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The dilatant-compactant transition in edifice-forming andesites

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While the mechanical behaviour of rock is often classified as brittle or ductile, ductile behaviour, defined simply as the capacity of a material to deform to a substantial strain without the tendency to localise the flow into faults, can be the result of a variety of microstructural deformation mechanisms, including microcracking (in the case of cataclastic flow); the description of ductility holds no mechanistic connotation. However, due to instances of compaction localisation, and that ductile behaviour can be driven by microcracking (i.e. brittle on the microscale), we have simplified our classification of the failure mode of rock to "dilatant" and "compactant".

The failure mode of lava—dilatant or compactive—depends on the physical attributes of the lava, primarily the porosity and pore size, and the conditions under which it deforms. The failure mode for edifice host rock has attendant implications for the structural stability of the edifice and the efficiency of sidewall outgassing of the volcanic conduit. In this contribution we present a systematic experimental study on the failure mode of edifice-forming andesitic rocks (porosity from 8 to 25%) from Volcán de Colima, Mexico. The experiments show that, at shallow depths (< 1 km), both low and high porosity lavas dilate and fail by shear fracturing. However, deeper in the edifice (> 1 km), while low porosity (< 10%) lava remains dilatant, the failure of high porosity lava is compactive and driven by cataclastic pore collapse. Although inelastic compaction is typically characterised by the absence of strain localisation, we observe compactive localisation features in our porous andesite lavas manifested as planes of collapsed pores.

In terms of volcano stability, faulting in the upper edifice could destabilise the volcano, leading to an increased risk of flank or large-scale dome collapse, while compactive deformation deeper in the edifice emerges as a viable mechanism driving volcano subsidence and destabilising volcano spreading. The mode of failure influences the evolution of rock physical properties: permeability measurements demonstrate that a fracture increases the permeability by about factor of two, and that compaction to an axial strain of 4.5% reduces permeability by an order of magnitude. The implication of these data is that sidewall outgassing may therefore be efficient in the shallow edifice, where rock can fracture, and impeded deeper in the edifice due to compaction. The explosive potential of a volcano may be subject to increase over time if the progressive compaction and permeability reduction cannot be offset by the formation of permeable fracture pathways in the upper edifice. The mode of failure of the edifice host rock is therefore likely to play an important role in dictating lateral outgassing and thus eruption style (effusive versus explosive) at stratovolcanoes.