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# Delineate Location of the Last Earthquake Case Study NW of Iran

**Hadi Jarahi**

*Department of Geosciences, North Tehran Branch, Islamic Azad University (IAU), Tehran, Iran*

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Email: hadijarahi@gmail.com

**Abstract:** The earthquake hazard is most important title in seismic design of buildings. One of ways to know this hazard is to know where the earthquake boundary is. Moreover, understanding of the future earthquakes location, can help to modify the seismic hazard maps. The b-values, is the effective parameter on future earthquake positioning. This study was conducted to variations of b-values in the Gutenberg-Richter relation were examined for tectonic earthquakes in the NW of Iran. Earthquake dates for this area are given from the ISC, NEIC and Engdahl catalogues for a period of 735 to 2017 were used for analysis. We separated earthquake catalogue in part 1(before 2000) and Part 2 (all events). Delineated zone from b-value distribution map in catalogue Part 1, showed us five seismic gap region (area A to E) with a potential for the occurrence of earthquakes in the near future. The results of Part 2 showed that in areas A, B and C the future earthquake had happened. Therefore, we are waiting for last seismic events in the D and E areas. This “seismic gaps” is a potential threat to the surrounding regions, such as the Nakhichevan and Rasht city.

**Keywords:** B-Value, Earthquake, Potential Area, NW of Iran

## Introduction

Main earthquakes of active fault (Berberian, 2014) of NW Iran such as N-Tabriz (Karimzadeh *et al*., 2013), Chaldiran (Jackson and McKenzie, 1984), Salmas (Berberian and Tchalenko, 1976) and other active faultshas widely opened up a discourse on the study of natural disasters in NW Iran earthquakes in particular (Masson *et al*., 2006). Lots of seismological papers tell us about the probability and prediction of an earthquake that will happen (Siame *et al*., 2002; Solaymani Azad, 2009; Talebian and Jackson, 2002), but the phenomenon still remains a problem and is more often wrong than right. Several research has been done on the b-value as a likely sign of a major earthquake (Zaho and Wu, 2008; Vasheghani-Farahani, 2014; Sadeghian, 2010; Nuannin, 2006). This paper focused on the b-value in the NW of Iran region where there is a history of large earthquakes occurred. The historical earthquake catalogue from the Ambraseys and Jackson (1998) and Berberian (1994; 2014) also showed that the social disaster followed these large events. In a range of last millennium, there have been number events of large earthquake in this region (Berberian, 2014). Base on Kanamori (1981) and Wyss (1973), the low value of b show the high stress areas. This is also implying very much due to fact that the great earthquake occurrences in the area are very rare even though in other regions (high b-value) have been hit by large earthquakes recently. As a step to look for other potential spots, we calculated the b-value to delineate the possible areas for large earthquakes in the future.

## Seismicity and Tectonic Setting

The active deformation of the Iranian plateau, as a tectonically active part of the Alpine-Himalayan tectonic belt, is controlled by the Arabian-Eurasian convergence. Beneath central Iran plate, Arabian plate subduction to northwestern part of Iran. The consequences of this phenomenon manifest itself in the high number of seismicity and the existence of active volcanoes such as Sahand and Sabalan (Berberian, 1983; Berberian and King, 1981; Berberian *et al*., 1982). Shortening is accommodated by distribution faulting and it makes regions with different seismotectonic features and active faults. Fault plane solutions of earthquakes in the study region indicate both strike-slip and thrust faulting, though the strike-slip faulting is prominent (Sella *et al*., 2002). Based on the recent Global Positioning System (GPS) studies, the rate of north-south shortening throughout the NW of Iran is 13±2 mmyr$^{-1}$, (Copley and Jackson, 2006) and the right-lateral shear of the overall belt occurs at a rate of 8±2 mmyr$^{-1}$ (Vernant *et al*., 2004). Recent GPS data taken from a station south of the N-Tabriz fault in northern Central Iran, in the center of the study area, indicates northward and eastward velocities with a rate of 11.2 and 3.2 mmyr$^{-1}$, respectively (Vernant *et al*., 2004; Masson *et al*., 2006). Numbers of historical earthquake have been happening in this part of the Iranian plate (Ambraseys and Melville, 1982; Berberian, 1994) by reactivate of active faults (Table 1 and Fig. 1). In 735 to 2017, record of more than 17 major earthquakes (over 6.5) shown that this area has a potential for large events.

