Lifetime of a Transient Atmosphere produced by Lunar Volcanism

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Summary

- The loss of transient atmospheres during the Moon's lifetime involves multiple processes, **Figure 1.**
- We examine the loss of millibar level CO atmospheres assumed to have been produced by volcanism (Needham and Kring 2017, NK17**), Figure 2**.
- At exobase temperatures < 400 K thermal escape of CO cannot remove the millibar atmospheres over the Moon's lifetime**, Figure 3**.
- Estimates of the lifetime of a transient atmosphere for various thermal and non-thermal loss processes are given in **Table 1**.

Figure 1: Schematic of Atmospheric Escape Processes

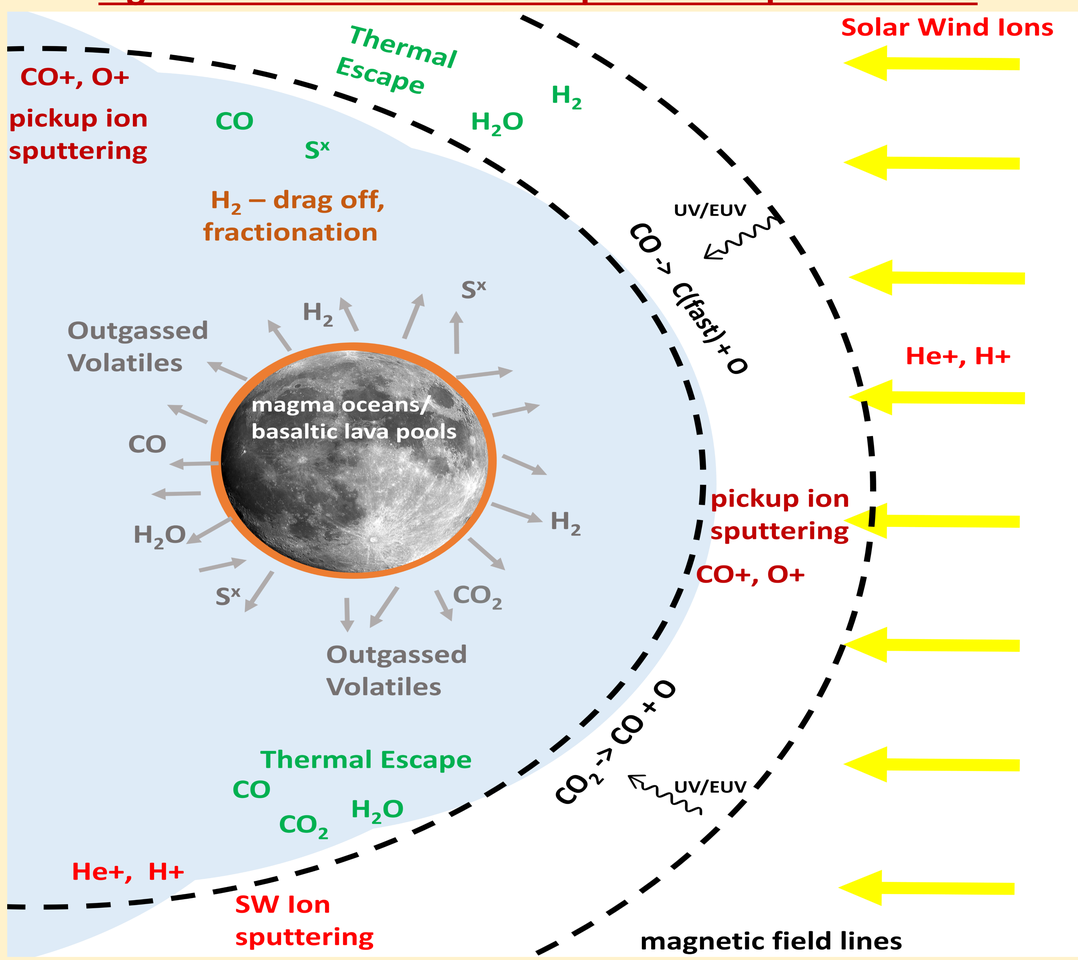

Figure 1: Atmospheric escape of a millibar lunar atmosphere depends on solar heating which drive its expansion and thermal escape, and solar wind and/or pickup–ion sputtering depending on the early lunar magnetic environment.

