

Origins and concentrations of volatiles in the interiors of the terrestrial planets

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Earth and the other terrestrial planets formed in the inner Solar System where temperatures were too high for volatile elements to condense; thus, volatiles now present in the interior of these bodies must have been predominantly added during the late stages of planetary formation. The presence of solar noble gases in the mantles of Earth and Mars shows that a small fraction of mantle volatiles was acquired by trapping of nebular gases (by adsorption, ion implantation, or gravitational capture [1]) or by incorporation of dust loaded with solar wind [2]. In contrast, the abundances and isotopic compositions of terrestrial H₂O, C, and N are consistent with a mass contribution of a few percent of carbonaceous chondrite matter, either as a “late veneer” [3] or by accretion of a few wet planetesimals during Earth’s formation [4].

To this date, no traces of “indigenous” solar gases have been detected in samples derived from the Moon’s interior. However, the isotopic composition of water in lunar volcanic glasses (LVGs) [5, 6] and apatites [7], as well as of nitrogen in LVGs [8], resembles that of the terrestrial (surface) reservoir or carbonaceous chondrites, suggesting that the influx of chondritic material to the inner Solar System also delivered volatiles to the lunar magma ocean (LMO) before solidification of the crust. The water concentrations of lunar samples indicate that the mantle contains a few tens to a few hundreds ppm H₂O [e.g., 6], which is comparable to the abundances inferred for the Martian mantle [9] but significantly lower than the water content of the bulk Earth (~1000-3000 ppm [4]). Notably, if a large portion of the late veneer was delivered to the Earth-Moon system after formation of the lunar crust, this material would not have contributed volatiles to the Moon’s interior, but, instead, would have been added to the lunar crust and/or lost to space.

[1] Pepin and Porcelli (2002) *Rev. Mineral. Geochem.* **47**, 191-246. [2] Trieloff *et al* (2000) *Science* **288**, 1036-1038. [3] Albarède *et al* (2013) *Icarus* **222**, 44-52. [4] Marty (2012) *EPSL* **313-314**, 56-66. [5] Saal *et al* (2013) *Science* **340**, 1317-1320. [6] Füri *et al.* (2014) *Icarus* **229**, 109-120. [7] Tartèse *et al.* (2013) *GCA* **122**, 58-74. [8] Füri *et al* (2013) *Mineralogical Magazine* **77**(5), 1123. [9] McCubbin *et al.* (2012) *Geology* **40**, 683-686.