
europlanet 2024
Research Infrastructure

Geology & Planetary Mapping
Winter School
07-11 February 2022

MERCURY

Dr. Valentina Galluzzi

Co-teachers: Dr. Cristian Carli, Dr. Francesca Zambon

Istituto Nazionale di Astrofisica (INAF), Istituto di Astrofisica e Planetologia Spaziali (IAPS)

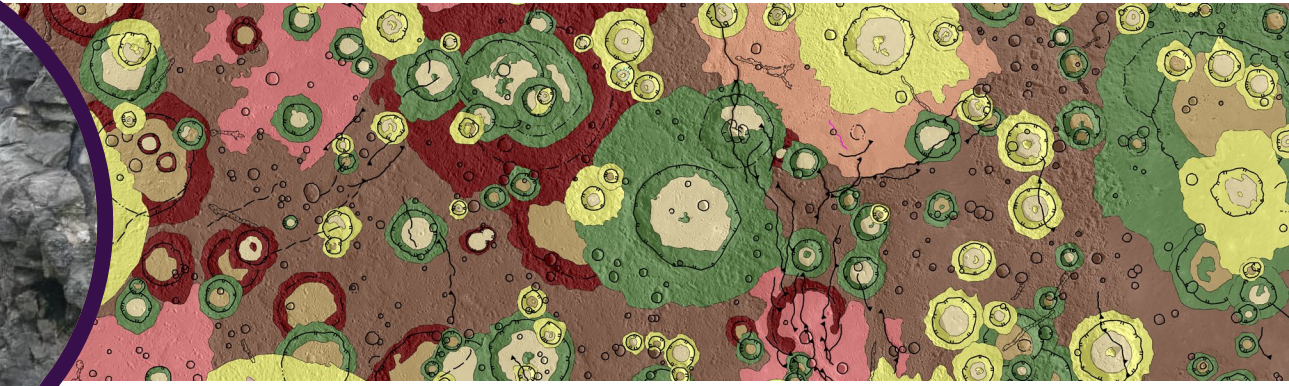
Geology & Planetary Mapping Winter School

EUROPLANET 2024 Research Infrastructure

European Union's Horizon 2020 - grant agreement No 871149.

GMAP
Geological Mapping

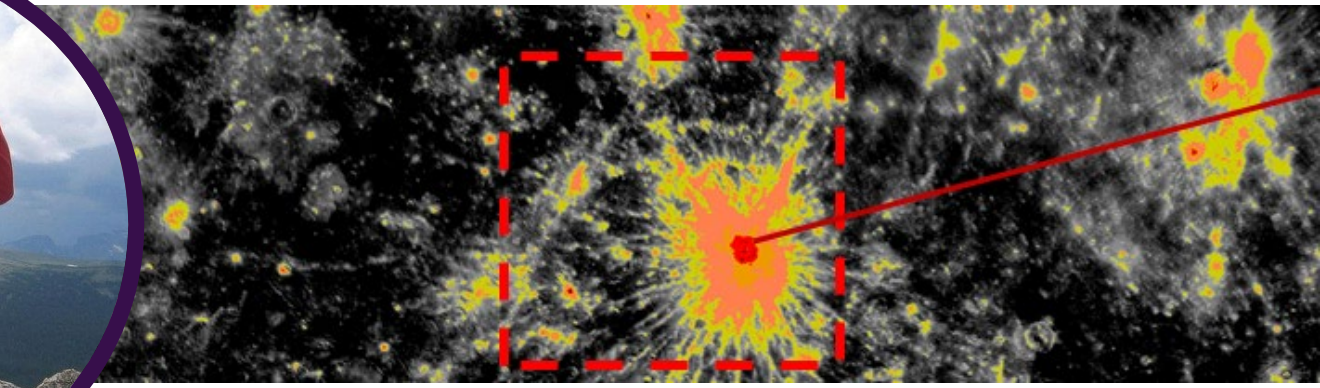
Mercury frontal lesson teachers:
Dr. Valentina Galluzzi



Valentina Galluzzi is a researcher at the National Institute of Astrophysics (INAF), Institute for Space Astrophysics and Planetology (IAPS) in Rome. She is a planetary geologist and works on Mercury geological maps and tectonics studying the datasets of past NASA missions. She works for the SIMBIO-SYS instrument onboard the ESA/JAXA BepiColombo mission that will picture Mercury once in orbit.

GMAP
Geological Mapping

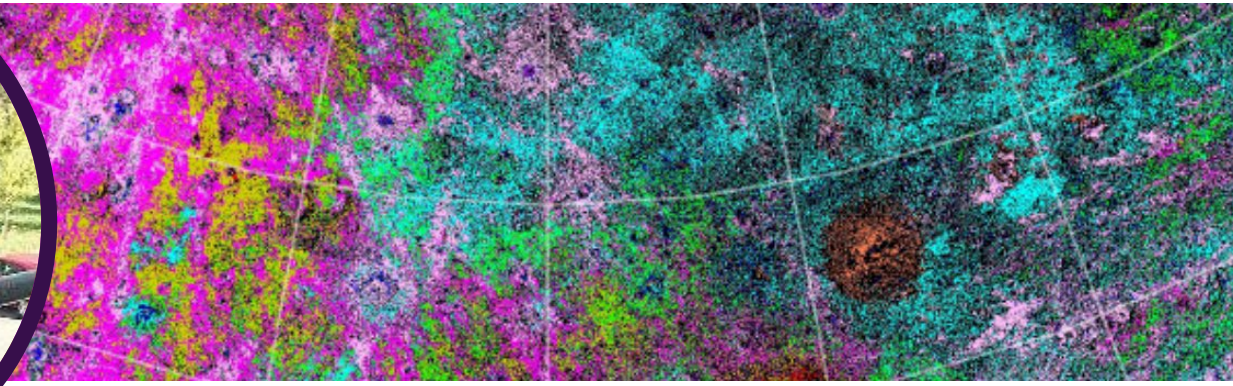
Mercury frontal lesson teachers:
Dr. Cristian Carli



Cristian Carli is a researcher at the National Institute of Astrophysics (INAF), Institute for Space Astrophysics and Planetology (IAPS) in Rome. He is involved in the ESA/JAXA BepiColombo mission to Mercury and works on spectral properties of potential Mercury's analogue surface material and on MESSENGER/MDIS multispectral analysis.

GMAP
Geological Mapping

Mercury frontal lesson teachers:
Dr. Francesca Zambon



Francesca Zambon is a researcher at the National Institute of Astrophysics (INAF), Institute of Space Astrophysics and Planetology (IAPS) in Rome.

She studies the mineralogy and surface composition of planetary airless bodies. For Mercury, she is involved in the ESA/JAXA BepiColombo mission and worked on the hyperspectral and multi-spectral data of the MESSERGER mission using spectral parameters and classification methods.

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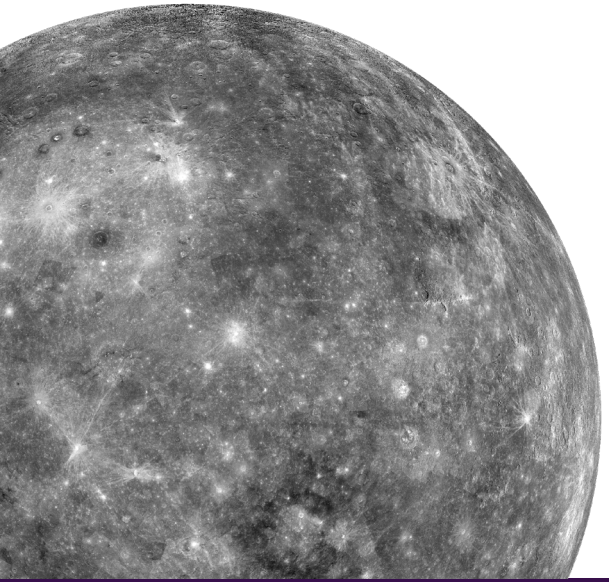
Mercury Day Schedule



09:00-10:00	**Mercury surface morphology**	V. Galluzzi
10:00-10:30	**Mercury surface composition**	C. Carli
10:30-10:40	Coffee Break	
10:40-11:10	**Mercury spectral analysis**	F. Zambon
11:10-11:50	**Mercury base data & mapping**	V. Galluzzi
11:50-12:00	Zoom link change for Mercury practical	
12:00-12:30	**Mercury practical introduction**	V. Galluzzi
12:30-14:00	Lunch	
14:00-17:50	**Mercury practical**	V. Galluzzi et al.
17:50-18:00	Reconveen to plenary room	
18:00-19:00	**Invited Talk: Mercury's Tectonics**	Prof. K. Crane

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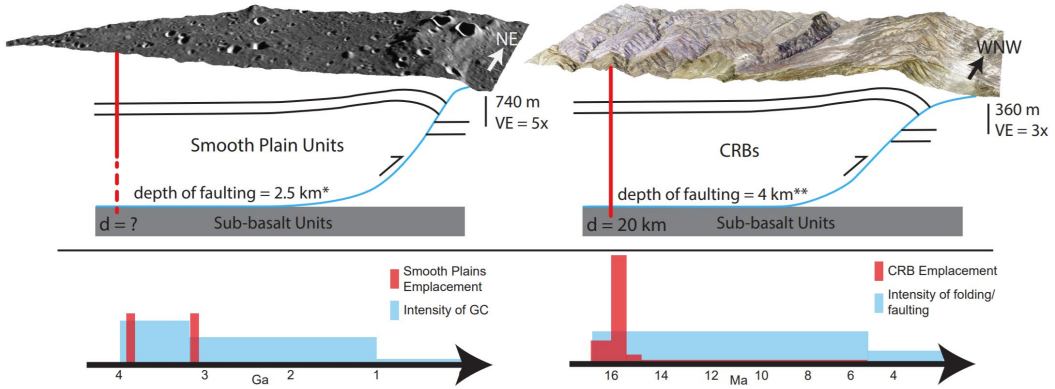
Invited Talk:
Prof. Kelsey Crane

Mississippi State University



I am an Earth analogue structural geologist, who loves blending statistics, tectonics, fieldwork, and geomechanics to address questions in planetary geology. I built my skillsets in field geology and mathematics with a BS in both subjects at the University of Tennessee in Knoxville. I continued to an MS in Geology and Geoscience Education at Purdue University where I learned that I also had a passion for teaching and sharing earth sciences. After a brief period of teaching high school, I pursued a PhD in geology at the University of Georgia where I began studying Mercury, especially through mapping and Earth analogue analysis.

I am now an assistant professor and mom at Mississippi State University where I strive for an inclusive and supportive lab and where my group and I continue to work together to study planetary tectonics using analogues.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 871149.

