A cometary source for water on Mars from D/H of Allan Hills 84001

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The sources and abundance of water on the Red Planet has long intrigued Martian researchers. Hydrogen isotopes have the potential to place constraints on these two problems, and have been used to suggest that Mars lost most of its water to early hydrodynamic escape [1-4] or through later atmospheric escape [5]. The dominant paradigm, wherein heavy isotope enrichments of hydrogen, nitrogen, carbon, and the noble gases in the present Martian atmosphere are due to past loss of the Martian atmosphere [1-3], has recently been challenged using results from the Rosetta mission [6]. Marty et al. [6] suggest nitrogen isotopes and noble gases are sourced from comets. They further suggest that D/H is the only Martian isotopic signature that can be unambiguously ascribed to atmospheric loss [6]. Here we suggest otherwise.

Using the Cameca ims 1270 at Hokkaido University we have re-analyzed apatite in ALH 84001 for D/H. We find δD =+1960±138‰ (2σ) for apatite in ALH 84001. This is ~1000‰ lower than [4] and is similar to the highest values of D/H found in this ~4.0 Ga sample by previous researchers [7, 8]. A δD of ~+2000‰ is also measured by the Curiosity Rover in ~3.0 Ga mudstones on Mars [9], suggesting that Mars was not losing atmospheric water to space between ~4.0 and 3.0 Ga. Recent work on water in shock glasses of Martian basalt EETA 79001 has suggested a δD of ~+1000-+2000‰ [10], and hypothesized that this is a global ice deposit. We also report new evidence for water with δD < +3000‰ in QUE 94201, consistent with alterations fluids of ~+2000‰. Here we suggest that this global ice reservoir has a δD~+2000‰, and has been present since at least 4.0 Ga. We suggest cometary delivery of this large surface water reservoir. This also implies that the majority of fractionation of D/H to present Mars atmospheric levels occurred since 3.0 Ga.

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Cometary noble gases measured by the Rosetta orbiter spectrometer for Ion and Neutral Analysis (ROSINA): planetary implications

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Comets are among the most pristine solar system materials. Their abundant volatile species, mainly in the form of ices, are intimately mixed with refractory silicate-rich phases and organics, the origins of which - either in the protosolar disk or the molecular cloud/interstellar medium - are actively debated.

The origin of cometary matter and the potential contribution of comets to inner planet atmospheres are long-standing problems that were central in the definition of the ESA Rosetta mission exploring Comet 67P/Churyumov-Gerasimenko (67P/C-G). Noble gases are key tracers for the origin(s) and processing of volatile elements in the nascent solar system and in planetary atmospheres. The analysis of argon in Comet 67P/C-G has shown that comets are rich in noble gases [1], suggesting that a significant fraction of these elements in the terrestrial atmosphere could be cometary [2].

The Double Focusing Mass Spectrometer ROSINA DFMS has detected during a dedicated period in May 2016 not only argon, but also krypton and xenon. In this talk we will present the results with special emphasis on Xe, and discuss the implications for solar system formation scenarios, as well as for the origin of volatile species on inner planets.

[1] H. Balsiger et al. Sci. Adv. 1, 8, e1500377 (2015). [2] B. Marty et al. EPSL. 441, 91 (2016).