Seismicity Evaluation of Central and Southern Iraq

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Abstract
This study covers the area bounded by latitudes 29° to 34° N and longitudes 39° to 48°E.The seismicity of area for the period 1980–2011 is evaluated. In this study the geological and topography were performed, regarding the historical seismicity. More than (145) events were re-analyzed in Iraqi Seismological Network (ISN) and the recorded data was subjected to statistical analysis. This study shows high activity in the east and very low activity in the west.
Keyword: Seismicity of Iraq, seismic activity.

التقييم الـزلزالـي لوسط و جنوب العراق

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الخلاصة:
تشمل هذه الدراسه المنطقة المحصوره بخطوط العرض (29–34) وخطوط الطول (39–48). وتم تقييم زلزالية المنطقة للفترة ما بين 1980– 2011. تضمنت الدراسه ايضا دراسة لجيولوجية و طوبغرافية المنطقة بالاضافة الى دراسة الزلزالية التاريخية.ولقد اعيد تحليل أكثر من (145) هزة أرضية في مرصد بغداد الزلزالي ومن ثم طُبق عليها التحليل الأحصائي.
هذه الدراسة تشير الى ان الفعالية الزلزالية لمنطقة الدراسة مختلفه، حيث تظهر زلزالية عالية في شرق المنطقة و فعالية زلزالية واطئه في منطقة الغرب.

1. Introduction:

Iraq is located in a relatively active seismic zone at the northeastern boundaries of the Arabian Plate. The corresponding Zagros-Tauros Belts manifest the subduction of the Arabian plate into the Iranian and Anatolian Plates. The largest number of earthquakes with the highest energy occurs in the upper 40 Kilometers of the earth’s crust. Deeper earthquakes occur with decreasing frequency [1]. The seismicity of Iraq has been studied by many researchers, such as (AL-Timimi Alsinawi and Ghalib, Mahmood, Issa, Al-Dabbagh, Ameer,). All the studies of the seismicity and seismotectonic of Iraq indicated that seismic activity is moderate to high at northern and northeastern boundaries, and decrease in the south and southeastern direction, [2]. 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 west and southwestern parts of the study area [3]. An earthquake catalogue was prepared for the studies area as bounded by longitudes (39º. 00 .48º. 00.) E and latitudes (29º. 00.-34º. 00‘) N for the period 1900-2011, Figure 1-.The Catalogue contains more than 145 events ranging in mb magnitudes between (3.1-5.3). An analysis was carried in this investigation to

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determine the various magnitudes, focal depths, and spatial and time distributions of earthquakes, and for each earthquake the following parameters were extracted: S-P (delay time), origin time, duration, azimuth, epicentral distance and epicenters.

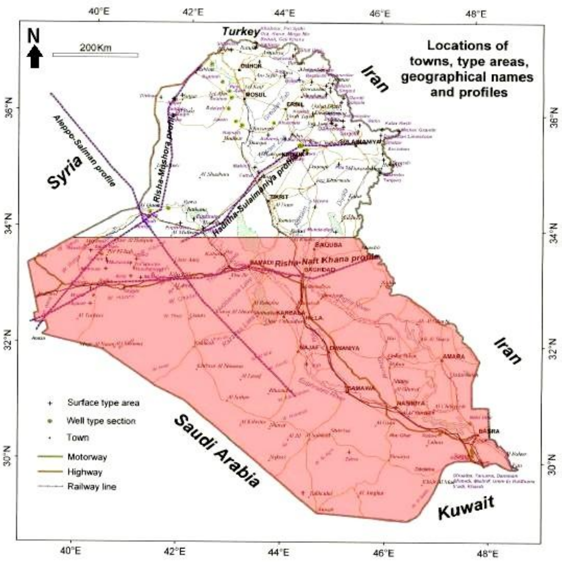

Figure 1- Map of the study area.