Mercury Surface Morphology

Dr. Valentina Galluzzi

Istituto Nazionale di Astrofisica (INAF), Istituto di Astrofisica e Planetologia Spaziali (IAPS)

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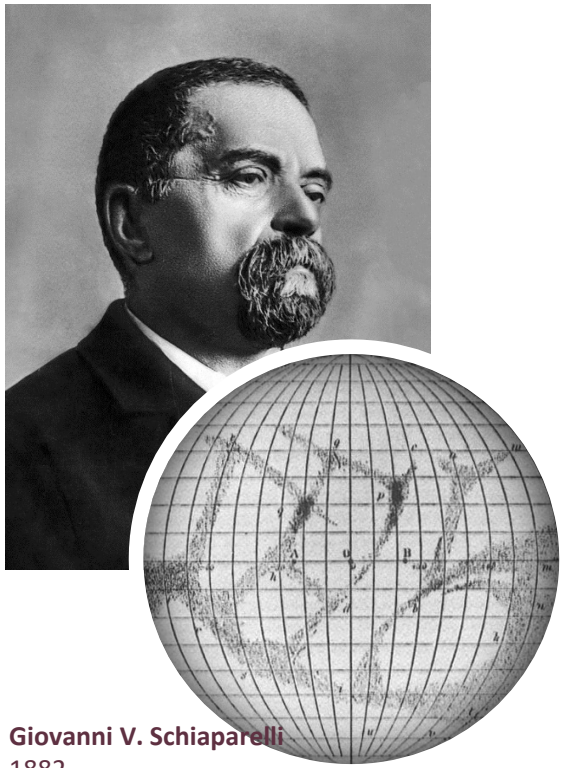
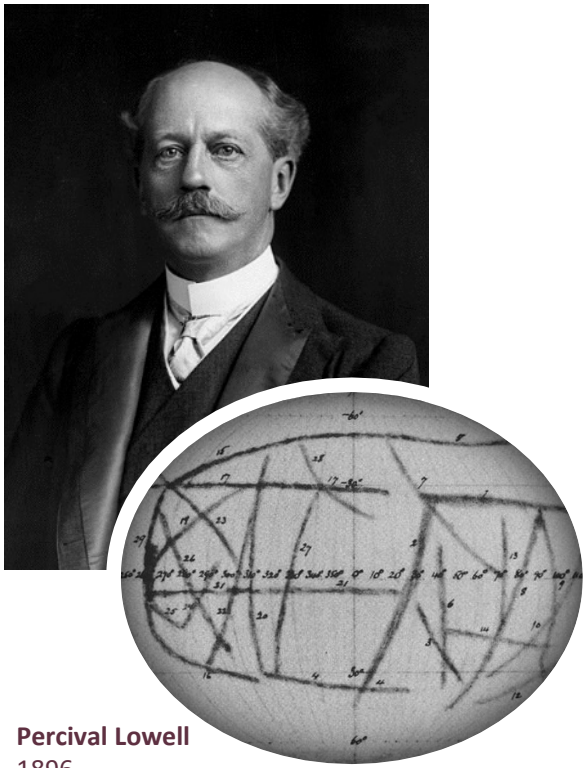
Observation of Mercury



Giovanni V. Schiaparelli
1882



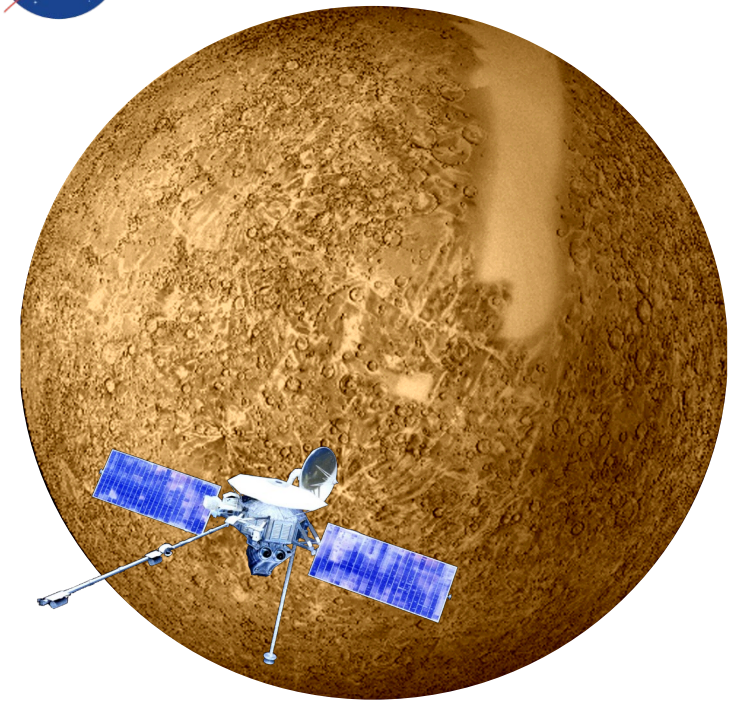
Percival Lowell
1896

Eugene M. Antoniadi
1934

Exploration of Mercury

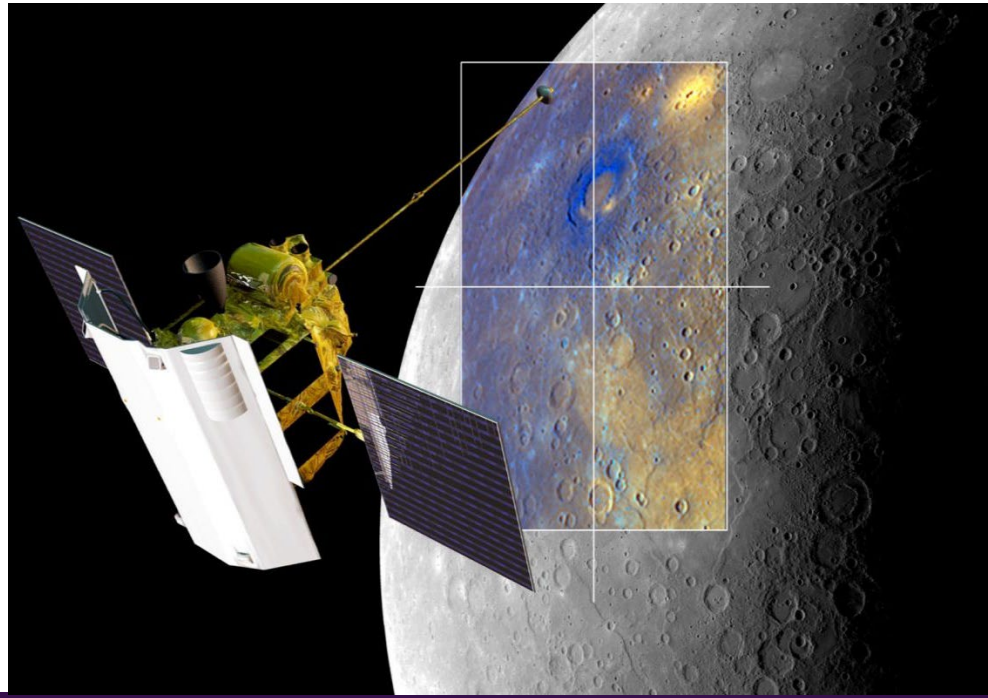
1973 – 1975 – Mariner 10

(Mariner Venus/Mercury 73 – Mariner-J)

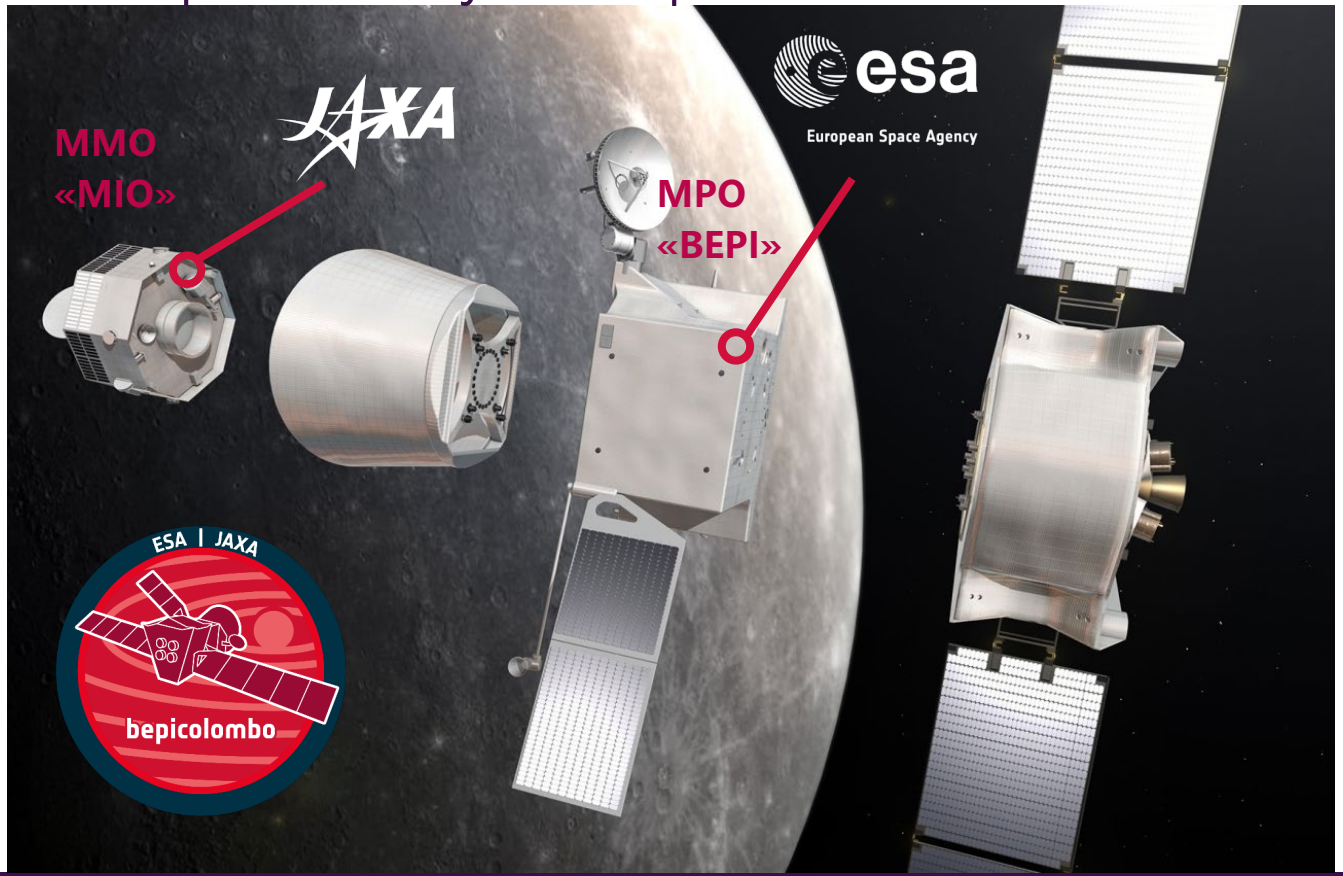


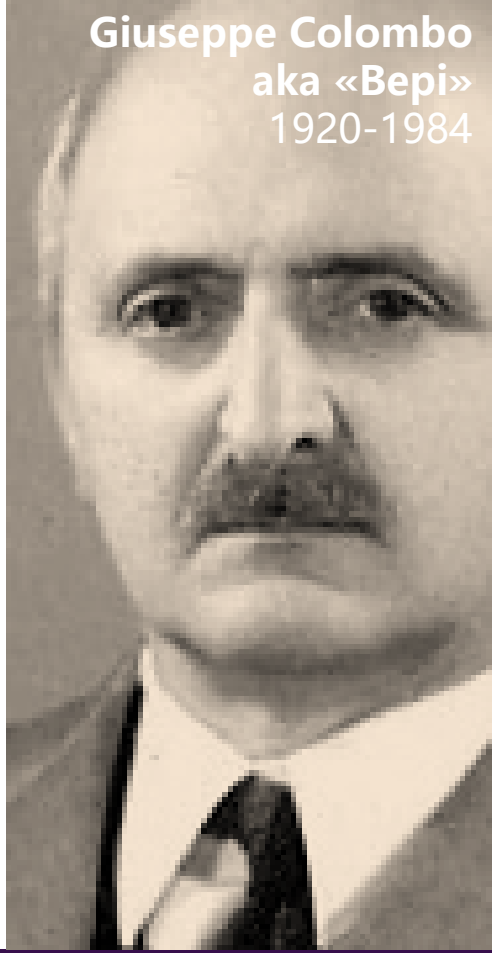
2004 – 2015 – MESSENGER

(MErcury Surface ENvironment, GEochemistry and Ranging)



