Geophysical Research Abstracts
Vol. 15, EGU2013-7617, 2013
EGU General Assembly 2013

Fracture and earthquake physics: Modeling precursory phenomena in a non-extensive statistical physics view.

Filippos Vallianatos

Technological Educational Institute of Crete, Laboratory of Geophysics and Seismology, Chania, Crete, Greece (fvallian@chania.teicrete.gr)

Understanding the physics of cracking and deformation is critical for understanding seismic activity in the earth. Each of these phenomena involve complex physical processes over a range of length scales from atoms to tectonic plates. Recent advances in physics, mechanics, materials science, seismology and solid earth geophysics are not often communicated across disciplines. This review will bring together a diverse interdisciplinary part of science to explore the physical processes that control deformation and rupture at all scales from laboratory results to field observations. The generation of transient electric current along with the appearance of acoustic emissions (AE) prior to rupture has been demonstrated in a number of laboratory experiments involving both dry and wet rock specimens. Herein we focus on a promising effect that is ubiquitous during brittle rock failure: the motion of charged edge dislocations (MCD) during crack opening and propagation (microfracturing). The emitted current appears very intense and non-linear just prior to failure, where massive crack propagation implies massive MCD processes. The origin of the PSC would be massive crack formation and propagation, which in the case of earthquakes is expected to be a short-lived process at the terminal phase of the cycle. Observable macroscopic ULF field would be generated by the superposition of fields generated by multiple simultaneous individual cracks and would evolve in correspondence with the crack propagation process.
Recently statistical physics has a remarkably successful work record in addressing the upscaling problem in earth physics. It is natural then to consider that the physics of an ensemble of fractures has to be studied with a different approach than the physics of a single fracture and in this sense we can consider the use of statistical physics not only appropriate but necessary to understand the collective properties of fracture processes. Since disorder and long-range interactions are two of the key components of fracture, we use a current generalization of Boltzmann-Gibbs (BG) statistical physics due to Tsallis, referred as non-extensive statistical physics (NESP), to explore the frequency –size distribution of fractures. The advantage of considering the Tsallis distribution is that, based on the principle of entropy, it can be related to statistical mechanics and reduces to the traditional BG statistical physics as a special case. Fracture involves phenomena such as fractality, long range interaction and memory effects. It is precisely such phenomena that constitute the scope of non-extensive statistical mechanics. On assuming a NESP expression of the scaling between frequency and geometrical size of fracture we show that at some distance r from the zone, the electric field and the magnitude of the earthquake are scaled. This indicates that electric and magnetic earthquake precursors may obey scaling laws that are direct consequence of the non extensive distribution of their generators and also implies that transient precursors may result from microfracturing and fragmentation processes in the earthquake preparation zone.
All the above are discussed in analogy with acoustic emissions observation, as analysed in the frame of natural time. Acoustic emissions exhibit complex correlations between space, time, and magnitude and as such they present a unique example for a complex time series. Applied the recently introduced method of natural time analysis, which enables the detection of long-range temporal correlations even in the presence of heavy tails, we find that the acoustic emissions exhibits features similar to that of the worldwide seismicity as presented in the Centennial earthquake catalogue which includes global seismicity event with magnitude Mw>7.0.

Acknowledgments. This work was supported by the THALES Program of the Ministry of Education of Greece and the European Union in the framework of the project “SEISMO FEAR HELLARC".