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Partitioning and oxidation state of Fe in the Earth's lower mantle

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The constitution of the Earth's lower mantle is of vital importance to understand the evolution of the Earth and its present state. Recent seismologic studies indicate more seismic discontinuities in the Earth's lower mantle than previously thought. These discontinuities are considered to be the consequence of iron spin transitions in magnesiowüstite (mw) and silicate perovskite (pv), resulting in a redistribution of Fe between the two phases and an accompanying sound velocity change. However, the effect of spin transitions on the partitioning behaviour of iron has so far only been observed in a system with simple olivine composition.

In order to address this problem further we performed 9 laser heated diamond anvil cell experiments in a pressure range of 25 to 140 GPa at temperatures corresponding to the geotherm at the respective pressure points. A pyrolitic lower mantle assemblage made of silicate perovskite and magnesiowüstite was synthesized in a multi-anvil apparatus at 25 GPa and 1700 ˚C; this material was used as starting material to exclude effects due to transitions of ambient phases to lower mantle phases in the diamond anvil cell (e.g., heat of fusion). Recovered samples were prepared for TEM analysis by focused ion beam milling. Chemical compositions and oxidation state of Fe were measured by means of EDX and EELS analyses, respectively.

The resulting partitioning coefficient K_D (Mg-Fe) between pv and mw keeps almost constant along the entire lower mantle pressure range between 0.4 - 0.6. However, at 32 GPa the $K_D$is significantly higher ($\sim$0.75). This value corresponds to the increase of $K_D$at the same pressure range observed by [1]. Thus, we can reproduce the trend observed by multi-anvil experiments. The $Fe^{3+}/\sum$Fe ratio in pv stays almost constant at around 0.5 over the entire lower mantle geotherm, whereas for mw the $Fe^{3+}/\sum$Fe ratio increases linearly from 0.03 to 0.20 over the studied pressure range.

Our study shows that there should be only one major discontinuity due to the partitioning behaviour of iron in the Earth's lower mantle. We will discuss the influence of spin transitions of iron in pv and mw on the partitioning behaviour.

[1] T. Irifune, T. Shinmei, C. a McCammon, N. Miyajima, D. C. Rubie, and D. J. Frost, Science (New York, N.Y.) **327**, 193-5 (2010).