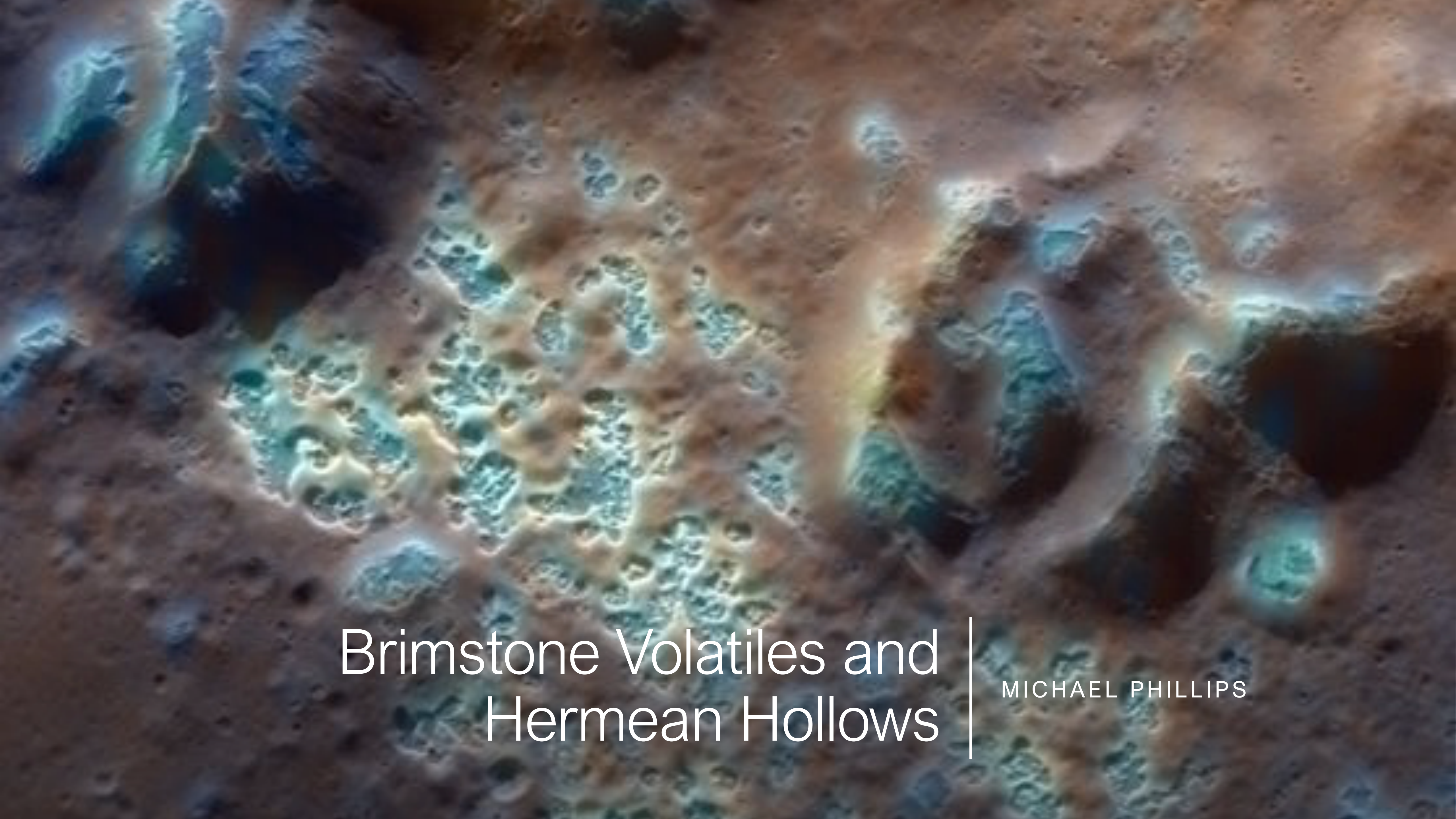
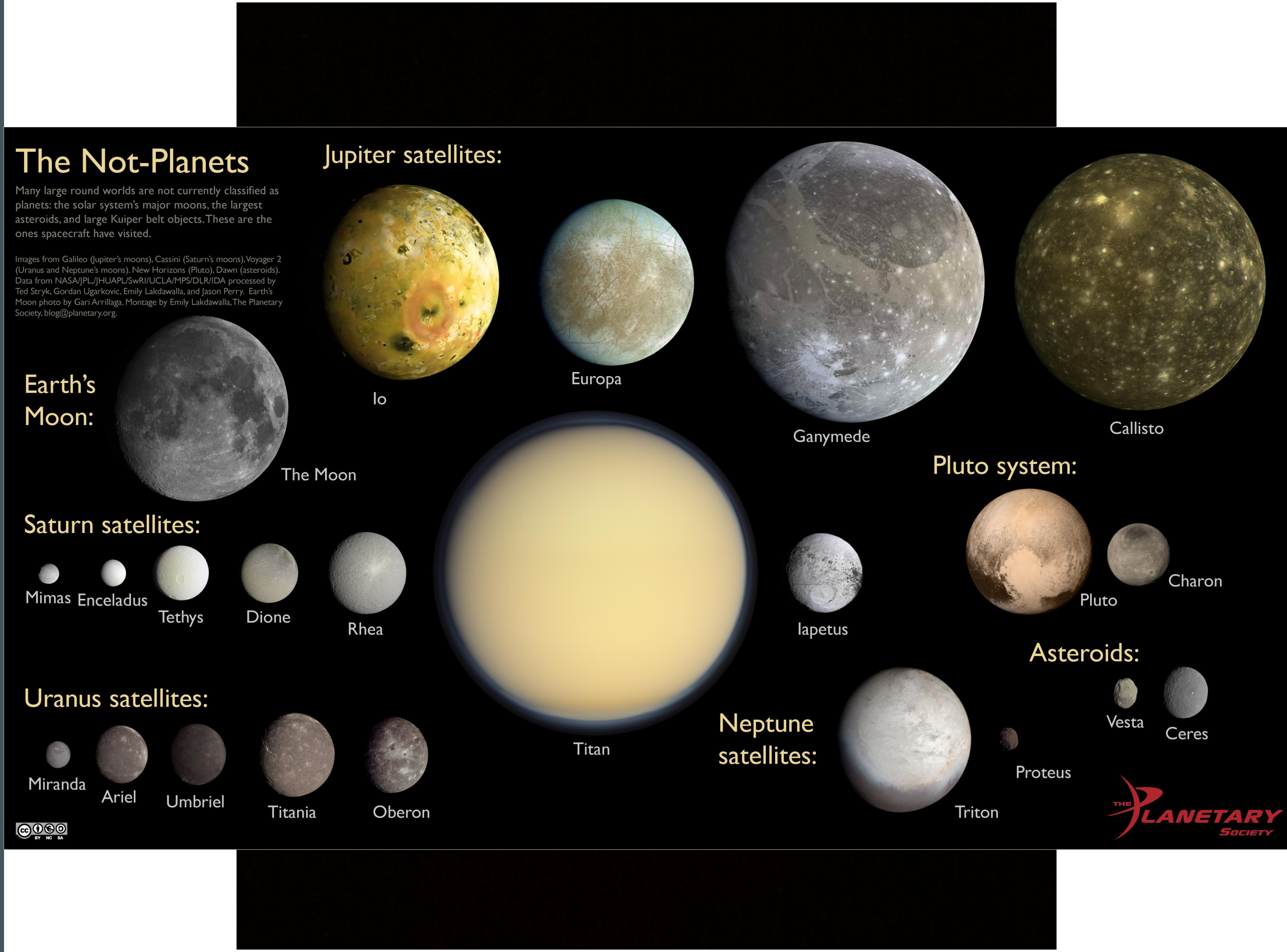


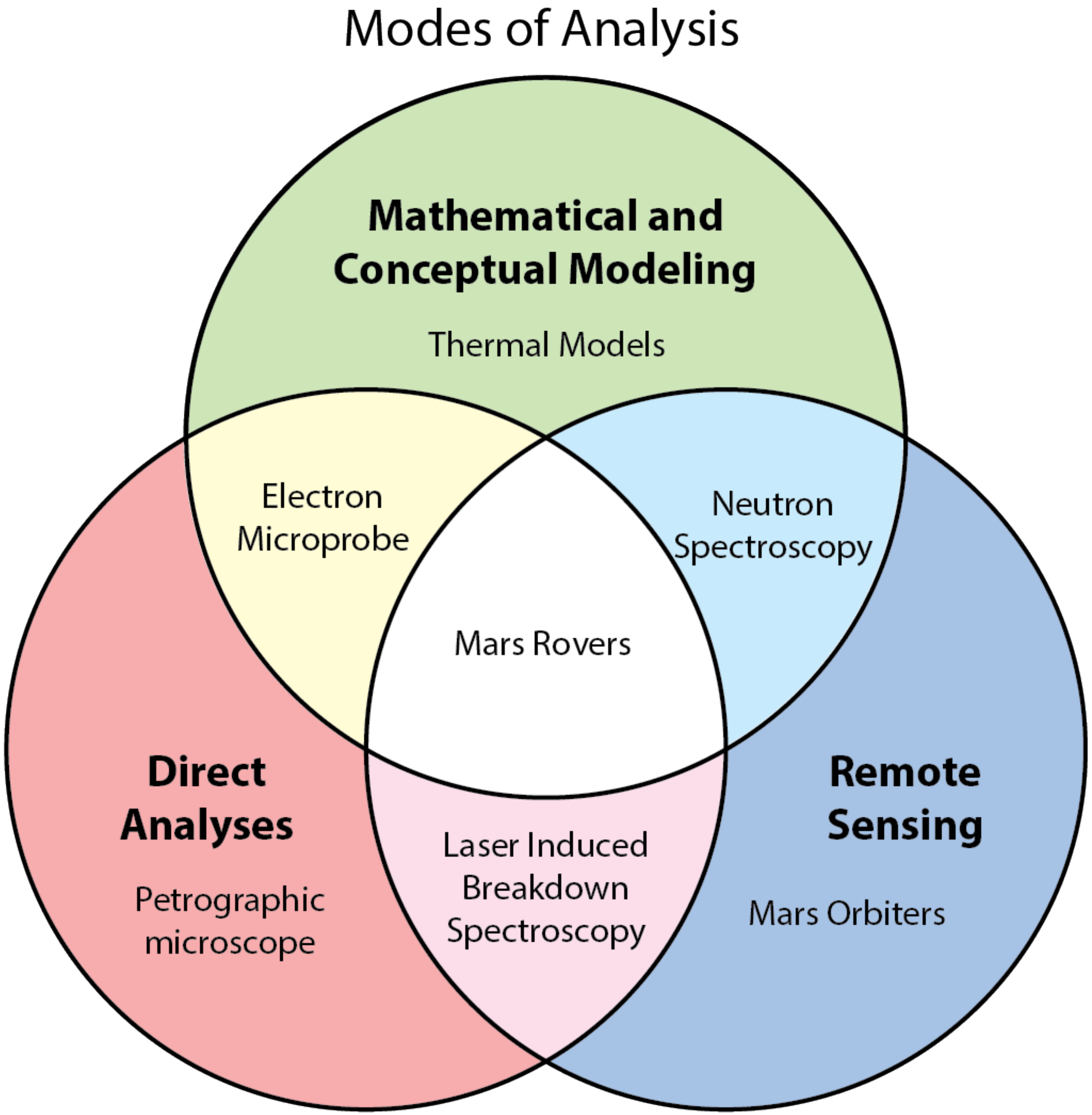
Brimstone Volatiles and Hermean Hollows

MICHAEL PHILLIPS

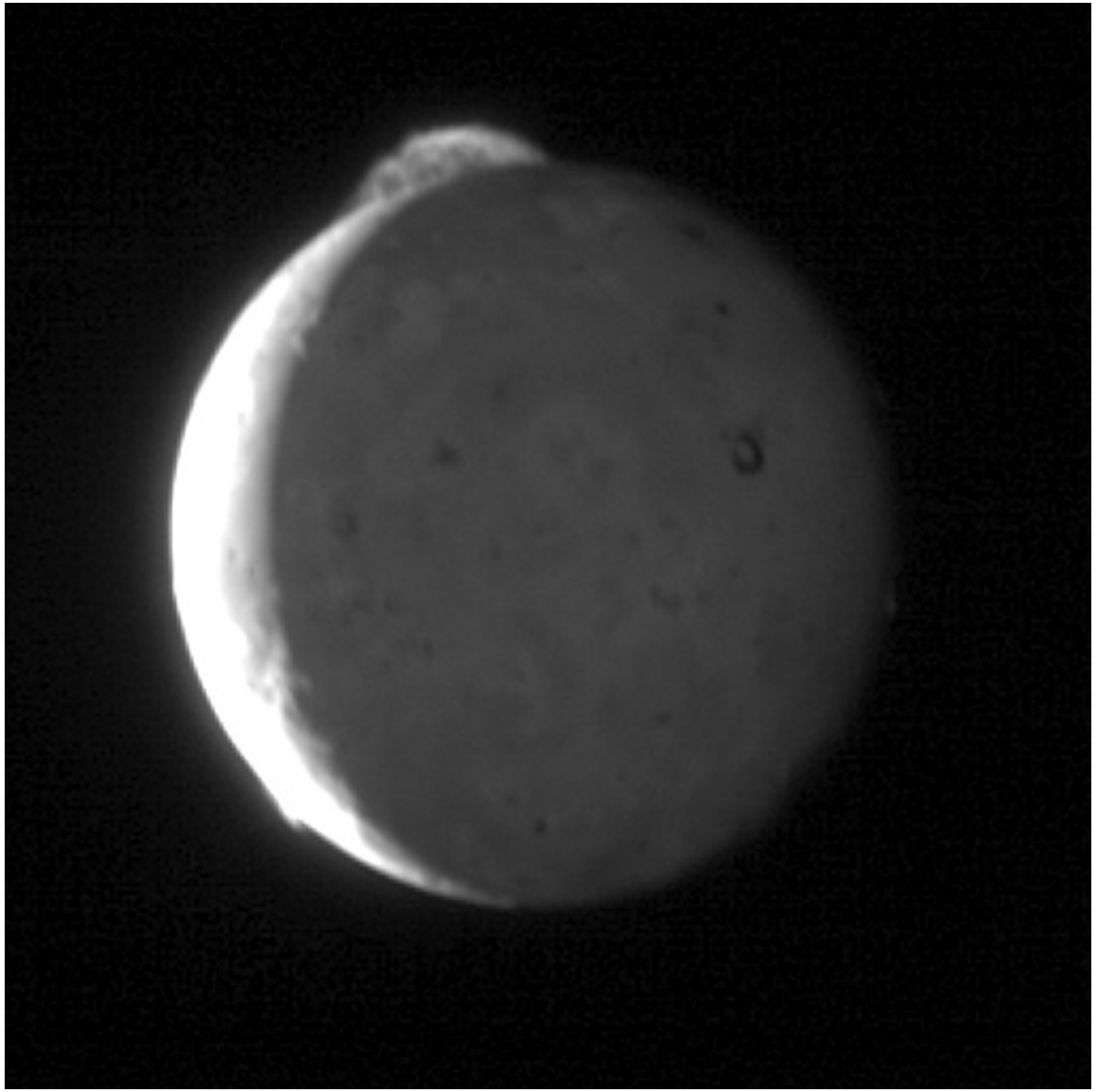
Planetary scientists study the planets and other “planetary bodies”.



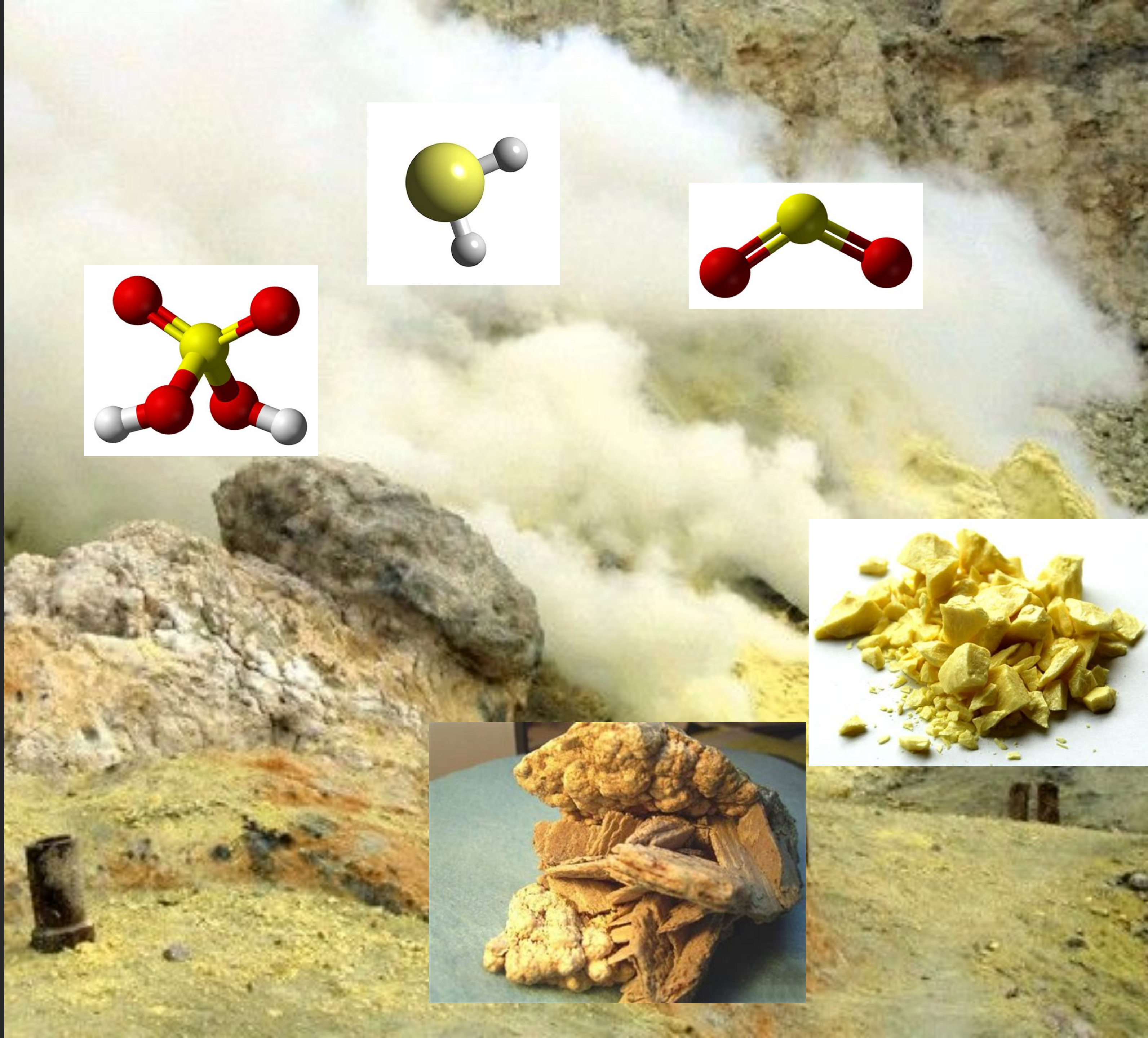
You can categorize the myriad ways to study planetary bodies into three modalities: direct analysis, remote analysis, and mathematical and conceptual modeling.



