DESIGNING A CLASSIFICATION SYSTEM FOR THE DEGRADATION STATES OF PYROCLASTIC VENTS ON MERCURY

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Introduction: Upon Mariner 10's first flyby of the planet Mercury in 1974, it captured images of expansive plains, thought to result from effusive volcanism; however, the question of whether these plains were volcanic [1] or impact derived [2] would remain unresolved. In January 2008, the MESSENGER (MErcury Surface, Space ENvironment, GEochemistry and Ranging) mission reached Mercury, and over the next 7 years would acquire complete global imagery. These data provided concrete evidence for effusive volcanism, and the first evidence for explosive volcanism on Mercury [3].

Upon its first flybys of Mercury, MESSENGER showed numerous high-reflectance deposits centered on irregularly shaped, rimless pits [3], ranging in size from 1-100s of km^2 in area. These rimless pits are hypothesized to be the source vents of explosive volcanic eruptions, and the surrounding high-reflectance deposits are pyroclastic deposits [4]. While determining the timeline of effusive volcanic activity on Mercury has been performed through crater size-frequency distributions [5], using such a method to investigate the duration of explosive volcanic activity is not useful, due to the much smaller scale of the pyroclastic deposits and the unusual cratering properties of the fine-grained deposit [6]. Instead, this project sought to assign three separate degradation classes to pyroclastic deposits on Mercury based on the host vent degradation state. This project thus focused on exploring the qualitative temporal range of explosive volcanism on Mercury. This analysis will allow us to explore whether vents on Mercury are generally old, generally young, or have well-distributed degradation states. By coupling this analysis with spectral analysis and chronostratigraphic markers [Jozwiak et al., this volume], we will be able to more fully establish the range and duration of explosive volcanism on Mercury.

The timing of volcanism on Mercury: *Effusive volcanism:* Images from MESSENGER provided a clear view of widespread plains resulting from large-scale effusive volcanic activity. Crater size-frequency distributions within these plains indicate that the main phase of effusive volcanism on Mercury ended around 3.5 Ga, with the largest volcanic plains being emplaced around 3.7 Ga [5]. Interior cooling (leading to a diminished magma supply) and contraction (as a result of horizontal shortening and a decrease in planetary radius by as much as 7 km) is the likely reason behind the cessation of widespread plains volcanism [8]. Despite this cessation in effusive volcanism, there is suggestive evidence that volcanic activity on Mercury did not end at this time. The presence of pyroclastic vents within Kuiperian-aged craters (base age of 1.0- 0.28 Ga [9]) indicate that explosive volcanism persisted in some volume until the recent geologic past [7, 10].

Explosive volcanism: Pyroclastic vents are distributed globally throughout Mercury, and are generally, but not exclusively, located inside impact craters [7, 11]. Vents exist within three morphologic classes, including 1) simple vent (featuring an elongated shape with steep walls and a narrow floor), 2) pit vent (roughly equal semi-major and –minor axes of vent dimensions, with wider floor profiles), and 3) vent with mound (one of the more enigmatic morphologies, featuring a central mound circumscribed by the vent) [7].

Methods: In order to provide a relative chronology of vent formation, we needed to devise a geomorphologic system for determining the qualitative state of vent degradation. Degradation state was assessed by investigating the morphologies of vent rims, walls, boundaries between floor-wall, and intra-vent features. We classified vents into three degradation classes: class 1 represents heavy degradation, class 2 represents moderate degradation, and class 3 represents little to no degradation/morphologically fresh. In order to anchor the class 3 (fresh) morphology, we began by focusing on vents located in Mansurian (1.7- 0.28 Ga [9]) and Kuiperian (0.28 Ga- present [9]) aged craters [7]. These craters are from the most recent geologic periods on Mercury, and therefore serve as a tie-point for our relative degradation morphologies. Fifteen vents are located in craters of Mansurian age, and one is located in a crater of Kuiperian age. Consistent morphologies observed in these vents included crisp and mostly continuous rims throughout the entirety of the vent, terracing and layering textures present on walls, a preserved boundary between the floor and wall, and distinctive boundaries between intra-vent features (such as potential subsidiary vents and pitted terrain) (Fig. 1). Vents such as the ones located in Tyagaraja (Fig. 1a) (Kuiperian-aged) and Lermontov (Fig. 1b) (Mansurian-aged) craters provide classic type examples of young vents.

