

Iron partitioning in natural lower-mantle minerals: Toward a chemically heterogeneous lower mantle

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ABSTRACT

The concentrations of Fe, Al, and Ni and their distributions were determined for all known natural assemblages of ferropericlaase (fPer) and bridgmanite (Bridg), coexisting as inclusions in deep-mantle diamonds from Brazil, Canada, Guinea, and South Australia. Based upon these data, it is likely that some areas within the deep lower mantle are iron-rich and differ markedly from a pyrolitic composition. In the lowermost lower mantle, Bridg is Al-rich and fPer is Ni-poor, witnessing the presence of a free metallic phase in the mineral-forming environment. The iron partitioning in the Bridg + fPer association [$K_D^{\text{Bridg-fPer}} = ([\text{Fe}/\text{Mg}]^{\text{Bridg}})/([\text{Fe}/\text{Mg}]^{\text{fPer}})_{\text{at}}$] in juvenile diamond inclusions is as low as 0.1–0.2. During ascent of the diamonds with their inclusions to the surface, the $K_D^{\text{Bridg-fPer}}$ eventually increases to values of 0.4–0.5 and even as high as 0.7.

The details of the element partitioning between natural Bridg and fPer in the lower mantle are as follows: iron in Bridg is ferrous Fe^{2+} in the A site, substituting for Mg^{2+} ; almost all iron in fPer is ferrous Fe^{2+} ; the share of ferric Fe^{3+} iron in fPer is $\text{Fe}^{3+}/\Sigma\text{Fe} = 8\text{--}12$ at%; iron concentrations in both Bridg and fPer increase with depth (pressure), reflecting the increasing Fe content in the lower part of the lower mantle, different from that of a pyrolitic model. Al in Bridg is mainly in the cation site B and partly in the cation site A, in both cases substituting for Si, Mg, and Fe with vacancy formation; and in the case of Al positioning into both B and A sites, a charge-balanced reaction occurs.

The natural samples show very diverse $K_D^{\text{Bridg-fPer}}$ values and elemental distribution that cannot be simply explained by our current understanding on alumina dissolution in Bridg and the spin transition of Fe^{2+} in fPer. These major differences between experimental results and observations in natural samples demonstrate the complex, inhomogeneous iron speciation and chemistry in the lower mantle.

Keywords: Lower mantle, ferropericlaase, bridgmanite, iron partitioning, pyrolite