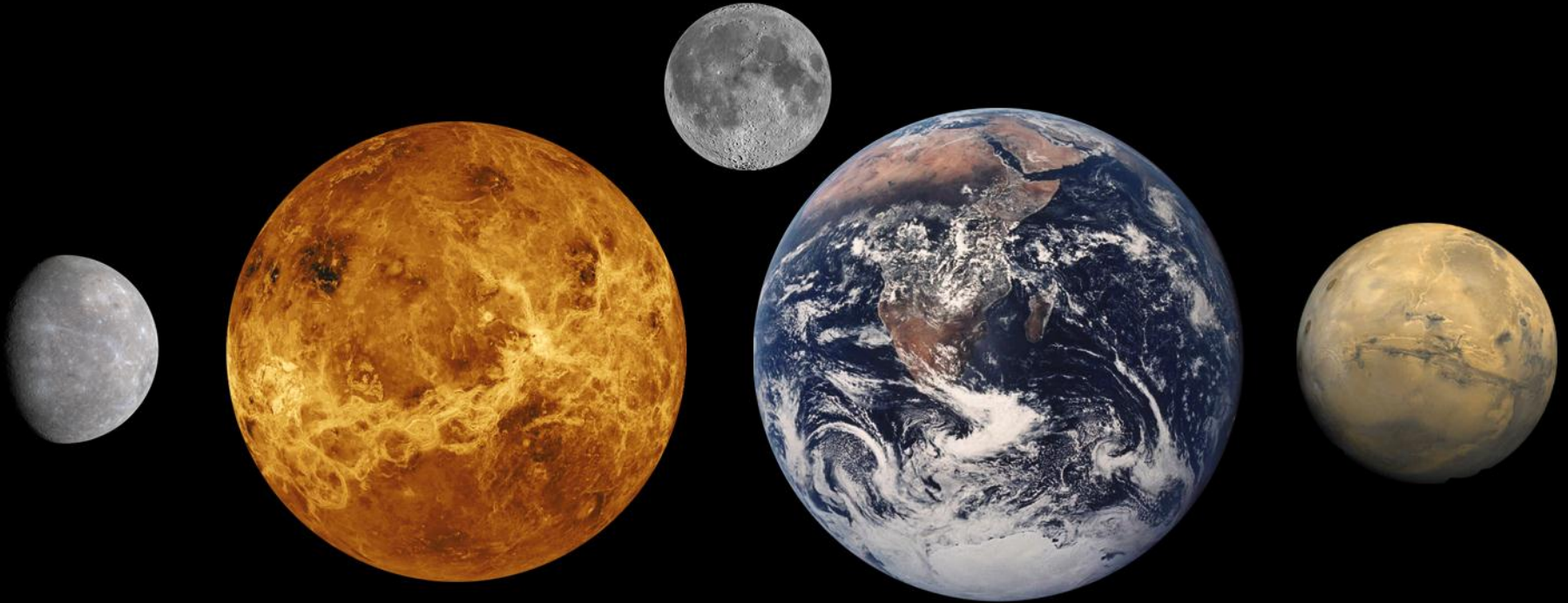


Plate Tectonics: An end member or outlier process?



T.R. Watters and M.M. Selvens

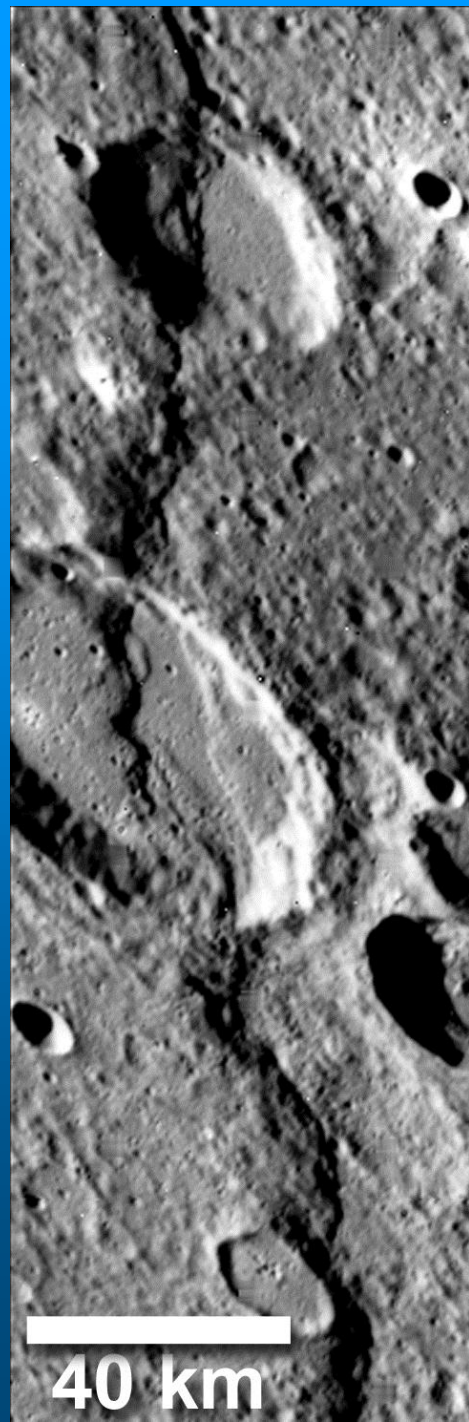
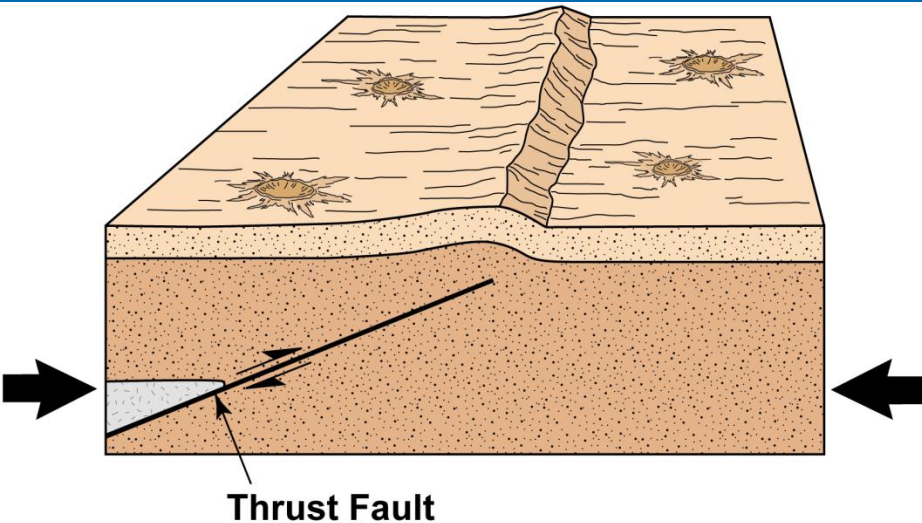
Life in the Cosmos: Workshop

Planetary Tectonics

- Is plate tectonics an expected outcome of the thermal evolution of Earth-like planets?
- Is plate tectonics a necessary condition for life?
- What can be learned by examining tectonic systems on the terrestrial planets of our Solar System?
- What is the relationship between the mass of a planet and the scale of contractional tectonics?