2. Geological setting

The study area divided into three parts: Southern desert, Western desert part and Mesopotamian plain part, Figure 2-. The Iraqi Desert covers considerable part of the whole territory, forming the region south and west of the Euphrates River. It is divided into Western and Southern Deserts; formerly they were known as "Al-Badiya Al-Shimaliya and Al-Badiyah Al-Jinoobiyah", respectively. The divide line between the two deserts is Wadi Al-Khir, [4]. The southern desert is a part of the stable shelf of the Arabian Platform, which is characterized by the presence of block tectonics and the absence of tectonic folds [5]. The Euphrates Fault Zone with NW – SE trend is the main feature along the northeastern part of the Southern Desert [6]. Abu Ghar – Busaiya and Al-Batin lineaments with NE – SW trend are also recognized in the internal parts of the desert. The western desert is divided into two parts, a stable one to the west and an unstable one to north and east. The boundary between the two parts of the platform is taken along.Anah – Abu Jir Fault Zones. The Rutbah Uplift and Ga`ara Depression are the main feature in the desert, [7].

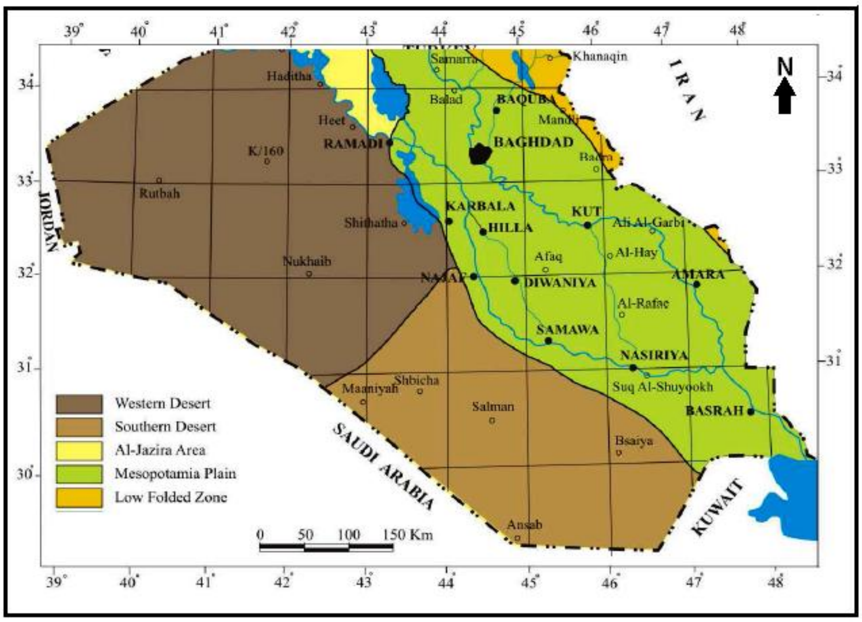

Figure 2- Location map of the syudy area.

3. Seismicity of the study area:

Information on seismicity within the study region is based on a completely revised earthquake catalogue compiled by IRAQI SEISMOLOGICAL NETWORK (ISN), which reveals that Iraq is subjected to annual seismic activity of different strength it shows the central and south of Iraq characterized by low to moderate seismic activity. The period from

(1980-2011) were also compiled. based on (ISN) earthquake catalogue, as show in Figure 3-.

The seismicity of the study area is in relation to the general seismicity of the Zagros-Tauros belt, which lies along a broad zone of deformation that forms part of Zagros-Touros belt, it located between Arabian plate and Iranian plate. Neotectonic activities and seismotectonic parts effects at each other produce a great seismicity in Iraq, [2]. The eastern side of the study area is a relatively wide zone of compressional deformation along the Zagros- Tauros active mountain belt, which is entrapped between two plates, the Arabian plate in the southwest and the Iranian plate in the northeast. Its deformation is related to the continuing convergent movement between these two plates, by north northeastward drift Arabian plate against Iranian plate [2]. Since, 1990 till now, the south and southeastern part of Iraq witnessed a number of small earthquakes some of them were felt by inhabitants. The felt earthquake had been recorded by the ISN during the August 2004. The first event was in 5/8/2004 while the second occurred on 28/8/2004. Both earthquakes have hit AL-refaee City /Amara Province and surrounding area. An Isoseimal map for the August 5th 2004 event is shown in Figure 4 A-, and map Figure 4B-, is for the August 28 2004 event. If we consider this region is quiet, the occurrence of earthquake in this region raised inevitable question about the probability of experiencing similar earthquake in other regions in the near future.

