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Melt viscosity as a principal factor controlling the dissolution rates of the lithosphere minerals in planetary and geological melts

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Planetary and geological melts produced at depth encounter rocks at a variety of conditions during their ascension towards the surface of planetary bodies. Reactions occur between the magma and surrounding rock material, but despite their potential importance for the regulation of magmatic differentiation, the rates of such interactions are rarely considered and poorly known. The aim of this work is to review the results of experiments and kinetic models for the dissolution of the main rock-forming minerals in aluminosilicate melts, that may be applied to partial melting of common rock types, and reactions between the melts and the rocks composing the lithosphere. A kinetic equation allowing the first-order prediction of mineral dissolution rates in planetary and geological melts was generated. The diffusion-controlled dissolution rate r (mol cm^{-2} s^{-1}) of common rock-forming silicate minerals in aluminosilicate melts at 1300 ± 20°C and <1 GPa pressure can be described by an inverse function of the viscosity of boundary layer melt (i.e. that formed at the crystal-melt interface) independent of silicate mineral composition according to:

$r = k \eta^{-n}$,

where the correlation coefficient $k = 4 \times 10^{-7}$ (mol cm^{-2} s^{n-1} Pa^n), $n = 0.5$, and η (Pa s) is the viscosity of the boundary layer melt. This function relating dissolution rate and melt viscosity is consistent with a simple detachment mechanism involving network-forming Si-O atoms during silicate mineral dissolution. This equation can be applied to the dissolution of the principal rock-forming minerals during melt-rock interactions in the lithosphere such as lithosphere assimilation. It shows that low-viscosity mafic-ultramafic magmas can be significantly more contaminated by lithosphere rock material compared to the high viscosity felsic magmas. This correlation for the main rock-forming minerals may be directly applicable to planetary lithosphere assimilation by magmas, magma mixing as well as the modeling of mantle metasomatism or other types of melt-rock interactions. Thus, the effect of the lithosphere assimilation of mantle-derived melts through the melt percolation is an important issue when interpreting the composition of MORB and OIB in terms of the mantle source composition.

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