By utilizing a methodology focused on the morphologic characteristics of the vent itself, our analysis was able to include vents not located within craters, a subset that had been previously unanalyzed. Additionally, this method allows us to decouple the relative degradation of the vent from the relative degradation of the crater. While it is understood that the pyroclastic activity of a vent must post-date its host crater, there is no specific timeframe on when the subsequent eruption might occur. For example, vents located along the Hesiod craters (Calorian in age) are classified as Class 3 (fresh) vents due to their extensive and well-preserved deposit coupled with preserved intra-vent features, despite the much heavier host crater degradation.

One of the largest, and possibly youngest, preserved deposits on Mercury is situated roughly 450 km northeast of Rachmaninoff crater. This pit vent (Nathair facula), despite lacking a young identifying host crater, provides a prime example of a morphologically fresh pyroclastic vent on Mercury. The western and northern segments of the rim are crisp and well preserved; although the southern rim appears muted, this is likely the result of eruption ejecta blanketing the rim border. Distinguishing features such as scalloping wall textures and separate layers of varying reflectivity are present, accompanying a noticeable contact between the floor and wall of the vent. Pitted terrain is also preserved on the floor of the northernmost segment (Fig. 1c).

On the opposite side of the degradation spectrum, a vent located within Hemingway crater (Calorian in age) appears to have experienced heavy degradation since its eruption. The floor of Hemingway crater includes a complex of multiple (up to 6) vents of varying degradation states (although all are most within the more degraded side of the classification spectrum). The western- and southern-most depressions have the greatest amount of degradation, with their rims and wall features being almost nonexistent. The texture of the vent complex floor matches that of the outside intercrater terrain. Most notably, a distinctly large crater crosscuts the vent complex in the northwestern segment. This crater appears to have displaced mixed pyroclastic and intercrater ejecta. Overall, the entire pyroclastic complex of Hemingway has been classified as Class 1; however, higher resolution imagery would allow for further classification of each subsidiary vent and provide insight as to which individual vent erupted first.

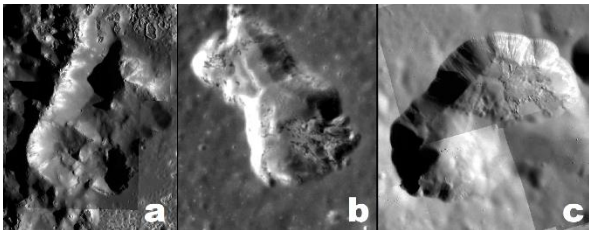

Figure 1: Three Class 3 vents. From left to right: Tyagaraja (simple vent, 196km^2 vent area); Lermontov (simple vent, 79km^2 vent area); NE Rachmaninoff (pit vent, 794km^2). Each show scalloped walls, a crisp rim, a distinct floor-wall boundary, and a preserved pitted floor. Projection is sinusoidal, North is facing at top of images.

Results: Of the 113 identified vents on Mercury, 10 were found to be within the Class 3 (freshest) range, 68 were within Class 2, and 39 were within Class 1 (most degraded), indicating that the majority of vents on Mercury have experienced some level of degradation following their eruption through tectonic deformation, impact cratering, mass wasting, or impact gardening. Vents of varying degradation states were found throughout host craters of all ages. In addition, no distinct pattern exists between vent type and degradation state, indicating that various eruption types have existed alongside one another. Overall, this analysis strengthens the interpretation that explosive volcanism on Mercury persisted well-past the cessation of smooth plains emplacement, into the recent geologic past.

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