THE TIMING AND DISTRIBUTION OF PYROCLASTIC VOLCANISM ON MERCURY.

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Introduction: Evidence confirming the timing and longevity of volcanism on Mercury is crucial to understanding the thermal evolution of the planet. Two types of volcanic landform can be used to determine the chronology of this activity: smooth plains and basin infills emplaced by fluid effusive lava flows; and smaller-scale bright, relatively red deposits surrounding pits that are believed to form by pyroclastic volcanism [1]. Recent work has suggested that the vast majority of the smooth plains were emplaced between 3.9 and 3.7 Ga [2], followed by less-extensive effusive volcanism, possibly up to 1 Ga [3]. The low volume of plains-forming volcanism in the latter part of the planet's history suggests that, due to secular cooling, large volumes of magma were no longer produced (perhaps due to a decrease in the vigor of mantle convection), and/or magma ascent to the surface was inhibited by compressive stress in the crust. In the latter scenario, pyroclastic volcanism could be favoured over effusive volcanism if the magmatic volatiles involved acted so as to promote fault movement [4], thus providing pathways for magma ascent even under a compressive regime. It has been noted that probable pyroclastic pits often occur at structurally-controlled locations within impact craters [5], which would be suitable sites for such a process. However, prior to this study, ages have not been determined for pyroclastic pits or deposits.

Here we present the results of a global survey of pyroclastic pits and deposits on Mercury, in which we have characterised their morphology and distribution. We present evidence that the most substantial pyroclastic deposits date to the period shortly after the end of the Late Heavy Bombardment (LHB), but that minor eruptions may have occurred more recently, possibly as recently as 1 Ga ago.

Pyroclastic landforms: In a global survey of MESSENGER images up to MDIS PSD release #9, we have identified 173 pits or pit complexes, 150 of which have associated deposits that are red relative to the Hermean average (Fig 1). These are substantially less common on regional volcanic plains than on other regional substrates, suggesting either that a large proportion of pyroclastic volcanism occurred prior to emplacement of the volcanic plains and has been hidden by the lavas, or that the physical properties of non-plains substrates are more conducive to pyroclastic volcanism than those of smooth plains. 80% of pit complexes with associated red deposits occur in impact craters or their proximal ejecta.

Using laser altimetry data and stereo-derived DEMs, we calculated pit depths ranging from 0.1 to 4.0 km. Some pits contain internal septa and appear to have formed by coalescence of several pits. Where there are clear cross-cutting relationships between

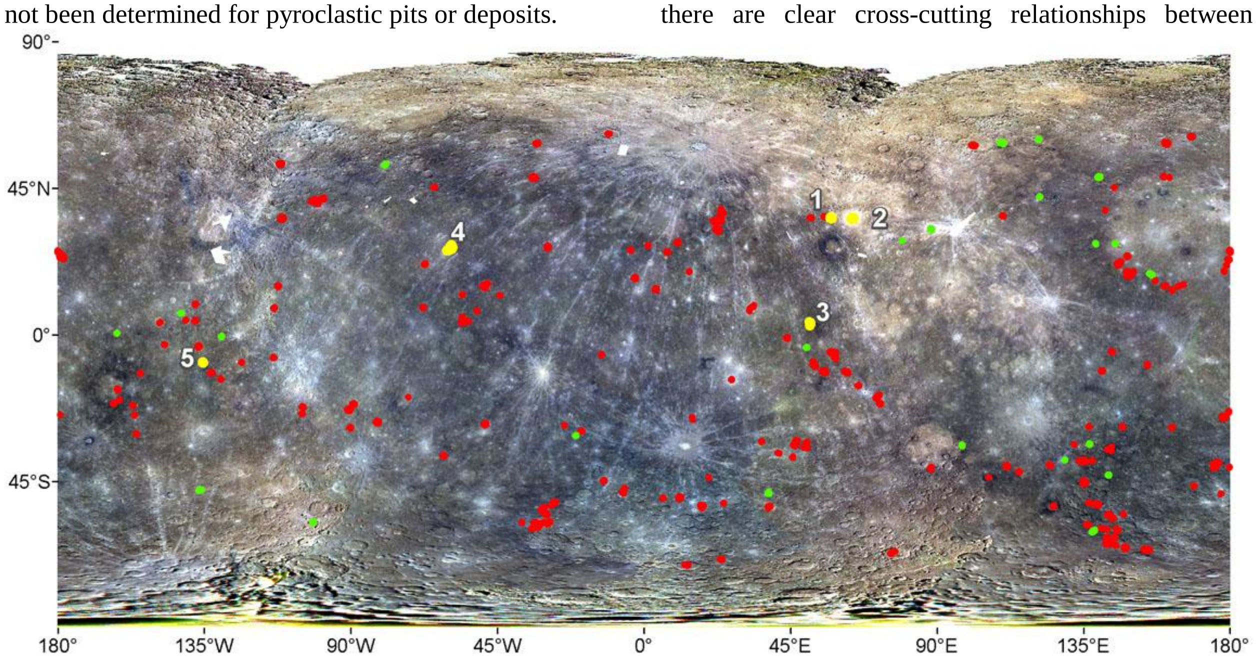

Fig. 1. Global distribution of pits: red - endogenic with surrounding red deposits; green - endogenic lacking surrounding deposits; yellow - locations for crater counting. (Base image: NASA/JHUAPL/Carnegie Washington)

these different parts, we suggest that volcanic activity was multiphase, with migration of the locus of pit formation over time [6].