Table 1: Escape rates and atmospheric lifetime of a transient Lunar Atmosphere

*Escape Process	Mass Loss (kg/s)	Escape Flux ($m^{-2}\,s^{-1}$) × 10^{12}	# Crossover mass (amu)	T (K)	r_x/r_M	Lifetime
NK17 (CO)	60	4.2	~28.0 - 28.3	300	2.8	~0.2 Myr
Thermal (CO, H_2)	0.9, 59	0.063, 58	~28 ~2.1 - 2.6	300	2.8	~13 Myr ~410 Yr
Thermal (CO, H_2)	948, 57	3.3, 2.7	~28.0 - 35.2 ~2.0 - 2.8	400	12.8	~0.01 MYr ~430 Yr
Energy Limited (CO)	27×10^4–55×10^4	700 – 7000	~66.6 - 413.7	400	2.0	~220 – 450 Yr
Photochemical (CO)	10	0.7	n/a	300	2.8	~1 Myr
Sputtering (CO)	7	0.49	n/a	300	2.8	~2 Myr

Table 1: Escape rates and lifetime of combined CO: ~3.8×10^{14} kg and H_2: 7.1×10^{11} kg atmosphere. Loss is driven by thermal escape; however, for exobase temperatures < 300 K solar wind and/or pickup ion sputtering dominate. Estimates of crossover mass show masses that can be dragged off during escape.

Figure 2: Transient Atmosphere Surface Densities

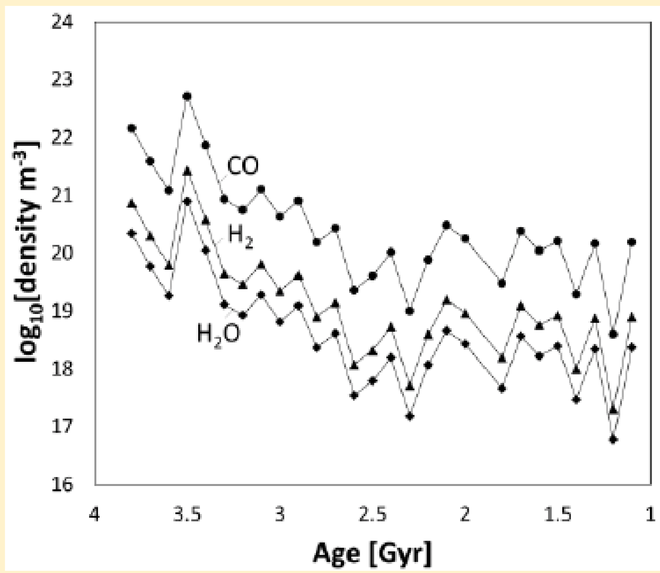

Figure 3: Lifetime against Thermal Escape

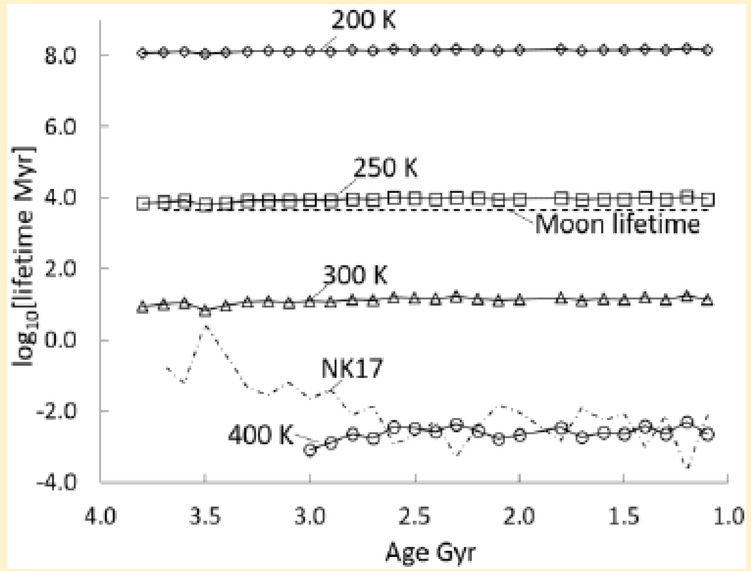

Figure 2: Surface densities versus lunar age produced from volcanism derived in NK17 (). In addition to S products significant amounts of CO and water products were outgassed. **Figure 3:** Lifetime of CO in the atmosphere against thermal escape require upper atmosphere temperatures above 300K.