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Fine-scale dissolution-reprecipitation during deuteric coarsening of cryptoperthites to patch perthites – an experimental study

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In this study deuteric coarsening of perthitic alkali feldspars to patch perthites was experimentally produced for the first time by reacting a synthetic, spinodally exsolved, intermediate alkali feldspar in de-ionized water at 400 to 600 °C and pressures of 200 to 1000 GPa. Run products were characterized using XRD, Raman spectroscopy, EPMA, FIB-SEM and (HR-)TEM. Patch perthites are commonly observed in granitic rocks that have been subject to late-stage fluid infiltration and subsequent alteration/metasomatism (e.g. Parsons and Lee, 2009).

Dry subsolvus tempering of initially homogeneous, intermediate alkali feldspars (Ab60Or40) at 550 °C for 32 days resulted in spinodal decomposition via interdiffusion of Na and K, forming in a lamellar intergrowth of Ab-rich and Or-rich phases (wavelength $\sim$32 nm, thickness $\sim$20 nm). Despite this phase separation the Si/Al tetrahedral framework remains completely coherent, resulting in the generation of strain along the lamellae interfaces. During the fluid-mediated replacement this strained, coherent cryptoperthite is replaced by an incoherent, very fine-grained (<100 nm) but significantly coarsened with respect to the precursor, polycrystalline intergrowth of albite and K-feldspar grains. This takes place via dissolution-reprecipitation (e.g. Putnis, 2009) along an interfacial fluid film resulting in the complete disintegration of the initial structure, a further separation of Na and K within the fluid film, and the precipitation of Afs end-members with compositions defined by the strain-free solvus.

The replacement appears to be isochemical and therefore the major driving force for this “mutual replacement” seems to be the reduction of coherency strain energy stored within the initial perthites (Brown and Parsons, 1993). It results in an extremely sharp reaction front across which topotactical relations are preserved. However, the accompanying phase separation results in structural misfit due to differences in lattice dimensions of the precursor, Ab-rich patches and Or-rich patches. A result of this misfit is the formation of dislocations visible in TEM along the patch perthite-cryptoperthite interface as well as along albite-orthoclase contacts within the patch perthite. Therefore the reaction interface is incoherent or semi-coherent at best. In addition, sub-crystals within the patch perthite are misoriented with respect to the initial crystal and each other.

Reaction-induced porosity is mostly located at grain edges and junctions. However, no 3D interconnectivity of porosity could be observed via FIB serial sectioning. On the other hand, Ab-Or sub-grain boundaries within the patch perthite do form a 3-dimensional network. Another striking observation is that both the mean size of sub-grains as well as the average size of pores increase with increasing distance from the reaction interface. This indicates that secondary coarsening of the initially very fine-grained intergrowth occurred, most likely driven by the reduction of interface and surface energy similar to the coarsening observed in multiphase ceramics (Vorhees, 1992). A consequence of this coarsening of albite and K-feldspar sub-grains is the constant redistribution of the porosity and the (sub-)grain boundaries within the patch perthite mosaic with time. This dynamically evolving porosity could provide an important transport mechanism for fluids through rocks even when the abundance and interconnectivity of the reaction-induced porosity is low, which is the case for patch perthites as can be seen in the 3D distribution of pores determined via FIB serial sectioning.

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