

Experimental development of patch perthite from synthetic cryptoperthite: Microstructural evolution and chemical re-equilibration†‡

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ABSTRACT

In this study, deuteric coarsening of a lamellar cryptoperthite to a patch perthite has been experimentally induced for the first time. An homogeneous alkali feldspar, bulk composition Ab60Or40, was produced by molten salt ion-exchange with a gem quality orthoclase from Madagascar. This was then annealed isothermally for 32 days at 550 °C. This resulted in a coherent lamellar cryptoperthite (periodicity 28 nm) probably by spinodal decomposition and subsequent coarsening. The cryptoperthite was then reacted with 20 wt% H₂O or 0.1 M HCl at 400 and 500 °C at 200, 400, and 1000 MPa for 96 h and for 192 h at 1500 MPa. At 1000 and 1500 MPa and 500 °C, the cryptoperthitic crystal fragments were partially replaced by a mosaic of albite and sanidine subgrains in the form of a patch perthite. Other than the Gibb's free energy of reaction as derived from the chemical potentials of the reactant and product phases, the second principle mechanism responsible for driving this reaction is interface-coupled dissolution-reprecipitation driven by a reduction in the coherency strain energy stored within the initial cryptoperthite. The main indicator of this is a change in the microtexture due to the destruction of the coherent lamellar cryptoperthite and its replacement by an assemblage of incoherent subgrains. Detailed mass balancing, based on XRD and EPMA data, indicate that conversion of cryptoperthite to patch perthite is not isochemical. Experimental formation of patch perthite appears to take place in two steps. Between the original cryptoperthite and the patch perthite, TEM investigation identified a "transition zone," characterized by a significant coarsening of the preexisting lamellar microstructure, without any sign of a loss in lattice coherency. This zone is probably the result of hydrous species diffusing into the cryptoperthite causing the H₂O-enhanced diffusion of Na and K and hence lamellar coarsening. In the second step, this coarsened microstructure is replaced by the patch perthite. The polycrystalline patch perthite is characterized by a very complex distribution of albite and sanidine sub-grains. Even the larger albite or sanidine patches are polycrystalline. This inevitably results in a three-dimensional network of grain boundaries characterized by high defect densities resulting from the structural misfit between the albite and sanidine sub-grains. An increase in average grain size with distance from the interface indicates that secondary coarsening of the initially, very fine-grained intergrowth occurred. This was driven by the reduction of interface and surface energy similar to the coarsening observed in multiphase ceramics. In addition, the newly formed patch perthite is highly porous despite the fact that the results obtained in this study show that the replacement of cryptoperthite by patch perthite is nearly isovolumetric ($\Delta V \sim -0.6\%$). The observed reaction-induced porosity results from differences in relative solubilities between the cryptoperthite and the patch perthite. Porosity abundance has been estimated at approximately 10 to 11 vol% based on the amount of quartz formed during the experiments. Three-dimensional investigations via FIB serial sectioning indicate almost no interconnectivity between pores. A consequence of albite and sanidine sub-grain coarsening is the constant redistribution of the porosity and the sub-grain boundaries within the patch perthite mosaic over time. This suggests that a dynamically evolving porosity could provide an important transport mechanism for fluid transport through rocks even when the abundance and interconnectivity of the reaction-induced porosity is low.

Keywords: Patch perthite, cryptoperthite, deuteric coarsening, reaction-induced porosity, element mobilization, secondary inclusions, albite, sanidine