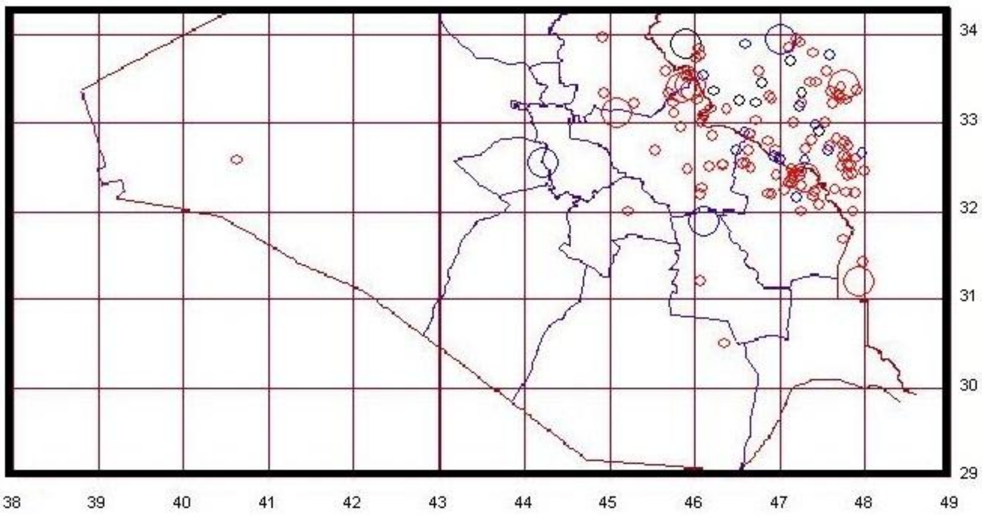

Figure 3- Epicentral map of the study area for the period (1980-2011).

