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THE 22nd OF NOVEMBER, 2013 EARTHQUAKE AT SOUTHEAST SHERWANA CASTLE, KALAR DISTRICT

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ABSTRACT

Sherwana castle, located 3.25 Km to the southeast of Kalar, was subjected in 22 November, 2013 to earthquake of magnitude 5.6 degree on the Richter scale. This event took place about 12.25 Km to the northeast from the castle. It caused damage to constructions especially in the second floor and within the areas around the castle. The event is followed by aftershocks that continued for two months; their influence is noticed in Khanaqin city and the Iraq – Iran border. Three historical events and 412 recent events within 50 Km radius in the area are documented. Their magnitudes range between (1.2 – 5.6) degrees. Seismotectonic map of the area shows a good relationship between the distribution patterns of epicenters to the geologic structures of the region. Isointensity map is constructed and shows the intensity to range between (I – VII) according to the Mercalli scale. Fault plane solution of 16 events in the study area indicates thrust with some strike slip and normal faulting along NW – SE planes.

الهزة الأرضية التي حدثت جنوب شرق قلعة شيروانة في 22 تشرين الثاني 2013 بقضاء كلار

حسنين جاسم محمد و عبد الكريم عبد الله تقي

المستخلص

تعرضت قلعة شيروانة الواقعة جنوب شرق قضاء كلار والتي تبعد عن مركز القضاء 3.25 كم إلى هزة أرضية بتاريخ 22 تشرين الثاني 2013 حيث بلغت قوتها 5.6 درجة على مقياس ريختر وتبعد 12.25 كم باتجاه الشمال الشرقي عن القلعة وسببت أضرارا إنشائية خصوصا بالطابق الثاني من القلعة والمناطق الواقعة حولها حيث ان هذه الهزة هي جزء من النشاط الزازالي الذي تعرضت له مناطق شرق قضاء خانقين والشريط الحدودي العراقي – الإيراني واستمر الى أكثر من شهرين. تم استعراض الزلزالية التاريخية والحديثة حول منطقة الدراسة بنصف قطر 50 كم منها ثلاث هزات تاريخية و (412) هزات حديثة تراوحت قوتها بين (1.2 – 5.6) درجة على مقياس رختر، رسمت خارطة زلزالية تكتونية التي بينت علاقة توزيع المراكز السطحية للهزات وتطابقها مع الوضع التكتوني في المنطقة. ورسمت خارطة الشدة الزلزالية في منطقة الدراسة حيث تراوحت الشدة مابين (I – VII) درجة على مقياس ميركالي المعدل. وتم تحليل ميكانيكية 16 هزة أرضية في منطقة الدراسة وتبين بأن الحلول أعطت ميكانيكية صدوع مضربية معكوسة مع صدوع اعتيادية بامتداد مستويات ذات اتجاه شمال غرب – جنوب شرق وهذا ما يتفق مع الوضع التكتوني والزلزالي في المنطقة.

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INTRODUCTION

Sherwana Castle, also written Sherwana Castle, lies about 3.25 Km to the southeast of Kalar, which is approximately 126 Km south of Sulaimaniyah Governorate. It was built in the era before Islam and lies on both banks of the Sirwan (Diyala) river which, forms the eastern boundary of the district, with major mountain ranges in the western part of the district, while the southern part is generally semi-flat (Al-Manmi, 2007) (Fig.1).

According to several historical sources and views, the castle was built by Muhammad Pasha Queijsro bag jaff (1866 – 1874 AD). It consisted of a basement and two floors in addition to octagonal room, located at the top. This castle was built on two hills; the first is an old hill and, according to the excavations, the castle belongs to several historical stages of the Islamic era (the Abbasid and Umayyad) in addition to Sasanian and Alkashih civilization. At the same time, a group of archaeological features and volcanic rocks are found which are likely to belong to the Middle Stone Age. The second hill is dated to the same period. Built on such elevated ground (about 12.3 m) the castle is given a wonderful fascinating sight. It also is decorated by set of inscriptions and decorations surrounded by magnificent towers. The castle is polygonal in shape. Its interior consists of a set of rooms with the main ones and hearth were geometrically structured (Khanam, 2005).

Fig.1: Location map of the studied area (from Google 2015)

- **Geological Setting**

The geology of Kalar district, based mainly on Jassim and Goff (2006), consists of: Jeribe Formation (Lower Miocene), composed of limestone and dolomite; Fatha Formation (Middle Miocene), composed of alternations of thick gypsum beds and limestone, with few thin beds of green marl and red claystone; Injana Formation (Upper Miocene), characterized by alternations of sandstone and claystone with siltstones; Mukdadiya Formation (uppermost Miocene – Pliocene), composed of alternation of pebbly sandstone and light brown claystone,

in fining upward cycles, and Bai Hassan Formation (Pliocene) largely composed of coarse and thick fluviatile and estuarine conglomerates. These formations are usually unconformably covered by recent deposits (Fig.2).

