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Crustal Structure ofSouthern Iraq from Cross-Correlation of Ambient Seismic Noise

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Abstract: *In this study, the ambient seismic noise cross-correlation technique is applied to estimate the thickness of the sedimentary column and crustal structureof southern Iraq. Continuous data from three seismic broadband seismic station were usedto calculatephase velocities of Rayleigh waves using time-frequency analysis. The observedphase velocities were inverted considering linear iterative inversion procedure and several 1-D shear wave velocity models in order to obtain thecrustal structureof the study area. The results show that the sedimentary thickness is around 10km(Vs 1.995-2.485km/sec),the Conrad discontinuity is located approximately at 22km depth (Vs 3.114-3.428km/sec),and the Moho discontinuity is located around 41km depth (Vs 3.827-4.708km/sec).*

Keywords: *Mesopotamian zone of Iraq, the crustal structure of southern Iraq, cross-correlation of ambient noise, Rayleigh wave phase velocities.*

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I. Introduction

Geology and tectonics of Iraq have been affected by the collision (convergent tectonic boundary) of Arabia with southern Eurasia (e.g. Berberian and King, 1981; Adams and Barazangi, 1984). The collision of Arabian and Eurasian plates started when the Neo-Tethys Ocean began closed in mid-Miocene (Dewey *et al*., 1986).Tectonically, southern Iraq is located with the Mesopotamianbasin or zone, which is unstable due to the neotectonic movements and the moderate earthquakes that occur frequently (Buday and Jassim, 1987 and Abdulnaby *et al*., 2016) (Figure 1).

The information available on the crust structures and upper mantle in Iraq is limited. The CGS(1974) in Jassim and Göff (2006)infers from gravity and magnetic data that the depth of basement rocks in the western part of the Mesopotamianzoneis about 8km and in the eastern part about 14km. In the regional investigation,Knopoffand Fouda(1975) proposed that the average crustal thickness is 34km in the northern Arabian plate using seismic methods, whichare based on surface wave dispersion. Gravity interpretation indicates that the crust thickness in Iraq is between 30km in the west and 45 km in the east and northeast (Alsinawi and Issa, 1986).

The fundamental object of this project is to estimate a velocity model of southern Iraq to be used from other seismologists in order to locate precise earthquake hypocenter, depth, and calculate Green's Function. In addition, the velocity model will indicate the thickness of sedimentary cover and the earth crust within southern Iraq.