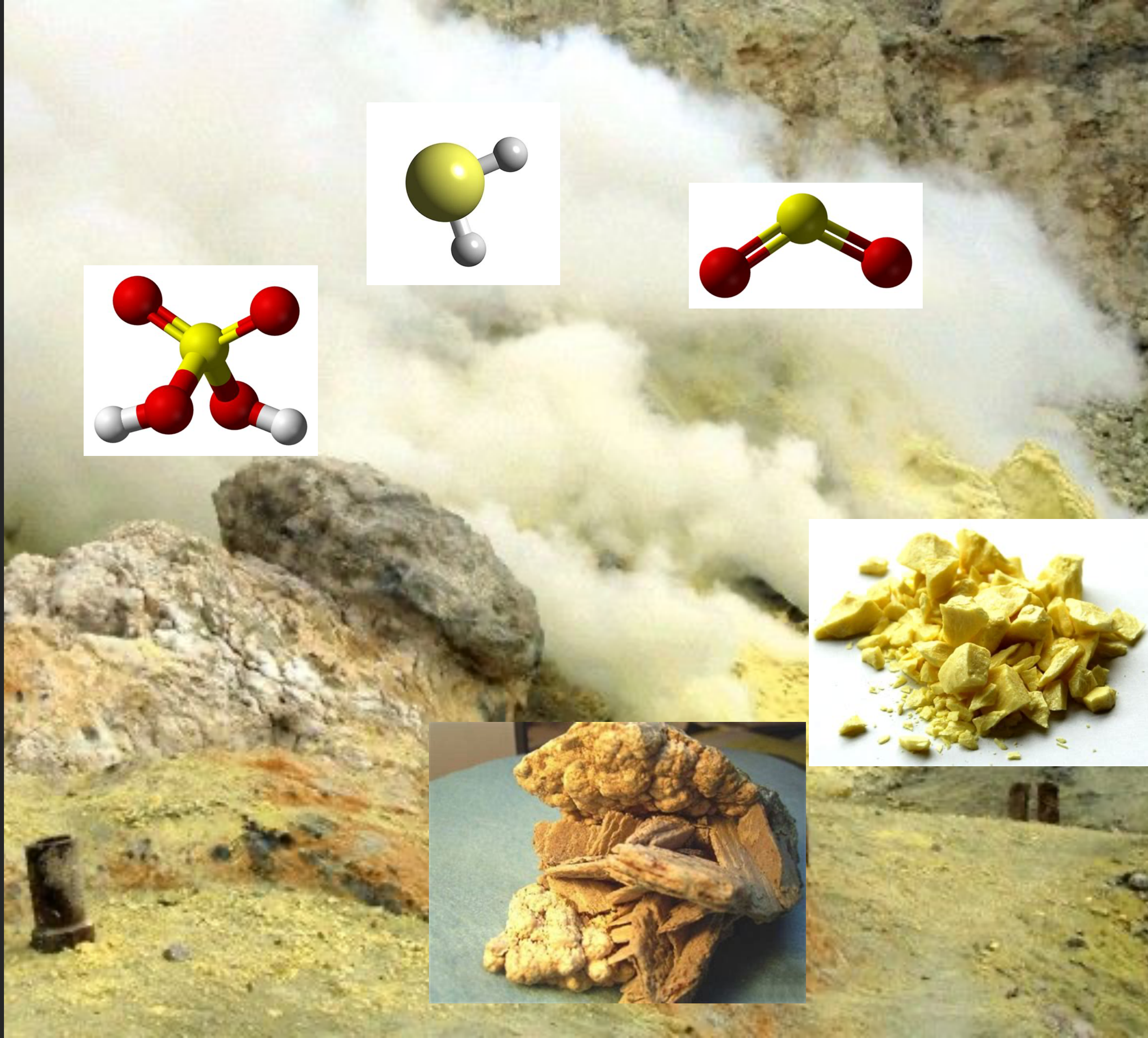
Days before the Voyager spacecrafts arrived at the Jovian system, Stan Peale and others predicted widespread and recurrent volcanism on Io mathematical models.

