INVESTIGATING THE AGE OF MERCURY'S PYROCLASTIC DEPOSITS. L. M. Jozwiak[1], N. R. Izenberg[1], C. Olson[1,2], and J. W. Head[3], [1]Johns Hopkins University Applied Physics Laboratory, Laurel, MD, USA. [2] University of Maryland, College Park, MD, USA. [3]Department of Earth, Environmental, and Planetary Science, Brown University, Providence, RI, USA (corresponding author: lauren.jozwiak@jhuapl.edu)

Introduction: The MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) mission [1] revealed for the first time, evidence for explosive volcanism on Mercury [e.g. 2]. Throughout the course of the mission, several researchers mapped the increasing evidence for substantial explosive volcanic activity [3-6], and following the mission end, a final catalog identifying 104 pyroclastic vents was produced [7]. The vents are distributed across the surface of the planet [6, 7], and unlike lunar pyroclastic deposits [e.g. 8], Mercury's pyroclastic deposits are not closely associated with the edges of impact basins, and appear to be anti-correlated with the locations of smooth volcanic plains deposits [7].

The geologic history of Mercury has been interpreted to fall into two distinct periods: early mercurian history was dominated by the successive emplacement of generations of effusive volcanic plains [9], followed by a protracted period of cooling and contraction dominated by the formation of lobate scarps and other compressional tectonic features [10, 11]. Crater size-frequency distribution studies of both smooth plains deposits, and lobate scarps support this bimodal geologic history. Effusive volcanic plains appear to have ceased formation ~3.5 Ga [12] during the early Calorian period. In contrast, lobate scarp formation and activation appears to have begun in the mid-Calorian period and extended through the remainder of Mercury's history [11, 13].

We now examine the ages of the pyroclastic vents to investigate how they fit into the overall thermal and geologic history of Mercury.

Stratigraphic Method: Unlike many planetary surfaces, crater size frequency distribution analysis cannot be used to determine the model age of pyroclastic deposits because of the difficulty in superposition relationships between craters on the deposit and under the deposit, and uncertainties in how the fine-grained pyroclastic material retains craters [14]. Instead, we utilize stratigraphic relationships between the pyroclastic vents and other local features of known stratigraphic age (i.e. impact craters) to place bounds on vent formation [5, 7].

Mercury's geologic history has been divided into 5 chronostratigraphic periods, from oldest to youngest: Pre-Tolstojian, Tolstojian, Calorian, Mansurian, and Kuiperian [15]. The degradation state of craters has then been correlated with each of these chronostratigraphic periods [15, 16]. The majority (82%) of pyroclastic vents are located inside of impact craters, such that the chronogratigraphic age of the host crater can be used to constrain the oldest possible age for a vent.

Goudge et al. [5] utilized this method to examine the ages of the 40 then recognized vents, and found that (using the degradation definitions of [15]) the majority of vents occurred in craters associated with the Tolstojian and Calorian period, although some vents also occurred in Mansurian period craters. Prockter et al. [17] revised the crater degradation classifications of Spudis and Guest [15] using MESSENGER data, and Kinczyk et al. [16] used these definitions to generate an updated global map of Mercury's crater chronostratigraphic ages. We used this updated crater degradation classification scheme to investigate the host crater ages of all the applicable vents in the Jozwiak et al. [7] catalog. We examined 70% of the vents on Mercury (Fig. 1), excluding those not located in craters and those located in craters with diameter less than 40 km (these craters were not classified by[16]). Our analysis indicated that the majority of vents were located in Tolstojian and Calorian period craters, similar to the result seen in Goudge et al. [5], however, given that the majority of impact craters on Mercury are associated with these periods, this result is unsurprising. Our analysis also revealed 10 vents associated with the Mansurian period and one vent associated with the boundary of the Mansurian and Kuiperian periods. These vents located in geologically young craters are striking because revised constraints on the ages associated with the mercurian stratigraphic periods suggest that the Mansurian began ~1.7 Ga, and the Kuiperian as recently as ~280 Ma [13]. Thus, explosive volcanism on Mercury was not confined to the early effusive volcanic period, and may have operated into geologically recent periods of Mercury's history. The stratigraphic dating method allowed us to determine that pyroclasttic vent formation occurred throughout Mercury's history, however, it does not address how vent formation is distributed throughout the planet's history.

