American Mineralogist, Volume 98, pages 304–318, 2013

Microtexture development during rapid cooling in three rhyolitic lava flows

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Abstract

The effects of water concentration and degassing history on the development of spherulites and flow banding were examined in three middle Tertiary rhyolitic lava flows from the Atascosa Mountains of southern Arizona. The Hell's Gate lava flow and the Atascosa lava flow host spherulites of strongly contrasting texture, and neither are flow banded. The Sycamore Canyon lava flow is a flow-banded rhyolite that hosts two populations of spherulites. Spherulites in the Hell's Gate lava flow consist of two to four generations of bladed radiating alkali feldspar crystals that increase in water concentration along their length. Needle-like radiating feldspar crystals in spherulites in the Atascosa and Sycamore Canyon lava flows are in some cases punctuated by concentric rinds of glass that are reservoirs for water rejected by the feldspar crystals. The differences in spherulite crystal morphology between the Sycamore Canyon and Atasocosa flows (both needle-like) and the Hell's Gate flow (bladed) may reflect a more rapid cooling rate of the Sycamore Canyon and Atascosa flows. Thick gray flow bands in the Sycamore Canyon lava flow host higher water concentrations than thin orange flow bands, suggesting that flow bands are zones of greater and lesser volatile concentration, deformed by stretching of the flowing magma. Temperature was uniform across the light and dark flow bands of the Sycamore Canyon flow, indicating that water concentration, one of the variables that controls diffusion coefficients, rather than temperature, controlled spherulite size in this case. Phenocrysts in the Hell's Gate lava flow are strongly resorbed, probably as a result of magma ascent along a near-adiabatic gradient that resulted in exsolution of water from the melt, and subsequent dissolution of existing quartz phenocrysts by the water-rich melt. Resumption of crystallization of anhydrous phases such as quartz and feldspar would have further enriched the melt in water, facilitating the growth of spherulites. Spherulites in two of the lava flows (Sycamore Canyon and Hell's Gate) increase in water concentration from core to rim, as would be expected in spherulites growing in melt enriched in water rejected by the growing feldspar crystals. Spherulites in the Atascosa rhyolite flow decrease slightly in water concentration from core to rim, possibly because the magma degassed during spherulite growth. Calculation of water concentration profiles in spherulites from all three rhyolite flows on the basis of Rayleigh fractionation of water between sanidine and rhyolitic melt shows that the very high water concentrations in spherulites (typically $>0.6 \times$ water concentration in surrounding glass) cannot be accounted for by Rayleigh fractionation. Instead it is likely that sanidine incorporated water as fluid inclusions and/or as water clusters during rapid crystal growth. Water concentration profiles in the glass surrounding spherulites do not preserve the high concentration zone at the spherulite boundary that has been observed in younger lava flows, so that spherulite growth rates cannot be calculated on the basis of mass-balance calculations of distribution of water during spherulite growth. Rather, the water concentration profile in the surrounding glass is a half plateau, the height of which is approximately equivalent to the far-field water concentration in the surrounding glass, indicating that water that accumulated at the spherulite/magma boundary diffused sufficiently rapidly to equilibrate with the surrounding magma as the lava flow cooled.

Keywords: Flow banding, FTIR, rhyolite, lava, spherulite