# MICROSEISMICITY AND SEISMOTECTONIC OF WEST ZAGROS (KARUN-IV SEISMIC NETWORK)

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## ABSTRACT

*The Karun-IV dam, which is located on the Karun River, is one of the most important concrete arch dams in Iran. The precise location of the dam is 31.601N and 50.475E and is in the mountainous region of high Zagros in Charmahal-va-Bakhtiari province. In order to study the induced seismicity of this dam, six short-period seismometers were installed around the dam and started to record shortly after impounding the dam. In this research, 11 months of continuous recorded data is employed to study the microseismicity of the network and adjacent regions. Approximately 400 events with magnitudes ranging between 0.1 and 4.0 have been located in this area. The seismicity is mainly focused in the middle and northeast of the network. Events in the middle of the network are mostly shallow (depth < 7.5 km) and have small magnitudes (M<2.5). Toward the northeast, the second concentration of seismic events exist with relatively larger magnitude deeper hypocenters (depth > 10 km). The depth distributions of events indicate two distinct seismogenic zones (in depths 6 and 15 km) which are well consistent with recent topographic images. Finally, the fault plane solutions of the events mainly show the thrust mechanism with an additional strike-slip component which is consistent with Zagros main mechanism.*

***Keywords* :** Karun-IV dam, Microseismicity, Seismotectonic, Fault, Mechanism

## 1. INTRODUCTION

The Karun-IV dam, which is constructed on Karun river and impounded in 2010 is the biggest concerete double curvature dam in Iran. This 230 meter-high dam, has a crest length of 440 meters and spillway capacity of 6150 $m^3/s$. The precise location of the dam is 31.601N and 50.475E and is in the mountainous region of high Zagros in Charmahal-va-Bakhtiari province. In order to study the induced seismicity of this dam, six short-period seismometers were installed around the dam and started to record shortly after impounding the dam. In this research, 11 months of continuous recorded data (from March, 2018 until February, 2019) is employed to study the microseismicity of the network and adjacent regions. The results could help study the possibility of induced seismicity a few years after impounding and also to discover the faults condition in this area.

## 2. TECTONIC SETTING

The interaction of different tectonic processes in the Middle East has resulted in complex lithospheric structures which are responsible for high seismic activities. Surface uplift and earthquakes of large magnitudes has occured in recent decades in several areas of Iran, such as Tabas ($M_w$=7.4, 1978), Roudbar ($M_w$=7.3, 1990), Bam ($M_w$=6.6, 2003), Ahar – Varzaghan ($M_w$=6.4 & 6.2, 2012), and Sarpol-e Zahab ($M_w$=7.3, 2017). This indicates that the crust is still being actively deformed. In particular, long–term convergence between Arabian and Eurasian continent is the cause of the ongoing intra-continental subduction and formation of the Anatolian-Iranian plateau and Zagros Mountains, characterized by high topography, reaching more than 4000 m. Further to the north, the collision zone extends to the Caucasus region including also the Caspian Sea rigid block (Stern and Johnson (2010)).

Based on the tectonic subdivisions of Iran (Berberian and King (1981)), the Karun-IV Dam is located in the Zagros folded and thrust belt (Figure 1). This area is mainly surronded between the Zaros forland basin in the west and high-Zagros mountains in the east which constitute of considerable anticlines (Berberian (1983)). Another significant geological unit around the Karun-IV dam is salt domes distribution which belongs to Hormuz salt (Bahroudi and Koyi (2004)).