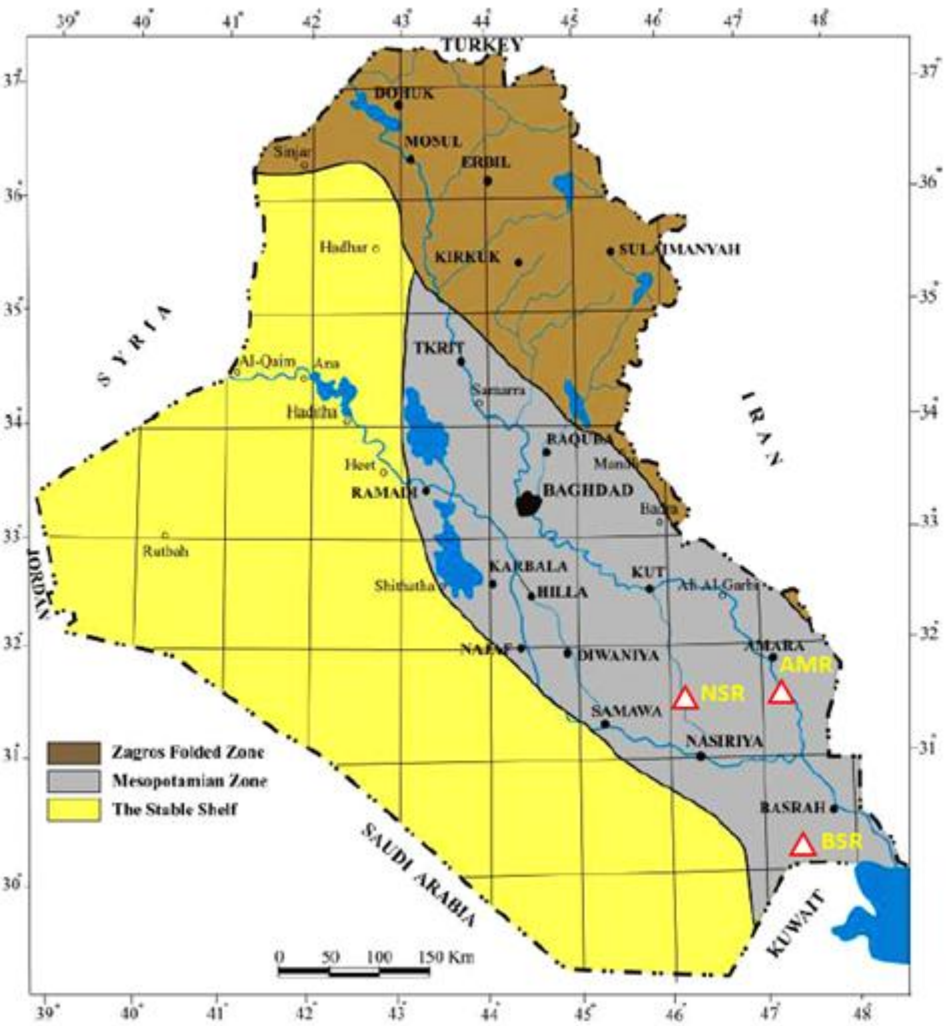

Figure 1: Tectonic divisions of Iraq according to Buday and Jassim (1987).Triangles are the broadband seismic stations in southern Iraq; these are Amara (AMR), Basrah (BSR), and Nasiriya (NSR).

II. Data and Methods

In 2014, threebroadbandseismic stations were installed in the Mesopotamian basin in Amara (AMR), Basrah (BSR), and Nasiriya (NSR) cities. The stations are equipped with Güralp CMG-40T/DM24. The data set consist of seismic waveforms recorded at three broadband seismic stations in southern Iraq.The data is recorded in GCF format and converted to SAC format. Since we are interested to extract Rayleigh waves, the vertical components were used. Table 1 shows the three stations paths with their distances, azimuths, and number and date of days of recorded data.

In order to process the raw seismic data, we applied a procedure similar to those described by Bensen*et al*.(2007) that includes (1) single-station data preprocessing, (2) cross-correlation and stacking, (3) measurement of dispersion, and(4) dispersion curves inversion for 1-D shear wave velocity profiles estimation. All these steps were conducted by usingthe Computer Programs in Seismology (CPS) by Herrmann (2013).

Table 1: Information of paths of the three station pairs used in this study.

Station pairs	Distance (km)	Azimuth (˚)	Data(days)	Julien(days)
AMR-BSR	192.56	167.62˚	61	305-365/2017
AMR-NSR	80.68	252.83˚	91	213-303/2015
BSR-NSR	215.47	318.58˚	92	122-213/2016

III. Results

Results of phase velocities of AMR-BSR, AMR-NSR, and BSR-NSR station pairs are shown in Figure 2. The left panels in the figure represent the phase velocity dispersion curves that were calculated from the traces that result from the cross-correlations of ambient noise of the three station pairs. The right panels in the figure represent the crustal structures that result from the inversion of the phase velocity dispersion curves. It is worth mentioning that the inversion procedure was conducted considering different inversion parameters, damping and weighting factors as well as different starting models. In all cases, we obtained similar final models that indicate a high degree of strength.