Relatively red pyroclastic deposits associated with pits cover areas from 37 to 39,900 km^2. These deposits commonly lack appreciable relief, with slopes <1°.

Age of pyroclastic deposits: At five locations where the proposed pyroclastic deposits were spectrally-dense and extensive, we counted superposed impact craters down to 5 pixels in size to determine their age. The locations of their associated pits (marked in Fig. 1) are:

1. N of Rachmaninoff basin
2. NE of Rachmaninoff basin
3. In the smooth fill of Picasso crater.
4. In the peak ring structure of Praxiteles crater.
5. Annular to the central peak of an unnamed impact crater. For age comparison, we also counted craters on a smooth lava plain 250 km WSW of this pit.

We obtained model surface ages from these counts using the production and chronology functions of Neukum et al. [7]. We also noted the degradation state of impact craters cut by endogenic pits globally and used this as a proxy for the crater's age [8] and so the maximum age of the pit.

We have identified four lines of evidence that suggest that the most substantial pyroclastic deposits date to shortly after the end of the LHB, approximately contemporaneous with major plains-forming volcanism, as follows: 1. Our crater counts on these deposits indicate model ages of 3.27-3.84 Ga. 2. The crater size-density distribution of smooth volcanic plains near location 5 is very similar to that of the pyroclastic deposit at that location. 3. Deposits from the pit north of Rachmaninoff basin overlie the basin's secondaries. Rachmaninoff has been dated to 3.6 Ga ±0.1 [3]. 4. The degradation state of Praxiteles and Picasso suggest a Calorian age (3.5-3.9 Ga) for those craters, establishing a maximum age for the superposed pyroclastic deposits.

In two cases, there is evidence that a younger pyroclastic deposit overlies an older, possibly effusive, deposit. In Picasso crater, curvilinear lobes extend over the crater floor from the pit (Fig 2). These have a model age of ~ 3.75 Ga. The crater size-distribution of the surface close to the pit, where a specrally-red deposit is evident, suggests later resurfacing ~3.27 Ga. Similarly, the crater size-frequency distribution of the spectrally-red deposit around the pit north of Rachmaninoff basin suggests that a thinner layer of deposits dating to ~3.29 Ga was emplaced over a thicker ~3.66 Ga deposit. Identification of the thinner pyroclastic layer at these locations is based on an underabundance of small craters and suggests that the layer is 42-52 m thick at Picasso and 57-71 m thick at N Rachmaninoff [9].

Furthermore, while the majority of pits within craters occur in those with a degradation state indicating a Calorian age or older, a substantial proportion (29% of pits with red deposits within craters) occur in younger, fresher-looking craters, including very fresh craters that may date to the last 1 Ga.

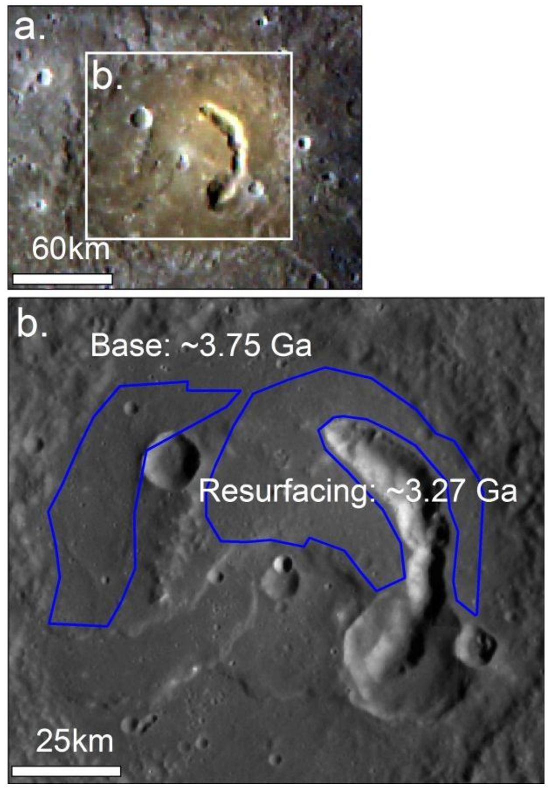

Fig. 2. Older lobate deposits around a pit in the floor of Picasso crater. Crater counts suggest younger, thinner relatively-red deposits overlie them. a. colour composite, b. monochrome closeup indicating model ages. Blue outlines: crater-counting areas. 50.2° E, 3.4° N (Images: NASA/JHUAPL/Carnegie Washington)

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