EVIDENCE OF PERVASIVE COLLAPSE OVER A BURIED VOLATILE-RICH CRUST ON MERCURY.
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Introduction: The finding of abundant volatile-bearing outcrops on Mercury's surface comprises one of the critical discoveries by MESSENGER (Mercury Surface Space Environment Geochemistry and Ranging) [1-7]. The role of devolatilization in the planet's landscape evolution remains uncertain. The current state of knowledge documents the presence of small, shallow hollows as potential sublimation byproducts [8-12]. Mass losses due to sublimation, however, were minor and resulted only in local landscape modifications. The key observation is that the hollows indicate a significant volatile content.

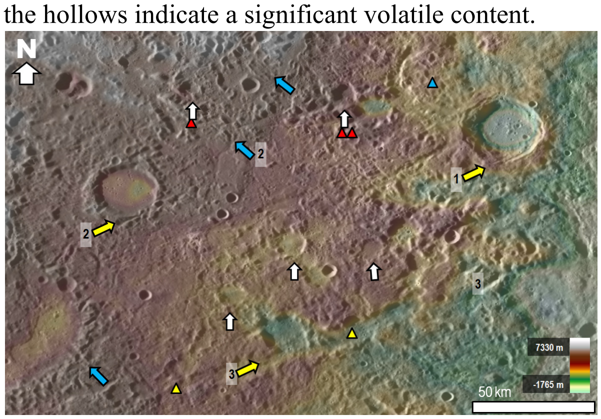

Fig. 1 Part of Mercury's chaotic terrains. Blue and yellow arrows, respectively, identify NW- and NE-trending alignments. Arrow 1 shows a crater wall marked by NE-trending fractures. A lobate deposit extends from the crater's northwestern margin, which we interpret as a reworked ejecta blanket flow (blue triangle). Systems of aligned ridges that partition the landscape are labeled "2". A broad furrow (labeled "3") is connected to a hilly area where collapse eliminated most pre-existing topography. White arrows identify small craters displaying various states of degradation. While the craters retain their circular outlines, there is also some tectonic reorientation of crater walls (e.g. crater identified by red triangle). This tectonic effect on the craters' shape lessens with increasing crater diameter (e.g., crater identified by two red triangles). The truncation of small craters (e.g., yellow triangle) attests to variability in the magnitude of local tectonically-induced resurfacing.

We propose that devolatilization of Mercury's buried volatile-rich materials generated the planet's chaotic terrains. These terrains consist of vast fields of ridges, mesas, and knobs made up of degraded rims of craters and a ruptured landscape of intercrater plains (Fig. 1).

Reassessing the Origin of Mercury's Chaotic Terrains: The 1974 Mariner 10 flybys of Mercury discovered some of the Solar System's largest and oldest chaotic terrains [13]. Schultz and Gault [14] proposed an origin by seismically-induced landsliding and impact by ejecta fallout related to the formation of the antipodal Caloris Basin.

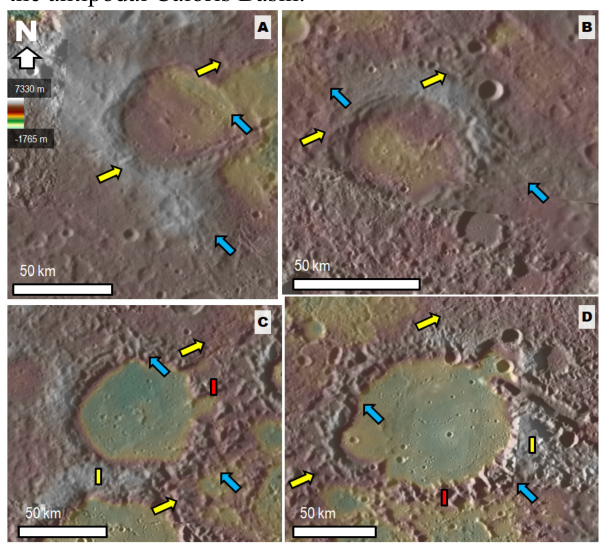

Fig. 2 Panels A to D show the increasing magnitude of broad-scale surface modifications along the NW- and NE- trending alignments (blue and yellow arrows). Yellow and red rectangles identify, respectively, relatively undisturbed and highly degraded impact crater margins and show evidence of regional variability in landscape modifications.

The lengths of Mercury's chaotic-terrain-forming promontories conform to NE- and NW- trending alignments (Figs. 1 and 2) across a broad region. These alignments are traceable over hundreds of kilometers and interconnect areas that exhibit varying degrees of chaotic terrain development (Figs. 1 and 2).

