Journal of Zankoy Sulaimani- Part A (JZS-A), 2013, 15 (2)

گۆڤاری زانکۆی سلیمانی- بەشی A

Study of earthquake waveforms from a new deployment of seismographic stations in northern Iraq

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Abstract:

This study is to investigate four different body wave phases from events recorded by eight modern broad-band seismographic stations (NISN) installed in northeastern Iraq. From this network of stations which is distributed in Kurdistan region, a three-component digital data obtained that have been recorded continuously at a rate of 100 sps. The analyses include identifying the P- and S-wave phases from different azimuths and locating the events. The processed local and regional earthquakes which have been recorded in the studied area were in the close proximity to the northeastern border of the Arabian plate and occurred over a period between (2010-2012). In this study, the hypocentral depths are derived from the picked arrival times of $P/P_g/P_n$, S/S_g and S_n phases and a map was drawn which depicts the epicentral distances for the analyzed waveforms. Furthermore, the source magnitude has been calculated from the amplitude of the wave energy. The resulting events distribution reveals a distinct picture of the interaction between seismicity and seismotectonics of the region. The highest seismicity rate seems to be confined to the exceedingly active northern section of the Zagros thrust zone.

Keywords: Body waves, amplitude, broadband filter, detection and travel-time.

1. INTRODUCTION

Seismic body waves, which propagate three-dimensionally, are more strongly affected then surface waves by refraction, reflection and mode conversion at the main impedance contrasts in the radial direction of the Earth [1]. This gives rise, with growing distance, to the appearance of more and more secondary seismic body-wave phases following the direct P- and S-wave arrivals in seismic records which significantly improves the precision and accuracy of seismic event locations, their source depth in particular. The crust varies strongly in its thickness, petrologic composition and internal structure due to folding and faulting. The resulting strong heterogeneities in its physical properties at scale length of several decameters to several kilometers cause intensive scattering of P and S waves in the typical frequency range for the recording of near seismic events (about 0.5 to 50 Hz) [2]. Seismic waves arriving at stations at local distances of up to about 1.3° or regional distances of up to about 15° (1° = 111.2 km) from the seismic source have travelled exclusively or dominatingly through the crust or the sub-crustal uppermost mantle. Seismograms recorded at distances D ≤ 15° are dominated by P and S waves that have travelled along different paths through the crust and the uppermost mantle of the Earth [3]. Due to its frequent seismic activity, this region has been selected and will continue to be of vital interest to the seismological community. The seismicity covers the entire width of the Zagros and defines a belt about 1500km long [4].

Historical seismicity investigations were carried in Iraq for the period 1900-1988; 90% of the more than 1000 events catalogued depict a magnitude (mb) range of 4.0-5.5. The focal depth range for more than 75% of the events ranged between 0-50 kms. An isoacceleration map was also constructed for various return periods and the trend of values increases towards the eastern, northeastern and northern directions [5].

2. SEISMIC NETWORK

The deployment of three-component broadband stations with STS-2 seismometers, Q330 digitizers, baler storage and solar power seismographic network (Fig.1) have greatly enhanced the recording and location of local and regional seismic activities in Iraq and surrounding regions, and it is expected to rejuvenate the study and practice of seismology in the country [6]. At present, there are three seismological data centers with internet connectivity at Sulaimani, Erbil and Baghdad observatories (Fig.1).

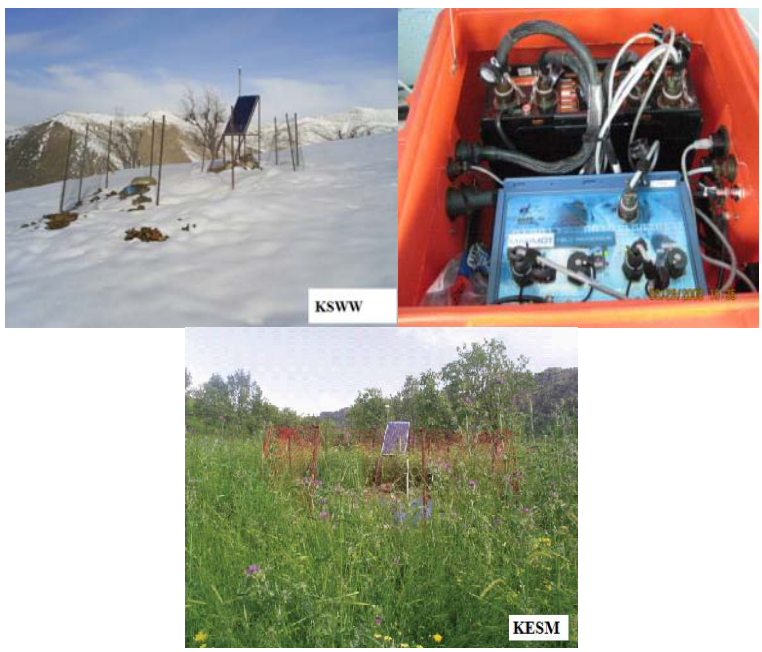

Fig.1: Shows two of the NISN stations, solar panels, GPS antennae with the STS-2 seismometer, Q330 digitizer and baler data storage.

