Quantification of feldspar nucleation rates in magmas across the P-T space

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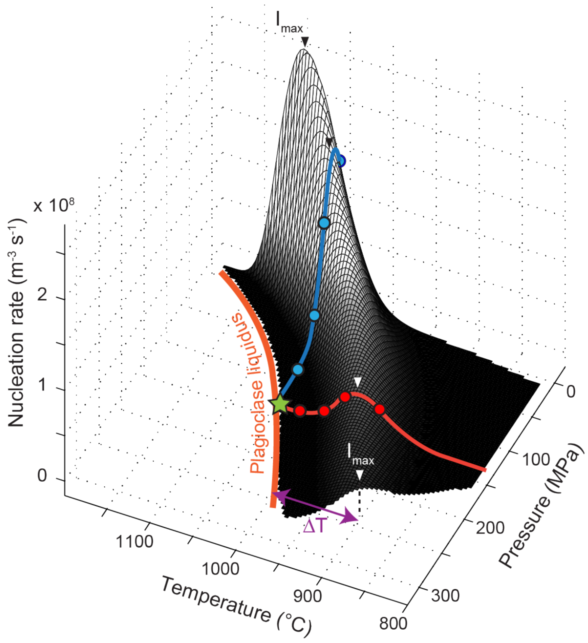
Crystallization partly governs the rheology of magmas. Hence, the rate at which magmas nucleate crystals in response to a thermodynamic perturbation ultimately determines eruptive behavior. Conversely, by examining the textural cargo of volcanic rocks collected at the surface (e.g. crystal numbers, sizes), petrologists aspire to retrieve the thermodynamic perturbation(s) that generated these textures, as well as the rates at which the magmas solidify. Laboratory experiments in which crystallization is stimulated by both cooling and decompression show that the degree of undercooling controls feldspar nucleation rates, irrespective of whether it is applied via cooling (ΔT) or decompression (ΔT_{EFF}). These findings are fundamental in that they allow extending equations derived from the classical nucleation theory (CNT) to any cooling or decompression path within the P-T feldspar phase diagram for a given magma. We develop a model of feldspar nucleation rates in different magmas (rhyolite and basaltic-andesite) derived from variations of the CNT, using currently-available thermodynamic and experimentally-derived textural parameters. We discuss the relative influences of the main acting variables (surface free energy, enthalpy of crystallization, undercooling) on obtained nucleation rates, and show how the model can be used to make predictions of feldspar textures within magmas that follow complex P-T paths towards the surface.



Exemple of a 2D nucleation landscape (pressure P, temperature T, and nucleation rate I) that can be used in predictive numerical models. The undercooling ΔT is the distance between any given point in the space and the feldspar liquidus. Also shown are the positions of maximum nucleation rates (I_{max}), and two P-T paths, one in which the magma only experiences cooling (red), the other only decompression (blue).