Constraints on atmospheric pressure on early Mars inferred from nitrogen and argon isotopic compositions

H. KUROKAWA[1*], K. KUROSAWA[2], T. USUI[3]

[1]ELSI, Tokyo Institute of Technology, 2-12-1 Ookayama, Meguro, Tokyo 152-8550, Japan (*correspondence: hiro.kurokawa@elsi.jp)
[2]PERC, Chiba Institute of Technology, 2-17-1, Tsudanuma, Narashino, Chiba 275-0016, Japan
[3]Dept. of Earth and Planet. Sci., Tokyo Institute of Technology, 2-12-1 Ookayama, Meguro, Tokyo 152-8551, Japan

Martian surface geomorphology suggests repeated episodes of liquid water runoff in the Noachian period. Global circulation under a relatively dense atmosphere could have transported the water-vapor to the icy highlands and created fluvial terrains by episodic melting events [1]. The dense atmosphere was lost from Mars, but the mechanism and timing are poorly constrained.

We constructed a one-box atmosphere-hydrosphere model with multiple species (CO_2, N_2, H_2O, and noble gases). We calculated the evolution of the atmospheric pressure and isotopic compositions taking into consideration impacts of asteroids and comets, atmospheric escape induced by solar radiation and wind, volcanic degassing, and gas deposition from interplanetary dust particles. A threshold for the atmospheric collapse was assumed following recent 3D global-circulation-model simulations [2]. The model was calibrated to reproduce the atmospheric composition of present-day Mars.

Whereas the nitrogen ($^{15}N/^{14}N$) and argon ($^{38}Ar/^{36}Ar$) isotopic ratios kept unfractionated values before the collapse, these ratios increased stochastically after the collapse. We found that the cases of an uncllapsed, moderately dense atmosphere ($> 10^{-1}$ bar) at 4.1 Ga are consistent with unfractionated nitrogen and argon isotopic compositions recorded in Allan Hills 84001 Martian meteorite [3]. This lower limit of the atmospheric pressure is valid regardless of the presence/absence of the Martian magnetic dynamo at 4.1 Ga because the atmospheric nitrogen can be removed by photochemical escape driven by solar radiation. We suggest that the moderately dense atmosphere was lost after 4.1 Ga by the impact erosion and the escape induced by solar radiation and wind.

[1] Wordsworth, R. *et al.* (2013) *Icarus*, **222**, 1-19. [2] Forget, F. *et al.* (2013) *Icarus*, **222**, 81-99. [3] Mathew, K. J. & Marti, K. (2001) *J. Geophys. Res.*, **106**, E1, 1401-1422.