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In defense of magnetite-ilmenite thermometry in the Bishop Tuff and its implication for gradients in silicic magma reservoirs

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Abstract

Despite claims to the contrary, the compositions of magnetite and ilmenite in the Bishop Tuff correctly record the changing conditions of T and f_{O_2} in the magma reservoir. In relatively reduced (ΔNNO < 1) siliceous magmas (e.g., Bishop Tuff, Taupo units), Ti behaves compatibly ($D_{Ti} \approx 2–3.5$), leading to a decrease in TiO_2 activity in the melt with cooling and fractionation. In contrast, FeTi-oxides are poorer in TiO_2 in more oxidized magmas (ΔNNO > 1, e.g., Fish Canyon Tuff, Pinatubo), and the $d(a\mathrm{TiO_2})/dT$ slope can be negative. Biotite, FeTi-oxides, liquid, and possibly plagioclase largely maintained equilibrium in the Bishop Tuff magma (unlike the pyroxenes, and cores of quartz, sanidine, and zircon) prior to and during a mixing event triggered by a deeper recharge, which, based on elemental diffusion profiles in minerals, took place at least several decades before eruption. Equilibrating phases and pumice compositions show evolving chemical variations that correlate well with mutually consistent temperatures based on the FeTi-oxides, sanidine-plagioclase, and Δ^{18}O quartz-magnetite pairs. Early Bishop Tuff (EBT) temperatures are lower (700 to ~780 °C) than temperatures (780 to >820 °C) registered in Late Bishop Tuff (LBT), the latter defined here not strictly stratigraphically, but by the presence of orthopyroxene and reverse-zoned rims on quartz and sanidine. The claimed similarity in compositions, Zr-saturation temperatures and thermodynamically calculated temperatures (730–740 °C) between EBT and less evolved LBT reflect the use of glass inclusions in quartz cores in LBT that were inherited from the low-temperature rhyolitic part of the reservoir characteristic of the EBT. LBT temperatures as high as 820 °C, the preservation of orthopyroxene, and the presence of reverse-zoned minerals (quartz, sanidine, zircons) are consistent with magma recharge at the base of the zoned reservoir, heating the cooler rhyolitic melt, partly remelting cumulate mush, and introducing enough CO_2 (0.4–1.4 wt%, mostly contained in the exsolved fluid phase) to significantly lower H_2O-activity in the system.

Keywords: Bishop Tuff, ilmenite-magnetite thermometry, TiO_2 activity, reduced magmas, "bright rims", melt inclusions, magma recharge, CO_2 effect