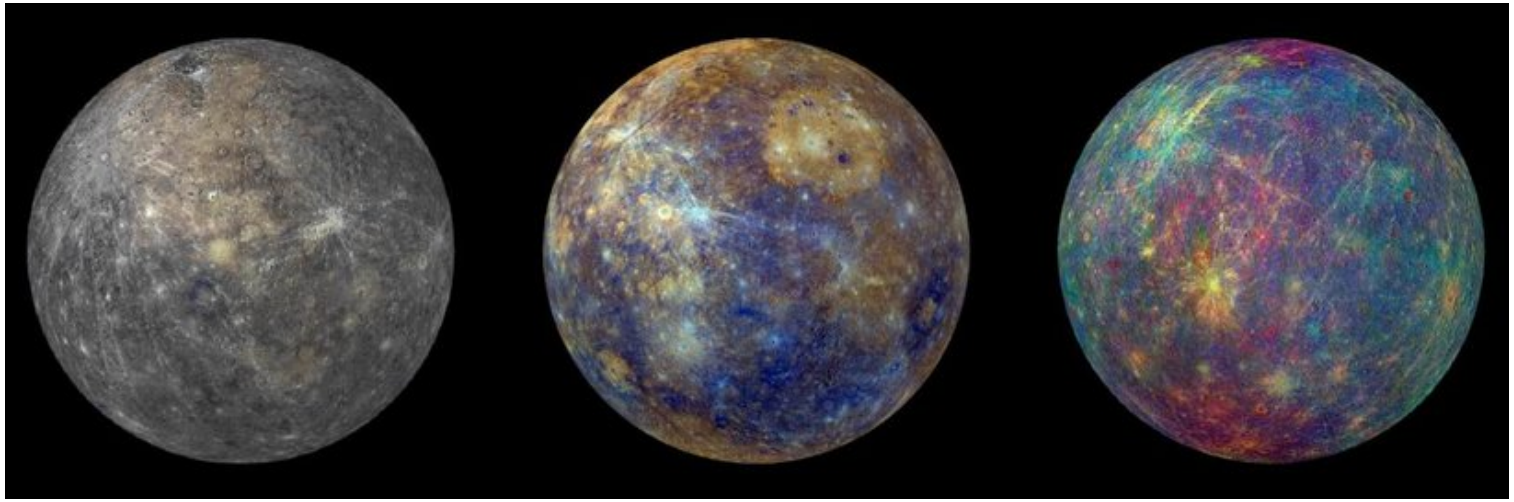


Brimstone

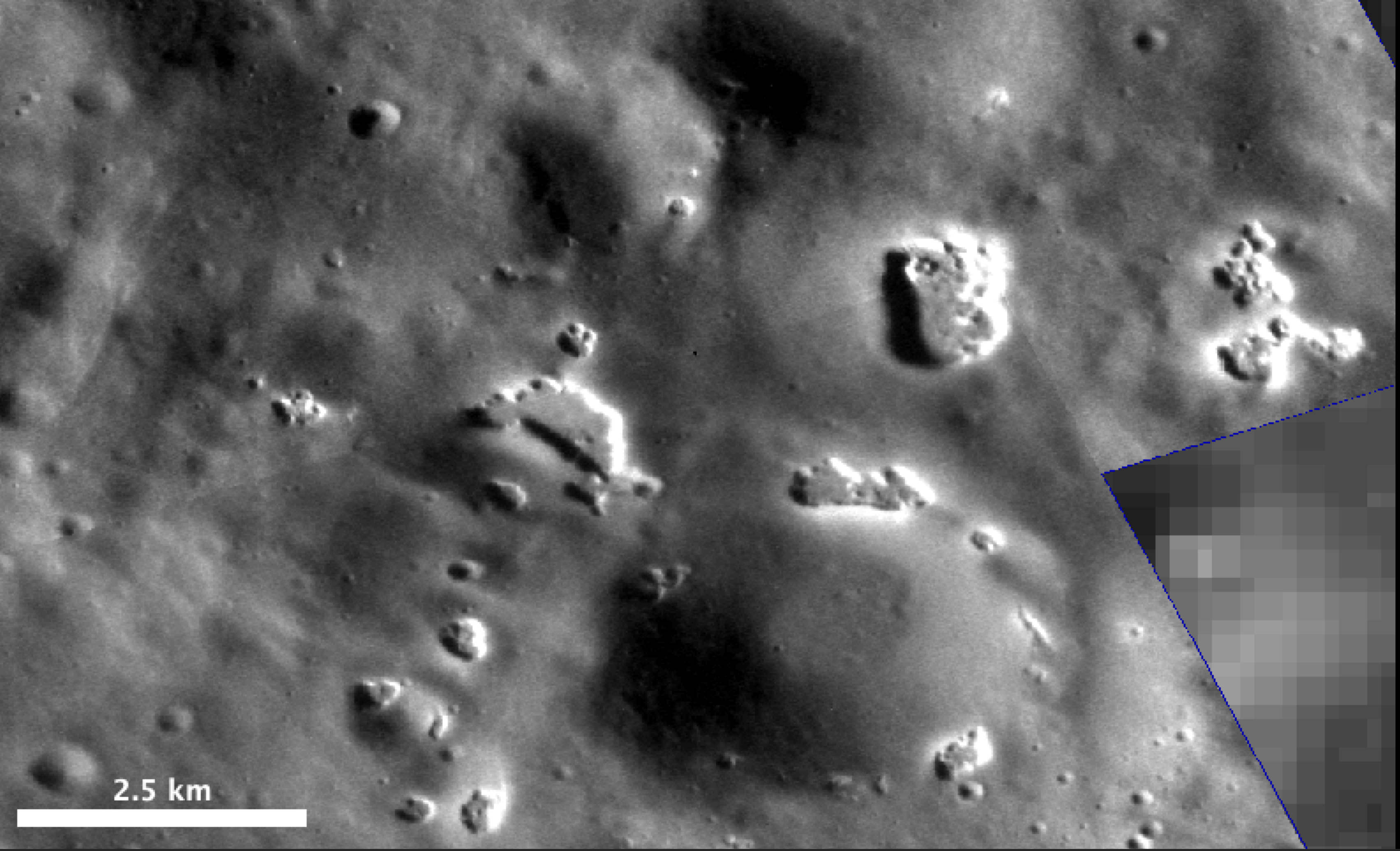


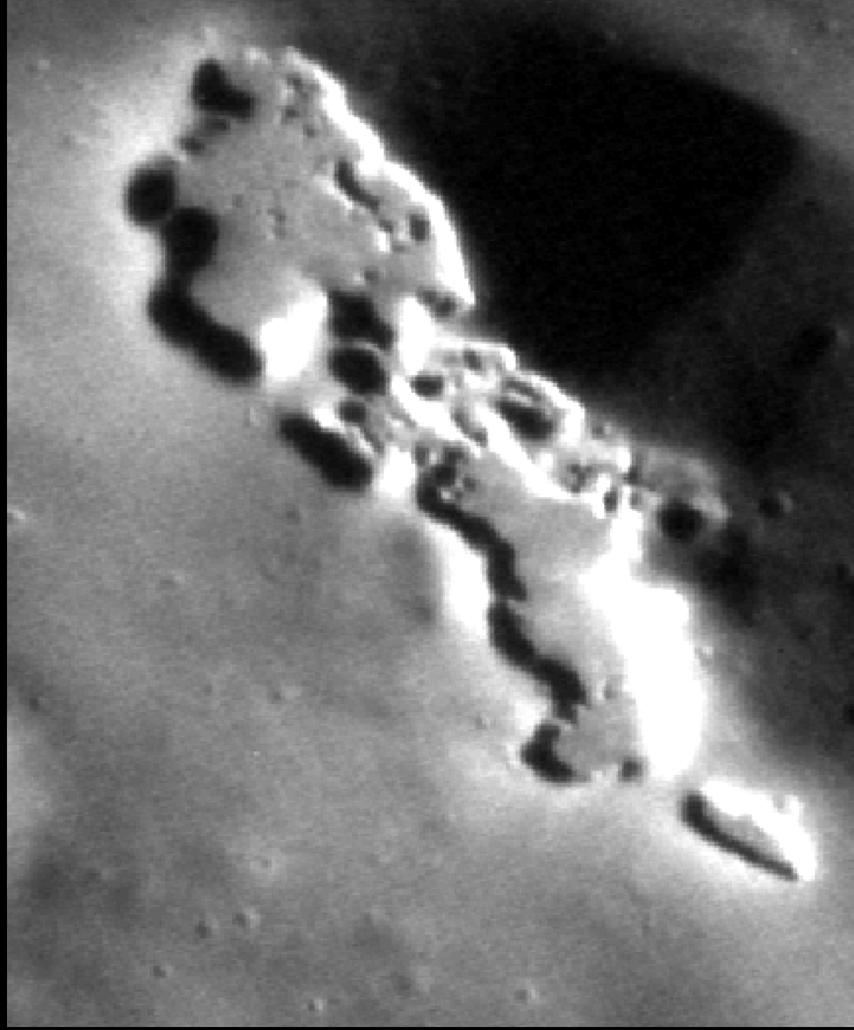
Volatiles





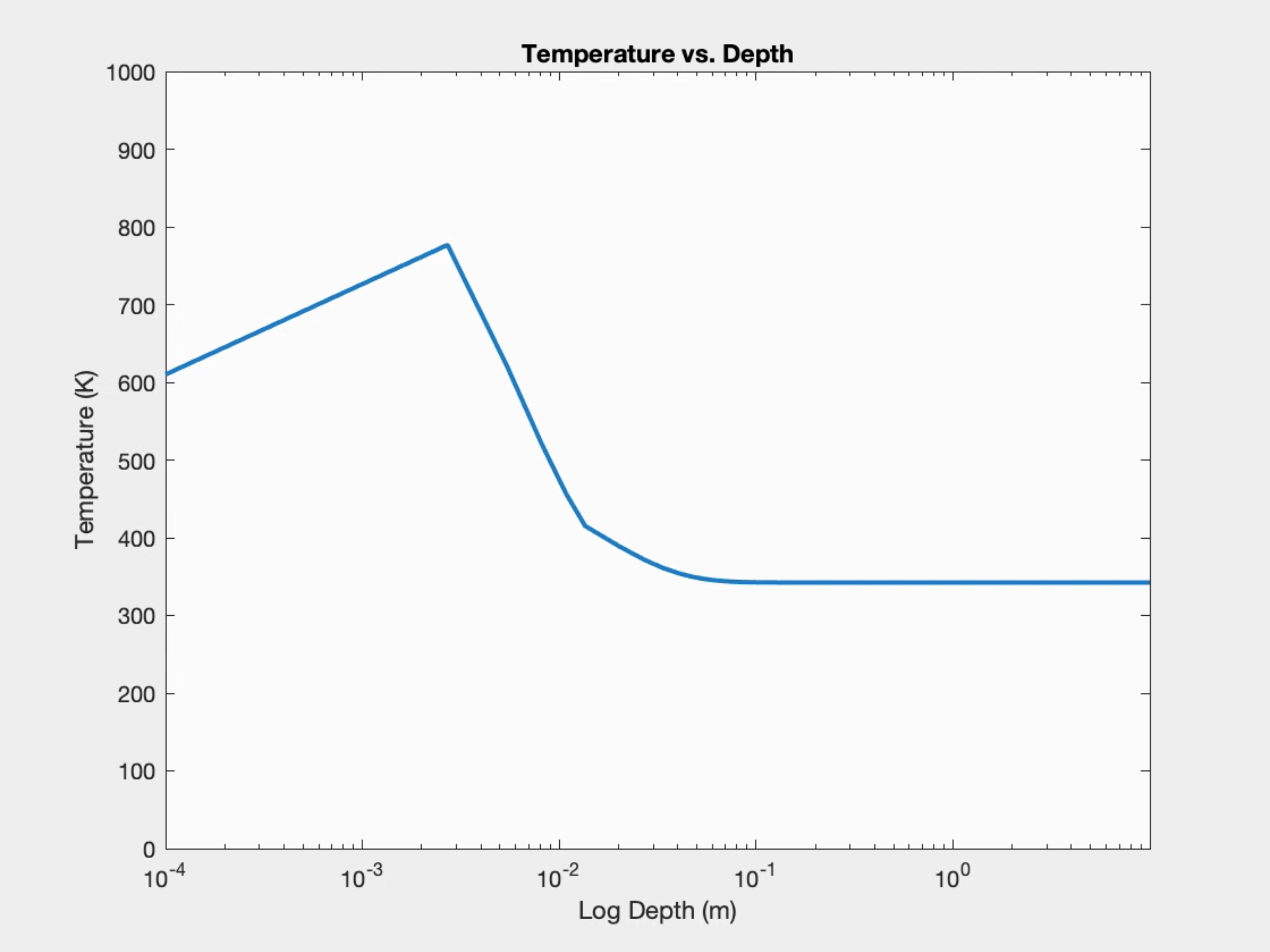

Hermean



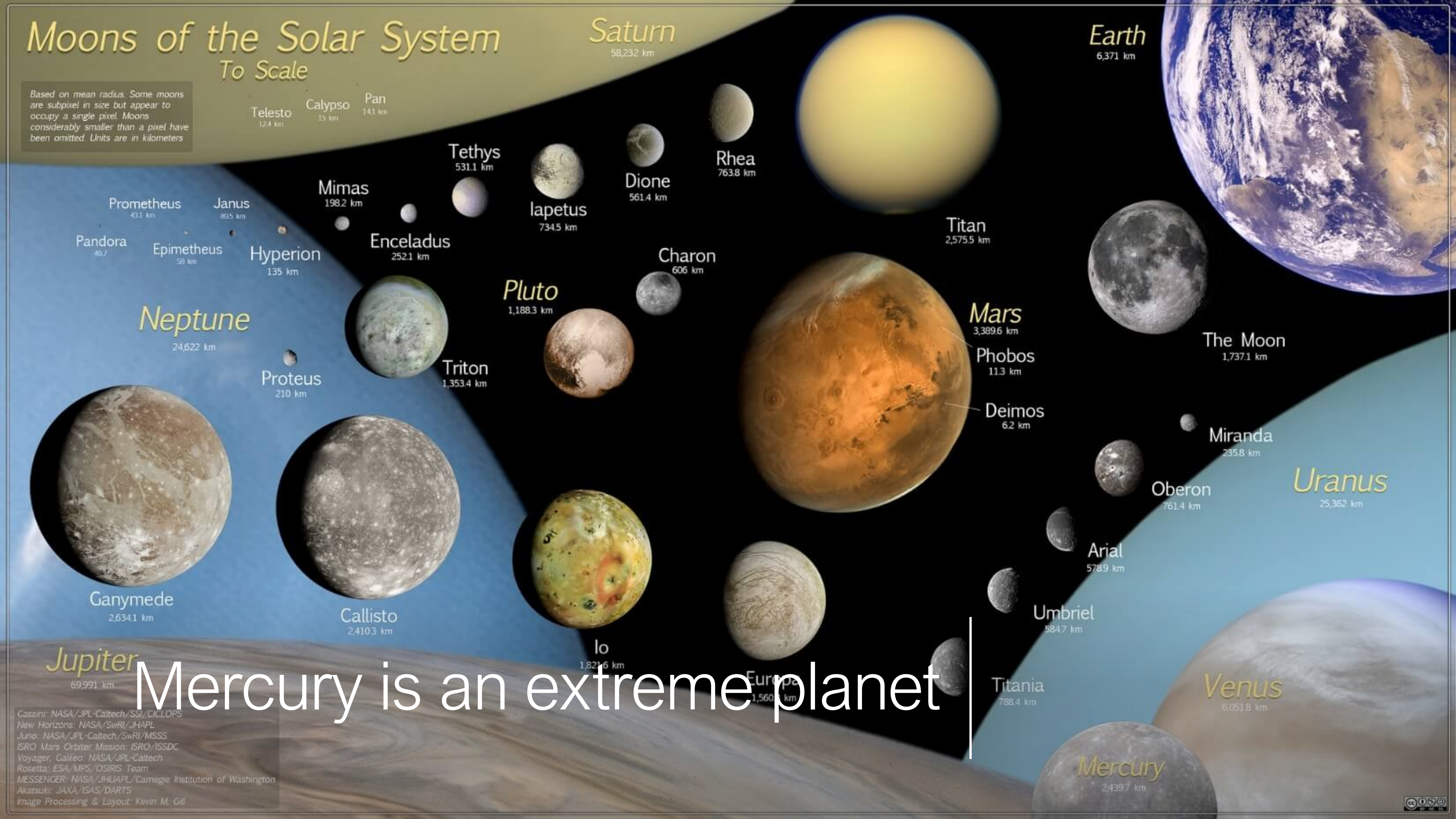


Hollows

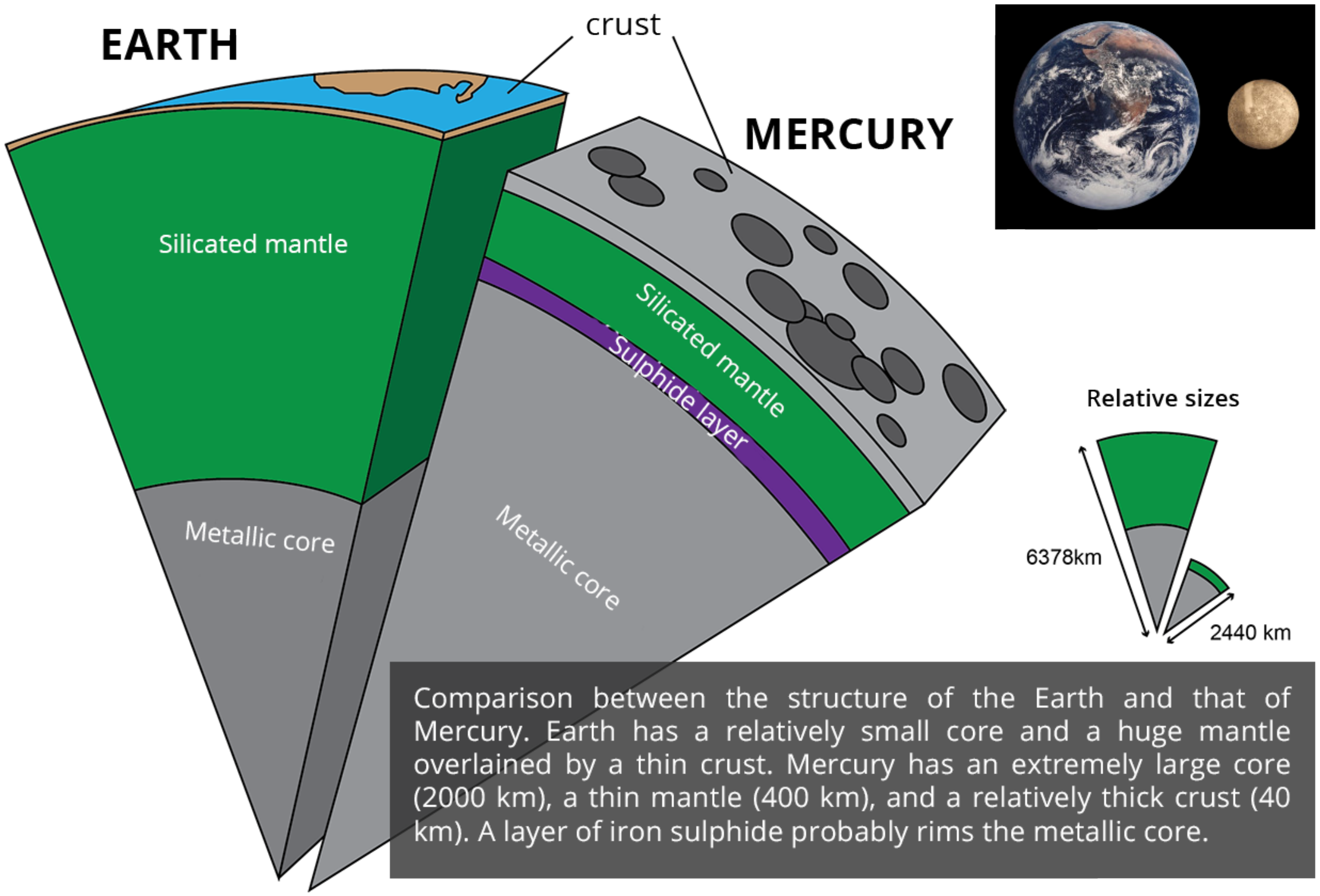
Using temperature and diffusion calculations to test the prevailing hollow formation model.



Mercury is an extreme planet

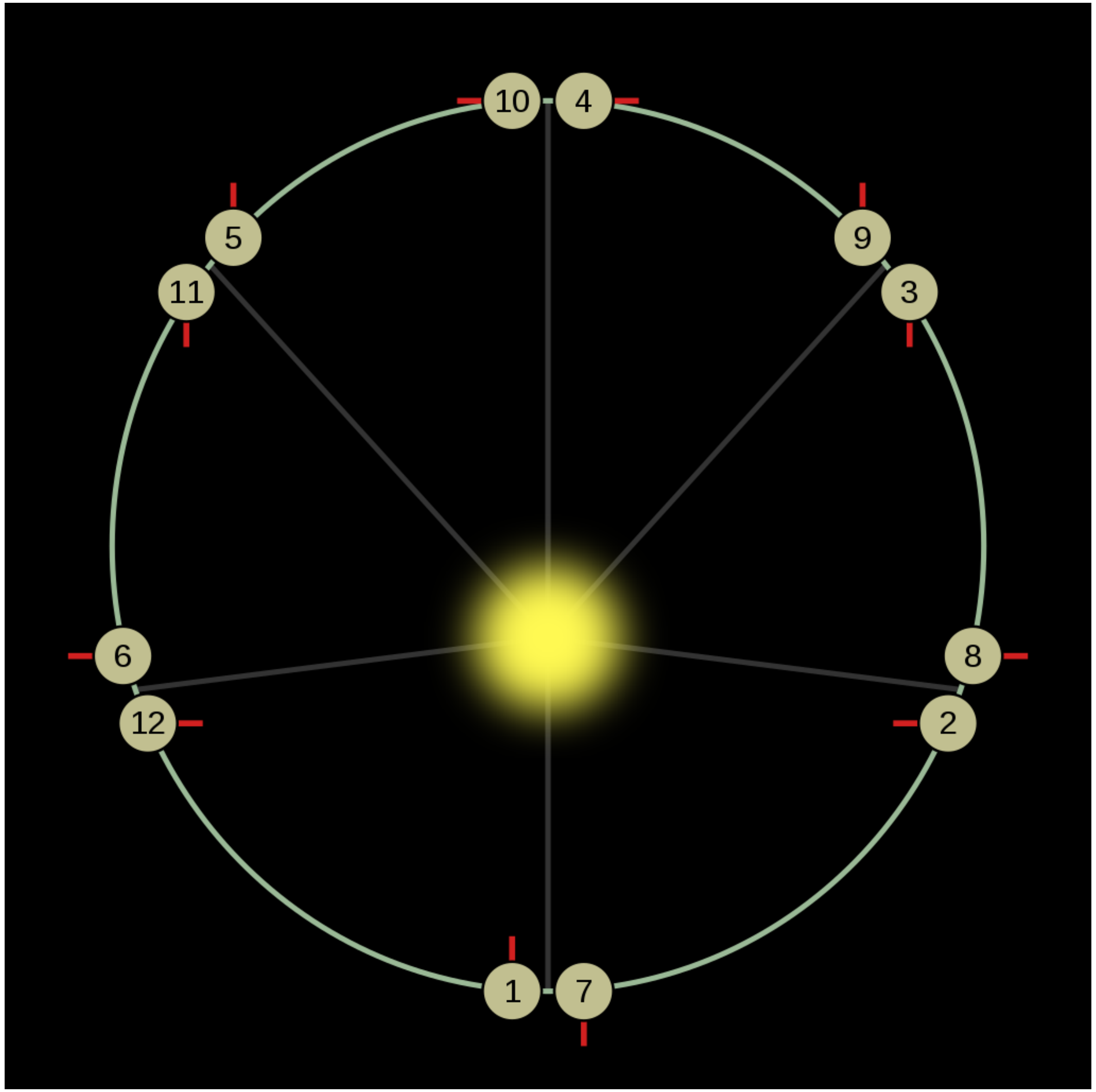


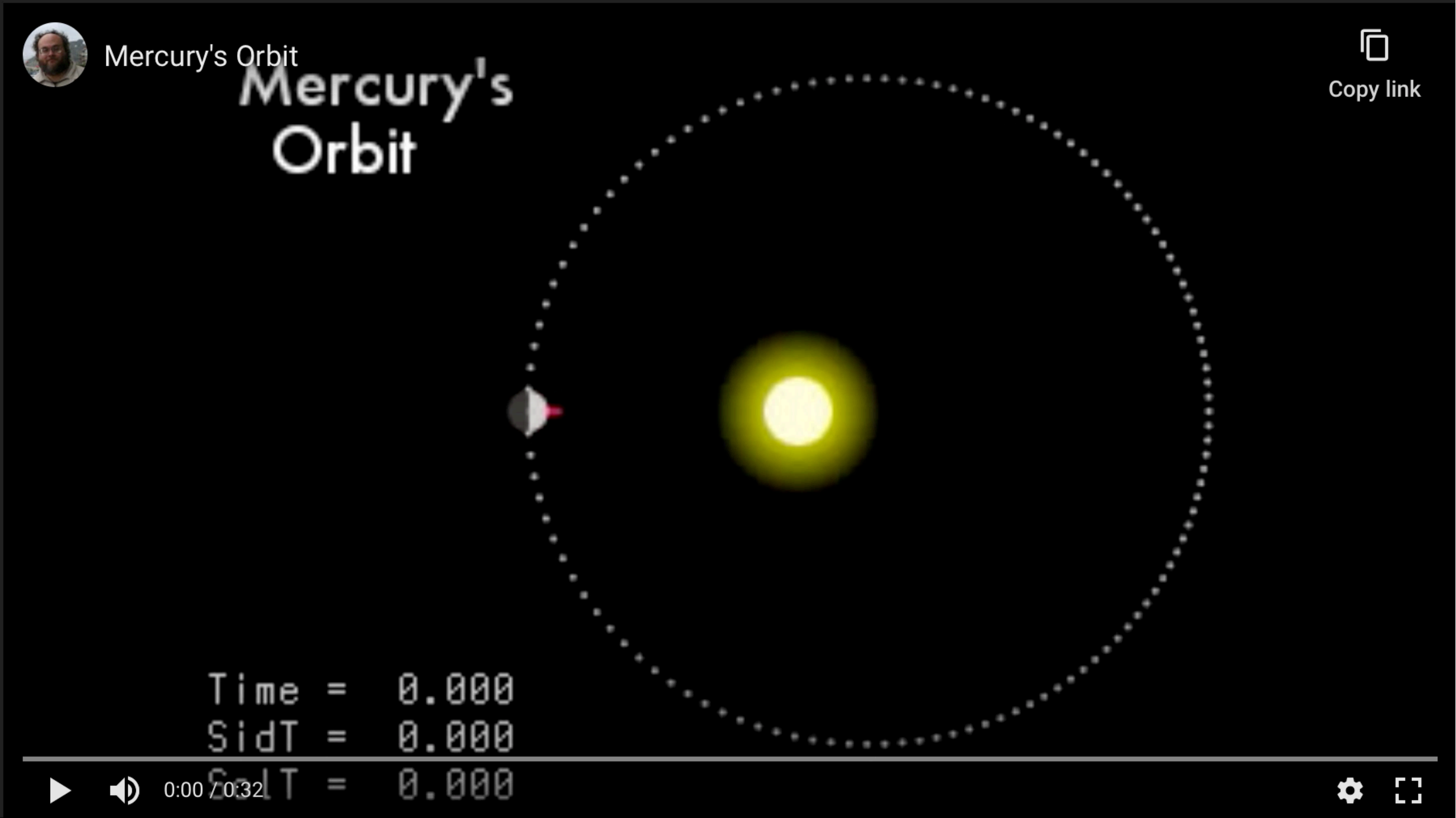
Mercury is almost all core.



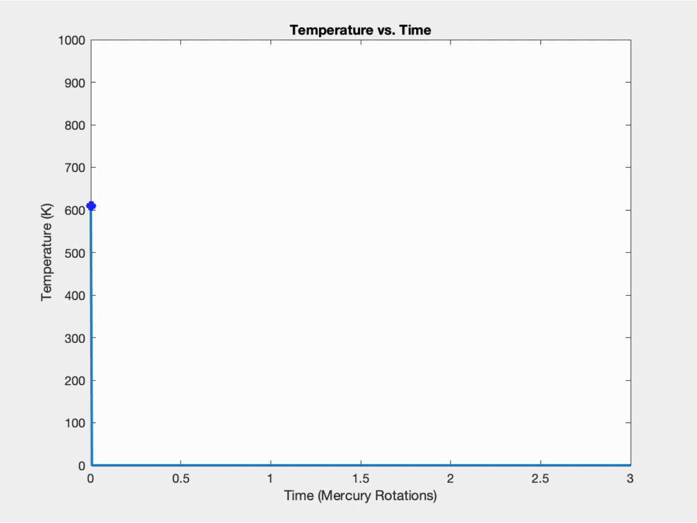
Comparison between the structure of the Earth and that of Mercury. Earth has a relatively small core and a huge mantle overlained by a thin crust. Mercury has an extremely large core (2000 km), a thin mantle (400 km), and a relatively thick crust (40 km). A layer of iron sulphide probably rims the metallic core.

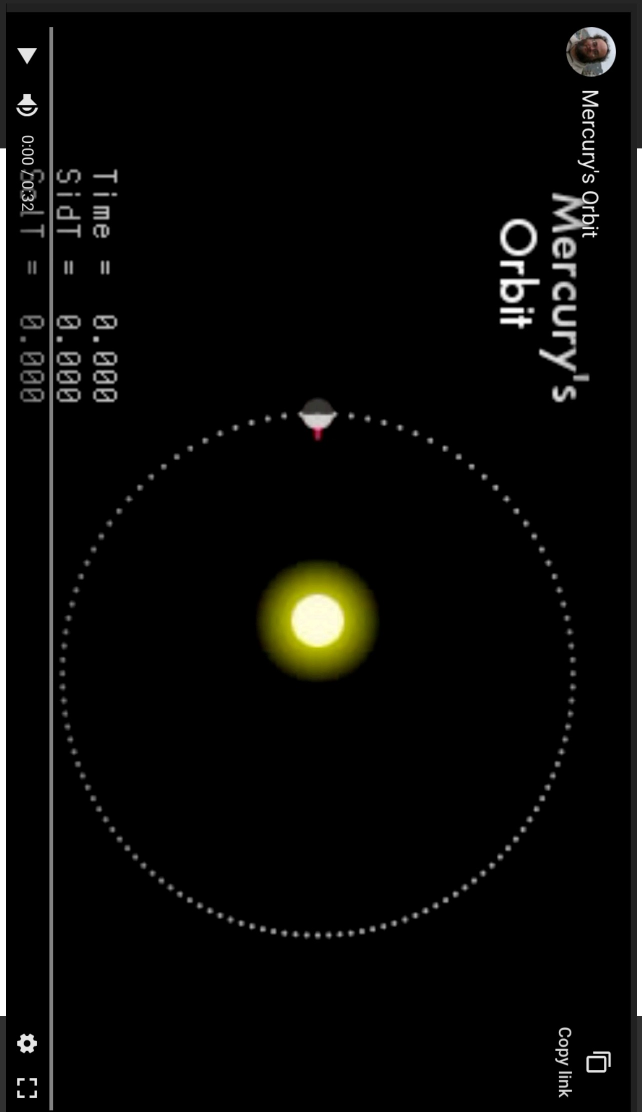
Mercury has a 3:2 spin:orbit resonance. It spins 3 times on its axis for every 2 orbits.

