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Internal overpressure and bedrock fluid-pore pressure conditions for failure around an inflating magmatic chamber: insight from hydromechanical elasto-plastic models

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We show from analytical and numerical elasto-plastic models, that internal overpressure in an idealized circular magmatic chamber embedded in the gravity field needs to raise well above the rocks tensile yield strength in order for failure to initiate at the chamber's wall. Then, shear failure occurs since the Mohr-Coulomb yield stress is achieved prior to the tensile threshold. As demonstrated in more detail in a companion contribution, modeled pressure thresholds and shear band geometries are comparable to conventional results obtained in tunneling engineering plasticity. Only when a high pore-fluid pressure state is present in the surrounding bedrock, is mode I tensile failure initiating from the chamber's walls associated to an internal overpressure close to the rocks tensile strength. We explore the effects of pore-fluid pressure in the pore space by two-way coupling of stress and deformation via evolution of the bedrock porosity. Our hydromechanical models indicate that the initial rock porosity near the chamber wall is a key parameter that strongly influences the change in fluid pressure, volumetric strain and effective normal stress, and, consequently, the initiation and propagation of shear failure. We show that a rock with a low porosity is more prone to fail, with changes in fluid pressure being able to generate additional deformation with respect to simply mechanical models. These results provide insight into how failure evolves in time and space around a volcanic chamber or an intrusive body, and how ground surface deformation related to volcanic inflation may be misinterpreted when plasticity and hydromechanics are not accounted for.