

Time scales of diffusive re-equilibration in bi-mineralic systems

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Simple recipes for evaluating time scales for diffusive re-equilibration of a trace element in bi-mineralic aggregates with and without presence of intergranular fluid are obtained through analysis of diffusion equations. Diffusive re-equilibration times depend on average grain sizes of the two minerals, diffusion coefficients and partition coefficients for the element in the two minerals, and volume fractions or volume fluxes of the minerals and fluid in the system. There are two time scales for diffusive re-equilibration in fluid-bearing systems. The fast time scale is proportional to fluid fraction and dominated by the mineral that has a faster diffusion rate. The slow time scale is bounded by the time scales of diffusion in the two minerals and determines the overall time scale of re-equilibration for the system. Presence of small amount of fluid does not lead to a reduction in the time scale of diffusive re-equilibration for the bi-mineralic aggregate. Percolation of fluid drives the system further away from equilibrium and increases the length and time scales for diffusive re-equilibration in the system. The time scales for subsolidus re-equilibration in bi-mineralic aggregates are determined by the minor's rule: the mineral that contains lesser amount of the trace element of interest in the system contributes more to the overall diffusive time.

Applications to REE redistribution among major rock-forming minerals in peridotites and eclogites highlight the importance of REE diffusion and partition in minerals. The time scales for subsolidus re-equilibration of REE in bi-mineralic eclogites are dominated by the rates of light REE diffusion in garnet and by the rates of middle and heavy REE diffusion in clinopyroxene. The time scales for subsolidus re-equilibration of REE in two-pyroxene bearing rocks are controlled primarily by the rates of REE diffusion in orthopyroxene. The time scales for diffusive re-equilibration of REE in melt-bearing two-pyroxene aggregates are determined by diffusion in clinopyroxene for light REE and by diffusion in orthopyroxene for middle to heavy REE. Presence of melt flow further expands the role of clinopyroxene. This contrasting behavior in diffusive time scale may provide a simple explanation for the ubiquitous chemical disequilibrium in light REE between clinopyroxene and orthopyroxene observed in mantle peridotites from a wide range of tectonic settings.