Chemical composition of the Earth's lower mantle

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An orthorhombic Mg-perovskite is generally accepted to be the dominant phase of the Earth's lower mantle. Information on its density and bulk and shear modulus under various pressures and temperatures is, therefore, of prime importance in determining the composition and properties of the lower mantle. Experimental reports of the bulk modulus of Al-bearing orthorhombic Mg-perovskite remain controversial. In previous studies of EOS for orthorhombic perovskite, chemical compositions were simple. However, the chemical composition of natural orthorhombic perovskite seems to be complicate. I investigated the pressure-volume EOS of orthorhombic perovskite possessing natural composition, which had some minor components, such as FeO, Al_2O_3, TiO_2, CaO, and Na_2O. The minor components of natural rock systems often play an important role in determining the physical properties of minerals.

In this study, I used a laser-heated diamond anvil cell (LHDAC), which made it possible to acquire precise data on a sample of Al-bearing Mg-perovskite under high pressure. I also used intense x-rays from a synchrotron radiation source. I investigated the pressure-volume EOS of orthorhombic perovskite possessing the pyrolytic (KLB-1 peridotite) composition up to a pressure of 80 GPa.

To determine the elastic parameters, the *P-V* data were fitted to the Birch-Murnaghan equation of state. When $Ko' = 4$ and Anderson's EOS of Au was used, the value of bulk modulus, Ko, was determined to be 272(8) GPa. Although Mg-perovskite is the dominant phase in the Earth's lower mantle, other phases, such as Ca-perovskite and magnesiowüstite, should be considered to understand the dynamics of the lower mantle. The EOS of KLB-1 peridotite, which is composed of Mg-perovskite, Ca-perovskite, and magnesiowüstite in the lower mantle, was determined using the reliable EOS of each phase. The Birch-Murnaghan equation of state of KLB-1 peridotite was calculated at room temperature: volume of $Vo = 22.80$ cm^3/mol, a bulk modulus of $Ko = 269$ GPa, and its pressure derivative of $Ko' = 4.0$. The density of KLB-1 peridotite at lower mantle conditions was also calculated for various temperatures. The calculated densities were then compared with seismologically derived average density profiles of the mantle. For a mantle temperature is of 2000 K at the top of the lower mantle, the density of the KLB-1 peridotite composition was found to be 0.4% lower than the seismologically determined density of PREM. This density mismatch is very small compared with the uncertainties in the experimental measurements and analysis. Therefore, our study suggests that the KLB-1 peridotite seems to be the bulk composition of the upper part of the lower mantle.

Mass-Independent Sulfur Isotope Records from the Hamersley Basin, Austrlaia

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We will present multiple sulfur isotope ratios ($^{34}S/^{33}S/^{32}S$) measured from a 2.4 to 2.7 Ga sedimentary sequence from the Hamersley Basin, Western Australia. The stratigraphically resolved records help us elucidate the Archean sulfur cycle and the mechanism of production, transportation and preservation of MIF signatures on the Archean Earth.

Our data is consistent with the presence of two sulfur reservoirs in the Archean ocean with distinct $\Delta^{33}S$ values ($\Delta^{33}S \sim \delta^{33}S - 0.515 \times \delta^{34}S$): seawater sulfate (with $\Delta^{33}S < 0$) and elemental sulfur (with $\Delta^{33}S > 0$) (Farquhar et al., 2000). Measured $\Delta^{33}S$ ranges from -2.5 to +8.2 ‰, varying systematically with $\delta^{34}S$. The large systematic variation in $\Delta^{33}S$ enables identification of the isotopic compositions of and exchange between those two sulfur reservoirs in the Archean ocean.

Sulfide sulfur from carbonate (~2.6 Ga) and banded iron formations (~2.45 Ga) are characterized by negative and relatively restricted ranges of $\Delta^{33}S$ but a wide range of $\delta^{34}S$. This suggests that microbial recycling of sulfur between reduced and oxidized species exchanged sulfur isotopes between sulfate and elemental sulfur on the Archean shelf environment. Such mixing would minimize the $\Delta^{33}S$ variation, and a large mass-dependent fractionation in $\delta^{34}S$ would be induced by bacterial reduction of sulfate.

On the other hand, sections of two hemipelagic sediments (~2.5 Ga) and (~2.7 Ga) are characterized by a large range and mostly positive values of $\Delta^{33}S$ that weakly correlates with $\delta^{34}S$. This suggests exchange of sulfur between the two reservoirs in deep water is less extensive than in shelf environments, consistent with a largely anoxic Archean deep ocean. It also suggests elemental sulfur reduction metabolism may have been widespread in the Archean open ocean.

Therefore, detailed documentation of Archean $\delta^{34}S$ and $\Delta^{33}S$ records both temporally and geographically not only provides new insights into early atmospheric chemistry but also maps the distribution and evolution of early sulfur metabolism on the Archean Earth.

References

Farquhar J., Bao H. and Thiemens M.H. (2000). *Science* **289**, 756-759