Volcanically-Induced Transient Atmospheres on the Moon: Assessment of Duration, Significance and Contributions to Polar Volatile Traps

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The presence of a transient lunar atmosphere of ~ 1 kPa pressure formed by volcanic outgassing during a period of peak lunar volcanic flux at ~3.5 Ga, and lasting up to about ~70 Ma before dissipating, was recently proposed on the basis of an analysis of geometries and ages of global mare volcanic deposits and their degassing patterns (Needham and Kring, 2017). We utilize forward-modeling of individual lunar basaltic eruptions together with the observed geologic record to predict eruption frequency, magma volumes, and rates of volcanic volatile release. We compare these with the broad-scale time-averaged peak flux estimates of Needham and Kring (2017). Typical lunar mare basalt eruptions are predicted to have volumes of ~10^2-10^3 km^3, to last less than a year, and to have a non-linear, but rapidly decreasing, release rate of varying volatile species during individual eruptions. The total volume of lunar mare basalts erupted is uncertain, but is small (~10^7 km^3, less than a few percent of the lunar crust) and the repose period between individual eruptions is likely to range from 20,000 to 60,000 years. We find that only under very exceptional circumstances (e.g., Schröter's Valley, the largest known eruption on the Moon) could sufficient volatiles be released in a single eruption to create a transient atmosphere, and that the frequency of eruptions in general was likely too low to sustain even a tenuous atmosphere for more than a few thousand years. These results suggest that transient, volcanically-induced atmospheres were very inefficient source mechanisms for delivery of volatiles to form deposits in permanently shadowed polar regions of the Moon, favoring volatile-rich impactors as the major source.