NE5C/2004G225

An in-situ X-ray diffraction study on kinetics of plagioclase breakdown at high pressure

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Introduction

High-pressure transformations in plagioclase occur in subducting oceanic crust associated with the gabbro-eclogite transformation. Although equilibrium phase relations for this transformation have been well studied, the processes of plagioclase breakdown are poorly known, which makes it difficult to constrain the depth of eclogitisation in subducting plates. Here we report experimental results on mechanisms and kinetics of plagioclase breakdown examined by in-situ X-ray observations.

Experimental

Two kinds of starting material were used in this study, sodic (natural albite, Ab98.0An0.4Or1.6) and calcic (natural labradorite, Ab45.0An51.8Or3.2) plagioclases. Theses plagioclases decompose into jadeite + quartz (coecite), and jadeite + grossular + kyanite + quartz (coecite), respectively, at around 1-2 GPa. In-situ X-ray diffraction experiments were carried out using multi-anvil high-pressure apparatuses MAX-80 installed at KEK, Japan. Kinetics of plagioclase breakdown was observed at 2.2-18.8 GPa and 273-973K (Fig. 1) by taking time-resolved X-ray diffraction profiles every 10-300 seconds. Because we used the pressure medium of boron+epoxy in the present experiment, some amount of water was contained in the sample. Transformation microstructures and water contents of recovered samples were investigated using SEM and FTIR, respectively.

Results and discussion

SEM observations show that the breakdown of plagioclase occurs by grain-boundary nucleation and growth processes. We observed that decomposition of calcic plagioclase was much slower than that of sodic plagioclase, which is almost identical to the effect associated with a 400-500K difference in temperature. This is probably because of the very complex reaction (dissociation into 4 phases) and the slow diffusion rate of Ca. Kinetic data obtained was analyzed based on the Avrami rate equation. The analysis suggests that the growth distance is proportional to t^0.5 (t: time), which implies the diffusion-controlled growth occurs in these transformations. Temperature dependences of the rate constant *k* are shown in Fig. 2. Extrapolations of obtained growth kinetics suggest that the breakdown of albite with the grain size of 5 mm can complete in 10000 years at 573K (~0.2 wt% H_2O). Growth kinetics in this reaction is enough fast compared to geological time scales (i.e., 10^6 years). On the contrary, the higher temperatures of around 873K are needed to complete the breakdown reaction of labradorite in geological time scales (~0.2 wt% H_2O). Breakdown of labradorite is a key reaction for the complex gabbro-eclogite transformation in subducting oceanic crust. The present study implies the possible existence of the untransformed oceanic crust if the water content is relatively low around 0.2 wt% H_2O.

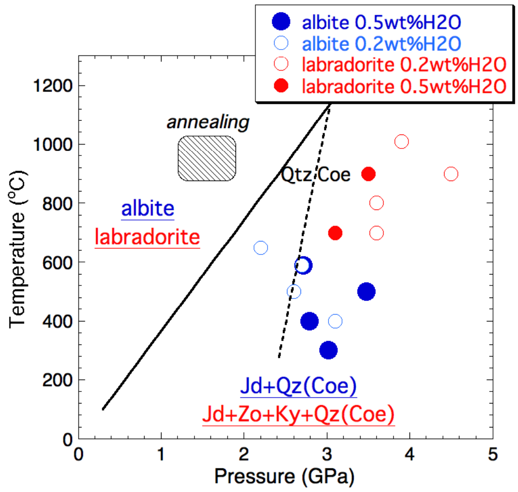

Fig. 1 P-T diagrams showing experimental conditions of the present study. Powdered samples were annealed prior to the transformation to make strain-free equi-granular polycrystalline samples.

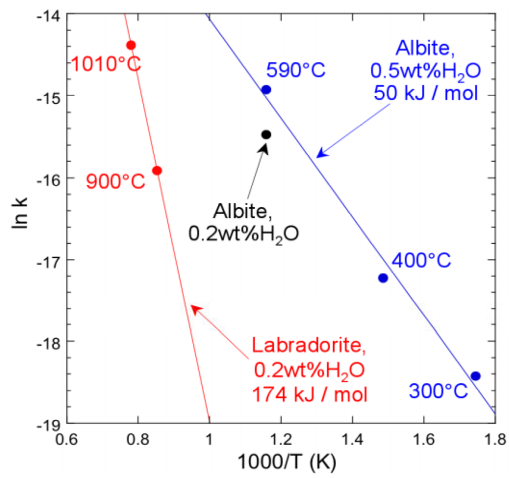

Fig. 2 Temperature dependence of rate constant k in the Avrami equation (n=0.5). The transformation of calcic plagioclase is much slower than sodic plagioclase.

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