



Geophysical study and monitoring of the recorded events nearby the Dokan Dam, NE Iraq

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ABSTRACT

In this study an attempt has been made to monitor and perform analysis to the occurred earthquakes recorded by the installed seismometers in the close proximity to the Dokan dam. Three-component continuous high resolution data logger seismometers had recorded thousands of seismic events from January to December 2013. Twenty five earthquakes were utilized for further processings that covered the studied area and surroundings. The analyses include identifying the body waves from different azimuths within optimal range of frequencies from 3 to 500Hz. The waveforms were used in determining the various source parameters including location, focal depth and magnitude from their arrival times and amplitudes. Epicentral map was drawn which depicts the epicentral distances of the events from the source. Furthermore, the estimated crustal structure below the studied area reveals that the seismic activities were occurred in shallow depths (less than 10 km) within the upper part of the crust and the resulted average values for the P- and S-wave velocities were 5.97 km/sec and 3.23km/sec respectively.

Keywords: *event waveform, magnitude, crustal structure, seismic signal.*

دراسة جيوفيزيائية ومراقبة الأحداث المسجلة قرب سد دوكان - شمال

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الملخص

تم إجراء رصد و تحليل الزلازل المسجلة بجهاز الساييزوموميتر المثبت بالقرب من سد دوكان في هذه الدراسة. سجلت الالاف من الهزات بدقة و باستمرار و على ثلاثة محاور خلال الفترة الممتدة بين كانون الثاني الى كانون الاول 2013. استخدم خمسة وعشرون زلزالا لمزيد من المعالجات و قد غطت المنطقة المدروسة والمناطق المحيطة بها. تم تحديد الموجات الجسمية للهزات والصادرة من اماكن مختلفة وبتردد (3 - 500 هرتز). واستخدمت الموجات لتحديد اماكن ،عمق و مقدار الهزات من ازمة وصول الموجات و سعتها. ورسمت خريطة لمواقع الهزات وبعدها عن المصدر. علاوة على ذلك تم ايجاد تركيب القشرة تحت منطقة الدراسة و يدل على أن الانشطة الزلزالية حدثت في أعماق ضحلة (أقل من 10 كم) داخل الجزء العلوي من القشرة . وان معدل قيم سرعة الموجات الأولية والثانوية هي 5.97 و 3.23 كم /ثا على التوالي.

الكلمات الدالة : شكل الموجة للحدث، المقدار، تركيب القشرة، الاشارة زلزالية.