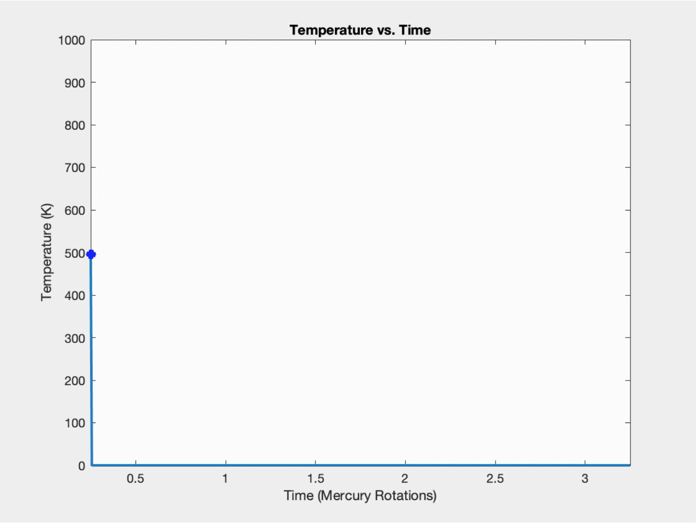


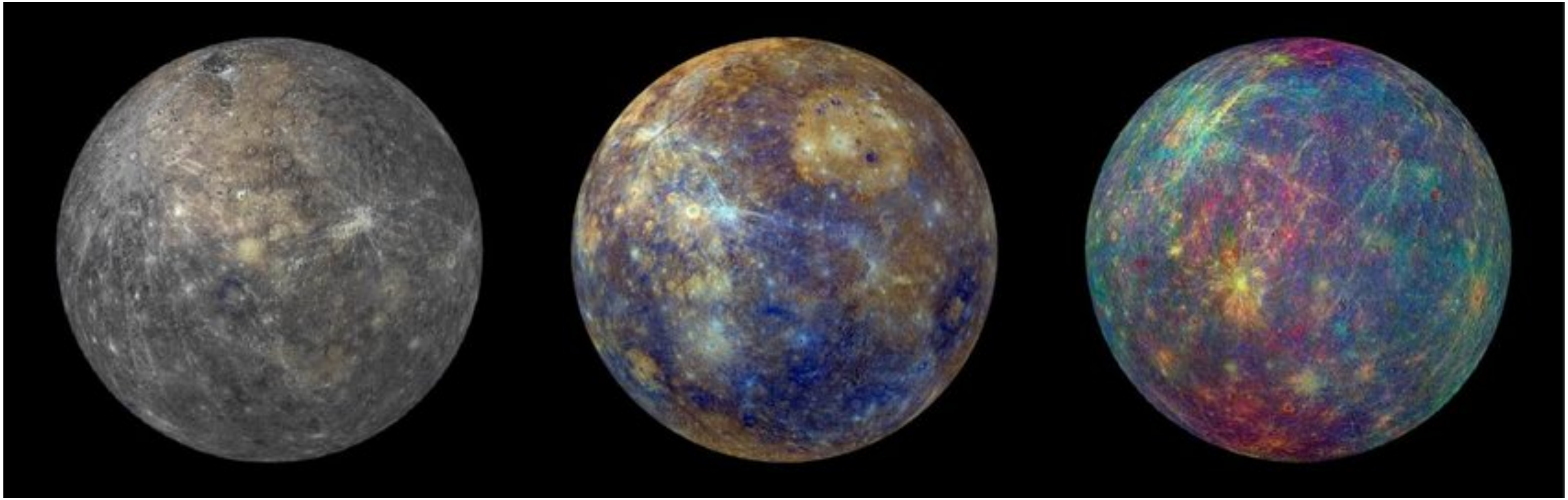

Mercury's Orbit
Copy link
Mercury's
Orbit
Time = 0.000
SidT = 0.000
SolT = 0.000
0:00 / 0:32

The effect of this orbit on the surface temperature of Mercury is… weird.

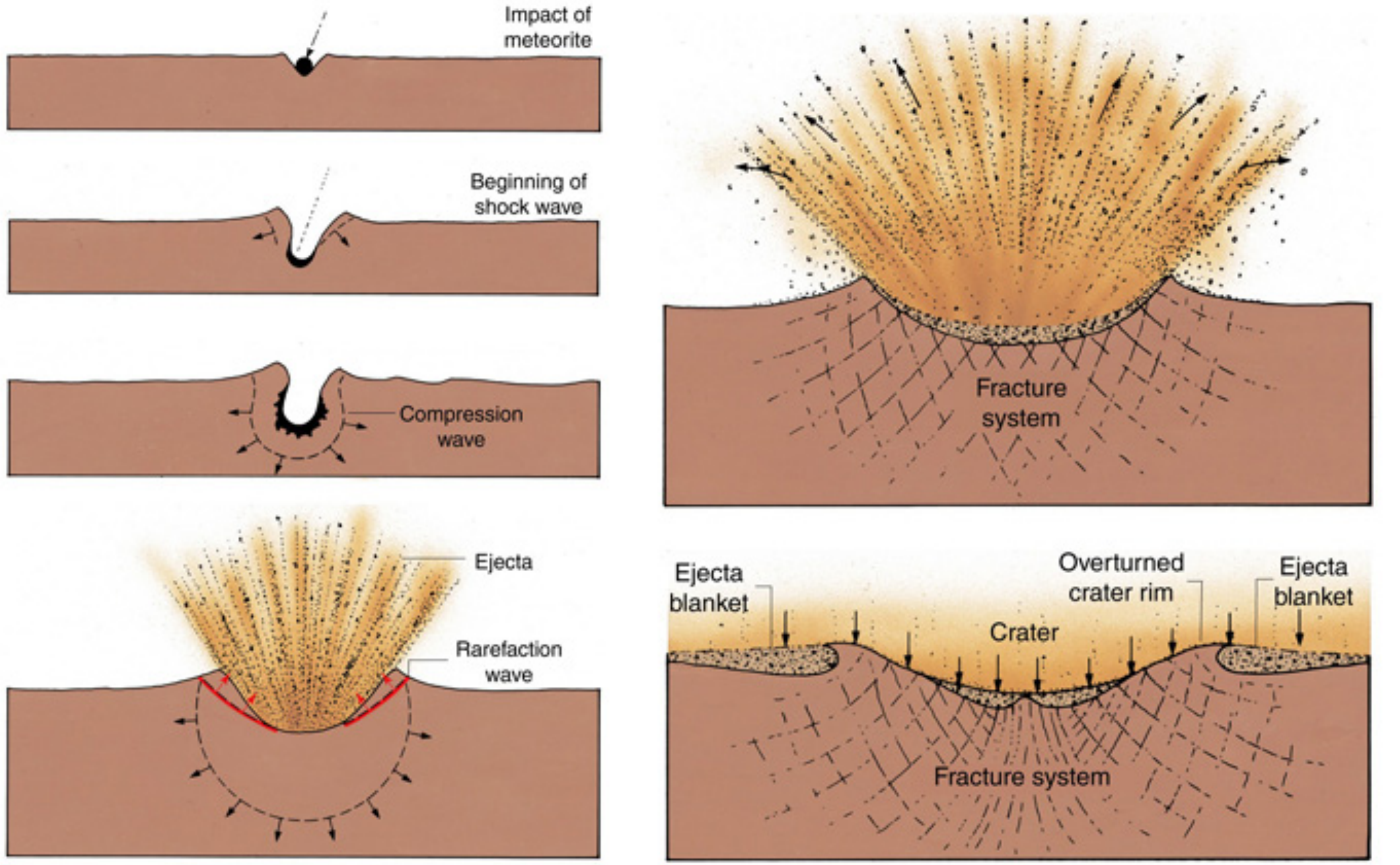


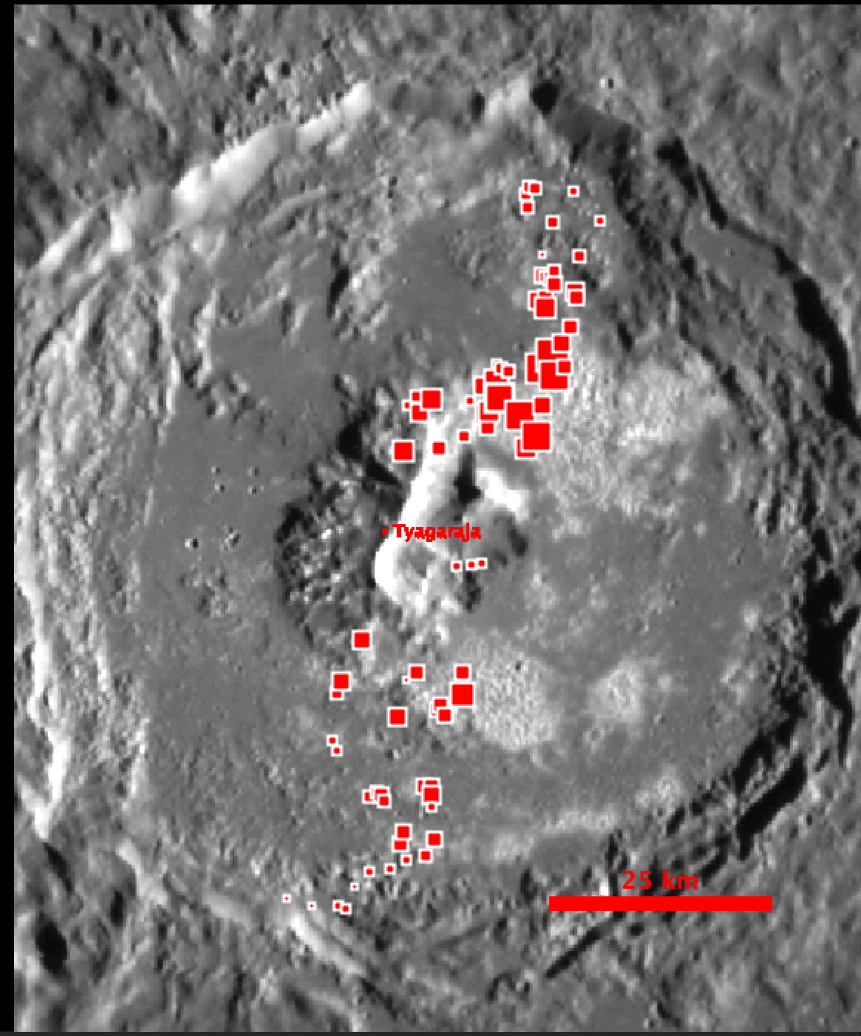






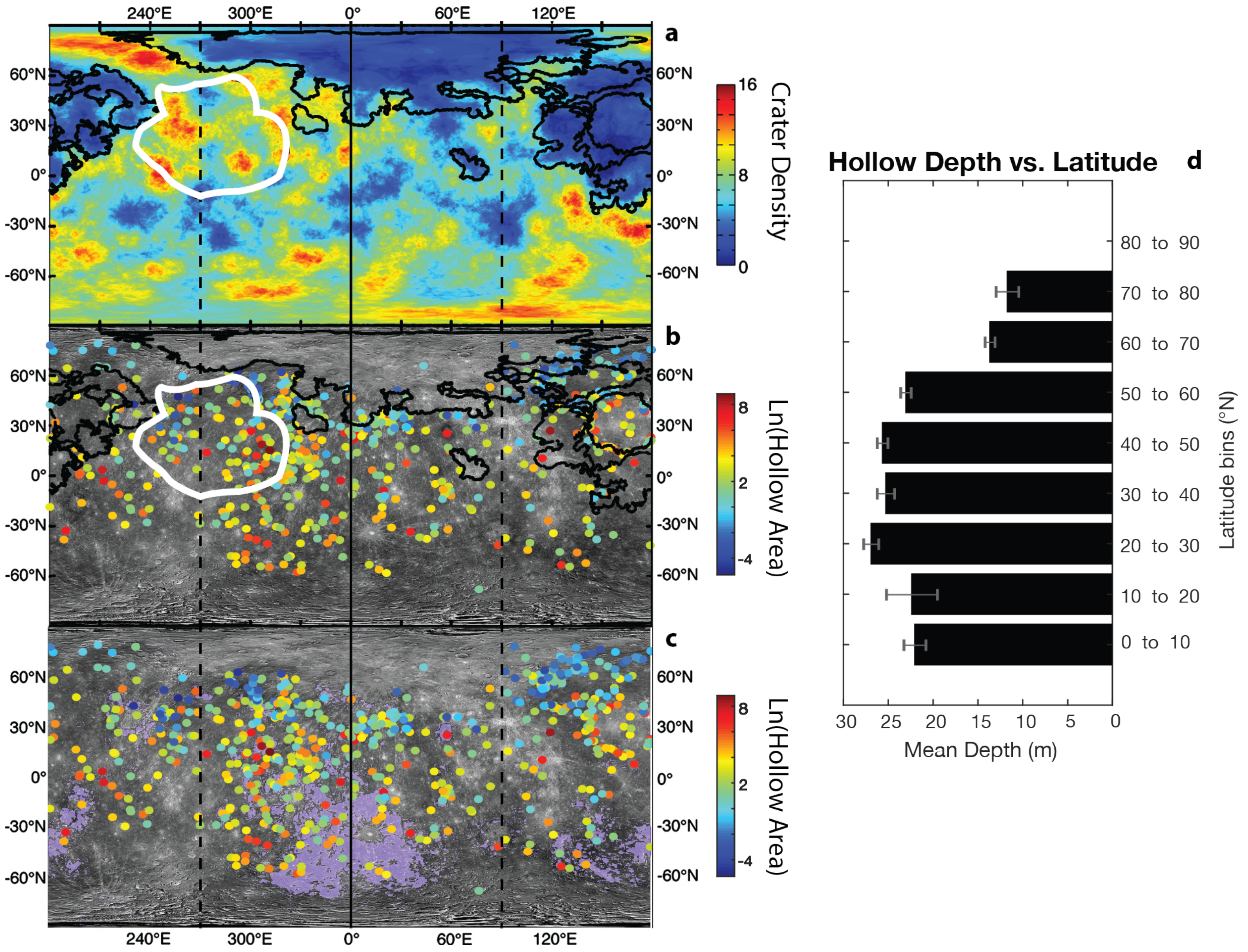
Hollows occur primarily in LRM, a major color unit of Mercury.



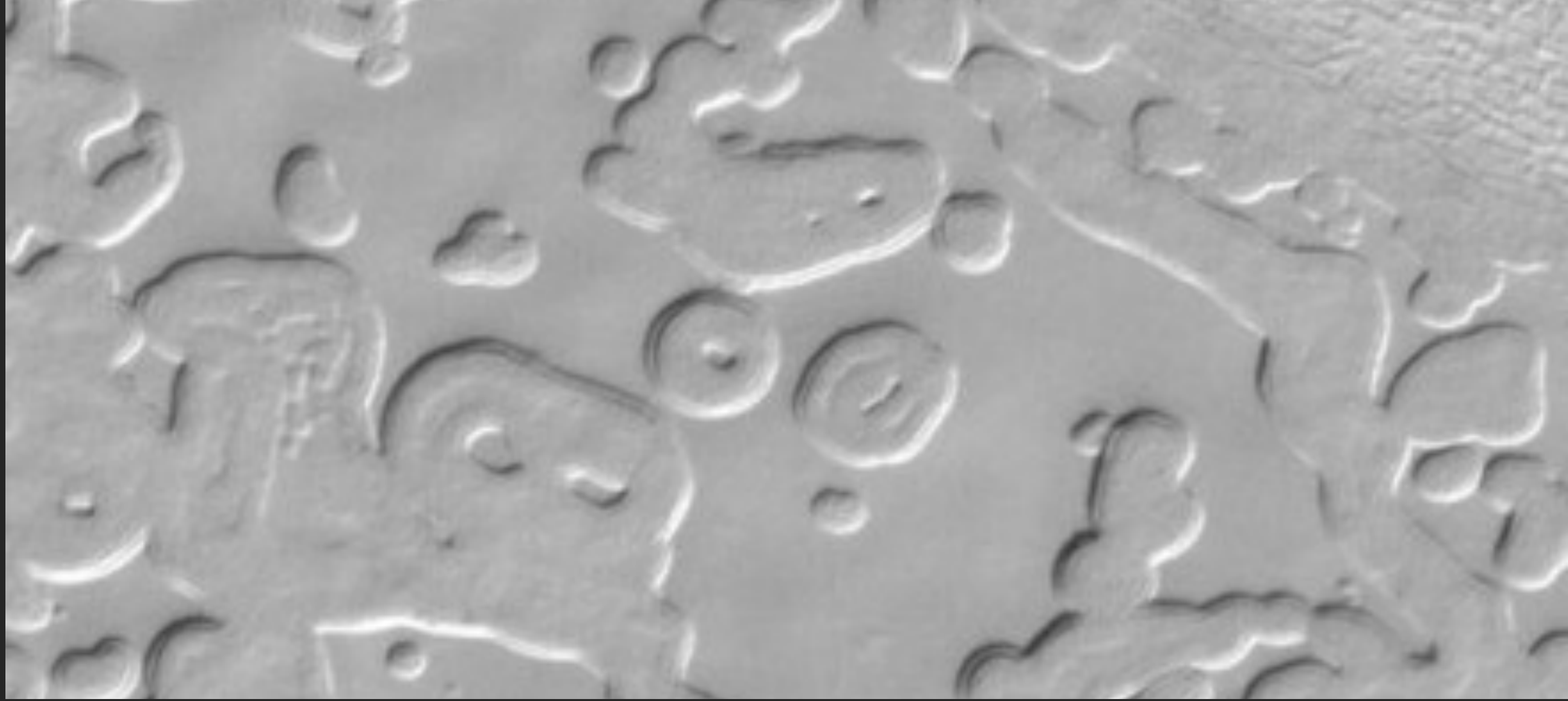


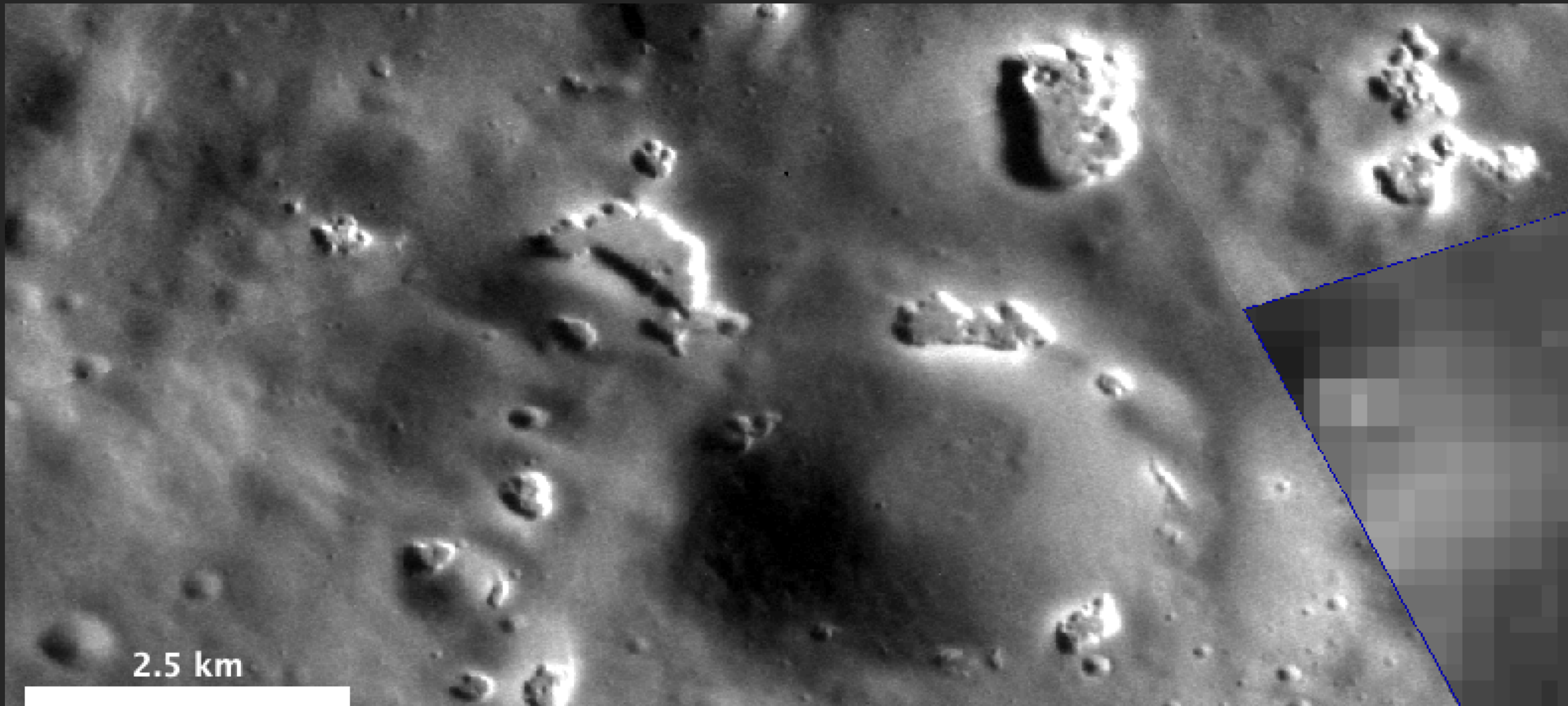
Hollows occur primarily in impact craters and related material.