Next Step to Mercury: the BepiColombo Mission

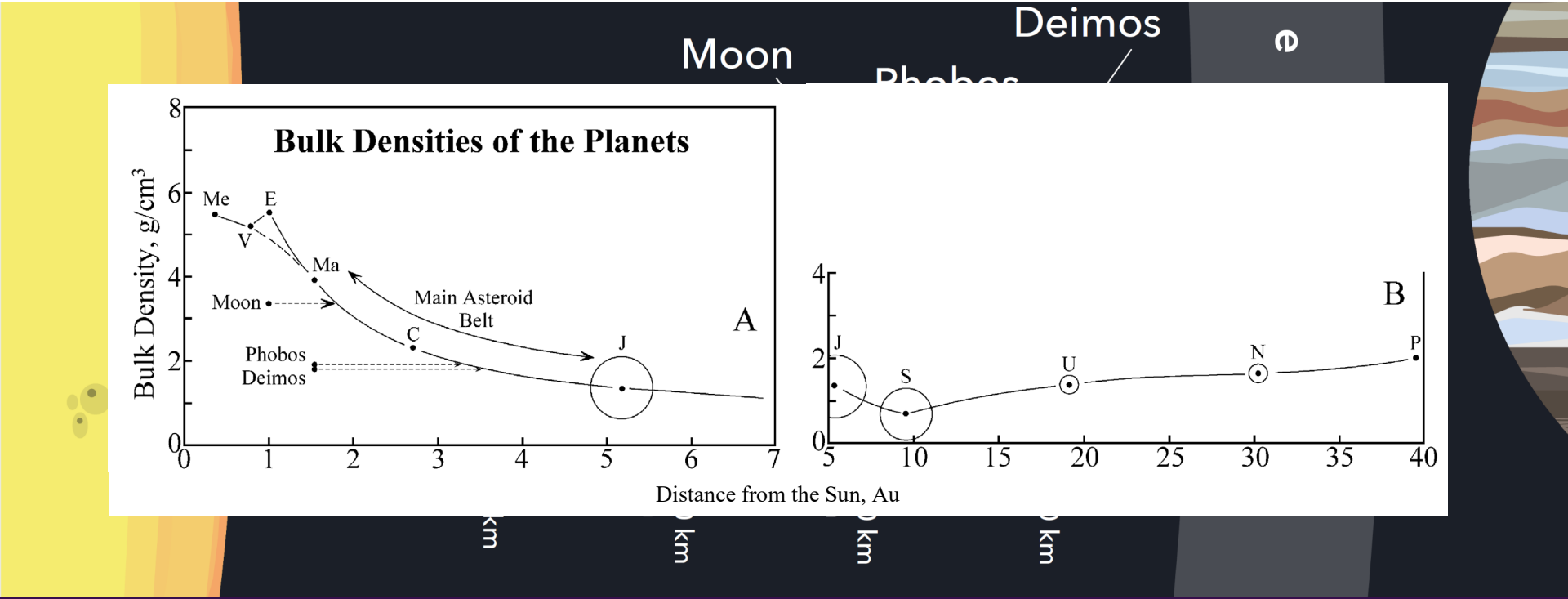




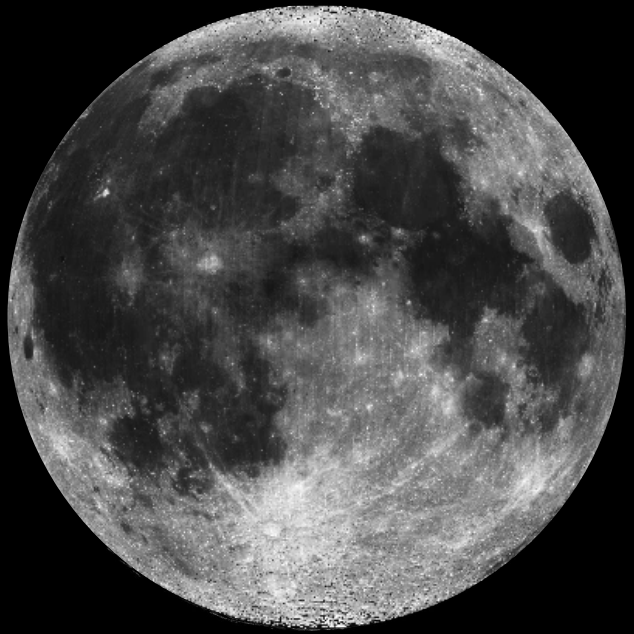
Giuseppe Colombo
aka «Bepi»
1920-1984

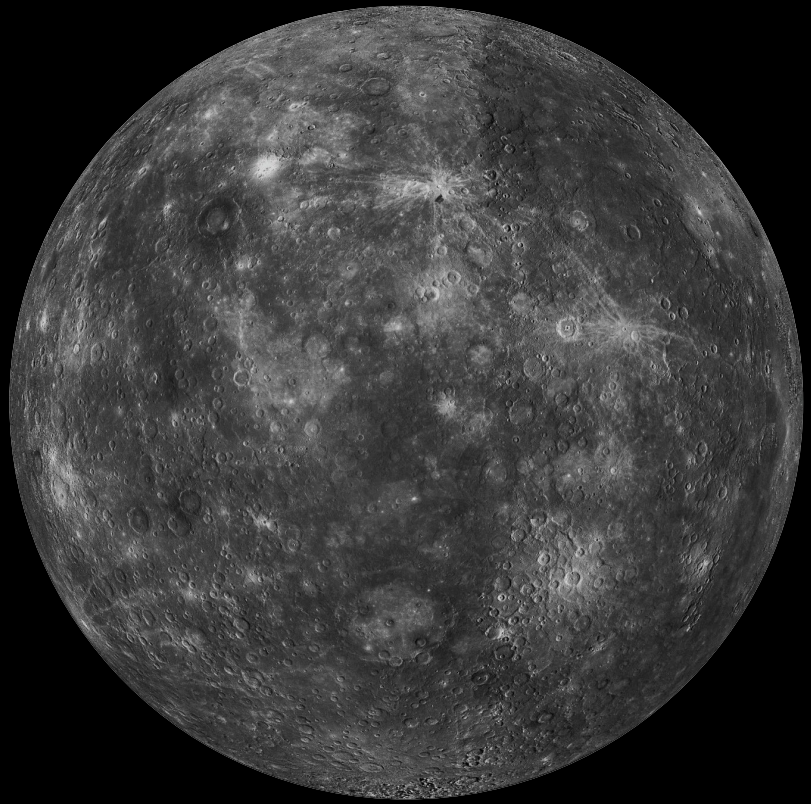
An Extreme Planet

- Mercury is the first planet of our Solar System and is part of the inner planets, which are rich in refractory silicates and metals that crystallized at high temperatures. → terrestrial/rocky planets

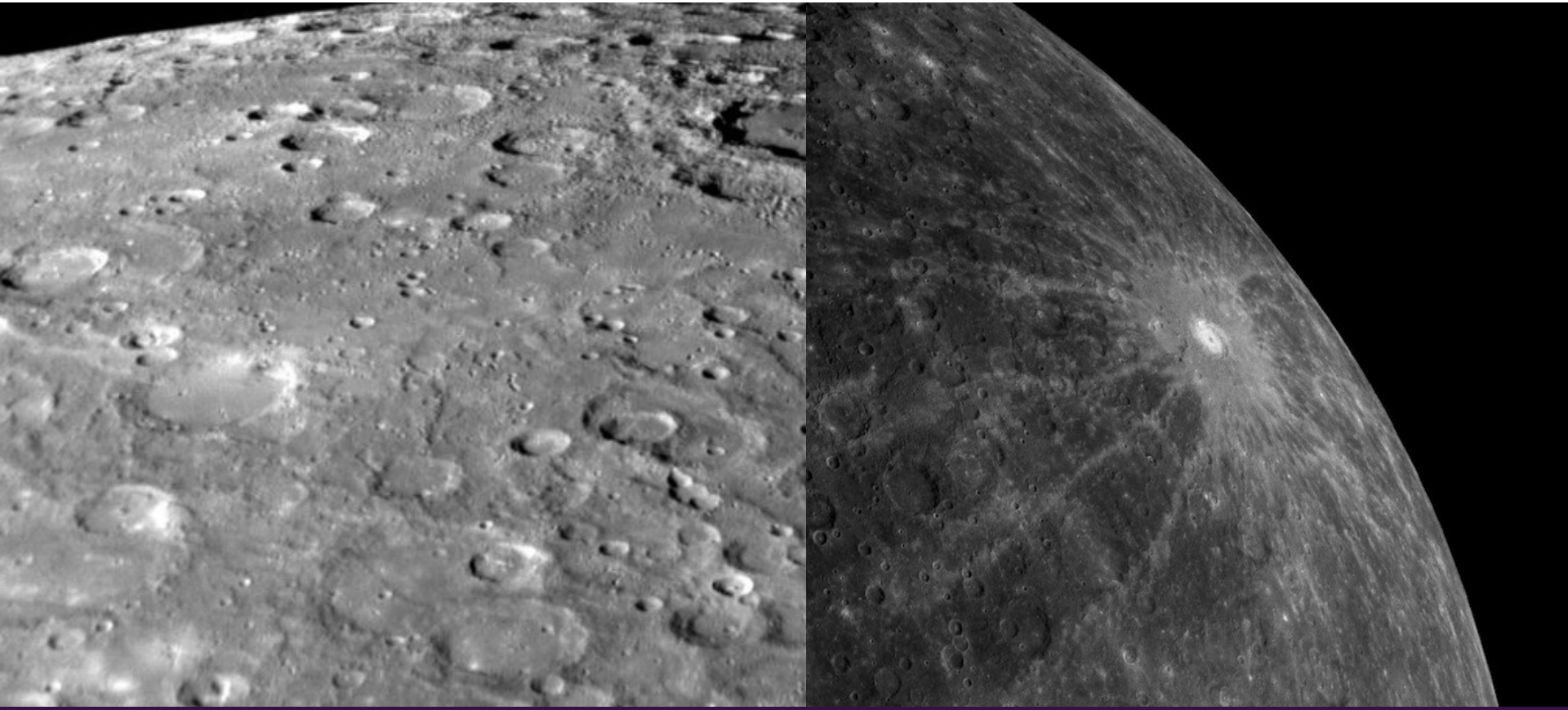


Merucy: an Extreme Planet

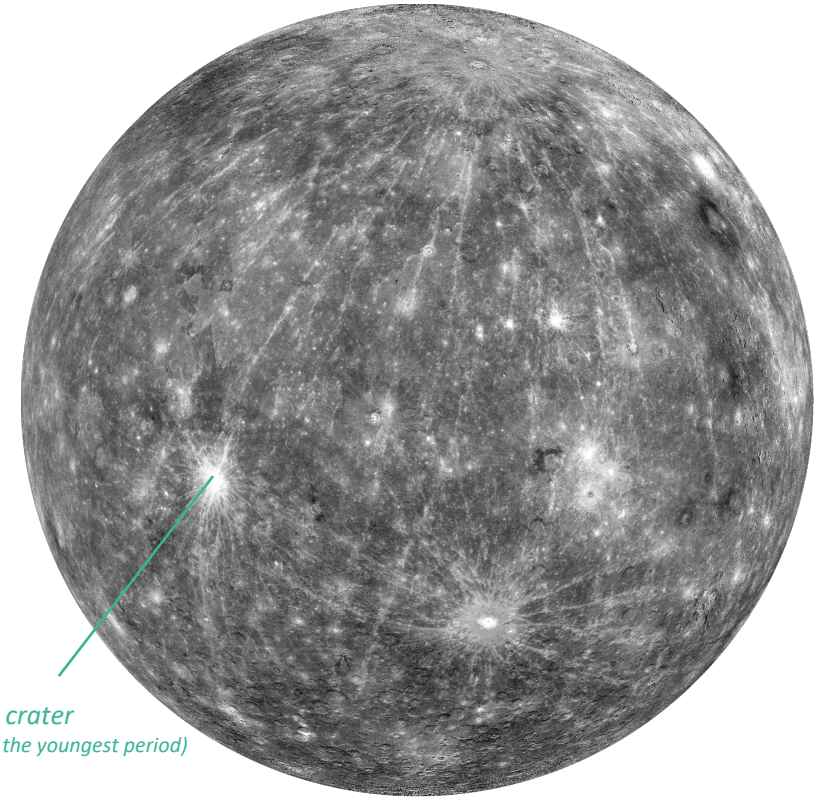




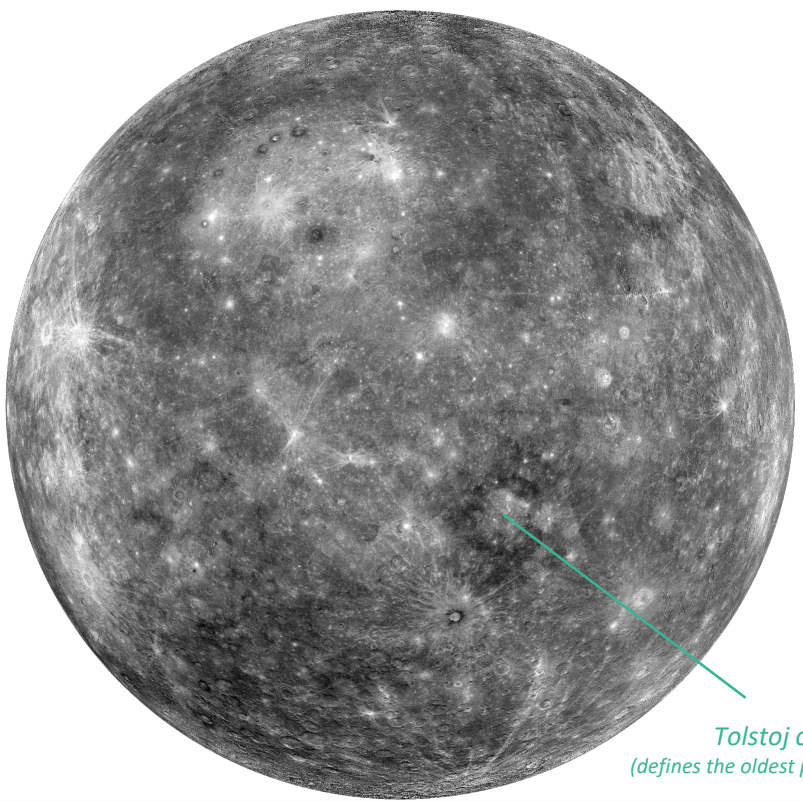
Densely cratered, not *heavily* cratered