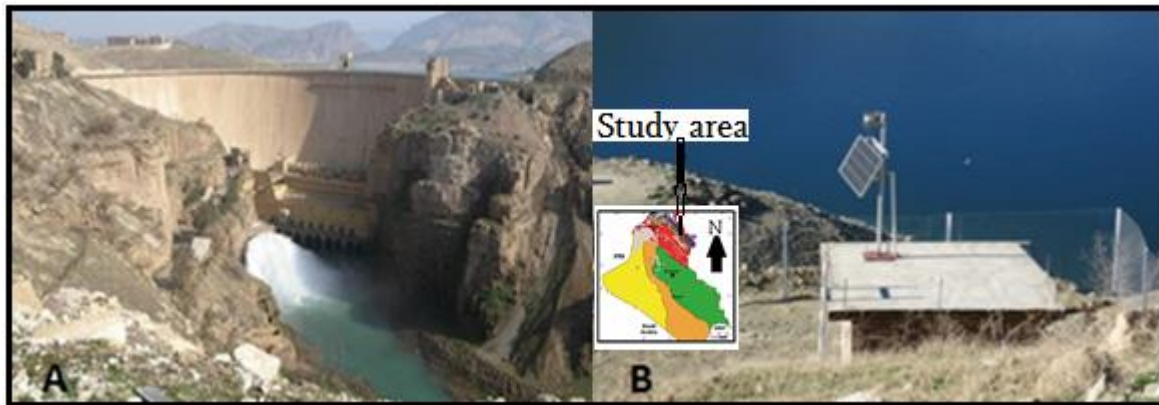


1.INTRODUCTION

In this paper an investigation had been done to gather the seismic data and to sift through this data to identify potential events. Iraq is located in the northern Arabian plate including the western edge of the zagros mountain range, where the convergent tectonic boundary between the Eurasian and Arabian plates is revealed by a fold and thrust belt[1]. In general, Iraq has a rather well-documented history of seismic activity. The seismic history for this region reveals annual seismic activity of different strength. The northern part of Iraq depicts the highest seismic activity with strong diminution of earthquakes in the southern and southwestern parts of the country [2]. The seismic activity when occurred, naturally or induced, the vibrations travel outwards through the ground from the source. Each event radiates seismic waves that travel throughout Earth, and several earthquakes per day produce distant ground motions that, although too weak to be felt, are readily detected with modern instruments anywhere on the globe [3]. Also, initial review of collected data and published bulletins confirm that a large number of occurring small events (magnitude < 4) are either not being recorded or detected by distant stations, or they are not being reported by the scarce number of neighboring seismic stations in Turkey and Iran.

2.SEISMIC INSTRUMENTATION

The study area is located at latitude $35^{\circ} 57' 22.6''$ and longitude $44^{\circ} 57' 13''$ in the northeastern part of Iraq. Dokan hydroelectric dam **Figure.(1)** is equipped with the seismic monitoring system, with its own internal GPS engine that receives accurate time signals to observe and detect the seismicity over time in three directions which greatly enhanced the triaxial force-based digitization at 24bit-sps recordings of local and regional seismic activities without the risk of losing any of the data. This is used to monitor the ground vibration of the crest, and records the effects that any large scale seismic events (earthquakes) may have on the structure of the dam.

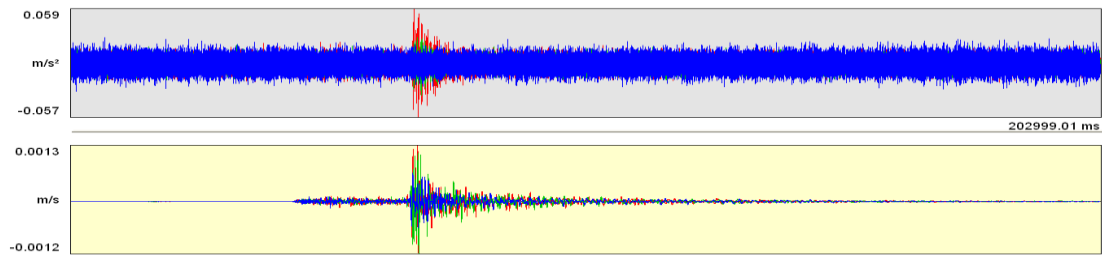


Figuer.(1): Photograph of the Dokan dam (A). The seismic station was sited on the concrete base and cemented to the top surface of the dam while the seismographs, solar panels and GPS antennae were positioned near to the edge of the water reservoir (B).

At present, there is seismological data center with internet connectivity beside the Dokan dam. Modern seismograms are digitized at regular time intervals and analyzed on computers. Also, seismographs include triaxial geophones were installed in shallow boreholes and powered by solar panels.

