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Reservoir growth through mixing of different silicic magma batches prior to the Minoan eruption of Santorini

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Magma reservoir growth through injection and mixing of different magma batches must precede large explosive eruptions and caldera collapse, but on what timescales? Chemically zoned crystals entrained in erupting magma preserve records of liquid evolution paths, mixing histories and crystal residence times, and can be used to unravel the final stages of reservoir assembly.

The 1610-1630 BCE Minoan eruption of Santorini discharged 30-60 km3 of crystal-poor rhyodacitic pumice (70.0-71.4 % SiO2, 850 °C, $\sim$15 vol% of plag > opx > cpx > mgt > ilm $\approx$ apat > pyrr set in rhyolitic glass) in four phases. Immediately prior to eruption, the rhyodacite was well mixed, both compositionally and thermally. Following the eruption, extrusion of crystal-poor dacitic lavas formed a 2.5-km3 edifice inside the caldera. Plagioclase crystals in the Minoan rhyodacite have two main regions: (i) a normally zoned inner region (An55-48) 130-250 μm thick, containing networks of glass inclusions; (ii) an outer, sawtooth-zoned region (An43-34) typically 60-80 μm thick, separated from the inner region by one or more resorption surfaces and a gap of 5-10 % An. About $\frac{3}{4}$ of crystals (independent of eruptive phase) have calcic cores (An88-65), and some rare ones have partially resorbed sodic (An33-10) cores. SIMS trace element (X) profiles of representative crystals were inverted to equivalent liquid compositions (Xliq) using published partition functions. Profiles for Sr exhibit no discernable diffusive re-equilibration with host melt during crystal growth. Calcic cores crystallized from melts with >200 ppm Sr (<56% SiO2), the inner region from melts with 110-170 ppm Sr (63-69% SiO2), and the outer region from melts with 60-80 ppm Sr (72-74% SiO2). The data are consistent with the conclusion of a previous study (Martin et al. Geology 38, 539-542, 2010) that the Minoan rhyodacite formed by mixing of two silicic magmas with different isotopic signatures. The less radiogenic magma was dacitic and formed the inner region of the crystals; the outer region formed from the (hybrid) rhyodacitic magma following mixing. Euhedral calcic cores are evidence that the dacite had mixed previously with basaltic andesite. The composition of the more evolved, and more radiogenic, magmatic component is not well constrained. Any crystals in this component must have been resorbed, the only possible remnants being rare sodic cores.

Although Sr compositions in the plagioclases are essentially primary, Mg suffered significant re-equilibration following crystal growth. Modelling of Sr and Mg profiles yields crystal ages greater than a couple of decades but younger than a few hundred years. These are very short compared to the gestation period ($\sim$15 ky) since the previous major eruption of Santorini. They may record a flash crystallization event in the dacitic magma when the it became water saturated during ascent and mixing.

The dacitic component of the Minoan reservoir was similar chemically and isotopically to the postcaldera Kameni lavas. We infer that, probably within several decades prior to the Minoan eruption, a large volume of Kameni-type dacitic magma was injected into a shallow reservoir of radiogenic, evolved rhyolite, and the magmas mixed to form chemically and thermally homogeneous rhyodacite. Once the rhyodacite had been erupted explosively, the dacite then continued to discharge as postcaldera lava. Final assembly of the Minoan reservoir appears to have occurred on a geologically short timescale prior to eruption.