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A cellular automaton model for the rise of magma

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Eruptions of volcanoes are complex natural events highly variable in size and time. Over the last couple of decades, statistical analyses of erupted volume and repose time catalogues have been performed for a large number of volcanoes. The aim of such analyses is either to predict future eruptive events or to define physical models for improving our understanding of the volcanic processes that cause eruptions. In particular, for this latter purpose we study a statistical model of eruption triggering caused by the fracturing of the crust above a magma reservoir residing in the crust. When the fracturing reaches the reservoir, magma is allowed to ascend because of its buoyancy. It will be found in batches along the transport region and it will ascend as long as fractures are developed to its tip; when a path is opened to the surface, an eruption occurs involving all batches connected to the opening.

We model the vertical section of a volcanic edifice by means of a two-dimensional grid and characterize the state of each cell of the grid by assigning the values of two dynamical variables: a time dependent variable e describing the status of the local stress and a time-dependent variable n describing the presence of magma. At first step of approximation, we treat the magma presence field n as a diffusing lattice gas, and, therefore, we assume its value to be either zero or one if the corresponding cell is empty or filled by magma, respectively. We study the probability distribution, P(V), of eruptions of volume V and the probability distribution, P(t), of inter-event time t and find that the model is able to reproduce, at least in a descriptive way, the essential statistical features of the activity of volcanoes.

A key component of magma is the quantity of dissolved gas as it gives magma its explosive character, because the volume of gas expands as the pressure decreases on raising towards the surface. Then, to more accurately describe the rise of magma in a volcanic structure, we have introduced in our model the presence of dissolved gas in the liquid. We relax the previous approximation made on the magma presence field n and treat it not as a step function, but as a continuous function, whose values reduce when pressure decreases as magma rises towards the surface. In particular, we focus on the modeling of Mt. Somma-Vesuvius volcano and, therefore, we consider basaltic magmas.