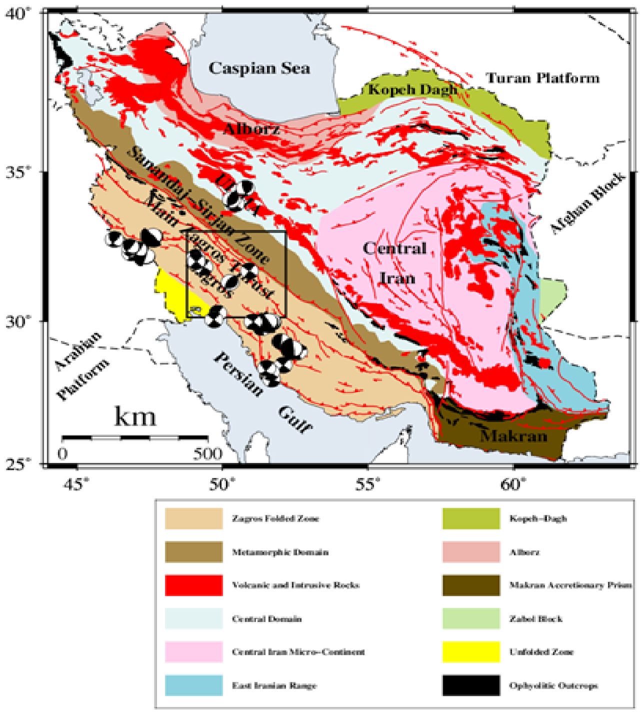


**Figure 1** : Geological map of the Iranian plateau including different seismotectonic Zones with CMT focal mechanisms (https://www.globalcmt.org/CMTsearch.html).

The wide presence of evaporitic structures, especially the thick Hormuz salinity formation controls the deformation style in the Zagros foreland basin, on account of its high plasticity (Bahroudi et al. (2003)). Geophysical databases suggest that the Zagros fold and thrust belt is actively deformed and shortened in geological time. In this area, the seismic events are confined to the depth of <30 km (Jackson and McKenzie (1984)) which indicate the presence of a thin seismogenic zone in this orogenic system. Also, the fault plane solutions mainly indicate reverse faults with dips of 30° – 60° striking northwest (Jackson et al. (1995)).

Recent modified catalogues (Engdahl et al. (1995)) indicate that destructive historical or instrumental earthquakes with magnitudes larger than 6.0 occurred in 1951, 1960, 1977 and 1978 in 100 km radius of Karun-IV dam, but the associaated focal mechanisms are not clear (Table 1).

**Table 1** : Main instrumental earthquakes in the last decade in 100 km radius of the Karun-IV dam

| Date | Time (UTC) | Latitude | Longitude | Depth | Magnitude |
|---|---|---|---|---|---|
| 1951/06/09 | 11:22:07 | 32.26 | 49.8 | 53 | 6.2 |
| 1952/08/04 | 01:49:44 | 31.66 | 49.93 | 69 | 5.5 |
| 1960/03/02 | 12:18:05 | 32.00 | 50.25 | ? | 5.8 |
| 1960/03/24 | 23:21:05 | 31.25 | 51.00 | ? | 6.0 |
| 1977/04/06 | 13:36:35 | 31.95 | 50.64 | 10 | 6.0 |
| 1978/12/14 | 07:05:21 | 32.12 | 49.63 | 18 | 6.2 |
| 1988/03/30 | 02:12:43 | 30.84 | 50.17 | 25 | 5.9 |
| 2019/07/08 | 07:00:32 | 31.72 | 49.45 | 10 | 5.8 |

The last significant earthquake in study area has occurred in 8th of July, 2019 near Masjed-Soleyman with M=5.8. Abundance of seismicity in study region indicate Arabian – Eurasian plate convergence which results in deforming the crust of this area. The charactersitics and distribution of significant seismic events (M > 5.5) around study area listed in Table 1. They are also shown on map in Fig. 1.

## 3. DATA AND RESULTS

The continuous data is extracted from a seismic network which was deployed around Karun-IV dam. This network constitutes of six Parsian three-component short-period seismometers with a natural frequency of 1 Hz. The sampling rate was 100 samples per second, and time was monitored by a GPS receiver in each station. Fig. 2 shows the arrangement of Karun-IV seismic network.

Microseismicity study is one of the most important parts of seismological researches. Using the high – quality distribution of small seismic events can help us to discover the characteristics of faults and active tectonic of study area (Nemati et al. (2013)).