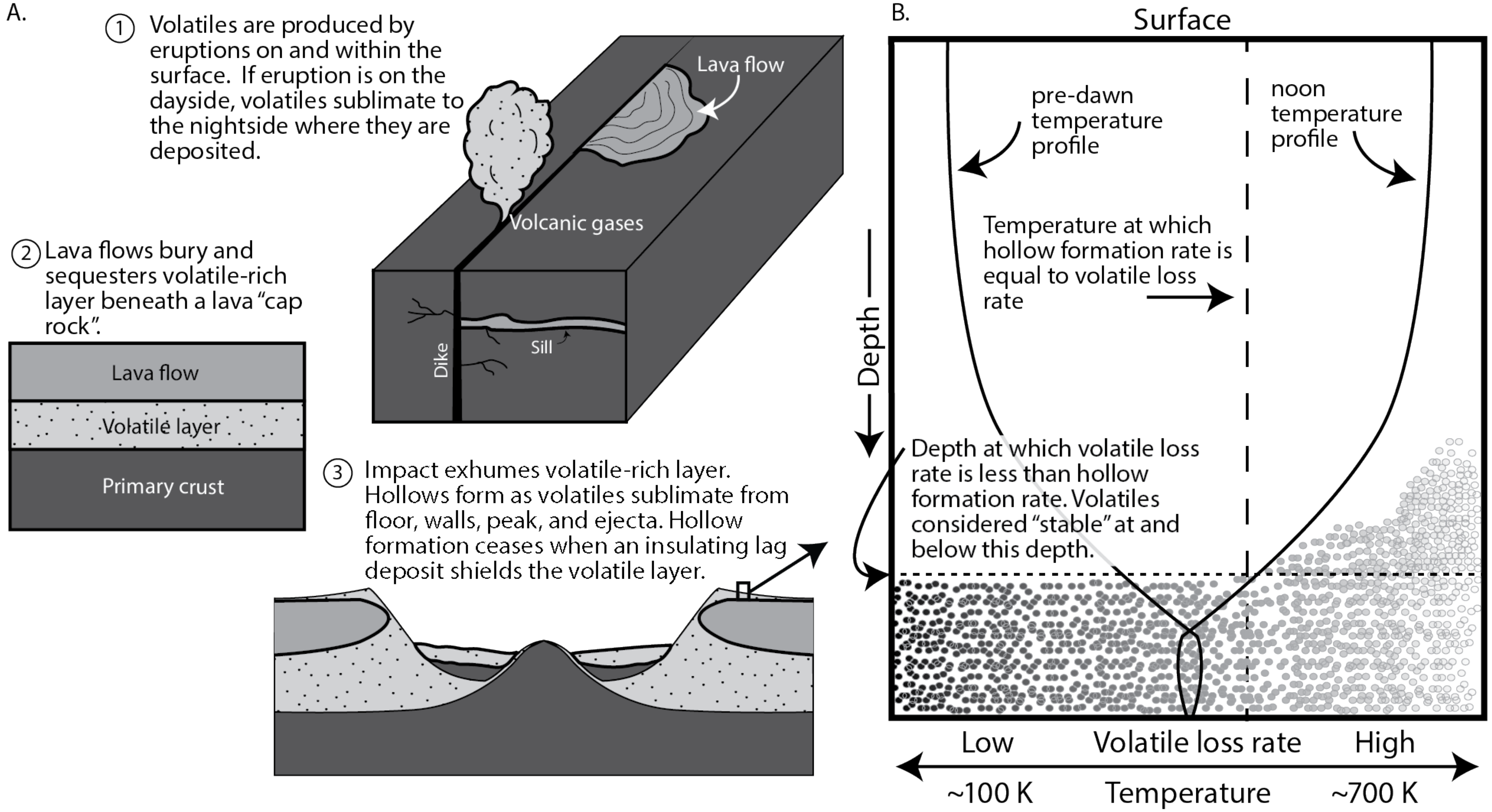
Hollows are deeper and cover more area at low latitudes than at high latitudes.



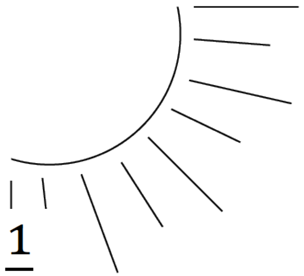
Hollow morphology suggests formation via sublimation.







Prevailing hollow formation model involves excavation, sublimation, and sequestration of a volatile-rich layer.

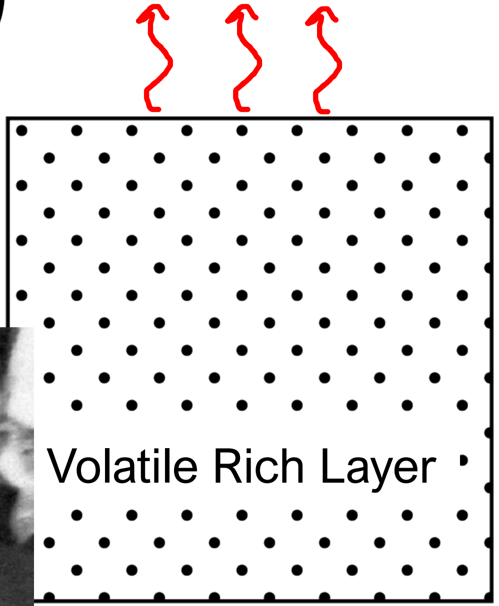


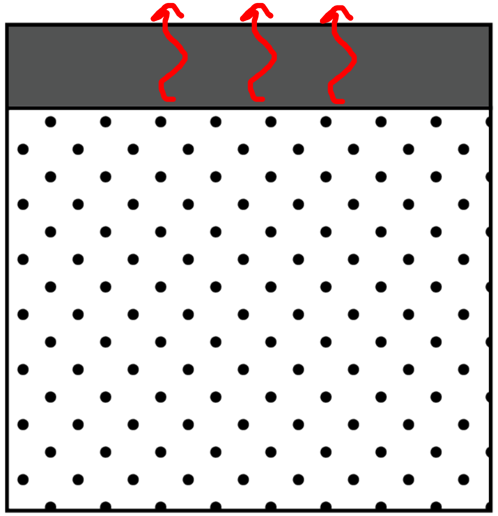
$$\rho c_p \frac{\partial T}{\partial t} = \frac{\partial}{\partial z} k \frac{\partial T}{\partial z}$$

Fourier 1822, gives you temperature as a function of depth and time.

$$E_i = P_v \left(\frac{\mu_i}{2\pi RT}\right)^{\frac{1}{2}}$$

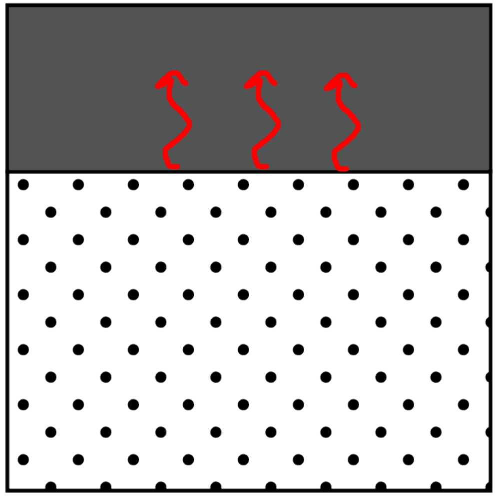
Hertz-Knudsen, give you sublimation rate from the surface





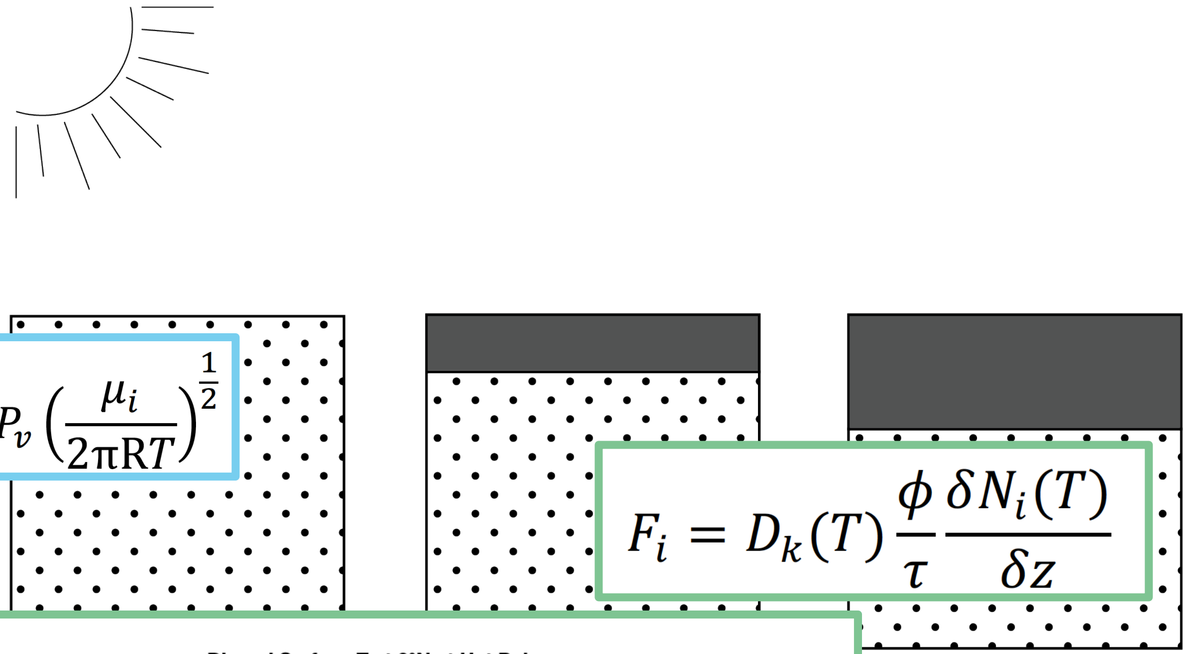
$$F_i = D_k(T) \frac{\phi}{\tau} \frac{\delta N_i(T)}{\delta z}$$

Fick 1855, gives you volatile diffusion through a porous medium.



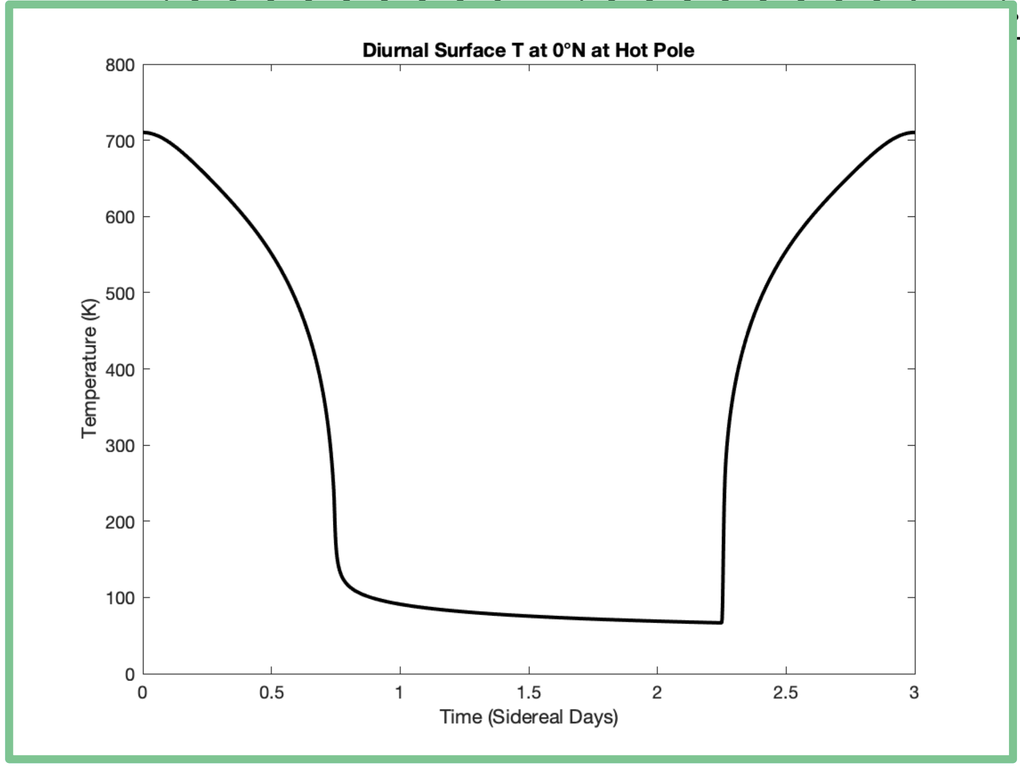
I calculated the sublimation rate of 57candidate hollow-forming volatile phases to narrow the list of plausible phases.

Two constraints for volatile phase: 1) must be volatile enough to sublimate at high latitudinal extent of hollow formation, 2) must be refractory enough to be sequestered under a lag deposit at the equator.



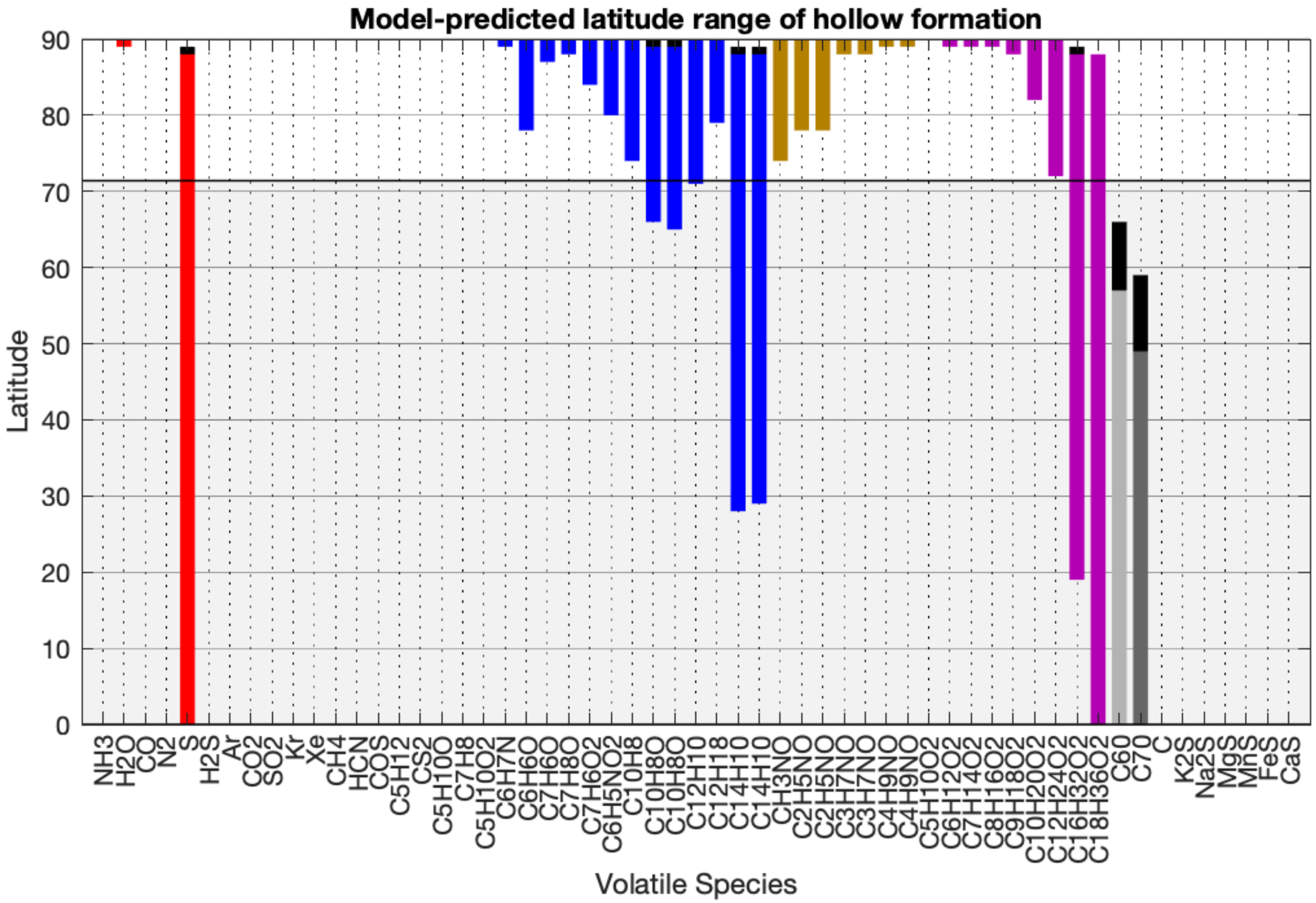
$$E_i = P_v \left(\frac{\mu_i}{2\pi RT}\right)^{\frac{1}{2}}$$