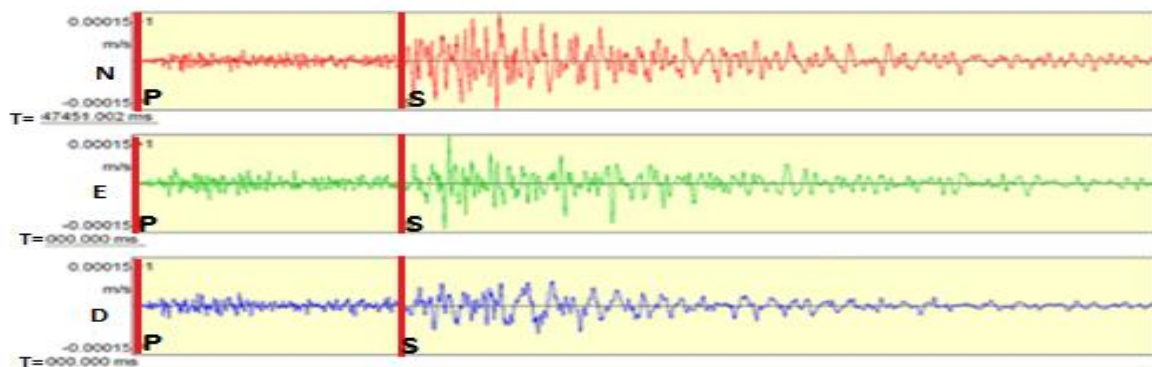
3.DATA PROCESSING AND SPECTRAL ANALYSIS

Seismic signals are made up of waveforms composed of different frequencies. Continuous analog data were converted into discrete digital data which is then analyzed and processed. More specifically, analog signals are sampled at a specific sampling frequency. The seismic waves observed in earthquake records manifest clearly non-stationary characteristics, as well as a wide frequency content [4]. These would be used to gain further information about individual event properties such as source location or other source parameters. In processing technique, the date and arrival-time (h-m-s) for each event is important. If events are triggered on noise rather than legitimate seismic data, it is possible to remove, the processing associated with this event or the events that are deemed to be noise. Noise may occur at certain frequencies, and are associated with an event which can be identified and removed from the true data signal by noise frequency filter. The most common signal processing operation is to filter the signals to enhance certain features and suppress others [5]. **Figuer.(2)** below shows unfiltered seismogram.



Figuer.(2): Shows unfiltered compressed seismogram.

Arrival times are processed which identify when the p-wave and s-waves are first detected. The P-wave and S-wave picks were fixed on the waveform **Figure.(3)**. Filtering is used to improve the quality of the signals by removing noise to obtain optimal Signal/Noise ratio at the time of P- and S-wave picks.



Figuer.(3): Shows fixed P- and S- waves after filtering on triaxial waveform.

Once the P- and S-picks have been adjusted, they were manually processed to obtain the optimal location. From the recorded arrival times on the seismograms, the direct P-waves from various azimuths and the actual distance from the hypocenter were determined. The event location is numerically approached in an iterative process from an initial trial solution. For each iteration, a correction vector (x, y, z, t) is calculated, based on least squares, and added to the previous solution to form a new solution. The iterative approach continues until a preset criteria is reached. The solution is derived from the time-distance equation[6]:

$$\{ (x_i - x)^2 + (y_i - y)^2 + (z_i - z)^2 \}^{1/2} = v(t_i - t)$$

Where x,y,z are coordinates of trial solution , x_i, y_i, z_i location of sensor i , v velocity t event occurrence time, t_i arrival time at sensor i .

P- and S-wave arrival times contributed to determining the location of the epicenter of an earthquake. The S-P intervals from different stations were estimated. Residual- time calculations were done, in an attempt to minimize the location error and to obtain the best-fit source-location solution. This may be an indication of arrival-time mispicks (which should be less than one). An important measure that is used in some source location processors is residual time. The residual time is the difference between the theoretical and observed arrival time at a given sensor. The distance between the epicenter and recording station i (epicentral distance) R_i , is obtained by the following equation[7]:

$$R_i = \frac{(t_s - t_p)}{(1/v_s - 1/v_p)}$$

Where $(t_s - t_p)$ = time difference taken from the earthquake record between the arrival of P- and S- waves , v_p = velocity of P- waves, v_s = velocity of s-waves.

Fast fourier transform is a mathematical routine used to convert seismic waveforms from the time domain to the frequency domain. Performing this maintenance on the data will help improve the performance of the arrival time pickers, and thus will obtain more accurate source location and source parameter calculations. It is important to note that events must be source located before source parameter calculations are performed [8].

Determining the magnitude and azimuth of the events is an integral part of processing earthquake data and is done routinely with nearly all earthquakes located, whether global or local. The magnitude of an earthquake is normally estimated by measuring the ground amplitudes record at stations. The general form of empirical equation defining magnitude is [9]:

$$M = \log (A/T) + Q (\Delta, h)$$

Where A is the maximum ground amplitude in micrometers of the wave used, T the wave period in sec, Q is an empirical function of epicentral distance, the distance and h is the focal depth. An example for the azimuth and magnitude determination for the event which occurred in 22 Nov 2013 is shown in **Figure.(4)**. Information about the frequency content, amplitude of the signals and using the hyperion programs ver.14.0 helped in estimating the source location. However, the 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. Consequently, the travel time can be used as a function of depth