Each seismological center is equipped with sun computers, 2.4 GHz spread spectrum radios VSAT dish, real time technologies and antelope data acquisition and processing system. The seismometers sit on concrete piers that are cemented to the bedrock. This study involves the detection of seismic wave phases propagating from different azimuths through the crust and uppermost mantle. The earthquakes that were recorded at the NISN (North Iraq Seismographic Network) stations were used (Fig.2). The ground motion was recorded continuously at a rate of 100 sps, yielding a database of high quality local and regional waveforms.

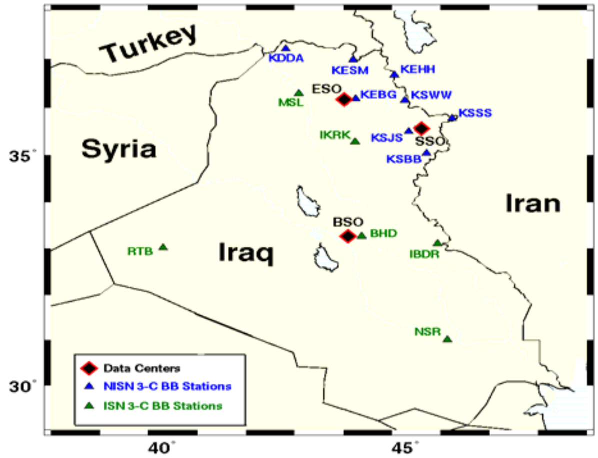

Fig.2: Map showing the spatial distribution of the NISN and ISN (Iraq Seismographic Network) stations which are marked with blue and green triangles, respectively. Seismological data centers at Erbil, Sulaimani, and Baghdad (black and red diamonds).

The parameters for NISN stations are given in Table (1) below.

Table(1): Station parameters of the (NISN)

Station name	Latitude(degrees)	Longitude(degrees)	Elevation(m)
KDDA	37.2125	42.8207	750
KEBG	36.1842	44.2581	722
KEHH	36.6764	45.0470	1725
KESM	36.9846	44.1981	1000
KSBB	35.0415	45.7092	550
KSJS	35.4965	45.3452	825
KSSS	35.7696	46.2362	1515
KSWW	36.1493	45.2624	1310

3. EVENT PROCESSINGS

The most basic and important processing task in seismology is to determine the arrival times of seismic phases since they provide the basic material for improved earth structure (1,2 and 3D) as well as being used for event location. Initially there are many unknown wiggles (phases) on the seismogram, however with better and better earth models, now we understand the presence of most of the phases but there are still 'abnormal' arrivals to be investigated. There is no unique standard definition yet for the distance ranges termed near (local) and regional or distant. In the following we consider a source as local if the direct crustal phases P_g and S_g arrive as first P- and S-wave onsets, respectively. In contrast, the phases P_n and S_n, which have their turning point in the uppermost mantle, are the first arriving phase of P and S waves in the regional distance range (Fig. 3). Accordingly, the local distance range may vary from region to regions and range between about 100 km and 250 km. The identification and reporting of such phases is of utmost importance for a better event location, and improved source depth in particular using the dbloc2 and dbpick programs with Antelope. We have relied on data for picking the arrival times of $P/P_g/P_n$, S/S_g and S_n phases. We also searched for any possible picks arrivals that to be used in the location of events and occur inside the networks.

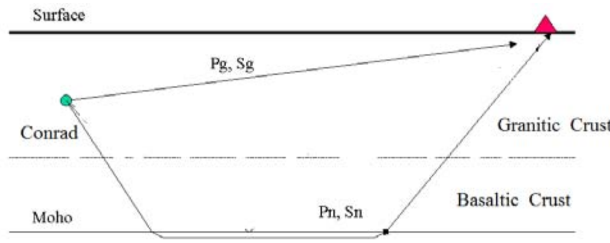

Fig.3: A simplified model of the crust showing the ray traces of the main crustal phases observed for near local and regional earthquakes.

