Seismic Precursors to Eruptions at Volcanoes in Extensional Stress Fields

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Volcano-tectonic (VT) seismicity is one of the most common precursors detected before volcanic eruptions. Previous studies have focused on quantitative analysis of precursory VT trends at volcanoes in compressional background stress fields, such as subduction zones. Using data from Mt Etna, in Sicily, we here extend analyses of VT behaviour to volcanoes in extensional background stress fields.

Before andesitic-dacitic eruptions at subduction-zone volcanoes, accelerations in VT event rate appear to evolve from early exponential trends, that may develop over several months, to a change that is faster than exponential (FTE) with time. The FTE trend tends to follow a hyperbolic increase (similar to an inverse-Omori trend) and can develop 10-14 days before eruption. In comparison, analysis of Etna´s flank eruptions of alkali basalt between 1977 and 2008 show that accelerations in precursory VT event rate preferentially change from initial exponential increases, over intervals of weeks, to FTE trends less than two days before eruption. FTE trends are thus strong indicators that an eruption may be imminent. However, although they may potentially provide warning times of days at subduction-zone volcanoes, analogous times are reduced to hours on Etna.

From their common occurrence, we propose that the exponential trends are related to an increase in the amount of damage around a volcano´s feeding system, caused by increases in magmatic pressure or by a local increase in tectonic extension. We further relate the abrupt nature of Etna´s FTE trend to the tensile propagation of a magma-filled fracture from a magma body to the surface. Propagation occurs when the damage accumulated around the magma body exceeds a critical value. The VT sequences, however, do not always culminate in an eruption. In such cases, fracture propagation must be halted underground by local stress barriers or by a decrease in the pressure gradient driving magma along the fracture. Even with a comprehensive model of precursory fracturing, therefore, eruption forecasts will be associated with an uncertainty due at least to a lack of knowledge of material heterogeneities and of local stress distributions in the crust along the path of a propagating fracture.