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The mass flux of volatiles from volcanic eruptions on Mercury

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Mercury has been extensively resurfaced by large, effusive lava plains [1–2]. Similar lava plains on the Moon, the maria, are known to contain volatiles [3–4] and are estimated to have outgassed ~10^{16} kg of CO and S and ~10^{14} kg of H_2O, with the bulk of volatiles being released during peak mare emplacement ~3.5 Ga ago [5]. If volcanic activity released substantial volatiles on the Moon [6–7], then it is possible that substantial volatiles were also volcanically released on Mercury, albeit with different chemical species [6–9]. Here we seek to understand the potential contribution of outgassing to volatile deposits, specifically for Mercury's volatile species (S, CH_4, Cl, and N-H).

We analyze the production function of volcanic plains deposits on Mercury and find that the volume of outgassed basalts on Mercury is 2 to 3 orders of magnitude larger than that predicted for the Moon [8]. We use a variety of experimental petrology studies [10–12] to predict the dominant species and their abundances associated with these eruptions on Mercury, providing estimates for both low-gas and high-gas scenarios for different oxygen fugacities (IW-3 and IW-7). The most prevalent volatile species predicted for Mercury (S, CH_4, and Cl) are 1 to 4 orders of magnitude more abundant than what is predicted for the most abundant volatiles outgassed on the Moon (CO, S, and H_2O) [5].

On the Moon, it has been predicted that volatiles outgassed from the formation of the maria may have been present in sufficient volumes to produce a transient atmosphere capable of aiding in the transport of H_2O to cold-trapping regions [5]. At mantle pressures and Mercury's extremely reducing conditions, H_2O is not predicted to be present in the magma [e.g., 6–12]. Therefore, Mercury's outgassed volatiles are of a different composition from the H_2O ice observed at Mercury's poles today [e.g., 13], and the polar H_2O-ice deposits are better explained by some external delivery mechanism (likely cometary impacts). But the fate of large volumes of volatiles other than H_2O is an important unanswered question for Mercury.

The large volumes of outgassed volatiles calculated here suggest that volcanism on Mercury may have resulted in the transient production of anomalously high atmospheric pressures of short lifetime due to solar proximity. If Mercury's atmospheric loss rate was insufficient to lose all of the erupted gases, then it is possible that ancient, outgassed volatiles remain trapped in the planet's

subsurface today. The fate of Mercury's outgassed volatiles is an important open question that we discuss in this work.

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