Spectral Characteristics Method: In order to further investigate some of the uncertainties of the stratigraphic method, and to further explore the temporal distribution of explosive volcanism, we incorporate data from the Mercury Atmospheric and Surface Composition Spectrometer – Visible and Infrared Spectrograph (MASCS-VIRS) [18]. Early analysis of VIRS data [5] identified two principle spectral characteristics of pyroclastic deposits: depth of UV absorptions, and reflectance at 700nm, and used these parameters to categorize vents into 4 spectral classes. It has been hypothesized [5] that the variations in reflectance at 700 nm are due to variations in space weathering, and therefore, deposit age. To test this hypothesis, we first use the VIRS dataset to extract the UV absorption depth and reflectance at 700nm values for all of the vents with sufficient data coverage, ~82% of vents. The methods for the data extraction and processing are found in Olson et al. [2018] [19]. These data were then used to generate 4 spectral types, similar to the spectral types identified by Goudge et al. [2014] [5]. We then plotted the same spectral parameters for each vent, but colored the data points according to the previously assigned host crater stratigraphic age [Fig. 2]. This plot suggests that host crater stratigraphic age is, in general, a poor predictor of overall deposit reflectance or other spectral properties. We observe that Mansurian and Mansurian/Kuiperian (here labeled just Kuiperian) craters (blue in Fig. 2) are generally clustered towards higher reflectance values, although not the highest observed values. If reflectance at 700 nm is indeed a proxy for deposit age, this would then suggest that vents can be much younger than the crater in which they have formed, and also that there may be younger vents than the recognized Mansurian/Kuiperian boundary crater. We are currently investigating the geomorphologic degradation of vents with high 700 nm reflectance compared to vents with low 700 nm reflectance. If reflectance at 700 nm is broadly correlated with vent age, we should expect to see morphologically fresh vents associated with higher reflectance values, and morphologically degraded vents associated with lower reflectance values.

Conclusions and Future Work: Utilizing a combination of stratigraphic analysis and spectral analysis, we have found evidence that explosive volcanism on Mercury extended well past the cessation of effusive volcanic activity, and into the more recent geologic periods of Mercury history. Continuing analysis of VIRS spectral parameters is giving us a new tool to explore the relative ages of pyroclastic vents, and by extension the relative temporal distribution of vent formation through Mercury's history. Our research is ongoing to fully investigate the utility of deposit reflectance as a proxy for deposit age.

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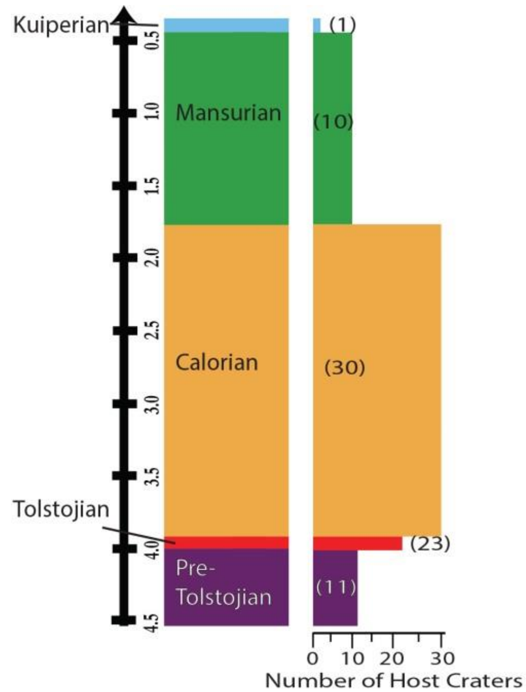

Figure 1: Distribution of pyroclastic vent ages based on the chronostratigraphic age of the vent host crater.

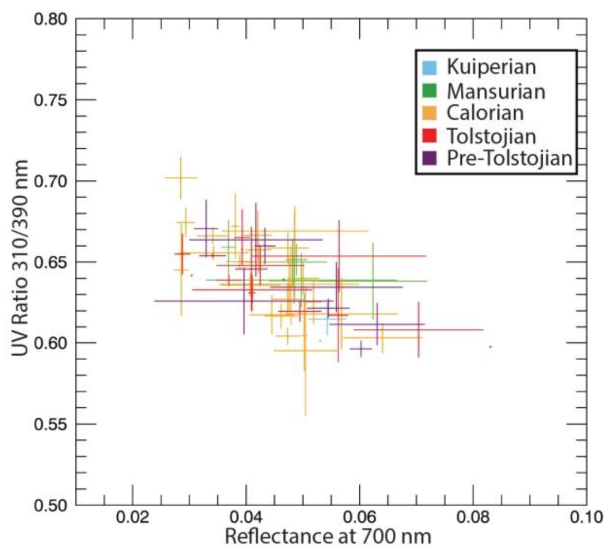

Figure 2: Spectral parameters of Mercury's pyroclastic deposits as a function of host crater stratigraphic age.