The Pb paradox, the giant impact and a young age for the moon

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Modern terrestrial Pb has an average composition that lies to the right of the geochron implying that the U-Pb system did not evolve from a solar system initial composition in a single stage as a closed system [1]. Instead, a significant global fractionation event must have occurred at an appropriate time and magnitude to increase the $^{238}U/^{204}Pb$ ratio (μ value) from its post-accretionary level. Using our new μ value of 1.7 for ordinary chondrites as a lower limit and Mars (μ=3) [2] as an upper limit for Earth's post-accretionary μ value, we submit that Earth accreted moderately depleted in volatiles, including Pb. The low amount of Pb in Fe-meteorites suggests that core formation did not significantly affect the U-Pb evolution of Earth, despite indications of a chalcophile nature for Pb under some conditions [3]. Accepting a present-day μ2 value of between 9.25-9.65 for Earth's mantle, Pb evolution models require that a U-Pb fractionation event must have occurred after 4.10 Ga. Lacking an alternative global event that would raise the bulk mantle mu value, we explore the possibility that this event corresponds to the giant impact that formed the moon. That Pb can be efficiently lost by devolatization during high temperatures that would accompany a giant impact is demonstrated by the extremely high μ values of differentiated angrite and eucrite meteorites. Accepting a 4.36 Ga age for lunar ferroan anorthosites [4] that require at least 30 Myr of cooling from a magma ocean, brackets the age of the giant impact between 4.41 and 4.39 Ga. We appreciate that such a young age for the moon's formation implies that reported pre-4.41 Ga crystallization ages for lunar rocks, including that for a single zircon [5], do not date primary crystallization, consistent with [6] and [7]. The collateral loss of other volatiles (including water) to space and highly siderophile elements (HSE) to the core immediately after the impact implies that water and HSE in the mantle arrived on Earth as a post-impact veneer.

[1] Allègre, C.A. (1969) *Earth Planet. Sci. Lett.* **5**, 261-269. [2] Gaffney, A.M. et al. (2007) *GCA* **71**, 5016-5031. [3] Wood, B.J. & Halliday, A.N. (2010) *Nature* **465**, 767-770. [4] Borg, L.E. et al. (2011) *Nature* **477**, 70–72. [5] Nemchin et al. (2009) *Nature Geoscience* **2**, 133-136. [6] Gaffney, A.M. & Borg, L.E. (2014) *GCA* **140**, 227-240. [7] Carlson, R.W. et al. (2015) *Phil. Trans. R. Soc. A* **372**.