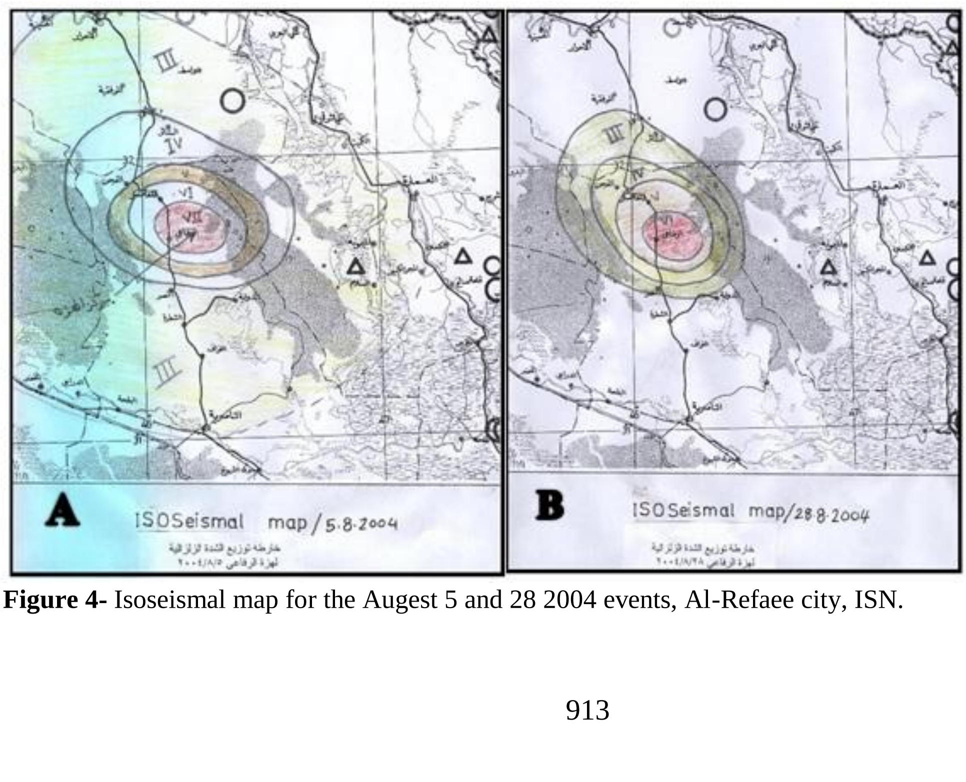

Figure 4- Isoseismal map for the Augest 5 and 28 2004 events, Al-Refaee city, ISN.

Earthquake Magnitude:

Magnitude is a measurement of the energy released by an earthquake; the first earthquake-magnitude scale was the Richter scale. Where Ms, Mb, Md, ML, Mw, were computed.

- Duration Magnitude (Md):

The concept of earthquake duration magnitude based on the realization that on a recorded earthquake seismogram the total length of the seismic wave train reflects its size [8]. In this study, two equations have been applied finding the MD, for earthquakes with epicentral distance less than (50) km and for earthquakes that has epicentral distance more than (50) km [9], as following:

For **Δ**< 50 Km:

measured by seconds.**Δ:** Epicentral distance. MD values for this study ranged from (1.8– 4.8).

$MD= 0.81 (LogD) + 0.47 (Log \Delta) + 0.35$

For **Δ**> 50 Km:

$MD= 1.31 (LogD) + 1.19$

Where: **D:** the duration of the earthquake and it's

The local magnitude (ML):

In this study the following formula is used to find the local magnitude depending on the magnitude duration, the values of ML ranged (1.7-4.8) [10]:

$ML = 0.0357 + 0.982 \times MD$

- Body wave Magnitude:

Magnitudes which can be determined by body -waves are m_{PV} and m_{PH} by P waves, m_{PPV} and m_{PPH} by PP waves, and m_{SH} by S waves.

Mb [11], equation is used, depending on ML values:

$Mb = 1.7 + 0.8\times ML - 0.01\times ML^2$

And for Ms [12], equation was used, as following:

$Ms = 2.08\times Mb - 5.65$

In this study Mb and Ms values were (3.1-5.3) and (0.7-5.4) respectively.

Moment Magnitude (Mw):

Moment Magnitude based on the seismic moment of the earthquake, which is equal to the rigidity of the Earth multiplied by the average amount of slip on the fault and the size of the area that slipped. In this study we use the following equation, [13]:

$Mw = 2/3 Ms + 2.34$

Mw ranged in values from (2.3-5.9).

Temporal distribution of seismicity

Earthquakes of more than (145) are reported Figure 3- to have occurred in the study area (29° to 34° N and 39° to 48° E), for the period from 1980 to 2011. The number of earthquakes/year is plotted in Figure 5-. This shows five high seismicity periods, 1988, 2001, 2009, 2010 and 2011.These high seismicity periods are attributed to a tectonic cause rather than being attributed to a result of the progress of earthquake monitoring in this region and surroundings in recent years.

Seismic energy release

The general seismicity of any area must be evaluated not only from the number of earthquakes recorded within a definite interval but also by the total energy release for these earthquakes [14]. [15] Discussed some of the simple relations giving logarithm of energy as a linear function of magnitude. The seismic energy relation [11]:

$Log E = 11.8 + 1.5 M$

Employing the surface wave magnitude (M) is used in this study. The measured energy ranged from ($7.5\times 10^{12} – 6.9 \times 10^{19}$) erg.

