**Iraqi National Journal of Earth Science**

www.earth.uomosul.edu.iq

# Earthquake Distributions in Sulaimaniyah, North of Iraq

**Suad Mohammed Ali** [1*], **Hanan Abdulqader Darweesh** [2], **Iman Malallah Jaafar** [3]

[1,2,3] *Department of Geology, College of Science, University of Basrah, Basrah, Iraq.*

**Article information**

**Received:** 24- Sep -2024

**Revised:** 19- Dec -2024

**Accepted:** 12- Feb -2025

**Available online:** 01- Apr– 2026

**Keywords**:
Sulaymaniyah,
Active Fault,
Magnitude,
Tectonic,
Zagros,

**Correspondence:**

**Name:** Suad Mohammed Ali

Email: suad.ali@uobasrah.edu.iq

## ABSTRACT

One of the main natural threats is earthquakes, which pose a serious threat to human life and property. To examine seismic activity in Sulaymaniyah, a city, statistically determined distributions of earthquake hypocenters, magnitudes, and epicenters were reviewed from 1900 to 2018. Three contour maps that indicate the distribution of earthquakes in the study region were created using the Intercontinental Seismological Center Bulletin. The spreading of earthquakes shows that there is an increase in the number of earthquakes and their magnitude in areas with active faults, specifically in the southeastern and northwestern parts of the city of Sulaymaniyah, at the collision ridges between the Arabian and Iranian plates, and a decrease in the intensity, number of earthquakes, and their seismic magnitude in the center of the city itself. This means that Sulaymaniyah is the most seismically active and dangerous region in northern Iraq because it is located along the Zagros-Taurus belt, which is one of the most active seismic belts.

DOI: 10.33899/injes.v26i2.56098, 

# توزيع الهزات الأرضية في السليمانية شمال العراق

**سعاد محمد علي[1]*، حنان عبد القادر درويش[2]، إيمان مال الله جعفر [3]**

*[3،2،1] قسم علوم الأرض، كلية العلوم، جامعة البصرة، البصرة، العراق.*

**معلومات الارشفة**

**تاريخ الاستلام:** 24- سبتمبر-2024

**تاريخ المراجعة:** 19- ديسمبر-2024

**تاريخ القبول:** 12- فبراير-2025

**تاريخ النشر الالكتروني:** 01- ابريل -2026

**الكلمات المفتاحية:**

السليمانية،

الصدوع النشطة،

المقدار الزلزالي،

التكتونك،

زاكروس،

**المراسلة:**

**الاسم:** سعاد محمد علي

Email: suad.ali@uobasrah.edu.iq

**الملخص**

تمثل الزلازل واحدة من التهديدات الطبيعية الرئيسية التي تشكل تهيدا خيرا على حياة الانسان وممتلكاته. لغرض دراسة النشاط الزلزالي في مدينة السليمانية، تم استخدام التوزيعات المحددة إحصائيا لمراكز الزلازل وقدرتها وبؤرها من عام 1900 إلى عام 2018. وتم إنشاء ثلاث خراط كنتورية تشير إلى توزيع الزلازل في منطقة الدراسة باستخدام نشرة مركز رصد الزلازل وبين انتشار الزلازل إن هناك زيادة في عدد ISC للزلازل وحجمها في المناطق ذات الصدوع النشطة وتحديدا في الأجزاء الجنوبية الشرقية والشمالية الغربية من مدينة السليمانية، عند مناطق التصادم بين الصفيحتين العربية والإيرانية، وانخفاض في شدة وعدد الزلازل وحجمها الزلزالي في وسط المدينة نفسها. وهذا يعني ان السليمانية هي المنطقة الأكثر نشاطا زلزاليا وخطورة في شمال العراق لأنها تقع على طول حزام زاغروس طوروس الذي يعد من أكثر الأحزمة الزلزالية نشاطا.

