Constraining caldera structures to understand geothermal fluid migration: insights from analogue modelling, and implications for the Los Humeros Volcanic Complex

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In the frame of the GEMex Europe-Mexico cooperation project (Horizon 2020 Programme; grant agreement No. 727550), we have performed a series of analogue models investigating the influence of pre-existing faults on caldera collapse and subsequent caldera resurgence. This experimental work aims at investigating the development of caldera collapse and resurgence structures, which may represent viable pathways for the migration of geothermal fluids. Although these models have addressed the process for a general point of view, they were designed using the geometrical parameters known for the Los Humeros volcanic complex (Puebla state – Mexico), which is currently exploited for energy production, and is likely related to the structural evolution of the caldera complex. Caldera collapse and resurgence are complex geological processes that remain elusive to investigate. Several numerical and analogue modelling experiments have attempted to analyse this process during the last decades (e.g., Acocella, 2007; Geyer & Martí, 2014, and references therein). Particularly, analogue models allow to monitor the progressive evolution and the deformation pattern resulting from caldera collapse/resurgence processes at a reduced scale (both of time and geometry). A general model integrating analogue models with geological evidence suggests that caldera collapse is accommodated by early outward-dipping reverse faults and subsequent inward-dipping normal faults, but some aspects remain barely addressed, such as the role of inherited structures during caldera collapse and resurgence processes. In our modelling, we have induced caldera collapse by draining out (and afterwards re-injecting in case of intra-caldera resurgence) an analogue magma from an analogue magma chamber, emplaced below a brittle sedimentary cover simulated by a multi-layered sand mixture. Pre-existing faults have been simulated either at the caldera margin(s) and/or above the caldera depression. The shape of the magma chamber was varied by imposing straight sides, simulating pre-existing fault discontinuities, and in some models the sand pack was pre-deformed by artificial dilation zones in different positions, simulating inherited fabrics within the brittle crust. Our models show that discontinuities may induce caldera ring-faults to deviate from standard evolution and that inherited fabrics may influence significantly the caldera collapse deformation pattern (by modifying and/or inhibiting the formation of specific caldera collapse structures), and eventually caldera resurgence. This may bear important implications for migration of geothermal fluids and consequently for their detection, providing insights into caldera collapse processes and associated geothermal reservoirs, helping to better constrain variables associated with reservoir investigation.

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