Frequency–magnitude relationship

The frequency–magnitude distribution of earthquake is well-expressed by the Gutenberg–Richter relation [11]:

$Log (Nc) = a – b M$

Where N is the number of earthquakes, and b are constants for a region. The parameter "a," showing the activity level of seismicity, exhibits significant variations from region to region as it depends upon the period of observations and area of investigation. The "b" parameter is a tectonic parameter that depend on provides the possibility of describing the stress and/or material conditions in the focal region. Figure 6- gives the magnitude distribution of the earthquake activity for the study area from 1980–2011. The figure gets the following relations:

$Log (Nc) = 2.35 – 0.16 M$

$Log (Nc) = 4.6 – 0.83 M$

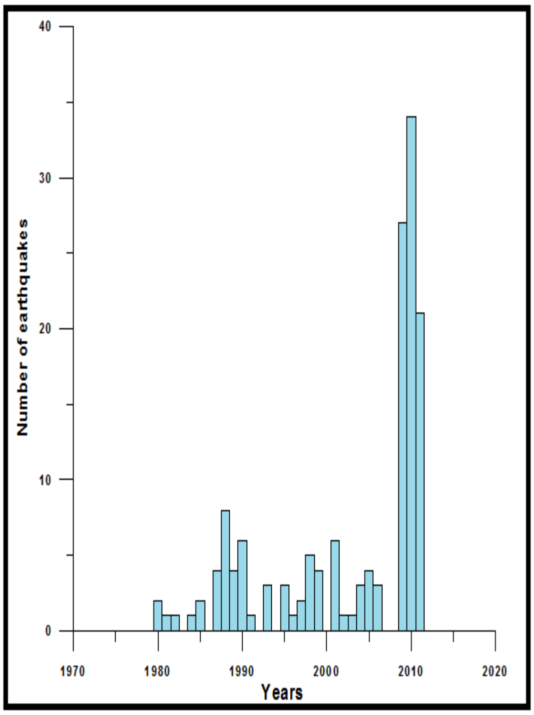

Figure 5- Temporal distribution of earthquakes for the period (1980-2011) of the study area.

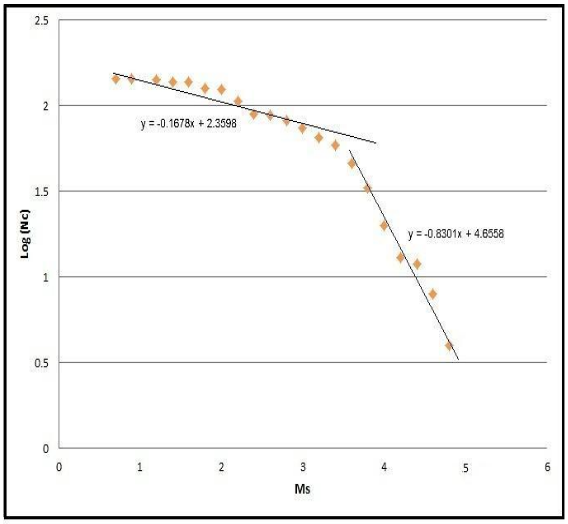

Figure 6- Magnitude - Frequency relationship of the study area.

From equations above there are two values for (a) and (b), The contrast between the values may be due to the difference in time periods or tectonic settings of the region, [16].

The two b-values are equals to (– 0.16), and (-0.83) and this according to [17] classification indicate a very low to moderate seismic tectonic activity, approximating the effect of the Alpine organic zone and platform block zones controlling the seismotectonic setting of the northern part of the Arabian plate, [3].

Hypocenter of earthquakes:

An earthquake's hypocenter is the position at the focal depth below the epicenter where the strain energy stored in the rock is first released, marking the point where the fault begins to rupture.

The depth of earthquakes gives us important information about the earth's structure and the tectonic setting where the earthquakes are occurring. Earthquakes can occur anywhere between the earth's surface and about 700 kilometers below the surface, [18]. For scientific purposes, this earthquake depth range of (0 – 700) km is divided into three zones:

1. Shallow earthquake: are between (0 and 70) km deep, and it is one of the most important types of earthquakes, where three-quarters of the earthquakes in the world located within these depths.
2. Intermediate earthquakes: are earthquakes with depth range between (70 – 300) km. Deep earthquakes: these earthquakes range between (300 – 700) km deep.