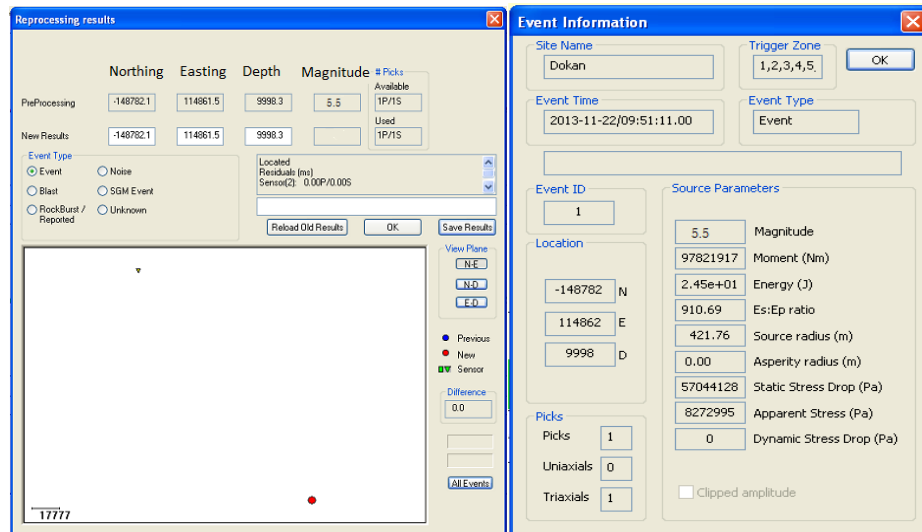


Figure.(4): Shows the azimuth and magnitude of the event occurred in 22Nov2013.

The estimated epicentral map and crustal structure represented by the S-wave velocity versus depth is shown in **Figure.(5)**.

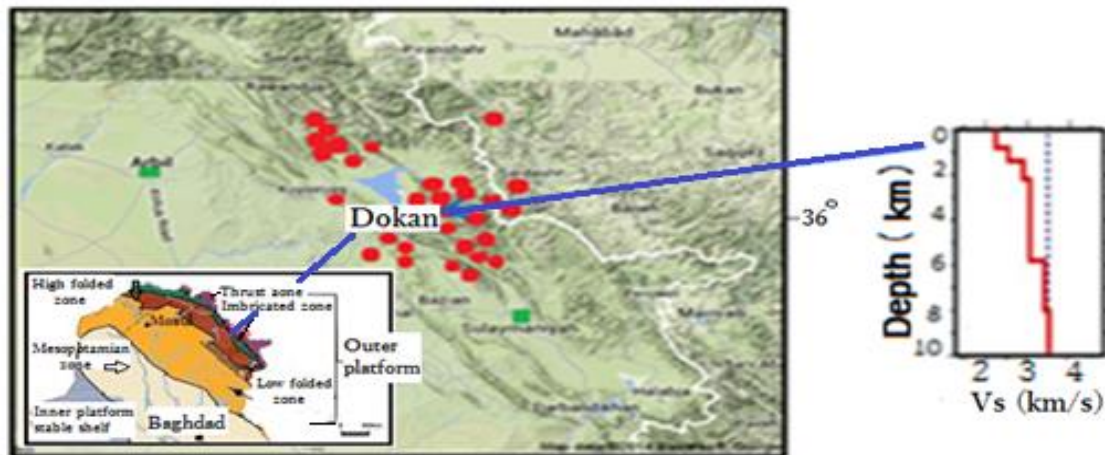


Figure.(5): Shows the plotted epicentral map and crustal structure below the studied area.

The red circles are the processed events occurred in 2013.

4.RESULTS

The calculated source parameters are illustrated in Table.(1) for the selected events occurred in 2013. The value of the magnitude was varied between 1.1 to 5.5. The maximum focal depth beneath the studied area is less than 10 km.

The total recorded event numbers occurred in 2013 versus magnitude were plotted in Figure.(6-a) which reveals that the magnitude of most of the events were between 1-2. Moreover, the estimated P- and S-waves velocities are nearly 5.97 km/sec and 3.23km/sec respectively as shown in Figure.(6-b).

