Power laws in volcanic systems

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Volcanoes constitute dissipative systems with many degrees of freedom. Their eruptions are the result of complex processes that involve interacting chemical-physical systems. At present, due to the complexity of involved phenomena and to the lack of precise measurements, both analytical and numerical models are unable to simultaneously include the main processes involved in eruptions thus making forecasts of volcanic dynamics rather unreliable. One characteristic seems to join most of volcanic phenomena, and it is their power-law distribution. In fact, many geophysical processes associated with volcanoes give rise to power-law size distributions, from involved geometries [3] to gas emission rates [1], through volumes of erupted materials [4] and eruption durations [2]. Power-law distributions indicate that besides a large number of small entities the considered process shows a small number, but not as small as expected, of large entities of the same type. Power-law relationships in natural systems are relevant because they have some intriguing features. They are scale free and thus have the same statistical properties at any scale and are not associated with one characteristic scale. In practice, this means that there is no single correct scale for their analysis because the same principles are valid irrespective of the temporal, spatial or strength scale of analysis, and also makes it technically wrong to apply traditional statistics based on variance and standard deviation (such as regression analysis) when dealing with power-law distributed phenomena. The power-law systems share the concept of "universality": it has been shown that completely different systems show similar power-law behaviour on approaching a critical state. Moreover, the indication of a power-law behaviour in some data cannot only explain specific kinds of dynamics that might govern the particular natural phenomenon, but, thanks to the universality, may also indicate a deep connection with other, apparently unrelated systems. While power-law distributions have received great attention in recent decades, the mechanisms behind them are still hardly debated, crossing self-organized criticality process to self-similar stochastic process described by exponential dispersion models. Here we will summarize the evidences of power law hypothesis for different aspects of volcanic systems, highlighting the possible consequences of such an assumption.

Keywords: Power Laws, Eruptions, Volcanic Dynamics.

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