Focal depths were recorded for all earthquakes in the study area based on the equation, which agreed upon [11]:

Log E= 8.8 + 2 Log h + 1.8 Ms

The focal depth of the events of the study area ranged from (5.0 - 24.7) Km. According to classification mentioned above, the range of the depths of earthquakes located within the shallow earthquakes less than 70Km Figure 7-.

Historical Seismicity:

Historical earthquakes mean all earthquakes that happened before 1900 A.M. and Iraq has a rather long-well documented seismic history. Iraq is located in a relatively active seismic zone, and most regions of the country was subjected to a seismic activity in the past, it is likely that this seismic activity continues in the future; therefor it is very important to study and analyses the past-earthquakes, [18]. The seismic history of Iraq reveals Iraq is subjected to annual seismic activity of different strength. [19] published a catalogue of historical earthquakes in Iraq were More than (30) events of Al-Dabbagh list are located in our study area, Figure 8-, and these earthquake activities were during the period 551 A.D. to 1873 A.D. Table (1) shows some of the historical events of the study area.

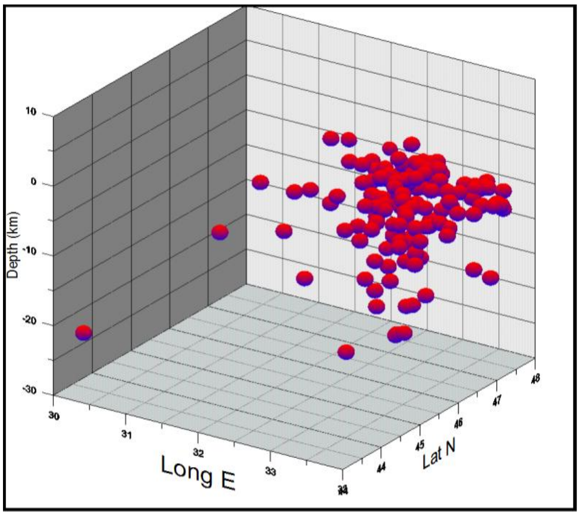

Figure 7- Hypocentral distribution of the seismic events in the studied zone.

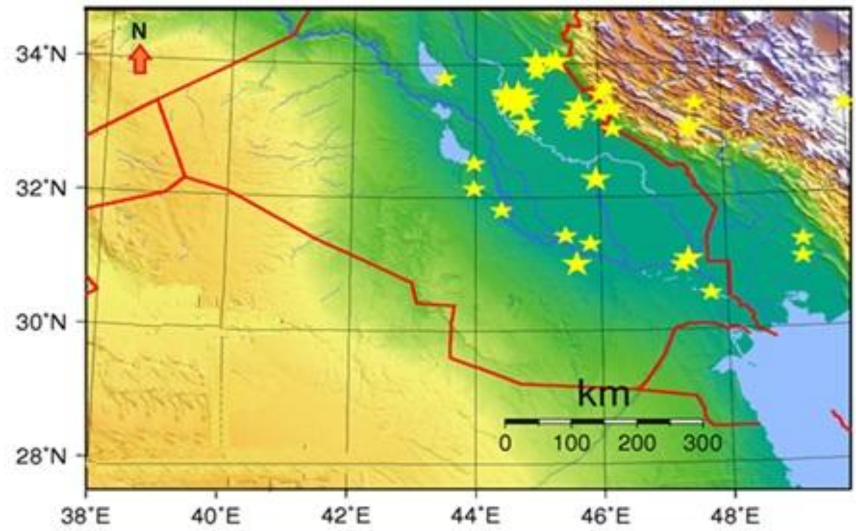

Figure 8- Historical events for the study area, (AL-Dabbagh, 1999).

Table 1: The historical seismicity of the study area, (Al-Dabbagh,1999).

