

Seismotectonic study of northern Iraq and surroundings from waveform inversion method



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Abstract:

This paper is to estimate the seismic velocities beneath the northern Iraq seismographic (NISN) stations and the surrounding regions using the recorded data from these stations. One and two-dimensional crustal and upper mantle structures determined using the waveform inversion method through different paths within the region. This technique applied to regional waveforms traversing Turkish-Iranian Plateau and the northern Arabian platform. The final models resulted from the inverted parameters (layer thickness, shear wave velocity, and attenuation) have been analysed. The results show an average crustal thickness of 30 km with bulk shear velocity of 3.9 km/sec and the event paths encounter thick sediments of the foredeep. Phase match filtering used to isolate the fundamental mode from other signals. The results indicate that the depth of the Moho varies considerably beneath NISN. It is relatively shallow (35–45 km) to the northwest and deeper (50–60 km) under the south-eastern portion of the area. The shear wave velocity values are higher in the platform than in the plateau and generally variations in crustal thickness and velocity found between the northern Arabian platform and the Turkish plateau.

Keywords: inversion, layer thickness and shear wave velocity.

Introduction

Estimating the seismic velocity structure beneath stations of the (NISN) and surrounding regions is the focus of this paper. Crustal velocities play an important role in seismicity and tectonic studies [1]. Tectonic activities along this suture are controlled by the northeast-moving Arabian plate and the accompanying westward escaping of the Anatolian block [2]. Iraq has a well-documented history of seismic activity. The historical seismicity provides a relevance to the recent seismicity. Tectonically Iraq is located in a relatively active seismic zone at the northeastern boundaries of the Arabian Plate. The

seismic history reveals annual seismic activity of different strength. The north and northeastern zones depicts the highest seismic activity with strong diminution in the south and southwestern parts of the country [3].

Stations of the North Iraq Seismographic Network (NISN) are located in north-eastern Iraq at an optimal location to capture the seismicity from three mingling tectonic features, the Arabian platform and the Anatolian and Iranian plateaus (Fig.1). The stations that recorded the events used in this study are equipped with broad band three component seismometers, Q330 and STS-2.



Fig.1 showing the Northern Iraq Seismographic Network (NISN).

The earthquakes that were recorded at the NISN stations were used. The ground motion was recorded continuously at a rate of 100 sps, yielding a database of high quality local and regional waveforms [4].

Data Analysis

Inversion and waveform modelling for estimating the crustal velocities is applied to the data using the computer programs in seismology, antelope data acquisition and processing system version (3.30)[5], which provide a valuable constraint on the computational process and the estimated seismic velocity structures. Evaluation of the resulting models will be performed through synthetic waveform analysis. The waveform inversion method is applied to regional waveforms traversing the region, to search wide range of models, to fit the observed data and to infer crustal and upper mantle structure. Inverting regional waveforms provides a better localized and resolved earth structure over regional distances [6].

A group of random models with parameter values that fall within user-set limits are first produced using a computer program. The program itself has many parameters which must be set. For each model, the forward problem is solved and a fitness value is assigned. Fitness values (objective function) decide the fate of the

models, which are either eliminated or allowed to transfer their traits to the next trial. The inversion solves for layer thicknesses, shear wave velocities, attenuation (Q) values in each layer, and body wave travel times.

Mathematically, the misfit between the synthetic signal S at r_1 and the observed signal s at r_1 is a function of the velocity model, and is expressed as:

$$F(\beta) = \sum_{1}^N \int_0^T (S(t, r_2, \beta) - s(t, r_1)) dt$$

Where $F(\beta)$ is the objective function, β is the model (shear-velocity, layer thickness and attenuation) as a function of depth, T is the time window, and N is the number of recording stations (or components for single station). The vector β (i.e., the model) that minimizes the function $F(\beta)$ is considered a solution to this problem.

Practically, the above formula used in this study is to find the variation of velocity of seismic waves beneath the earth's surface with different layer thicknesses as a function of depth and to estimate the average shear velocity along the propagating paths from the source to the receiver (NISN). Epicentres of the events determined with their magnitudes. Paths of two representative events are plotted which occurred beneath Zagros-Taurus plateau (Fig.2).