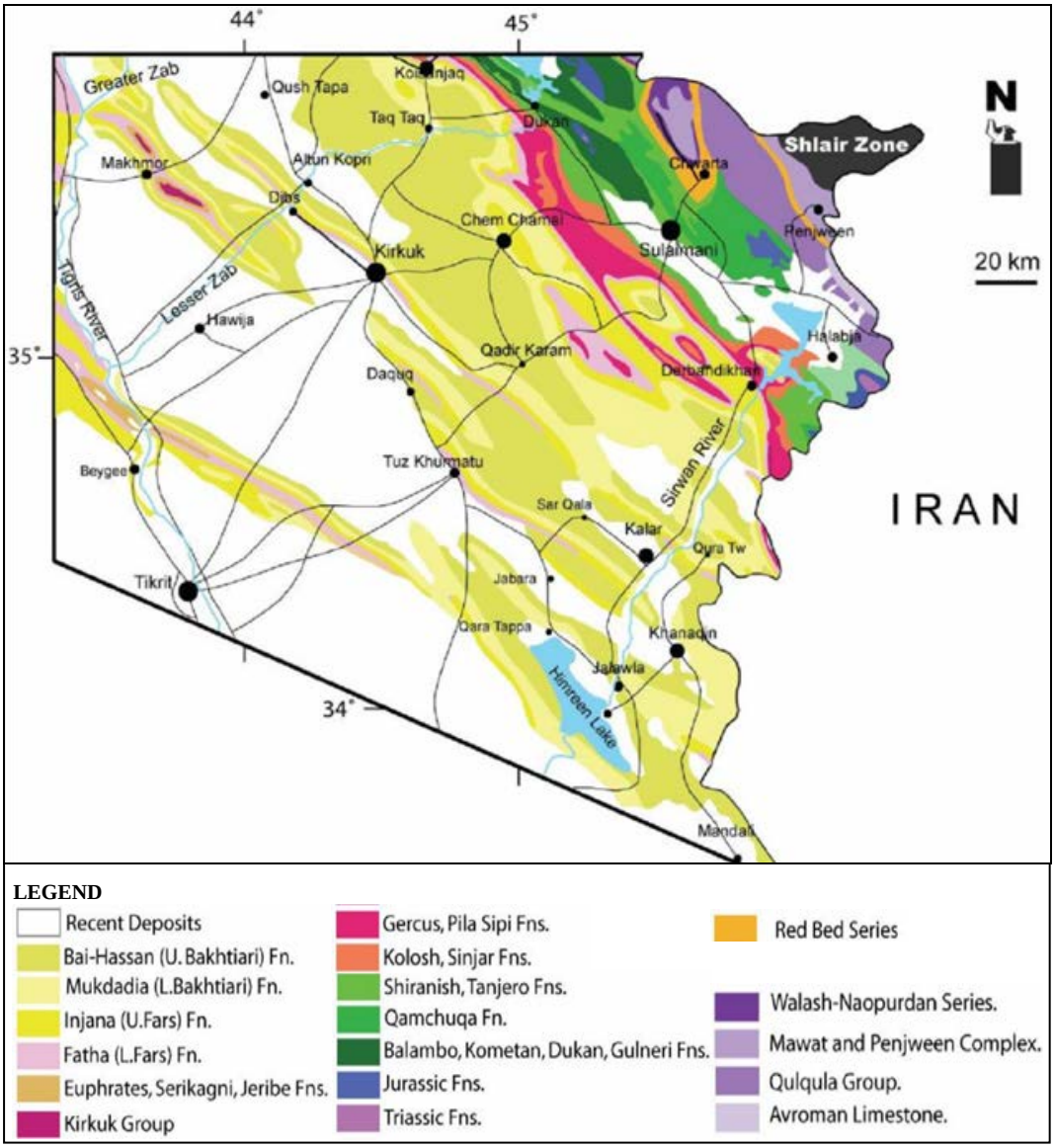

Fig.2: A geological map of the study area (Ibrahim, 2009, after GEOSURV)

– Structure and Tectonics: Tectonics and geology of Iraq have been influenced by the collision of Arabia Plate with southern Eurasia Plate (Berberian and King, 1981 and Adams and Barazangi, 1984). The studied area is located in the northeastern part of the Arabian Plate. It is considered as a part of the Zagros Fold-Thrust Belt (Fouad, 2012, Fig.3). According to Ditmar's tectonic subdivision (Ditmar *et al*., 1979), the study area lies within the Low Folded Zone. Most of the folds are buckle folds such as Hatra – Bekhme fault, Fatha – Houran fault and Diyala faults. The zone includes Hemreen – Makhul subzone that is structurally the deepest part of the Low Folded Zone. It is the depocentre of the Neogene molass, but it has been a subsiding unit during the Mesozoic and Tertiary (Jassim and Goff, 2006).

