# THE DISTRIBUTION OF B-VALUE IN DIFFERENT SEISMIC PROVINCES OF IRAN

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**ABSTRACT :**

The Gutenberg–Richter relation is a well known empirical relation in earthquake seismology which represents the frequency of occurrence of earthquakes as a function of magnitude. The a-value and the b-value are constants of this relation. The a-value is related to the seismic activity and so to the time and the volume of the considered window. The b-value (size distribution) is a measure for the relative abundance of the strong to the weak earthquakes and is considered to be related to the tectonic regime of the area under consideration. The b-value value anomalies may be an indication of the anomaly of the low or the high stress levels, anomaly in the thermal gradient or the crustal heterogeneity. Some studies have discussed the spatial and temporal variations of the b-value before large earthquakes and the spatial variation of the aftershocks. In this paper it has been tried to look into the variations of the b-value and the a-value in different seismic provinces of Iran during last decade. The data has been extracted from the Iranian seismological center (IRSC). Then different relations have been developed for each province.

**KEYWORDS:** a-value, b-value, Gutenberg–Richter relation, frequency of occurrence, spatial and temporal changes.

## 1. INTRODUCTION

The Persian Plateau locates within the continental collision zone between the Eurasian and the African plates with recent volcanic, high mountain ranges and active faults. The collision between the two plates uplifted mountain ranges like the Alborz and the Zagros in Iran. One of the main regional tectonic features is the Central Iranian Block that consists of Tabas, Lut, Posht-Badam and Yazd blocks. The borders of these blocks are strike-slip faults which are subject to rotation. Epicenters of most destructive earthquakes show good coincidence with these tectonic ties. Figure 1 shows the recent seismicity of Iran. Major regional faults show strike-slip movement. The approximate rate of convergence between Arabia-Eurasia was already estimated about 30 mm/yr at longitude 50$^o$E and 40 mm/yr at longitude 60$^o$E (Jackson, 1992; DeMets et al., 1994; Chu and Gordon, 1998) but present GPS measurements has estimated lower values for the deformation in Iran. Vernant et al., 2004, suggested about 20 mm/yr for the last Ma which is distributed as: the Zagros (10 mm/yr), Alborz (8 mm/yr) and eastern-Iran (16 mm/yr). Convergence is partitioned into shortening perpendicular to the strike of the fold and faults. Active deformation is not uniformly distributed and consists of shortening, thickening, reverse and strike-slip faulting plus subduction of the oceanic crust. While a great part of the shortening is taken up in mountain building (Alborz, Zagros and Kope-Dagh) and earthquakes, some parts are accommodated in Central-Iran. One can roughly divide the active faults of Iran to reverse and strike-slip faults. Central Iran is bounded by Alborz in north-east, Kope-Dagh in north, Zagros in south and south-west, Makran in south-east and Helmand in east. This region has gone under different mountain building phases and is characterized by concurrent magmatism and metamorphism especially within early Paleozoic, middle Triassic, early Jurassic and early Cretaceous (Berberian, 1981). The seismicity pattern of the Persian Plateau show nonuniform distribution that is concentrated across the active fold-thrust mountain belts surrounding the relatively aseismic undeformed rigid and stable block (Berberian, 2005). Destructive earthquakes are one of the features of the regional seismicity. Many urban and industrial complexes has been developed near mountain foothills that are usually bordering of active faults, so great earthquakes along such faults has been destroyed many cities during historical and recent times (Ambraseys and Melville, 1982; Berberian, 1995). Interaction between reverse and strike-slip faults has been revealed by several clusters of earthquakes (Berberian, 1999). It seems that Seismicity is of shallow type and takes place 20 km around active fault zones that surround nearly stable microplates. Active faults in Iran are mainly short length compressive faults located within active fold-thrust border zones plus the strike-slip faults seen over narrow zones accompanied with reverse sub-faults. This is an example of the complex tectonic behavior of reverse and strike slip faults. The seismic cycle of each fault is an important feature for probabilistic modeling employed for seismic hazard analysis; however rupture on a fault may help to initiate rupture on the adjacent faults even with different sense of motion (Harris et al., 1995). Coseismic rupture studies are mainly realized by teleseismic modeling that usually use segmentation of rupture in time and space (e.g. studies on Rudbar, Golbaf and Zirkuh earthquakes). Slip vectors and velocity fields will reply to some of the questions also. The main features revealed by mechanism solutions are consistent with strike-slip and compressive motions. Around Zagros the reverse solutions are dominant while in Alborz, Kope-Dagh and Central-Iran strike-slip solutions grow in number. Focal depth of earthquakes in Iran are within 5-20 km (upper continental crust), although in the regions associated with subduction (e.g. Makran) one would expect for deeper earthquakes. One of the sharp seismological tools to study seismic sources and related active faults is CMT solutions. Figure 2 shows CMT (Harvard University) solutions obtained for territory of Iran. Seismicity can be regarded as a scale to discuss the temporal and spatial earthquake activities in a region in different scales. One of the tools to provide such discussions is applying the frequency-magnitude (Gutenberg-Richter) distribution to data and to compute the a-value and the b-value of the same formula. The b-value plays a key rule in present seismic hazard study theories and procedures. So in this study the seismicity parameters of the frequency-magnitude distribution have been derived for different zones in Iran.