Mercury's Main Features...from monochrome basemaps

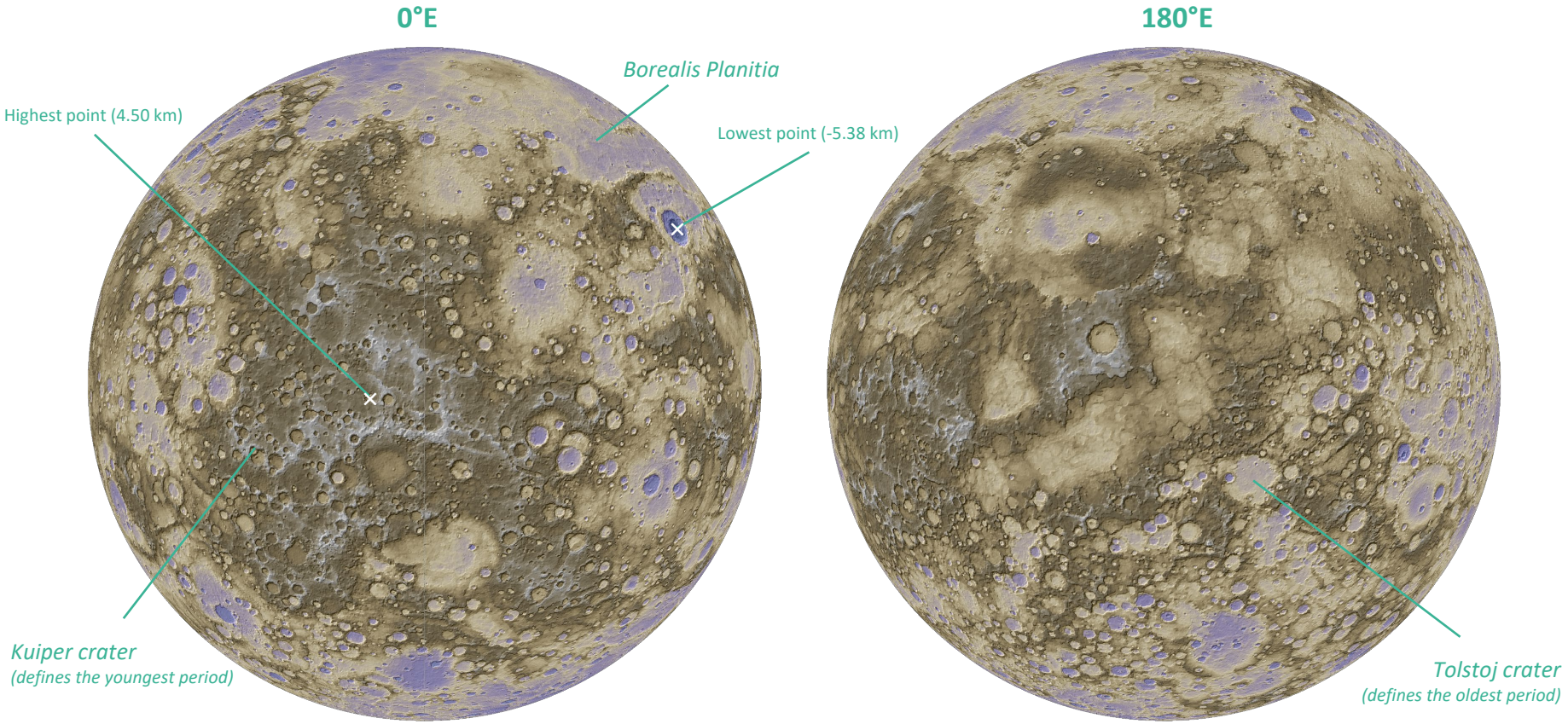


Kuiper crater
(defines the youngest period)

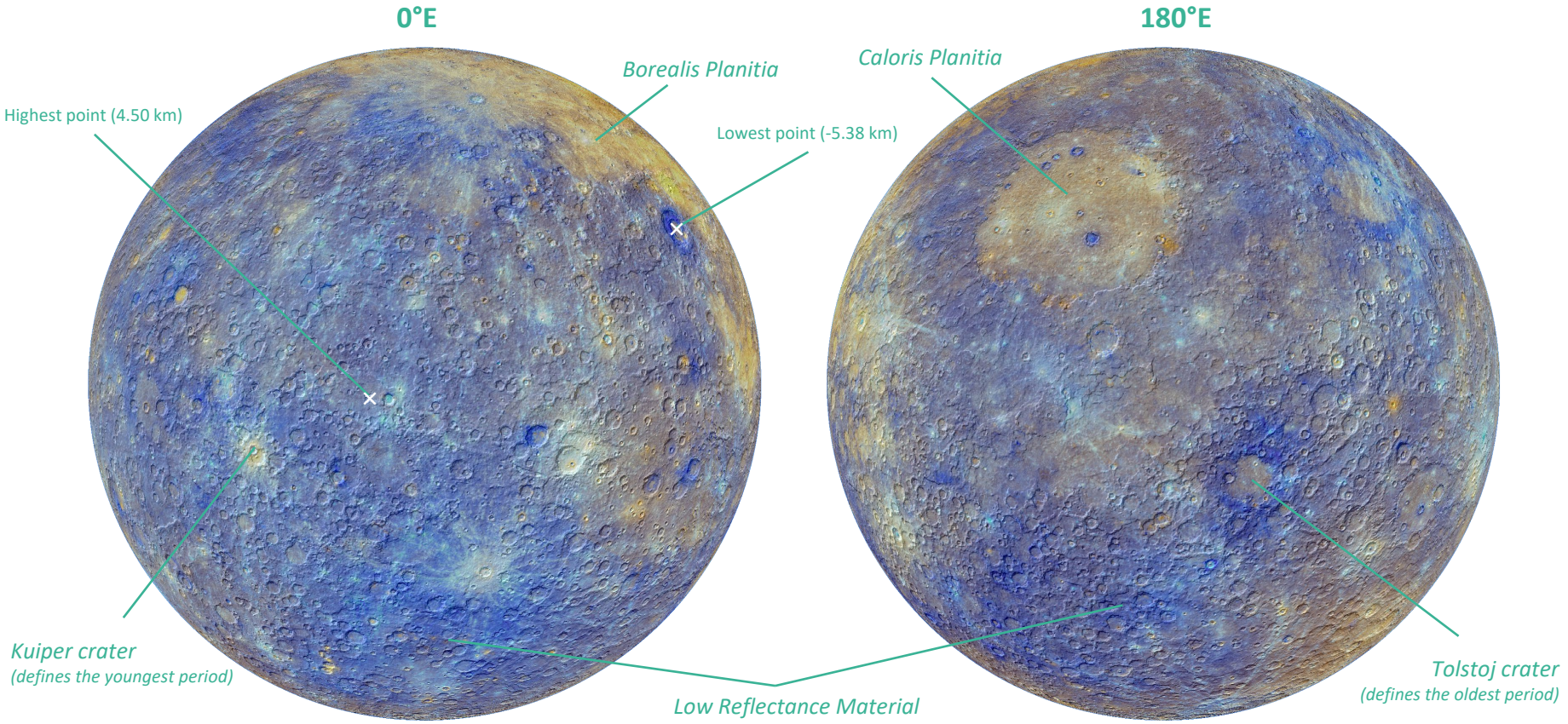


Tolstoj crater
(defines the oldest period)

Mercury's Main Features...from topography



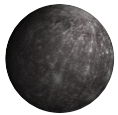
Mercury's Main Features...from false colors

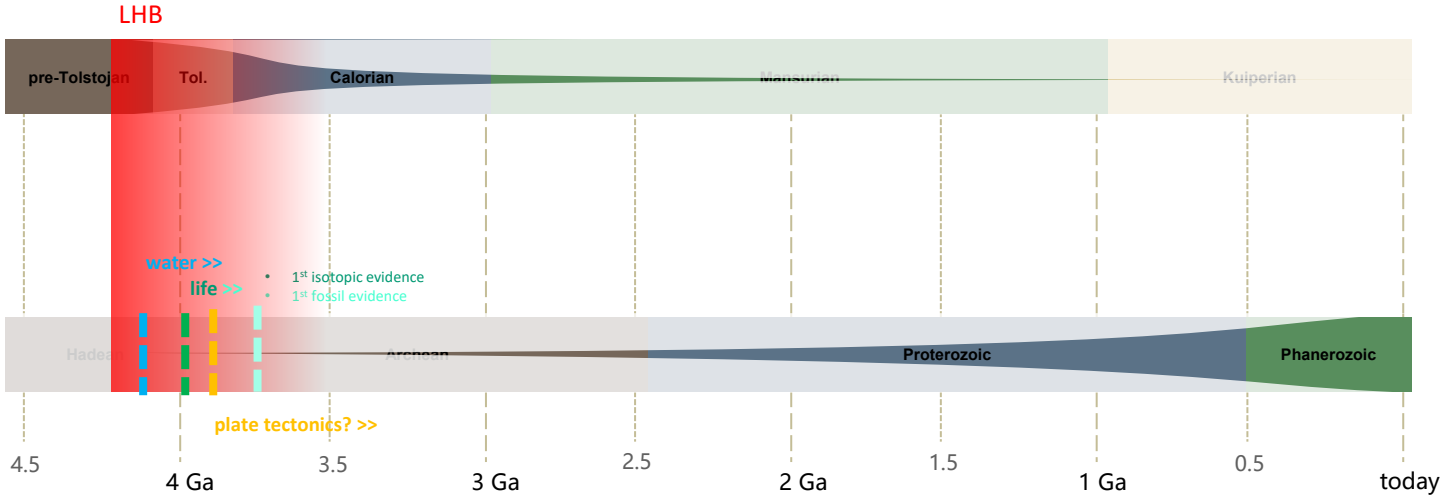


Two Complementary Worlds

Why is it so important to study the surfaces of worlds like Mercury?