DOI: 10.33899/injes.v26i2.56098, 

## Introduction

Sulaymaniyah city is located in the north-east of Iraq, near the border with Iran, with longitudes 44-46 °E and latitudes 34-37 °N. It is located at an altitude of 2895 feet and is the fourth most populous Iraqi governorate, with a population of 2.5 million. According to Sissakian et al. (2014), Iraq is situated on the Arabian Plate's extreme northeastern region, where it collides with the Eurasian Plate. The primary structures generated by this collision, which is still ongoing, are mostly in the northwest-southeast trend, in the eastern, northeastern, and northern parts of Iraq. Iraq is located on the Shalair Terrane, an area of the country that is part of the Eurasian (Iranian) plate, in the far northeast of the nation. The rifting along the northeast African coast and the Red Sea and the Gulf of Aden opening up caused the Arabian plate, which includes Syria, the West of Iran, Jordan, and Iraq, to start separating from the continent of Africa (Fig. 1).

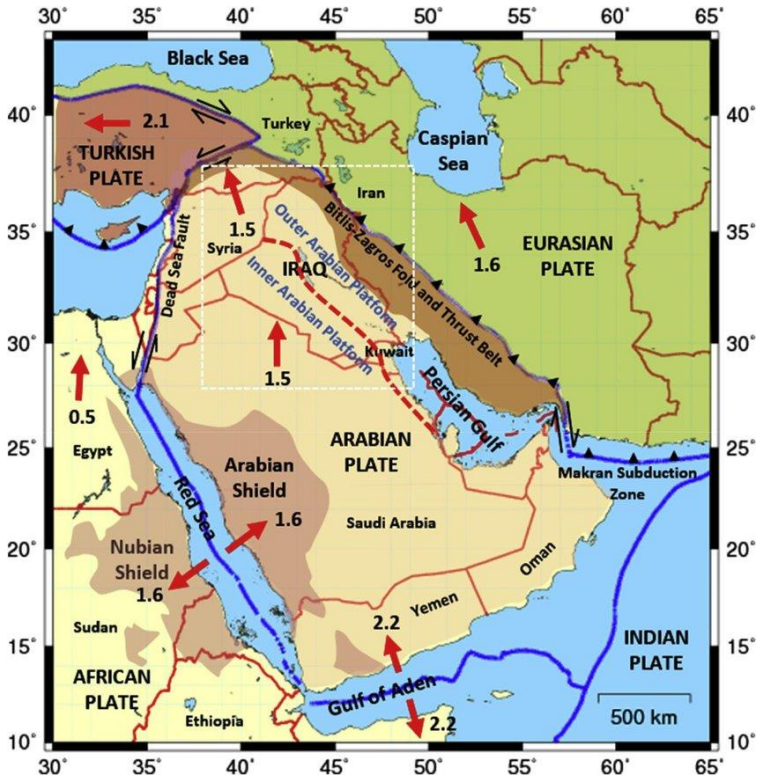


**Fig. 1. The Arabian Plate's Tectonic Setting. The millimeters per year of plate motion are indicated by red arrows.**

Sulaymaniyah is located in the High Folded Region (Fig. 2), which is situated inside the outer platform of the western Zagros Fold-Thrust Belt. The High Folded Region has structural and elevated terrain topography due to the association of the basement in deformation beneath the sedimentary layer by faulting. This region has several closely spaced, high-amplitude, narrow, and inverted folds of varying sizes and geometric shapes (Fouad, 2010).

The importance of this study lies in the fact that earthquakes are very important natural events because they help predict their future occurrence, thus providing better protection for humans and creatures and protecting the country from the collapse of its economy due to material losses. It is known that Sulaymaniyah is frequently exposed to earthquakes because it is in contact with the Iranian border, which is considered an active area, and some of these earthquakes may be damaging.

In seismology, the distribution of earthquakes is one of the important subjects investigated by many seismologists (Kagan, 2007; Kagan, 2010; Kagan and Jackson, 2016). They also studied (Hussien and Abdulnaby, 2019) earthquake distributions of the Mesopotamia Plain in Iraq by creating three contour maps of the number, depth, and magnitude, utilizing the International Seismological Center bulletin, to have a better knowledge of the seismic activity in the study area.

To fit the seismic data, Lillo et al. (2018) employed the Birnbaum-Saunders distribution and its maximum value variant. This application found that the maximum-value Birnbaum-Saunders distribution was more effective for describing seismic occurrences than the traditional model of extreme value distributions, discovering the association between Southern California earthquake magnitudes (Nicholls et al., 2018), and the findings show that it is positive. The association between the magnitude of earthquakes in SCEDC data and their aftershocks is consistent with the observed correlation between the greatest earthquakes in the GCMT catalog and their aftershocks.