## 2.0 SEISMICITY PARAMETERS

The Gutenberg–Richter relation (Gutenberg and Richter, 1944) is one of the well known empirical relations in

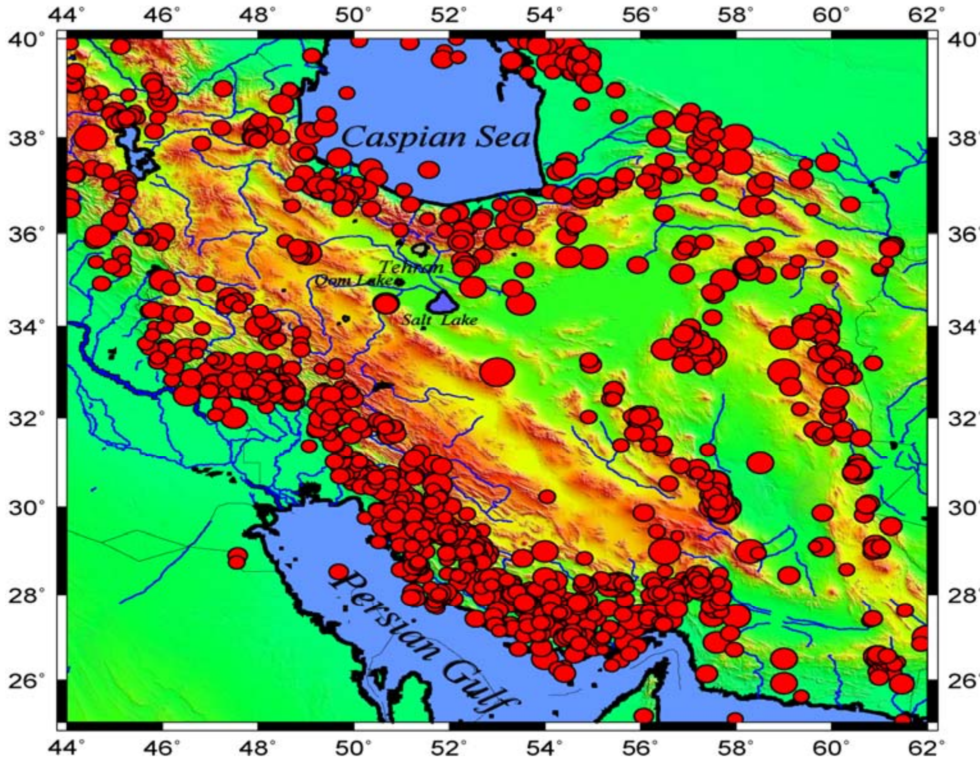


Figure 1 seismicity of Iran.