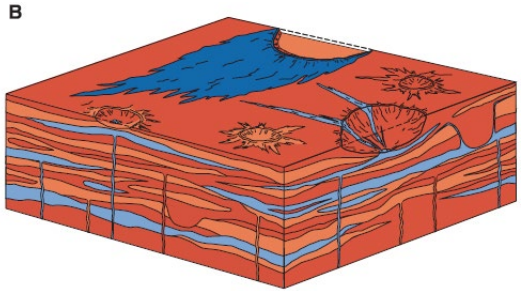
- Its surface evidence is complementary to that of the Earth
- Its surface is the fossil remnant of the origin of our Solar System
- Its surface is «unpolluted» by atmosphere processes or plate tectonics





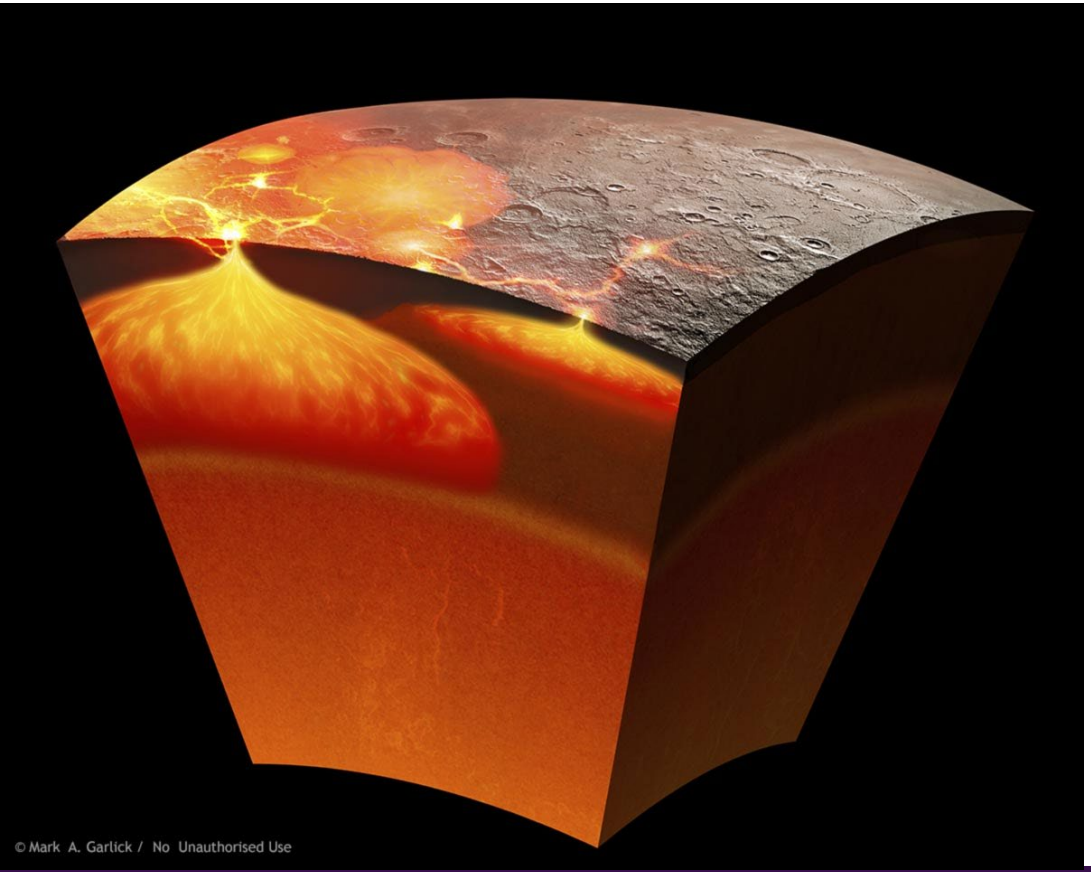
Compositional Variability

- This image shows Mercury in false colors as derived by channel-mixing of NASA MESSENGER images.
- The absence of an atmosphere let's us appreciate the **geological diversity** of the planet.
- The whole planet is covered by **volcanic units**.

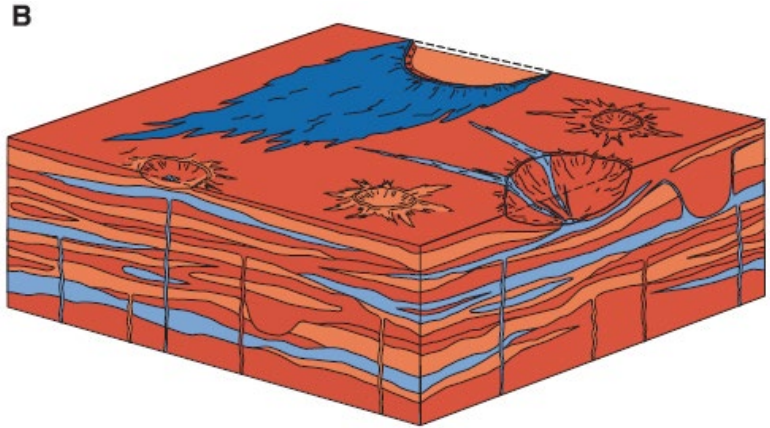


Denevi et al. 2009 (Science)

Secondary Crust



- Differently from the Moon highlands, Mercury has a **secondary resurfaced crust**.
- The low-reflectance terrains are probably evidence for the **old primitive crust**.

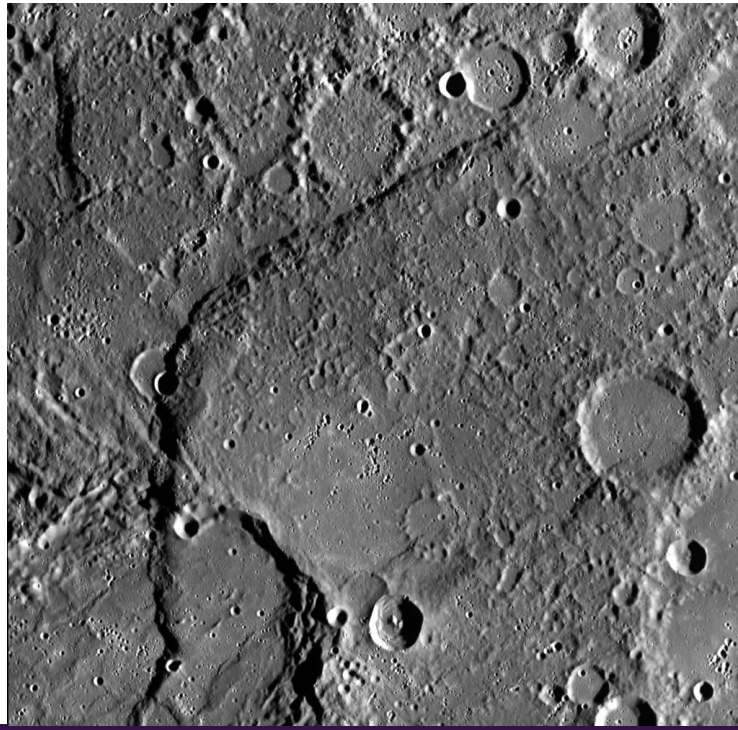


Denevi et al. 2009 (Science)

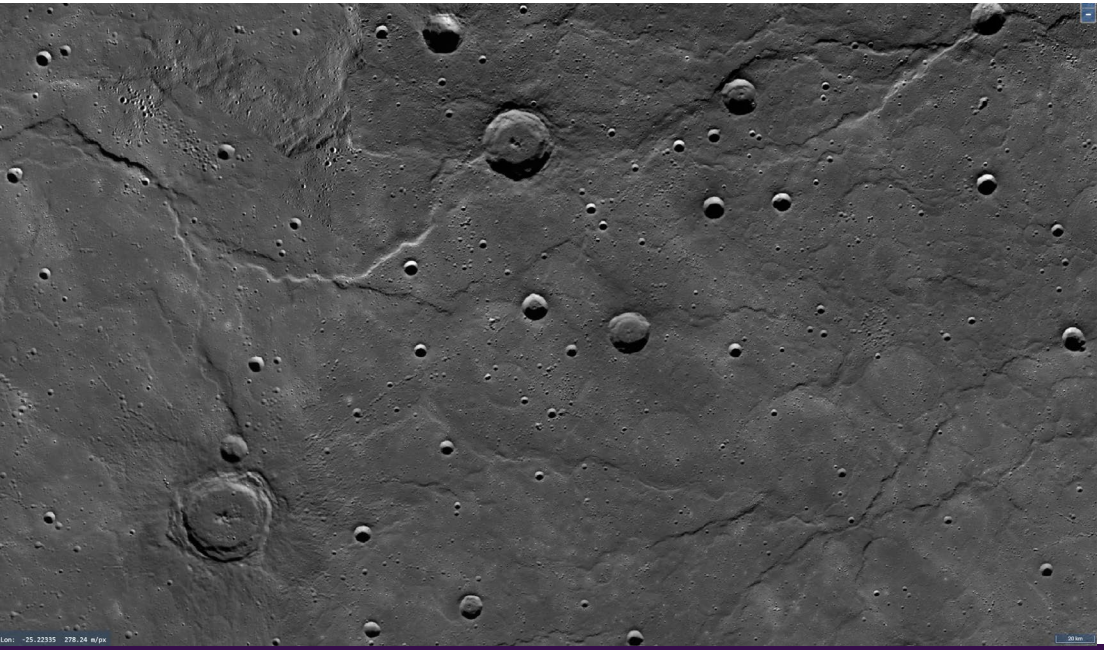
The Scarps of Mercury

Lobate scarps and *wrinkle ridges* are common on Mercury as on the Moon
Lobate scarps are dominant and widespread on the surface.

Beagle Rupes



Borealis Planitia wrinkle ridges



It's Mercury's Fault(s)!

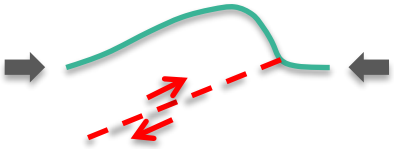
- **Lobate scarps** are asymmetrical reliefs, with a steep scarp on one side and a gentle slope on the other side. They can reach 1000 km in length and 3 km in height.

These are defined by the IAU descriptor term "*rupes, rupēs*" and named after scientific expeditions.

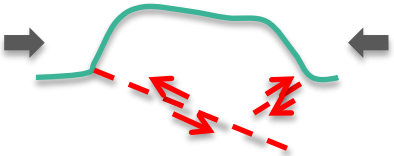
- **High relief ridges** are symmetrical reliefs, can reach 600 km in length and 1 km in height. They are likely the expression of a main thrust (main lobate scarp) associated to a back thrust (minor lobate scarp on the opposite side).

These are defined by the IAU descriptor term "dorsum, dorsa" and named after Mercury scientists.