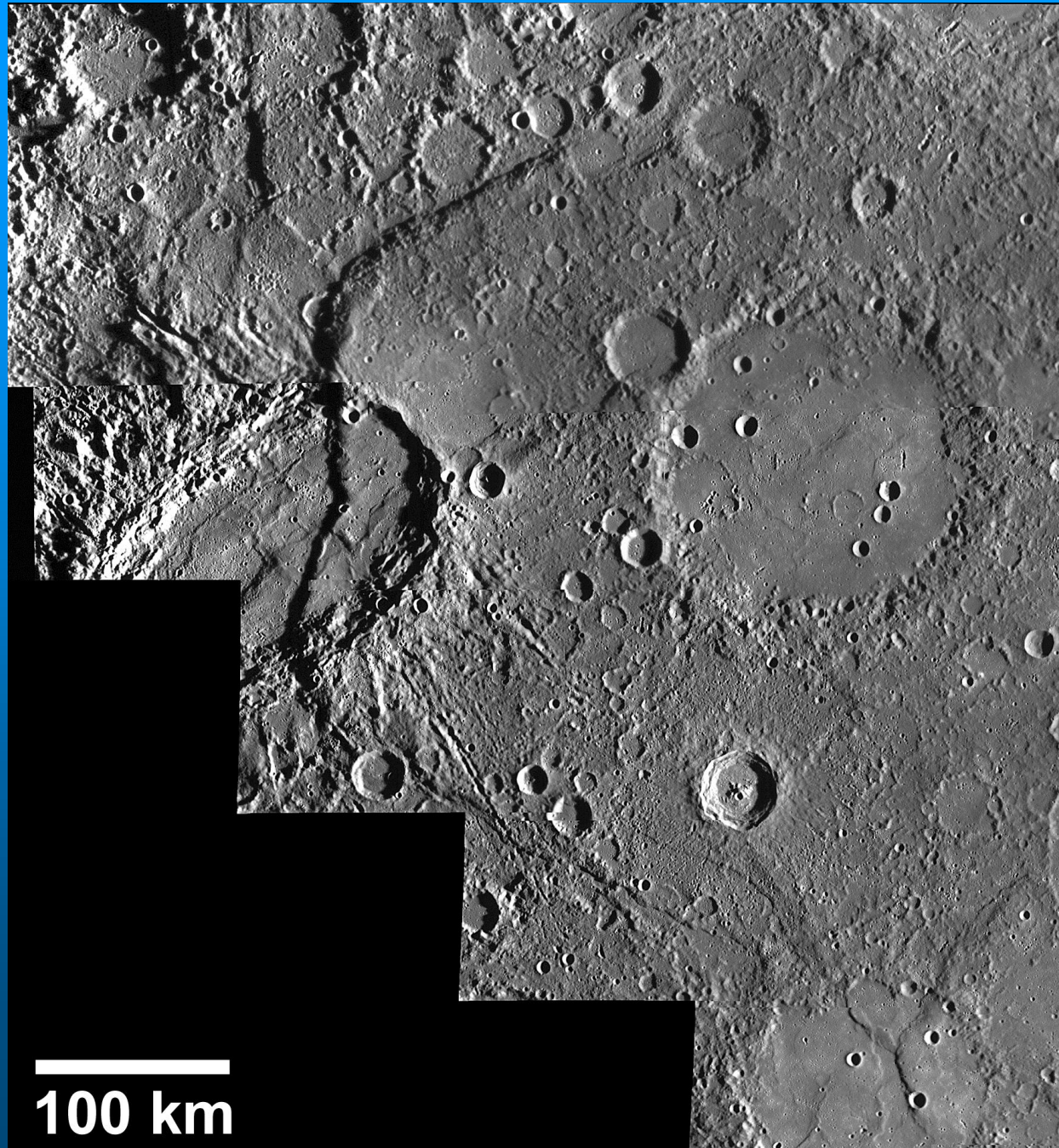
Mercury - Lobate Scarps

- Crustal shortening is the dominant form of deformation in the imaged hemisphere.
- Lobate scarps are the most widely distributed tectonic landform.
- Offset crater floors and walls indicates that lobate scarps are the expression of surface-breaking thrust faults.



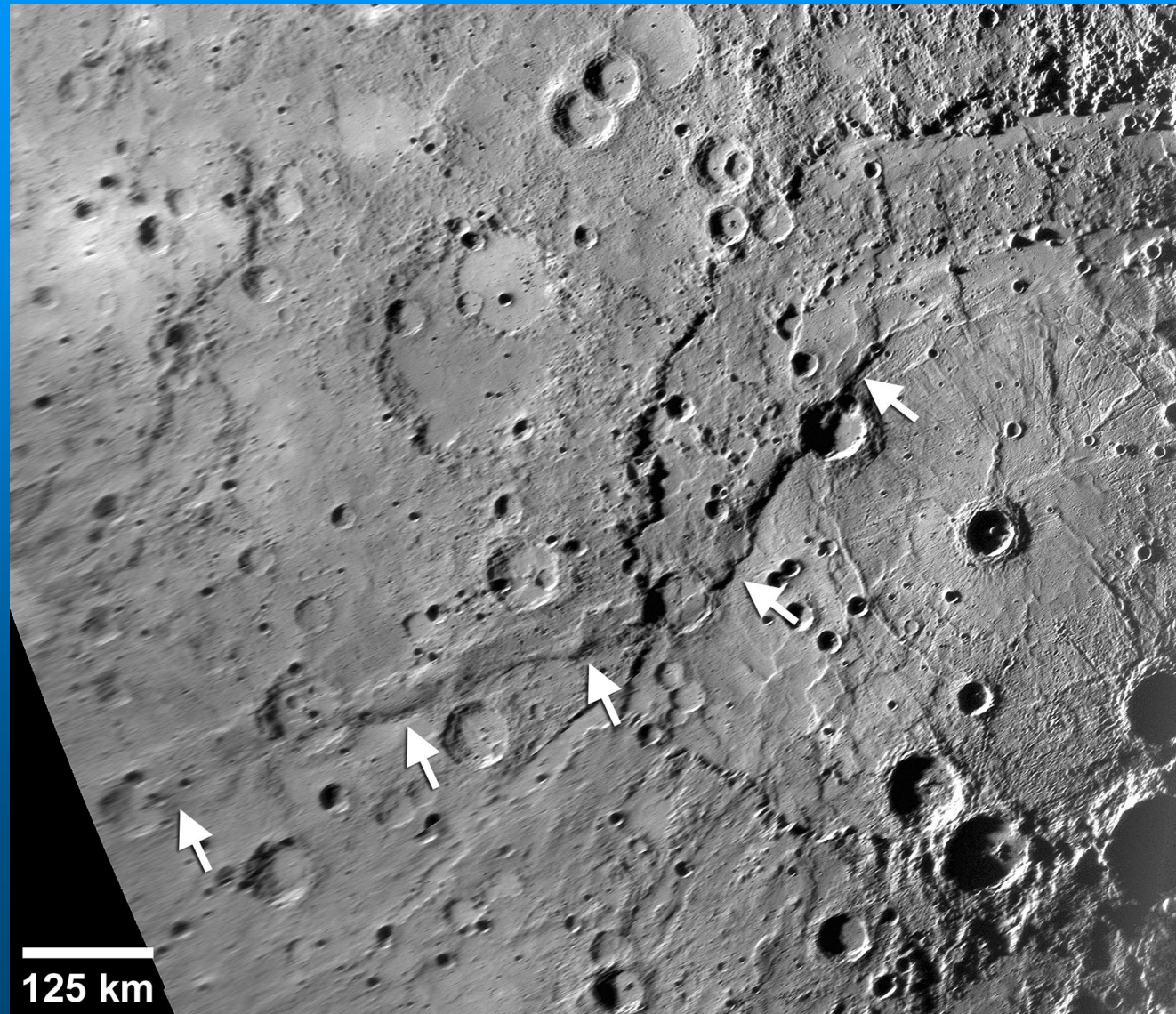
Lobate Scarps

- This prominent lobate scarp is over 600 km in length and is informally named Beagle Rupes.
- The scarp cuts and offsets the floor of a large elliptically-shaped crater that was flooded by smooth plains material and deformed by wrinkle ridges.



