Early cometary delivery of water to the inner solar system: Clues from the Moon and Mars

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How the Earth and the terrestrial bodies of the inner solar system received water and volatile elements is currently debated. Hydrogen isotopes may distinguish possible solar system reservoirs that could have been involved in this process, such as the Sun, chondritic meteorites, comets, trans-neptunian bodies, Kuiper-belt objects and interstellar organic matter[1]. While chondritic material has long been favored for delivery of water to the Earth[2], the role of cometary ices cannot be ignored[3,4].

Our studies of Apollo lunar rock samples show that there is a high D/H component of lunar hydrogen that is commonly carried by apatite[5]. We have found abundant evidence that this high D/H is likely a lunar mantle signature, and that low D/H is likely due to later hydrogen isotope exchange with a D-poor component in the near lunar surface. The source of the high D/H component could be comets[5] or H isotope fractionation during the proto-lunar disk stage[6], magma ocean stage[6] or final lava degassing[8,9] of earth or chondritic water.

The high D/H of apatite, carbonate and glass in ancient Martian meteorite ALH 84001 has long been ascribed to atmospheric loss processes[10-12]. We have re-analyzed apatite in ALH 84001 and find apatite δD~+2000‰, similar to the most D-enriched glasses and carbonate in the 4.0 Ga veins of ALH 84001[11,12]. This is also similar to values of D/H measured by Curiosity at Gale Crater in ~3 Ga clay minerals[13], suggesting that the Martian surface had a constant δD of ~+2000‰ from 3.0-4.0 Ga. We will explore if comets played a role in the high D/H of early Mars.

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