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EARTHQUAKES AND SCALE-INVARIANCE

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Abstract. We propose that the widely observed and universal magnitude-frequency Gutenberg-Richter relation or the Pareto distribution of seismic moment is a mathematical consequence of the critical branching nature of earthquake process in a brittle fracture environment. These arguments are confirmed by recent investigations of the seismic moment distribution in global earthquake catalogs and by the results on the distribution of dislocation avalanche sizes in crystals. Whereas in study of crystal avalanches initial conditions are under control of an experimenter, the geometry and mechanical properties of earthquake fault zones are the result of self-organization into a critical stationary state. To confirm this, we consider possible systematic and random errors in determining earthquake size, especially its seismic moment. These effects increase the estimate of the parameter β of the power-law distribution of earthquake sizes. In particular, we find that estimated β-values may be inflated because the relative moment uncertainties decrease with increasing earthquake size, earthquake clustering, complexity of any earthquake source and influence of earthquake depth distribution. Taking all these effects into account, we propose that the most accurately determined β-value of 0.63 could be reduced to about 0.52–0.56; i.e. close to the universal constant value (1/2) predicted by theoretical arguments. We also consider possible consequences of the universal β-value and its relevance for the theoretical and practical understanding of earthquake occurrence in various tectonic and Earth structure environments. Simple considerations of the finiteness of seismic moment flux require that the Pareto relation be modified at the large size end of the moment scale. This problem is generally solved by tapering the distribution using an by additional parameter usually called the *corner* moment (M_c). We suggest that similar to the results obtained in study of crystal dislocation avalanches, plastic flow of rocks is due solely to brittle deformation by earthquakes with constant universal exponent $\beta = 1/2$ but with varying corner moment. Recent studies of earthquake size distribution obtained by Inbal *et al.* (Science, 2016) also suggest that small earthquakes occur in the upper mantle but their corner moment is small. Using earthquake data and comparative crystal deformation results may help us understand the generation of seismic tremors and illuminate the transition from brittle fracture to observations of plastic flow.