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Seismicity of Iraqi western desert and surroundings: As an example of continental intraplate seismicity

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Abstract. Seismicity of Iraqi western desert and surroundings was investigated using a complete and unified magnitude earthquake catalog covering the interval from 1900 to 2017. A marked rise in number of the events in the study area was observed after the year 2000 compared to the previous years. The magnitude of majority of the recorded events ranged from 2 to 3.5 Mw. The value of b-constant in frequency-magnitude relation is 0.7. The epicentral distribution shows that the western desert is aseismic to very low seismicity area compared to the surrounding regions. The epicenters were clustered in five seismogenic zones. The focal depths division of the events exhibits that majority of the earthquakes occur in the upper crust. A causal relation may be between the study area seismicity and the zones of weakness and /or stress condensation at the fault intersections.

Keywords: intraplate, seismicity, magnitude, Iraqi western desert

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1. Introduction

The earthquakes occur at the tectonic plate boundary are defined as interplate earthquakes, while earthquakes take place in a tectonic plate interior are known intraplate earthquakes [1]. Seismologists distinguish between intraplate earthquake occur along faults within mobile zones and faults run inside stabilized areas. The movable zones are zones that have experienced provincial distortion over a wide region adjacent to a boundary of plate, whereas the stabilized zones are adequately distant from the boundary of the plate and also stabilized in the sensation that they have not been influenced by significant tectonic events during the Cenozoic Era. [2]. Intraplate seismicity characterized by complexity of the spatio-temporal distribution compared to interplate seismicity [3], long recurrence periods and absence of associated surface rupturing [4], depth shallower than 15km and low b- value [5]. The driving forces of intraplate earthquakes are not well understood. Different models were proposed by authors to explain the origin of intraplate earthquakes such as, reactivation of preexisting weakness zones [5], stress concentration and flexural stress [6]. Microseismicity of western desert in Iraq were investigated by Al-Heety [7] and Alsinawi and Al-Heety [8]. Intraplate seismicity of Iraqi western desert was studied by Al-Heety [9]. The objective of the current work is to study the western desert and surroundings seismicity as an example of continental seismicity.

2. Material and methodology

2.1. Earthquakes catalog

The earthquake catalog of the study area was evolved from the International Seismological Center (ISC) Bulletin (http// www.isc.ac.uk/gtevents/search/catalogue).

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The obtained catalog covers the interval from Jan.1900 to Dec.2017. Since the ISC bulletin includes different authors for earthquake data, event that is repeated more than once is necessary to eliminate. In ISC bulletin, earthquakes are stated in different magnitude scales, the body–wave magnitude scale mb, local magnitude M_L, and duration magnitudes, M_D. The critical stage to investigate seismicity of any region, is compiling a unified magnitude and complete catalog.

2.2 Unified magnitude

The moment magnitude (Mw) was selected as the unified magnitude scale for seismicity and assessment of seismic hazard because it more correctly characterizes the earthquake source size [10]. The earthquake catalog of the study area was unified and homogenized with respect to M_w. Different empirical equations between Mw and the other scales of magnitude (mb, ML, and MD) were reported by various investigators. We selected the following relations proposed by Allmann et al. [11] to convert ML into Mw:

$$M_w = 0.594\, M_L + 0.985 \qquad (M_L < 2) \tag{1}$$

$$M_w = 1.327 + 0.253\, M_L + 0.085\, M_L^{\;2} \qquad (2 < M_L < 4) \tag{2}$$

$$M_w = M_L - 0.3 \qquad (M_L > 4) \tag{3}$$

To convert m_b and M_d to M_w, we used the two following empirical relations introduced by Kadirioglu and Kartal [12]:

$$M_w = 1.032\, m_b + 0.0223 \tag{4}$$

$$M_w = 0.794\, M_d + 1.342 \tag{5}$$

2.3. Catalogue completeness

2.3.1. Completeness magnitude

The magnitude above which it is regarded fully recorded is defined as catalogue completeness [10]. The smallest magnitude at which 100 percent of occurrences in a space–time volume may be identified is called the magnitude of completeness (Mc). [13]. In this study, Mc was determined using Wiemer and Wyss's "maximum curvature" approach [14]. When the data's negative b value trend stabilizes to resemble a straight line, a catalogue will be regarded complete in terms of events with M > Mc [15]. The Mc value for the study area is Mw 2.1 as shown in Figure 1.