The Frequency and magnitude equation (Gutenberg and Richter, 1944) are very commonly used in the modeling of earthquake hazard, mostly related to the earthquake precursors and probabilistic seismic hazard Assessments.

We use the catalogue of earthquakes from the year 735-2017 to be applied in the equation along NW of Iran, from 43 to 50 longitudes and 35 to 40 latitudes. An earthquake catalogue has been declustered and resulting 2450 independent earthquake events with magnitude above 3.0. We made tow kind on earthquake catalogue part 1 start from 735 to 2000 (As controlled variable) and Part 2 from 735 to 2017. All of the calculations were done for both of catalogues. We used the device ZMAP (Wyss *et al*., 2001) to show the result of calculation of cumulative number of earthquake and Frequency-Magnitude Distribution (FMD) (Fig. 2 and 3). From that graphic solution we've got Mc = 4.7, b-value = 1.21+-0.1, a-value = 5.94 for Part 1 and Mc = 3.0, b-value = 0.7+-0.01, a-value = 3.52 for Part 2.

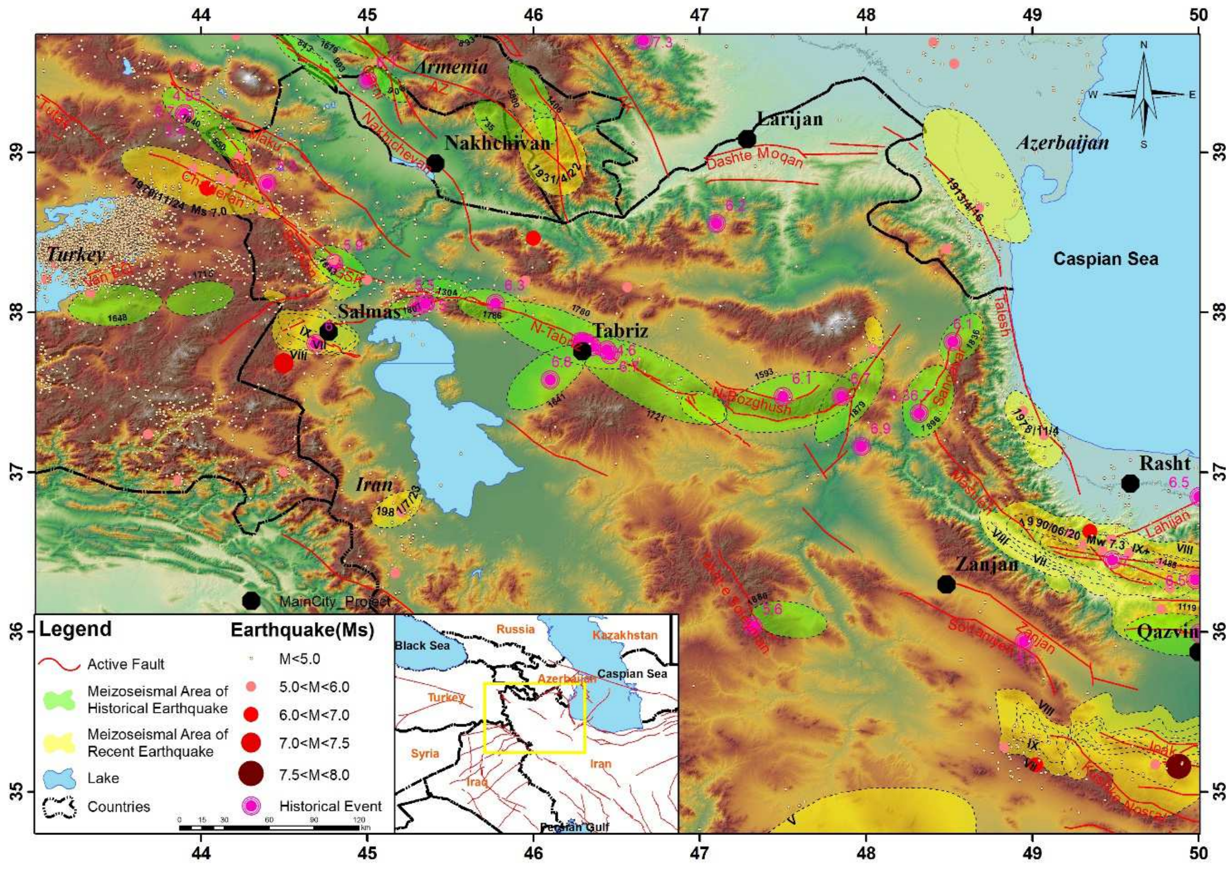


Fig. 1. Seismotectonic Map of NW Iran. (Major earthquake description in Table 1)

