Faulting Style and b-Value: A Global Perspective

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Abstract

The b-value in the frequency-magnitude relation provides significant information to understand seismicity, seismotectonics, and seismic hazard analysis. In this study, we investigated the relation between the b-value and faulting style on a global scale. The used data were extracted from the Global Centroid Moment Tensor (GCMT) catalog. The least square fit and maximum likelihood methods were used to calculate the b-value. The obtained results show that thrust, strike-slip and normal-faulting earthquakes, occur in regions of low, intermediate, and high b-values, respectively. Our results are in good agreement with the previous works, and we found that the study scale does not affect the hypothesis of a general relationship between faulting style and the b-values ($b_{normal} > b_{strike\text{-}slip} > b_{reverse}$).

Keywords

b-constant • Normal fault • Reverse fault • Strike-slip • Maximum likelihood

1 Introduction

The distribution of earthquake size follows the power law proposed by Gutenberg and Richter [1] in the form: $Log_{10}N = a - bM$, where N is the cumulative number of earthquakes with magnitude $\geq$M. The *a* and *b* constants describe the seismic activity and the event-size distribution, respectively. The possible relations between the b-value and geophysical parameters were investigated by many authors, such as, material heterogeneity [2], stress state [3], earthquake depth [4], heat flow [5], and with faulting style [6]. The potential relation between the b-value and faulting type was studied on local and regional scales, in California, Japan [6], Italy [7], and India [8]. These studies reported high b-values in normal faulting regions, and intermediate and low values in strike-slip and reverse faulting regions, respectively. The lack of studies at the global scale motivated us to carry out this work. The aim of this study was to investigate the potential relation between the b-values and the faulting type, particularly, pure normal, pure reverse and pure strike-slip faults.

2 Data and Methods

The source of the used data is the Global Centroid Moment Tensor catalog GCMT (http://www.Globalcmt.org/CMTsearch.html). The catalog covers the period from Jan. 1976 to Dec. 2005. We selected only the shallow (depth less than 70 km) pure normal, strike-slip and reverse faults events and excluded the oblique faults events. When selecting earthquakes, we took into account the uncertainties in estimating the rake of slip which represents ±5°. In this study, the fault plane solution of 2575 earthquakes of Mw equals or larger than 5 was used to investigate the relation between the b-value and the faulting type, Fig. 1 Calculating the magnitude of completeness (Mc) of the earthquake catalog was a necessary step for correctly estimating the values of *b* and *a* [9]. There are two methods to calculate the b-value: the Least Square Fit (LSF) and the Maximum Likelihood (ML). In the LSF-method, the log values of the cumulative number of earthquakes (Nc) are plotted against magnitude (Mw). In the ML method, the b-value is estimated using the following equation [10]:

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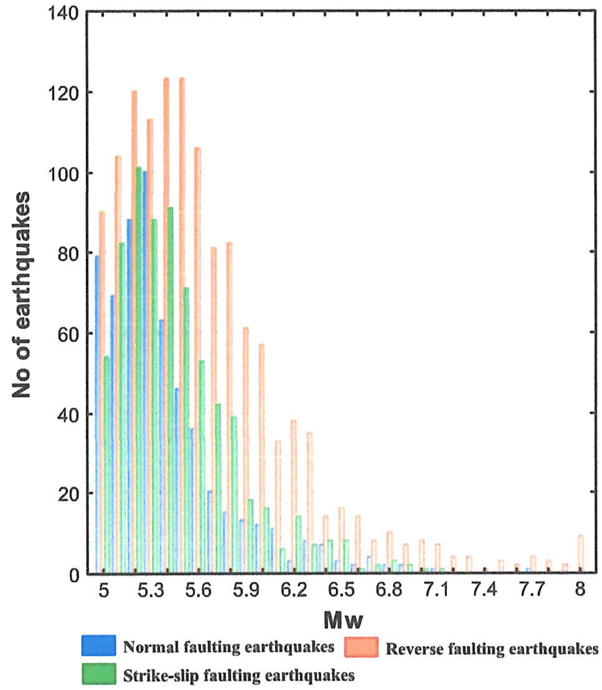

Fig. 1 Number of earthquakes as a function of magnitude

$$b = \frac{\mathrm{Log}_{10}e}{(M_{mean} - M_c)} \quad (1)$$

where M_{mean} is the mean magnitude of a sample of earthquakes with M > Mc, Mc is the magnitude of completeness and $\log_{10}e = 0.4343$. An uncertainty of the b-value is estimated by Aki [10]:

$$\delta_b = \frac{b}{\sqrt{N}} \quad (2)$$

where N is the number of earthquakes. In our study, we used both methods mentioned above to estimate the b-values for pure normal, reverse, and strike-slip faulting earthquakes.