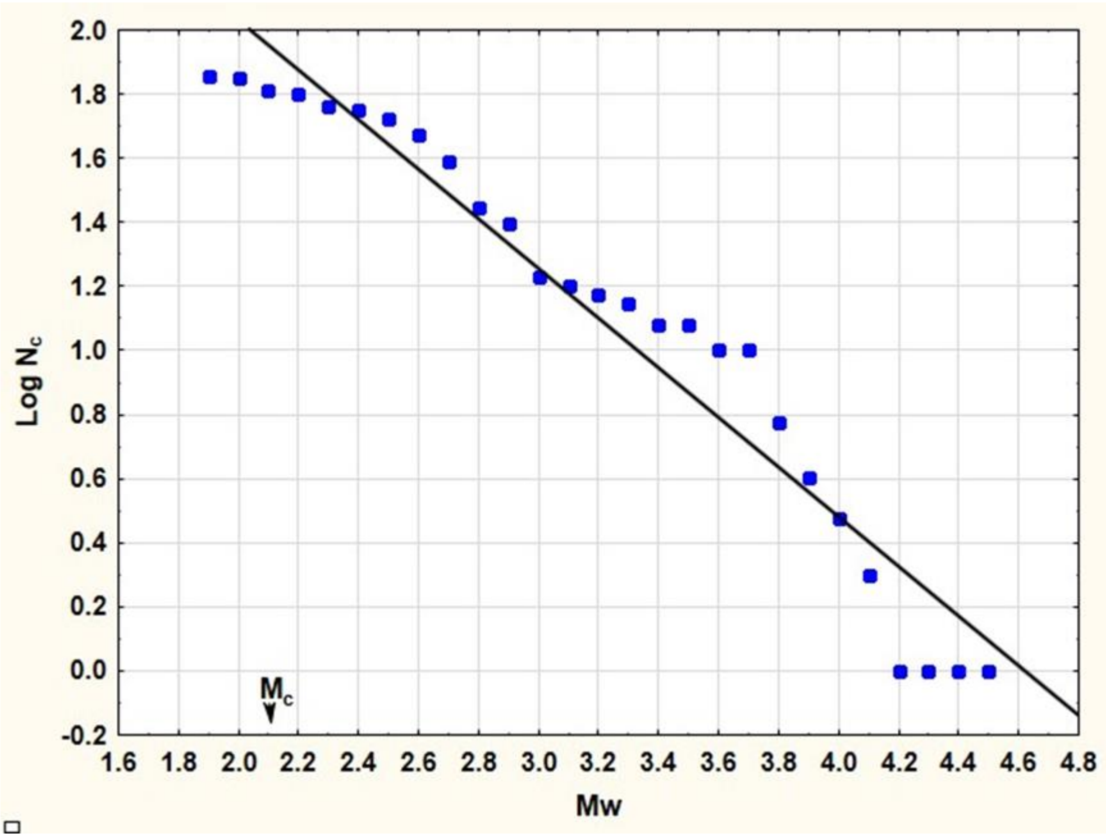

Figure 1: Completeness magnitude M_c of earthquake catalogue of the study area.

2.3.2. Catalogue completeness time

The earthquake catalogue's data completeness levels are established by analyzing cumulative number of occurrences against time graphs assuming that the most recent change in slope occurred when the data for magnitudes was collected bigger than the magnitude of the reference became complete [16].The cumulative number of earthquakes versus the time for the study area is shown in Figure 2. The beginning of change in slope of the total number of earthquakes versus the passage of time occurs at 2000. The earthquake catalog of the study area can be considered complete since 2000 for earthquakes with Mw ≥ 2.1.