Lobate scarps

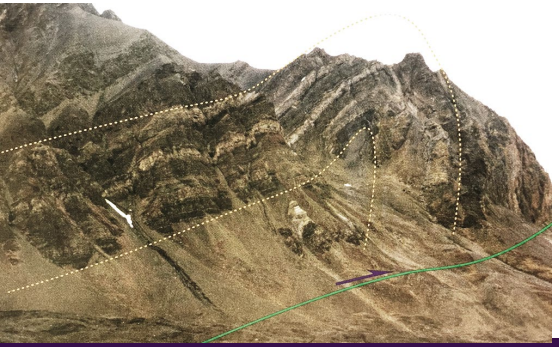


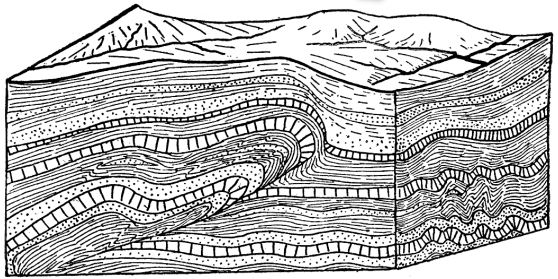
High relief ridges

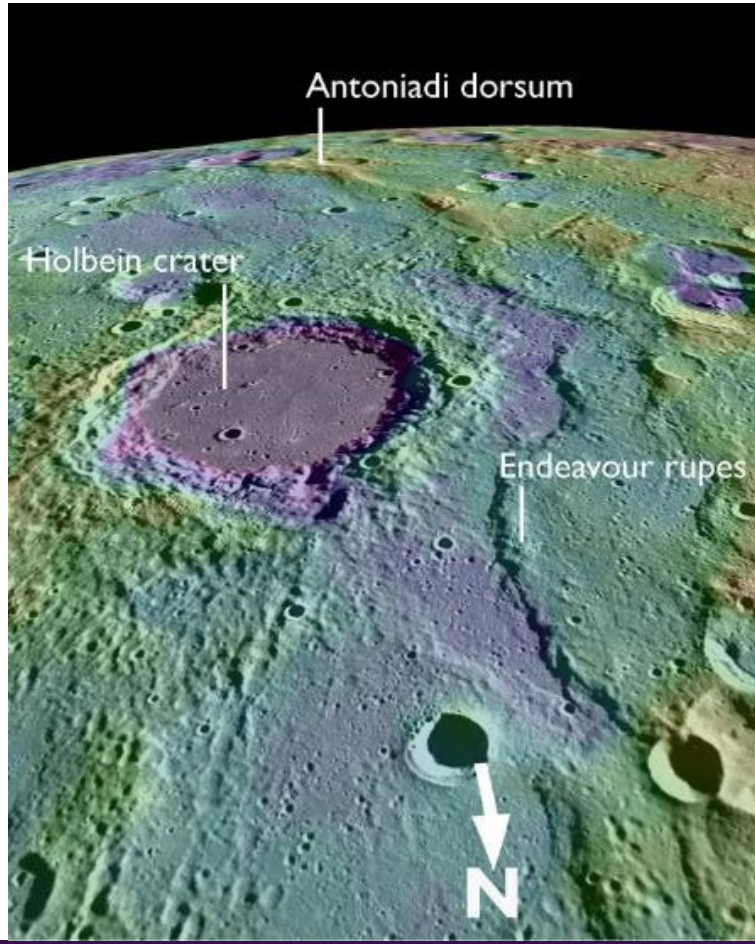


Wrinkle ridges

Svalbard

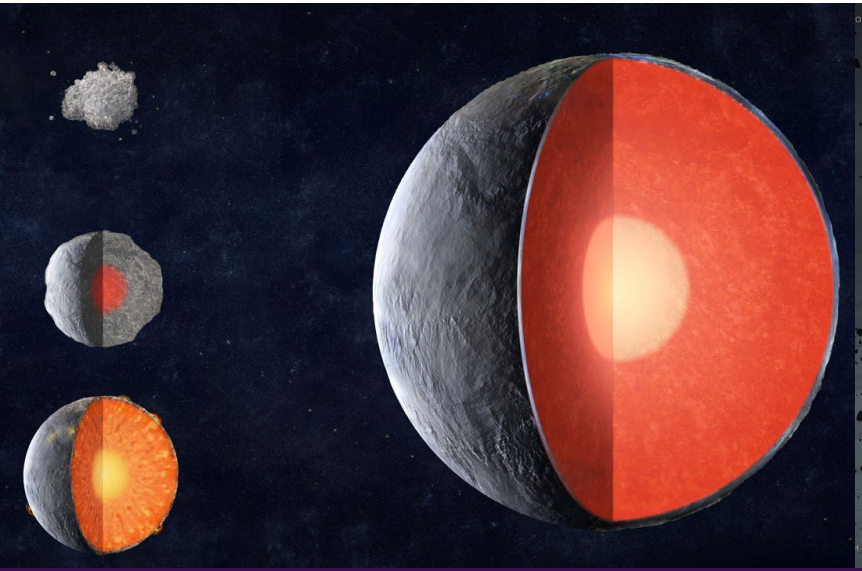




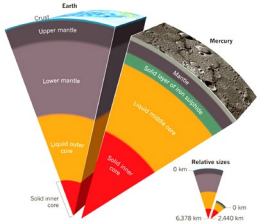


A step back: Formation of the planets

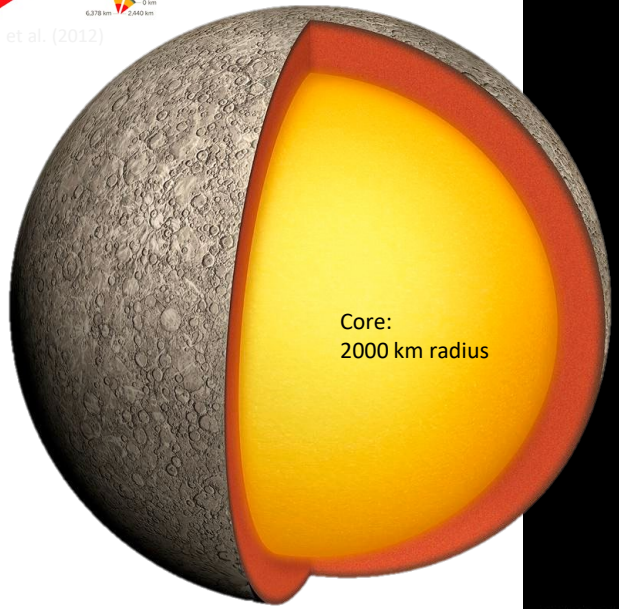
- The planet-forming material gathers in a process known as accretion.
- Gravitational grain-by-grain accretion produced clusters of planetesimals that moved in nearly coincident circular orbits.
- Planetesimals *aggregate* forming larger planetesimals and eventually protoplanets.
- By growing larger in size, the forming planet *increases in temperature* and this energy causes the material to *heat up and melt*.
- Upon melting, *layers form and separate*. The *heavier elements sink* to the bottom, the *lighter ones float* to the top.
    - This process is known as differentiation.



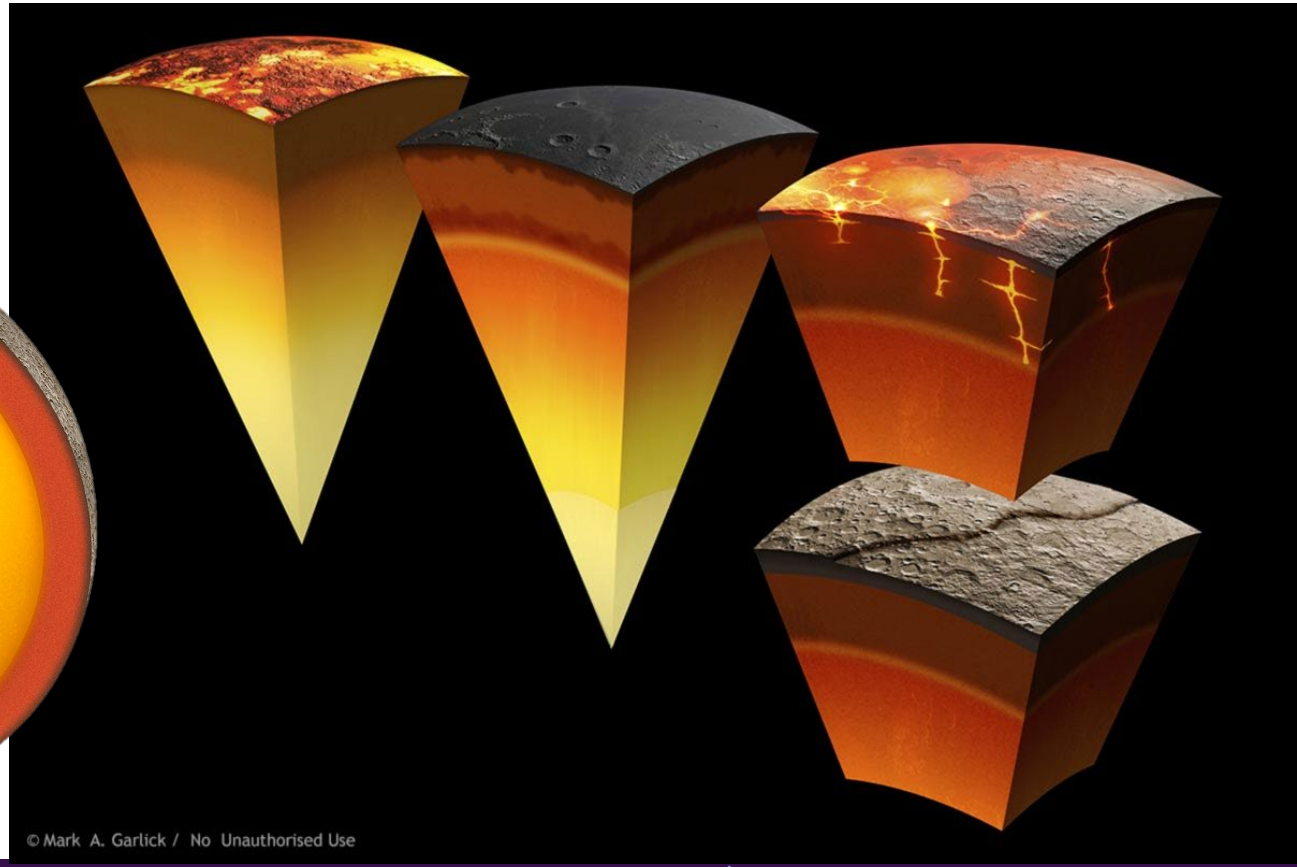
Mercury: A Big Heart



Stevenson et al. (2012)

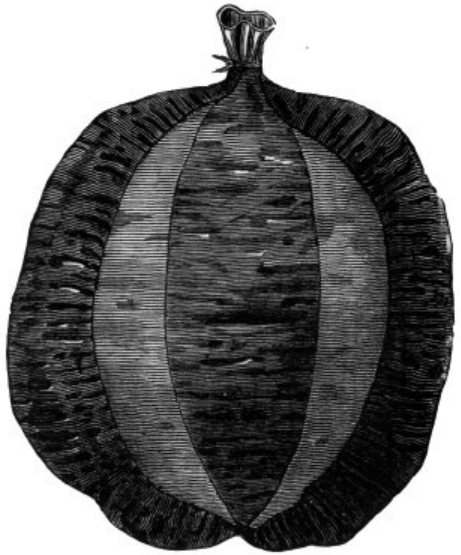


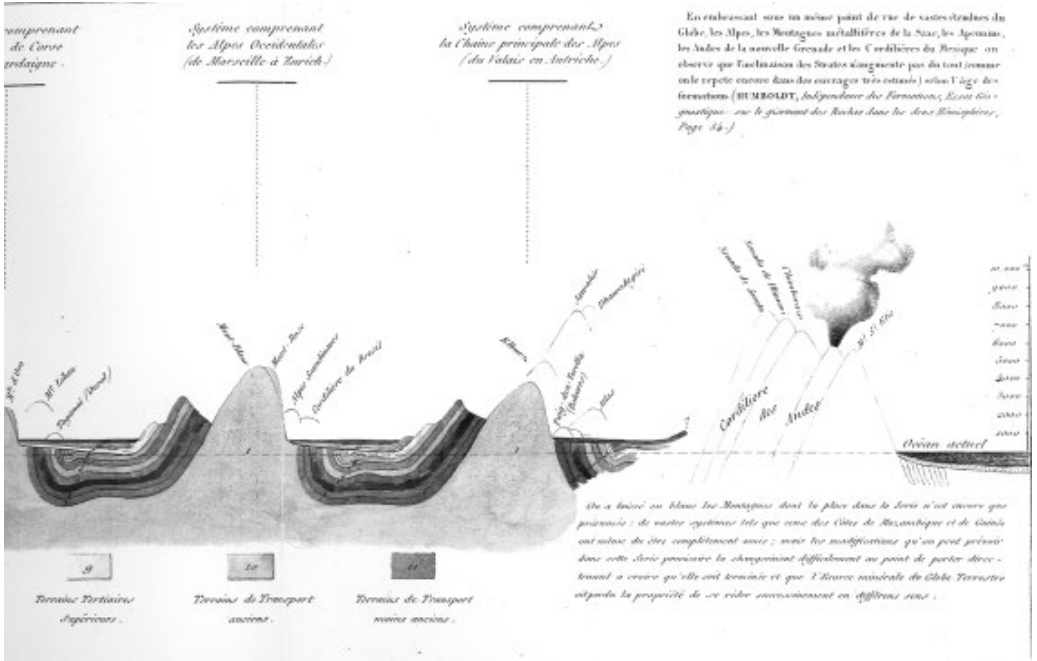
Core:
2000 km radius



An abandoned theory for Earth's mountain ranges formation...

