Formation of rhyolite at the Okataina Volcanic Complex, New Zealand: New insights from analysis of quartz clusters in plutonic lithics†

KARINA A. GRAETER1,*, RACHEL J. BEANE1, CHAD D. DEERING2, DARREN GRAVELY3 AND OLIVIER BACHMANN4

1Department of Earth and Oceanographic Science, Bowdoin College, Brunswick, Maine 04011, U.S.A.
2Department of Geological and Mining Engineering Sciences, Michigan Technological University, Houghton, Michigan 49931, U.S.A.
3Department of Geology, University of Canterbury, Christchurch 8140, New Zealand
4Institute of Geochemistry and Petrology, ETH Zurich, NW Clausiusstrasse 25, 8092 Zurich, Switzerland

ABSTRACT

Granitoid lithic clasts from the 0.7 ka Kaharoa eruption at the Tarawera volcano (Okataina Volcanic Complex, Taupo Volcanic Zone, New Zealand) provide insight into the processes of rhyolite formation. The plutonic lithic clasts of the Kaharoa eruption consist of (1) quartz phenocrysts, which are often grouped into clusters of two to eight quartz grains, (2) plagioclase phenocrysts (mostly ~An60 with up to An90 cores), and (3) interstitial alkali feldspar. Quartz orientations obtained through electron backscatter diffraction (EBSD) methods show that 78% of the 82 analyzed clusters have at least one pair of quartz grains with the dominant dipyramidal faces matched. Variations in cathodoluminescence (CL) zoning patterns of the quartz suggest that quartz clusters came together after initial crystal growth and that many quartz crystals were subject to one or more resorption events. The process of quartz crystals with different magmatic histories coming together into common relative orientations to form clusters is indicative of oriented quartz synneusis and suggests a history of crystal accumulation. The quartz clusters are interpreted to have formed as part of a crystal cumulate mush within a shallow magma chamber where quartz crystals rotated into contact along their dominant dipyramidal faces during hindered settling and/or compaction. The preservation of oriented quartz clusters from the Kaharoa plutonic lithics thus provides evidence for synchronous, shallow pluton formation from a cumulate mush during active silicic volcanism. This result is consistent with models whereby melt-rich, high-silica rhyolite formation occurs via interstitial melt extraction from a low-silica rhyolite mush in the shallow crust.

Keywords: Cathodoluminescence, cumulate, EBSD, rhyolite formation, Taupo Volcanic Zone

INTRODUCTION

In young, rhyolite-generating regions such as the central Taupo Volcanic zone (TVZ), any potential plutonic portions of the magma system have not been exposed by uplift or erosion. Without exposure of the plutonic portions, the connection between volcanic and plutonic processes remains uncertain, with multiple models proposed for rhyolite formation. Toward one end of the spectrum of models, eruptable felsic magma forms slowly at shallow depths through the processes of crystal fractionation and interstitial melt extraction from an incrementally built intermediate crystal mush, which is preserved as a cumulate in the rock record (cf. Bachmann and Bergantz 2004; Hildreth and Wilson 2007; Deering and Bachmann 2010). Toward the other end of the spectrum, plutonic, and volcanic systems are only distantly related, with eruptable felsic magma generated at greater depths and residing transiently in the upper crust. Hence, the plutonic leftovers are largely unrelated to the waxing stage of the system when melt-rich magma is erupted (Glazner et al. 2004).

To address differences in the models, coeval silicic plutonic and volcanic units should be directly compared. In the TVZ and other young volcanic regions, fully crystalline lithologies are confined to plutonic lithics—exhumed fragments of holocrystalline rock that solidified before or concurrent with eruption. The source of the plutonic fragments is the magma reservoir in which the magma resides prior to eruption. Plutonic lithics obviously reflect high degrees of crystallization and imply that, in active volcanic complexes, at least some portions of the magma reservoir reach the solidus. Therefore, these lithics can help better connect the plutonic and volcanic processes.

Interpretation of plutonic lithics requires care as they may originate from different stages of the magmatic evolution of a volcano: (1) magma crystallized along the carapace during previous episodes of eruption (Charlier et al. 2003; Bacon and Lowenstern 2005; Bachmann 2010), (2) an earlier solidified or chemically distinct injection of magma into the shallow crust that is unrelated to active rhyolite formation (Keller 1969; Lowenstern et al. 2000; Charlier et al. 2003; Vazquez et al. 2007), or (3) a