Volatile budgets and the late veneer

ALEX N. HALLIDAY[1]*

[1]Department of Earth Sciences, University of Oxford, Oxford, OX1 3AN, U.K. (correspondence: alexh@earth.ox.ac.uk)

The late veneer hypothesis was proposed to explain the budgets of refractory highly siderophile elements (HSEs) in the bulk silicate Earth (BSE) [1], which are too abundant to be in equilibrium with core-forming metallic liquids at low pressures. It was argued that they were added in chondritic proportions after the core formed. It has also been proposed that Earth's volatiles were added as part of this veneer after the Moon forming Giant Impact [e.g. 2]. However, a late veneer does not explain Earth's volatiles. The similarities in moderately siderophile elements [3] and identical isotopic compositions of Si [4] and W [5] in the BSE and Moon provide evidence that terrestrial core formation and accretion were limited following the Giant Impact [6]. For example, a veneer of ordinary chondrites [7] would need to be <0.3±0.3% to be consistent with W isotopes [6]. The H/C/N ratios of the BSE (including all surface budgets) are strongly non chondritic. The estimated BSE H/N is 45 whereas carbonacous chondrites have H/N <15 [8]. If Earth's N was contributed by a CI chondritic veneer, more than 70% of the H would need to be accreted from an additional source [8] requiring that major portions of Earth's volatiles predate any putative chondritic late veneer. Earth's Ne, Ar and Kr are also too abundant to be explained with a chondritic veneer. Cometary ices do have enriched Ar relative to major volatiles [9]. This would explain Earth's heavy noble gases but with amounts that are too small to also explain the H, C and N [8]. A more likely scenario is that after incorporation of early Solar components, Earth acquired most of its volatiles during main stage accretion. This included noble gases, in roughly chondritic proportions, with some fractionation from amorphous ices. A mechanism is required that will also fractionate the BSE's H, C and N from each other, as well as deplete them relative to noble gases. Possibilities for this are losses to space and partitioning into Earth's core before and / or during the Giant Impact [8,10]. However, a volatile rich late veneer does not readily explain the data.

[1] Chou (1978) *Proc.Lun.SciConf.* **9**, 219–230. [2] Albarède (2009) *Nat.* **461**, 1227–1233. [3] Drake *et al* (1989) *GCA* **53**, 2101–2111. [4] Armytage *et al* (2012) *GCA* **77**, 504–514. [5] Touboul *et al* (2007) *Nat.* **450**, 1206–1209. [6] Halliday (2008) *Phil.Trans.R.S.L. A***366**, 4163–4181. [7] Walker *et al* (2002) *GCA* **66**, 4187–4201. [8] Halliday (2013) *GCA* **105**, 146–171. [9] Stern *et al* (2000) *ApJ* **544**, L169-L172. [10] Hirschmann & Dasgupta (2009) *ChemGeol* **262**, 4–16.

The D/H ratio of the Deep Mantle

L. J. HALLIS*[1,2], G. R. HUSS[1,2], G. J. TAYLOR[1,2], K. NAGASHIMA[2] , S.A. HALLDÓRSSON AND D.R. HITLON

[1]University of Hawaii NASA Astrobiology Institute (*Correspondance: lydh@higp.hawaii.edu)

[2]Hawai'i Institute of Geophysics and Planetology, University of Hawaii, 1680 East-West Road, Room 503, Honolulu, HI 96822

The ratio of deuterium (^{2}H) to hydrogen (^{1}H) in the Earth's atmosphere has changed over geological time. The lighter hydrogen isotope (^{1}H) is preferentially lost to space via Jeans (thermal) escape, hence the atmosphere slowly becomes relatively enriched in deuterium and the ^{2}H/^{1}H ratio increases. To measure the initial ^{2}H/^{1}H ratio of the Earth we must sample a reservoir that has been totally isolated from surface processes.

Plate tectonics is known to drag surface water down into the upper mantle, but primitive areas of the lower mantle may be isolated from this circulation, hence uncontaminated by surface hydrogen [1,2]. Certain mantle plumes, such as those that formed the Hawaiian Islands, Iceland, and Baffin Island, appear to have tapped into primitive, un-degassed, deep mantle sources, as evidenced by helium isotope ratios in rock samples from these regions [2,3]. Therefore, ^{2}H/^{1}H analyses of hydrous melt inclusions from erupted lavas at these sites could give an accurate value for the Earth's primordial water. However, oxygen isotope data suggest that some contamination from crustal material does occur in areas where the crust is thick (e.g., Iceland and Baffin Island) [4]. Therefore, comparisons between oxygen and hydrogen isotope data should be made for samples from these areas.

We are currently measuring the ^{2}H/^{1}H and ^{18}O/^{16}O ratios in pristine olivine melt inclusions and glasses from numerous Icelandic and Baffin Island basaltic units [5,6]. A number of these units contain some of the highest ^{3}He/^{4}He ratios currently measured worldwide, indicating a primitive deep mantle origin [2,6]. Others have lower ^{3}He/^{4}He ratios. Helium isotope variations will enable us to determine whether samples with higher (more primitive) helium isotope ratios correspond to lower hydrogen isotope ratios.

[1] Williams and Hemley (2001) *Annu. Rev. Earth Planet. Sci.* **29**, 365-418. [2] Jackson *et al* (2010) *Nature* **466**, 853-856. [3] Stuart *et al* (2003) *Nature* **424**, 57-59. [4] Gurenko A. A. and Chaussidon M. (2002) *Earth. Planet. Sci. Lett.* **205**, 63-79. **[5]** Francis D. (1985) *Contrib Mineral Petrol* **89**, 144-154. **[6]** Füri *et al* (2010) *Geochim. Cosmochim. Acta* **74**, 3307-3332.

www.minersoc.org
DOI:10.1180/minmag.2013.077.5.8