Rembrandt Basin & Tectonic Landforms

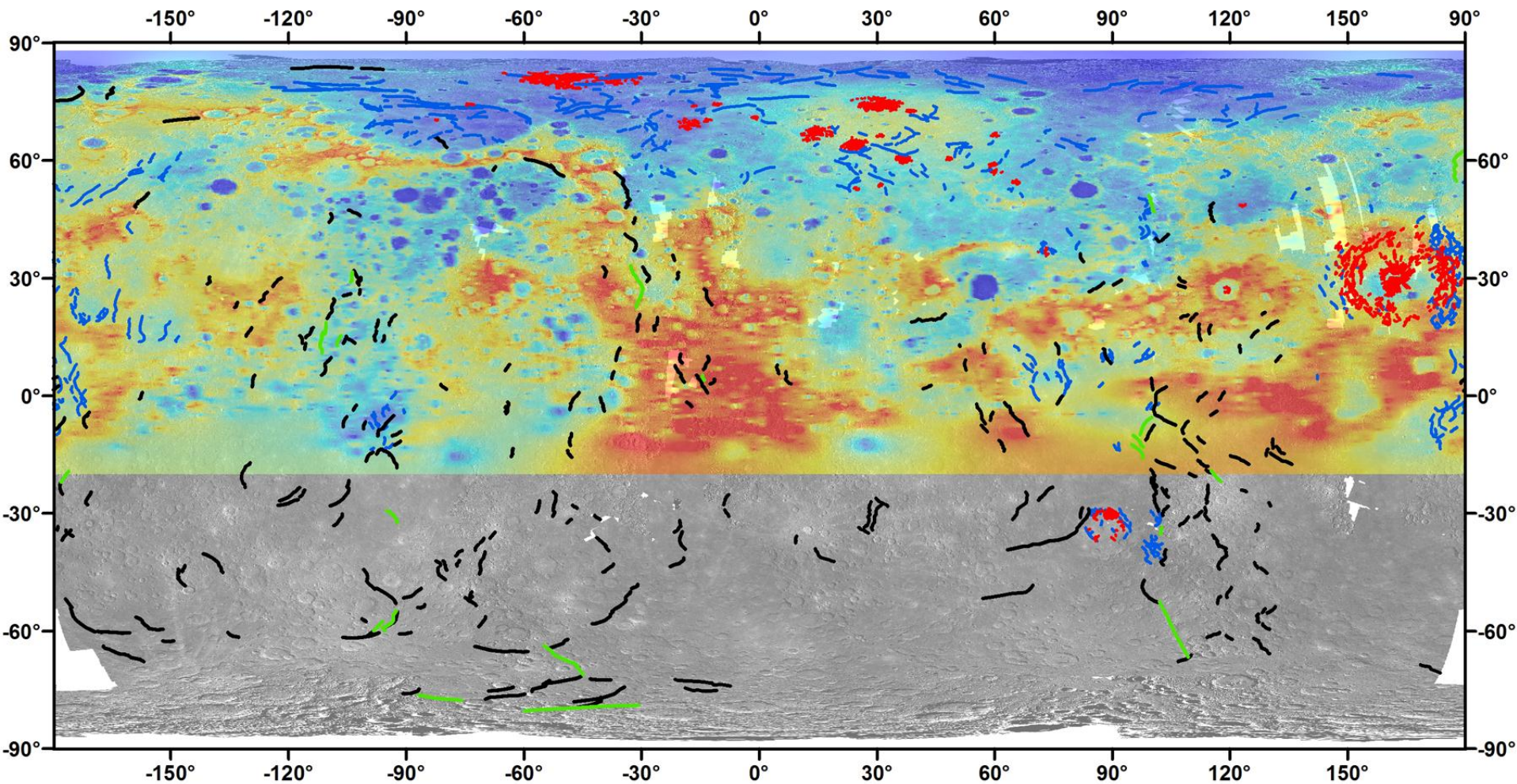
- The latest event in the tectonic history of the Rembrandt is the formation of a crosscutting lobate scarp.
- With a length of ~1000 km, it is the longest thrust fault scarp yet found on Mercury.
- This lobate scarp also holds the record for the number of crosscut impact features.



- The distribution of mapped tectonic features, particularly the lobate scarps.

Preliminary Tectonic Feature Map of Mercury

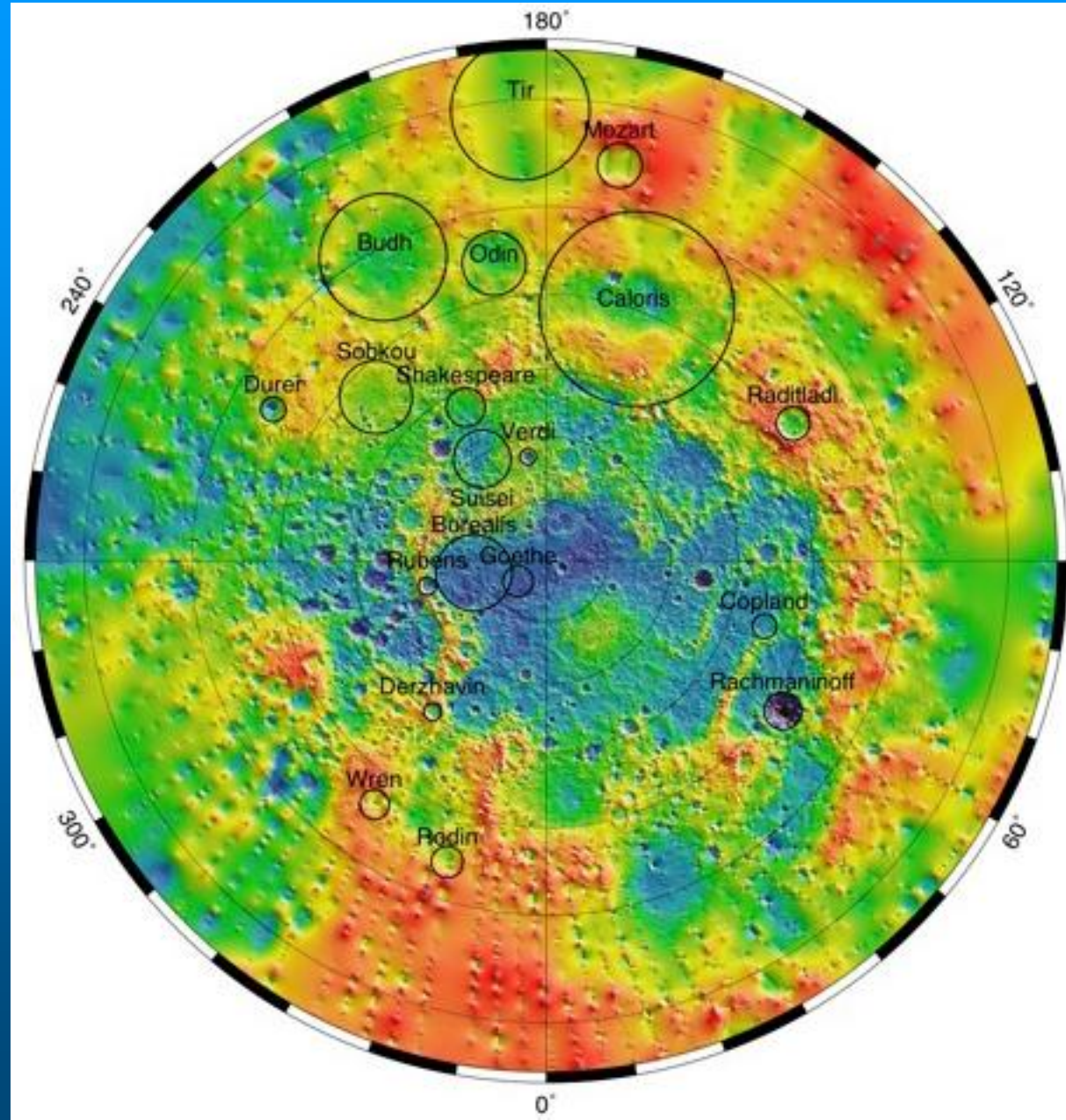
- Dominant trends in the spatial distribution and orientations are



Mercury Digital Elevation Models

Polar conformal map to 5° N
G. Neumann /GSFC

- Evidence of long wavelength topographic features!
- Caloris Basin
- Northern Plains
- Rembrandt Basin