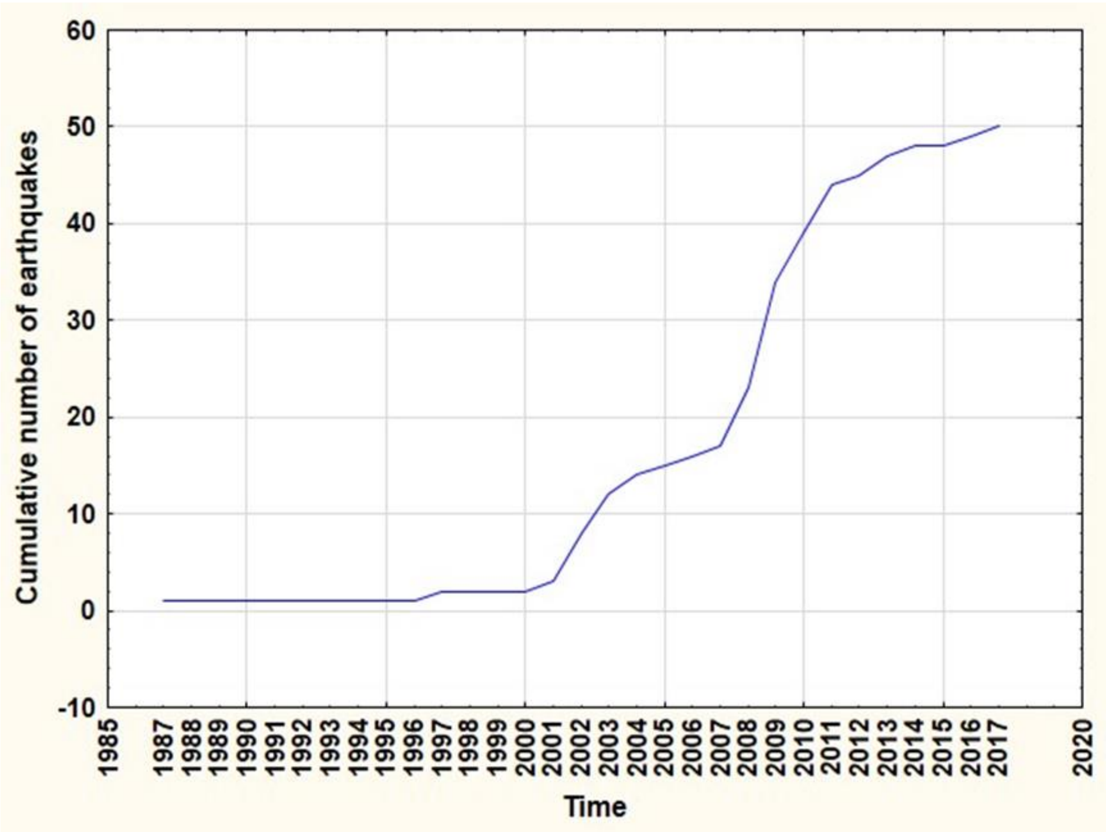

Figure 2: The accumulative number of earthquakes versus time.

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2.4. Seismicity of the study area

2.4.1. Temporal distribution of seismicity

The temporal distribution of the earthquakes that struck the research area is shown in Figure 3. The figure shows a remarkable increase in number of the earthquakes that happend in the study area after the year 2000 compared to the previous years.