There are very little research has been conducted in locating earthquakes without using the P and/or S arrivals [7]. A total of fifty earthquakes were processed. Seismic waves from an earthquake that occurred at time (t) and at a location x=(x,y,z) known as hypocenter are recorded by seismic station at position $x_i=(x_i,y_i,z_i)$ with velocity (v) and arrival times d_i, where:

$$d_i = T(x,x_i) + t = 1/v\ [(x-x_i)^2 + (y-y_i)^2 + (z-z_i)^2]^{1/2} + t$$

The travel times depend only on the distance between source and receiver, | x-xi |. The P_g and P_n are should be picked on HHZ axis while S, S_n and S_g are more obvious on HHN or HHE components(Figs.4 and 5).

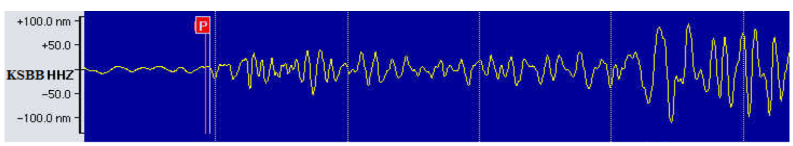

Fig.4: Seismogram showing an example of the detection of P-wave.

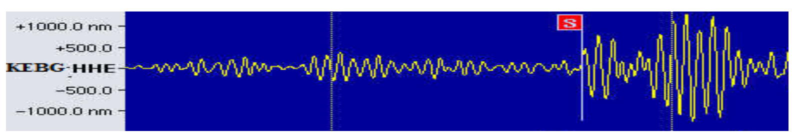

Fig.5: Seimogram showing the S-wave detection.

While the Earth acts as a low-pass filter by attenuating higher frequencies most effectively, a mechanical seismograph is a second order high-pass filter. Additionally, seismic signals are superposed and, in the case of low signal-to-noise ratio (SNR), sometimes completely masked by seismic noise. Therefore, one of the main issues in applied seismology is to ensure high SNR or, where conditions are bad, to improve it by suitable ways of data acquisition and processing [8]. The success of SNR improvement largely depends on our understanding of the ways in which seismic signals and noise differ. In this study, the detection of seismic wave phases involved the application of multiple filter technique for the events to represent the observations perturbations. Many filters tested to minimize the signal-noise ratio (Fig.6).

With signal P-and S- wave detection, the weighted residual time remains should be less than one. The run iteratively had been repeated until a good fit obtained (Fig.7)

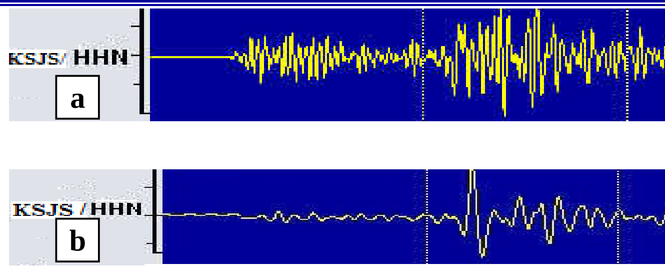

Fig.6: Overlay of a record segment shows (a) Unfiltered seismogram, (b) broadband filtered seismogram applied to enhance the signal to noise ratio.

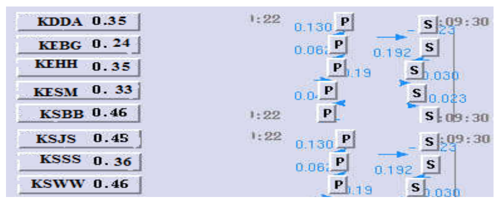

Fig.7: An overlay showing the iteration process of the weighted time residual of the P- and S- wave that detected by the NISN stations.

In the figure 8, the picked high-frequency P_g, P_n, S_g and S_n waveforms are presented. The proper identification and careful analysis helps to avoid wrong source association, improves epicenter location and provides useful data for the investigation of the deeper interior of the Earth. The focal depth is best controlled when phases are included in the location procedure [9].

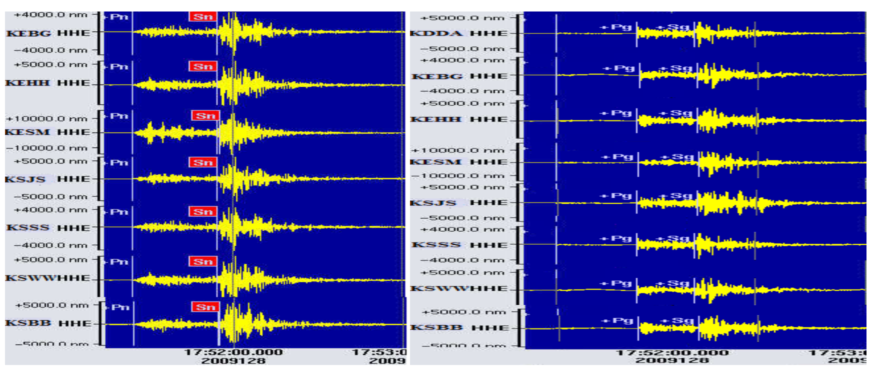

Fig.8: Showing the picked high-frequency P_g, P_n, S_g and S_n waveforms.