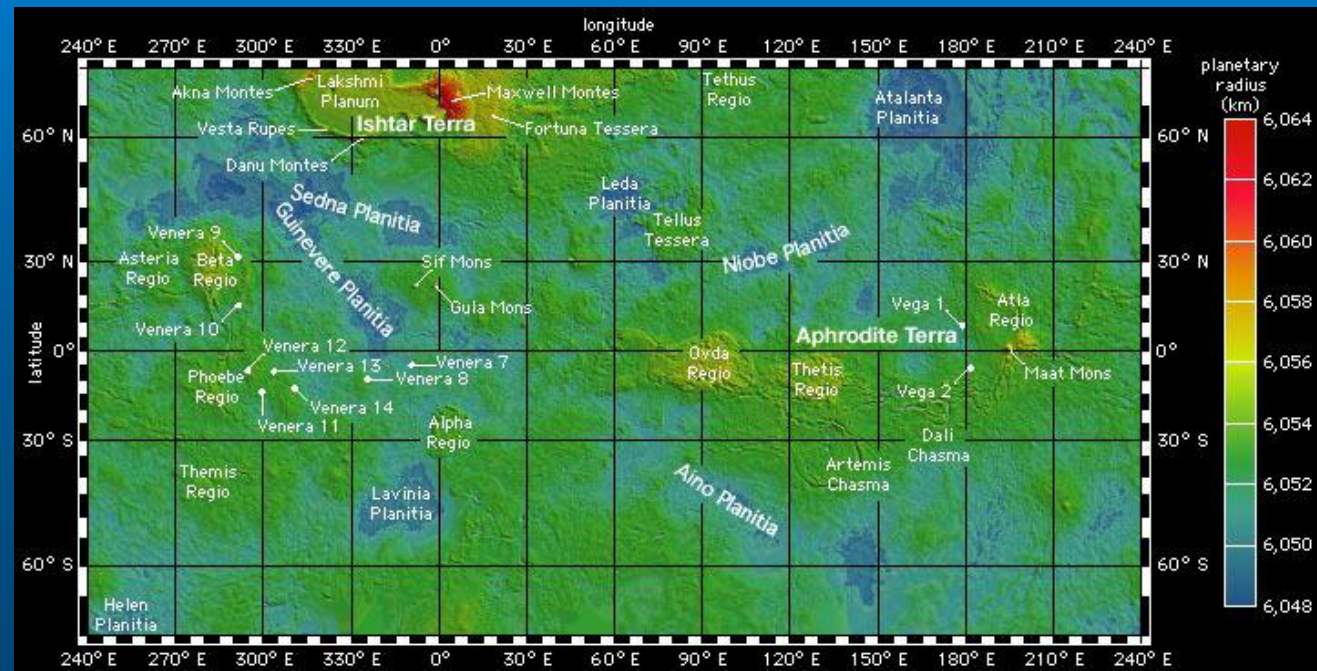
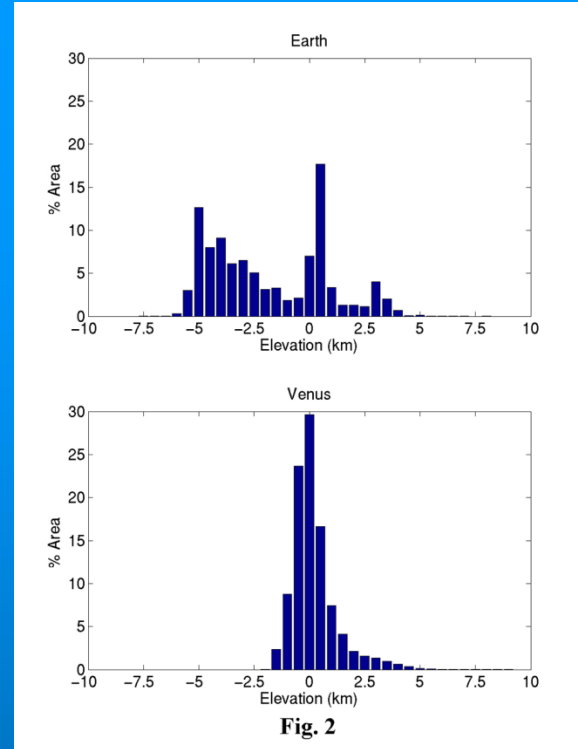
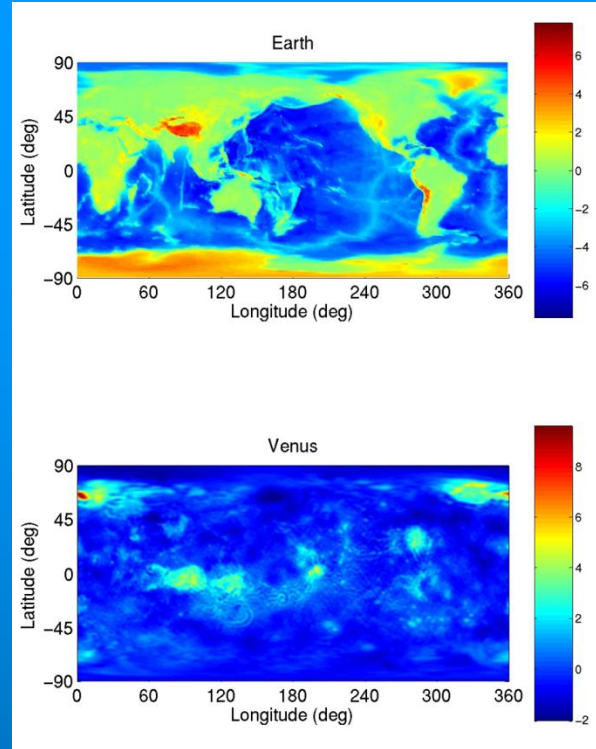
Tectonics of Venus

- In spite of the similarity in bulk density and size to Earth, geologically Venus took a very different path.
- Atmospheric pressure (95 bars) and surface temperature (737 K).
- Liquid water cannot exist on the surface.
- Exposed surface is very young (<1 Ga).