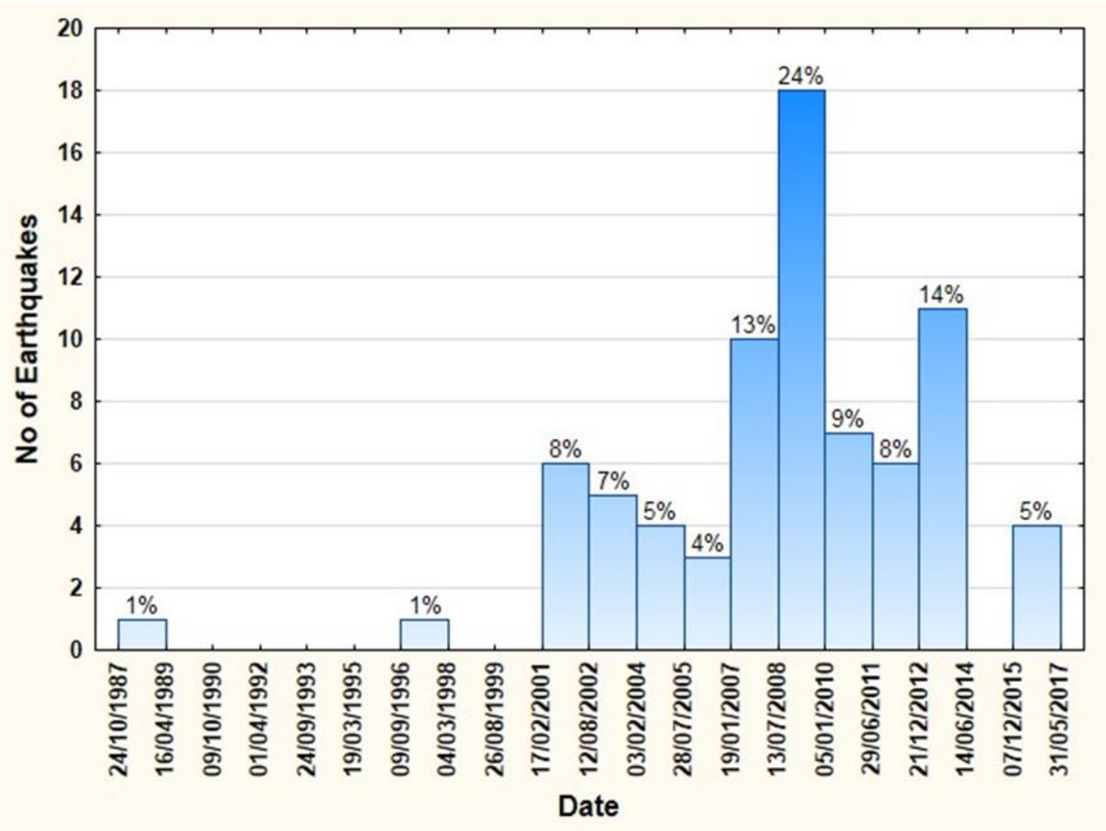

Figure 3: distribution of the earthquakes with time in the study area.

2.4.2. Magnitude distribution of the earthquakes

The earthquakes number as function of magnitude in the study area is shown in Figure 4. It shows that the high percent of earthquakes ranges in size from 2.5 to 3.0 Mw and the majority of earthquakes ranges in size from 2 to 3.5 Mw.

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2.4.3. Frequency – magnitude relationship

The Gutenberg- Richter equation [17] expresses the relationship between earthquake frequency and magnitude as follows:

$$LogNc = a - bM \tag{6}$$

Where *Nc* denotes the total number of earthquakes of magnitude M. The constants for the area are a and b.The *a* - constant indicates the seismic activity level of the