In this work, a distribution of earthquake numbers, depths, and magnitudes within Sulaymaniyah is researched and plotted. The research was presented to evaluate the earthquake catalog of Iraq and prepare details regarding the spatial distribution of seismic events in Sulaymaniyah.

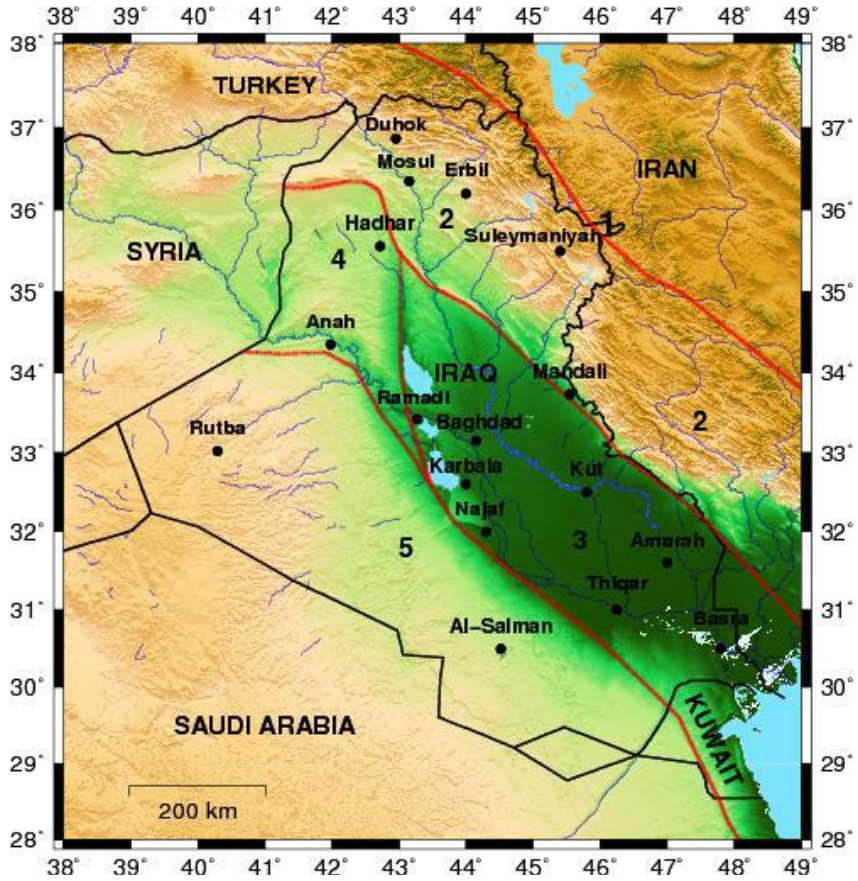


**Fig. 2. Iraq's tectonic divisions by Fouad (2010). (1) Zone of Sanandaj-Sirjan. (2) Fold-Thrust Belts for Zagros.**

Catalog of Earthquakes

In 1964, the International Seismological Centre (ISC) was established to collect, process, and archive seismic stations and net bulletins. It also prepares and disseminates the final summary of seismicity worldwide. One of its major responsibilities is maintaining the ISC Bulletin, which has been the world's longest-running, definitive record of seismicity. This entails collaborating with about 130 seismic networks and data centers worldwide. The Earthquake Center Bulletin's earthquake data was gathered to calculate the magnitude of seismic activity that occurred on the Mesopotamian Plain between 1900 and 2018. There are several reasons to use the ISC Bulletin. First, the accuracy of the location of the explosion epicenter is very high compared to other catalogs. Second, earthquakes reported by regional databases, including the Earthquake Research Institute, the Kuwait Institute for Scientific Research (KISR), the Iranian Seismic Center (IRSC), and the Kandili Observatory, are included in the ISC Bulletin.

## Methodology

In this study, contour maps of the number of earthquakes, their depth, and their distributions were drawn (Figs. 3, 4, and 5) based on the Bulletin of the International Study Center for a period of 118 years from 1900 to 2018. To draw these maps, circles with a diameter of 0.25 degrees were chosen, and the center of each of these circles is situated where latitude and longitude converge.

Hence, a set of lines of longitude and latitude was drawn at 0.25 degrees to cover the entire study area. At each intersection point, the maximum depth, the number of earthquakes, and the maximum magnitude were found to fall within the circle (Table 1). The contour line on a map is the line that joins points of equal value. This is how the three contour maps of the number, depth, and magnitude distributions of earthquakes were drawn.