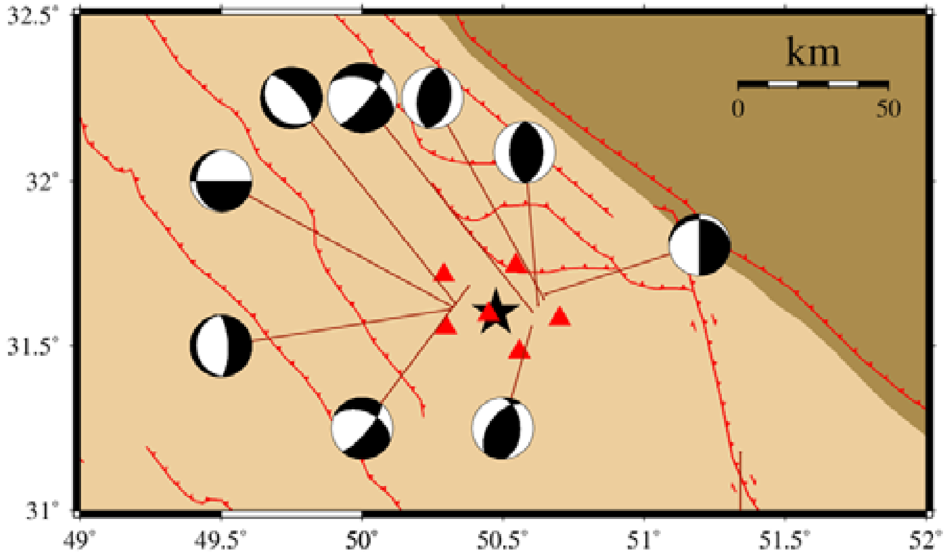


**Figure 2** : The location of Karun-IV dam (black star) and six seismic stations (red triangles).

Fig. 2 shows the fault plane solution of few seismic events in study area. Based on this figure, the main fault plane solution of these events is the thrust mechanism with an additional strike-slip component which is well consistent with Zagros tectonic (Walpersdorf et al. (2006)). Fig. 3 illustrates the epicentral distribution of located earthquakes in study area. Based on this figure, the seismicity is mainly focused in two regions of study area which are marked with blue circles. The first region is located inside the Karun-IV seismic network, which can be interpreted as induced seismicity due to huge water loaded behind the dam. Induced seismicity by reservoir activities has two types. In the first type, the seismicity is due to the filling of the reservoir while in the second type small earthquakes occurred after a certain period of time from the beginning of the reservoir impounding (Piccinelli et al. (1995)). As can be seen from Fig. 3, the second concentration of seismic events is toward the northeast of network. This seismicity can be related to Zagros tectonic activities. The distribution of seismic events in Fig. 3 is exactly parallel to Zagros main trend (northwest-southeast).

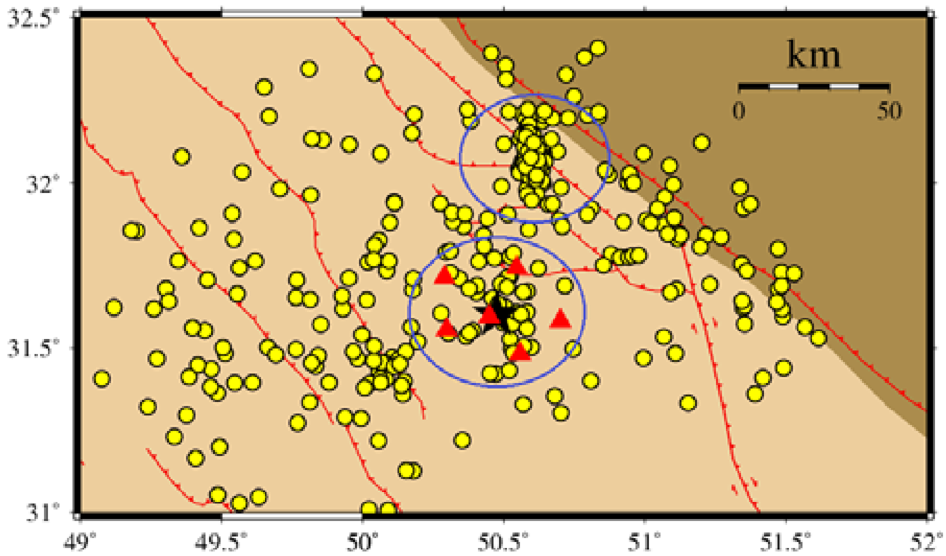


**Figure 3** : The distribution of earthquakes around the dam.

In this research, approximately 400 events in different magnitudes were located around the dam. Fig. 4 shows the magnitude distribution of located earthquakes. Based on this figure, most of the events in this region are in magnitude range of 1.1 to 2.1. A significant number of earthquakes have larger magnitudes. Fig. 5 shows the depth distribution of located earthquakes. As can be seen here, focal depths are mostly scattered around two distinct depths of 5 and 15 km which can be interpreted as two seismogenic layers beneath the network. These focal depths are well consistent with depth values suggested as seismogenic zone for Zagros in recent years (Hatzfeld et al (2003); Yamini-Fard et al. (2006)).