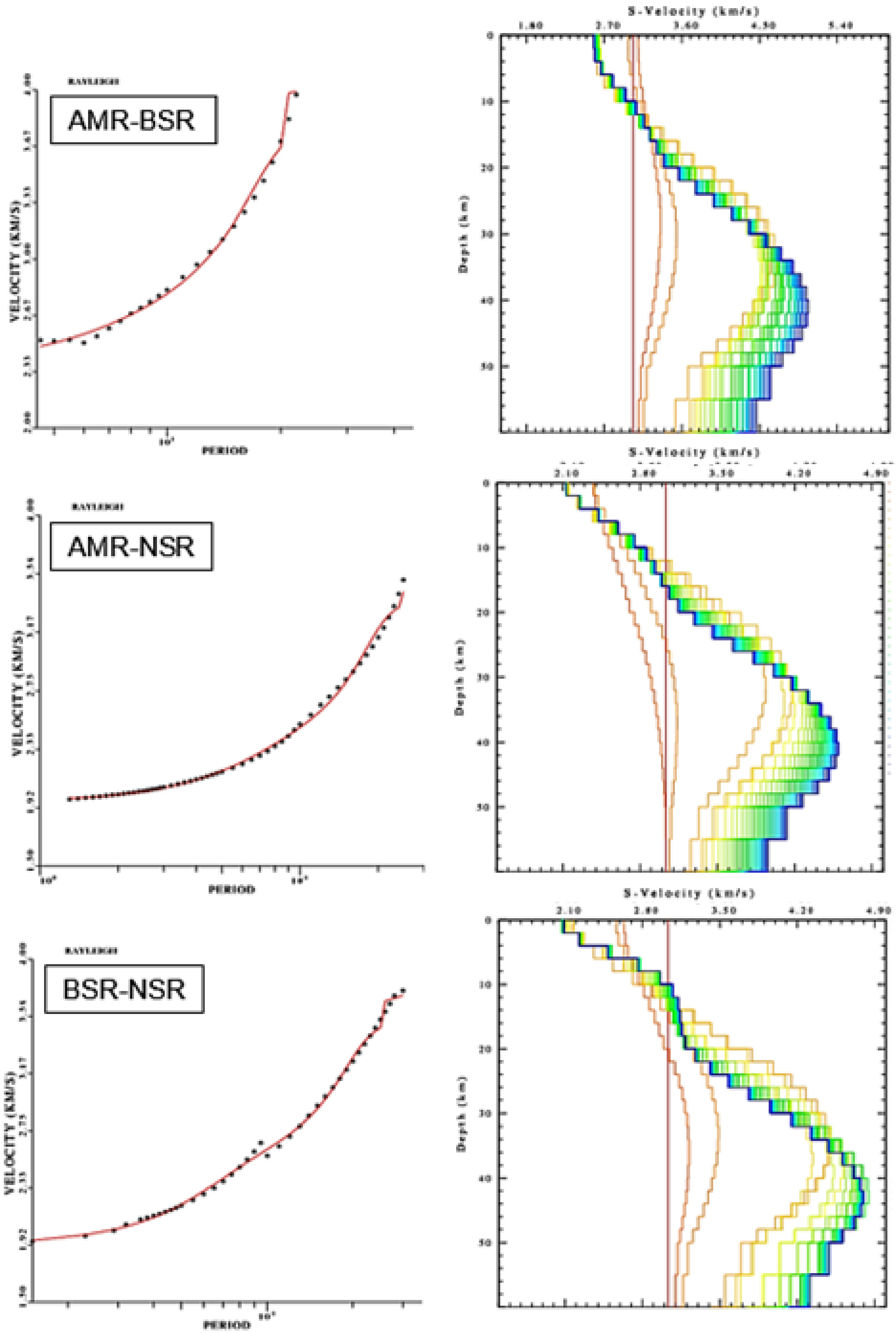

Figure 2: Dispersion curves of phase velocities (left panels) and their inversion in (right panels) for the three station pairs; these are the AMR-BSR, AMR-NSR, and BSR-NSR. Initial half-space velocity modelis used for inversion.

From the three crustal structures, the final velocity model was conducted as shown in Table 2 and Figure 3. The results depict that the sedimentary thickness is approximately 10km with an average shear wave velocity ranges from 1.995 to 2.485km/sec. The Conrad discontinuity, which is the boundary between the upper and lower crust, is located approximately at 22km depth with shear wave velocity ranges from 3.114 to

3.428km/sec. The Moho discontinuity, which is the boundary between the lower crust and upper mantle, is around 40 to 42km depth with an average shear wave velocity ranges from 3.827 to 4.708km/sec.

Table 2: Crustal structure of southern Iraq from the cross-correlation of ambient noise of three broadband seismic stations.