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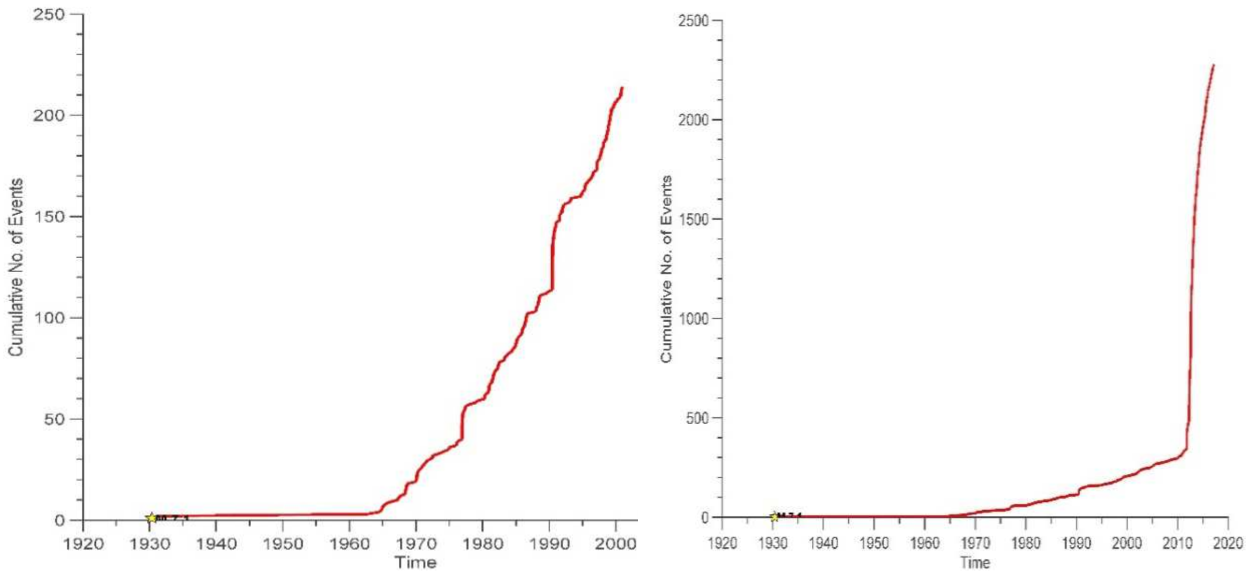


Fig. 2. Cumulative number of earthquakes. The left charts are related to Part 1 and the right for Part 2