No.	Date	Location	Coordinate		Depth (Km)	Ms	Intensity
			Lat.	Long.			
1	570	S. Baghdad(Medain)	44.6	33.1	9	5.5	VIII
2	859	Baghdad,Medain	44.6	33.1	5	3	V
3	299	Kufa	44.4	32	7	4.5	VII
4	363	Wasit	46.9	33.6	5	3	V
5	590	Jazira,Najaf	44	32.1	5	3.5	VI
6	650	Baghdad	44.4	33.3	8	5	VII
7	1671	Tharthar lake	43.6	33.9	9	4.4	VII
8	1827	Zurbatya,Badra, Baghdad	46.1	33.2	9	5.2	VII
9	1867	Mendili,Jalwla, Baghdad	45.2	34	30	7	VIII
10	1873	Baghdad	44.4	33.4	5	3.5	VI

Data Analysis

Data analysis deals with seismogram analysis and extraction of seismic parameter values for data extracted from Iraqi seismological network (ISN). Describing the basic requirements in analog and digital routine observatory practice i.e., to:

· recognize the occurrence of an earthquake in a record;
· identify and annotate the seismic phases;
· determine onset time and polarity correctly;
· calculate the azimuth;
· determine source parameters such as the hypocenter, origin time, magnitude, source mechanism, etc.

In this study the events divided into: Analog data and Digital, and for each earthquake the following parameters were extracted: S-P (delay time), origin time, duration, azimuth, epicentral distance and epicenters.

Table 2: Data analysis for some earthquakes in the study area.

No.	station	Date	origin time	S-P (sec)	Z	N	E	Azimuth	duration (sec)	Δ◦	Δ (km)
1	BHD	14-12-80	14:08:13	24	U	N	E	91	260	1.45	161.2
2	BHD	21-2-80	13:57:54	35	U	N	E	106	110	2.52	280.2
3	BHD	9/7/1981	2:53:20	19	U	S	W	56	100	1.42	157.9
4	BHD	30-04-82	17:27:50	21	D	S	W	80	268	1.47	163.5
5	BHD	21-10-84	23:40:20	33.5	D	S	W	21.8	380	2.25	250.2
6	BHD	21-03-2009	21:13:05	34	D	S	E	101	248.4	2.44	271.33
7	BHD	8/3/2009	23:58:28	23	U	N	W	104	311.5	1.8	200.16
8	BHD	23-11-2009	21:19:39	25	D	N	E	103	79	2.1	233.52
9	BHD	23-11-2009	21:20:56	25	D	N	E	103	74.4	2.1	233.52
10	BHD	5/8/2009	21:10:48	32	U	N	W	111	151.2	1.2	133.44

4. Conclusions:

The main conclusions that may be drawn from this paper are:

1-More than (145) earthquakes were re-analyzed for the study area bounded by longitude (39-48) and latitude (29-34), recorded by Iraqi eismological Network (ISN), for the period from (1980-2011). The study area was subjected to more than (30) historical earthquakes.

1. Earthquake magnitude were extracted and they range as (1.7-4.8), (3.1-5.3), (0.7-5.4), (2.3-5.9), (1.8 – 4.8), for local Richter magnitude (ML) body wave magnitude (Mb) surface wave (Ms), Moment magnitude (Mw) and duration magnitude respectively.

2. The radiated seismic energy were calculated using (Richter, 1958) formula, the results were ranged between ($7.5*10^{12}$ – $6.9*10^{19}$) erg.

3. Focal depth were computed for all earthquakes in the study area, it's ranged from (5-24.7) Km, that makes the depth of the study area earthquakes located within the shallow earthquakes.

4. The temporal distribution for the recorded events of the study area, show the period from (2009-2011) is the highest period of seismic activity followed by the period from (1988-1990).

5. Epicentral map for the study area is developed using the ISN accessible Iraqi seismicity data, this map showed a recent seismicity in the NE of the study area, that might be due to the development of devices or increasing the monitoring stations or due to tectonic settings.