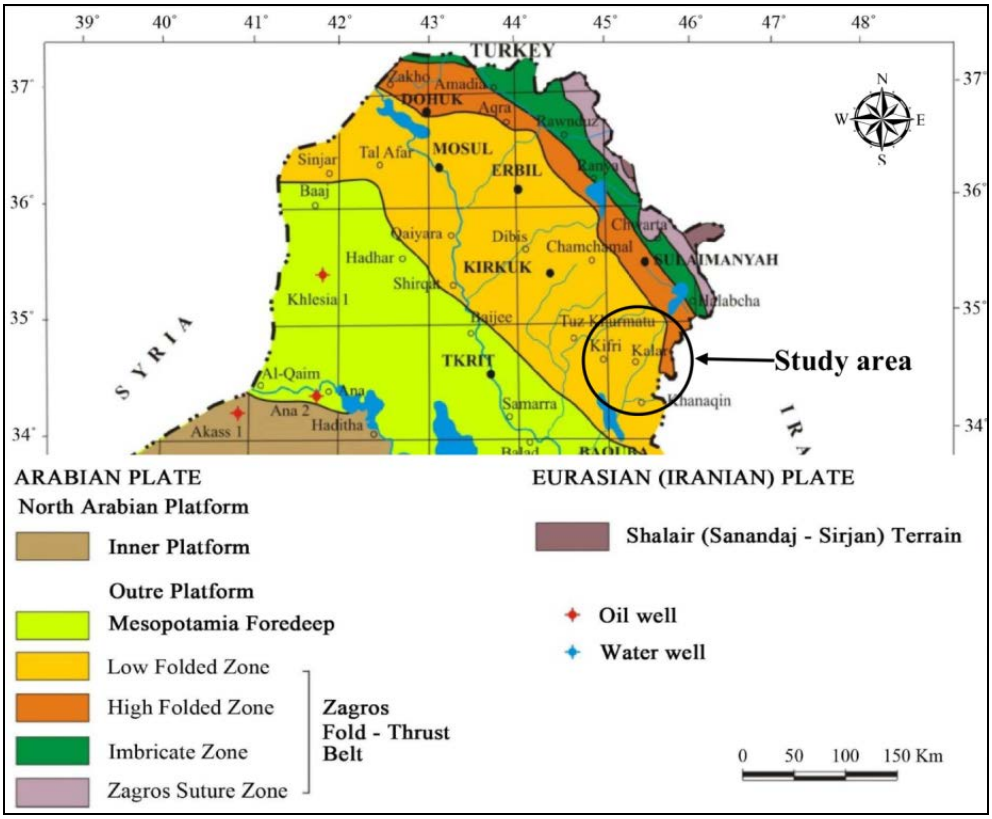

Fig.3: Location of the study area relative to the tectonic zones (Fouad, 2012)

SEISMOTECTONICS OF IRAQ

Iraq experiences an appreciable level of earthquake activity since it is tectonically located between the African-Arabian plate and the Alp-Himalayan sub-belt which is one of the seismically active zones of the world. Owing to this unique geographical location, the eastern and northeastern parts of the country are directly influenced by the seismicity of the Alpine-Himalayan orogenic system (Zagros – Tauros range) (Al-Abbasi and Fahmi, 1985).

The areas east of the Tigris River form the seismically active areas, and about 80% of the earthquakes recorded specifically in Iraq have occurred in that area (Al-Sinawi and Al-Qasrani, 2003).

The area is characterized by high mountain range and shallow somewhat diffused seismicity; it is one of the most seismically active continental regions of the world with well-documented history of earthquakes. The majority of the earthquakes, however, occur in the continental crust of the Arabian Plate beneath the Zagros Fold-Thrust Belt. Most of the epicenters are concentrated along the Zagros – Taurus folded belt. However there is also seismic activity situated along the Sinjar – Herki, Hadhar – Bukhme, Anah – Qalat Dizeh and Sirwan transversal fault. The transversal faults were active during the Pliocene folding; they are still active at the present. The Hemreen and Makhul anticlines have visibly deformed features along the Anah – Qala Dizeh sinisteral slip at Fatha area (Fig.4).

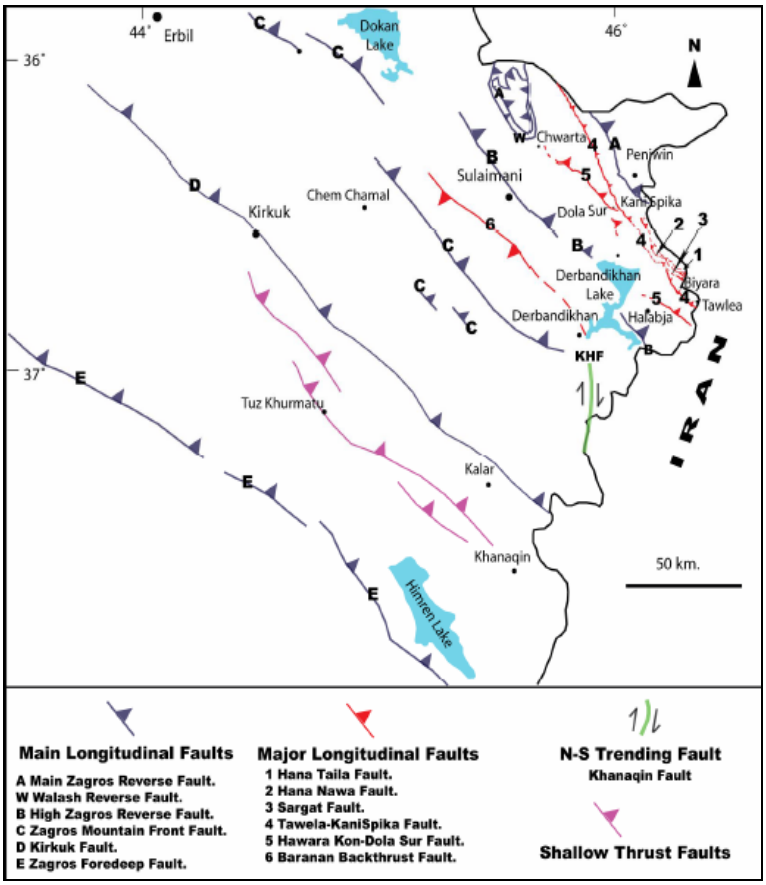

Fig.4: A structural map of the study area (Ibrahim, 2009)