4. SEISMIC STRUCTURE RESULTS

The processed events are assigned an origin ID number, Latitude (Lat), Longitude (Long), and an event origin time in hh:mm:ss. The phase arrival time of body waves are determined by reading the relative onset-time difference in seconds or minute between identified phases. The residual time (difference between observed and theoretical travel times) is measured and the location of the epicenter have been calculated and plotted. The plotted map (Fig.9) depicts the calculated epicenter values of the events versus their depth.

For improved determination of epicenter distance, the measurement of travel-time differences are very important. Seismic waves travel along paths between the source and receiver and the average velocity of the body wave phases can be derived. The predicted northwest-southeast trending Zagros plate boundary marked on the map from the alignment of most of the plotted epicenters.

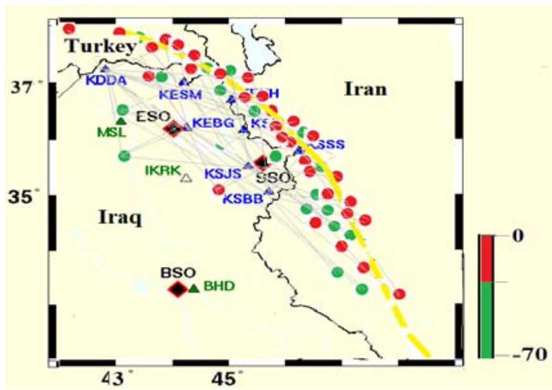

Fig.9: Epicenteral map depicting the processed events for the period Jan 2010 to April 2012. Events are shown as small circles and are color coded by depth (scale on right). The estimated northwest-southeast trending Zagros plate boundary is marked with yellow line. The grey lines are the wave paths that traverse the region from the source to the stations (or receivers).

The derived average velocity of the body wave phases (P_g and S_g) from the inversion of Travel-Distance T-D curve of the waveform data are equal to 5.97 km/s and 3.52 km/s respectively. The determined average velocity of (P_n- and S_n) are equal to 8.25 km/s and 4.56 Km/s respectively. The source magnitude(m_b) that has been calculated from the amplitude of the wave energy for the events ranged from 2.6 to 4.7 in Richter scale. The Travel-Distance curve has shown in the figure (10) for the body wave phases (P_n, P_g, S_n and S_g) which has traversed the studied area.

However, one should be aware that crustal structure and velocities may differ significantly from region to region, and that the event location can be significantly improved when local travel-time curves or crustal models are available [10].

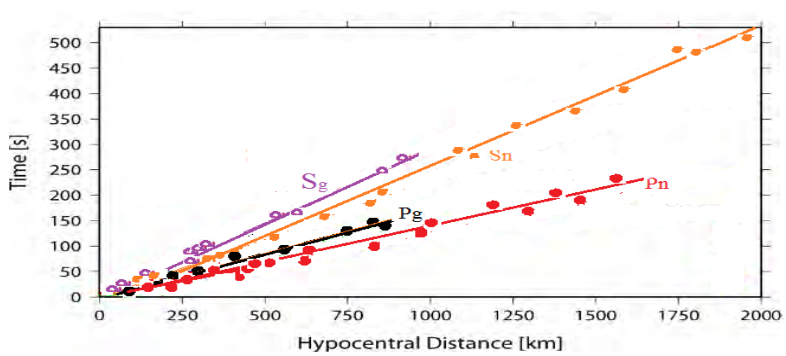

Fig.10: Travel-time distance curve of the processed events which are color coded for the waveform phases.

5. CONCLUSIONS

In this study the followings can be concluded:

1. The northwest-southeast trending Zagros plate boundary could be estimated from the overlay of most of the epicenters. A large number of historical earthquakes besides recent ones are associated with tectonic boundaries. The overall seismicity of the studied area is influenced mainly by the Zagros systems.
2. For the northern Zagros region, P_g and S_g arrival times are less than P_n and S_n as the later will penetrate deeper. The events can be considered to be a crustal earthquake and most of the earthquakes are shallow in depth.

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