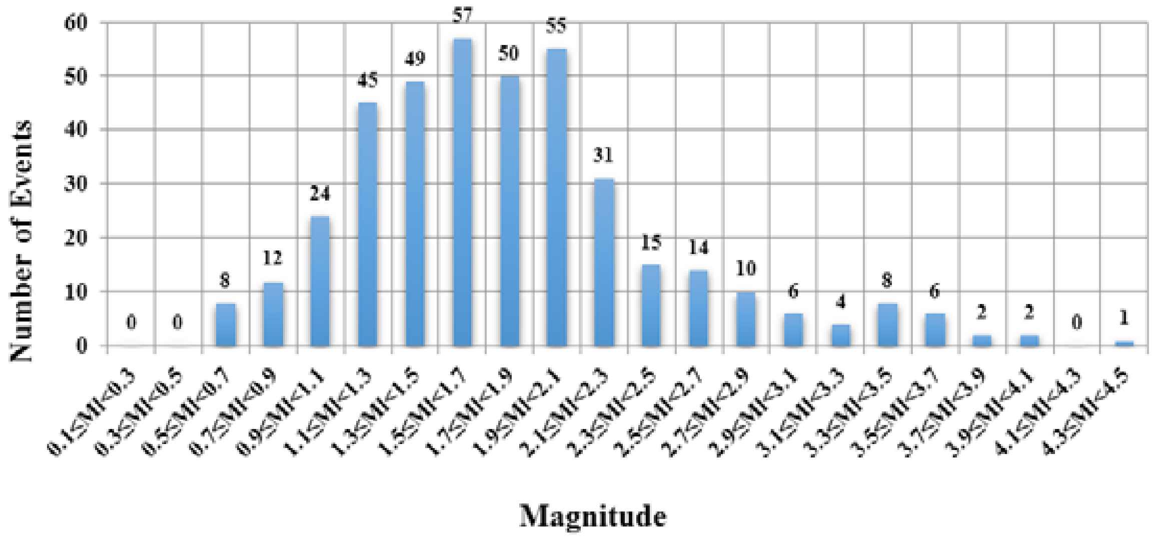


**Figure 4** : The accumulation of seismic events in different magnitudes in study area.

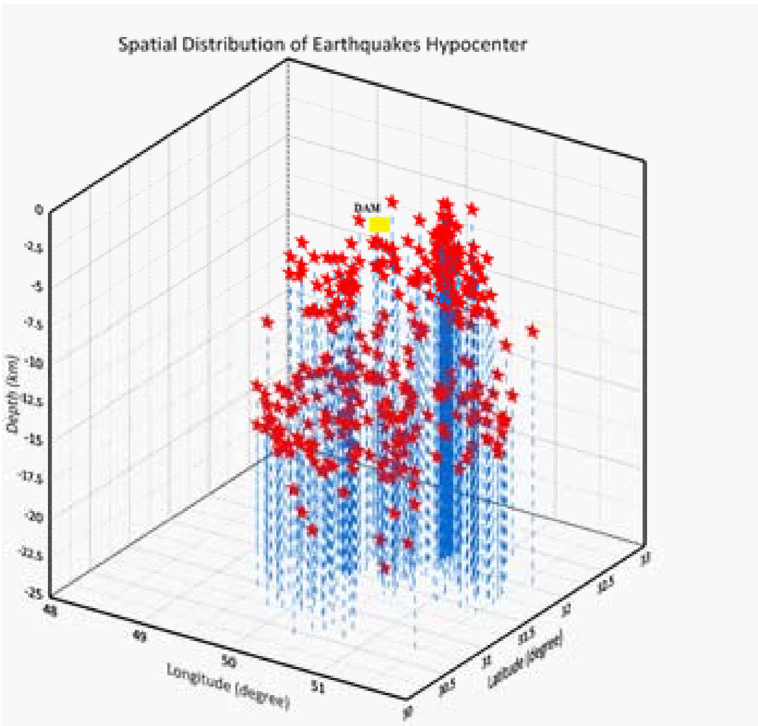


**Figure 5** : Depth distribution of located seismic events around the Karun-IV dam. Yellow square indicates the location of dam.

