Differentiation of rhyolites in the mid-upper crust as revealed by analysis of melt inclusions from the Taupo Volcanic Zone, NZ

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My recent post-doctoral research at the University of Tasmania focused on the differentiation and degassing of rhyolitic magmas in the Taupo Volcanic Zone (TVZ) of New Zealand. The TVZ is a unique arc in that volcanism in the central segment of the arc is dominantly rhyolitic in composition. The origin of the voluminous rhyolitic magmas has been debated; some researchers have supported a model where rhyolites were formed primarily by melting of metasedimentary crustal rocks (e.g., Ewart and Stipp, 1968; Cole, 1979) or by some combination of mixing, assimilation and fractional crystallization (e.g., Graham et al., 1995). However, recent models suggest that the TVZ rhyolites can be produced by a multi-stage process of crystallization and melt extraction from a basaltic parental melt (e.g., Deering et al., 2008, 2011). The evolution of the rhyolites in the mid-upper crust is also complicated. Studies of the bulk rock chemistry of TVZ rhyolites have demonstrated that most eruptions involve mixing or mingling of at least two rhyolitic magma batches (e.g., Nairn et al., 2004, Smith et al., 2004, 2010, Shane et al., 2007, 2008a, 2008b, Saunders et al., 2010), and observation that is supported by studies of zoning in erupted phenocrysts and zircon crystals (e.g., Charlier and Wilson, 2010; Smith et al., 2010).

In order to better understand the complex differentiation of rhyolitic magmas of the TVZ, we have analyzed quartz-hosted melt inclusions and pumice glasses from eight recent (<~50 ka) eruptions from the Okataina Volcanic Center (OVC) of the TVZ. We found that the OVC rhyolites are volatile-rich, with ≤6 wt% H_2O and ≤0.25 wt% Cl. Interestingly, melt inclusions from all eight eruptions recorded similar ranges in melt H_2O contents (~4-6 wt%, suggesting that all melts stalled in the mid-upper crust at pressures of ~100-200 MPa. Similarly, all magma batches have similar differentiation histories. In all eruptions, the melt inclusion trace element compositions reflect a complex history of magma mixing and crystal fractionation. Variations in melt inclusion incompatible trace elements (U, Th) suggest that individual melt batches underwent ~20-25% crystal fractionation at depth, and these estimates are identical for all eruptions studied. Melt inclusion U and Th concentrations generally overlap with pumice glass U and Th, indicating that little to no crystallization occurred post-melt inclusion entrapment at depth. Thus, it appears that the magma batches feeding these eight separate, and geochemically distinct, eruptions all stalled at similar depths in the mid-upper crust and underwent similar amounts of crystal fractionation prior to eruption. These similarities, despite differences in bulk geochemistry and mineralogy, suggest that the upper crustal density and/or structure controls the stalling and storage depth of rhyolitic magmas in the Taupo Volcanic Zone.

This research highlights the complexities of arc rhyolite geochemistry, and indicates that analysis of melt inclusions can be a beneficial tool for discerning the complex differentiation histories of these melts.