We note from the table below that the largest number of earthquakes and the highest magnitude are at a circle (30.31) at a shallow depth of the Earth's crust (30 km), as it was near the earthquake that occurred on November 11, 2017, as well as near the active fault extending in a north-south direction, which is a fault. Khanaqin, which confirms that these areas are more dangerous, and their maximum depth was 35 km.

**Table 1: A set of 0.25° latitude and longitude that covered the study lines was utilized to create contour lines at each circle center for the number, maximum depth, and maximum amount.**

| *Cycle (0.25 degrees)* | *Lat.* | *Long.* | *NO. of earthquakes* | *Max.mag (mb)* | *Max. depth (km)* | *Cycle (0.25 degrees)* | *Lat.* | *Long.* | *NO. of earthquakes* | *Max.mag (mb)* | *Max. depth (km)* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *1* | 36.25 | 44.5 | 26 | 4.7 | 49 | 17 | 35.5 | 45.25 | 39 | 5.1 | 35 |
| *2* | 36.25 | 44.75 | 32 | 4.7 | 49 | 18 | 35.5 | 45.5 | 39 | 5.1 | 35 |
| *3* | 36.25 | 45 | 45 | 5.5 | 49.6 | 19 | 35.5 | 45.75 | 45 | 5.1 | 35 |
| *1* | 36.25 | 45.25 | 60 | 5.5 | 52.6 | 20 | 35.5 | 46 | 57 | 4.9 | 35 |
| *5* | 36 | 44.75 | 60 | 5.5 | 52.6 | 21 | 35.25 | 44.75 | 94 | 5.1 | 35 |
| *6* | 36 | 45 | 31 | 5.6 | 53.2 | 22 | 35.25 | 45 | 62 | 5.1 | 35 |
| *7* | 36 | 45.25 | 40 | 5.5 | 35 | 23 | 35.25 | 45.25 | 38 | 5.1 | 35 |
| *8* | 35.75 | 44.57 | 41 | 5 | 35 | 24 | 35.25 | 45.5 | 69 | 5.1 | 35 |
| *9* | 35.75 | 45 | 38 | 5 | 35 | 25 | 35.25 | 45.75 | 116 | 5.7 | 35 |
| *10* | 35.75 | 45.25 | 36 | 5 | 35 | 26 | 35.25 | 46 | 120 | 4.7 | 35 |
| *11* | 35.75 | 45.5 | 40 | 5 | 35 | 27 | 35 | 45 | 39 | 4.6 | 35 |
| *12* | 35.75 | 45.75 | 50 | 4.8 | 35 | 28 | 35 | 45.25 | 50 | 4.7 | 35 |
| *13* | 35.65 | 45.7 | 50 | 4.8 | 35 | 29 | 35 | 45.5 | 152 | 4.9 | 35 |
| *14* | 35.75 | 46.25 | 29 | 4.9 | 35 | 30 | 35 | 45.75 | 434 | 5.7 | 35 |
| *15* | 35.5 | 44.75 | 76 | 5.1 | 37.5 | 31 | 34 | 45.25 | 138 | 6.8 | 35 |
| *16* | 35.5 | 45 | 48 | 5.1 | 37.2 | | | | | | |