3 Results

The magnitudes of completeness Mc are 5.1, 5.1 and 5.2 for reverse and normal events and strike-slip events, respectively. The b-values calculated by both methods are shown

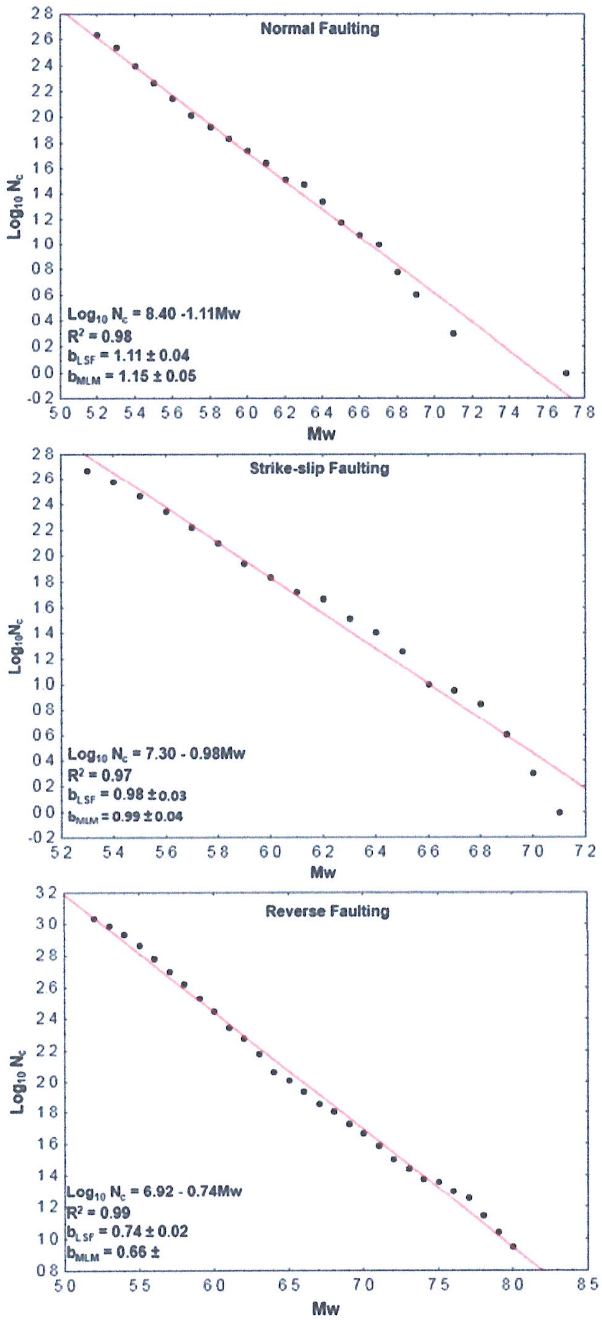

Fig. 2 Frequency-magnitude distribution of different faulting styles earthquakes. b_{LSF} value is calculated by least square fitting, b_{MLM} is calculated by maximum likelihood method

in Fig. 2.The main trend for the derived b-values for the three faulting styles is: $b_{normal\ faulting} > b_{strike\text{-}slip\ faulting} > b_{reverse\ faulting}$. Both calculation methods show the same trend.

4 Discussion

As far as we know, the present study is the first attempt to investigate the relation between b-values and faulting style for a global earthquake catalog. Previous studies investigated the potential relation between b-values and faulting style only on local and regional scales [6–8]. These studies showed that normal faulting events typically show higher b-values, while strike-slip and reverse events have intermediate and low b-values, respectively. Schorlemmer et al. [6] found that the b-value acts as a stress meter, and that it is inversely proportional to the differential stress. Recently, Wu et al. [11] investigated the relation between b-values and crustal stress in a young orogenic belt in Taiwan. They found that high b-values correlate with normal faulting, and intermediate and low b-values correlate with strike-slip and reverse faulting, respectively. In the Mexican subduction zone, normal faulting events occur in high b-value regions while reverse events occur in low b-value regions [4]. Our results are therefore consistent with the linear decrease of the stress state from normal to strike-slip to reverse [6, 7]. Scholz [12] found that b-values decrease linearly with the differential stress in the continental crust. The low b-values reflect high differential stress while high b-values indicate low differential stress.

5 Conclusion

Investigating the relation between different faulting types and b-values for a 30-years long global catalog of earthquakes reveals that reverse faulting is associated with low b-values, while normal and strike-slip faulting are associated with high and intermediate b-values, respectively. We thus found that the scale of the study, whether local, regional or global, does not affect the relation between the b-values and the faulting type. We note that these findings do not depend on the calculation method for estimating the b-values.

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