

Influence of coupled diffusion and viscous creep on the composition of metasomatic reaction bands

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We explore the feedback between reaction induced stress and component diffusion. Rim growth experiments in the system MgO-FeO-SiO₂, where orthopyroxene reaction rims were grown between olivine and quartz were made. Two different matrix-inclusion arrangements were used: In a single capsule vol. 10% of olivine grains (150 µm grain size) were immersed in a polycrystalline quartz matrix and, in a second compartement, the opposite matrix-inclusion arrangement was chosen using the same starting materials (San Carlos Olivine and synthetic quartz). The orthopyroxene rims that were formed around quartz inclusions in the olivine matrix were 11.6 µm after 80 hours run duration, in contrast, the orthopyroxene rims that formed around olivine inclusions in the quartz matrix were only 6.1 µm thick on average. Provided that run conditions and water fugacities were similar in both compartements of the assembly, this suggests mechanical feedback of the matrix with the rim growth reaction. We present a rate law for diffusion controlled reaction rim growth in spherical geometry and link it to the accomodation of the volume change of reaction by viscous creep. For the experimental conditions of 1000°C, 1 GPa and a strain rate of 10⁻⁶ s⁻¹ we infer a transition from diffusion controlled growth to creep controlled growth for effective bulk viscosities on the order of 10¹⁶ to 10¹⁷ Pas. In the diffusion controlled regime, growth zoning with sharp compositional gradients within the reaction rim may develop due to local equilibrium constraints. If viscous creep takes over rate control, compositional gradients across the growing rim tend to degrade and the original growth zoning may be obliterated. Pronounced growth zoning observed in many naturally formed reaction rims may thus be taken as an indication of diffusion controlled growth.

Transport, interface and rheological controls on the kinetics of mineral reactions

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We investigate three examples of reaction microstructures and textures using electron and ion beam techniques with high spatial resolution. In particular we are interested in the role of diffusion, interface energy and rheology during mineral reactions and their influence on microstructure and texture evolution. This is motivated by the notion that the latter determine geo-materials macroscopic properties.

First we discuss findings from natural and synthetic examples that corroborate fast diffusion along grain and phase boundaries. There diffusion may be enhanced by the presence of an amorphous phase even at homologous temperatures well below unity. In the context of reaction rim formation short circuit diffusion along grain and phase boundaries may lead to complex chemical patterns with equilibration domain sizes well below the grain size. In a second example we explore the potential of Cahn-Hilliard theory to describe mineral exsolution. We present numerical models of exsolution in ternary feldspar, which are compared with microstructures and chemical patterns from natural perthites. From this comparison we infer that fractionation of the anorthite component into albite-rich exsolution lamellae may be rate limiting during the coarsening stage, because of slow Al-Si interdiffusion in the silicate framework. The anorthite content of albite-rich lamellae appears to be a sensitive and robust monitor of the cooling history. Finally, we explore the feedback between reaction induced stress and component diffusion. Rim growth experiments in the system MgO-FeO-SiO₂ seem to indicate that, provided the materials involved are mechanically strong, reaction induced stress may slow down or even quench net transfer reactions. Our analysis indicates that the rheologies of polycrystalline quartz and olivine are well within the range of mechanical properties required for deformation by creep to take over reaction rate control.