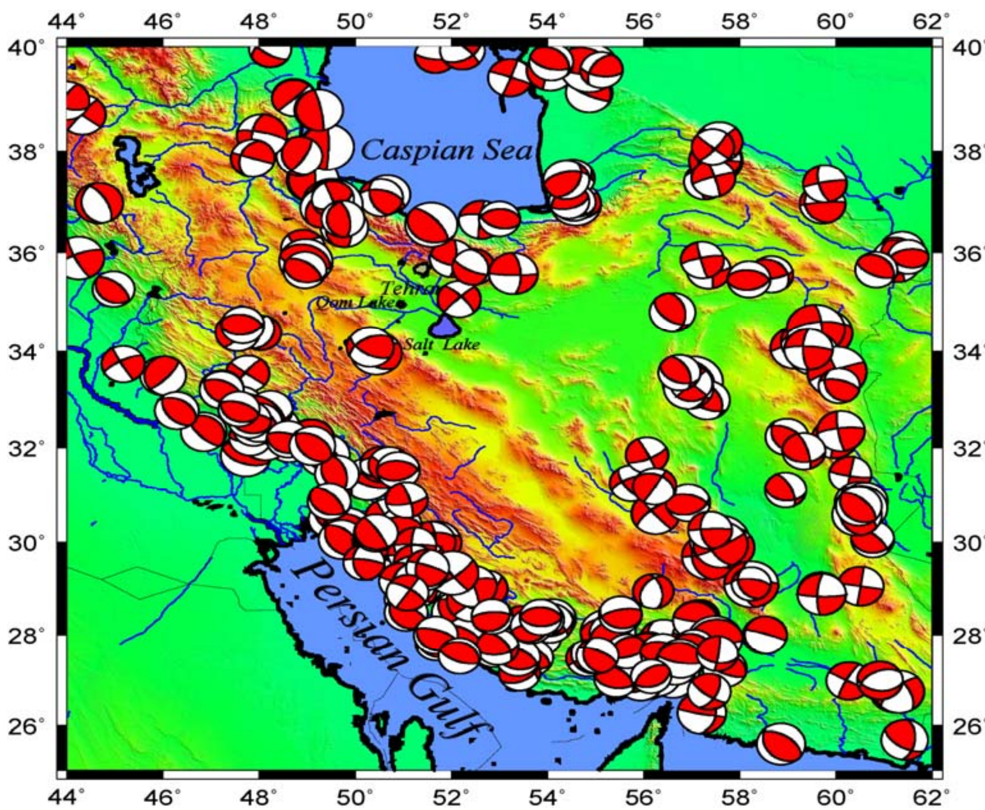


Figure 2 CMT solutions in Iran.

seismology. It presents the frequency of occurrence of earthquakes as a function of magnitude (Eqn. 2.1):

$$\log_{10} N = a - bM \tag{2.1}$$

that $N$ is the cumulative number of earthquakes with magnitude greater than $M$ where a-value (seismic activity) and b-value (size distribution) are constants to be determined. The b-value has been observed to change spatially and temporally. Several studies revealed spatial variations in the frequency-magnitude distribution in different tectonic regimes (Wyss et al., 1997; Wiemer and Wyss, 1997). There are some studies that spatial and temporal changes in b-values were detected prior to large earthquakes, (Murase, 2004; Nakaya, 2006). Material heterogeneity and thermal gradients (Mogi, 1962; Warren and Latham, 1970) may cause changes in the b-values. Wyss et al., 2001, showed that the low velocity zone started around a volume with high b-value in the subducting slab at 140 to 150 km in depth, which may be an indication of magma generation at high b-value anomalies. The b-value in the deep earthquake zones of Alaska and New Zealand is high at 95 km of depth (Wiemer and Benoit, 1996). This observation was interpreted that high pore pressure was due to dehydration in the subducting slab. Therefore, high b-value anomalies may show an area in a descending slab. The low velocity zone in the mantle wedge was thought as a path of magma in the northeastern Japan (Nakajima et al., 2001). Several studies showed that the b-value is different for small and large earthquakes (Hamilton and McCloskey, 1997; Ikeya and Huang, 1997). High and low shear stresses may cause earthquakes with low and high b-values (Wyss, 1973; Schorlemmer et al., 2005). Along the creeping zone of the San Andreas fault, earthquakes have high b-values, maybe because of possibly low stress (high pore pressure). Another observations propose that spatial variation in the b-value of aftershocks is related to the rupture process of the main shock (Bayrak and Ozturk, 2004). Since there are different possibilities for b-value variations it will be difficult to suggest the correct model for anomaly in b-value observations. Almost all seismic hazard studies which reflect in seismic hazard maps rely on the idea of constant b-value, so temporal and spatial variations in the b-value will affect existing seismic hazard maps. However there are suggestions that the b-value is essentially constant (Kagan, 1999).

