IS EARTH'S ORIGINAL D/H RATIO PRESERVED IN THE DEEP MANTLE? L. J. Hallis[1,2], G. R. Huss[1,2], K. Nagashima[1], G. J. Taylor[1,2], S. A. Halldórsson[3] and D. R. Hilton[3]. lydh@higp.hawaii.edu. [1]Hawai'i Institute of Geophysics and Planetology, Pacific Ocean Science and Technology (POST) Building, University of Hawai'i, 1680 East-West Road, Honolulu, HI 96822, United States. [2]University of Hawai'i NASA Astrobiology Institute. [3]Scripps Institution of Oceanography, University of California, San Diego, La Jolla, CA 92037.

Introduction: D/H analyses of martian meteorites have mostly produced data reflecting the highly fractionated, deuterium-rich nature of the martian atmosphere [1-5]. However, recent research indicates that the martian interior retains its primordial D/H ratio, which is similar to terrestrial reserviors [6]. In this case, water in Earth and Mars may have originated from the same source material. Hence, this D/H similarity supports recent dynamical models of Solar System formation, which suggest material in the inner Solar System was homogenized by the migration of Jupiter [7] (Table 1). However, these inferences are based on the assumption that the Earth's D/H ratio has not changed significantly over geological time. Although the process is stronger on Mars, Jeans (thermal) atmospheric escape also occurs on Earth. Therefore, the current atmosphere should be relatively enriched in deuterium compared to that of the early Earth. To measure the initial D/H ratio of Earth we must sample a reservoir that has been completely isolated from surface processes.

Table 1: Previously measured major terrestrial, martian and cometary reservoir δD reservoirs (adapted from [6]).

Reservoir	δD (‰)	2σ (‰)
Terrestrial Oceans [8]	0	
Terrestrial Ice Sheets [8]	-300 to -400	
Terrestrial Meteoric Water [9]	>0 to +130	
Terrestrial Mantle [10-19]	-140 to +60	
Comet Hartley 2 [20]*	6	300
Comet P/Halley [21]	888	92
Comet Hyakutake [22]	813	625
Comet Hale-Bopp [23]	1063	
Martian Atmosphere [24]	4200	
Martian Mantle [6]	<188	62

*Comet Hartley 2 is a Jupiter family comet, whereas P/Halley, Hyakutake and Hale-Bopp are all Oort cloud comets.

Plate tectonics is known to transport surface water down into the upper mantle, but primitive areas of the lower mantle may be isolated from this circulation, and hence remain uncontaminated by surface hydrogen [25-26]. Certain mantle plumes, such as those that formed the Hawaiian Islands, Iceland, and Baffin Island, appear to have tapped into primitive, and relatively undegassed, deep mantle sources, as evidenced by high $^3He/^4He$ isotope ratios in rock samples from these regions [26-27]. Therefore, D/H analyses of hydrous melt inclusions from undegassed erupted lavas at mantle plumes could provide a more accurate D/H value for the primordial Earth.

We measured the D/H ratios of olivine-bound melt inclusions in two picrite samples from Baffin Island [28], and three basalt samples from Iceland [29], using the Cameca ims 1280 at the University of Hawaii. To assess any possible contamination from crustal material, we are also collecting oxygen isotope data from the same sample suite [30].

Results: The terrestrial upper mantle has a typical δD range of between +60 and -140 ‰ [10-19]. The measured Icelandic samples contain melt-inclusions with δD values within this range (Fig. 1), and indistinguishable from our measured standard materials (basaltic glass standards D52-5 and D51-3, δD = -51.7 and -51.1, respectively). In contrast, both Baffin Island samples contain melt inclusions with strongly negative δD values. Baffin Island sample PI-16 contains melt inclusions with δD between -76 and -158 ‰. These values are still within error of the typical terrestrial upper mantle range (Fig. 1), although they are towards

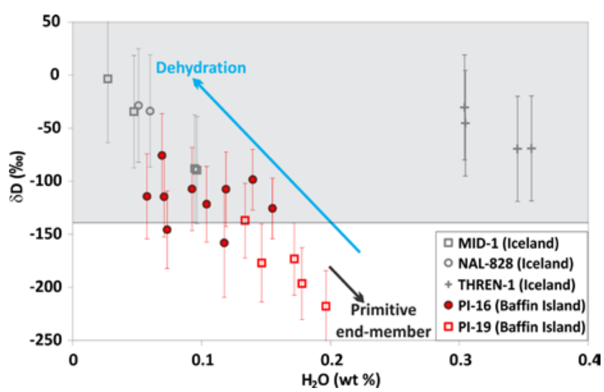

Fig. 1: δD (‰) vs. H_2O (wt %) plot, showing the insversley proportional relationship between the D/H ratio and water contents of measured Baffin Island and Icelandic olivine-bound melt inclusions. The high water content of inclusions within Icelandic basalt THREN-1 may indicate meteoric water infiltration. Alternativley, these inclusions could be the product of a comparatively water rich parental melt. 2σ uncertainties are shown for δD. The grey region represents the extent of δD range for the terrestrial upper mantle.

its lower extreme. Baffin Island sample PI-19 contains even more deuterium-depleted melt inclusions (δD = -139 to -220 ‰), most of which are beyond the typical terrestrial mantle range if a 2σ uncertainty is adopted. PI-19 melt inclusions also show a strong negative correlation between δD and water content. This correlation is probably caused by melt inclusion dehydration during olivine residence in the hot uncrystallised melt – the lighter hydrogen isotope is preferentially lost during degassing/dehydration [31]. This dehydration trend is also strongly evident in the inclusions of Icelandic basalt MID-1. If the water-rich inclusions of THREN-1 are excluded, the dataset as a whole shows a strong dehydration trend, from the water-poor and relatively deuterium-rich inclusions of MID-1 to the relatively water-rich and deuterium-poor inclusions of PI-19. A similar dehydration trend is evident within the measured melt inclusons of THREN-1, although the water-rich nature of these inclusions raises the possibility of meteoritc water infiltration. Oxygen isotope data should resolve this issue – low $\delta^{18}O$ values (< 5 ‰) in these inclusions will indicate involvement of meteoric water.

Implications: Baffin Island basaltic material has been shown to have the highest He isotope ratios measured anywhere on Earth, indicating the incorpertation of a primitive deep mantle endmember in the basaltic parental melt [26-27]. Icelandic basalts also have high He isotope ratios, although to a lesser degree than the Baffin Island samples. The two measured Baffin Island samples contain melt inclusions with more strongly negative δD values than the measured Icelandic samples. In addition, the most water-rich inclusion measured in PI-19 has the most negative δD value. Thus, the hydrogen isotope data presented here indicate the presence of a deuterium depleted hydrogen/water source in Earth's deep primitive mantle. The difference in melt-inclusion δD between samples PI-19 and PI-16 may be the result of a smaller proportion of the primitive endmember in PI-16, but He isotope data from these two specific samples is required to prove this.

Recent studies [32-33] have calculated that the D/H of the Earth may have increased significantly (possibly +100-200 ‰ [33]), due to H_2 degassing after the Giant Impact. Our data suggests that primitive areas of the Earth's deep mantle may retain D/H ratios similar to the Earths original ratio. Recent hydrogen isotope data from lunar samples, indicating strongly negative δD values (as low as -400 ‰) in undegassed intrusive lithologies [34], lend support to this conclusion.

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