$$F_i = D_k(T)\,\frac{\phi}{\tau}\,\frac{\delta N_i(T)}{\delta z}$$

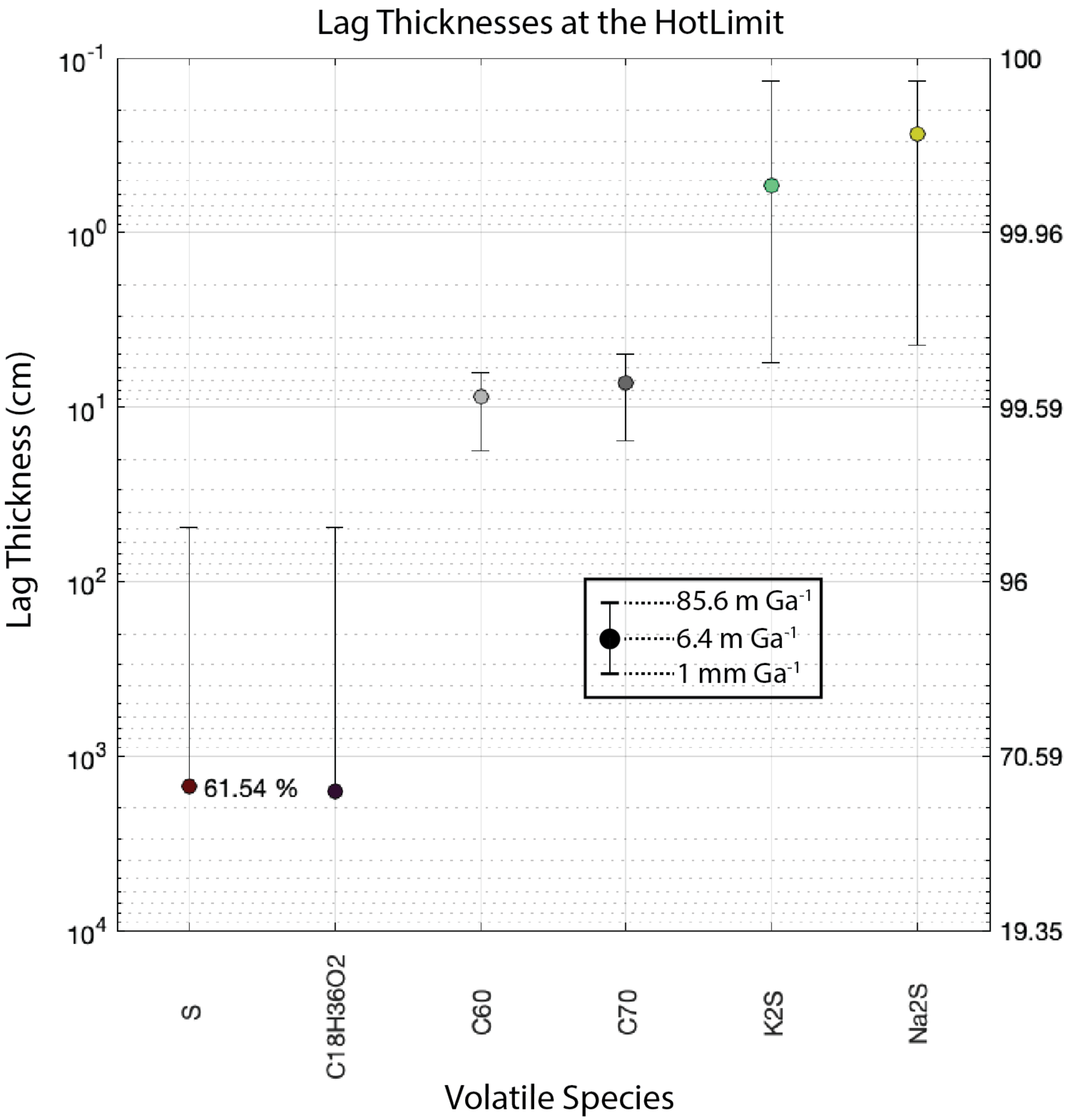


$$\rho c_p \frac{\partial T}{\partial t} = \frac{\partial}{\partial z} k \frac{\partial T}{\partial z}$$

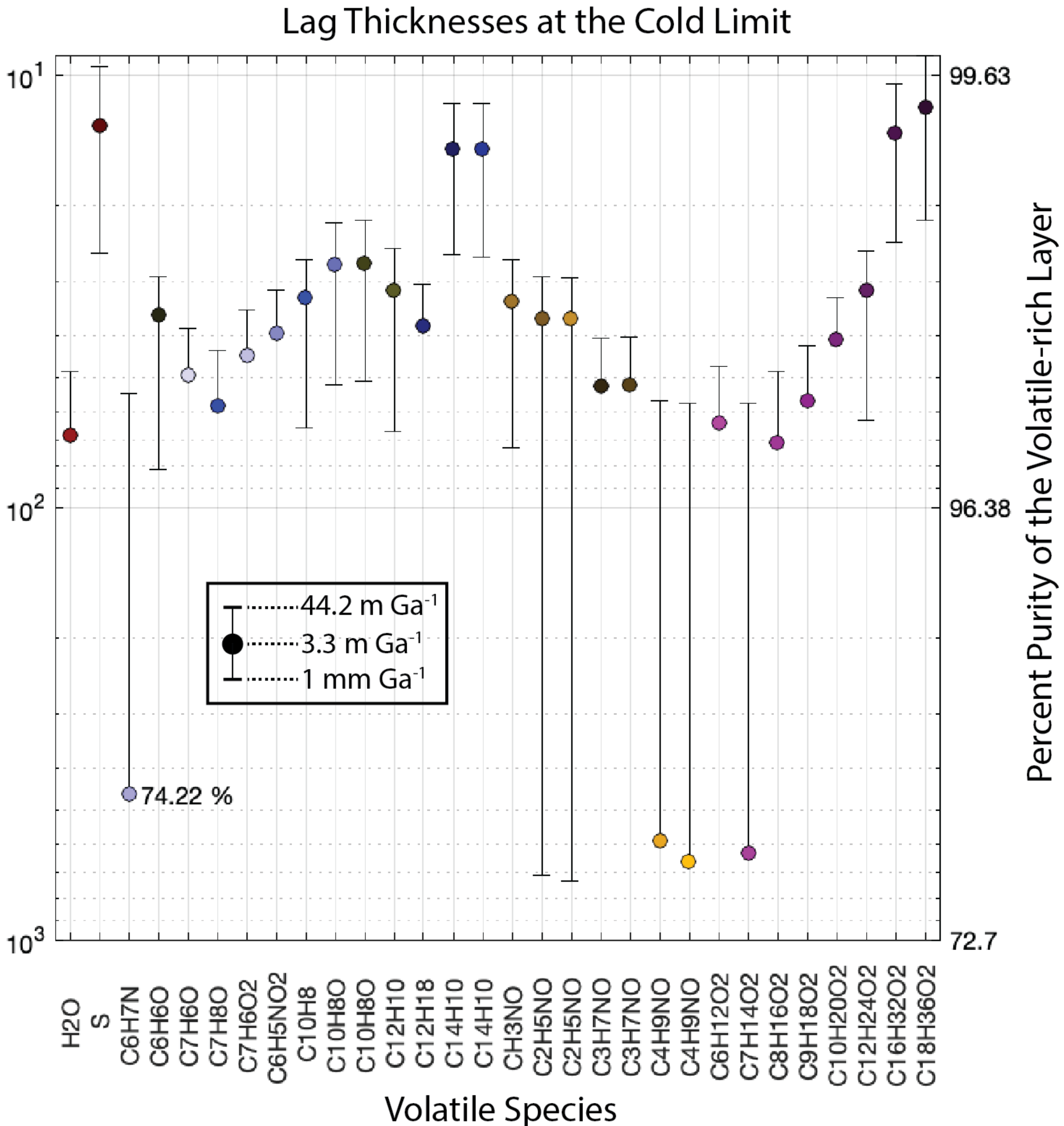
Only elemental sulfur, stearic acid, and ± fullerenes fit the bill.

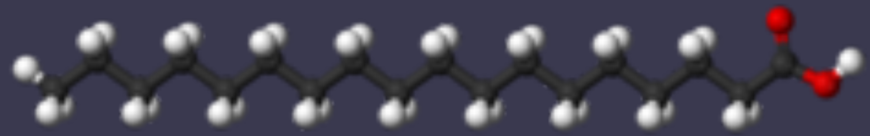


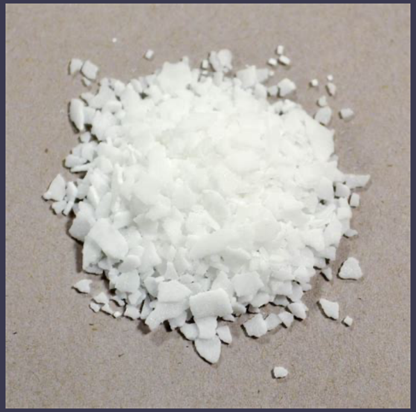
These volatiles would have to occur in relatively pure layers.



These volatiles would have to occur in relatively pure layers. Especially at high latitudes.







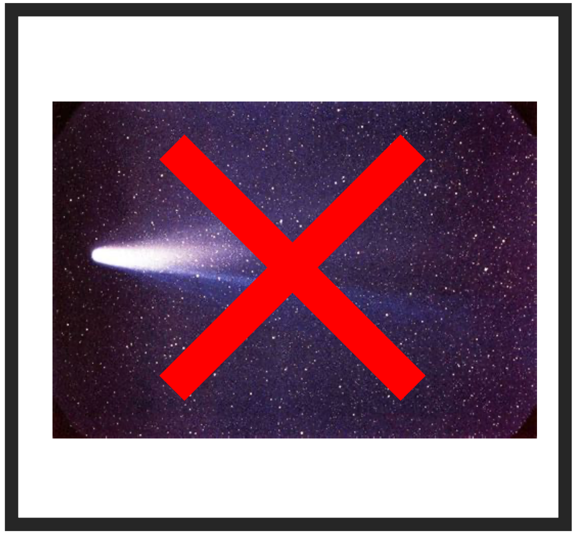
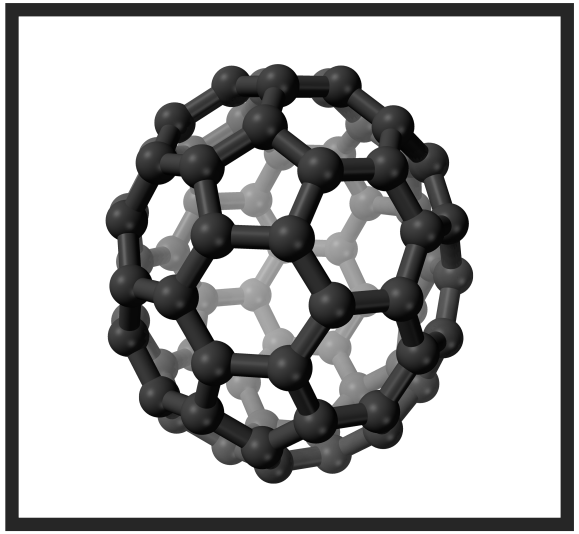
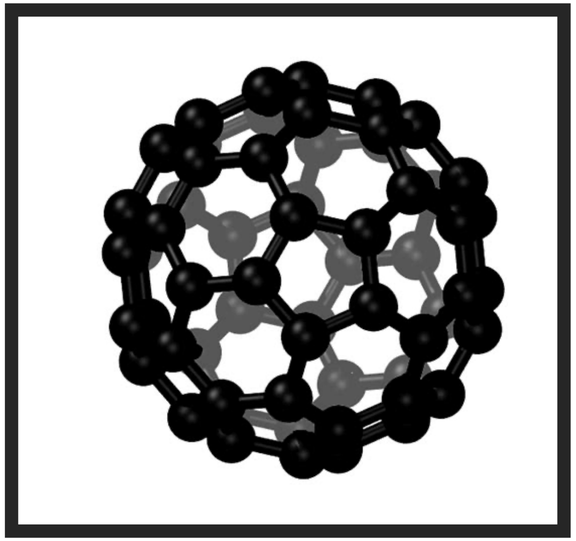
Could stearic acid exist on Mercury in enough volume to account for hollows?

No.

Could fullerenes exist in enough abundance to account for hollows?

Fullerene Facts:

1. Named after Buckminster Fuller, the creator of the geodesic dome.
2. Condense spontaneously from carbon vapors.
3. Are found in the interstellar medium, and in association with lightning strikes and impact craters on Earth.

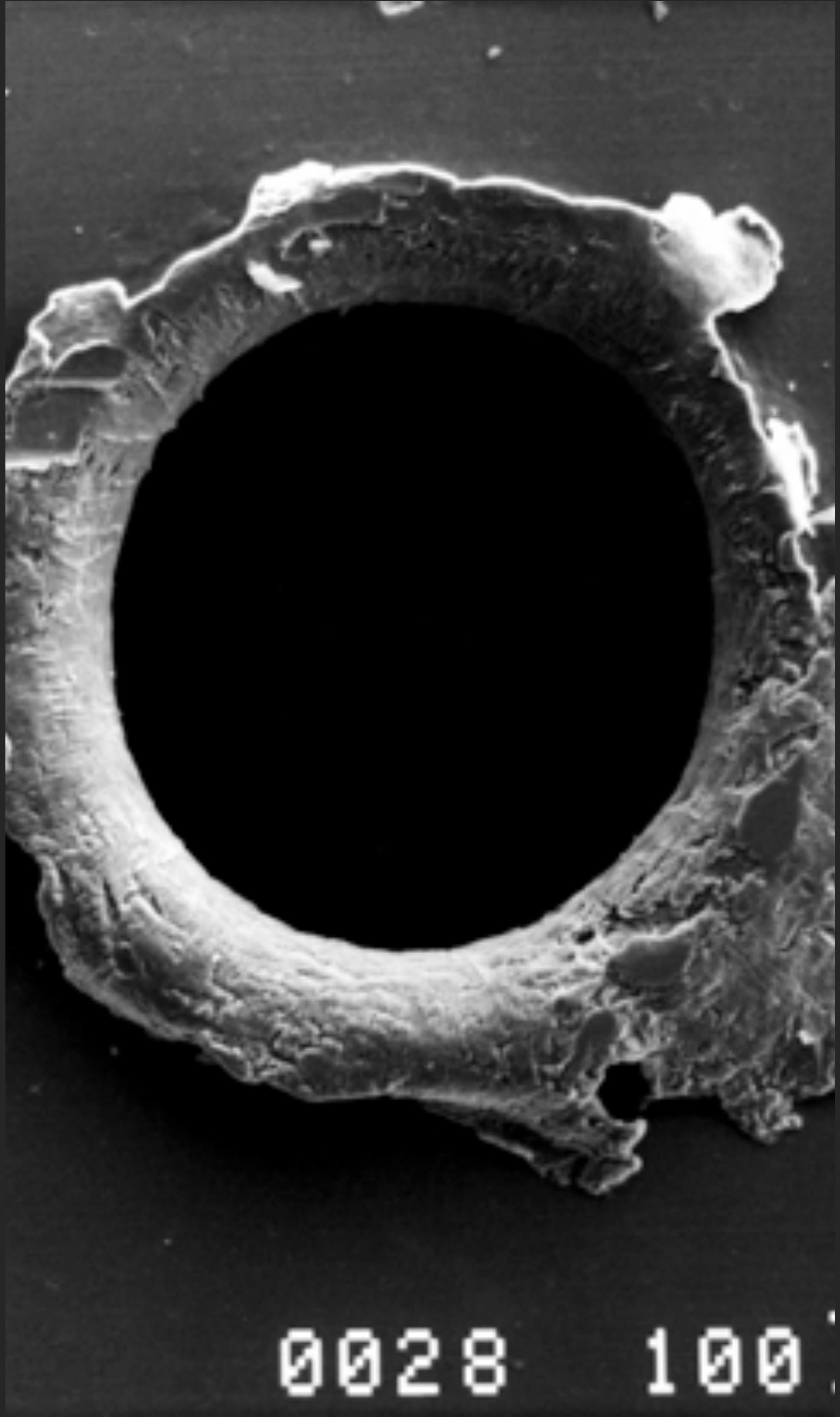

Could space weathering of Mercury's primary graphite crust have produced fullerenes?

Hollow volume expressed as a global layer:

- 1.87 to 3.61 cm-thick

Estimate for fullerene production on Mercury:

- 0.6 to 48 μm-thick.

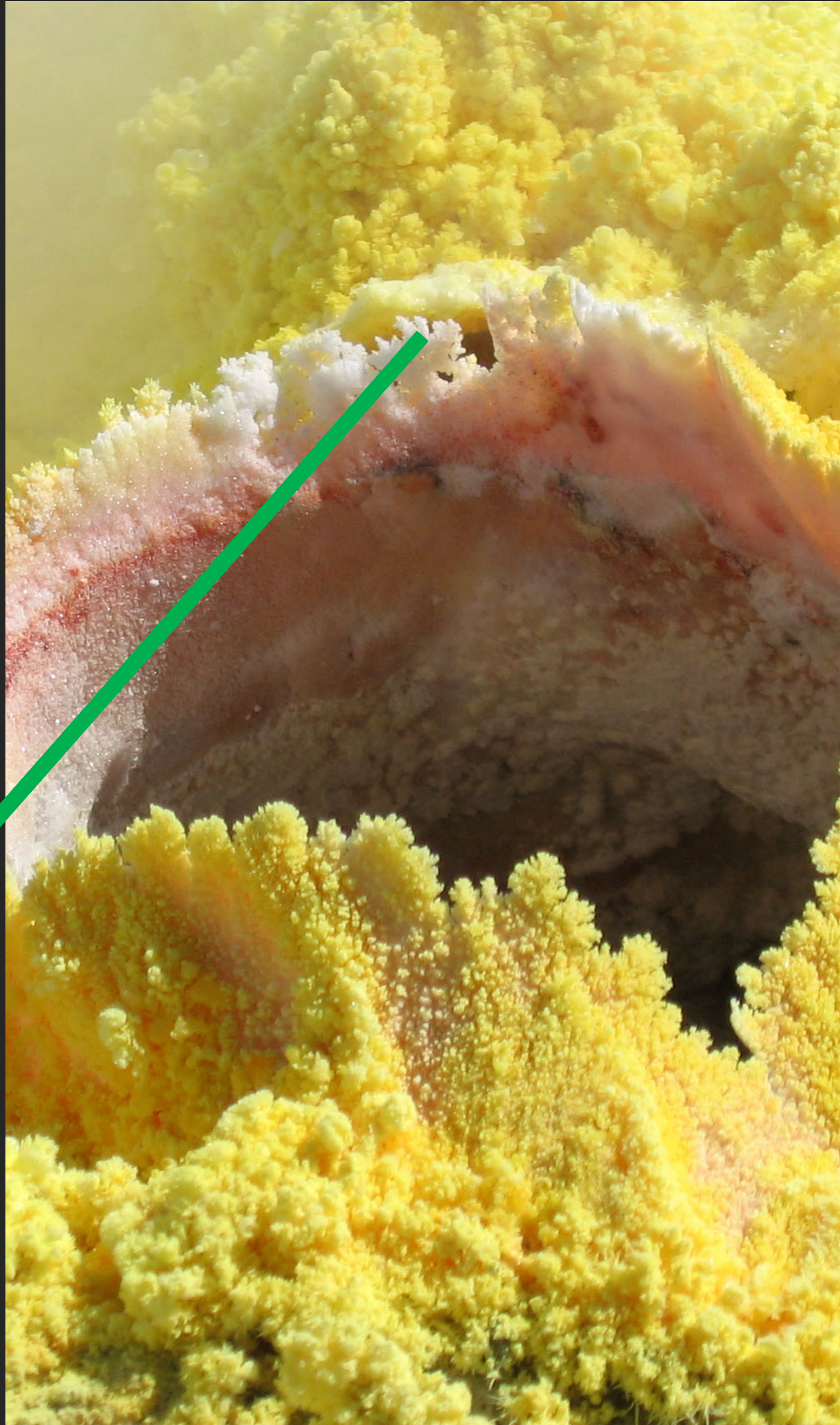


Could extensive volcanism on Mercury have produced enough Sulfur?

