COMPOUND VOLCANOES ON MERCURY – IMPLICATIONS FOR VENT MIGRATION AND LONGEVITY

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Introduction: Volcanic vents on Mercury were first recognized in images from MESSENGER’s first flyby by virtue of their non-circular (scallop-edged) and ‘rimless’ nature [1,2]. Many are at the centre of spectrally red spots with diffuse outer edges, interpreted as pyroclastic deposits [3,4,5]. MESSENGER images from orbit offer higher resolution views than those obtained during flybys, and reveal previously unseen details within and around vents. Orbital stereo imaging and laser altimetry demonstrate the depth of the vents and, in contrast, the generally subtle nature of the edifices hosting the vents [5,6], which are more subdued than the ‘broad, low shield volcano’ morphology interpreted from flyby images [1].

On Earth, a ‘compound volcano’ is defined as a ‘volcanic massif formed from coalesced products of multiple, closely spaced vents’ [7]. We show terrestrial examples for comparison with those on Mercury in Figure 1. Vents tend to be active sequentially, rather than simultaneously. If the same is true of Mercury this provides support for complex (possibly prolonged) histories of activity. We have previously [6] presented evidence to argue that a ‘kidney shaped’ vent (Red Spot 3, RS-03, of [3]) in the SW of the Caloris basin represents a compound volcano, where the locus of activity (the active vent) has migrated to and fro by about 25 km.

Here we illustrate the RS03 vent complex (Figs 2-5) and several similar examples (Figs 6-9). Pyroclastic deposits from these vents overlie volcanic plains (or the lava fill of craters). Thomas et al. [8] present crater counts suggesting ages of 3.2-3.8 Ga for several pyroclastic deposits. We suggest that local vent migration has been widespread on Mercury, and argue that some of these compound volcanoes could have been individually active at episodic intervals over prolonged (>1 Ga?) periods. Inspect the figures and read their captions for more discussion.

Fig 1 Compound volcanoes on Earth. Left: Lascar, Chile. Image 7 km across. Overlapping volcanic craters on an andesitic composite cone volcano that rises more than 2 km above its base. Right: Masaya, Nicaragua. Overlapping and nested volcanic craters on a basaltic shield near the centre of a much larger caldera. Image 3 km across.

Fig 2 Candidate vents in the SW of the Caloris basin. (a) Regional mosaic of WAC images. (b) Sketch map of same area. RS-03 vent complex is at 22.3°N, 146.2°E. Inset: lettered individual vents within RS-03.

Fig 3 The same area as Fig 2 in colour (RGB = 1000, 750, 430 nm). The diffuse ‘red’ deposit centred on RS-03 is apparent.

Fig 4 Mosaics of NAC (a-c) and WAC (d) images of the RS-03 vent area, on the same projection as Fig 2. Emission angles of 30-45° for (a-c) cause some distortion in steep internal areas, but (d) is based on near-nadir-viewing image (emission angle 1.6°). Note the cross-cutting relationships between vents, and the preservation of fine-scale texture within vents F,G,H,I (Fig 2 inset). These suggest sequential activity, which could have been spread over a long (Ga?) timescale.

Fig 5 The edifice hosting the RS-03 vent complex is subtle, and has less effect on the local topography than wrinkle ridges. The left figure locates three MLA (Mercury Laser Altimeter) profiles, and highlights two wrinkle ridges. The red profile is the only one to cross the vents themselves, and record a depth of 1.0 km before becoming too noisy. The right figure shows the blue profile after removal of the regional slope. The edifice, such as it is, lies between 60 km and 160 km along the horizontal scale. The corrected flank slope is 0.21° on the north and 0.07° on the south. See Fig 7 for discussion of vent topography.

Fig 6 Detail from MESSENGER NAC high resolution targeted images covering SW Caloris candidate vent 5 (see Fig 2 for location). Left: solar incidence angle 66.0°, emission angle 50.3°, raw pixel size 48 m. Right: solar incidence angle 26.7°, emission angle 8.5°, raw pixel size 28 m. Each image is 33 km across.

Fig 7 MLA profile crossing SW Caloris candidate vent complex 5. This is non-noisy, with good returns across the whole feature. Note the profile lacks a flat bottom (an inference that can also be made about vents within RS-03) and suggests excavation by explosion and/or collapse into a conduit, rather than the piston-subsidence typical of calderas (such as those on Mars).

Fig 8 Rothery et al. [6] suggest that the distribution of vents in SW Caloris is controlled by the Pantheon Fossae radial graben system – not otherwise known to extend this far from the centre of the basin, but possibly existing at shallow depth below basin infill lavas. There is no hypothesised large-scale structural control in our other examples.

Fig 9 Two candidate compound vents on ancient plains. Left: vent to the north of Rachmaninoff, 57.5°E, 35.9°N. Image 55 km across. Right: arcuate compound vent near the centre of a unnamed 80 km degraded, smooth-floor crater (43.6°E, 5.2°S) Image 32 km across.

Fig 8 Two candidate compound vents inside craters. Left: vent in Kipling crater (71.37°E, 19.15°S) Image 40 km across. Right: arcuate compound vent near the centre of a unnamed 80 km degraded, smooth-floor crater (43.6°E, 5.2°S) Image 32 km across.

Summary/Discussion points:

• When several vents can be recognized inside a common perimeter, this is a compound volcano
• On Earth, such vents are generally active sequentially rather than simultaneously
• On Mercury, cross-cutting relationships and textural differences (sharp versus muted) can be used to infer sequential activity
• On Mercury these vents are dominantly explosive, rather than effusive
• Evidence of caldera ring-faults and trap-door subsidence is so far lacking
• Vents do not construct significant edifices around themselves
• Was latest activity explosive or collapse?
• Could the duration of activity at a compound vent exceed a billion years?
• What is the volatile phase driving the explosive eruptions?
• Is magma required at all? Could these be sites of predominantly vulcanian eruptions?