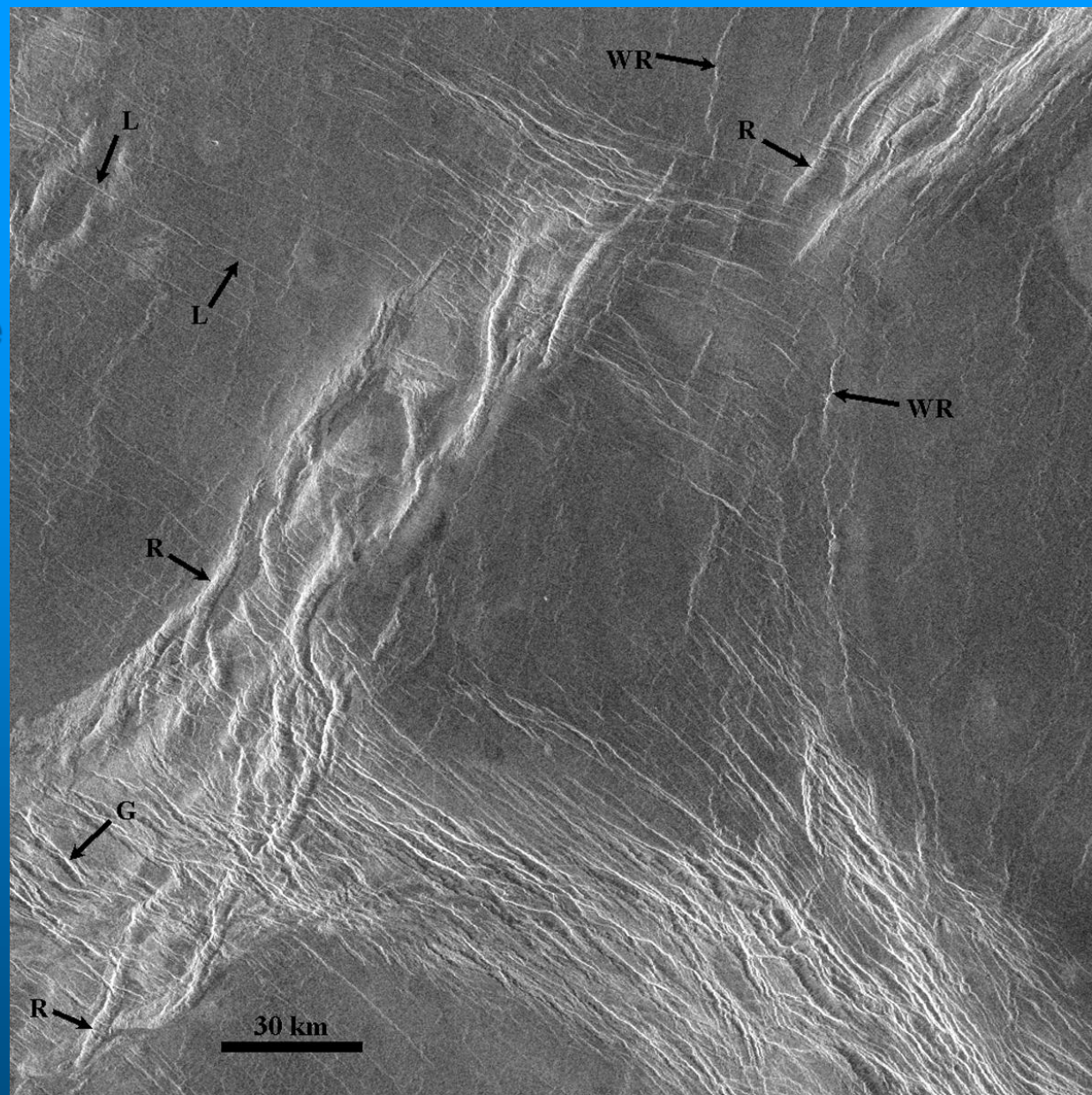
Tectonics of Venus

- No evidence in topographic data of crustal subduction or plate boundaries.
- Earth's bimodal distribution in elevation is a result of plate tectonics.
- Aphrodite Terra and Ishtar Terra are the two major uplands.



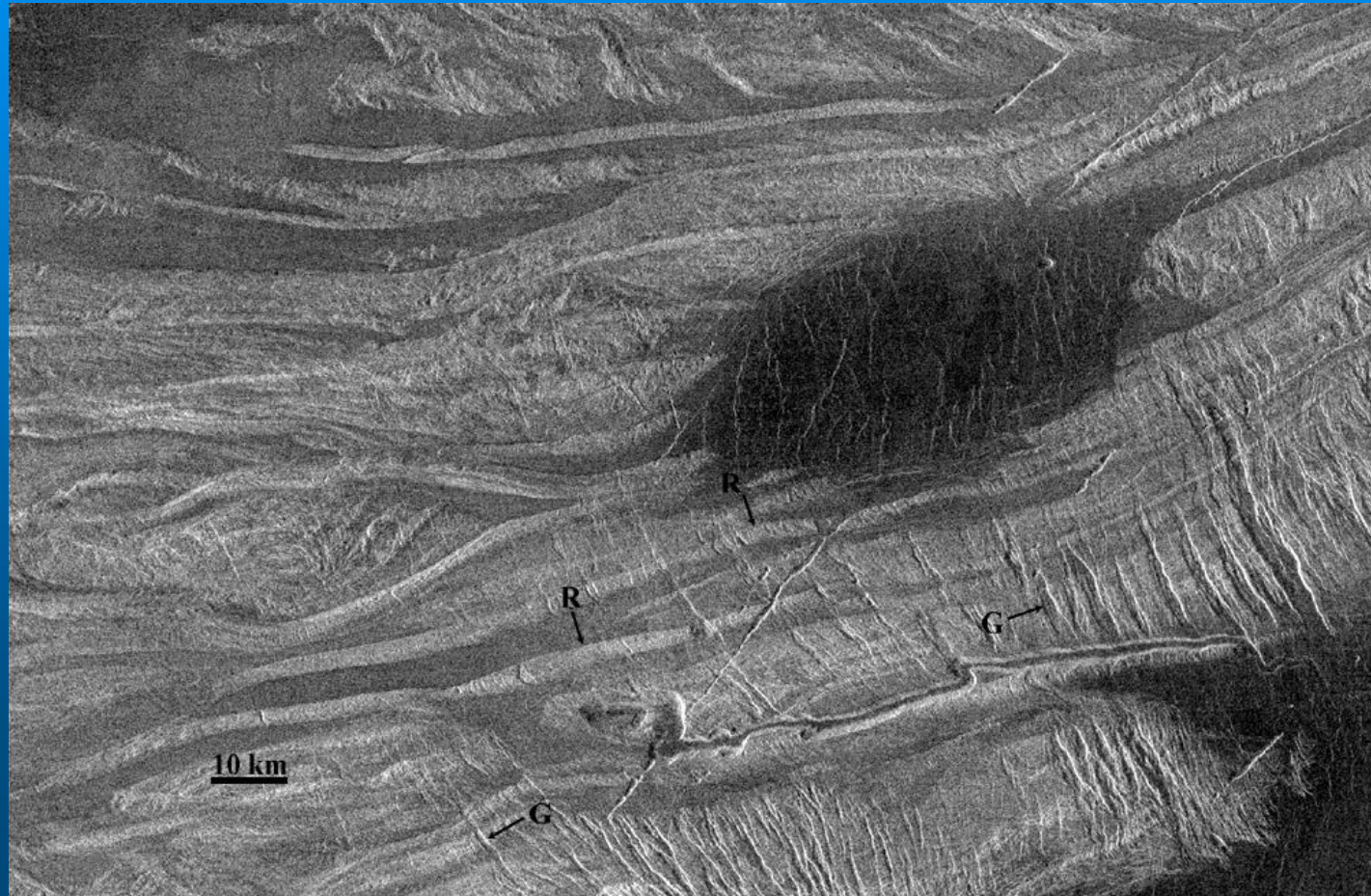
Ridge Belts

- Ridge belts are long, relatively narrow elevated regions that are widely distributed on the plains.
- They can vary in width from tens to hundreds of km in width, and from hundreds to several thousand km in length.
- Ridge belts are often regularly spaced, 300 to 400 km.
- Fracture belts are also common.