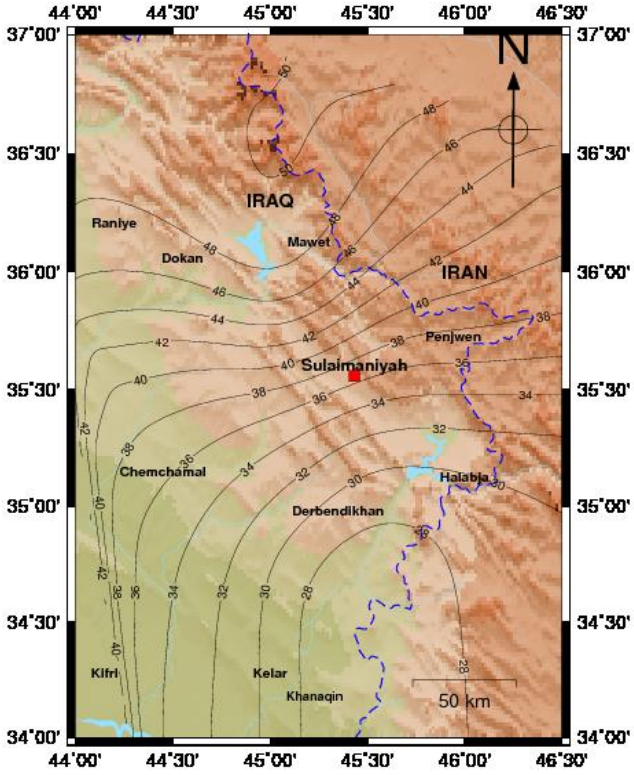


**Fig. 3. Earthquake depth distributions covering 118 years, from 1900 to 2018, that were drawn using the ISC bulletin as a basis.**

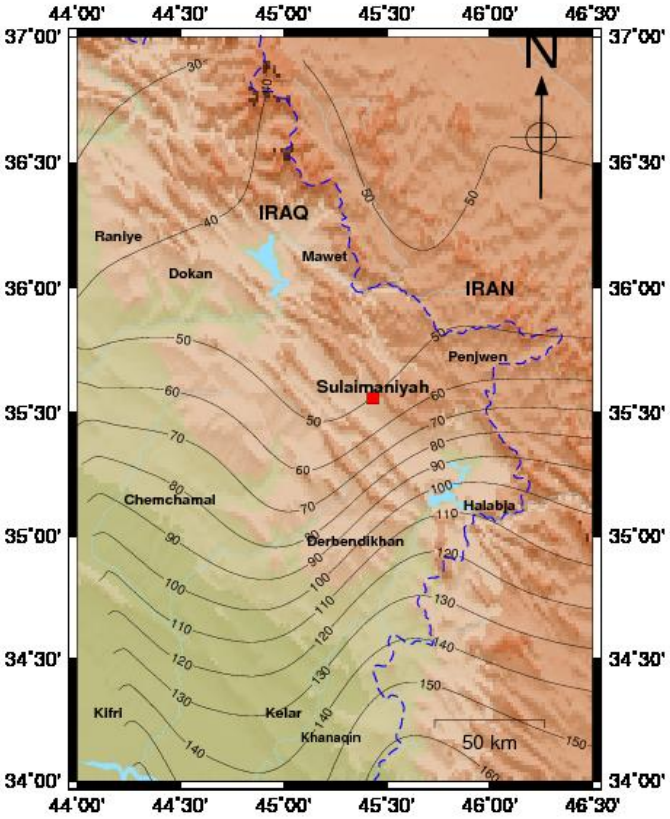


**Fig. 4. Earthquake number distributions covering 118 years, from 1900 to 2018, that were drawn based on the ISC bulletin.**

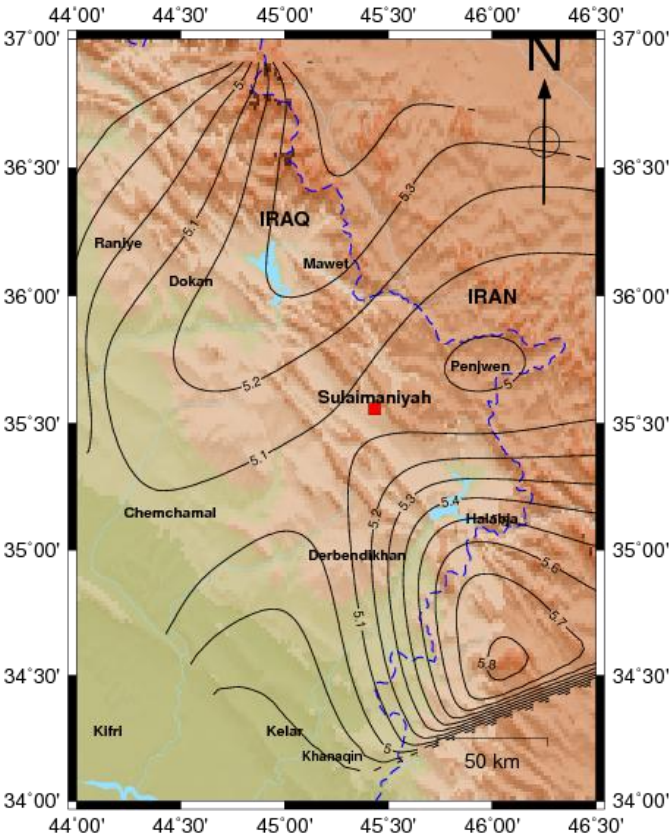


**Fig. 5. Earthquake magnitude distributions covering 118 years, from 1900 to 2018, that were drawn based on the ISC bulletin.**

