NE5C/2004G225

Kinetics of albite 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 and in parent bodies of heavily shocked chondritic meteorites. Although equilibrium phase relations for these transformations 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 and P-T-t conditions during shock events in parent bodies. Here we report experimental results on mechanisms and kinetics of sodic plagioclase (albite) breakdown examined by in-situ X-ray observations.

Experimental

Starting material used in this study is natural albite, (Ab98.0An0.4Or1.6) which decomposes into jadeite + quartz (coecite) 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 albite breakdown was observed at 2.2-6.0 GPa and 273-923K by taking time-resolved X-ray diffraction profiles every 10-300 seconds. Transformation microstructures and water contents of recovered samples were investigated using SEM and FTIR, respectively.

Results and discussion

Time-resolved X-ray diffraction patterns during the transformation are shown in Fig. 1. In case of the grain size of about 20 micron in the present study, the reaction proceeds rapidly at temperatures of 673-773K and overpressure (dP) of more than 2 GPa from the equilibrium boundary. We observed that the albite breakdown becomes very slow near the equilibrium boundary (dP of about 0.5 GPa) even at higher temperature of 923K probably due to difficulties of nucleation processes. SEM observations show that the breakdown of albite occurs by grain-boundary nucleation and growth processes. Water contents of samples recovered were estimated to be 0.2-0.5 wt% H_2O on the basis of FTIR measurements.

Kinetic data obtained indicates that the growth distance is mostly proportional to t^0.5 (t: time), which implies the diffusion-controlled growth mechanisms (Fig. 2). Extrapolations of obtained growth kinetics suggest that the breakdown of albite with the grain size of 5 mm can complete in 10^4 years at 573K. Growth kinetics in this reaction is enough fast compared to geological time scales (i.e., 10^6 years) The depth of the albite breakdown in subducting plates is possibly controlled by nucleation kinetics.

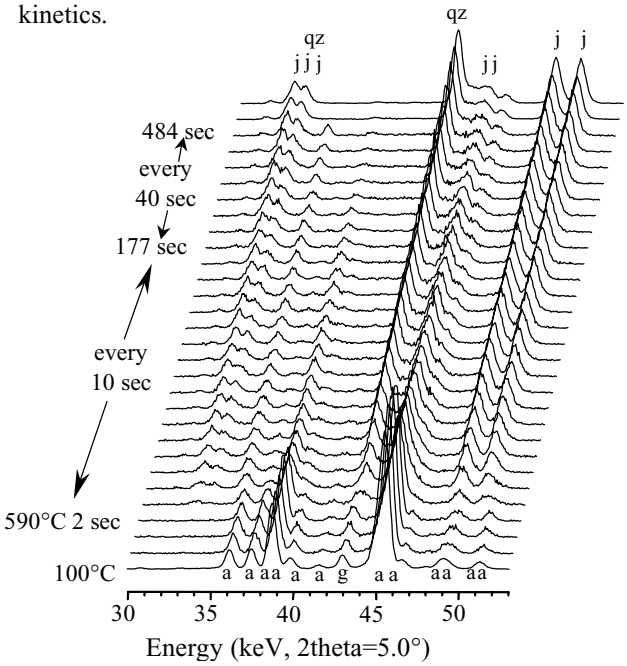

Fig. 1 Time-resolved XRD patterns showing albite (a) breakdown into jadeite (j) and quartz (q) at 2.7 GPa and 863K.

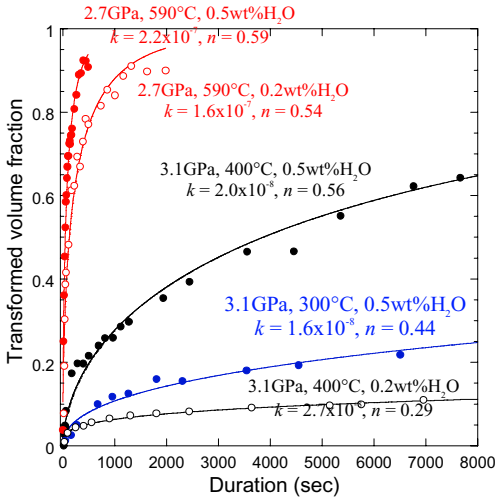

Fig. 2 Time dependence of transformed volume fraction. Kinetic data were fitted using the rate equation for grain-boundary reaction. Growth distance at time t can be described by kt^n. Rate constants k and n are shown.

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