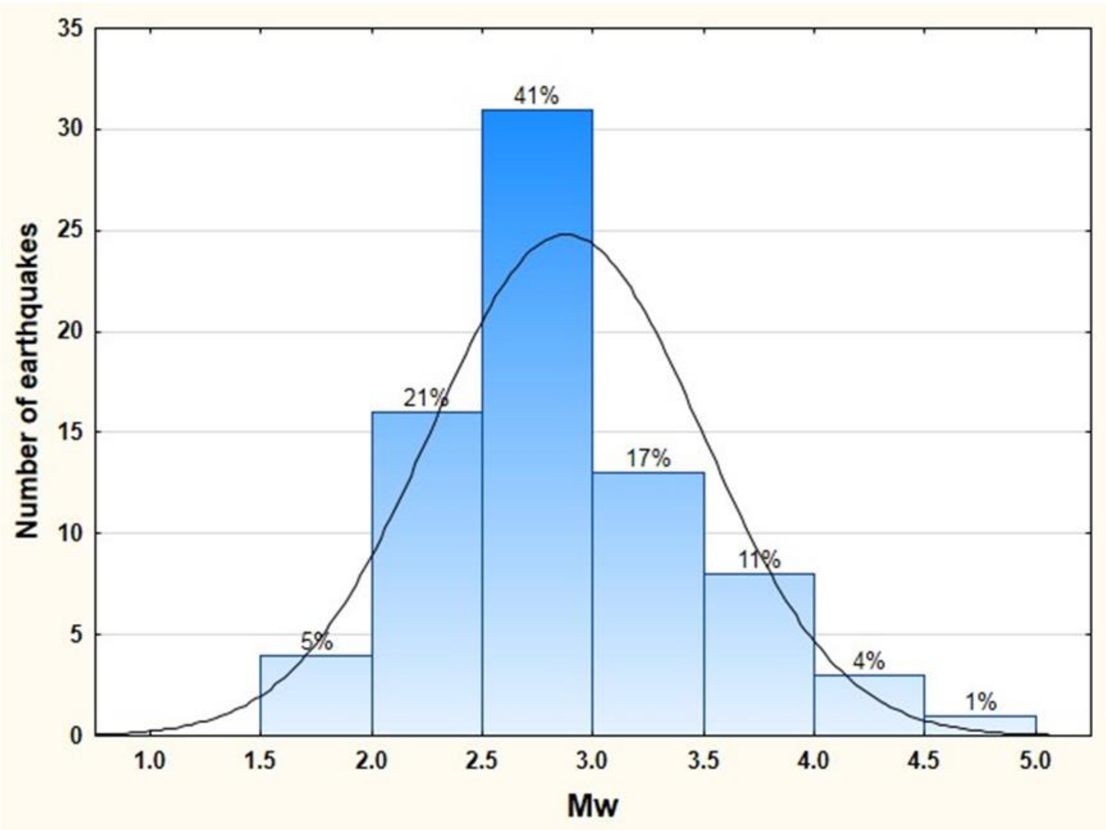

Figure 4: The number of earthquakes as function of magnitude.

area. The *b*-constant is a tectonic factor that describes the stress state in the area. The study area's a and b constants were computed using the least square fitting method. The *a* and *b* constants values are 3.43 and 0.7, respectively.

2.5. Spatial distribution of earthquakes

2.5.1. Distribution of earthquake epicenters

The spatial distribution of events epicenters (M ≥ 2.1) occurred in the studied area for the period from Jan.1900 to Dec.2017 is illustrated in Figure 5. The epicenters distribution map shows that the western desert is aseismic to very low seismicity area compared to the surrounding regions. The map also shows linear and areal distribution patterns of earthquake epicenters in the study area.

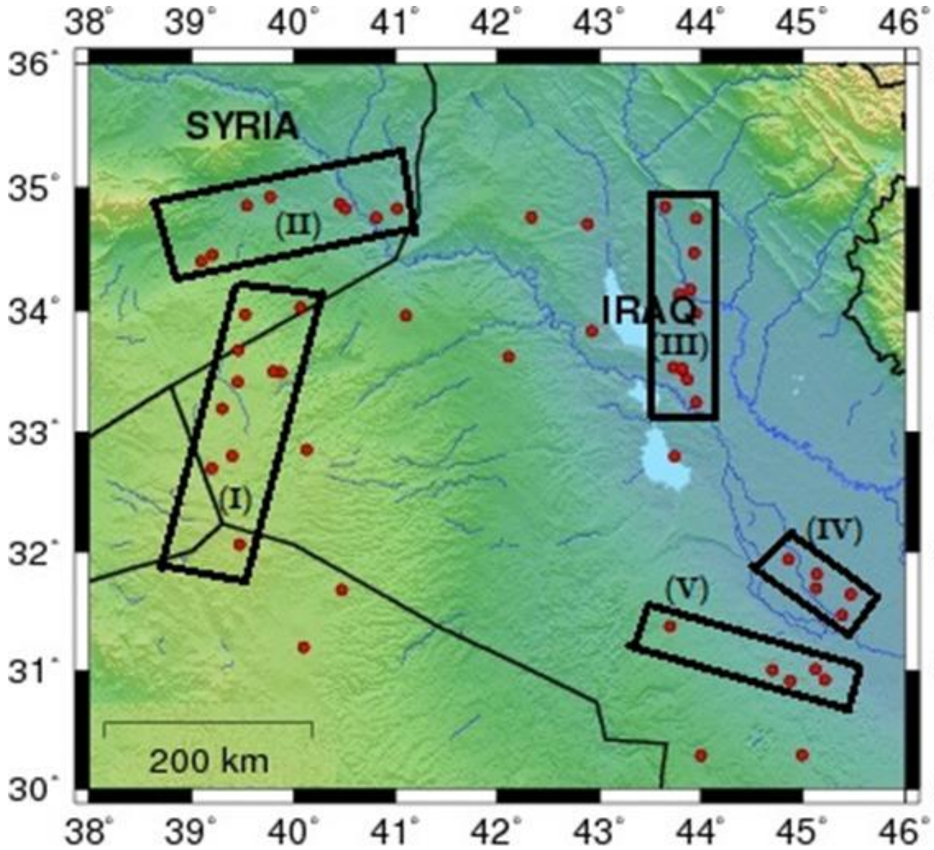

Figure 5: The epicenters distribution map of earthquakes in the western desert and surroundings.

2.5.2. Distribution of earthquake hypocenters

The hypocenters distribution of earthquakes (M ≥ 2.1) took place in the studied area for the period from Jan.1900 to Dec.2017 is shown in Figure 6. Majority of earthquakes occur in the upper crust, according to the focal depth distribution of earthquakes. There is a clustering of earthquakes at a focal depth of 33km and this may not reflect the true distribution pattern.

