

Diffusion and reaction in multicomponent partially molten silicates: Dissolution-precipitation

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The essential features of the kinetics of crystal-melt reaction in multicomponent partially molten silicates will be illustrated using numerical examples for mono-mineralic and bi-mineralic systems. Diffusion equations for the independent components in the melt and crystals, subject to the phase diagram constraint and moving boundary conditions at the crystal-melt interfaces, were solved numerically in 1D using a finite difference method. The input parameters are the liquid and solid compositions of the crystals (for major elements) or crystal-melt partition coefficients (for trace elements), initial crystal-melt proportions, and diffusion coefficients of the independent components in the melt and crystals.

One of the unique features of diffusion and reaction in high-temperature multicomponent two-phase aggregates is dissolution and reprecipitation. If the interstitial melt is initially under-saturated with respect to the crystals, the crystals will dissolve, but only at earlier times. Because the rate of diffusion in the melt is much faster than that in the solid, the bulk melt composition quickly evolves to the liquid composition of the dissolving crystals. Since the interiors of the crystals are still over-saturated with respect to the melt, dissolution reverses to precipitation that finally stops when the concentration gradients in the solids are eliminated. An important consequence of dissolution and reprecipitation is the acceleration of crystal-melt re-equilibration in partially molten silicates. Potential implications include, but not limited to, isothermal partial melting in the laboratory, disequilibrium partial melting in the nature, crystal-melt trace element partitioning in the lab and nature, and crystal-melt reaction in magma bodies. Animations showing the effects of dissolution-precipitation on major and trace element distributions during partial melting and crystal-melt reaction will be presented.

How solid solution minerals react with melt during diffusion-reaction

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Melt-rock reactions occur ubiquitously as magmas ascend and differentiate. Activity gradients can readily drive diffusion of chemical species between juxtaposed partial melts of different lithologies. The mechanism by which minerals re-equilibrate with melt as it dynamically changes composition by diffusion is fundamental to diffusion-reaction (DR) processes. Piston cylinder DR experiments suggest that solid-solution minerals do not re-equilibrate by solid-state diffusion nor by dissolution-precipitation; instead, mineral rims remain in exchange equilibrium with melt while mineral cores adjust composition and buffer chemical changes of the melt.

Two examples illustrate this process: 1) In a 2 hr DR experiment between partially molten basanite and peridotite (Lundstrom, *G³*, 2003), Mg diffuses from peridotite to basanite, increasing the bulk MgO content of the basanite. However, the MgO content of the basanite melt only increases slightly because the cores of olivines in the basanite increase in Mg# relative to their starting composition. Notably, olivine rims maintain Mg-Fe exchange with the melt. 2) In a 13 day DR experiment between partially molten gabbro and basaltic andesite, a plagioclase-rich boundary layer develops at the lithologic interface as Ca diffuses into the basaltic andesite (as predicted by models using IRIDIUM; Boudreau, *Comput. Geosci*, 2003). Like the olivine case, plagioclase rims in this zone maintain Na-Ca exchange equilibrium with the melt but mineral cores become highly anorthitic (up to An₉₀). Isotopic tracers show that these cores are in full chemical communication with the melt as they grow.

To generalize, solid-solution minerals adjust to dynamically changing melt composition by maintaining rim-melt equilibrium as cores chemically exchange with melt. In the case of plagioclase, this appears to occur by formation of small melt channels that traverse the crystal rim based on SEM images (TEM work is scheduled). By cores taking up the incoming flux, these minerals buffer changes in melt composition. Important implications of this finding include: 1) the presumed age stratigraphy of rims being "older" than cores is not valid; 2) mineral-melt equilibration is much more rapid than solid-state diffusion. Diffusion through channels in the crystal could cause fractionation of isotopes, explaining "non-traditional" isotope variations observed in mantle minerals.