Early evolution of water D/H in the hydrogen-rich proto-atmosphere on the Earth

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The origin of the Earth's ocean has been investigated by examining deuterium/hydrogen ratios (D/H) of various sources of water such as water-rich meteorites (e.g., Carbonaceous Chondrites: CC), comets, and the solar nebula. The average D/H of CC is very similar to the current D/H of the Earth's ocean. On the other hand, D/H of comets are larger by about a factor of two than one of the Earth's ocean, and D/H of the solar nebula is smaller by about a factor of seven. Consequently, the main source of the Earth's ocean has been though to be CC or adequate mixing of comets and the solar nebula. However, it is not clear that D/H of a water source is preserved during the formation of the ocean and/or evolution of the ocean and atmosphere. In the atmosphere on the early Earth, a significant amount of hydrogen likely existed because of gravitational attraction of the surrounding solar nebula or reduction of water in the presence of metallic Fe. In that situation, water is enriched in deuterium by the isotopic exchange reaction between water and hydrogen molecules. Moreover, the hydrogen-rich atmosphere also becomes rich in deuterium due to mass fractionation by hydrodynamic hydrogen escape, resulting in further deuterium enrichment of water. Here, we will present the D/H evolution of the ocean and the hydrogen-rich proto-atmosphere, and constrain the water source of the ocean.