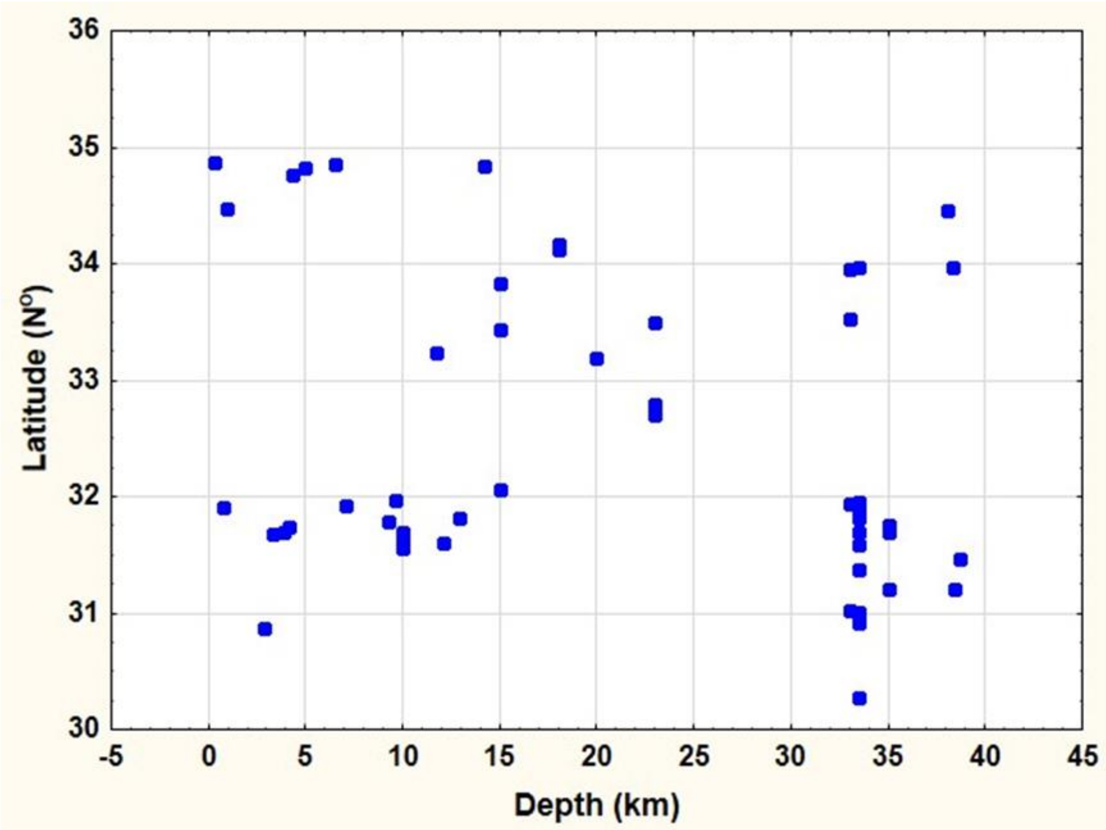

Figure 6: The hypocenters distribution map of earthquakes in the western desert and surroundings.

3. Discussion

3.1. Temporal and spatial distribution of earthquakes

The temporal distribution of earthquakes in the study area showed an aseismic period before 2000 with two low seismic activity periods, between 1987-1989, and 1996-1998, and increase in number of earthquakes was recorded after 2000. This result can be attributed to the expansion of seismic monitoring stations in the studied area and surroundings in recent years and/or to an increasing in seismic activity. Intraplate earthquakes often occur in temporal clusters on faults that have been active for a long time before becoming quiet while other faults are active, according to paleoseismic data [3, 18, 19]. The locative distribution patterns of continental intraplate earthquakes in the study area show clustering of earthquakes in five linear seismic zones and scattering outside of these seismic zones, Figure 5. The spatial patterns of historical and instrumentally recorded in intraplate environments around the world show Scattering activity and spatial clustering in seismic zones over large regions [3].

