A simple model for REE diffusion in silicate minerals and melts

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Purpose of this study

The purpose of this study is to develop a general model for describing REE diffusion in silicates. We will show that there may be two time scales for REE diffusion in minerals and melts: a fast time scale and a slow time scale. The former may be important when there are major element concentration gradients in the system.

The model

Silicate melts and crystals are multicomponent systems. The diffusive flux of a REE (J_{REE}) in such a system depends not only on the concentration gradient of REE but also those of major elements. Without loss of generality, we can express the diffusive flux of REE as

$$J_{REE} = -D_{REE}\frac{\partial C_{REE}}{\partial x} - D_{Major}\frac{\partial C_{Major}}{\partial x}\,. \quad (1)$$

In the standard treatment of REE diffusion in silicates, J_{REE} is given by an effective binary diffusivity (D_{EBD}), viz.,

$$J_{REE} = -D_{EBD}\frac{\partial C_{REE}}{\partial x}\,. \quad (2)$$

Diffusivities in Eqs. 1 and 2 are related to each other:

$$D_{EBD} = D_{REE}\left(1+\frac{D_{major}}{D_{REE}}\frac{\partial C_{major}}{\partial C_{REE}}\right). \quad (3)$$

This is the thesis of the present study.

In the absence of major element concentration gradients, diffusion of a REE in silicate mineral or melt is determined by its own mobility or diffusivity (D_{REE}). However, in the presence of major element concentration gradients, diffusion of a REE can be significantly speeded up and potentially dominated by the second term on the RHS of Eq. 1. Hence, there may be two time scales for REE diffusion in silicates under some circumstances. This has broad implications for modeling and understanding REE and other trace element diffusion in silicate minerals and melts. For example, Eqs. 1-3 can be used to interpret some apparently unusual or inconsistent results for REE diffusion in silicates. Examples of their applications to REE diffusion in olivine and basaltic melts will be discussed.