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Elastic dilation and plastic shear failure around three dimensional inflating magma reservoirs

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Volcanic eruptions are partly controled by the elasto-plastic state of the bedrock surrounding a crustal inflating magma chamber. We present here three-dimensional numerical models of elasto-plastic (time-independent) shear failure and study the influence of cylindrical, oblate, spherical and prolate magma chamber geometries. Also, we document model results obtained from including or excluding the gravity term and the internal angle of friction in order to assess the implication of these parameters often discussed when fitting geodetic data from monitored volcanic areas. We illustrate the full elasto-plastic deformation evolution of the system for increasing internal overpressures and show how plastic domains develop in diffuse or localized deformation patterns.
For (2D) cylindrical chambers, shear failure develops forming two connecting plastic domains from the surface and from the chamber wall, via localised shear bands. Around spherical and prolate chambers, these two plastic domains rather form diffuse cones. Contraction surrounding prolate chambers promotes dike failure at the apex. For oblate symmetrical chambers, shear bands initiate at the elongated horizontal tip and bend back towards the center and the surface, different from 2D geometries where shear bands connect the tip directly to the surface. In contrast, for oblate asymmetrical chambers, shear bands form in their cylindrical section and vanish along their elongated direction. Diffuse elastic dilation at their tip may enhance pore connectivity there, suggesting that magmatic fluids may migrate there through the pore space, either extending laterally the magma chamber itself or combining with bedrock plastic failure nearer to the crest and to the surface, forming alternating patterns of magma migration toward the surface. These results are briefly discussed in comparison to the Laguna del Maule inflating volcanic system and the Torres del Paine pluton, Chile.