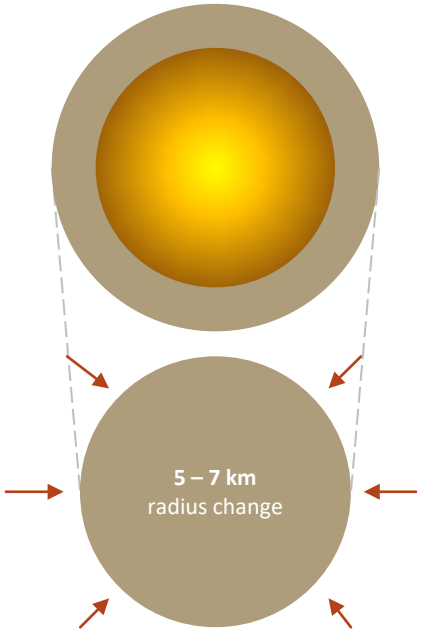
- Leonce Elie de Beaumont
- Earth is in a contractional state (1829)

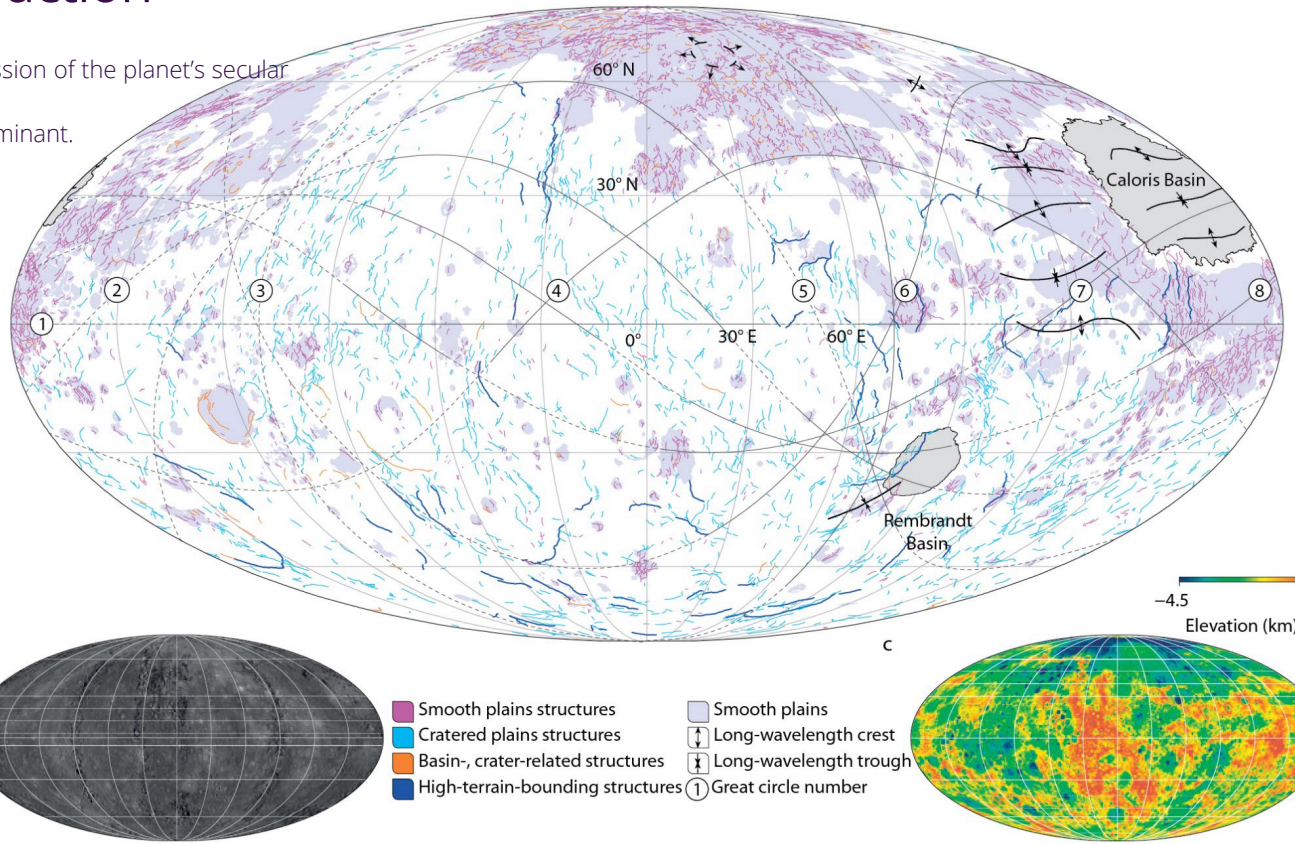




Mercury's Global Contraction

- The scarps of Mercury are the surface expression of the planet's secular cooling.
  - » Global contraction tectonics is dominant.



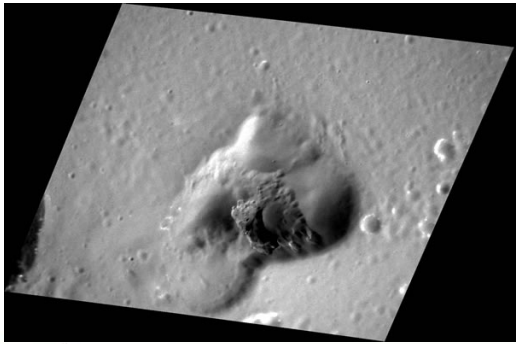


Byrne et al. (2014, Nature Geoscience)

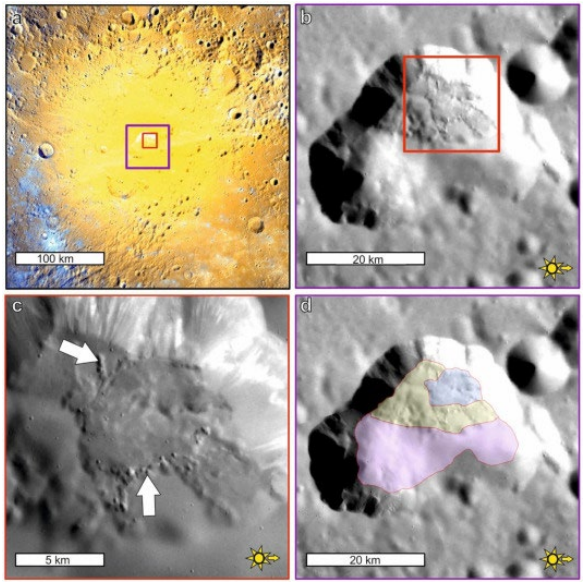
Explosive Volcanism

- Several volcanic vents surrounded by pyroclastic deposits are present.
- They appear as irregular pit craters with no rim.
- In false colors the pyroclastic deposits have a bright orange color.

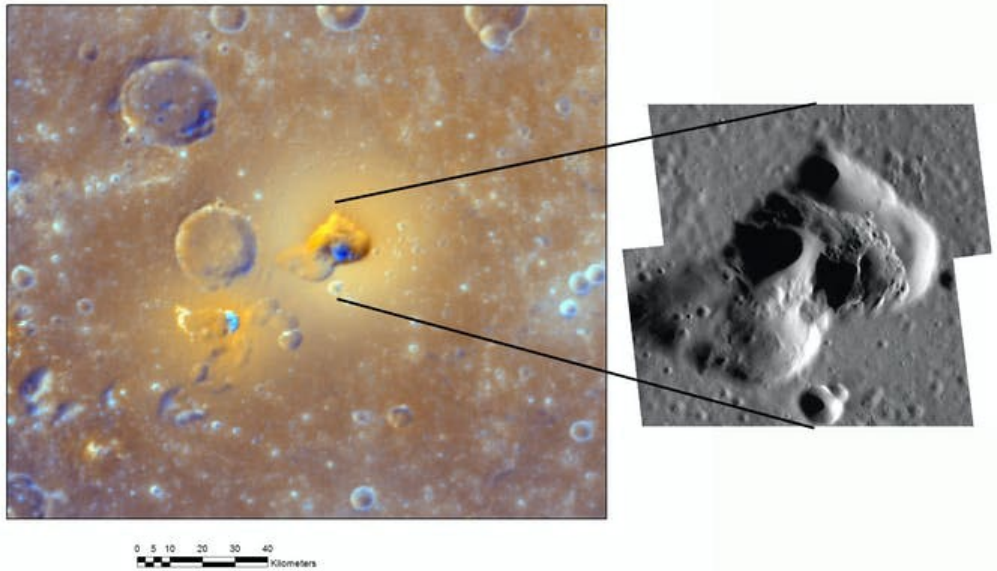
These are defined by the IAU descriptor term of *"facula, faculae"* and named after the word "snake" in various languages.



Agwo Facula

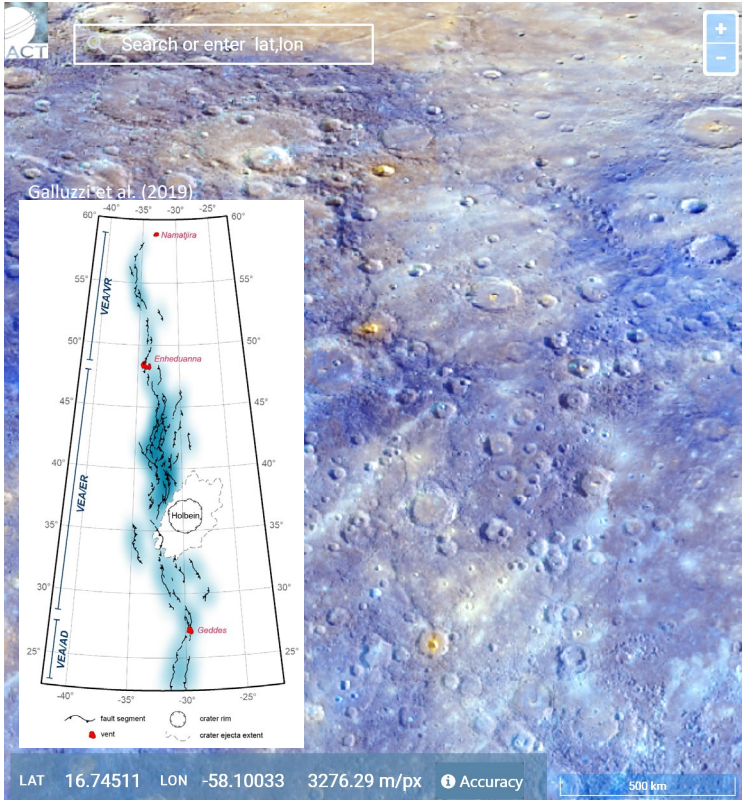


Pegg et al. (2021)

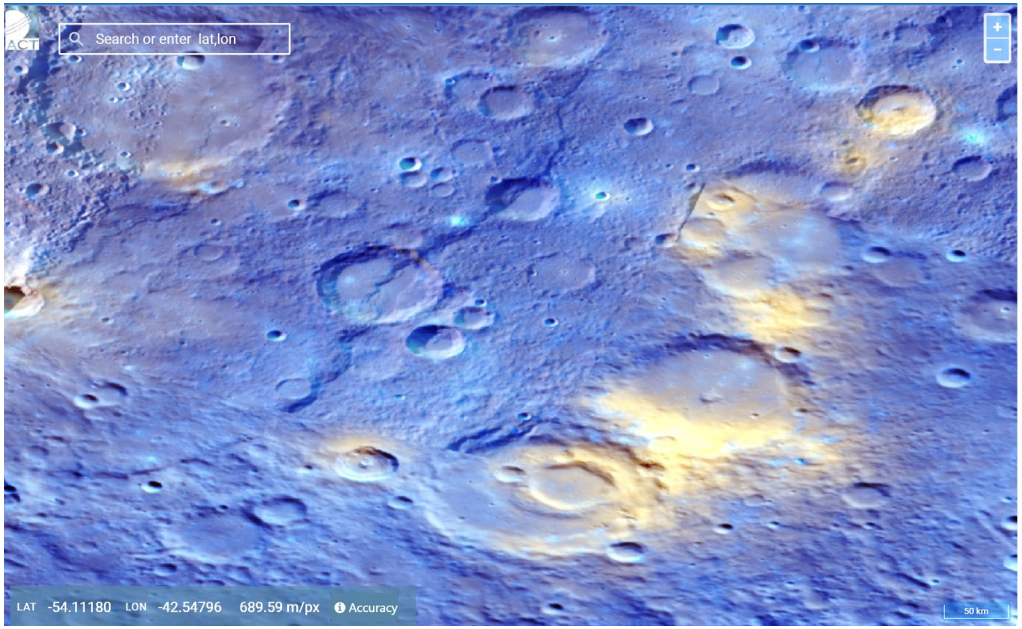


Head and Wilson (2012)