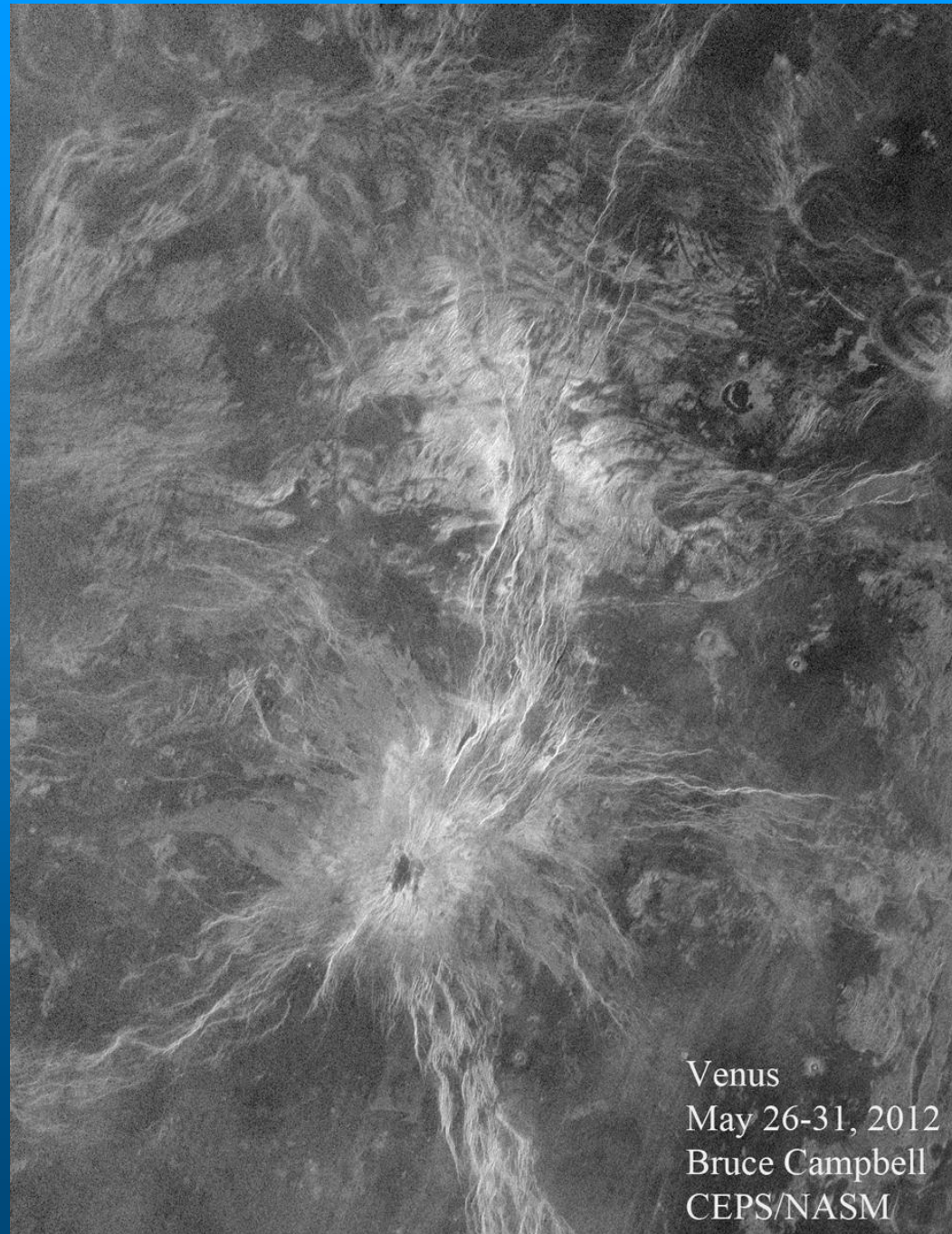
Tessera Terrain

- Tessera are complex tectonic systems that consist of at least two sets of structures that intersect at high angles.
- Tessera may be contractional, extensional or both and in places its difficult to determine what process dominated.
- Tessera may have formed by mantle downwelling.
- Are tessera related to either catastrophic or uniformitarian resurfacing of Venus?



Recent Activity?

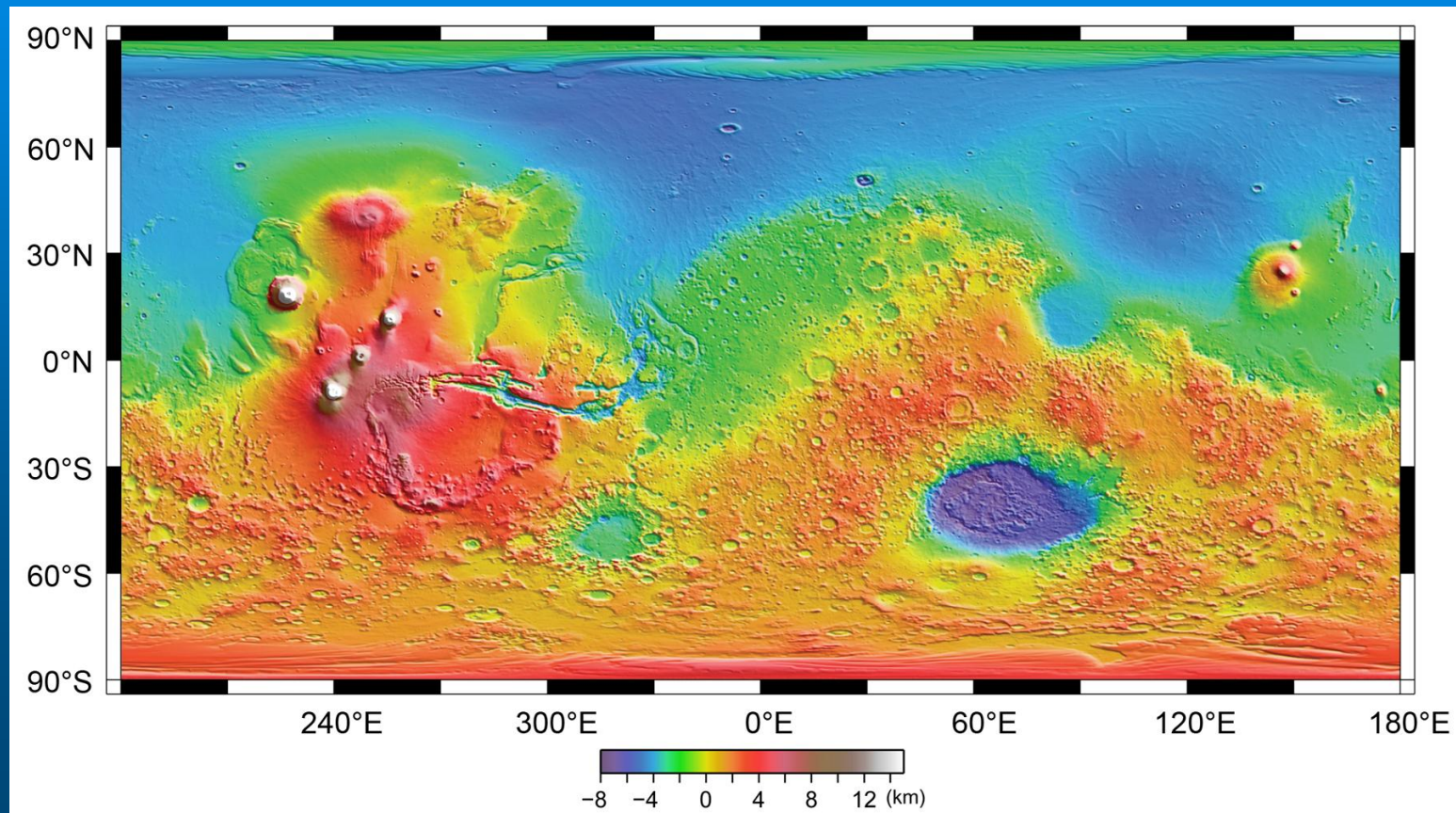
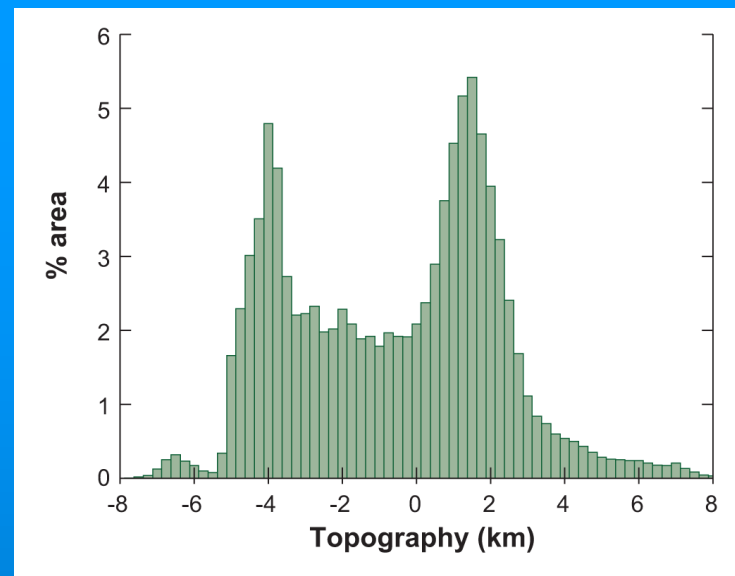
- The young apparent age of the crust of Venus suggests much of the tectonics and volcanics may be recent.
- New Earth-based observations using the Arecibo Observatory in Puerto Rico and the Green Bank Telescope in West Virginia are being examined for evidence of recent activity.



