Correlation between $A_i$ fault parameter and statistical frequency of earthquakes along depth: a case study in Southern California

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Abstract

Using a selected earthquake catalog and focal mechanisms from Southern California, we investigated a connection between statistical and geometric quantities extracted from Gutenberg-Richter law exponents, such as $b$-value and $A_i$, this is a quantification of fault kinematics, closely related to Anderson's fault parameter $A_i$. However, while $A_i$ is calculated from empirical observations, the $b$-value is derived from seismological data. We think that $A_i$ may help us to find an equation to explain $b$-values distributions according to kinematic features and depth. We managed the conditions of SCN selected earthquakes by Hauksson. Ving and Skrami with features from focal mechanisms compiled by the same authors, to obtain a large focal mechanism dataset (from ~5000-8000 upper magnitude values for lessor quality ones), its spatial resolution too sufficient to investigate $b$-values along depth for both well distinguished kinematic classes. We also analyzed how frequency-magnitude relates to the stress field of Southern California, especially comparing results from mostly linear theory to depth ranges against nonparametric $b$-values. We then performed multiple regressions of $b$-value vs $A_i$ at various depth ranges and tested their statistical significance. The equation we found could be formulated as for frequency-magnitude distributions in three-dimensional space, useful for seismic hazard assessment.

Introduction

We define $A_i$ as the magnitude of stress ratio function $\lambda = \frac{\sigma - \sigma_{max}}{\sigma_{max} - \sigma}$. It is related to Andersonian fault parameter $A_i$ (Simpon, 1997), however the former is dependent on rake angles rather than known fault setting in an area like the latter. For the main tectonic regime (dilatant, transversal, reverse) we found three different sets of results: the rake angles of the focal mechanism. We related this quantity to the Gutenberg-Richter law (Gutenberg, 1944): $\log N = a + b \cdot M$ and in particular to its slope $b$ as calculated from Aki's maximum likelihood method (Akaike, 1970). However, the $b$-value is dependent on differential stress ($\sigma - \sigma_{max}$) and its relative magnitude to other stress components. Here, we relate this parameter to the latter's value for $b$-values and we are looking for evidence of its general law under different depth-ranges. We used the idea of a unique $b$-value and $A_i$ distribution, and a critical stress ratio ($\sigma - \sigma_{max}$) for each of these classes.

Fig. 1 (left): modified Dinsmore hypocent with geometric construction of main $A_i$ faults (right): kinematic groups with corresponding rake and $A_i$ values.

Data and $b$-value distributions

B-value dependence on differential stress will be considered (Scholz, 1972) and we assume that the differential stress is a function of the angle of rake ($A_i$). As a result, we define $\lambda$ as the angle of rake ($A_i$) and the angle of the fault plane ($\beta$).

Fig. 2 (left): 3D block diagram of Community Fault Model v. 5.2 and relocated focal mechanisms used in this work.

Fig. 3 (right): Magnitude of completeness in Southern California area.

Fig. 4 (left): weighted probability density function of focal mechanisms, selected by kinematic groups. (Center): weighted cumulative pdf of focal mechanisms. (Right): cumulative released seismic energy. Lines are colored according to kinematic groups: Normal = blue, Bilateral = grey, Reverse = red. Total data = black.

Fig. 5 (right): A vs differential stress at analyzed depths with Lowess surface smoothing.

Fig. 6 (left): histogram of rotation errors of original relocated earthquakes, selected by relocation algorithm.

Fig. 7 (right): $b$-value profiles for each kinematic group. Parameters for calculation are indicated inside bottom box.

Fig. 8: normalized frequency-magnitude distributions and respective completeness and $b$-value for each kinematic group. Left to right: Normal, Bilateral, Reverse, Total.

Fig. 9 (left): $b$-value distribution along depth of all focal mechanisms and linear regression parameters. Dashed line: $b$-values of all focal mechanism irrespective of depth.

$b$-value vs $A_i$ regressions

Several possible models to explain $b$-value vs $A_i$ relation were employed in three different depth ranges (3-7 km, 7-10 km, 10-15 km) and tested using Akaike Information Criterion (AIC). Mc and $b$ uncertainties are calculated by using the equation $\sigma = \frac{1}{\sqrt{2\pi \cdot \text{MC}}}$ of Petruccelli et al. (2019).

Conclusion

Several possible models to explain $b$-value vs $A_i$ relation were employed in three different depth ranges (3-7 km, 7-10 km, 10-15 km) and tested using Akaike Information Criterion, to evaluate if such models to able along depth. $A_i$ vs differential stresses are displayed accordingly within some depth ranges. Lorentz smoothing surfaces of both relation along depths are also displayed.

Fig. 10 (up): block diagram of $b$-value distribution in Southern California with CFM v.5.2. Fig. 11 (middle): block diagram of $b$-value along depth, without dependency from faulting style, for each depth range. Fig. 12 (down): $b$-value in depth diagram in selected regions of Fig. 11.

Fig. 13 (left): $b$-value vs $A_i$ at, as analyzed depths with Lorentz surface smoothing.

Fig. 15 (right): A vs differential stress at analyzed depths with Lorentz surface smoothing.

Table 1: results of regression used in Fig. 14.

References


Petruccelli et al. (2019a, b).}


