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Seismic Precursors to Eruptions at Volcanoes in Extensional Stress Fields

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Quantitative analyses of seismic precursors to volcanic eruptions have focussed on volcanoes in compressional background stress fields at subduction zones. We here use the results from new laboratory rock-fracture experiments on alkali basalt from Mt Etna, in Sicily, to extend studies to volcanoes in extensional stress fields.

Sequences of volcano-tectonic (VT) earthquakes before flank eruptions on Etna can develop over months-years, during most of which the cumulative number of events increases exponentially with time. To recreate field conditions, we used the fault jog method to generate an extensional stress. Two parallel slots, 2 mm wide, were cut at 30° to the axis in cylindrical samples, 40 mm across and 110 mm long. The perpendicular offset between slots was held at 10 mm, but the slot overlap was varied from 0 to 10 mm. Water saturated samples were deformed under triaxial stress at a strain rate of $10^{-5}s^{-1}$, 60 MPa confining pressure and 20 MPa pore fluid pressure. Axial strain, volumetric strain and the number of acoustic emissions (AE) and their energy were measured as proxies for the accumulation of crack damage within each sample.

Our first results show exponential increases with time in the cumulative number of AE events (analogues of VT events). The trends are consistent with a new theoretical model for which the exponential trend is characterised by the energy stored in the atomic structure at absolute temperatures and confining pressures above zero. The characteristic stored energy can be calculated knowing the rock composition, temperature and confining pressure. In our experiments, the exponential trends yield values for the characteristic stored energy of 28-36 MJ m^{-3}. These compare well with the calculated values of 32 (+/- 20%) MJ m^{-3}. The good agreement suggests that field precursors can be used as a basis for deterministic forecasts of eruptions.