Table 1. List of main events (M>6.5) at NW of Iran

| No. | Date | | | Epicenter | | | Magnitude | | |
|---|---|---|---|---|---|---|---|---|---|
| | Year | month | day | Lat. | Lon. | $I_{oMMI}$ | Ms | Mw | Ref. |
| 1 | 735 | | | 39.700 | 45.600 | | 6.5 | | Ambraseys and Melville (1982) |
| 2 | 1042 | 11 | 4 | 38.120 | 46.330 | IX+ | 7.3 | 7.3 | Berberian (1994) |
| 3 | 1127 | | | 36.350 | 43.540 | VIII+ | 6.8 | 6.7 | Berberian (1994) |
| 4 | 1179 | 4 | 29 | 36.250 | 44.300 | VIII | 6.6 | | Berberian (1994) |
| 5 | 1273 | 1 | 18 | 38.130 | 46.280 | VIII+ | 6.5 | 6.4 | Berberian (1994) |
| 6 | 1304 | 11 | 7 | 38.050 | 46.460 | VIII+ | 6.7 | 6.6 | Berberian (1994) |
| 7 | 1503 | | | 37.400 | 43.800 | | 6.9 | | Ambraseys and Melville (1982) |
| 8 | 1641 | 2 | 5 | 37.900 | 46.100 | VIII+ | 6.8 | 6.7 | Berberian (1994) |
| 9 | 1648 | 3 | 31 | 38.300 | 43.500 | VII | 6.5 | | Ambraseys and Melville (1982) |
| 10 | 1696 | 4 | 14 | 39.100 | 43.900 | 1 | 7.0 | | Ambraseys and Melville (1982) |
| 11 | 1715 | 3 | 8 | 38.400 | 43.900 | VII | 6.6 | | Ambraseys and Melville (1982) |
| 12 | 1721 | 4 | 26 | 37.900 | 46.700 | 1 | 7.7 | | Ambraseys and Melville (1982) |
| 13 | 1780 | 1 | 8 | 38.120 | 46.290 | IX+ | 7.4 | 7.3 | Berberian (1994) |
| 14 | 1840 | 7 | 2 | 39.500 | 43.900 | IX | 7.4 | 7.3 | Berberian (1994) |
| 15 | 1844 | 5 | 13 | 37.500 | 47.970 | IX | 6.9 | 6.8 | Berberian (1994) |
| 16 | 1879 | 3 | 22 | 37.800 | 47.850 | VIII+ | 6.7 | 6.6 | Berberian (1994) |
| 17 | 1899 | 5 | 9 | 37.569 | 43.727 | VII | 6.5 | | Ambraseys and Melville (1982) |
| 18 | 1930 | 5 | 6 | 38.240 | 44.600 | IX | 7.2 | 7.1 | Berberian and Tchalenko (1976) |
| 19 | 1962 | 09 | 01 | 35.710 | 49.810 | IX | 7.2 | 7.0 | Priestley *et al*. (1994) |
| 20 | 1976 | 11 | 24 | 39.083 | 44.030 | IX | 7.2 | 7.0 | Berberian (1979) |
| 21 | 1990 | 6 | 20 | 37.007 | 49.210 | IX+ | 7.4 | 7.3 | Berberian (2014; Zare *et al*., 2014) |
| 22 | 1997 | 02 | 28 | 38.096 | 48.033 | VIII | 6.1 | 6.0 | Zare *et al*. (2014) |
| 23 | 2002 | 6 | 22 | 35.572 | 49.085 | VIII | 6.6 | 6.6 | Walker *et al*. (2005) |
| 24 | 2011 | 10 | 23 | 38.729 | 43.447 | | 7.1 | 7.1 | Talebi *et al*. (2015) |
| 25 | 2012 | 8 | 11 | 38.329 | 46.826 | VIII | 6.7 | 6.4 | Berberian (2014) |

Variation of b-value

## Spatial Variation of B-Value

To delineate the spatial variations of b-value, we divided the study area into grids, then b-value was calculated for each grid for constant radius and number of events. In this study, these parameters are determined from the area with a radius of 600 km or a minimum of 40 earthquakes with 0.20×0.20 processing grid. From the b-value distribution map resulted, we find five areas named A, B, C, D and E (Fig. 4). These areas have different variation of b-value range (Table 2). As it is shown, in Fig. 4 (left

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map) all of five areas have low values of b. The range of variety is 0.8 to 1.1 and all selected areas are matched to seismic sources that have potential for future earthquake. The right map in Fig. 4 showed the b-value distribution for complete earthquake catalogue. As it stands, in areas A, B and C the future earthquake happened. As it mentioned before, we separation earthquake catalogue to tow part because we need controlled variable. Therefore, it's expected that the future earthquake will happen on D and E areas.