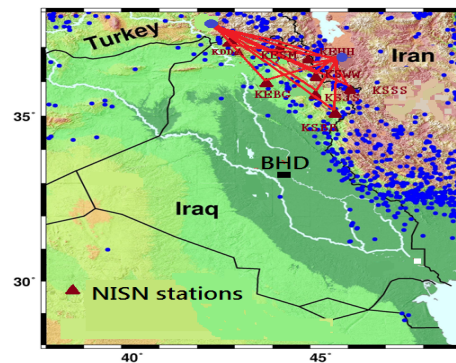


Fig.2 showing the epicentres of the events (blue dots). Wave propagation paths (red lines) to the receivers are plotted.

In this waveform inversion, we parameterized the velocity model using shear-wave velocities, layer thicknesses, and Q values in each layer as unknowns. The distribution of the propagation paths covers a large portion of the thrust, folded and foothill zones.

One-dimensional velocity structure between the source to stations represented

by the relationship between the shear wave-velocity and the depth of the crust along the propagation path of the events. Figure.3 shows the average velocities beneath the stations (KDDA, KESM, KEHH and KEBG) and the stations (KSWW, KSSS, KSJS and KSBB).

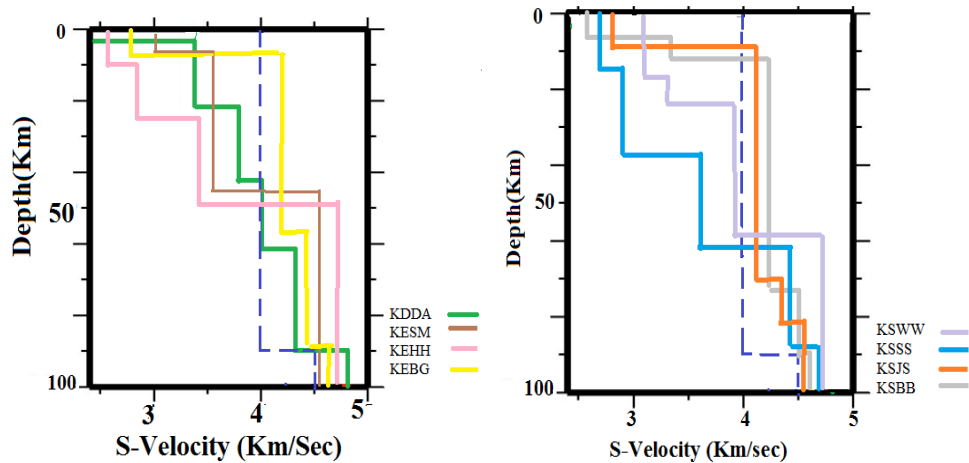


Fig.3 shows the velocity structure from the source to NISN stations relative to their depth. The stations are colour coded.

The comparison between observed and synthetic waveforms in (Fig.4) shows a good match. Two stations (KSSS and KSBB) as examples are presented.

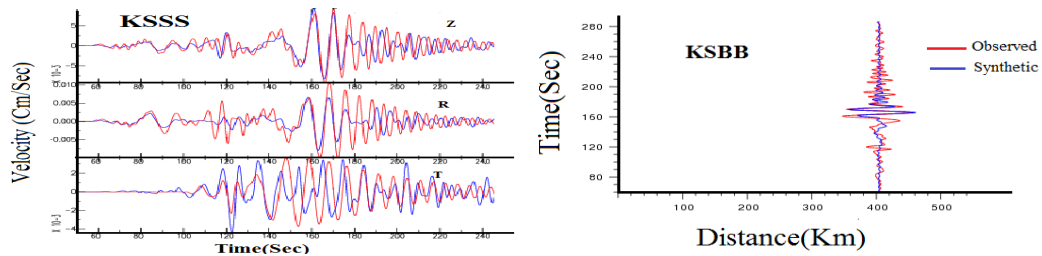


Fig. 4 shows the comparison between synthetic and picked observed waveforms.

The comparison between synthetic and observed waveforms for the (KEKZ-KSWW-KSSS) stations are shown in (Fig.5). Events that occur along the strike of more than one station provide a station geometry that can be utilized to study lateral variations in the crustal and upper mantle structure beneath these stations.

