Effects of superheating on olivine morphology and composition

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Magmas can become superheated if (a) they decompress adiabatically (*1*, *2*), (b) they decompress under H_2O-undersaturated conditions (*3*); (c) they are formed by meteorite impacts (*4*), or (d) they are diluted by a fluxing agent (*5*). Canonical studies note a correlation between superheating and anhedral crystal morphologies, disequilibrium phase abundances, compositional zoning, and failure of crystals to nucleate (*6*–*9*). Despite these influences on crystallization in nature and in the lab, superheating has rarely been treated as an experimental variable.

We performed dynamic crystallization experiments to study the effects of superliquidus thermal history on the morphologies and compositions of subsequently-grown olivine crystals. An ultramafic volcanic rock with abundant olivine was fused above the liquidus temperature, held for 0, 3, or 12 h, cooled at 25 °C h^{-1}, and quenched from 200 °C below the liquidus. Changes in olivine morphology and a departure from compositional equilibrium are both correlated with superheating magnitude, parameterized as the integrated time above the liquidus (°C h). We infer that superheating produces a delay in nucleation, in turn causing rapid crystal growth, which produces morphological and compositional disequilibria. Our results indicate that laboratory superheating exerts a control on the composition of crystallized olivine and suggests that natural olivine CaO and NiO contents may exhibit disequilibrium partitioning if grown rapidly, e.g., in the aftermath of superheating.

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