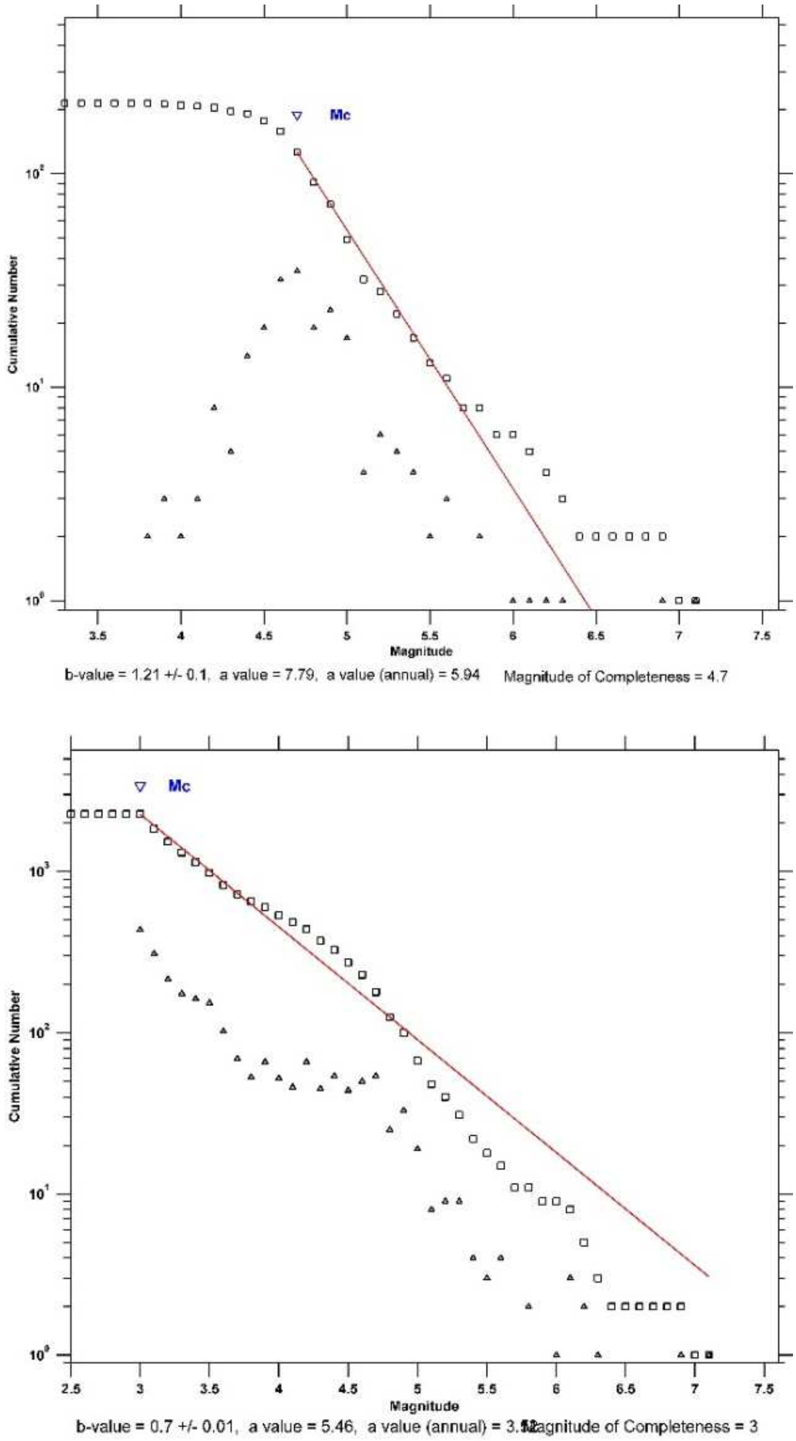


Fig. 3. Frequency- Magnitude Distribution (FMD) from 1900-2017 earthquake catalogue. The red thin line represented Gutenberg-Richter equation, log N = a-bM. The left charts are related to Part1 and the right for Part2