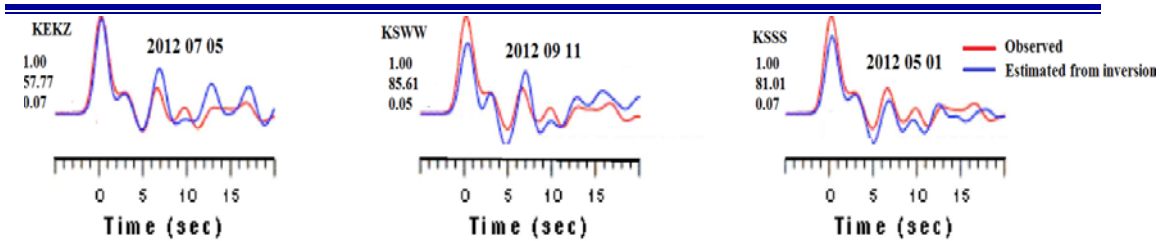


Fig.5 Samples of the inversion process for three regional events recorded at station KEKZ, KSWW and KSSS.

The waveform-inversion technique implemented using the programs in seismology for a laterally varying medium to constrain the inter-station models that form a two-dimensional laterally varying structure along the path. Model parameterizations are similar to the one-dimensional case. Each structure represents a segment of the propagation

path from the source (Turkish-Iran) to the stations. Figure 6 is a two-dimensional velocity structure across northern Arabian platform obtained by using inversion scheme, where the fundamental mode surface wave are calculated with respect to laterally varying crustal structure for the event occurred in the northwest of Iran.

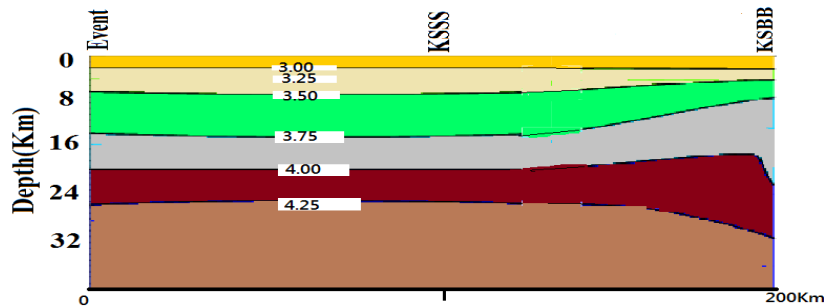


Fig. 6 depicts two dimensional structure modeling.

The theoretical group velocity dispersions calculated for the models and compared it with observed dispersion (Fig. 7). The iteration process continued using fundamental filter modes which provides a visual means to evaluate the models.

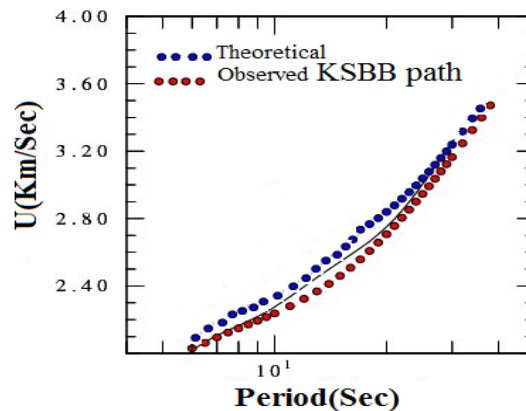


Fig.7 shows comparison between theoretical and observed group velocity dispersion for one of the stations (KSBB).

Results

The result of the inversions were evaluated based on the waveform fit of the synthetic seismograms to the data, and the visual comparison between the theoretical dispersion curves of the resultant velocity models and the observed dispersion curves for those source-receiver paths. Excluding the Mesopotamian foredeep layer from the crustal structure of the event path, we will have an average crustal thickness of 30 km with bulk shear velocity of 3.9 km/sec and the event paths encounter thick sediments of the foredeep. The average velocities were determined along the propagation paths between the events (the source) and the stations, this is equivalent to assigning a depth to each point along the travel time curve.

Phase match filtering used to isolate the fundamental mode from other signals. The results indicate that the depth of the Moho varies considerably beneath NISN. It is relatively shallow (35–45 km) to the northwest and deeper (50–60 km) under the south-eastern portion of the area.

Conclusions

- 1- The results reveal variations in crustal thickness and velocity between the northern Arabian Platform and the Turkish plateau.
- 2- In general, the shear wave velocity values are higher in the platform than the plateau.
- 3- The crust significantly thickened in the Plateaus, to accommodate the collision between the Arabian and Eurasian plates. Based on the determination of the epicentres of the events recorded by NISN stations,
- 4- The distribution of epicentral distances are valuable for statistical analysis and provide better means for their use in ground motion applications in study area.

References

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