

Pressure and temperature dependence of water solubility in forsterite: Implications for the activity of water in the Earth's mantle

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The storage capacity of water in the upper mantle largely depends on water solubility in mantle olivine. Such solubility provides a fundamental information required for petrological, geophysical and geochemical models of the mantle. Previous experimental studies have shown that the water solubility in olivine increases with increasing water fugacity up to 12 GPa at 1100°C (Kohlstedt *et al.*, 1996) and with increasing temperature at 0.3 GPa (Zhao *et al.*, 2004). This latter contrasts with the incorporation of water in transition zone phases such as wadsleyite and ringwoodite for which water solubility decreases with increasing temperature.

The goal of this study was to determine the dependence of water maximum concentration on temperature at pressures higher than 0.3 GPa. We performed experiments at 3, 6 and 9 GPa, and temperatures ranging from 1000 to 1400°C in the MgO-SiO₂-H₂O system using a multi-anvil apparatus. The starting material consisted of forsterite and enstatite in the 1:1 molar ratio with 1 to 5 wt% H₂O. The samples were analyzed using scanning electron microscopy, electron microprobe and polarized Fourier transform infrared spectroscopy. Results show that water solubility in olivine increases with temperature only at 3 GPa. At 6 and 9 GPa, the water solubility reaches a maximum at low temperatures then decreases at high temperatures. These results agree with recent observations at 12 GPa in the MgO-SiO₂-H₂O system (Smyth *et al.*, 2006). Such behaviour is explained by the change in water fugacity as a function of pressure and temperature due to dissolution of silicate component in the fluid. The solubilities determined in this study allow to correct for this effect and permit to establish a new model of water activity in the mantle for silicate-water fluid coexisting with olivine and enstatite.

References

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Compared Mg isotope compositions of plants, rocks and waters

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Magnesium is directly involved in the biological cycle. Mg plays a major role in photosynthetic processes, as it is the central core of the chlorophyll molecule. It activates many specific enzyme systems, and helps to regulate internal transport of other major ions such as P and K. Mg in plants comes from soil minerals and atmospheric deposits. Mg absorbed from soil solution by roots is transferred to shoots where it can be stored for months to hundred of years. Plants can therefore be responsible for considerable Mg mobilization on a basin scale (mean plant Mg content is ~2000ppm). Chlorophyll can be significantly enriched in light isotopes [1]. The aim of this study is to determine Mg isotope fractionation during Mg uptake by roots and Mg translocation within the plant, and to estimate their potential impact on the isotope signature of continental waters.

We first developed a new chemical procedure to separate Mg from both geological and biological matrices. Plants, clays and granites can display significant contents in alkali, Al and some transition elements such Fe, Mn and Zn which are difficult to separate from Mg with a typical cation exchange resin. We then investigated Mg isotope fractionation induced by two plants (clover, ray grass), grown under experimental conditions, on various Mg-rich substrates (phlogopite, magnesite, nutritive solution). $\delta^{25}\text{Mg}$ and $\delta^{26}\text{Mg}$ were measured using the MC-ICP-MS.

Regular measurements of Cambridge-1 standard solution indicate long term reproducibility for $\delta^{26}\text{Mg}_{\text{DSM3}}$ better than 0.15‰ (2 σ). $\delta^{26}\text{Mg}$ for Cambridge-1 (-2.61‰), as well as for silicate (BE-N, -0.28‰), carbonate (CaLs, -4.59‰), seawater (BCR-403, -0.93‰) and river water (SRM1640, -1.28‰) reference materials are in agreement, within errors, with published values [2, 3]. $\delta^{26}\text{Mg}$ for plant, soil and granite reference materials are presented for the first time. The plants and organic matter analysed (rye flour BCR-382, sealettuce BCR-279 and natural wavy hairgrass) display $\delta^{26}\text{Mg}$ ranging between -0.58‰ and -1.15‰, greater than published values for chlorophyll [4]. A forest soil (TILL-1) yields a $\delta^{26}\text{Mg}$ of -0.40‰. The two granites (DR-N and GA) display $\delta^{26}\text{Mg}$ of -0.50‰ and -0.75‰ respectively.

Preliminary results for experimentally grown plants highlight different Mg isotope signatures of different organs of plants. A decrease of $\delta^{26}\text{Mg}$ from roots to shoots is observed, demonstrating isotope fractionation during Mg internal transfer. The respective roles of plant species, Mg internal recycling, and soil Mg bioavailability will be discussed.

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