Matrix rheology effects on reaction rim growth: coupled diffusion and creep model

D.W. Schmid (1), R. Abart (2), Y.Y. Podladchikov (1), and R. Milke (2)

(1) PGP Oslo, (2) Freie Universität Berlin

Chemical reactions and phase changes generally involve volume changes. In confined settings this will cause a mechanical deformation of the matrix that surrounds the reaction sites where the volume change takes place. Consequently mineral reactions and the mechanical response of the rock matrix are coupled. The work of Milke et al illustrates this coupling with experiments where quartz and olivine react to form enstatite reaction rims under ambient conditions of 1GPa and 1000°C. They demonstrate that for identical run conditions the thickness of the reaction rims depends on whether quartz grains are embedded in an olivine matrix or olivine grains are included in a quartz matrix. The experimental conditions, results, and the large volume change of the reaction (-6%) leave only viscous creep as a viable matrix response to the reaction progress. We develop a model for this reaction that combines reaction diffusion of chemical components through the growing rim and viscous creep of the matrix. The resulting rate law for reaction rim growth in spherical geometry shows that the progress rate is proportional to the reaction overstepping and controlled by the slower of the two competing processes; either diffusion or creep. If diffusion is rate limiting the usual linear proportionality between rim growth and sqrt(t) results. However, if viscous creep is rate limiting then the reaction rates are slowed down and may become effectively stopped, not unlike the thermal closure of Dodson (1973). With respect to the experiments of Milke et al. we infer the effective viscosity of the two matrix materials, i.e. polycrystalline quartz and olivine, to differ by approximately one order of magnitude with the quartz being the stronger one. The absolute values of the inferred viscosities correspond well to published flow laws. The rheological properties of natural rocks are well within the parameter range for which significant mechani-

cal control on reaction rim growth is expected. This implies that for the interpretation of natural reaction rims and corona structures both diffusion and mechanical control need to be accounted for. In addition the mechanical effect also needs to be considered when interdiffusion coefficients are retrieved from rim growth experiments. This should also be considered for geospeedometry analyses. Furthermore the closure due to slow creep of the matrix is expected to be even more important, compared to the experiments, under colder crustal conditions and may contribute substantially to the frequent observation of only partially completed reactions. Mechanical closure may be an important mechanism in the kinetic displacement of the boundaries between the stability fields of phase assemblages.