An estimate of sulfur produced during volcanism expressed as a global layer:

- 7.5 to 550 m-thick

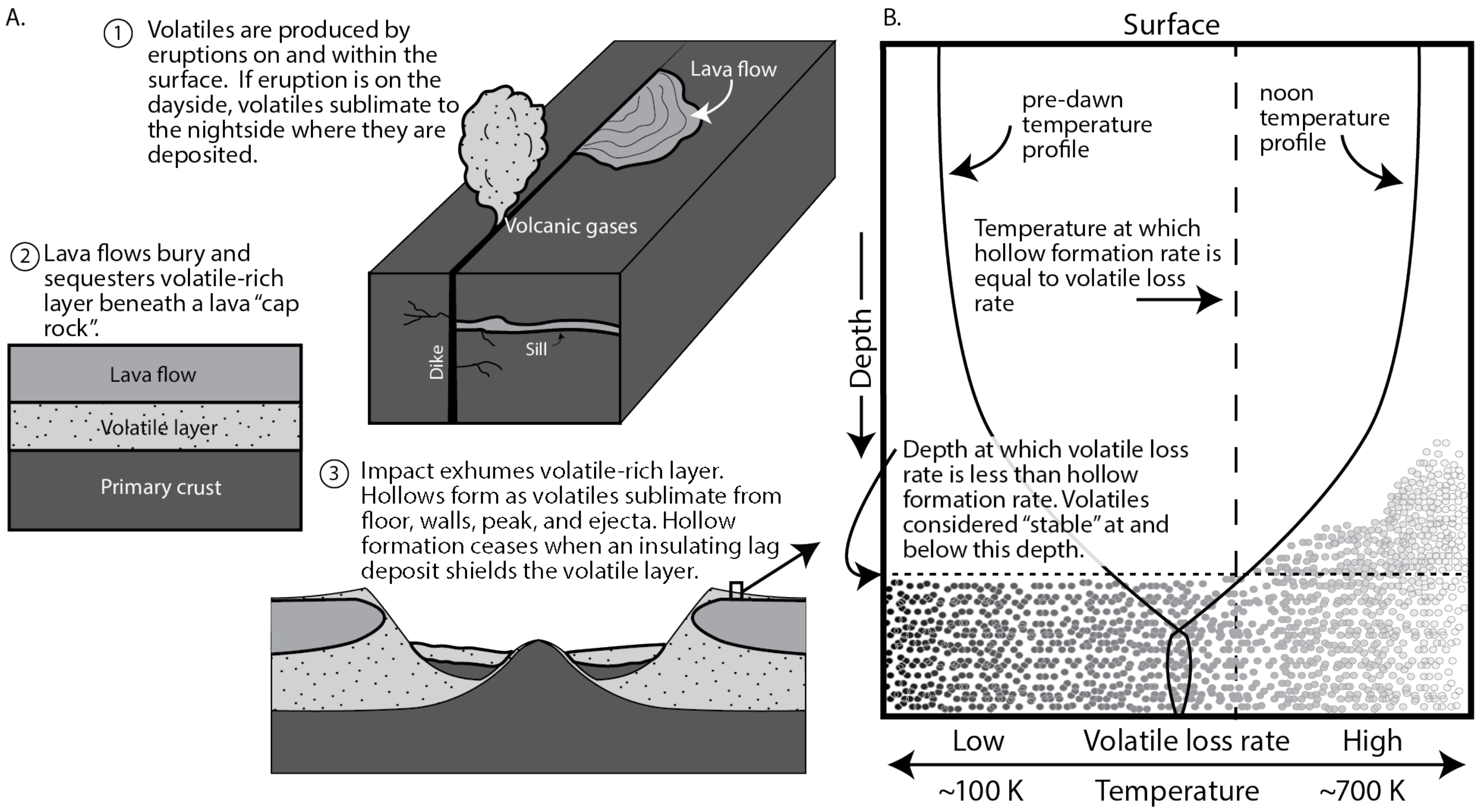
Even if <1% of this volcanic sulfur was elemental S, it would be sufficient to account for hollows.



Does the prevailing hollow formation model work with elemental S as the volatile?

Requirements:

- Concentration
- Burial/sequestration
- Exhumation by impacts



Concentration could occur through global volatile transport.

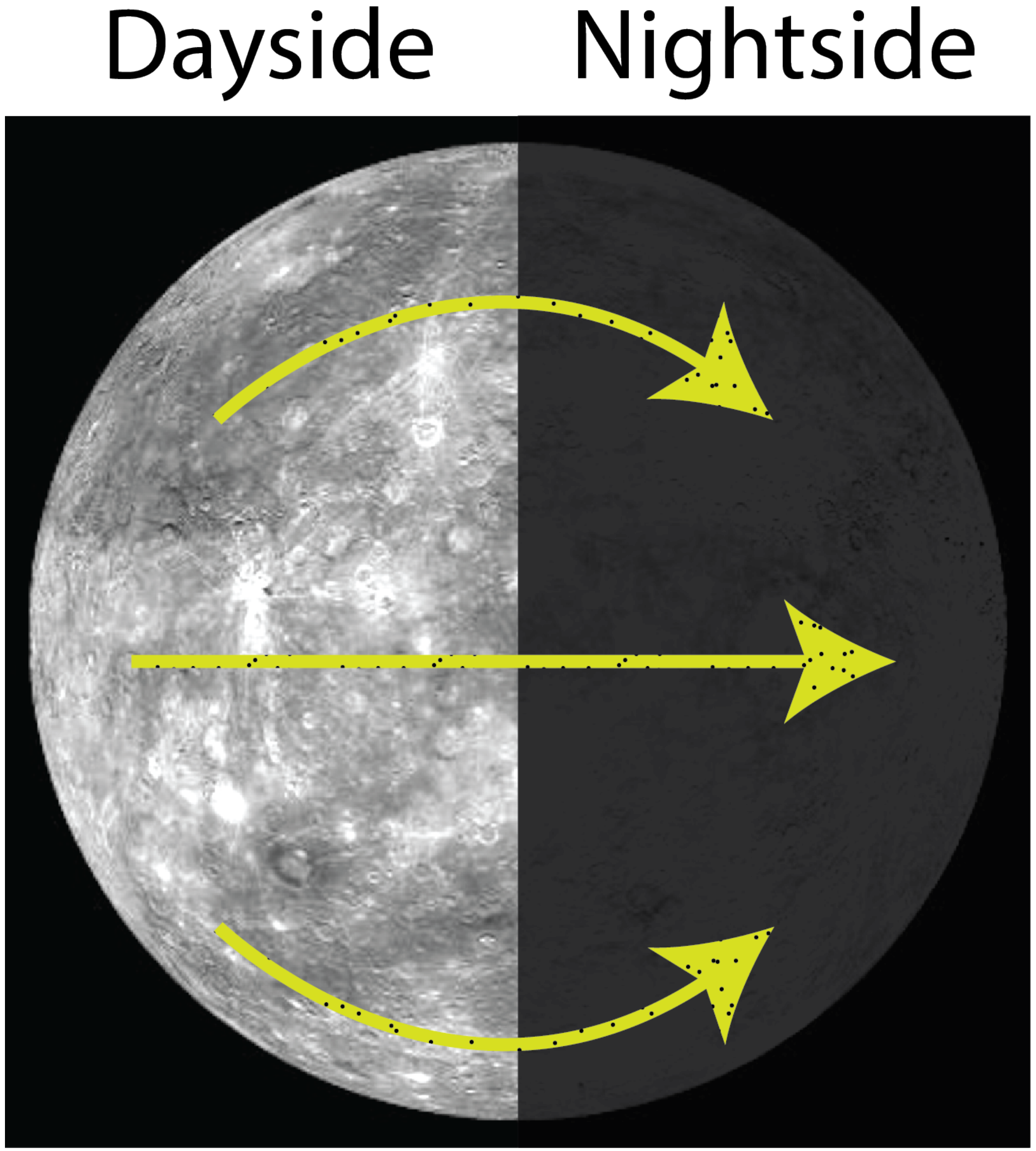
Especially if Mercury's ancestral orbital resonance was 2:1.

Sublimation rate on dayside:

- 4 m/yr to 120 m/yr

On nightside:

- Basically 0 m/yr

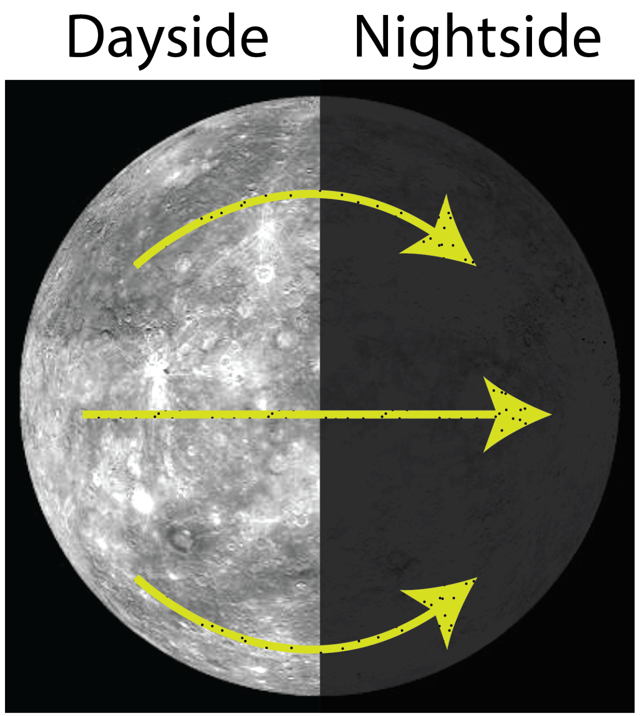


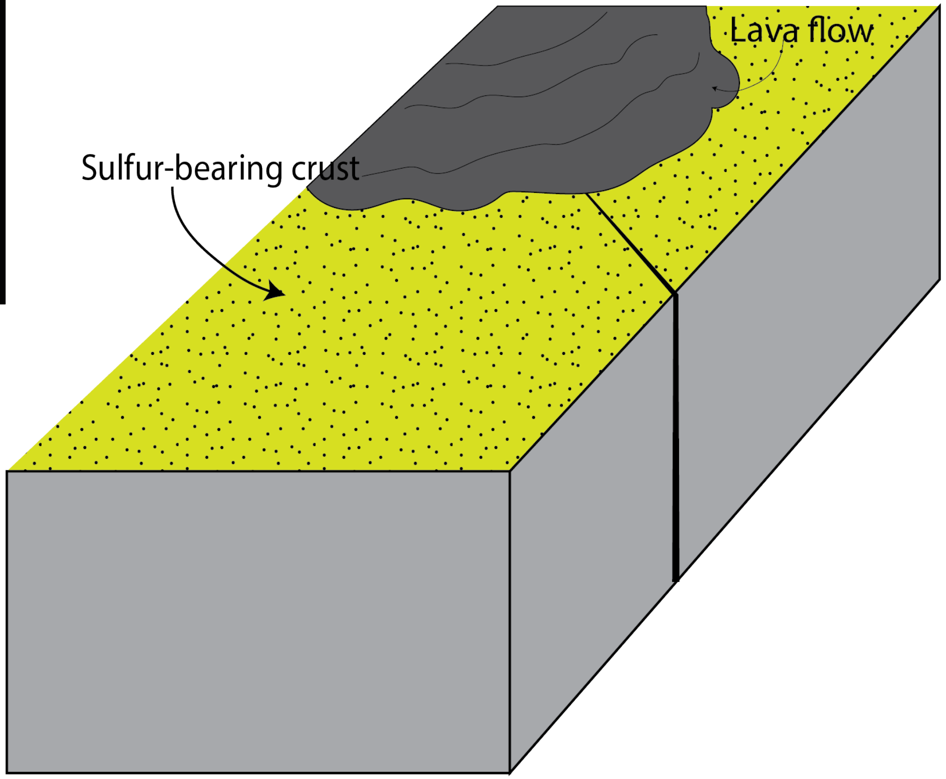
Burial could occur via volcanism.

Does the prevailing hollow formation model work with elemental S as the volatile?

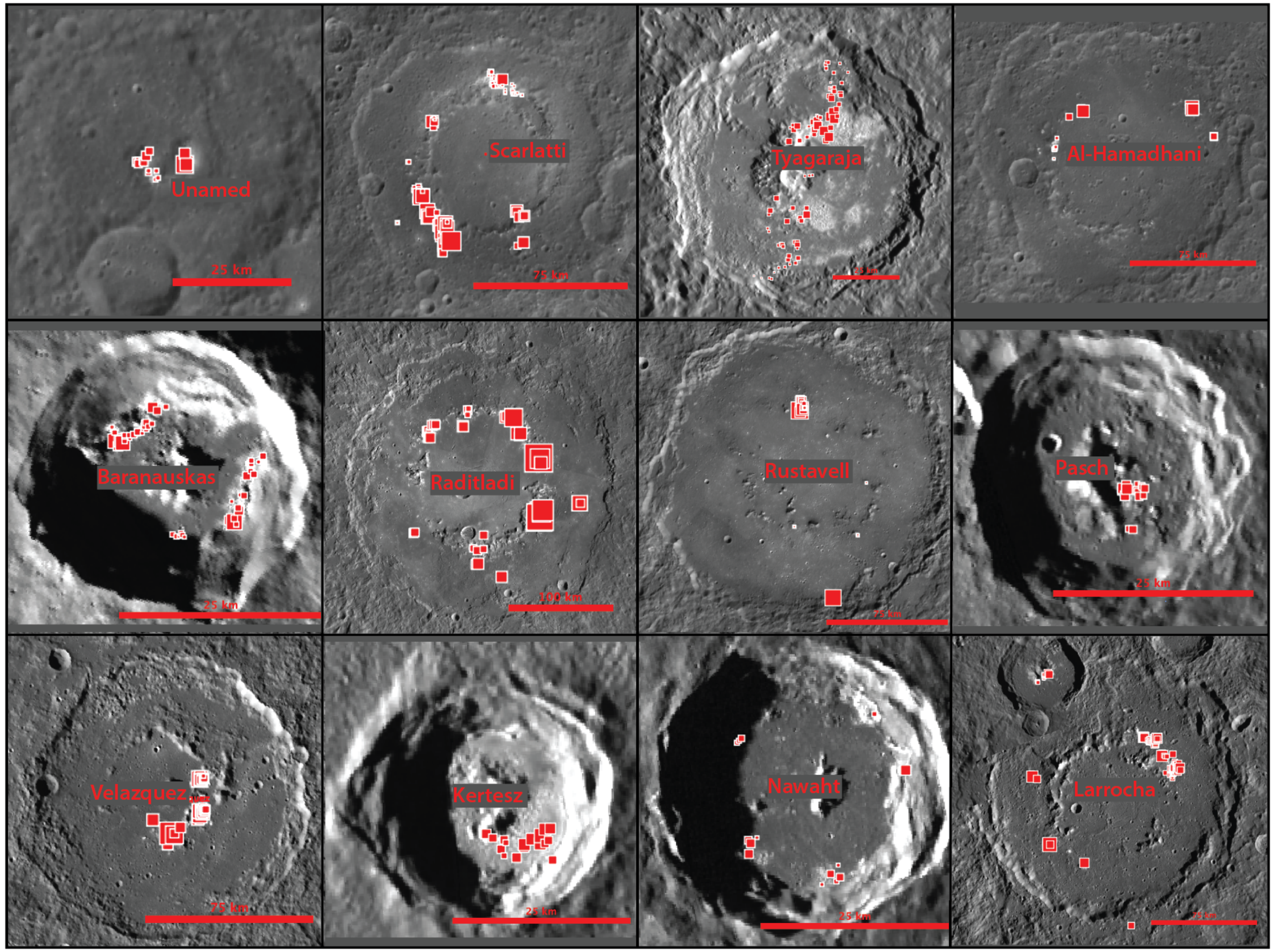
Requirements:

