Geophysical Research Abstracts
Vol. 21, EGU2019-5551, 2019
EGU General Assembly 2019

Dissolution and precipitation of forsterite in a thermal gradient: implications for cellular growth of olivine phenocrysts in basalt and melt inclusion formation

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Rates and timescales of volcaninc and magmatic systems can be deciphered by crystal morphology that strongly depends on the temperature regime of the system (degree of undercooling and cooling rate). In order to simulate low degrees of undercooling, we developed an original experimental setup that imposes a thermal gradient to monocrystalline forsterite cylinders in a basaltic melt. As forsterite solubility is sensitive to temperature, the forsterite on the high temperature side undergoes dissolution and the dissolved components are transported toward the low temperature side where a layer of newly grown forsterite forms.

A striking feature is that the precipitation process does not produce a planar front of forsterite advancing at the expense of liquid: the growth front shows a fingered outline in 2D, with solid lobes separated by glass tubes that are perpendicular to the growth front. We ascribe this texture to cellular growth, a type of growth that had not been experimentally produced so far in silicate systems. The development of cellular growth requires low degrees of undercooling (a few °C) and large crystal-liquid interfaces (∼1mm across or more), and it occurs at a growth rate of the order of 10-9 m/s. We found natural occurrences of cellular growth on the rims of olivines from basanites, but otherwise cellular textures are poorly documented in natural volcanic rocks. Melt inclusions were produced in our experiments, showing that they can form in olivine at relatively slow rates of growth (10-9 m/s or lower).