Mg isotope composition of the bulk silicate earth constrained by first princeples calculation

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Comparisons of stable isotope composition of the bulk silicate earth (BSE) with chondrites have provided a plethora of important insights into the Earth's generation and evolution processes. Many recent studies argue that the Earth may have similar Mg isotope composition with the CI chondrites, suggesting that planetary accretion or mantle melting does not significantly fractionate Mg isotope composition [e.g., 1,2]. Because mantle samples from the depths greater than 150 km are rare, most studies used basalts and spinel-peridotite xenoliths representing the BSE assuming no measurable variation of δ^{26}Mg (<0.1‰) at the mantle's P-T conditions. However, recent studies clearly show that substantial equilibrium Mg isotope fractionation could occur to mantle minerals due to different C.N. and ionic strengths of Mg in the minerals [e.g., 3,4]. Thus it is necessary to examine the assumption before using shallow mantle samples to represent the BSE.

We use first-principles calculation to predict Mg isotope variations in mantle minerals with depths down to the core-mantle boundary. Our results show that increasing temperature dramatically decreases isotope fractionation, while increasing pressure can enhance it. Therefore, significant fractionation of Mg isotopes between mantle minerals at high P-T can still be expected. Along the mantle's geotherm, $\Delta^{26}Mg_{olivine-garnet}$ varies from ~0.5‰ (2GPa) to 0.2‰ (13.4 GPa, ~410 km), owing to the combined effects of different C.N. (6 in olivine vs. 8 in garnet) and increasing temperature. Wadsleyite is enriched in heavy Mg isotopes relative to olivine and ringwoodite likely due to mineral structure change. At 670 km discontinuity, ringwoodite (C.N.=6) is isotopically heavier than Mg-perovskite (C.N.=8) by 0.28‰ while it is identical with periclase (C.N.=6).

Our preliminary results suggest that Mg isotope compositions of the mantle peridotites could be quite heterogeneous. This brings up some uncertainties when extrapolating δ^{26}Mg of the BSE from basalt and spinel-peridotite data. Specifically, olivine and garnet, the two dominant Mg-bearing minerals in the upper mantle, show varying Δ^{26}Mg by ~ 0.3‰ with increasing the depth, meaning that olivine, garnet, or both have variable δ^{26}Mg. Therefore, it is difficult to predict variations of δ^{26}Mg of olivine and garnet along the temperature-pressure gradient. As δ^{26}Mg of the bulk mantle is a weighted average of the six- and eight- coordinated minerals, Mg isotope composition of the BSE may still be an open question.

[1] Bourdon B. et al. (2010) ***GCA***, 74: 5069-5083. [2] Teng F.-Z. et al. (2010). ***GCA***, 74: 4150-4166. [3] Liu S.-A. et al. (2011) ***EPSL***, 308: 131-140. [4] Schauble E.A. (2011) ***GCA***, 75: 844-869.

Weathering of mafic rocks and early animal evolution in the Ediacaran of South China

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Acanthomorphic acritarch fossils, including some interpreted to be early animal embryos and the resting stages of Metazoa offspring, first appear in the Doushantuo Formation of the Yangtze Gorges area (YGA)[1]. Previous investigators have linked the rise of acanthomorphic acritarchs to the termination of the Marinoan glaciation and diversafacation of early eumetazoans, but without specific ties to conditions in the YGA. Recently, however, Bristow *et al*. suggested that non-marine environments might have hosted the acanthomorphic acritarchs preserved in YGA[2]. Their principal argument supporting the non-marine hypothesis is the appearance of the trioctahedral clay mineral saponite in the lower part of Doushantuo Formation, which can form in alkaline conditions (pH > 9) most commonly found in non-marine settings. However, other possibilities exist for its formation. For instance trioctahedral clays can forms during weathering of mafic rocks.

Major and trace elemental compositions of the Doushantuo Formation from the YGA imply that sediments overlying the cap carbonate reflect two distinct sources. Member 2 was derived from surrounding Neoproterozoic mafic-to-ultramafic rocks, and Members 3 and 4 were likely sourced from recycled sediments with an average shale composition. Using a coupled geochemical and sedimentological approach we argue that the trioctahedral clay mineral saponite in the lower Doushantuo of the YGA are better explained as weathering products from the regional mafic-to-ultramafic hinterland delivered by rivers to a shelf lagoon of the Yangtze Gorges Basin. Therefore, the saponite of the YGA and the associated fossils are easily interpreted within a marine depositional context and, thus, the semi-restricted setting may have favored deposition of sediments with a local provenance signature.

Although weathering of mafic volcanics commonly leads to the formation of a mix of trioctahedral and dioctahedral clays, there have been reported cases of the formation of predominantly trioctahedral clays. Further, trioctahedral clays are the dominant products during the early stages of mafic rock weathering, with subsquent formation of dioctahedral clays. Thus, it is reasonable to imagine that rapid weathering rates after the Neoproterozoic Snowball Earth favored trioctahedral clay formation and preservation.

[1] Yin *et al.* (2007) *Nature* **446**, 661-663. [2] Bristow *et al*. (2009) *Proc. Natl. Acad. Sci. USA* **106**, 13190-13195.