EGU24-13606, updated on 20 May 2024
https://doi.org/10.5194/egusphere-egu24-13606
EGU General Assembly 2024

The role of regional stress and pre-existing faults on collapse caldera onset and architecture

Matias Villarroel[1], John Browning[1,2], Martin Schöpfer[3], Carlos Marquardt[1,2], and Pamela Jara[4]
[1]Departamento de Ingeniería Estructural y Geotécnica, Pontificia Universidad Católica de Chile, Santiago, Chile (mvillarroel.lastra@gmail.com)
[2]Departamento de Ingeniería de Minería, Pontificia Universidad Católica de Chile, Santiago, Chile
[3]Department of Geoology, University of Vienna, Vienna, Austria
[4]Departamento de Ingeniería en Minas, Facultad de Ingeniería, Universidad de Santiago, Santiago, Chile

Collapse calderas form when the roof of the magma chamber collapses downwards as a consequence of magma withdrawal due to either over- or underpressure within the chamber during large eruptions. Caldera morphology, orientation, and internal architecture can be influenced by the tectonic conditions within the crust. Various theoretical, field, and modeling studies have suggested that collapse calderas are shaped by a combination of outward-dipping reverse faults and inward-dipping normal faults. However, the role of the regional stress field and pre-existing crustal faults in shaping a caldera or modifying the conditions of fault nucleation is less clear. This is important since many calderas form in areas that are subjected to regional stresses and of intense crustal faulting. This study utilizes two-dimensional Distinct Element Method (DEM) models to explore the influence of regional stresses and pre-existing structures on collapse caldera evolution and resulting geometric style. To do so we model a crustal segment comprised of a shallow magma chamber that gradually decreases in volume, mimicking the process of magma withdrawal. To address the interplay between the stress regime and the dynamics of caldera collapse we applied the Rankine Stress Limit to Coulomb's friction law, which relates the shear stress (τ) to the effective normal stress (σ'_n). This provides both active (k_a) and passive (k_p) limit stress states for a cohesionless material, by assuming a critically stressed crust with a friction angle □□, thus it is defined the earth pressure coefficient (□□) being the horizontal (σ_h) to vertical (σ_v) effective stress ratio: k = σ_h / σ_v. For a cohesionless rock mass with friction angle □□ the coefficients are: k_a = 1–sin□□/1+sin□□ $= 1/k_p$. Therefore, k is 1 for the isotropic case, k < 1 for extension (k_a) and k > 1 for compression (k_p). The effective vertical stress is, for a normally pressurized rock mass, given by: $\sigma_v = \rho' g h$, where $\rho' = \rho_{bulk} - \rho_{fluid}$ is the buoyant density, g is gravity and □ the depth. Pre-existing faults are represented by cutting the rigid blocks and assigning contact properties to the resulting facets. Our findings demonstrate that both the critical underpressure for collapse onset and the internal architecture of calderas are significantly influenced by the regional stress field of the crustal segment in which they are embedded. Moreover, the pre-existing faults do change both the geometry and style of collapse indicating an important role during caldera formation. By testing various fault spacings and properties, we identified parametric ranges within which pre-existing faults either contribute to or refrain from

influencing the overall collapse geometry. These findings hold significance in reconstructing the underlying processes from well-preserved collapse calderas and in comprehending the conditions required for future collapses at potential caldera volcanoes.