## Results and discussions

### Faults in the study area

The study area contains several active fault lines (Fig. 6). Tectonic changes in Iran and Iraq caused many earthquakes as a result of these faults. In addition, over the last 11 years, there have been 25,000 earthquakes reported in the Zagros Mountains. With different magnitudes, these can lead to major destruction. The main fault responsible for the November 12, 2017, 7.3 magnitude earthquake remains to be determined. The Iranian Seismic Center (ISC) has determined its location, but the earthquake occurred near an active fault called the main Zagros reverse fault. The epicenter of the earthquake occurred 45 kilometers from the city of Halabja in Sulaymaniyah. There is also an active north-south strike-slip fault between the Iraqi-Iranian borders northeast of Mawet City and the Iraqi-Iranian border east of Khanaqin (Ibrahim, 2009).

Ali (2018) studied some active faults in the Zagros earthquake belt, based on the geographical distribution of earthquakes, which are collected in clusters, indicating the presence of active faults in their locations. This study was conducted by relying primarily on descriptive earthquake data collected from Onur et al. (2017). The resulting catalog with corresponding Mw sizes. Although intense seismic activity is mainly concentrated along the Zagros Belt, the catalog covers seismic activities in the region from 1900 to 2012 with a magnitude from 3.0 to more than 6.

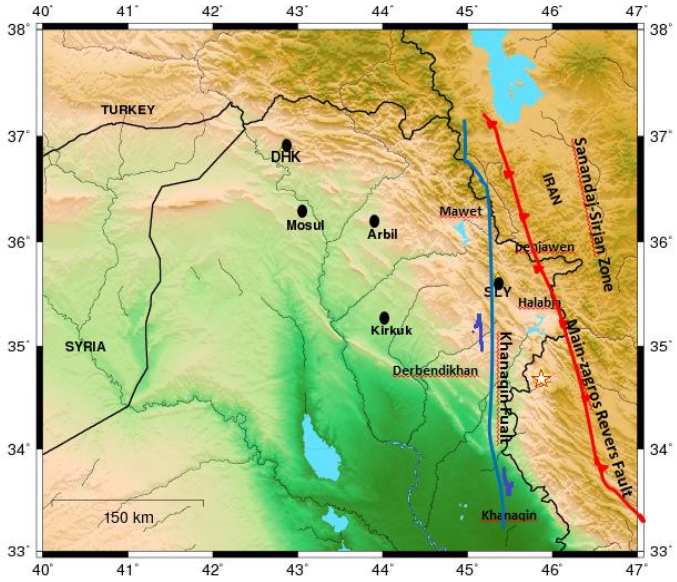


**Fig. 6. Important fault lines in the area, with a star marking the epicenter on December 17, 2011.**

## Activity of seismicity

Earthquakes occur and are mostly concentrated along the folded belts of Zagros and Taurus, and seismic activity is distributed heterogeneously and dispersed throughout this region. Because of the rotating motions within the Arabian plate itself and because of the changes in the shape along the Arabian plate's border where it collides with the Turkish and Iranian plates, the deformation along the belt is heterogeneous (Al-Sinawi, 1997). Iraq is considered moderately seismically active based on its tectonic location on the Arabian Plate and the active collision boundary with Iran. In general, the seismic activity in Sulaymaniyah is mainly affected by the systems of Zagros and Taurus, with some new tectonic activation of the upper crust (Jassim and Göff, 2006) (Fig. 7).

Several destructive earthquakes occurred in Iraq, and the International Seismic Bulletin States that Iraq has thousands of earthquakes, according to the Center (ISC), and countries that bordered between 1900 to 2022 Figure 4 displays the geographical distribution of the magnitudes of earthquakes. From the figure, it is also clear that Sulaymaniyah is seismically active. Earthquakes of magnitude 6.9 have occurred over the past 100 years.

