Metamorphic reaction kinetics at anhydrous to water-saturated conditions

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Metamorphic coronas and reaction rim structures are examples of a net-transfer reaction, where pre-existing mineral phases react to new phases. Growth of these metamorphic structures indicates a change in physical parameters such as pressure or temperature. One of the most important parameters that controls reaction rim growth is the presence of volatiles, which can affect rim thicknesses, phase stabilities or rim microstructures (e.g., Gardés et al. 2012). This implies that reaction rims have the potential to decipher the P-T-t-X history of a sample of interest.

In this study, reaction rim growth experiments were performed between periclase and quartz at nominally anhydrous to water-saturated conditions between 3 to 4 kbar and 1100 to 1300 °C for 66-168 h. Controlled minute amounts of water were added through OH-doped periclase, which allowed to perform experiments at controlled water-undersaturated conditions. For water-saturated experiments that contain wt% amounts of H_2O, controlled amounts of water were added in the form of brucite powder to the samples.

At anhydrous conditions, no reaction rim formed implying that water acts as a catalyst, and a minimum fluid threshold is needed to initiate metamorphic re-equilibration. In all experiments that used either water-doped periclase or brucite as source of water, the rim sequence Per | Fo | En | Qz developed. At water-undersaturated conditions, addition of minute amounts of water results in an increase in the overall reaction rim growth rate by more than 2 orders of magnitude while the relative forsterite/enstatite ratio increases from 0.6 to 2.4. At water-saturated conditions, growth rates reach a plateau valeau between 10^{-15} and 10^{-14} m^2/s while forsterite/enstatite thickness ratios vary between 3 and 12.

This implies that reaction rim growth rates have the potential to monitor variations in water activity at those grain boundaries that serve as fast pathways for component transport at water-undersaturated conditions during metamorphic and metasomatic reactions in natural systems, allowing them to be used as sensitive “geohygrometers”. Additionally, the effect of water on relative layer thicknesses may provide an application for reaction rim microstructures to be used as new physico-chemical gauges that will allow us to discriminate between water-undersaturated and water-saturated conditions during metamorphic events.

Gardés E, Wunder B, Marquardt K, Heinrich W (2012): The effect of water on intergranular mass transport: New insights from diffusion-controlled reaction rims in the $MgO-SiO_2$ system. - Contr Mineral Petrol 164, 1–16