Relationship between vents and faults



- Vents are sometimes found within impact craters and/or aligned with fault systems
- Volatile ascent is aided by highly fractured terrains
- Overpressure caused by contraction may be responsible of the explosive activity



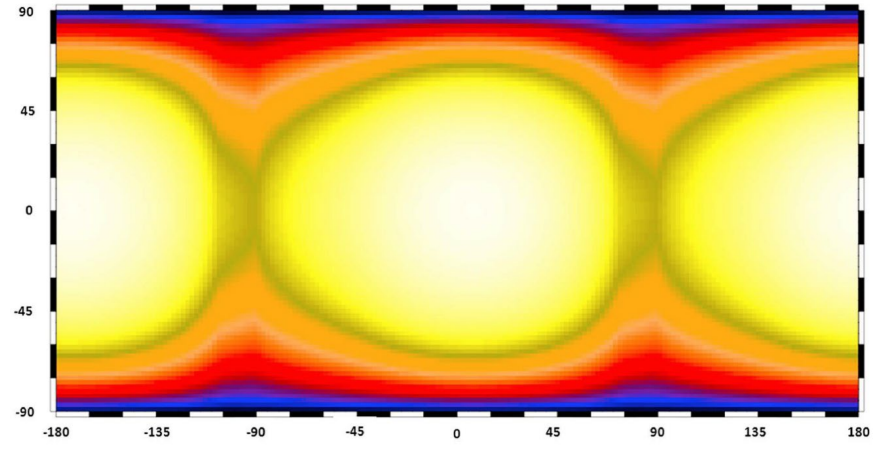
Mercury's Extreme Temperatures

- Mercury's crust undergoes high temperature changes.
- This is due to Mercury's high eccentricity, vertical axis, and spin-orbit resonance (3:2)

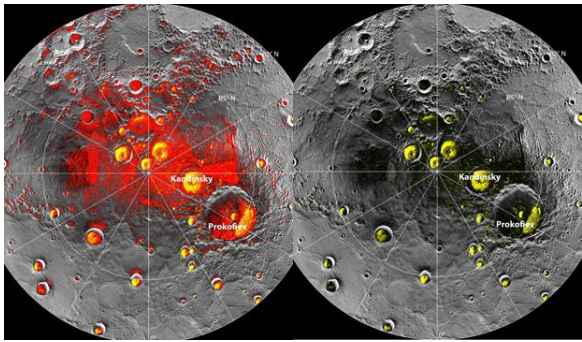
- Two kind of "temperature poles":
  - Cold Poles: North and South poles that host Permanently Shadowed Regions (PSR)
  - Hot Poles: 0°E and 180°E where the Sun at noon corresponds to Mercury's perihelion.

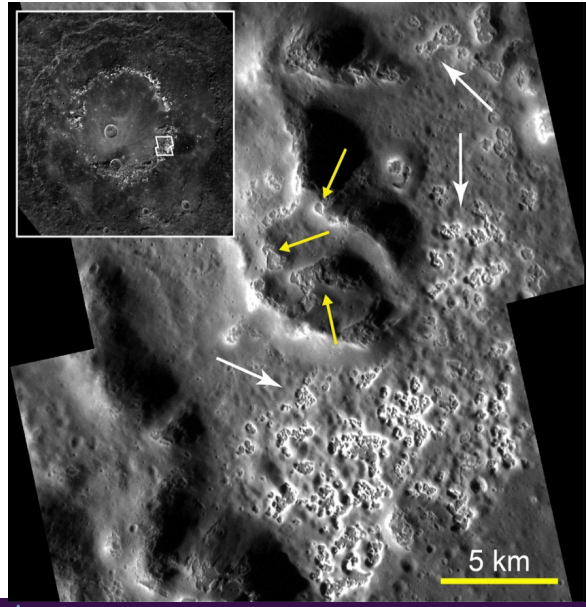
- Consequences on the crust
- Cold Poles: Water ice within the PSRs
- Hot Poles: Volatile escape and hollows widespread and scattered at mid-low latitudes.

Vasavada et al. (1999)



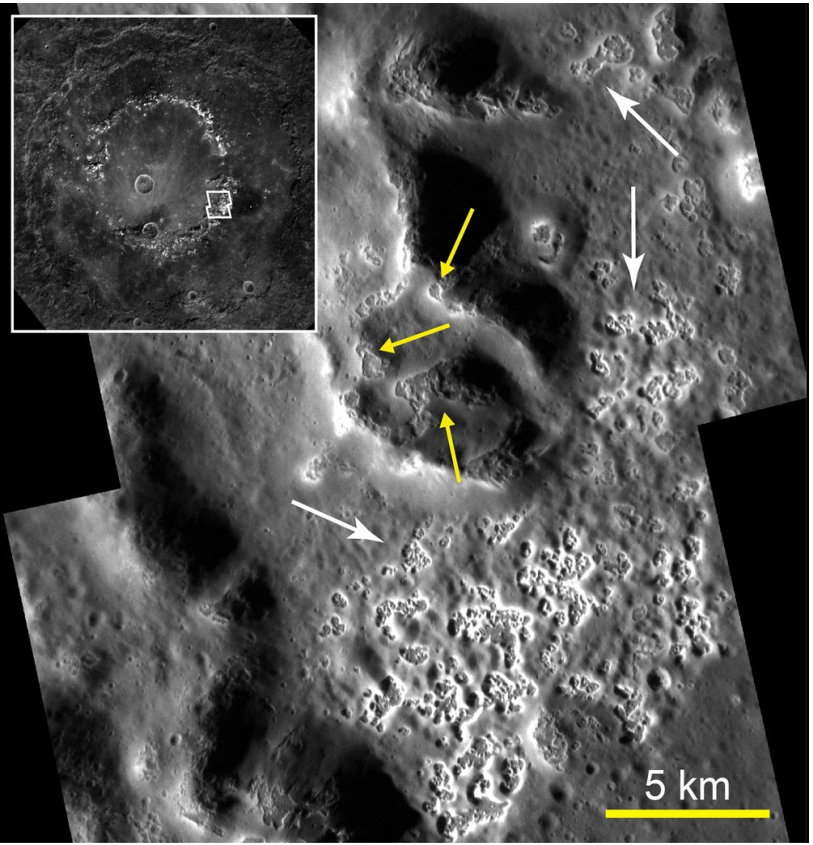
Max 450°C – Min -180°C

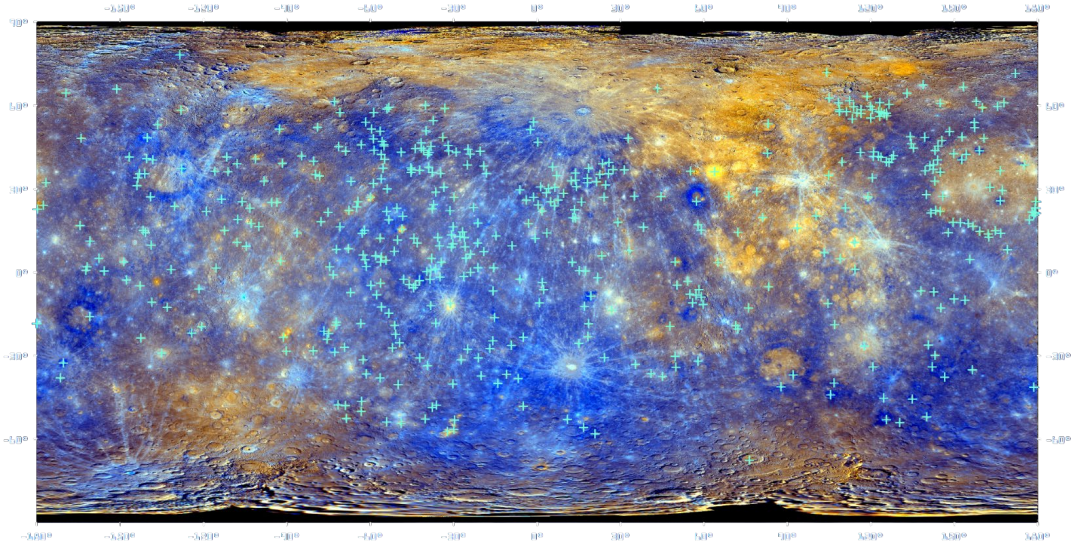




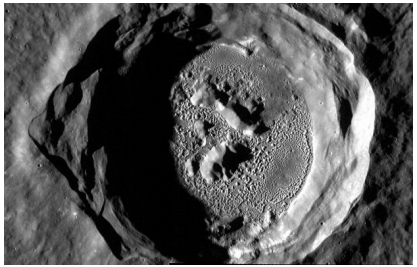
Blewett et al. (2011, Science)

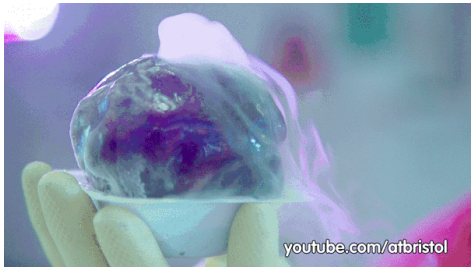
Mercury Hollows: Hot-Poles vs Crustal Composition





The correlation is stronger with the low-reflectance material (Thomas et al., 2014)





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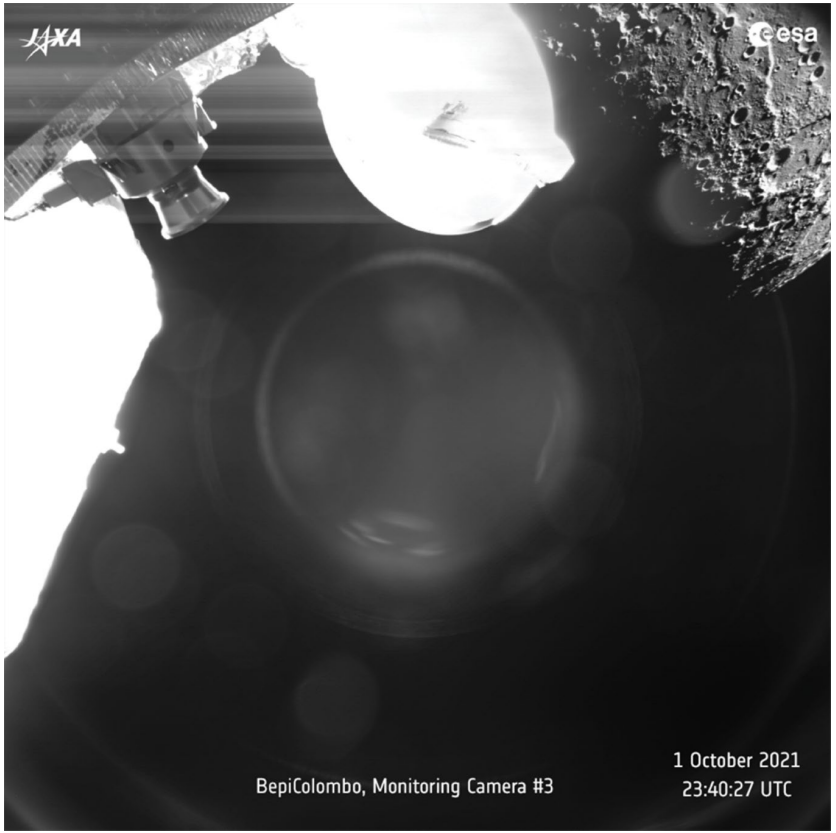

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