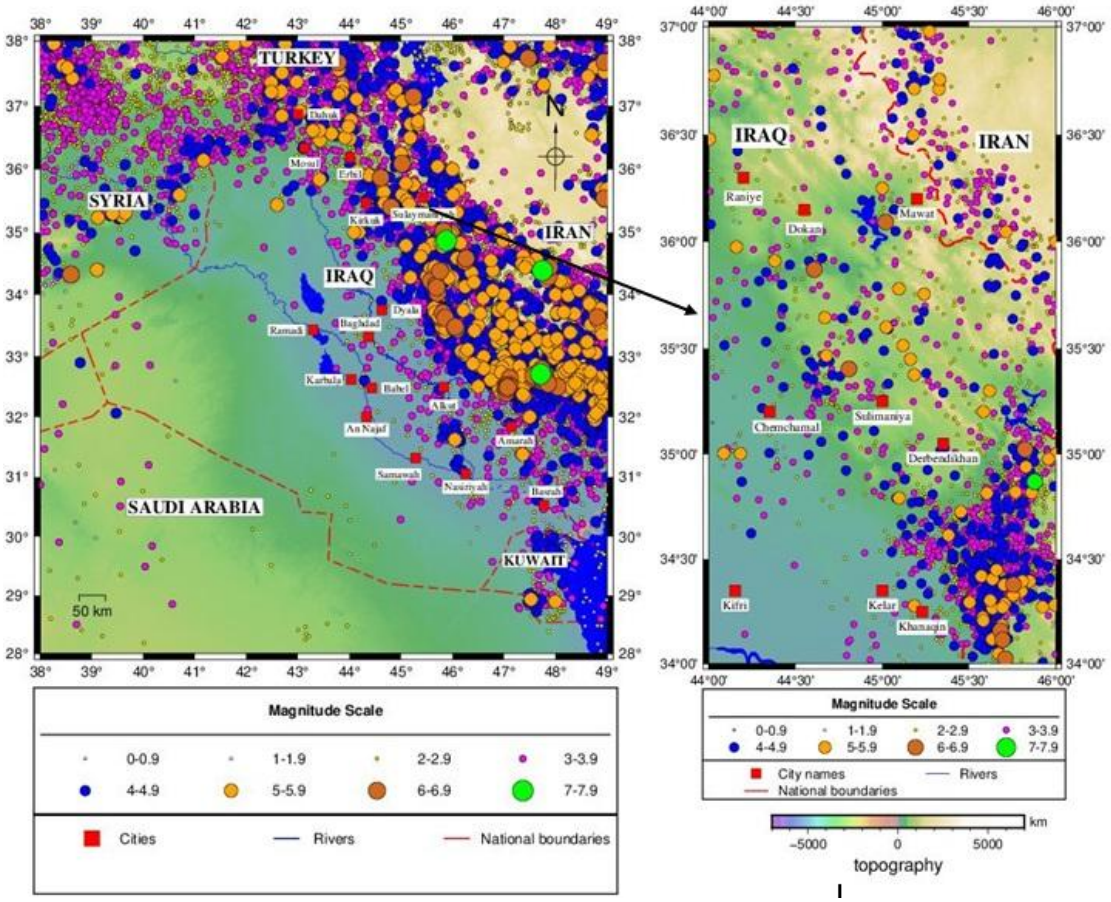


**Fig. 7. The map of Iraq's earthquakes and those of its neighbors, depending on the ISC Bulletin for the years 1900-2022. The figure on the right represents the study area.**

## Conclusions

Regarding the contour map of the earthquake magnitude distributions in the study area, there are two areas witnessing major earthquakes, one of which is located to the southeast of the city of Sulaymaniyah, and the other is located to the northwest of the city. This means that the city center is surrounded by high seismic activity, but the city itself did not witness high seismic foci.

The seismic activity in the two regions is due to the presence of two faults, one of which is located to the southeast of the city, which is the Khanaqin fault, and the other to the northwest of it, which is an extension of the main Zagros reserve fault. The contour map of the number of earthquakes confirms that the number of earthquakes in two areas is large and decreases as we move away from the city center. Likewise, the depths of the earthquakes increase toward the city center, and they are shallow depths ranging from 28 to 48 km.