Based on Gutenberg and Richter (1942) studies on the relation between distribution and magnitude of earthquakes in a small region, the following equation is presented:

$$log_{10}N = a - b\,m log_{10}N = a - b\,m \quad ...(1)$$

In which, N is the number of earthquakes in magnitudes equal or larger than M, and 'a' and 'b' are constant coefficients.

Generally, 'a' parameter depends on observation duration and study area scale (Gutenberg and Richter (1942)). In other words, 'a' reflects the seismotectonic property of the earth. 'b' is relates to seismicity potential of the region (Farahani et al. (2014)). This study presents new insights for a better understanding of the seismic activity and assessment of seismic hazard in the region around the Karun-IV dam from local data. Therefore, the Gutenberg – Richter linear equation has been solved using earthquakes data of Karun-IV dam seismic network as below (Fig. 6):

$\log N = 3.6169 - 0.759M_l$ $\log N = 3.6169 - 0.759M_l$ ...(2)

*b* value can explain the relative density of large and small events and can be applied in seismic hazard studies, spatio-temporal prediction and earthquake physics (Ashtari, (2009)).

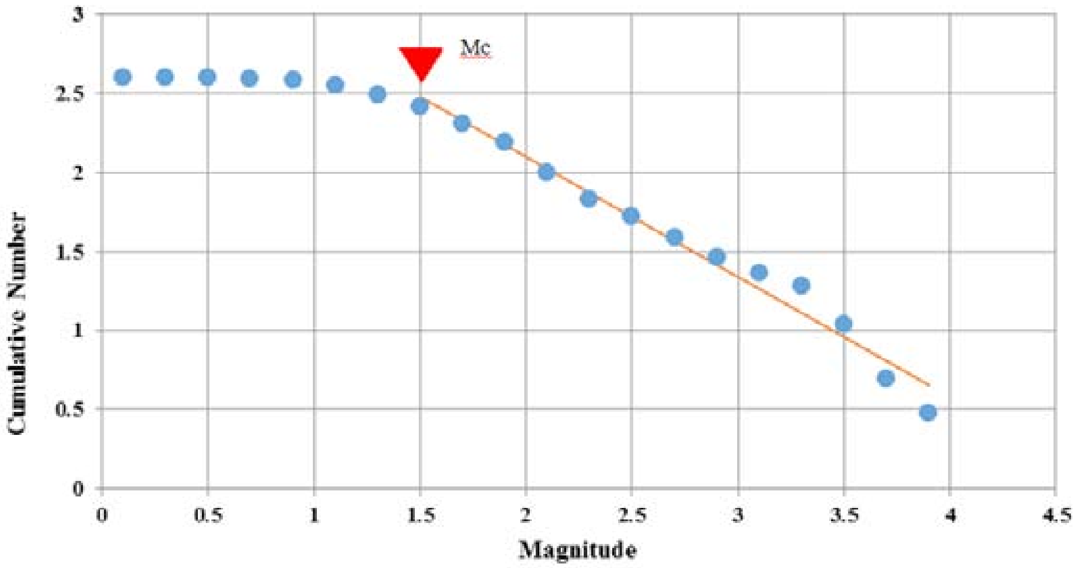


**Figure 6** : Cumulative events of study area employed to obtain Gutenberg – Richter coefficients.

## 4. CONCLUSION

In this study, the seismic events, recorded in six short-period seismometers around Karun-IV dam were analyzed to investigate the seismicity and seismotectonic of the study area. Approximately 400 events were located around the Karun-IV dam in the middle of Zagros. The locations indicated two distinct accumulations of seismic events in study area. An accumulation of microseismicity inside the seismic network was observed which can be related to huge stored water behind the dam that can activate micro faults and fractures in the region. The second group of events, accumulated in northeast of the seismic network, can be interpreted based on tectonic activity of Zagros. Depth distribution of seismic events presents two distinct seismogenic zones in approximately two distinct depths of 5 and 15 kilometers beneath the study area which are well consistent with previous studies. Fault plane solutions of the selected events in study area suggest that the main focal mechanism is almost thrust with an additional strike-slip component that in well agreement with recent GPS studies.

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