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Statistical physics characterization of the frequency-magnitude distribution and its spatial variability in the Yellowstone volcano-tectonic system

Kalliopi Chochlaki (1,2), Georgios Michas (1,2), Filippos Vallianatos (1,2)

(1) UNESCO Chair on Solid Earth Physics and Geohazards Risk Reduction, Technological Educational Institute of Crete, Chania, Greece. (gmichas@hotmail.com), (2) Laboratory of Geophysics and Seismology, Technological Educational Institute of Crete, Chania, Greece.

The Yellowstone National Park is a supervolcano with a rich hydrothermal system that consists of more than 10.000 thermal features and presents extensive seismic activity. In order to analyze seismicity, the Gutenberg-Richter's law is widely used, proposing that the energy distribution of earthquakes leads to a power law approximation. Recently, the frequency-magnitude distribution is studied inside the framework of Non-Extensive Statistical Physics, introduced by Tsallis (1988, 2009) utilizing the fragment-asperity model, as modified by Telesca (2012), which represents an evolution of the Gutenberg-Richter's law within the Statistical Physics framework. This model describes earthquake dynamics in a non-extensive content, taking into consideration the memory effects that such a complex system presents and the existence of long range interactions among the earthquakes. It has been applied to several earthquake catalogs (e.g., Michas et.al, 2013; Vallianatos et al., 2016) and volcano related seismicity (Vallianatos et al., 2013) describing the energy distribution over wider range of magnitudes than the G-R law, which above some threshold magnitude can be considered as a particular case. Due to crustal heterogeneities, volcanic areas are not characterized by a unique frequency-magnitude distribution but several variations are observed, mostly in the vicinity of magma chambers and in areas where release of magmatic gases is noticed. For this reason, the frequency-magnitude distribution was spatially mapped throughout the Yellowstone volcanic area for the period of 1996 to 2016 in order to analyze the variation of the entropic index qE, which characterizes the asymptotic power-law regime of the distribution and thus the proportion between smaller and larger size earthquakes. Then we investigate its correlation with the innumerous hydrothermal processes that take place inside the Yellowstone area. Detailed mapping of the frequency-magnitude distribution can inform us about the plumping system of a volcano and improve our understanding of the dynamics and the geothermal processes that take place in active volcanic areas.

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