Distributions of earthquakes indicate that there are many earthquakes, and their magnitudes increase near the Iraqi-Iranian border, where the maximum magnitude reached more than 6. Evidence of this is the presence of the Khanaqin fault as well as a major reverse fault resulting from the Arabian and Iranian plates colliding, which causes earthquakes to occur from time to time in the region. Sulaymaniyah is a more dangerous area, especially the areas near the active faults mentioned above, which are close to the Iranian border.

Contour maps of the distribution of earthquakes can be considered a database for improving modern structural concepts in this region, which can significantly reduce the severity of the consequences for society. Sulaymaniyah City Council should use this information to avoid building across these geological hazards. However, the risks associated with the known fault movement caused by the earthquake in the new development area can be reduced. The

Sulaymaniyah region is considered unstable due to the presence of many major faults in different directions.

## Acknowledgements

We thank the organization for providing the earthquake parameters to the Global Centroid-Moment-Tensor (GCMT) and the International Seismological Center (ISC) Project for plotting all maps in this study.

## References

Ali, S.M., 2018. Crustal structure and seismic active faults in Sulaimaniyah, Northern Iraq, and surrounding regions. Unpublished PhD Thesis, College of Science, University of Basrah, Iraq.

Alsinawi, S.A., 1997. Fundamentals of seismology. Abadi Center for Publications and Studies, Sana'a, Yemen (in Arabic).

Fouad, S.F.A., 2010. Tectonic and Structural Evolution of the Mesopotamia Foredeep, Iraq. Iraqi Bulletin of Geology and Mining. 6 (2), pp. 41-53.

Badria, A.H. and Wathiq, A.G., 2019. Earthquake Distributions of the Mesopotamia Plain, Iraq Journal of Applied Geology and Geophysics (IOSR-JAGG) e-ISSN: 2321–0990, p-ISSN: 2321–0982. Vol. 7, Issue 2 Ser.

Ibrahim, A.O., 2009. Tectonic style and evolution of the NW segment of the Zagros Fold-Thrust - Belt, Sulaimaniya Governorate, and Kurdistan Region NE Iraq. Unpublished PhD Thesis, College of Science, University of Sulaimaniya, Iraq.

Jassim, S.Z. and Göff, J.C., 2006. Geology of Iraq. DOLIN, sro, distributed by the Geological Society of London.

Kagan, Y.Y., 2007. Earthquake spatial distribution: the correlation dimension. Geophysical Journal International, 168(1), pp. 1175–1194. https://doi.org/10.1111/j.1365-246X.2006.03251.x

Kagan, Y.Y., 2010. Statistical distributions of earthquake numbers: the consequence of the branching process. Geophysical Journal International, 180 (3), pp. 1313–1328. https://doi.org/10.1111/j.1365-246X.2009.04487.x

Kagan, Y.Y. and Jackson, D.D., 2016. Earthquake rate and magnitude distributions of great earthquakes for use in global forecasts. Geophysical Journal International, 206 (1), pp. 630-643. https://doi.org/10.1093/gji/ggw161

Lillo, C., Leiva, V., Nicolis, O. and Aykroyd, R.G., 2018. L-moments of the Birnbaum-Saunders distribution and its extreme value version: Estimation, goodness of fit and application to earthquake data. Journal of Applied Statistics, 45 (2), pp. 187-209. https://doi.org/10.1080/02664763.2016.1269729

Nichols, K., Trevino, E., Ikeda, N., Philo, D., Garcia, A., and Bowman, D., 2018. Interdependency amongst earthquake magnitudes in Southern California. Journal of Applied Statistics, 45 (4), pp. 763-774. https://doi.org/10.1080/02664763.2017.1313965

Sissakian, V.K., Fouad, S.F., Al-Ansari, N., Knutsson, S., 2014. Deformational Style of the Soft Sediment (SEISMITES) within the UppermosPart of the Euphrates Formation, Western Iraq, Jour of Earth Sciences and Geotechnical Engineering, vol. 4, no. 4, 71-86. ISSN: 1792-9040 (print), 1792-9660 (online) Scienpress Ltd.

Onur, T., Gok, R., Abdlnaby, W.G., Mahdi, H., Numan, N.M. S., Al-Shukri, H., Shakir, A.M., Ghlaib, H.K., Ameen, T.H., and Abd, N.A. 2017. Comprehensive earthquake catalog for Iraq in terms of moment magnitude. Seismological Research Letters. Vol. 88, Number3. https://doi.org/10.1785/0220160078