Schultz and Gault [14] hypothesized that repositioning of impact crater rim materials due to severe seismicity implies that the outlines of larger impact crater populations dominated the chaotic terrain patterns. Our geologic characterization of these terrains reveals that, in addition to the linear terrain arrangements, there is retention in the circularity of most impact crater outlines, which is independent of their diameters (Fig. 1). An exception is the presence of tectonically aligned rims, which alters the circularity of some small craters (Fig. 1). We find that chaotic terrains exhibit varying degrees of landscape modification. Some terrains show lineations that mark, but do not significantly disturb, the pre-existing cratered landscapes (Fig. 2A and B). On the other hand, there are other areas characterized by the presence of promontories arranged in circular and linear patterns, which reflect the distribution of pre-existing faults and crater rims (Fig. 2C and D). Local variations in the magnitudes of resurfacing include the sharp boundaries shown in Figs. 1 and 2.

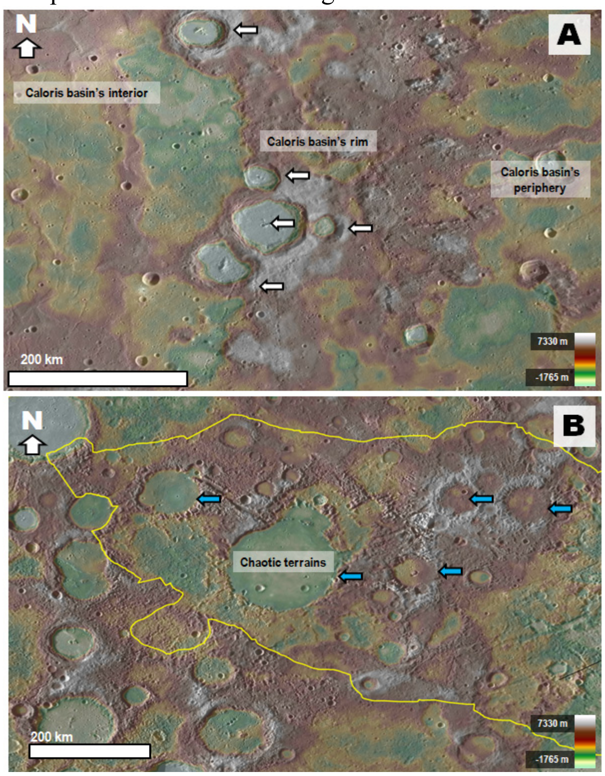

Fig. 3 **(A)** White arrows identify Late Heavy Bombardment impact craters that are superposed on the Caloris Basin rim. **(B)** Blue arrows identify a crater population that likely developed during the same period, but within the chaotic terrains (A yellow line defines the approximate outer boundary). These craters are all degraded, to varying degrees, into chaotic terrains.

We present another critical finding: Mercury's chaotic terrains formed significantly later than the Caloris Basin impact. Numerous large impact craters, formed during the Late Heavy Bombardment, are superposed on the Caloris Basin's rim, comprising a superposed crater population (white arrows, Fig. 3A). Craters that formed during this period appear modified within the chaotic terrain regions (blue arrows, Fig. 3A); indicating that collapse must have taken place appreciably after the Caloris basin impact event.

Chaotic Terrain Formation as an Indicator of a Volatile-rich Crust: These observations rule out the catastrophic seismic rupturing of crater rims as the origin of Mercury's chaotic terrains, highlighting the need for an alternative hypothesis. We propose that collapse along pre-existing linear patterns result from fracturing, slumping, normal faulting, and extensional rifting into a buried volatile-rich crust. This destruction was likely gradual, episodic, and was mostly limited to the interiors of the rifted valleys. The collapse may have halted due to the development of a lag of volatile-depleted materials that were sufficiently thick so as not to be ruptured by tectonically induced slope changes. This same kind of process has been proposed to control the dimensions of sublimation hollows [12]. An alternative is that chaotic terrain formation completely depleted the upper crustal volatile-rich components.

Preliminary Conclusions: Results of our on-going investigation indicate that Mercury's chaotic terrains probably formed due to large-scale upper crustal devolatilization and consequential large-scale mass loss, during episodes of extensional tectonism. Chaotic terrain formation continued after the Late Heavy Bombardment and following the development of broad thrust fronts associated with global contraction. Other areas surrounding the chaotic terrain were affected by the same tectonic trends, but they did not experience collapse. This observation may indicate lower volatile contents, a deeper burial location, or different thermal structure. There is also evidence of volcanism taking place within the chaotic terrain region, but after collapse had already modified the regional topography. The chemical nature of the volatiles is unknown.

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