3.2. Magnitude distribution and frequency-magnitude relationship

Figure 4 shows that the high percent of earthquakes have magnitudes between 2.5 and 3.0 Mw and the majority of earthquakes have magnitudes between 2 and 3.5 Mw. This result indicates that the earthquakes occurred in study area have low magnitude. The obtained b-constant value equals to 0.7. In previous study, Al-Heety [9] found that the b-constant value in the western desert in Iraq was 0.54. The intraplate regions characterize by low b-constant value [5]. Intraplate earthquake frequency magnitude-distribution differs from interplate earthquake frequency - magnitude distribution. [20]. Intraplate environments may or may not have b- constant values that are considerably lower than 1 [21]. In the active intraplate fault system at Koyna-Warna, Western India, the b-constant values range from 0.74-0.93 [22].

3.3. Hypocenters distribution

The hypocentral distribution of the earthquakes occurred in the studied area during the observing period is shown in Figure 6. It demonstrates that the bulk of earthquakes happen in the upper crust. The clustering of earthquakes at a focal depth of 33km and this does not reflect the reality of distribution pattern because" the depth of 33km is typically reported in hypocentral catalogs, like from NEIS or ISC, when the depth is not well constrained by the phase data. Basically, 33 km means that the earthquake is assumed to be shallow in many earthquakes areas. But the values are not determined directly from the data" (Göran Ekström, personal communication). In continental locations, the majority of intraplate earthquakes occur in the upper crust. [5, 9, 23].

3.4. Genesis of intraplate continental seismicity

Elucidation the origin of intraplate continental seismicity is a great challenge several controversial mechanisms have been presented to explain why continental seismicity occurs. These mechanisms were classified into two types: the mechanisms that include zones of weakness, and the other mechanisms that include stress concentration [24]. The weakness zones include the crustal rift and failed rift zones that are caused by last major orogenic processes [25]. The mechanism of weakness zones is widely accepted to explain why intraplate continental seismicity occurs. Cases of the locative association between intraplate continental earthquakes and faults flexures have observed [4, 26]. Intraplate continental earthquakes are frequently caused by both mechanisms .The obtained result shows five linear seismogenic zones, Figure 3. These linear seismic zones may be associated with weak zones reactivated by the stresses resulting by a movement of the Arabian plate and its collision with the Eurasian plate. A preferable grasp of the seismic sources of the study area requires information related to stress distribution and micro-earthquakes monitoring that provide an opportunity to assess the composite focal mechanism that determines the zone of weakness over which the earthquakes occur.

4. Conclusions

The temporal distribution of earthquakes showed increase in their number after the year 2000. The spatial distribution of earthquakes exhibited a clustering in five linear seismogenic zones scattering outside these zones. The obtained b-constant value is 0.7. This value is consistent with the intraplate regions. Majority of earthquakes occurred in the upper crust. A causal relation may be between the study area's seismicity and the weakness zones and /or stress concentration at the fault intersections.

References

[1] Shimazaki K 1976. Intra-plate seismicity and inter-plate earthquakes: historical activity in Southwest Japan. *Tectonophysics*, **33**: 33-42.

[2] Bodin P 2011. Seismicity, Intraplate. In: Gupta H.K. (eds) Encyclopedia of Solid Earth Geophysics. Encyclopedia of Earth Sciences Series. Springer, Dordrecht. https://doi.org/10.1007/978-90-481-8702-7_162.

[3] Li, Q, Liu M and Stein S 2009. Spatiotemporal complexity of continental intraplate seismicity: insight from geodynamic modeling and implication for seismic hazard estimation. *Bull. Seismol. Soc. Am.*, **99**:52-60.

[4] Gangopadhyay A and Talwani P 2003. Symptomatic features of intraplate earthquakes. *Seis.Res.Lett*., **74**: 863-883.

[5] Talwani P 1989. Characteristic features of intraplate earthquakes and the models proposed to explain them. In: Gregersen , S., Basham, P.W.(Eds.), earthquakes at North- Atlantic Passive Margins: neotectonic and Post-glacial rebound . NATO ASI Ser. C., *Mathematic and Physical Sciences*: 563-579.

[6] Assumpcao M, Schimmel M, Escalante C, Barbosa J , Rocha M and Barros L 2004. Intraplate seismicity in SE Brazil: stress Concentration in lithospheric thin spots. *Geophys. J. Int.*, **159**: 390-399.

[7] Al-Heety E A 1985. Microseismicity of Ga'ara Area,western desert. M.Sc.thesis, University of Baghdad, 145p, unpublished.

[8] Alsinawi S A and Al-Heety E A 1987. Microseismicity of Ga'ara: an example of intraplate seismicity. Proceedings regional crustal stability and geological hazards, December, 1987, Beijin, China : 7-12 .

