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How caldera collapse shapes the shallow emplacement and transfer of magma in active volcanoes

Fabio Corbi (1), Eleonora Rivalta (1), Virginie Pinel (2), Francesco Maccaferri (1), Marco Bagnardi (3), and Valerio Acocella (4)

(1) GFZ German Centre for Geosciences, Section 2.1, Telegrafenberg, 14473 Potsdam, Germany., (2) ISTerre, Université Savoie Mont-Blanc, IRD, CNRS, Campus Scientifique, Le Bourget du Lac F73376, France., (3) COMET, School of Earth and Environment, University of Leeds, Leeds LS2 9JT, UK., (4) Dipartimento di Scienze, University of Roma Tre, L. S.L. Murialdo, 1, 00146, Rome, Italy.

Calderas are topographic depressions formed by the collapse of a partly drained magma reservoir. At volcanic edifices with calderas, eruptive fissures can circumscribe the outer caldera rim, be oriented radially and/or align with the regional tectonic stress field. Constraining the mechanisms that govern this spatial arrangement is fundamental to understand the dynamics of shallow magma storage and transport and evaluate volcanic hazard. Here we use numerical models to show that the previously unappreciated unloading effect of caldera formation may contribute significantly to the stress budget of a volcano. We first test this hypothesis against the ideal case of Fernandina, Galápagos, where previous models only partly explained the peculiar pattern of circumferential and radial eruptive fissures and the geometry of the intrusions determined by inverting the deformation data. We show that by taking into account the decompression due to the caldera formation, the modeled edifice stress field is consistent with all the observation. We then develop a general model for the stress state at volcanic edifices with calderas based on the competition of caldera decompression, magma buoyancy forces and tectonic stresses. These factors control the shallow accumulation of magma in stacked sills, consistently with observations as well as the conditions for the development of circumferential and/or radial eruptive fissures, as observed on active volcanoes. This top-down control exerted by changes in the distribution of mass at the surface allows better understanding of how shallow magma is transferred at active calderas, contributing to forecasting the location and type of opening fissures.