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Effect of Volcanically-Induced Transient Atmospheres on Transport and Deposition of Lunar Volatiles.

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While the origin of lunar polar volatiles remains an open question, their most likely sources are volcanic outgassing or volatile-rich impactors. Both such sources are sporadic in nature and are characterized by release of large amounts of volatiles over a short period of time and long periods of repose between such events. If a sufficient amount of volatiles was generated in such a delivery event, a transient collisional atmosphere could form. Such an atmosphere, if it persists for a long enough time, would protect certain volatiles (like water) from photodissociation and escape to space and would promote their transport to the polar cold traps where they could be stored and preserved for billions of years. Hence, such transient atmospheres could have a significant impact on the distribution and abundance of volatiles currently observed on the Moon. Here we study such a hypothetical atmosphere that could have been formed due to volcanic outgassing during the peak of lunar volcanic activity at ~3.5 Ga and investigate its longevity, climatology and effect on volatile transport.

We employ the ROCKE-3D [1] planetary climate model to simulate processes in a volcanically-induced lunar atmosphere. We use orbital and radiation parameters corresponding to conditions at 3.5 Ga (17.8 days rotation period and a solar constant 75% of the modern value). For most experiments we use zero obliquity, though we investigate the effect of non-zero obliquity on atmospheric stability and volatile transport. We assume a CO_2-dominated atmosphere in accordance with predictions of our chemistry model [2]. For the atmospheric thickness we follow the argument of Head et al. [3] that due to long periods of repose between the volcanic events the atmosphere would not accumulate above the pressure of a few microbars, and thus we limit our parameter space to a range of 1 microbar to 1 mb surface pressures. To investigate the ability of such an atmosphere to transport volatiles we set up a typical volcanic eruption experiment [4] and

follow the fate of the outgassed water.

In most of our experiments the atmosphere was stable, though in some cases a small non-zero obliquity (a few degrees) was needed to prevent a collapse due to CO_2 condensation at the poles. We found that even very thin atmospheres were efficiently transporting volatiles to the poles. The efficiency of transport sometimes was higher for thinner atmospheres, most likely due to a stronger circulation cell. We also found that water transport efficiency depended on initial conditions at the surface. A water-free dry surface suppressed re-evaporation, thus reducing the total flux of outgassed water to the poles. But even in the case of dry soil, water transport was efficient with 19% of outgassed water delivered to the poles in just a few months (for the 10 microbar atmosphere).

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