- Volcanism on Mercury: The question of whether Mercury’s smooth plains were of volcanic or impact origin was resolved by the MESSENGER Mission.
- MESSENGER also revealed that volcanism on Mercury differed from that of the Earth and Moon.
- Shorter duration
- Little evidence of floor-fractured Craters
- Scarce evidence of enor-mous rilles
- No major volcanic rocks
- No large shield volcanoes.
- Style more akin to flood basalt volcanism.
- The presence of Pyroclastic Vents and Deposits was a major surprise.
- Initial physical volcanological analyses of the pyroclastic deposits and their source vents (1.2) suggested that the magmas associated with these eruptions were very volatile-rich, similar to some lunar and terrestrial magmas.
- Determination of the characteristics of the vents of Mercury. Isolation state, and the effects of partial melting and speciation on magma generation, ascent and explosive and effusive eruptions.

**The Problem**

Do the source vent and pyroclastic deposit morphology and morphology contain definitive information on the volatile abundance and composition of mantle melts?

- To address this question:
  - What can 1) the nature of the source vents, and 2) the ranges of pyroclastic deposits from their associated source vents, tell us about:
    1) The eruption style (effusive degassing, explosive, plinian, hawaiian, strombolian, volcanic?)
    2) The eruption duration, episodicity, and length of any repose period (single event or repeated activity?)
    3) Can the pyroclastic eruption vent and deposits be confidently used to infer the volatile content of the source magmas?
    4) What is the nature of the eruption source (active dike, stalled dike, wall, thrust fault, shallow or deep focus?)
    5) What are the ages of the pyroclastic vents and deposits and how are they related to the record of effusive volcanism?
    4) What can the geologic setting and associations of the source vents and pyroclastic deposits tell us about these questions?

- Pyroclastic eruptions represent rapid transfer of magmatic volatiles from depth to the surface.
- The nature, morphology, mineralogy and age of deposits and vent structures provide important evidence for assessing modes of eruption, volatile species and abundances, dispersal, transient atmosphere contributions and potential surface alteration processes.
- On Mercury, a large number of individual pyroclastic vents and deposits have been documented, and many ages extend to pre-existing volcanic plains geologic history.

- We use deposit and vent characteristics and volumes, and their relatively young ages, to assess the nature of candidate dike-emplacement events and related periods of gas venting to the surface.
- We find that primary gas formation (propagating dike-tips) combined with significant secondary gas enrichment (stalled dikes) could result in rapid transient volatile venting to the surface, in concentrations that do not necessarily represent the abundances in the primary magma.

**Modeling Dike Emplacement and Pyroclastic Eruptions on Mercury: Implications for Volatile Sources, Abundances, and Fates**

**Our Approach**

**Explosive Volcanism on Mercury**

- Explosive volcanic activity was not anticipated for Mercury, which was expected to be depleted in volatiles.
- However, at least 37 deposits morphologically consistent with emplacement by explosive activity have been identified.
- The contrast between the small volumes of pyroclastics and the large volumes of flood lavas on Mercury is striking.
- The sources of the deposits are rhyolite, generally irregular pits, ~5–35 km in diameter.
- Consideration of the energetics of eruptions in a vacuum shows that to reach the observed deposit radius, mainly in the range 20–50 km, required the erupting magmas to contain ~4000 to 12000 ppm CO or the equivalent (inversely proportional to the molecular weight) of other volatiles.
- Candidate volatiles depend on the oxidation state of Mercury’s interior and include CO, N2, C2S, C2S2, C2S3, Cl, O2, or COS (reducing interior, most likely) or CO2, CO, H2O, SO2, or SO3 (oxidizing interior, less likely).
- Equilibrium release from ascending magmas of up to 12000 ppm volatiles is not expected given the current understanding of Mercury’s composition and oxidation state.
- Also the mechanism of formation of the pits associated with the deposits is unclear.
- This suggests that some process may be required to concentrate volatiles into the tops of ascending dikes that fail to breach the surface to form lava flows.

**Candidate Formation Models**

A) Lunar floor-fractured crater formation model (Schultz, 1975; Jozwiak et al., 2012, 2013). Blocks/collapsing in shallow subaerial crater floor, leading to low explosive, crater floor and peripheral diking from all sides.
B) Sill/laccolith with dike-tip overshoot model (Wilson and Head, 2018). Geometry similar to A, but includes dike-tip overshoot, leading to crater floor spall, localization of volatile-magmatic overflows over dike-tip region.
C) Surface dike degassing model. Dike propagates to surface without interruption and explosively vents.
D) Stalled dike degassing model. Dike stalls at some depth beneath crater floor, secondary volcanic buildup, leading to explosive degassing after sufficient volatile build-up.
E) Thrust fault degassing model. Dike propagating from deep below the surface to thrust fault, localization of volatile-rich magmatic outflow or volatile to propagate along thrust fault and explosively vent of surface along leading edge of thrust fault-related landform.

**References**

James Head, Steve Parmant, Lauren Jozwiak, and Ariel Deutsch.

Dept. of Earth, Environmental and Planetary Science, Brown University, Providence, RI 02912 USA.

Planetary Exploration Group, Johns Hopkins University Applied Physics Laboratory, Laurel, MD, USA;

NASA Ames Research Center, Mountain View, CA, USA.