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Forcasting vent location by probabilistic inversion of volcanic edifice stresses

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Volcanoes may erupt dominantly at their summit or on their flanks, depending on a number of reasons including edifice shape, magma composition, tectonic setting. At calderas, which lack a summit to focus ascending magma, eruptive vents are often scattered within or around the caldera rim, distributed in patterns that may have shifted over the history of the volcanic complex. The scattered nature of vent patterns means that volcanic hazards affect vast areas; forecasting the future vent opening location are a necessary input to hazard models. Generally, forecasts are produced in a data-driven way, based on the distribution of previous vents. However, the small number of vents on which to rely on, their low spatial density and any shift of vent patterns in time make forecasting of future vents difficult to asses.

Here we show that magma pathways, and thus future vent locations, may be forecasted based on the physics of magma transport by dyking, whose propagation direction is controlled by stresses. We combine stress-controlled trajectory simulations with a Monte Carlo inversion scheme for the stress history of the volcano, constrained by the location of past vents, to define a probabilistic stress model for the volcano. Trajectories and vent location for future eruptions can then be forecast based on such probabilistic stress model.

We apply our new approach on Campi Flegrei (Italy). We find that observed shifts in vent patterns are controlled by a delicate balance between regional/local stresses and the stresses induced by surface loads (including topography and volcanic deposits), which at most volcanoes varies in time due to eruptive activity. The resulting stress balance governs the curvature of the trajectories of ascending dykes and thus the location of future vents. Our method offers a mechanical explanation for the vent clustering and migration observed over the successive eruptive epochs at Campi Flegrei.

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