- **Historical Seismicity**

Iraq has a long well documented history of seismic activity. Many seismic events have been documented for the period from 1260 BC through to 1900 AD. These historical events define a well established pattern of seismic activity, which correlates well with the geological and tectonic setting of the country and agree with the modern epicenter determination after 1900 AD (Jassim and Goff, 2006). Historical earthquakes mean all earthquakes that occurred before 1900 A.M. (Alridha and Jasem, 2013). Table (1) shows the historical earthquakes within a circular area of radius 50 Km around the Castle of Sherwana area. It is noted that three earthquakes have intensities range from (VII – VIII) with magnitude range of (5 – 7) degree, while their depths lie between 8 to 30 Km (Al-Dabbagh, 1999).

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

No	Date		Locality	Coordinates		Mag (Richter scale)	Depth (Km)	Approx Intensity
	A.H	*A.D*		*N*	*E*			
1	347	–	Baghdad – Hulwan	34	45	5	8	VII – VIII
2	11 Shawwal 529	–	Zagros – Mosul – Baghdad	34	45.5	5.3	5	VII
3	–	12 Apr 1867	Mendili – Jalawla – Baghdad	34	45.2	7	30	VIII

- **Recent Seismicity**

This refers to all earthquakes which occurred after 1900 A.D (Alridha and Jasem, 2013). Regarding the studied area, (412) earthquakes were detected and recorded by ISN (Iraqi Seismic Network) within a circular area of radius of 50 Km for the period 1970 – 2014 with magnitude range of (1.2 – 5.6) degree, Fig.5. Most of these events range between (2.0 – 2.9) degree, as shown in Figure (6). Most of these earthquakes struck eastern Khanaqin city and the Iraq – Iran border in 2013 as shown in Figure (7). Parts of the epicenters of the earthquakes are located along the NW – SE structures of the study area. The map of Figure 5 may summarize the emerging relation between the distribution pattern of epicenters to the structures and tectonics of the area.

