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# Are dykes just filled hydraulic fractures? - Inelastic deformation and emplacement mechanisms of igneous tabular intrusions

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Igneous tabular (sheet) intrusions such as dykes, sills and cone sheets, are fundamental elements of volcanic plumbing systems, as they represent the dominant pathways for magma transport and the main feeders of volcanic eruptions. When magma is intruded in the Earth's crust, it makes its space by pushing and breaking the host rock, which can result in intense inelastic damage and fracturing. To understandand quantify the distribution of such intrusion-induced deformation patterns *in the host rock* is thus essential to resolve magma emplacement dynamics.

Sheet intrusions with their low thickness-to-length aspect ratios, resemble fractures. Based on this resemblance, tabular intrusions have been expected to form like (hydraulic) fractures propagating as tensile cracks with sharp and pointy tips, and assuming purely elastic deformation of the host rock. Even if some field observations support this theory, there is growing evidence that other mechanisms, involving significant inelastic deformation of the host rock, accommodate dyke and sill emplacement.

This contributionprovidesa summary review onthe role of inelastic deformation on the emplacement of tabular intrusions. (1) Field observations show that intrusion tips can be rounded, blunt, and the host deformation accommodating their propagation exhibits inelastic, compressional deformation, in drastic contradiction with theoretical predictions. (2) 3D and 2D laboratory experimentsof magma emplacement in a cohesive Mohr-Coulomb crusthighlightthat magma-induced inelastic deformation, in the form of shear damage and faulting, are first-order transient mechanical precursors for the propagating magma. In addition, these experiments show that the cohesion and friction properties of the model host rock are first-order parameters controlling the formation of intrusions of various shapes, including dykes, plugs, cone sheets, sills and laccoliths. (3) Elasto-plastic numerical models highlight that shear failure is the dominant mechanism to accommodate intrusion growth as soon as heterogeneities are introduced. We conclude that heterogeneities within the host-rock may locally "seed" shear faults ahead of the magmatic intrusion in the propagating direction, in good agreement with field observations. Given that rocks are naturally heterogeneous at multiple scale, these models suggest that shear failure is likely to be a common mechanism for accommodating magma propagation.

Overall, our field observations andmodelresultsshow that the brittle Coulomb properties of rocks, and their heterogeneities,must be accounted for revealing the nature and distribution of fractures and inelastic damage accommodating the emplacement of igneous tabular intrusions.