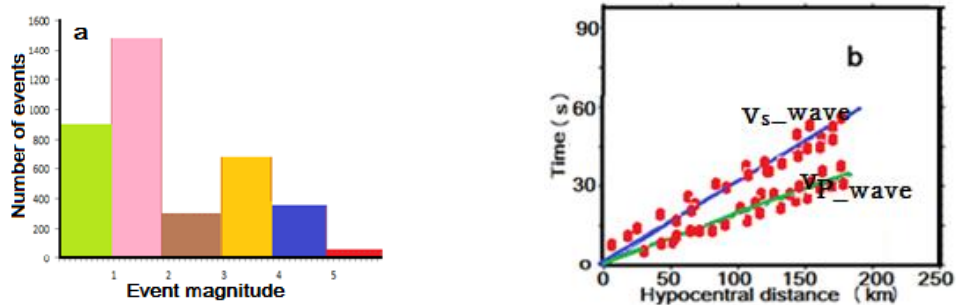


Figure.(6):(a) Shows the total number of events (in 2013) versus magnitude and (b) the time versus hypocentral distance.

Series of events occurred in 22-25 Nov.2013 as clusters of earthquakes in this region. They are differentiated from the other events by the observation that no single earthquake in the sequence is obviously the main shock and not succeeded by series aftershocks with magnitudes ranging between 1.6 and 5.5.

Table.(1): Shows the source parameters for the selected events occurred in 2013.

Serial Time	EvtTime	Depth	Distance	Azimuth	Magnitude
14:06:04	1/7/2013	9998.4	74449.2	44.9	2.6
16:35:29	2/3/2013	9998.4	77019.6	73.9	3.1
16:37:23	2/17/2013	9998.4	73021.2	42.0	3.0
9:05:24	3/7/2013	9453.7	55742.4	63.1	2.0
9:23:22	3/13/2013	9998.3	184279.2	276.6	3.7
7:47:20	5/15/2013	9998.3	142354.8	193.2	3.0
6:55:33	8/22/2013	9998.4	64310.4	176.0	2.4
7:15:41	10/1/2013	9998.4	60631.2	64.3	2.2
1:44:35	11/4/2013	1093.2	2545.2	181.4	2.8
21:31:11	11/22/2013	9998.3	200130.0	167.6	5.5
21:30:50	11/22/2013	9998.3	199306.8	162.1	5.5
9:51:09	11/22/2013	9998.3	194031.6	144.1	5.5
21:50:10	11/23/2013	3032.7	10012.8	348.0	1.4
23:18:42	11/23/2013	177.6	25603.2	164.5	1.7
2:26:16	11/24/2013	9998.3	208555.2	158.7	4.1
6:20:27	11/24/2013	9998.4	71022.0	60.3	3.5
23:51:10	11/24/2013	1348.9	20210.4	161.6	1.6
21:03:22	11/24/2013	9998.3	206808.0	134.0	4.9
1:29:55	11/25/2013	6304.5	58464.0	337.8	1.9
6:29:38	12/2/2013	9998.4	52399.2	91.0	1.9
10:24:52	12/9/2013	3369.8	3654.0	227.6	1.2
10:34:30	12/22/2013	4046.6	25359.6	308.2	2.2
10:43:00	12/22/2013	9998.4	67964.4	90.0	4.3
10:43:23	12/22/2013	8089.4	44772.0	90.0	3.7
9:55:17	12/23/2013	9998.4	71887.2	6.4	2.1

5.CONCLUSIONS

In this study it can be concluded that the detected swarms of earthquakes striking the area in a relatively short period of time were possibly associated with the relative movements of the Eurasian and Arabian tectonic plates. While the large number of occurring small events (magnitude < 3) as shown in the histogram for the event bulletin of 2013 **Figure.(6-a)** might be due to the raising and lowering of the water level in the reservoir. Collectively, tectonic movements and the extra water pressure were assessed as very high threats to the area.



Also, there are clear differences in magnitude values. Those differences in magnitude values reveal changes in the seismicity of the studied area. Furthermore, the focal depth values indicate that all the recorded events in the study area were shallow earthquakes and occurred within the upper crust (lithosphere). Furthermore, during possible earthquake shaking, it is important to consider seismic effects on the dam to ensure the safety of the dam under seismic loading.

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