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INVESTIGATING PETROLOGIC INDICATORS OF MAGMATIC PROCESSES IN VOLCANIC ROCKS

Nucleation rates of spherulites in natural rhyolitic lava

James E. Gardner[1,*], Kenneth S. Befus[2], James M. Watkins[3], and Travis Clow[1]

[1]Department of Geological Sciences, Jackson School of Geosciences, The University of Texas at Austin, Austin, Texas 78712-0254, U.S.A.
[2]Department of Geosciences, Baylor University, Waco, Texas 76798, U.S.A.
[3]Department of Geological Sciences, University of Oregon, Eugene, Oregon 97403-1272, U.S.A.

Abstract

The rates of nucleation and crystal growth from silicate melt are difficult to measure because the temperature–time path of magma is often unknown. We use geochemical gradients around spherulites in obsidian glass to estimate the temperature–time interval of spherulite crystallization. This information is used in conjunction with new high-resolution X-ray computed tomography (HRXCT) data on the size distributions of spherulites in six samples of rhyolite obsidian lava to infer spherulite nucleation rates. A large data set of geochemical profiles indicate that the lavas cooled at rates of $10^{-2.2}$ to $10^{-1.2}$ °C/h, and that the spherulites grew at rates that decreased exponentially with time, with values of $10^{-0.70}$ to $10^{0.30}$ μm/h at 600 °C. Spherulites are estimated to have begun nucleating when undercooling [ΔT, = liquidus T (≈800 °C) minus nucleation T] reached 100–277 °C, and stopped when ΔT = 203–365 °C, with exact values dependent on assumed cooling and growth rates. Regardless of rates, we find that spherulites nucleated within a ~88–113 °C temperature interval and, hence, began when $\Delta T \approx 0.65–0.88 \times T_L$, peaking when $\Delta T \approx 0.59–0.80 \times T_L$. A peak rate of nucleation of 0.072 ± 0.049 $cm^{-3}\ h^{-1}$ occurred at 533 ± 14 °C, using cooling and growth rates that best fit the data set of geochemical profiles. While our inferred values for ΔT overlap those from experimental studies, our nucleation rates are much lower. That difference likely results from experimental studies using hydrous melts; the natural spherulites grew in nearly anhydrous glass.

Keywords: Spherulite, nucleation rate, growth rate, cooling rate, Yellowstone, obsidian, Invited Centennial article