[9] Al-Heety E A 2010. Intraplate earthquakes in Iraqi Western Desert. *Journal of Kirkuk University – Scientific Studies*, **5**: 31-49.

[10] Al-Heety E A 2014. A complete and homogeneous magnitude earthquake catalogue of Iraq. Arab J Geosci., **7**:4727–4732. DOI 10.1007/s12517-013-1131-y.

[11] Allmann B, Edwards B, Bethmann F and Deichmann N 2011. Determination of MW and calibration of ML (SED) – MW regression. – Appendix A to ECOS-09 Earthquake Catalogue of Switzerland, Report SED/RISK/R/001/20110417.

[12] Kadirioglu F and Kartal R 2016. The new empirical magnitude conversion relations using an improved earthquake catalogue for Turkey and its near vicinity (1900–2012). *Turkish J Earth Sci*., **25**: 300-310. doi:10.3906/yer-1511-7

[13] Woessner J and Wiemer S 2005. Assessing the quality of earthquake catalogs: estimating the magnitude of completeness and its uncertainty. *Bull. Seismol. Soc. Am.* **95**:684–698.

[14] Wiemer S and Wyss M 2002. Mapping spatial variability of the frequency-magnitude distribution of earthquakes. Advances in Geophysics **45** DOI: 10.1016/S0065-2687(02)80007-3

[15] Yadav R, Bormann P, Rastogi B, Das M and Chopra S 2009. A homogeneous and complete earthquake catalog for northeast India and the adjoining region. *Seismool Res Lett* **80**:609–627

[16] Gasperini P and Ferrari G 2000. Deriving numerical estimates from description information: the computation of earthquake parameters, in “catalogue of strong Italian earthquakes from 461 B.C. to 1997”. *Ann Geofis* **43**:729–746.

[17] Gutenberg B and Richter C F 1944. Frequency of earthquakes in California. *Bull. Seismol. Soc. Am.* **34**:185–188.

[18] Crone A J , De Martini P M, Machette M N, Okumura K and Prescott J R 2003. Paleoseismicity of two historically quiescent faults in Australia: implications for fault behavior in stable continental regions. *Bull. Seismol. Soc. Am*. **93** 1913–1934.

[19] Camelbeeck T, Vanneste K , Alexandre P, Verbeeck K , Petermans T , Rosset P, Everaerts M , Warnant R and Van Camp M 2007. Relevance of active faulting and seismicity studies to assess long term earthquake activity in Northwest

Europe, in Continental Intraplate Earthquakes: Science, Hazard, and Policy Issues, S. Stein and S. Mazzotti (Editors), Special Paper 425, Geol. Soc. Am., Boulder, Colorado, 193–224.

[20] Brazitis D and Conder J 2016. Microseismicity of the intraplate Northern Wabash fault system and La Salle Anticlinorium, Illinois Basin, U.S.A. *Seismol. Res. Lett.* **87**: 1479-1486. DOI: 10.1785/0220160119.

[21] Merino M, Stein S, Liu M, and Okal E 2010. Comparison of seismicity rates in the NewMadrid and Wabash Valley seismic zones. *Seismol. Res. Lett*. **81**: 951–954.

[22] Shashidhar D, Mallika K, Mahato C R, Maity B S and Satyanarayana H V 2017. Recent seismicity patterns and microearthquake activity on an active intraplate fault system at Koyna-Warna,Western India. *Journal Geological Society of India* **90**: 798-801.

[23] Cattaneo M, Augliera P, Paroloi S and Spallarossa D 1999. Anomalously deep earthquakes in northwestern Italy. *J Seismolog* **3**:421– 435.

[24] Assumpção M, Ferreira J, Barros L, Bezerra H, frança G, Barbosa J, Menezes E, Ribotta L, Pirchiner M, Do Nascimento A and Dourado A 2014. Intraplate seismicity in Brazil: Intraplate Earthquakes, Pradeep Talwani (ed.) Cambridge University Press.

[25] Schulte S and Mooney W 2005. An updated earthquake catalog for stable continental regions: reassessing the correlation with ancient rifts. *Geophys J Int* **161**:707–721.

[26] Talwani P 2017. On the nature of intraplate earthquakes. Journal of Seismology 21: 47-68. doi:10.1007/s10950-016-9582-8