## 3.0 DATA AND ANALYSIS

Different seismic stations have been installed in Iran as a part of seismic monitoring to help seismic hazard studies. Some three component stations have been installed from the sixties for this purpose. Tehran Station, Tabriz station, Mashhad station and shiraz station are of the first seismic stations in the country. Later the events recorded by the Iranian Long Period Array (ILPA) were also used to study regional seismicity. ILPA was comprised of seven stations equipped with long-period seismometers located southwest of Tehran (Akasheh et al., 1976). This network was not appropriate to study the seismicity around Iran because it just included a 30 km diameter circle area. After the great 1990 Rudbar earthquake, which also shook Tehran, the Institute of Geophysics, University of Tehran started to install new stations in Iran. Since 1996 the new stations have been installed in different provinces of Iran based on digital technology and radio transmission in order to improve the coverage of seismic sources of the country. Each station includes three short period seismometers, digitizer and transmitter. Continuous data is sent by transmitting lines to the central station where they will be time-stamped and a STA/LTA algorithm detect events and record them on the provided storage media. The magnitude scale of the processed earthquakes is Mn. The recorded events of theses stations have been used to study the seismicity parameters in: Alborz, Azarbaijan, Central-Iran, East-Iran, Kope-Dagh, Makran and Zagros. Seismicity parameters have been computed by zmap (Wiemer and Zuinga, 1994). The original catalogue of events (from 1996 to 2007) has been declustered by the method proposed by Reasenberg 1985. Figure 3 show the magnitude distribution of the declustered events. The a-value and the b-value plus the Mc (magnitude of completeness) for each region have been estimated and presented in figures 4, 5, 6, 7, 8, 9 and 10. All the b-values are under one, the maximum b-value belongs to Alborz and the minimum b-value happened in Azarbaijan and the b-values for central-Iran, East-Iran, Kope-Dagh, Makran and Zagros are 0.79, 0.75, 0.88, 0.71 and 0.89 respectively. These values are an indication of abundance of larger earthquakes relative to smaller earthquakes. However it is not possible to precisely discuss the reason of such values. In other words one should consider the temporal evolution of the seismic station coverage in interpretation of these results.

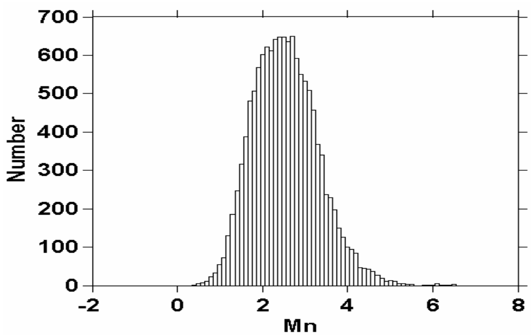


Figure 3 Histogram of declustered earthquakes.

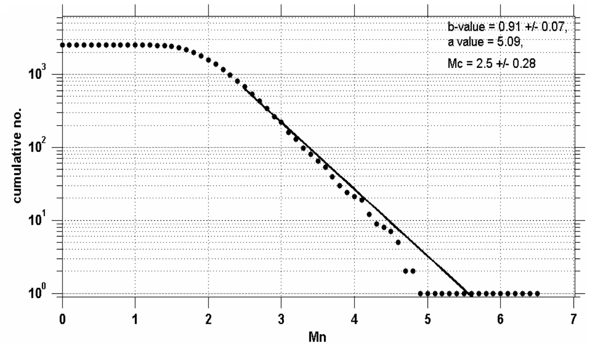


Figure 4 Seismicity parameters in Alborz.

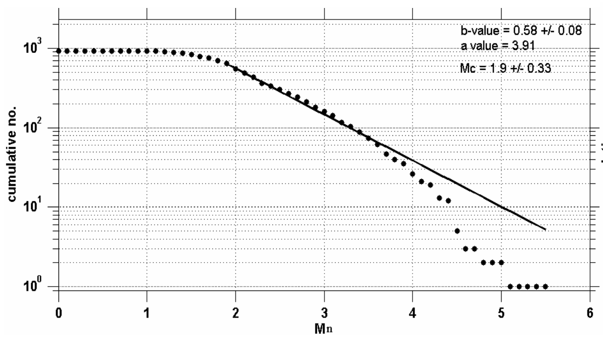


Figure 5 Seismicity parameters in Azarbaijan.

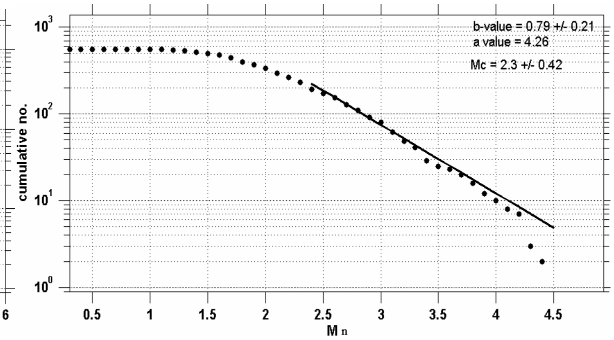


Figure 6 Seismicity parameters in Central-Iran.

