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Elasto-plastic localised shearing and diffuse dilatation modeled around a 3D inflating magma chamber

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A three-dimensional numerical model of failure around an upper crustal magmatic chamber is presented, by applying an increasing magmatic pressure at the chamber walls. In a cylindrical geometry (equivalent to 2D plane strain), the failure domain develops first from the surface downwards then from the chamber wall upwards, and these two zones connect with increasing pressure to form a pair of connected conical blocks consistent with plastic slip line theory. In contrast in a spherical chamber, shear failure initiates and develops from the chamber's crest towards the surface, no localised shear band develops at depth, the plastic domain remains diffuse. However at the surface radial elliptic outwards patterns develop. Localised shear zones do not develop at depth in prolate chambers either. In turn in oblate chambers, shear bands develop above the central vertical axis, similarly to 2d patterns, and vanish progressively along the horizontal elongated axis. At the edge of the horizontal elongated axis outside the chamber, tensile domains develop due to the extra vertical pull induced there by the internal overpressure. The critical internal pressure for bedrock failure is, as in 2D, dependent on the state of internal fluid pressure within the bedrock, that reduces the depth-dependent component of the Coulomb yield stress. This critical overpressure and the onset of failure is compared with previous studies on the dependency on chamber shape. Furthermore from the stress field distribution, one can infer that magmatic fluids propagate out of the chamber in competition either along the sub-vertical shear zones connecting to the surface, or laterally as they flow within the deeper lateral dilation zones where porosity is created. Lateral propagation of magmatic fluids is thus favored in the case of oblate chambers, as opposed to prolate chambers where porosity is reduced by compressional stresses along the vertical walls, and thus where vertical flow (eg. diking?) is favored.