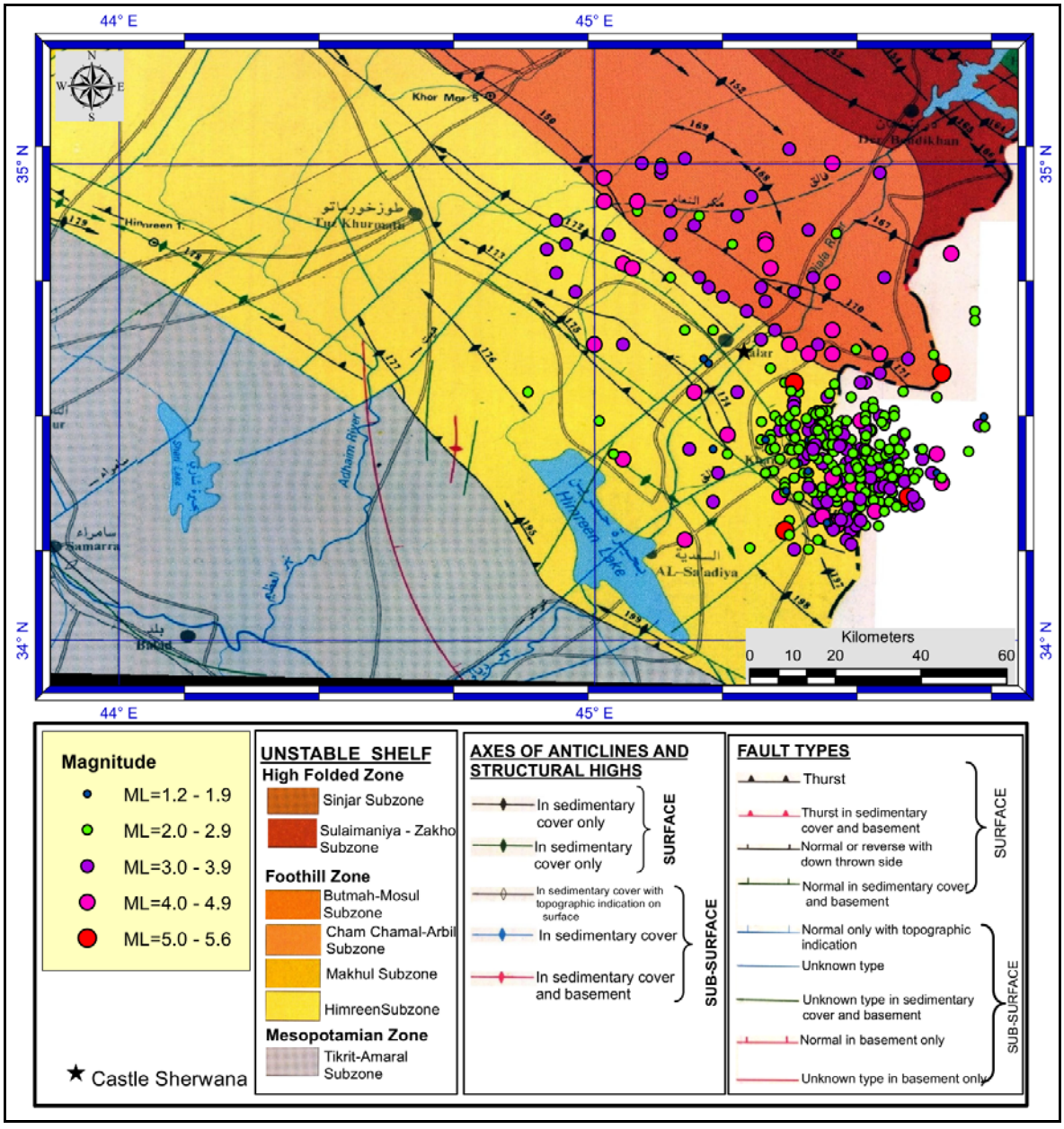

Fig.5: Seismotectonics of study area

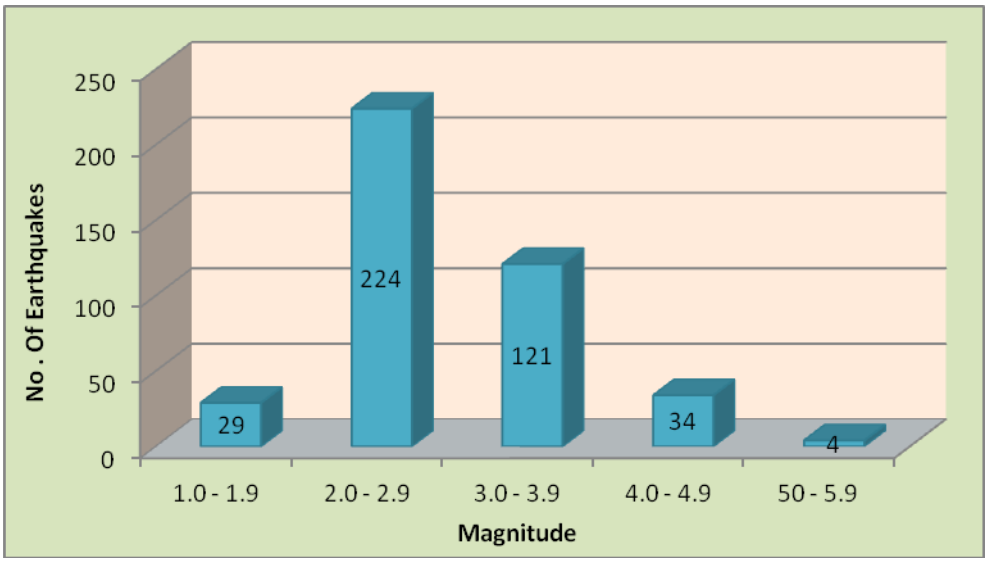

Fig.6: Number of earthquakes with their magnitudes in the study area

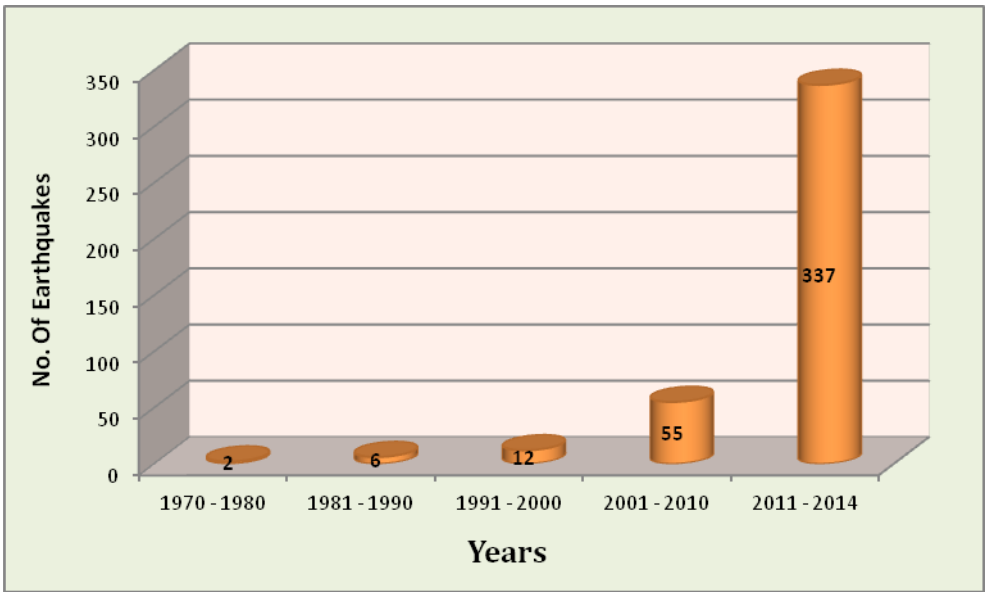

Fig.7: Number of earthquakes within a circular area with radius of 50 Km for the period 1970 – 2014 in the study area

- **Earthquake Intensity**

The intensity of an earthquake is based on the damage to structures, damage to the ground surface, and observed effects on people and other features (Richter, 1958). The Modified Mercalli Intensity Scale is a measure of the amount of shaking (and damage) at a particular site. The intensity of an earthquake will vary depending on the distance of site relative to the epicenter (Wald *et al.*, 1999). Earthquakes cause severe damage to archaeological and historical buildings such as dislocation and cracking and sometimes collapse and other hazards that commensurate with the seismic intensity and duration (Stiros, 1988).