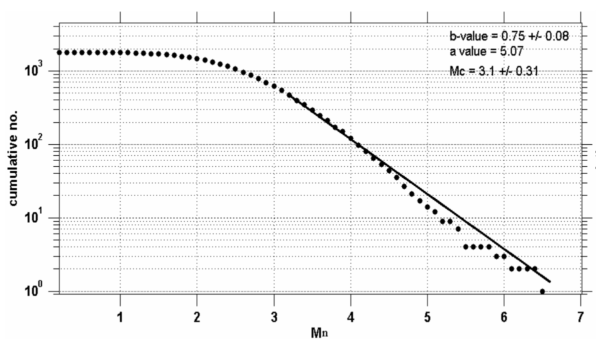


Figure 7 Seismicity parameters in East-Iran.

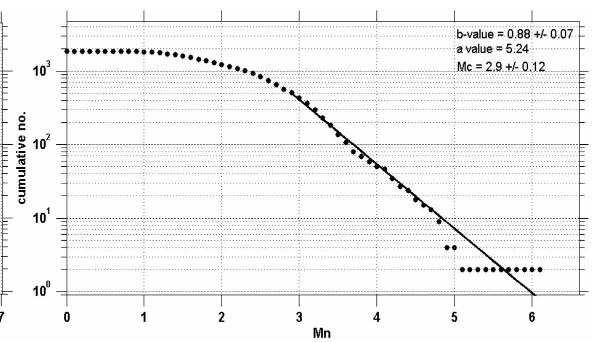


Figure 8 Seismicity parameters in Kope-Dagh.

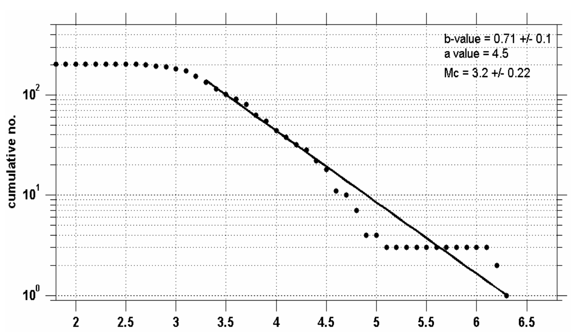


Figure 9 Seismicity parameters in Makran.

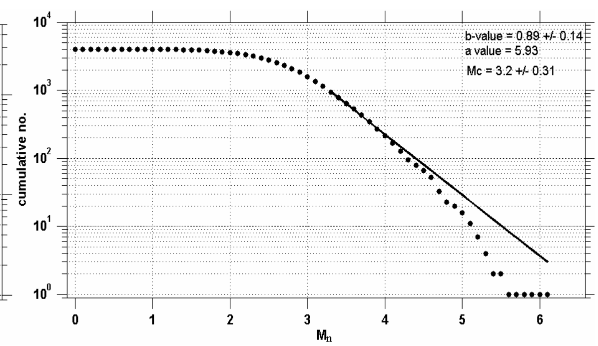


Figure 10 Seismicity parameters in Zagros.

## 4.0 CONCLUSIONS

The b-values in several regions have been computed and presented in this paper. Between the previous studies one can refer to the values derived by Nowroozi and Ahmadi, 1986 (N & A). The values have been compared in table 1. The important difference is in seismic activity (a-values) that N & A values are systematically lower. This can be attributed to the improvement of seismic station coverage in this study, although the regions for two studies are not exactly the same. On the other hand the b-values of this study are higher for Alborz, Central-Iran, East-Iran and Kope-Dagh and lower for other zones.

Table 1 Comparison between seismicity parameters.

| Region | Nowroozi and Ahmadi, 1986 | | this study | |
|---|---|---|---|---|
| | a-value | b-value | a-value | b-value |
| Alborz | 3.6935 | 0.7776 | 5.09 | 0.91 |
| | 1.8490 | 0.4944 | | |
| Azarbaijan (Maku-Zanjan in N & A) | 3.3338 | 0.8191 | 3.91 | 0.58 |
| Central-Iran | 2.4947 | 0.6192 | 4.26 | 0.79 |
| East-Iran | 2.5724 | 0.6321 | 5.07 | 0.75 |
| | 3.1637 | 0.7273 | | |
| Kope-Dagh | 3.5461 | 0.7502 | 5.24 | 0.88 |
| | 1.8506 | 0.4935 | | |
| Makran | 4.5262 | 1.0194 | 4.5 | 0.71 |
| Zagros | 4.8465 | 0.9623 | 5.93 | 0.89 |
| | 4.6752 | 0.9220 | | |

Then for computing seismicity parameters in order to study seismic hazard, it seems that in the light of recent studies new seismotectonic provinces should be introduced first, however this subject has not already been studied thoroughly.

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