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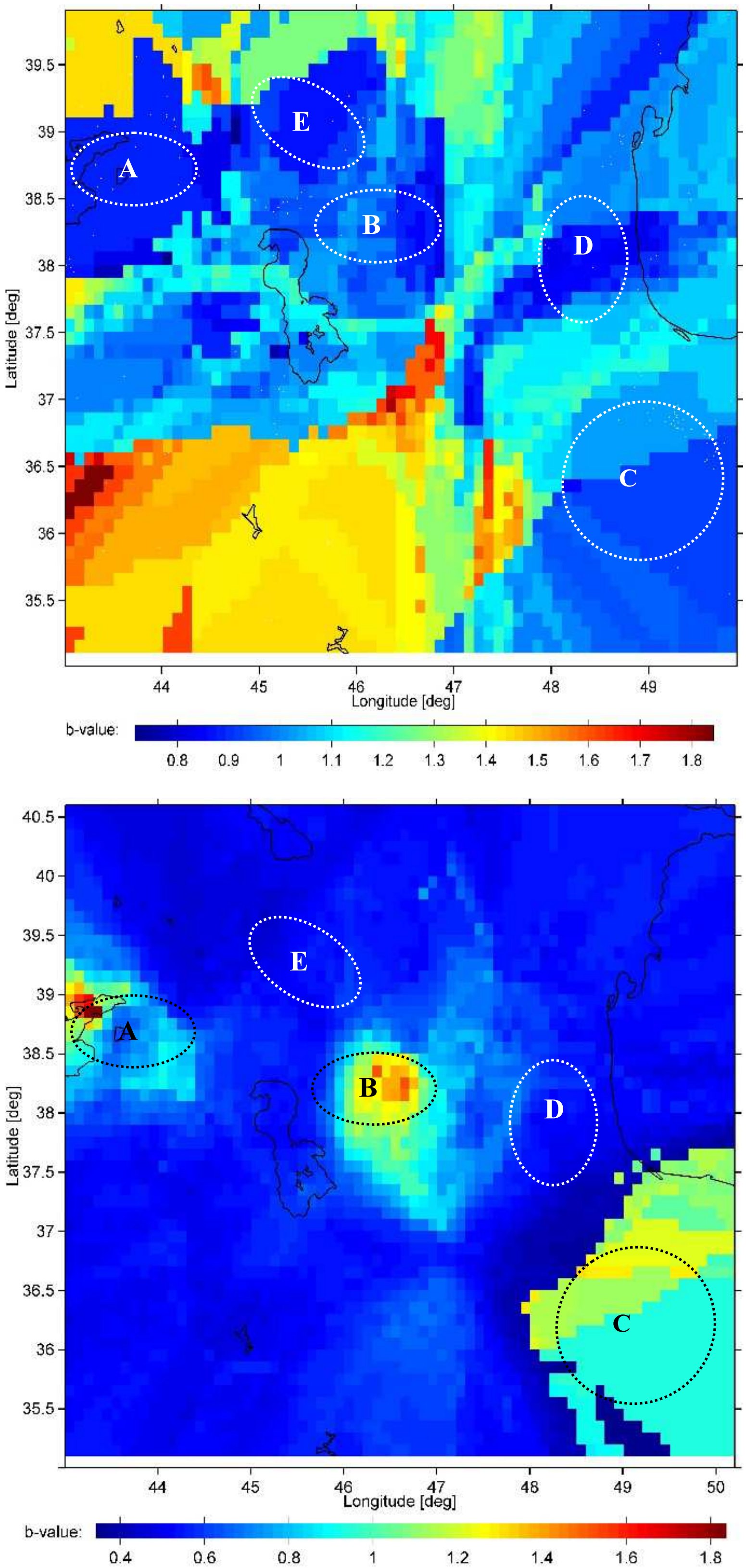


Fig. 4. Spatial variation of b-values on the NW of Iran, five area are shown by dash rings. The left charts are related to Part 1 and the right for Part 2

Table 2. The variation of b-value in selected areas

| Selected area | Matched seismic source | B-value Part 1 | Part 2 | Earthquake event |
|---|---|---|---|---|
| A | Van lake fault | 0.80 | 1.85 | Happened |
| B | Varzeghan fault | 0.95 | 1.60 | Happened |
| C | Manjil Fault | 1.10 | 1.30 | Happened |
| D | Sangavar and Talesh Faults | 0.80 | 0.80 | Waiting for last |
| E | Nakhichevan | 0.80 | 0.80 | Waiting for last |

## Conclusion

The concept of b-value variation has been applied properly to simulate the b-value in the NW of Iran. The b-value variation in this region is calculated based on multiple source catalogue from 735 until 2017 with a range of magnitudes from 3.0 to 7.7:

- The b-value maps showed that this parameter take increase depending on time
- Delineated zone from b-value distribution map in catalogue Part 1, showed five seismic gap regions (area A to E) with a potential for the occurrence of earthquakes in the near future. The results of Part 2 showed that in areas A, B and C the future earthquake had happened

Therefore, we are waiting for last seismic events in the D and E areas. This "seismic gaps" is a potential threat to the surrounding regions, such as the Nakhichevan and Rasht city.

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## Ethics

This article is original and contains unpublished materials. The corresponding author confirms that all of the other authors have read and approved the manuscript and there are no ethical issues involved.

## Data and Resources

Data retrieved from theInternational Seismological Centre (ISC), On-line Bulletin, http://www.isc.ac.uk, Internatl. Seismol. Cent., Thatcham, United Kingdom, 2014.

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