Layer	Depth (km)	VP (km/s)	VS (km/s)	Density (gm/cm^3)
Sediment 1	0.0-2.0	3.781	1.995	2.264
Sediment 2	2.0-10.0	4.527	2.485	2.415
Upper crust	10.0-22.0	5.583	3.114	2.598
Lower crust	22.0-40.0	7.159	3.827	3.056
Moho	40.0-42.0	8.441	4.708	3.474

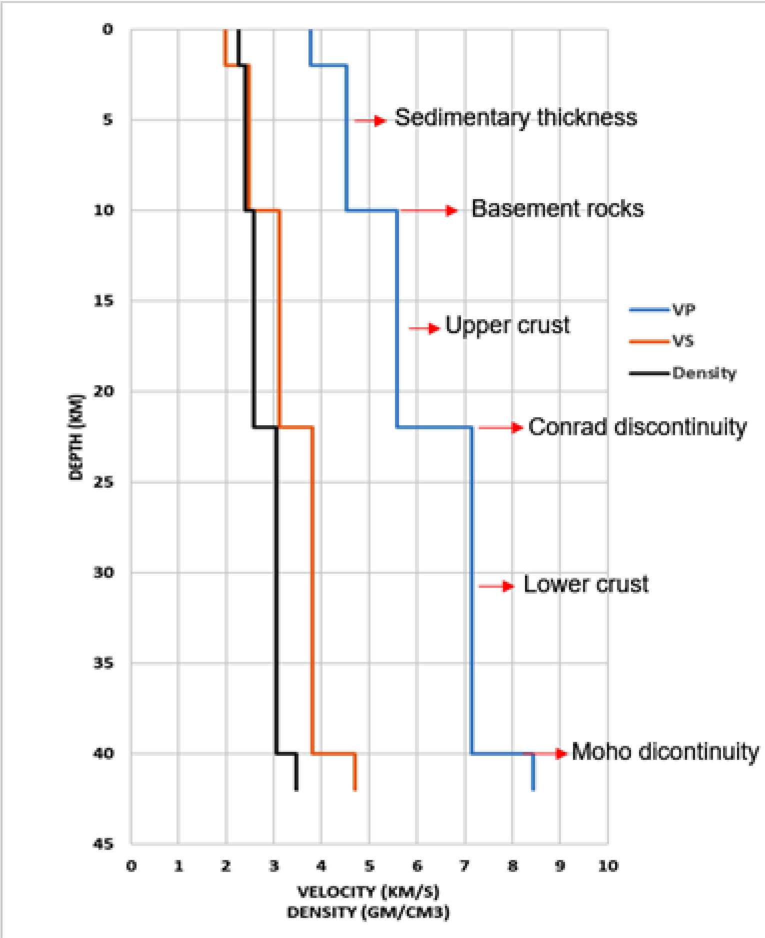

Figure 3: Crustal structure of southern Iraq from the cross-correlation of ambient noise of three broadband seismic stations based on Table 2.

IV. Discussion and Conclusions

The cross-correlation of ambient noise is a novel technique that can be applied to calculatethe crustal structure of an area that has seismic stations with sufficient seismic continuous records. In the areas with thick sedimentary cover, such as the Mesopotamian basin,estimating crustal velocity model from phase velocity dispersion curves is more accurate than the group velocity. For this reason, three broadband seismic stations in southern Iraq were used to conduct the crustal structure using the cross-correlation of ambient noise technique. The procedure that has been described by Bensen*et al*. (2007) was adopted in this study and was applied using the CPS package of Herrmann (2013).

The final crustal structural modelwas obtained through the inversion of phase velocity of Rayleigh waves. Due to the short distances between stations with high frequencies, thevelocity model providesreasonableinformation on the most superficial layers of the sedimentary column and upper crust structure. However, the short distances between stations do not provide clear information on the deeper crustal structure, which is the Moho discontinuity. Therefore, the results of Moho depth that conducted from this study need to confirm through using another technique such as the inversion of P-wave receiver functions.

The final crustal structure velocity model of southern Iraq consists of the sedimentary thickness of 10km(Vs 1.995-2.485km/sec), upper crust with 12km thick (Vs 3.114-3.428km/sec),and estimated Moho discontinuity of around 41km (Vs 3.827-4.708km/sec).

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