

Nucleation: an existential problem in an extreme environment

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Solid and vapor phase nucleation dictate a magma's textural evolution and contribute to determining how (indeed, whether) it erupts. Understanding nucleation in a phenomenological sense as well as in a theoretical sense is essential for interpreting magmatic processes occurring at depth and developing conduit flow models with predictive power. For any given phase and system, the thermodynamic force driving transformation, the characteristics of melt transport, the energetics of interfaces, and a raft of observations are required to begin evaluating the efficacy of classical nucleation theory. The understanding of aqueous systems is advancing rapidly [1]. Igneous environments pose different challenges: magmas are highly refractory, reactive with potential containers, and redox sensitive.

Using dynamic crystallization experiments, a novel application of rock magnetism, and aggressive microprobe methodologies, our group is addressing phase nucleation in several contexts. (a) We critically evaluate the thesis [2] that linear viscoelastic relaxation theory [3], developed to explain glass transition phenomena, adequately describes olivine nucleation kinetics in olivine-melilitite. (b) We examine the apparent paradox [4] posed by magnetite-poor rhyolite magmas that are erupted from depths incapable of providing the supersaturation required for homogeneous bubble nucleation. (c) We observe a threshold value of liquid viscosity above which basalt crystallization ceases; the value is common to rapid cooling in the lab (72 °C h⁻¹) as well as gradual cooling within the modern Kilauea reservoir, suggesting that crystallization kinetics play a role in buffering the compositions of erupted magma.

[1.] D. Gebauer, A. Völkel, H. Cölfen, *Science*. **322**, 1819–1823 (2008). [2.] F. Vetere *et al.*, *Chem. Geol.* **354**, 233–242 (2013). [3.] D. B. Dingwell, S. L. Webb, *Eur. J. Mineral.* **2**, 427–449 (1990). [4.] T. Shea, *J. Volcanol. Geotherm. Res.* **343**, 155–170 (2017).