The dark side of zircon: Textural and chemical evidence for volatile saturation in subvolcanic Yellowstone magma reservoir

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The Island Park-Mount Jackson series in the Yellowstone volcanic field (USA) is a suite of rhyolitic domes and lavas that erupted between the caldera-forming eruptions of the Mesa Falls Tuff (1.3 Ma) and the Lava Creek Tuff (0.63 Ma). Combined zircon U/Pb geochronology, Raman spectroscopy, oxygen isotopic and trace elemental compositions document a variety of magmatic environments of magma storage prior to the eruption of these lavas.

Based on comparison with co-erupted melt compositions and textural criteria, four zircon compositional groups are identified that record different stages along a continuous magmatic evolution from trace element-poor to extremely fractionated rhyolitic melts (with >1000 ppm U in zircon). These U-rich zircon domains are dark in cathodo-luminescence images and show additional and broadened Raman peaks, indicating that substitution of non-stochiometric trace elements may lead to new molecular bonds and distortion of the crystal lattice. Some of these zircon domains contain inclusions of U-Th-REE phases, likely originating from dissolution-reprecipitation of metastable trace element-rich zircon in the presence of a fluid phase.

Rhyolite-MELTS simulations indicate that at the conditions required to produce the observed enrichment in trace elements, a fluid-phase can be expected to be present. These findings illustrate that zircons can be assembled from a variety of co-existing magmatic environments in the same magma reservoir, including highly fractionated volatile-rich melts at the magmatic-hydrothermal transition.