The Timing and Distribution of Pyroclastic Volcanism on Mercury

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1. How long was Mercury volcanically active?

Why does it matter?
• Active volcanism is a key indicator of the thermal and physical state of the planet.
• Understanding how it changed through time provides constraints for models of the planet’s formation and post-formational history.

Effusive volcanism
Recent work suggests Mercury’s extensive smooth lava plains were emplaced between 3.9 and 3.7 Ga [1]. Less extensive effusive volcanism may have occurred up to 1 Ga [2], but this has recently been called into question [3].

Explosive volcanism
Evidence of explosive (pyroclastic) volcanism is seen in the form of irregular pits with surrounding relatively bright and red deposits [4]. It has recently been suggested that this continued into the last 3 Ga [5], indicating that explosive volcanism may have outlived explosive volcanism. Dating this style of volcanism thus has the potential for revealing the full duration of volcanic activity on Mercury.

We have used crater-counting and superposition relationships to investigate the distribution and timing of explosive volcanism on Mercury. Our results show that it had a long duration, from 3.8 Ga (contemporaneous with smooth lava plains emplacement) to as recently as 1 Ga.

2. The distribution and morphology of pyroclastic landforms

• We examined images taken by the MESSENGER spacecraft up to March 2013 to identify the sites of explosive volcanism (Fig. 2, right).
• We found:
  • 149 locations where irregular pits 0.1 to 4 km deep are surrounded by probable pyroclastic deposits
  • 25 locations where similarly bright and red deposits occur on subtly pitted ground.
• Laser altimetry data and stereo-derived digital terrain models show that the deposits commonly have little relief.
• However, a minority have appreciable thickness and are potential targets for dating via crater counting.

3. Evidence for pyroclastic volcanism from 3.8 to < 1 Ga

A: Pit annular to a crater central peak
• Pyroclastic deposit model age: 3.8 Ga, contemporaneous with nearby smooth volcanic plains.
• The anomalously low density of smaller craters (seen as a step in the cumulative plot, right) suggests further resurfacing c. 3.6 Ga by a deposit ~ 60 m thick.

C: Picasso crater
• The crater floor, which appears to be lava, possibly from the pit, has a model age of 3.75 Ga.
• A step in the curve (right) for craters on pit-proximal deposits indicates pyroclastic resurfacing at 3.4 Ga.
• The position of this inflexion indicates these deposits are ~ 52 m thick.

E: North of Rachmaninoff
• The cumulative crater density (right) shows two phases of resurfacing.
• Larger craters indicate resurfacing at 3.65 Ga. This is either emplacement of Rachmaninoff ejecta (which pyroclastic activity overlaps) or pyroclastic activity.
• Smaller craters suggest an overlying ~ 60 m thick layer with model age 3.29 Ga.

4. Conclusions
1. The products of explosive volcanism are widespread on Mercury.
2. This activity had a long duration, from at least 3.8 Ga to < 1 Ga.
3. This duration is considerably longer than that of high-volume plains-forming volcanism.
4. This may be attributable to ongoing compression in the crust, which would inhibit magma ascent and allow concentration of volatiles at shallow depths, leading to explosive eruption.

5. References