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Binary phase relations between ringwoodite and bridgmanite + ferropericlase: implication for sharpness of the 660-km discontinuity

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Short wave-length seismic reflections from the 660 km discontinuity indicate that the 660-km discontinuity is extreme sharp, namely less than 2 km thick. Since the Earth's mantle is considered to consist of ferromagnesian silicates, and the 660-km discontinuity is usually attributed to dissociation of ringwoodite to bridgmanite + ferropericlase, the extreme sharpness of the 660-km discontinuity must be explained by the pressure interval of the ringwoodite + bridgmanite + ferropericlase three-phase region. However, the thickness less than 2 km corresponds to a pressure interval less than 0.1 GPa. Such a small pressure interval was too difficult to investigate by means of high-pressure experiments.

In this study, we have determined the binary loop of ringwoodite + bridgmanite + ferropericlase at a temperature of 1700 K. More concretely, we simultaneously determined transition pressures with Mg_2SiO_4 and $(Mg_{0.7}Fe_{0.3})_2SiO_4$ compositions by means of in situ X-ray diffraction in a multi-anvil press to estimate pressure difference between the Mg end-member transition and the ringwoodite – bridgmanite – ferropericlase – stishovite four-phase coexistence. Then, we estimated the compositional width of the binary loop by means of thermochemical calculation using data available in literature.

The striking difference from previous investigations is that the four-phase coexistence is located at a higher pressure than the Mg end-member transition at 1700 K. The pressure difference was found to be 0.14 ± 0.11 GPa. The compositional difference between ringwoodite and bridgmanite + ferropericlase satisfying the observation by in situ X-ray diffraction is 1 mol% at this temperature. This difference becomes smaller with temperature, and virtually zero at temperatures of 2000 to 2300 K.

From these investigations, we have concluded that the thickness of the ringwoodite + bridgmanite + ferropericlase binary loop is essentially zero at mantle temperatures, which explains the sharpness of the 660-km discontinuity.

Core Mantle Coevolution

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