Venus
May 26-31, 2012
Bruce Campbell
CEPS/NASM

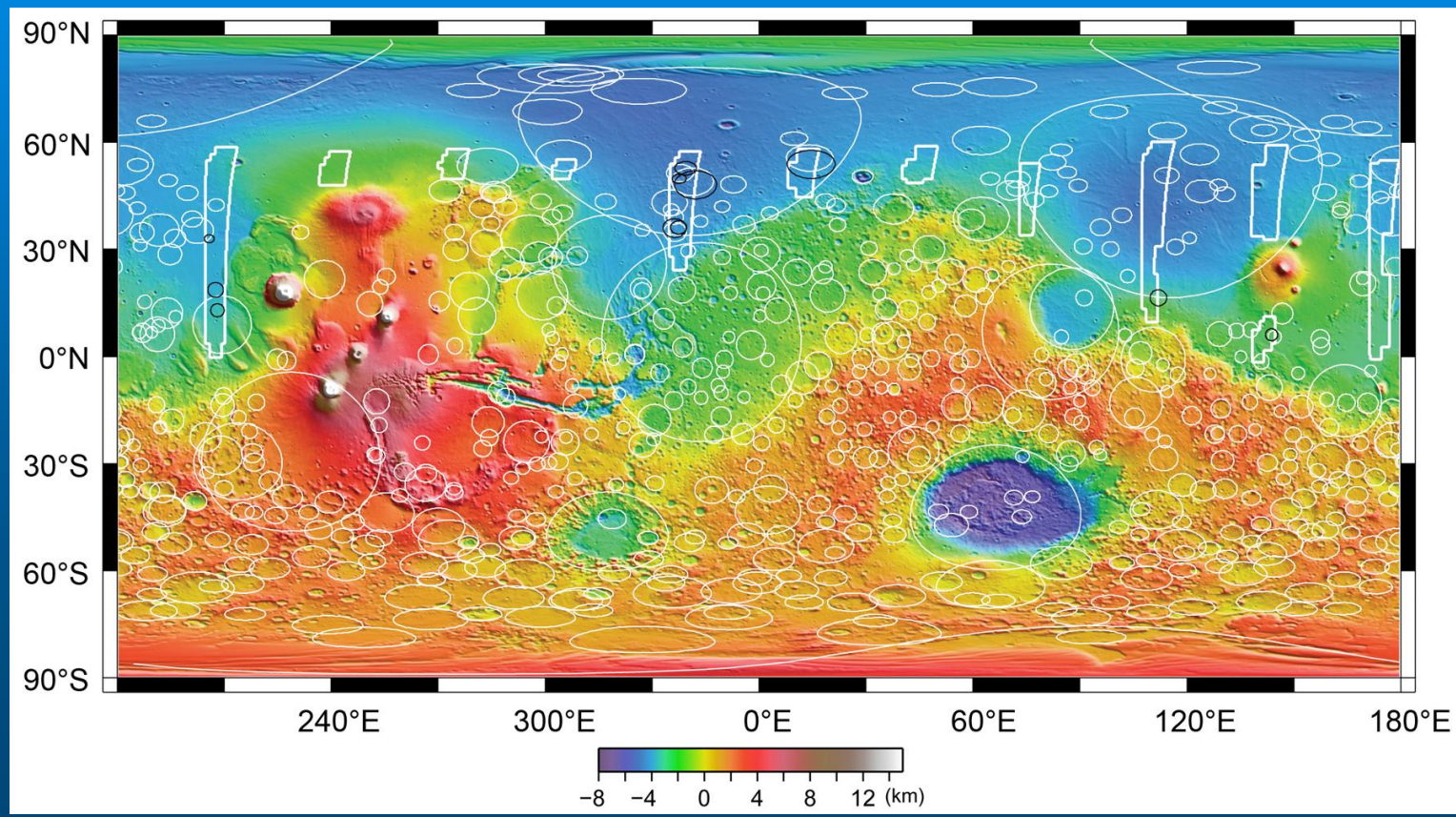
Mars Tectonics

- The elevation difference between the southern highlands and the northern lowlands – the crustal dichotomy – is comparable to that between Earth's continents and ocean floors.



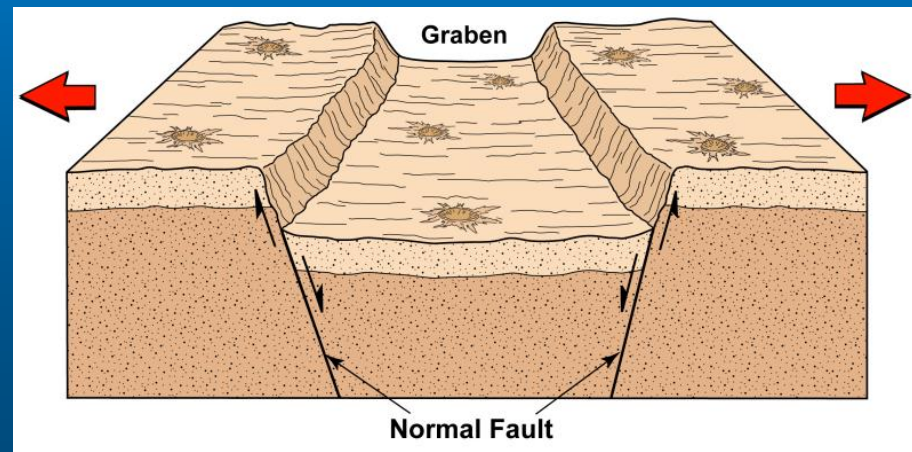
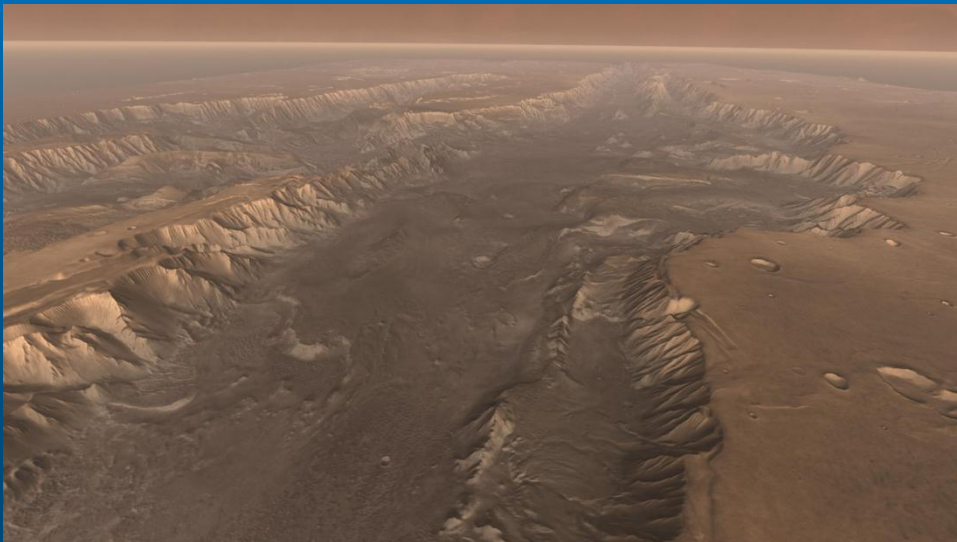
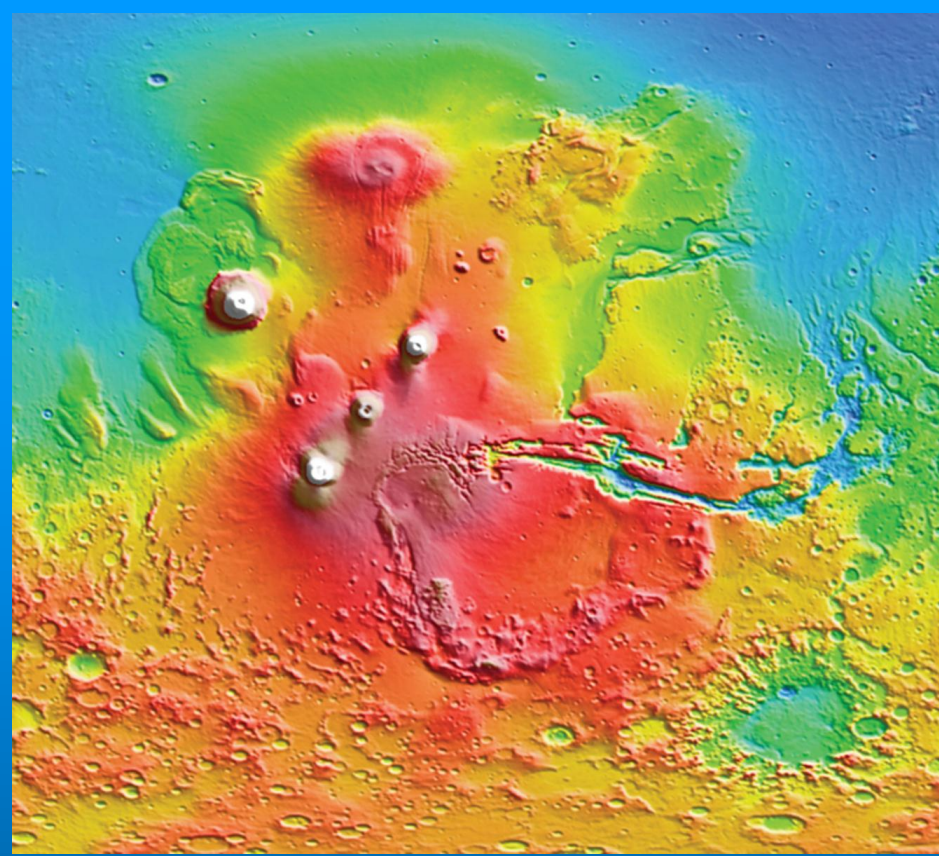
Mars Tectonics

