Supervolcano eruptions driven by melt buoyancy in large silicic magma chambers

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The geological record shows abundant evidence for rare, but extremely large caldera-forming eruptions of siliceous magmas that dwarf all historical volcanic episodes in erupted volume and environmental impact. Because of the large size of the magma chambers that feed these eruptions, the overpressure generated by magma recharge is insufficient to fracture the cap rock and trigger an eruption. For these thick magma chambers, the buoyancy of the magma potentially creates a sufficient overpressure capable of fracturing the cap rock, but the lack of data on the density of rhyolite melts precludes the appropriate estimation of the overpressure and the role of buoyancy in initiating supervolcano eruptions. The density of rhyolite melts has not been determined at super-liquidus temperatures or elevated pressures because traditional techniques, including Archimedean methods, sink/float experiments and acoustic measurements, are limited by the high melt viscosity.

In this study, we measured the density of rhyolitic/granitic melts with 0, 4.5 and 7.7 wt. pct. of dissolved water at geologically relevant conditions, generated in a Paris-Edinburgh large volume press: 0.9 to 3.6 GPa, 1270 to 1950 K. Before and after each density measurement, the molten state of the sample was verified by X-ray diffraction. The density of the melt was determined in situ from the X-ray attenuation coefficient of the sample. The acquired data were combined with available ambient pressure data on super-cooled liquids to derive a third order Birch-Murnaghan equation of state that accurately predicts the partial molar volume of dissolved water and the density of rhyolite melts as a function of pressure, temperature and water content.

Application of the melt equation of state to calculate the overpressure at the roof of supervolcano magma chambers for a range of conditions/configurations indicates that magma buoyancy provides a significant background overpressure, which in many cases may suffice to initiate an eruption. Thus, although magma recharge and mush rejuvenation, volatile saturation or tectonic stress may be important triggers for specific eruptive episodes, the initiation of a supereruption does not a priori require such a trigger.