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Magma plumbing beneath collapse caldera volcanic systems

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ABSTRACT

Advancing our knowledge of caldera volcanoes enables better assessment of hazard and more efficient harnessing of resources. In this paper we review developments in concepts of magma storage and transport during the life cycle of caldera plumbing systems. We draw together: a) geological, geochemical and petrological data from intrusions and eruption deposits; b) geophysical and geochemical data from modern restless calderas; and c) geological and structural evidence from ancient calderas as well as numerical and analogue models. Overall, magma plumbing systems beneath calderas develop incrementally as magma rises, intrudes and rejuvenates to accumulate a volume sufficient to erupt and drive subsidence of the chamber roof to form a caldera. The magma plumbing system may then reside relatively unchanged or continue to re-intrude on a variety of scales and cause continued eruptions, crustal resurgence, or new cycles of caldera formation.

Large magma volumes characteristic of calderas may evolve as a single progressively-enlarging reservoir or through the rapid amalgamation of small, initially-independent magma pockets. Eruptible magmas may reside at depths of up to 17 km, but typically lie at shallower depths as a caldera system evolves. Timescales of sub-caldera magma residence reveal two remarkable concepts: (1) portions of melt within a magma may remain molten for > 10^6 years, and (2) melt can be created and mobilized in a few thousand years or less.

Geophysical and geochemical data illustrate the present state of active sub-caldera plumbing systems and their development on timescales of hours to years. These studies commonly reveal aseismic, low-velocity zones at depths >6 km with spatial extents that can be larger than the caldera. The seismic attributes are consistent with rock hosting magma bodies of variable volume and melt content. These are commonly overlain by shallower low-velocity zones linked with ground deformation. The exact nature of these shallower zones is unclear, but interpretations often include shallow sills and laccoliths, and hydrothermal circulation is likely a key process as well.