THE DEVOLATILIZED LANDSCAPES OF MERCURY: NEW INSIGHTS AND MAJOR UNCERTAINTIES.

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Introduction: For nearly half a century, we have known that major impact events, volcanism, and tectonism formed widespread landscapes on Mercury. However, the emerging evidence of current-day volatile-rich surface and subsurface materials on Mercury, from their formation to their removal over billions of years, as well as their connection to these long recognized processes, is poorly understood [1-9]. Here, we outline some new insights into the landscapes resulting from volatile cyclicity on Mercury.

Mercury's Chaotic Terrains as Residues Devolatilized Crust: Investigations of Mercury's images obtained by the 1974 Mariner 10 flybys showed extensive cratered landscapes degraded into vast knob fields, known as chaotic terrain. For nearly half a century, these terrains were considered the result of powerful ground-shaking and massive ejecta fallout produced by the antipodal Caloris basin impact [10]. However, this hypothesis is incompatible with (1) surface age calculations showing that this chaotic terrain formed approximately two billion years after the Caloris basin and (2) discovered multiple chaotic terrains that are not situated antipodally to impact basins [9]. An alternative explanation, supported by the presence of significant relief losses in these terrains, is an origin due to upper crustal devolatilization and consequential large-scale collapse [9]. However, a major uncertainty that we are seeking to resolve is that of the necessity of a massive volatile aggregation mechanism within the context of a global crustal stratigraphy generally consisting of a primordial carbon flotation crust situated beneath thick stacks of lava and megaregolith layers.

Clustering of the Permanently shadowed Craters: Previous investigations show that Mercury's North Pole contains permanently shadowed craters with large interior ice deposits [11-14]. The distribution of these craters is unusual in that they form a tightly packed cluster. These closely-spaced craters are surrounded by broad plains with highly degraded craters and relatively few superposed craters. This plains unit also lacks the larger crater population present in the adjoining highlands. We found evidence that the circum-polar plains and adjoining cratered regions formed in a crustal layer originally composed of volatile-rich materials that are not able to retain impact-induced relief. The apparent higher degree of crater obliteration in the plains areas is consistent with reduced topography due to significant sublimation from solar heating on steep sun-facing slopes within the cratered landscapes. In this hypothesis, the magnitude of volatile removal increases with the total yearly duration of solar illumination, explaining the transition from the cratered terrains to their enclosed circum-polar plains. We propose that the permanent shadows in the polar craters could effectively hinder volatile-losses from the crater interior walls. If this hypothesis is correct, the proposed "thermal-armoring" would effectively stabilize rim-forming volatiles at the pole, hence producing the north polar cluster of well defined, permanently shadowed craters. In the surrounding volatile plains at slightly lower circumpolar latitudes, where permanent shadows are rarer or absent, crater rims and walls would have collapsed due to sublimation. We are currently developing thermal models to bound the types of volatile materials (and lag materials left after their sublimation) that could comprise the north polar region of Mercury.

The Hollows: Mercury's hollows are currently considered to be areas of volatile loss from surface and near-surface materials [15, 16] formed during geologically recent times. Here, we propose that volatile removal leading to the formation of the hollows did not occur within the plains that they modify. Instead, the devolatilization likely occurred from within an extremely ancient volatile-rich stratigraphy, which the plains now broadly cover. A critical issue concerns the age of the plains. Based on the hollows' shapes, the plains have been compared to the Martian "Swiss-cheese" terrain observed on the south polar CO_2 ice cap [16]. However, this Martian polar deposit is highly unstable and tied to current, ongoing cycles of deposition and removal. In stark contrast, our crater counting on the hollows-bearing plains returns extremely ancient ages, suggesting that their emplacement occurred over a billion years ago. Furthermore, when considering the timescales, it appears paradoxical that the plains do not exhibit evidence of broad-scale deflation due to the removal of volatiles. Even if the degree of metastability of the volatile materials were low, hundreds of millions or billions of years would have led to (near) complete removal. Our view is that the hollows formed when the lithic plains were fractured, creating volatile release conduits from the hypothesized buried layer, linking their youthful appearance to recent degassing, but not necessarily to the timing when those fractures formed. This hypothesis brings up the question of how the plains themselves formed. We observe that these plains drape over, not just the crater interior flats, but also ridges and parts of the proximal ejecta blanket zones. Hence, we suggest a desiccation and fallout origin. In the absence of an atmosphere, the fallout likely happened from plumes emanating from the crater floors. We attribute the creation of the plumes to overpressure dust-laden gas eruptions, which followed the impact-heating of a buried volatile-rich crust. Our thermal simulations indicate that this mantling process for creating the plains could have taken hundreds of thousands of years, perhaps affecting the composition and characteristics of Mercury's exosphere.

Our Current Work and Expected Results: A key goal is to determine how these landscapes and the processes that apparently formed them are connected through cycles and discrete events. We will detail some of these models in two upcoming publications. Our scenarios will explain the origin of a primordial volatile-rich layer, its connection to widespread chaotic terrain formation and clustering of the north polar permanently shadowed craters, and the formation of widespread younger volatile-rich plains, regionally modified by sublimation pits (hollows).

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