THE INFLUENCE OF FAULTING STYLE AND TECTONIC REGIME ON THE FREQUENCY-MAGNITUDE DISTRIBUTION: A GLOBAL SURVEY

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One of the ongoing debates in seismological research concerns the understanding of the frequency-magnitude distribution (FMD) of earthquakes, its potential variations on different scales, and its significance and interpretation. The large amount of publications on FMD reflects the importance of a proper understanding: observed spatial and temporal variations in Gutenberg and Richter (1944) GR relation $b$-value are often interpreted in a seismotectonic context, unraveling a wide range of processes that take place in the Earth’s crust. In fact, evidences from natural seismicity and laboratory measurements suggest an inverse relation between $b$-values and differential stress (Amitrano, 2003; Scholz, 1968, 2015): on local to regional scale, portions of highly stresses crust, like asperity structures, should result in lowering of $b$-value, indicating potential future rupture patches, while low stress zones should result in increasing of $b$-value.

We want to propose a global synoptic picture of earthquakes frequency-magnitude distribution dependence on different tectonic regimes through a map of the GR relation $b$-value. Spatial patterns of $b$-values (higher for extensive and normal faulting regimes, lower for compressive-to-thrust faulting regimes and intermediate for heterogeneous zones) highlight the main global seismotectonic structures (oceanic ridges, subduction zones and continents). Moreover, our global $b$-value data independently distinguishes between previously established (Uyeda, 1982) types of subduction zones: a young, hot, slow-moving, low dipping angle, high buoyant slab (Chilean-type) produces high normal and shear stresses on the plate interface (low $b$-value), whereas an old, cold, fast-moving, high dipping and heavy slab (Mariana-type) produces lower stresses (high $b$-value).

Differences in $b$-value for different tectonic styles are in line with Anderson (1905) theory of faulting: thrust faults are under higher stress with respect to normal faults, with strike-slip lying in
the middle between them. We confirm the general relation of previously reported (Schorlemmer et al., 2005) dependence of $b$-value on rake angle $\lambda$ of focal mechanisms (FMs): maximum and minimum $b$ are found for normal ($\lambda \sim -90^\circ$) and thrust ($\lambda \sim 90^\circ$) mechanisms respectively, even with smaller subsets of selection. However, as would be expected from Anderson (1905) theory of faulting, different fault orientations within thrust and normal regimes might influence $b$-value behavior, since thrust faults dip less with respect to normal faults. We firstly detect such variations into a plunge-based ternary representation (Fröhlich, 1992) of FMs, mostly in the normal-thrust parts of the diagram. Then, we combine the ternary analyses of $b$ with analytical fault modeling and provide a new relation of $b$-value with differential stress to be applied for dip-slip fault modeling.

Our findings provide a supplementary set of strong evidences for $b$-value dependence on state of stresses combing fault modeling and new data analyses technique: the remarkable consistency between the systematic $b$-value patterns and the well-known global tectonic features reflects theoretically expected stress differences in all considered details. We think that our results significantly improve the credibility that well assessed $b$-value variation is meaningful for physical interpretations and for seismic risk assessments.

References