- Concentration
- Burial/sequestration

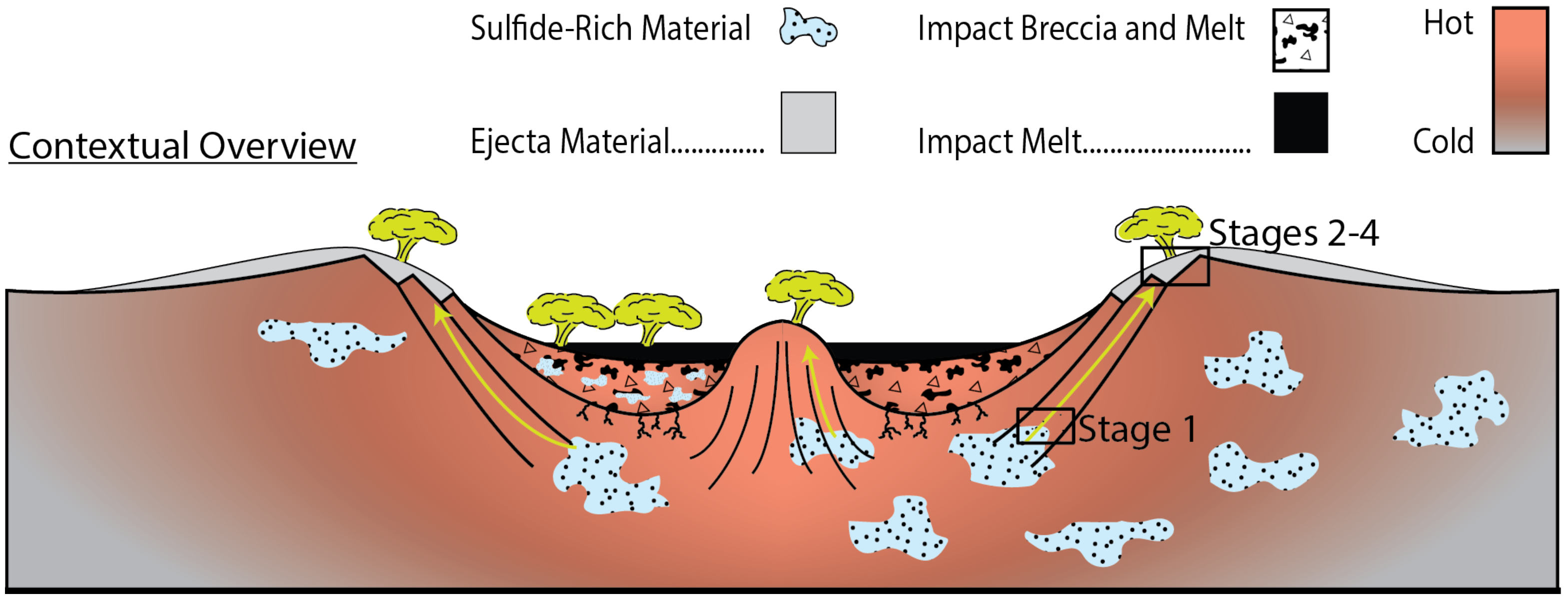




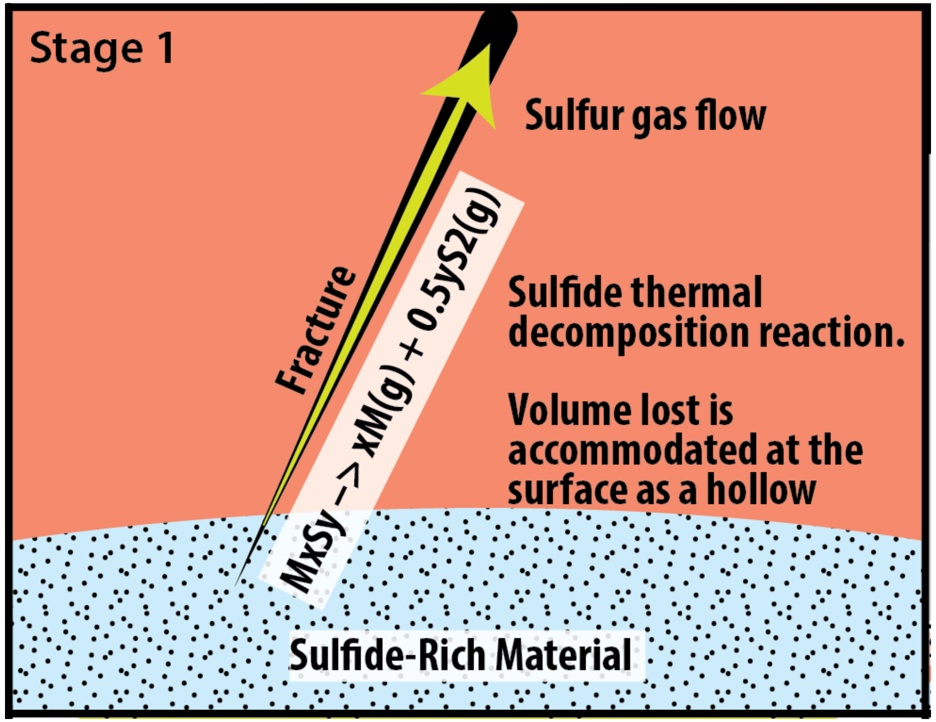
Could Sulfur survive the impact exhumation process? Do the distributions of hollows match what would be expected if impacts exhumed the material?

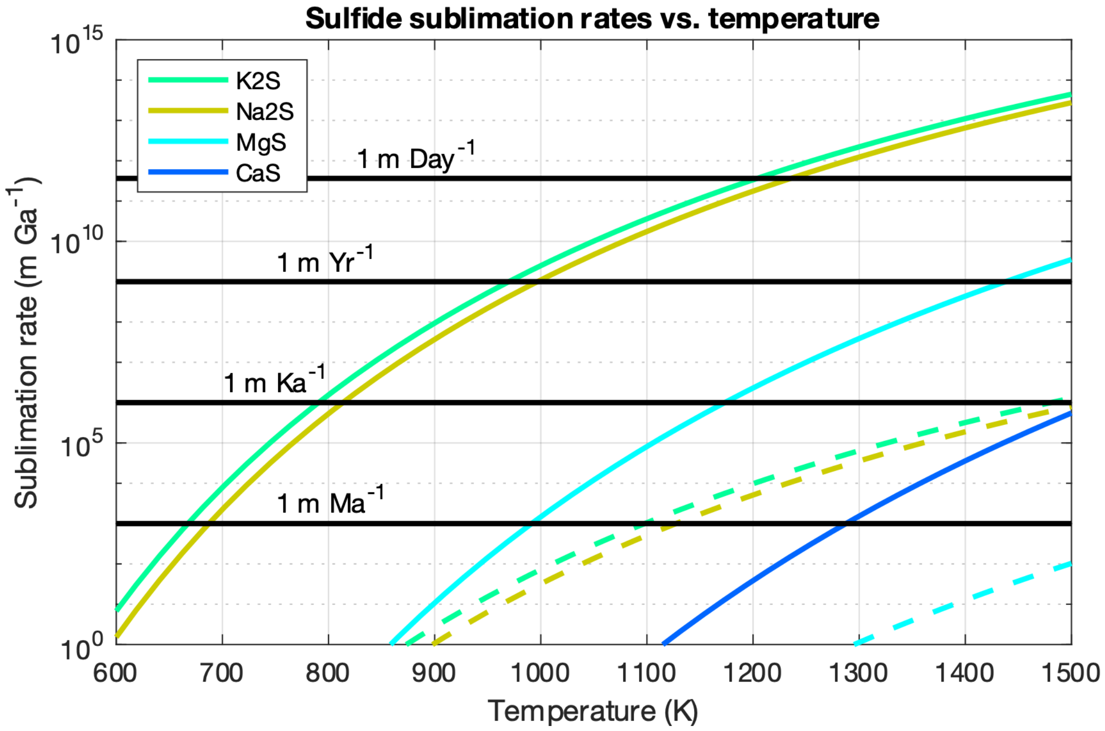


I propose a different model for hollow formation in impact-induced hermeothermal systems.

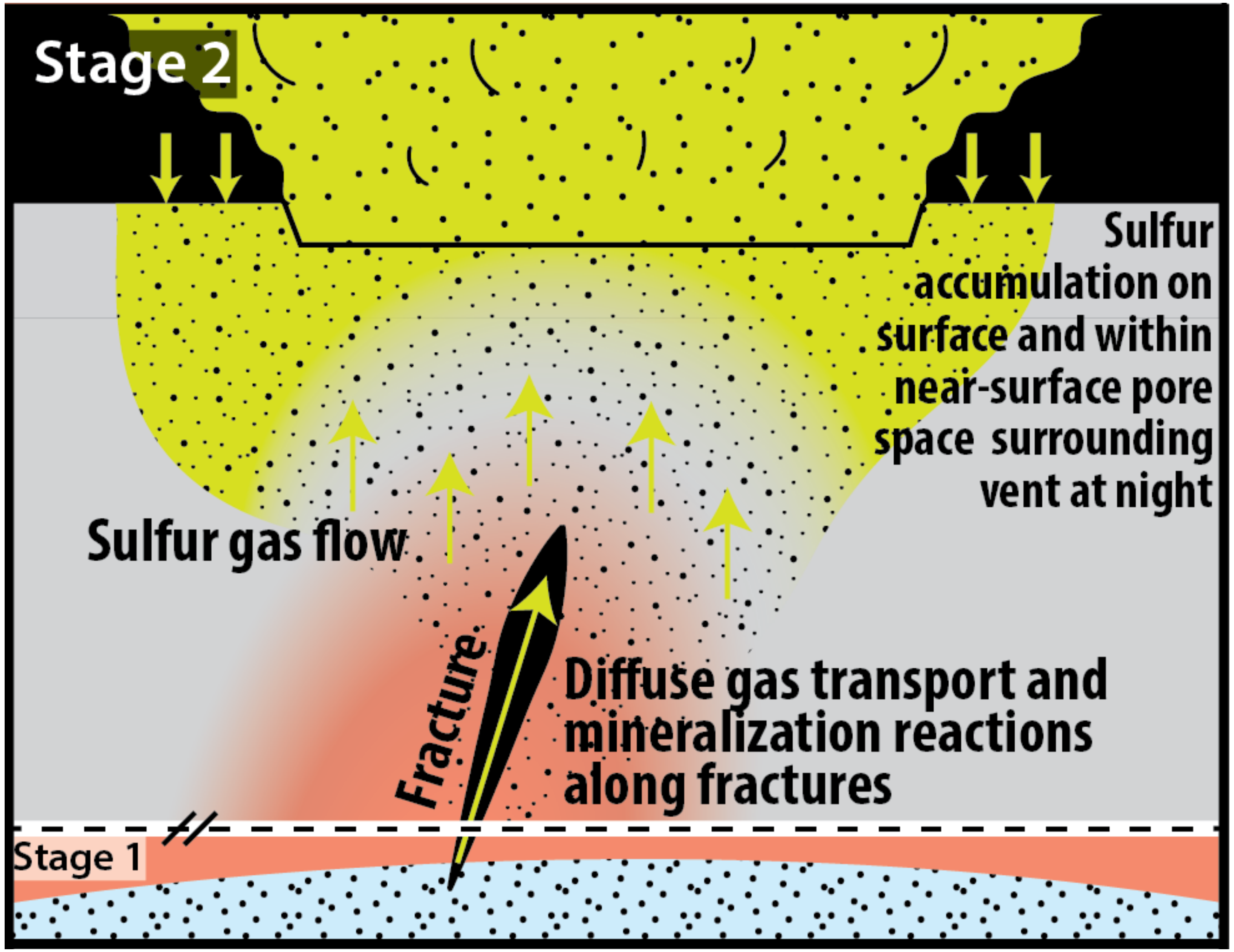


Sulfide decomposition at the temperatures achieved in the vicinity of an impact proceeds at a sufficient rate to generate hollows.

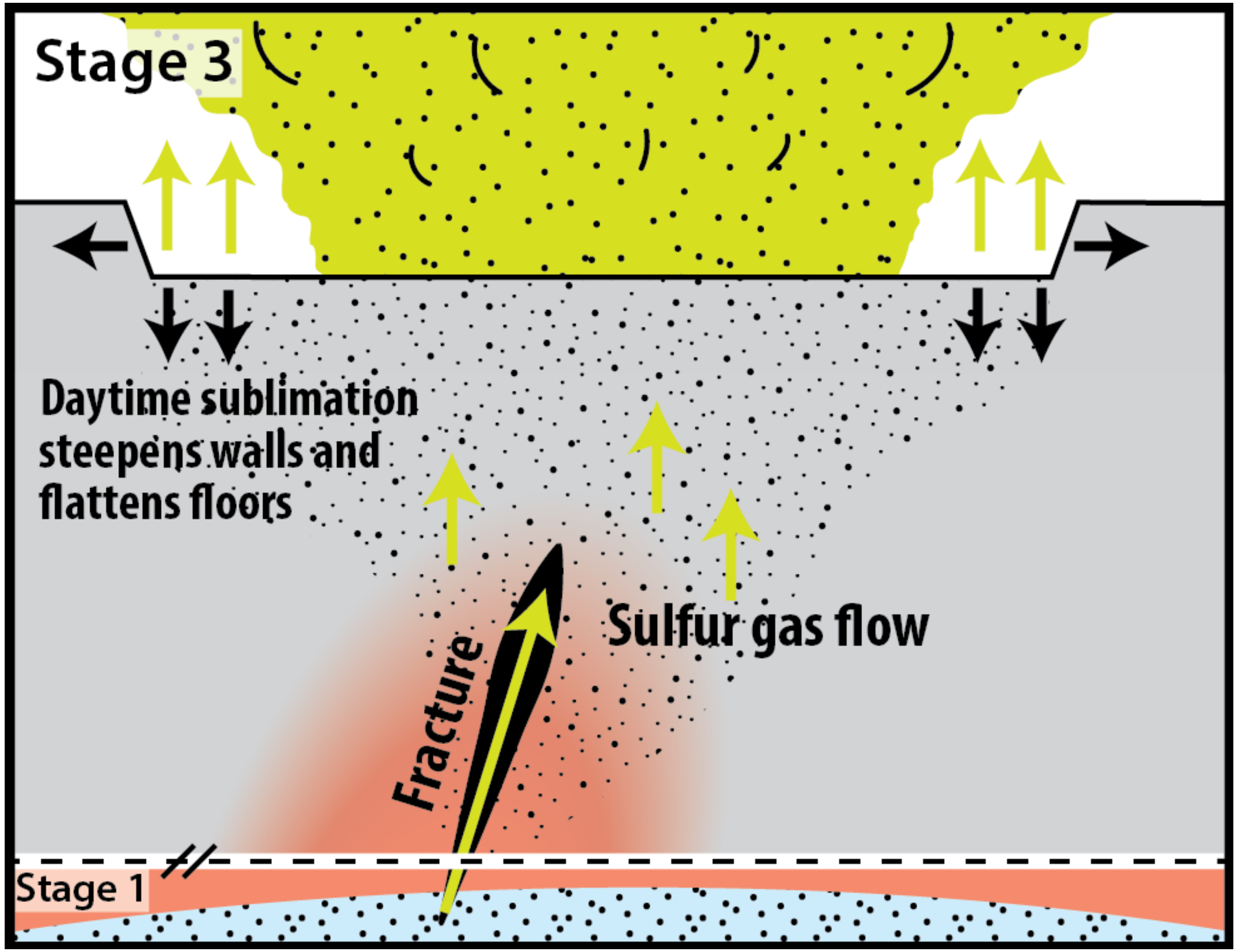




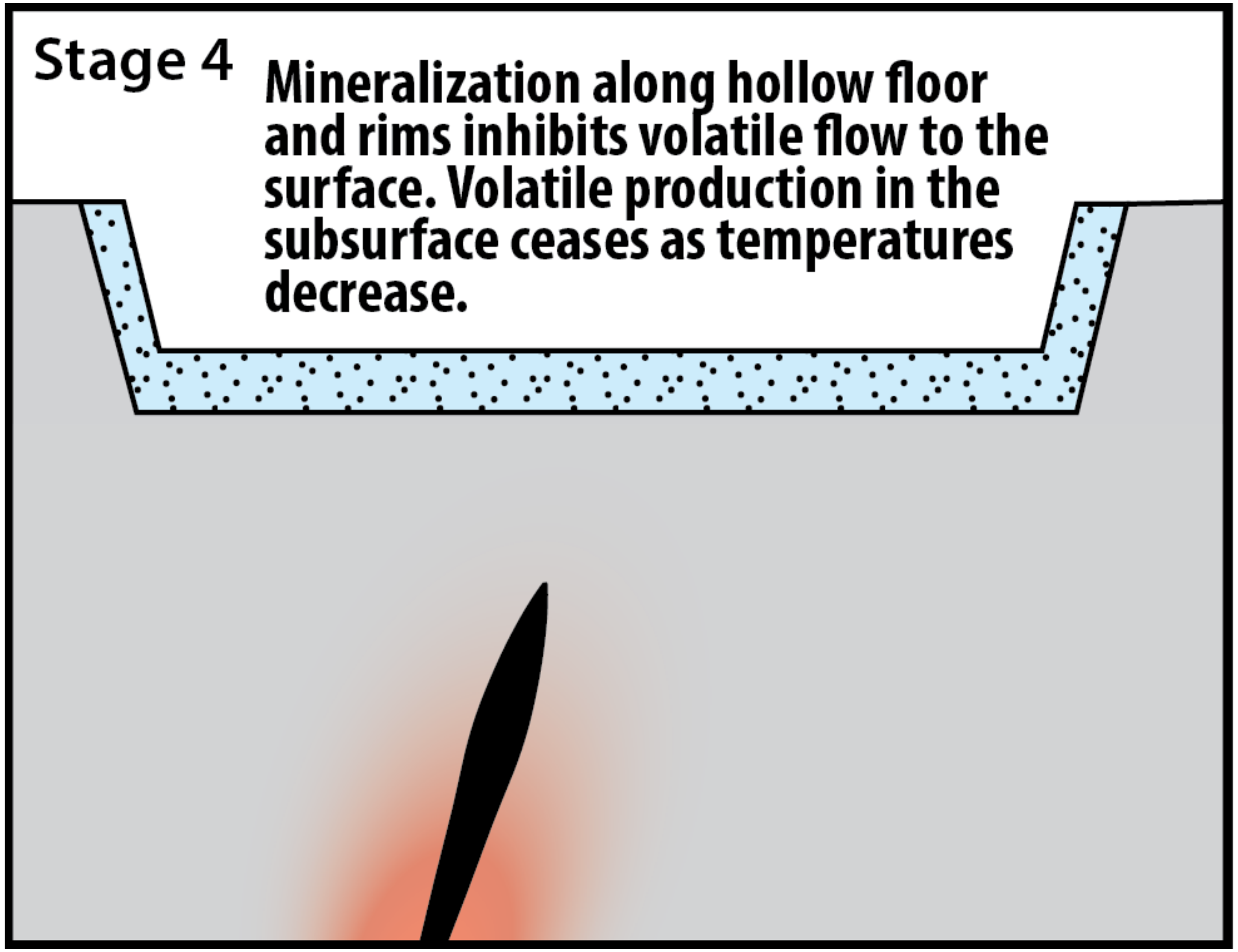
The surface of Mercury is very cold at night, allowing for deposition of sulfur and sulfur gases in the vicinity of fumarole vents at night.



During the day, the volatiles on the surface and in the near-surface surrounding vents would sublimate.



Reprecipitation of sulfides (and, likely, other minerals) and cooling of the impact site would preclude further transport of volatiles.



If hollows form in hermeothermal systems, perhaps studying them presents an opportunity for comparative planetology with Earth, Mars, and Ceres.