H_2O paradox and possible solutions

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The concentration of H_2O in the mantle plays a significant role in the viscosity and partial melting and hence the convection and evolution of the mantle. Even though the composition of the primitive mantle (PM) is thought to be well known [1-2], the concentration of H_2O in PM remains paradoxial because different methods of estimation give different results [3]: using H_2O/Ce ratio in MORB and OIB and Ce concentration in PM, the H_2O concentration in PM would be $(300 \overset{\times}{\div} 1.5)$ ppm; using mass balance by adding surface water to the mantle and assuming that the mass of the degassed mantle is about 1/2 of the whole mantle [3-4], H_2O concentration in PM would be $(900 \overset{\times}{\div} 1.3)$ ppm [2-3]. In this report, I explore possible solutions to reconcile the paradox.

One possible solution to the above H_2O paradox is to assume that some deep Earth reservoirs with high H_2O/Ce ratios have not been sampled by MORB and OIB, meaning that the H_2O/Ce ratio approach is not reliable. The best candidate of such a deep reservoir is the D" layer. The second possible solution is to assume that the entire mantle was degassed early during the magma ocean stage, which lowered H_2O/Ce ratio in the whole mantle. However, due to the low H_2O concentration and high H_2O solubility in the magma ocean, the amount of early degassed H_2O is expected to be negligible. The third possible solution is to assume that ocean water only paritally came from mantle degassing, but partially from extraterrestrial sources such as comets [5]. This scenario would work as long as the contributing comets and asteroids have average D/H ratio similar to that of ocean water [6]. In this scenario, the composition of the bulk silicate earth (meaning mantle+crust+oceans+atmosphere) would not be the same as PM, at least for H_2O. Extraterrestrial contribution is also able to reconcile difficulties in Ne and Ar systematics [3].

In conclusion, the likely solution to the H_2O paradox is extraterrestrial contribution to ocean water, indicating PM contains only about $(300 \overset{\times}{\div} 1.5)$ ppm H_2O. Another possible solution is the storage of materials with high H_2O/Ce ratio in the D" layer, indicating PM contains about $(900 \overset{\times}{\div} 1.3)$ ppm H_2O but no PM is sampled by MORB and OIB.

[1] McDonough & Sun (1995), *Chem. Geol.* 120, 223. [2] Palme & O'Neill (2014), *Treatise on Geochemistry* **3**, 1. [3] Zhang (2014), *Treatise on Geochemistry* **6**, 37. [4] Zhang & Zindler (1989), *JGR* **94**, 13719. [5] Chyba (1987), *Nature* **330**, 632. [6] Hartogh et al. (2011), *Nature* **478**, 218.