On Friday, the 22 November 2013 at 6:51:25 UTC (Fig.8), an earthquake occurred at a distance of 15 Km to the southeast of Kalar and 12.25 Km from Sherwana Castle. The earthquake was of magnitude 5.6 degrees on the Richter scale. This earthquake is part of a swarm of earthquakes that struck Khanaqin area and the Iraq – Iran border for the first time in the known recorded historical seismicity of the area. More than (270) quakes were recorded by the Iraqi Seismic Network (ISN) including eleven events felt by the people living in the provinces of Diyala, Kirkuk, Sulaimaniyah , Baghdad, Kut, Babylon and Diwaniyah. The effect of the earthquake, which took place on the 22nd of November, 2013, was very clear in the castle of Sherwana and the surrounding areas; including cracks of houses, buildings and the walls of the second floor of the castle. The domes of the old, local market were also damaged. The severity of damage depends on the location relative to the epicenter, age of the affected houses and buildings and the type of the construction materials. Figures (9) are different examples from the affected Sherwana castle. Isointensity map is constructed and shown in Figure (10). It shows the intensity ranges between (I – VIII) according to the Mercalli scale.

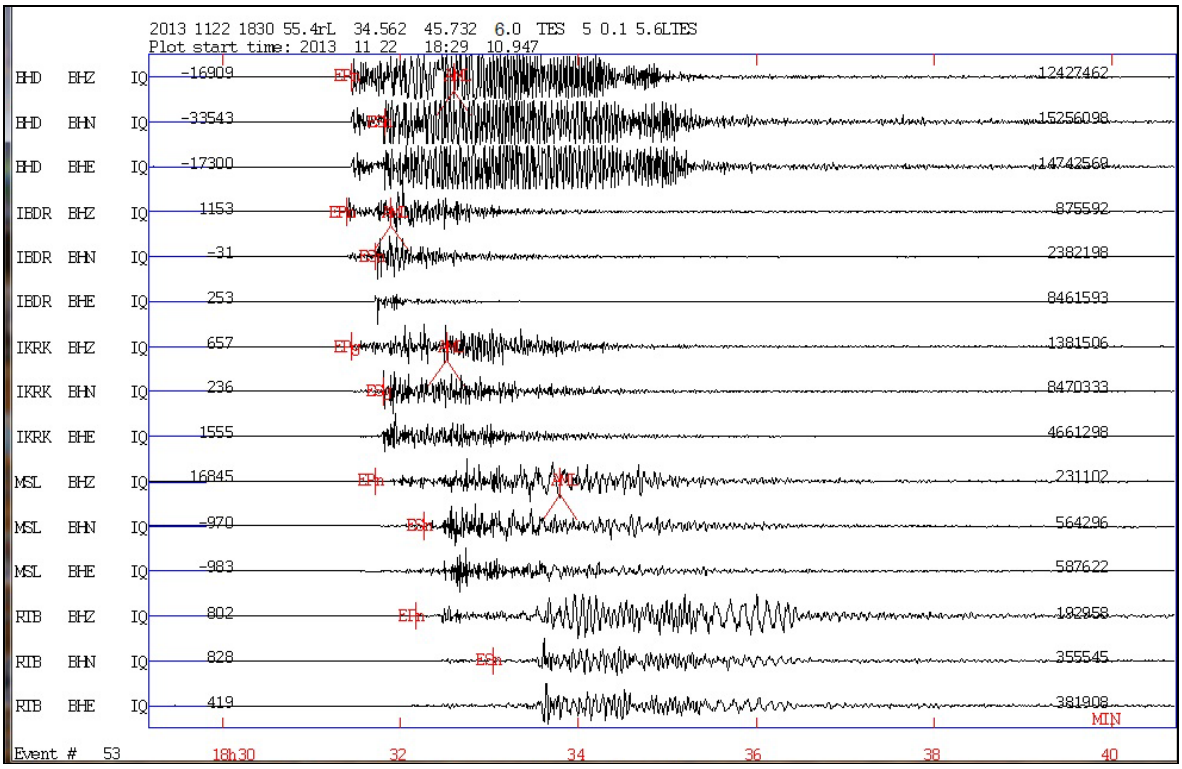

Fig.8: Seismogram records of the major event (ML= 5.6) using broadband stations from Iraqi Seismic Network (Baghdad [BHD], Badra [IBDR], Kirkuk [IKRK], Mosul [MSL], Rutba [RTB] stations), and reviewed by Seisan software in raw data form. Text in the first line on the top contains information about the seismic event that the trace belongs to. Date of the seismic event is 22/ 11/ 2013; origin time is 06: 51: 25; coordinates are 34.540 as latitude and 45.425 as longitude, the depth is 6 Km. This event is one of the 412 events of the dataset of the present study. The components are Z, N, E of 10 samples per second (BHZ, BHN, BHE)

Fig.9: Cracks in a roof, a wall, and the fallen plaster pieces in the second floor in Sherwana castle

