Reductive decomposition of phase D by formation of Fe-bearing aluminous bridgmanite

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Water is thought to be transported as hydrous minerals through subduction of slabs at least to depths reaching the transition zone. Nominally anhydrous lower mantle minerals (e.g. bridgmanite (Brm)) can incorporate a limited amount of water. Therefore, water could be hosted by hydrous minerals such as phase D (phD) in the lower mantle. Brm contains significant amounts of Fe^{3+} ($Fe^{3+}/\Sigma Fe > 0.1$) even when coexisting with metallic iron. The Fe^{3+} content increases with increasing Al_2O_3 in Brm, and exceeds 0.5 relative to total iron in lower-mantle Brm. Therefore, the formation of Brm could extract oxygen from hydrous minerals (reduction of OH to H_2) through the deposition of Fe metal. In this study, we demonstrated this reduction reaction using phD with a Kawai-type multianvil press.

The starting materials were sintered Al-free and aluminous phD (Al-phD) pre-synthesized at 27 GPa and 1100 K, a natural olivine single crystal (Olv) and pyroxene as $(Mg_{0.9}Fe_{0.1})(Si_{0.9}Al_{0.1})O_3$ (FeAl-En) synthesized at 1300 K at controlled oxygen fugacity ($PO_2 \approx IW$). Sintered Al-free phD and Al-phD were combined with Olv or sintered FeAl-En in Au capsules. The samples were pressurized to 27 GPa and heated at 1100 K for 1 hour.

No reaction between Al-free phD and Brm + ferropericlase aggregate formed from Olv according to SEM data. In contrast, a 4 μm fine-grained layer consisting of SiO_2 and an amorphous phase was found with TEM on the boundary between Al-phD and Brm aggregate formed from FeAl-En. The present results strongly indicate that the decomposition of phD is accompanied by the formation of Fe-bearing aluminous Brm. It is suggested that phD decomposes by reduction at depths to 720 km and that no water is transported into the deeper part of the lower mantle.