Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.38236

Retention and loss of volatile elements following the Moon-forming giant impact

KAVEH PAHLEVAN[1], ANDREW YOUDIN[2] AND PAOLO SOSSI[3]

[1]SETI Institute
[2]University of Arizona
[3]ETH Zurich

Earth is thought to have accreted its volatile inventory before or during the Moon-forming giant impact [1], suggesting that volatile elements experienced the thermal extremes of the lunar formation event. Models of atmospheric loss associated with the giant impact have primarily focused on the mechanical escape, in which shock waves propagating through the body of Earth accelerate a fraction of the atmosphere to unbound trajectories [e.g., 2]. The thermal component – in which the resulting post-impact planet maintains high enough temperatures to produce a hydrodynamic outflow analogous to the solar wind – has been almost entirely neglected, with rare exceptions [e.g., 3]. Accordingly, the conditions under which terrestrial planets in the hot aftermath of giant impacts can lose volatile elements in a thermally-powered hydrodynamic outflow are not well constrained.

To facilitate the first description of hydrodynamic outflows with high-temperature gas-phase equilibria, we have computed the adiabatic index of gas mixtures in the C-O-H-Na system at the relevant P-T conditions (including thermal dissociation and redox buffering), a set of calculations that constrain the thermal structure of post-giant impact atmospheres and form an important component of the criteria for the onset of thermally-driven hydrodynamic outflows [e.g., 3]. In contrast to earlier studies [4,5], we find that the criterion for hydrodynamic onset from the proto-lunar disk was met, indicating that the proto-lunar disk atmosphere was subject to hydrodynamic outflows into interplanetary space towards the end of its condensation, producing the lunar volatile depletion. By contrast, we find that the post-giant impact terrestrial atmosphere was hydrostatic and behaved as a closed-system, setting the stage for volatile-rich Hadean Earth evolution. We will present model results [6] for the onset and character of hydrodynamic outflows with which the dichotomy of retained (terrestrial) and lost (lunar) volatile reservoirs can be understood.

[1] Greenwood et al. 2018 Science advances, 4(3), eaao5928.
[2] Genda and Abe, 2005 Nature, 433(7028), 842-844.
[3] Genda and Abe, 2004, Lunar Planet. Sci. XXXV
[4] Pahlevan and Stevenson, 2008, GCA 72(12) A716
[5] Nakajima and Stevenson, 2018, EPSL, 487, 117-126.
[6] Pahlevan et al. submitted to EPSL