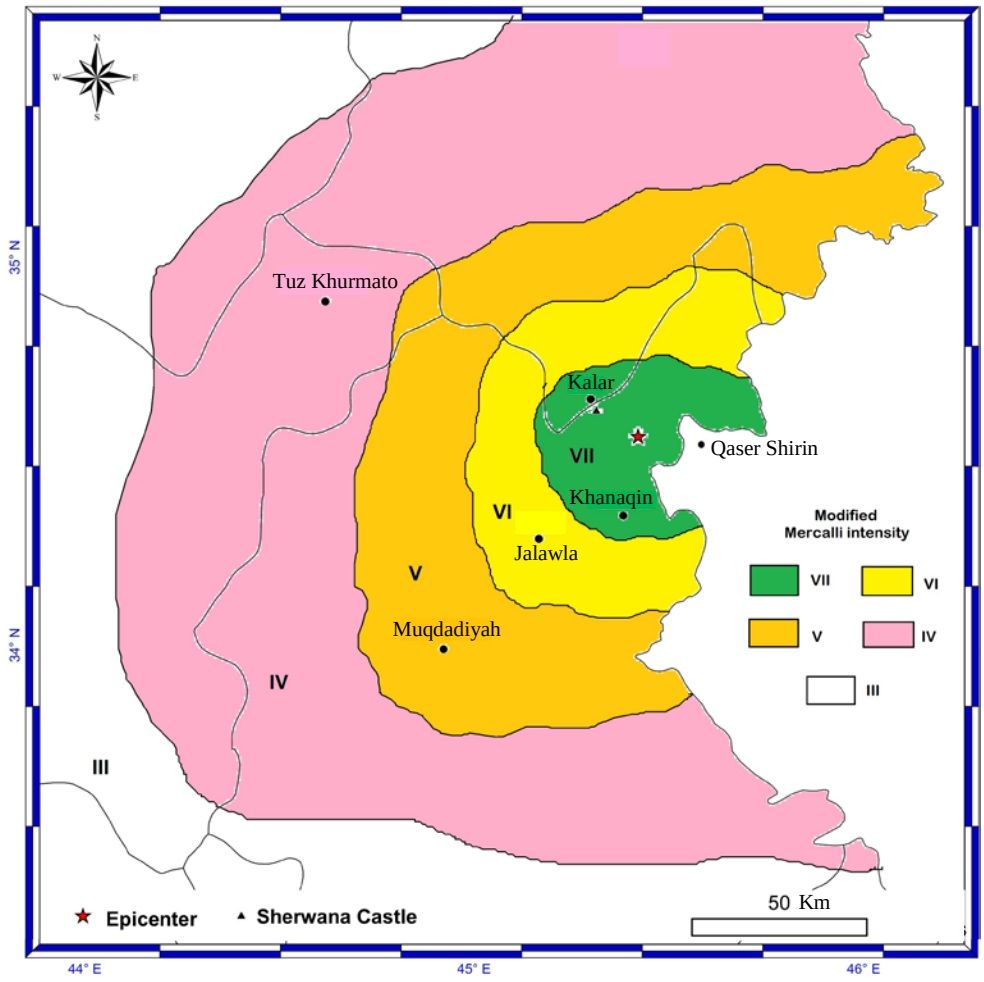

Fig.10: Isointensity map of the study area

- **Earthquake Focal Mechanism**

The focal mechanism or the fault plane solution can provide useful information of structure and kinematics of faults and can constrain the crustal stress field in which the earthquakes occur (Vamvakaris *et al*., 2004). The focal mechanism indicates the orientation of the fault and the slip on the fault relative to a geographical coordinate system. The focal mechanism is the most important parameter to be determined once the location and magnitude are known and it is used to determine the actual geometry of the faults as well as inferring the stress regimes of a particular region. All methods of determining fault plane solutions are based on the radiation pattern that the seismic earthquake source sends out (Havskov and Ottemoller, 2010).

Focal mechanism solution of 16 earthquakes with magnitudes range from 4.0 to 5.6 within the present area were analyzed using Seisan computer software. The output of each focal mechanism solution includes the strike orientation, dip angle, and rake angle for the two plane solutions, which are the fault plane and auxiliary plane. Table 2 shows results of lists of the fault plane solutions of the 16 events and Figure 11 shows map of the focal mechanism solutions based on Table 2. The results show thrust faulting with strike-slip component to be the most common style of faulting in the study area along planes of SE – NW trend due to the anticlockwise rotation of the Arabian Plate, while those that show a different solution with some normal faulting are located in limited areas.

Table 2: Results of earthquake focal mechanism using broadband stations from (ISN)

Date	**Origen. Time (UTC)**	**Lat *N***	**Long *E***	**Depth km**	**Mag (Richter scale)**	**Fault .Plane In degrees**			**Auxiliary .Plane In degree**		
						Strike	***Dip***	***Rake***	***Strike***	***Dip***	***Rake***
2011/04/06	19:17:10	34:32	45.53	05	4.4	190	12	– 60	340	80	– 96
2011/04/07	05:15:57	34:92	45.02	05	4.1	171	18	– 94	355	72	– 89
2011/04/08	04:27:38	34.97	45.02	10	4.3	178	17	– 77	344	73	– 94
2013/11/05	04:03:39	34.92	45.09	09	4.1	146	62	59	81	41	134
2013/11/22	06:51:25	34.54	45.42	10	5.6	155	69	105	298	25	56
2013/11/22	10:09:59	34.46	45.56	12	4.0	158	66	93	331	24	83
2013/11/22	18:30:55	34.56	45.73	11	5.6	141	55	87	326	35	94
2013/11/22	18:44:03	34.24	45.51	09	4.2	166	57	93	339	33	84
2013/11/22	19:24:02	34.32	45.54	12	4.1	128	71	101	277	22	61
2013/11/22	21:02:31	34.24	45.50	13	4.4	140	64	83	336	27	104
2013/11/23	06:52:04	34.34	45.61	16	4.1	151	62	103	305	31	67
2013/11/23	23:26:23	34.23	45.40	10	5.1	170	66	99	328	26	71
2013/11/24	18:03:12	34.26	45.48	09	4.6	138	63	33	32	61	149
2013/11/24	18:05:42	34.30	45.66	14	5.5	139	58	51	16	49	135
2013/11/25	02:01:56	34.34	45.50	12	4.2	143	67	105	289	27	59
2013/11/25	03:23:04	34.27	45.59	10	4.2	134	55	89	316	35	91

