Coupled geodetic and volcano-tectonic precursors to eruptions

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The two precursory signals most commonly recorded before eruptions are increases in the rate of ground deformation and the rate of occurrence of local volcano-tectonic (VT), or microseismic, earthquakes. A popular expectation is that both parameters will accelerate with time during a precursory sequence. The behaviour of each parameter is thus typically analysed as an independent time series and changes in the rates are used to evaluate whether an eruption is imminent.

Although rates of precursory VT events commonly accelerate with time throughout a precursory sequence, the accompanying rates of ground deformation more usually tend to approximately constant values and may accelerate only during the final stages of the sequence (e.g., Refs. 1 and 2). A constant rate of ground deformation, therefore, cannot be used to indicate a stable change in a magmatic system. Indeed, geodetic and seismic changes are directly coupled: whereas ground movement measures total deformation (e.g., elastic and inelastic), microseismicity is a proxy for the inelastic component of deformation due to fracturing. The conditions for bulk fracture are determined by the amount of damage accumulated in a rock and so are related to the proportion of total deformation caused by fault movement. As damage proceeds, inelastic deformation contributes an increasing proportion to the total deformation and, hence, the corresponding VT event rate accelerates (Ref. 3). Even though deformation rate alone may have limited application for forecasting eruptions, its behaviour with time determines the contemporaneous accelerations in VT event rate that may, in turn, constrain deterministic forecasts of eruptions.

Recent theoretical studies suggest that the amount of damage, measured by the total number of VT events, follows an exponential increase with total deformation until shortly before eruption, at which stage the two parameters may increase in proportion to each other (Ref. 3). To obtain greater insight into how damage accumulates in the crust, therefore, future monitoring strategies should be designed to analyse changes in VT event rate with the rate of ground deformation, in addition to recording how the individual rates vary with time.

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