6. A frequency-magnitude formula for the studied area was represented, giving two equations as following:

Log (Nc) = 2.35 – 0.16 M
Log (Nc) = 4.6 – 0.83 M

The values of (b) constant were computed to be (0.16) and (0.83). b-values indicate a very low to moderate seismic tectonic activity and that change in activity may be due to the change in tectonic setting of the region.
7. High seismicity periods: 1988, 2001, 2009, 2010 and 2011, are attributed to a tectonic cause rather than being attributed to a result of the progress of earthquake monitoring in this region and surroundings in recent years.

Referances:

1. Alsinawi, S. A. **1972**. "*The Prospects of Seismological Research in Iraq*". Proceedings of the First Scientific Conference of the FSR, Baghdad, pp:162-174.
2. Alsinawi, S.A., **2002**. *Seismicity, Seismotectonics, Crustal Structure and Attenuation Data on Iraq*. The RELEMER Meeting, Antakya, Turkey, 12-14 December, 2002.
3. Alsinawi, Sahil A. and Ghalib, H. A. **1975** "*Historical Seismicity of Iraq*". Bull. Seis. Soc… Amer., Vol. 65, No. 5, pp:541-547.
4. Al-Bassam, K.S., **2007**. *Geology of Iraqi Western Desert.* Iraqi Bulletin Geol. Min., Special Issue, pp:1− 4.
5. Buday, T. and Jassim, S.Z., **1987**. *The Regional Geology of Iraq*. Vol.2, Tectonism, Magmatism and Metamorphism, Abbas, M.J. and Jassim, S.Z. (Eds). GEOSURV, Baghdad, Iraq.
6. Ma'ala, K.A., **2008**. *Tectonic and Structural evolution of the Iraqi Southern Desert*. Iraqi Bull. Geol. and Min.,Special Issue, pp:35–52.
7. Sissakian, V.K. and Buthaina S. M,. 2007. Geology of Iraqi Western Desert (Stratigraphy). Iraqi Bulletin Geol. Min., Special Issue, pp:51− 124.
8. Bisztricsany, E. A., **1958**, *A new method for the determination of the magnitude of earthquakes*. Geofiz. Kozl., pp:69-76.
9. Iraqi seismological Network, ISN.
10. Fahmi K. J. , Ayar B. S. , Hassan I. A. , 1988), *The Takab seismic gap—forecasting a major earthquake occureence off northeastern Iraq;* Journal of Geodynamics, vol. 10, issue 1, pp:43-72
11. Richter, C. F. **1958** .*Elementary Seismology*. W.H. Freeman and Co., San Francisco pp:768.
12. Marshall, P. D., 1970. Aspects of spectral difference between earthquakes and underground explosions, Geophys. J. R. astr. Soc.. 20, pp:397-416.
13. Al-Heety E. A. **2011**, *Seismicity and seismotectonics of Libya: as an example of intraplate environment*. Arabian Journal of Geosciences . 6, pp:193-204.
14. Fuis, Gary; Wald, Lisa. **2002**. *Rupture in South-Central Alaska—The Denali Fault Earthquake of 2002*. USGS. Retrieved 2008-04-20.
15. Bath.M. **1979**. *Introduction to Seismology*. 2nd edition. 428 PP., 124 figs, 33 tables. Basel: Birkhäuser. Price sFr. 56.00. ISBN 3 7643 0956 3.
16. Issa, A.A., **1983**. *Seismicity and Seismotectonics of Iraq*, M.Sc. thesis , University of Baghdad,142p, unpublished. (Arabic reference).
17. Miyamura, S. **1962**. *Magnitude frequency relation of earthquakes and its bearing to geotectonics*. Proc Japan Academy 38, pp:27.
18. Alsinawi, S. A. **1988**. *Historical Seismicity Of the Arab Countries*. Proceedings of the Third Arab Seismological Seminar- King Saud University, Riyadh, Saudi Arabia, 7, pp:11-33.
19. Al-Dabbagh H. A. **1999**. *Review and analyses of some earthquakes events in Iraq*. M.Sc. thesis, University of Baghdad, p:116. (Arabic reference).