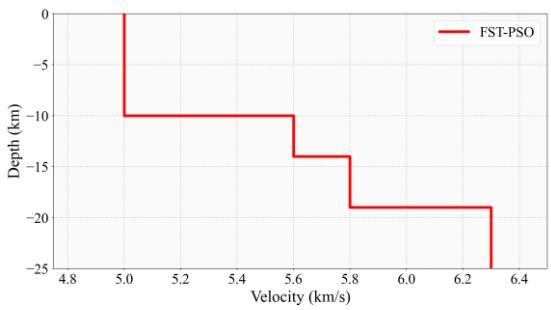

Figure 2. One-dimensional velocity structure of the upper crust in Central Zagros.

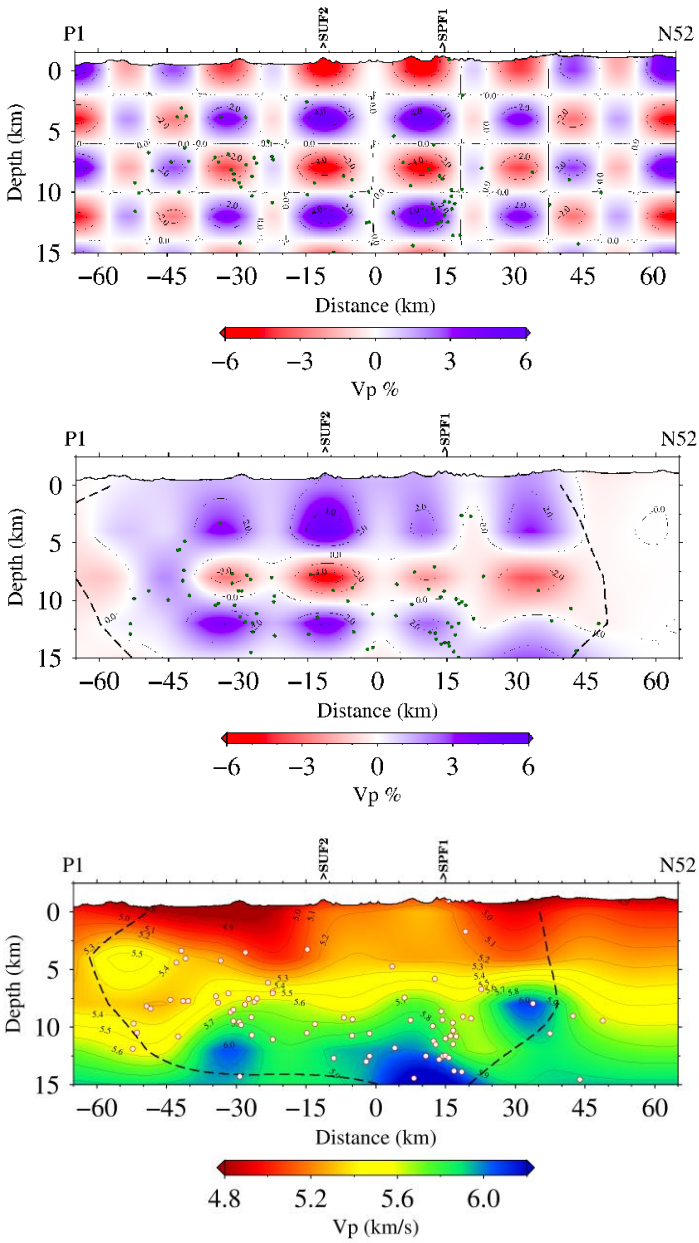

Figure 3. Results of the synthetic checkerboard test for the study cross-section (Top: The forward modeling, Middle: The resolved cells after synthetic inversion, Bottom: The resulting tomographic image showing absolute Vp). Black dashed lines depict the well-resolved area, with SF<1.5.

To obtain the final velocity model (Fig. 3), lots of work have been done by analyzing the resolution matrix, model parameterization and spread function, with respect to the results of synthetic checkerboard tests, which finally led us to a 15 × 15 × 4 (km) grid configuration, with the maximum spread function of 1.5. Based on the synthetic test, our results are almost poor within the first 2 kilometers from the surface. The contrast velocity observed at the western parts of this profile is also questionable as the resolution is weak. However, beneath the depth of 2 km, especially between 5 to 15, the tomographic result will be accurate enough due to a high resolution from the checkerboard test at this bound. In these parts (lower half of the profile), several high-velocity zones, with Vp of more than 6 km/s are observed. In shallower parts, the velocity changes are gentler and there is no obvious anomaly.

CONCLUSIONS

According to our study, in general, the results of tomography picture can be divided into 4 steps, which will be referred to in order:

1. The velocity range calculated for Ghir region, 4.8 < Vp (km/s) < 6.3, is in agreement for carbonate rocks (5 < Vp < 6.5), which are the most important compounds of the Central Zagros formations (see Fig. 2 at Najafi et al., 2014).
2. In shallower parts, up to the depth of 5 km, there is a relation between high velocity zones and high topographical structures. Therefore, the high Vp velocity observed at the western part of our profile can be related to the existence of the Homa anticline (see Najafi et al., 2014). However, this might not be completely reliable due to the poor synthetic test.
3. The three high-velocity zones at deepest parts, which are also colored by blue, show the over-thrusting faults located at the crystalline basement, introducing the blind faults of the region. Tatar et al (2004) in this region already suggested both northeastward and southwestward dipping of the faults, which here we observe both dipping again by tomography.
4. Above the basement faults at depth ranging from ~6 to ~9 km located in the center of the section, the velocity contours seem to be more horizontal and not be affected by faults, suggesting the existence of the detachment layer at this part decoupling the shallower parts (sediments) from the basement.

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