高圧鉱物の逆相転移カイネティクス

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Back-transformation kinetics in high-pressure minerals

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High-pressure minerals stable at deep mantle pressures have been naturally found on Earth such as shocked meteorites and diamond inclusions, which provides important constraints on detailed processes of planetary collisions and deep mantle dynamics. Because the timescales are limited in these dynamic processes, the reactions often remain incomplete and/or metastable state. Additionally, it is necessary to consider the possibility of the backward reactions to the low-pressure phases. The kinetics on the forward reactions have been widely discussed for this topic, however those on the backward reaction had been very limited so far. Here we present some experimental results on mechanisms and kinetics of the back-transformation.

A conventional method combining MA-type high-pressure apparatus with synchrotron white X-ray (MAX-80@PF-AR NE-5C, SPEED Mk.II@SP8 BL04B1) was used to observe back-transformation behaviors and their kinetics at 0-10 GPa and 300-900°C by collecting XRD data every 10-200 sec. The starting materials are polycrystalline ringwoodite (Rw), bridgmanite (Brg), and lingunite (Lgn), those were synthesized by using another MA press (QDES) at Kyushu Univ. in advance.

Time-resolved XRD measurements have revealed that, in contrast to Rw that simply transforms to the low-pressure polymorph olivine (Ol), Brg and Lgn do not directly transform to their low-pressure phases, but through the amorphous state. In Brg, the amorphization temperature rapidly increases with pressures from 300°C at 1 GPa to 800°C at 7 GPa, whereas the crystallization temperature does not. As a result, Brg directly back-transformed to high-pressure clinoenstatite (HP-CEn) at around 800°C and 8 GPa. Analysis of kinetic data on the back-transfotmation in Rw and Brg by the Avrami rate equation suggested the rapid nucleation in Rw to Ol and Brg to HP-Cen transformation, and slow nucleation in the crystallization of Opx from amorphous Brg. The amorphization kinetics of Brg is too fast to be constrained by the present kinetic data. On the basis of P and T dependencies of these reaction rates, we can construct P-T-t kinetic boundaries for survival of high-P phases and formation of low-P phases in a given timescale. For example, in the timescales of 0.1 to 10 sec generally considered for shock events in the early solar system (Fig. 1), Rw transforms to Ol at 700-900°C and 800-1000°C at ~1 GPa and ~10 GPa, respectively. Brg is thought to become amorphous state when decompression less than 800°C. At higher than 800°C, Brg rapidly transforms to HP-CEn, and then low-pressure CEn (LP-CEn).

Both high-pressure and low-pressure phases are enigmatically present in shocked meteorites and diamond inclusions. To precisely understand their P-T-t histories, not only the forward, but also the backward reaction kinetics shown here need to be considered.

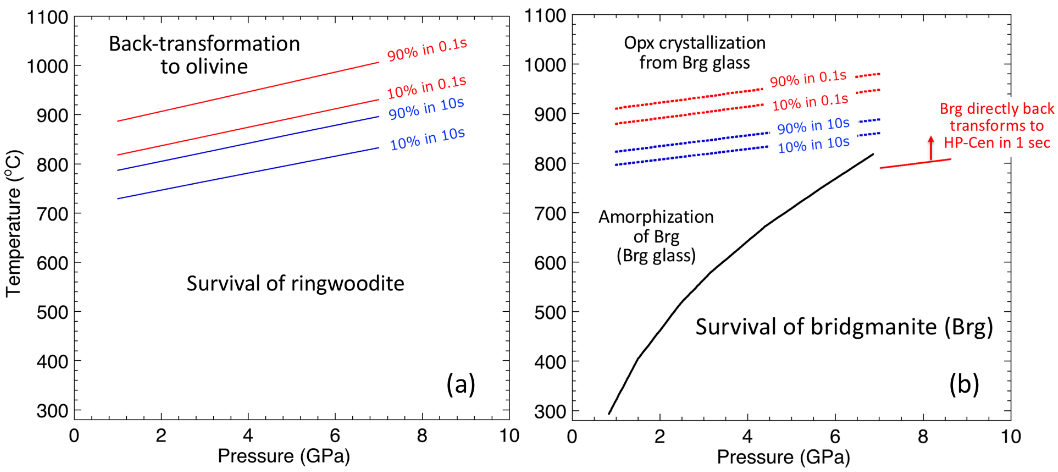

Fig. 1 P-T-t kinetic boundaries for the back-transformation in ringwoodite (a) and bridgmanite (b) estimated from the experimentally obtained kinetic data.

Keywords: high-pressure mineral, back-transformation, kinetics, shocked meteorite, diamond inclusion
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