Elasto-Plastic FEM Models Explain the Emplacement of Shallow Magma Intrusions in Volcanic Complexes

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Abstract

We present numerical models and field data that aid understanding of volcano-tectonic processes related to the propagation of inclined sheets and dykes under a stress field resulting from the inflation of a shallow magma chamber. Structural field data from the classical Cuillins cone-sheet complex (Isle of Skye) show that sheets have a constant average dip angle (45°), with pure dilational or hybrid shear-dilational kinematics. A transition to radial dykes occur over a critical distance from the axis of the volcanic complex. Our 2D axial-symmetric and 3D elasto-plastic finite element models, which consider the total stress field including gravity, tectonics and magma overpressure, suggest that only in the case of an inflating oblate shallow magma chamber cone-sheets can develop. They are not predicted with spherical or prolate magma chambers and/or under deflation. Cone-sheets are predicted immediately above the magma chamber, whilst radial dykes dominate beyond a critical distance of 1-1.2 diameters of the chamber. These results may be used to infer, from observations on the sheet and dyke pattern at surface, the geometry and tensional state of magma chambers under active volcanoes. We will conclude showing examples from Fernandina (Galapagos) and Ascraeus Mons (Tharsis Rise, Mars), where this concept has been applied to infer the deep structure and dynamics of large volcanoes.

Reference

1. Bistacchi A., Tibaldi A., Pasquarè F.A., Rust D., 2012. The association of cone sheets and radial dykes: data from the Isle of Skye (UK), numerical modelling, and implications for shallow magma chambers. Earth and Planetary Science Letters. DOI: 10.1016/j.epsl.2012.05.020.