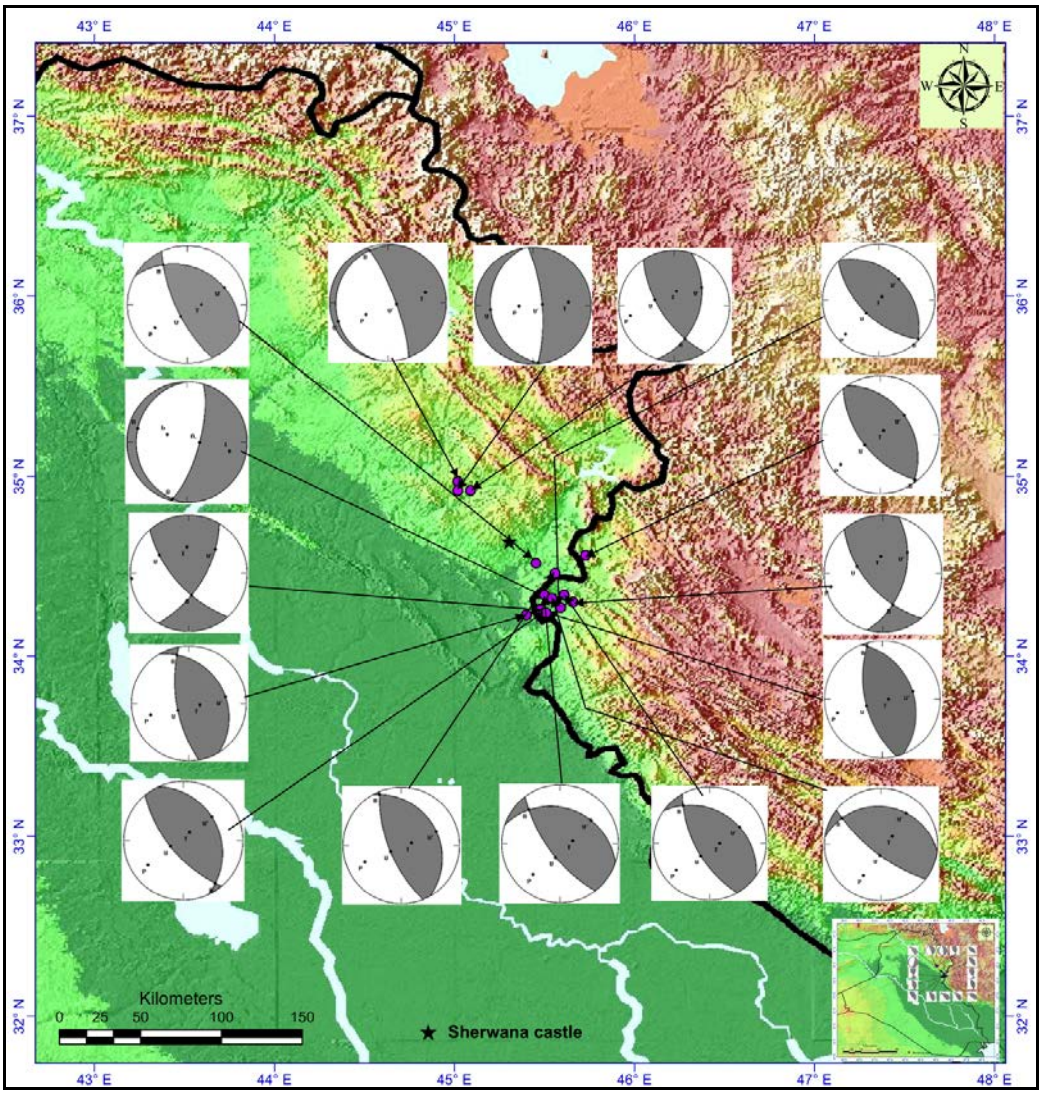

Fig.11: Focal mechanism solutions for 16 earthquakes in the study area shown in a lower hemisphere equal-area projection based on Table 2

CONCLUSIONS

- The epicenter of the earthquake is located about at 12.25 Km southeast of Sherwana castle.
- Three historical earthquakes are recorded in the study area.
- (412) events occurred within a circular area of radius 50 Km around Sherwana castle for the period 1970 – 2014 with magnitude range of (1.2 – 5.6) degree and most of the events range between (2.0 – 2.9) degree.
- The effect of the earthquake in the Sherwana castle includes some cracks in the wall of the second floor of the castle, beside the damage of the domes of local old market.
- Isointensity map shows the intensity ranging between (I – VIII) according to the Mercalli scale.
- Seismotectonic map for the studied area shows the distribution pattern of epicenters relative to the structure and tectonic of the area.
- Fault plane solutions of 16 events in the area indicate thrust with some strike slip and normal faulting along planes with NW – SE direction.

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