- Population of quasi-circular depressions (QCDs) and MARSIS radar sounder detected buried basins indicates the northern lowlands crust is at least as old than the heavily cratered highlands crust.
- No significantly younger crust on Mars akin to Earth's oceanic crust.



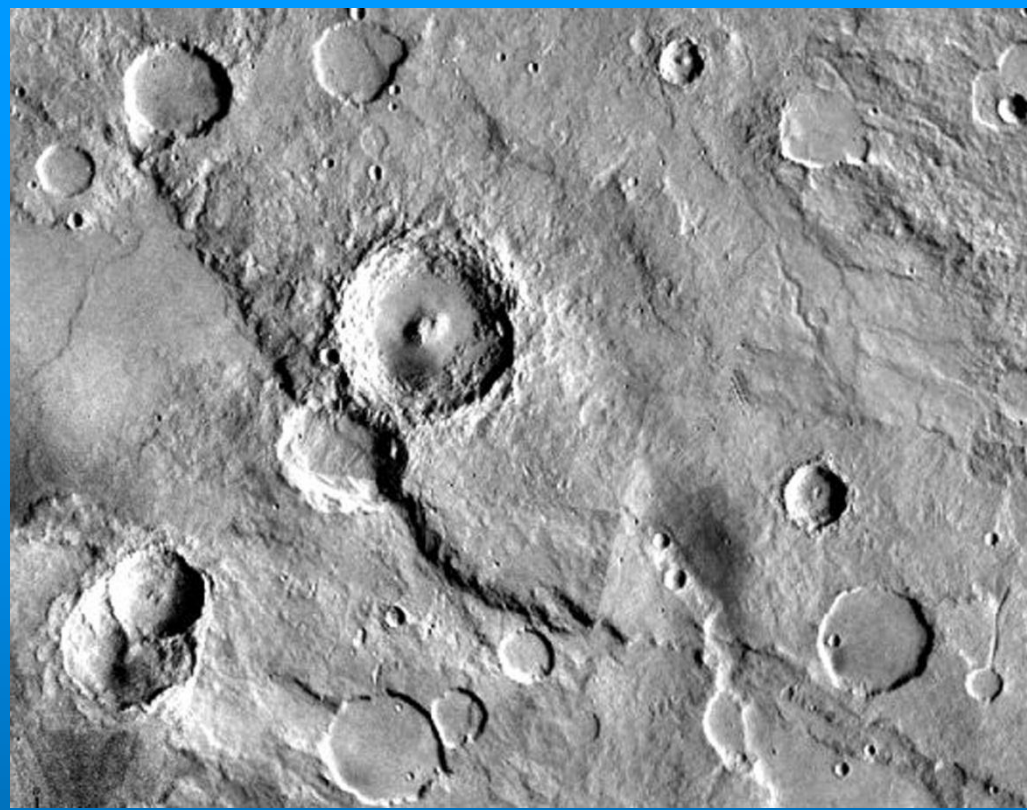
Tharsis Region

- The greatest concentration of tectonic landforms is associated with the Tharsis volcanic-tectonic province.
- The largest tectonic feature is Valles Marineris, a rift zone with troughs (graben) up to 10 km deep, hundreds of km wide, and several thousand km long.

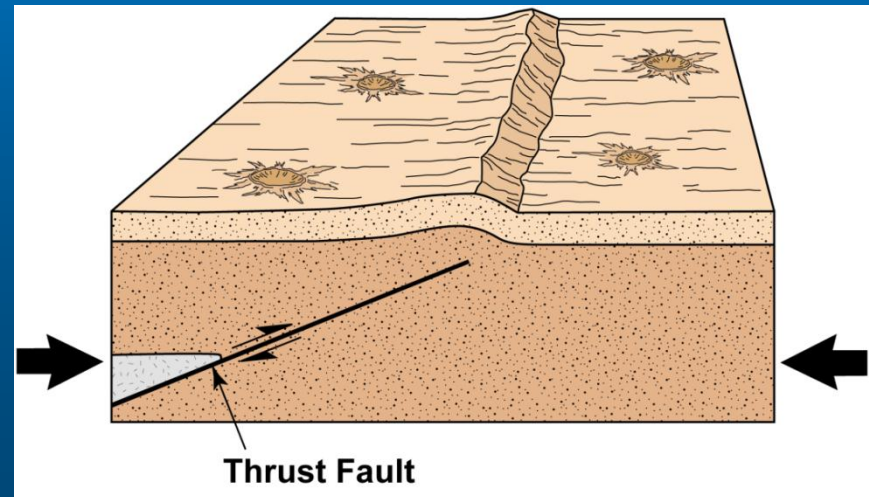
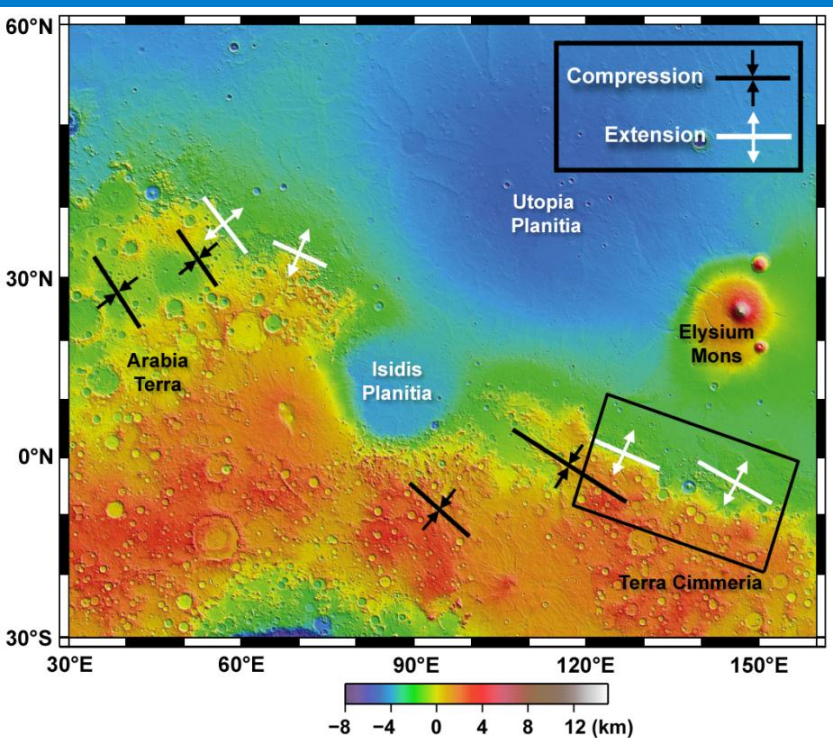


Lobate Scarps

- Like those found on Mercury, lobate scarps are found in the eastern hemisphere.
- Many, including Amenthes Rupes one of the largest on Mars, are found along the Dichotomy Boundary.

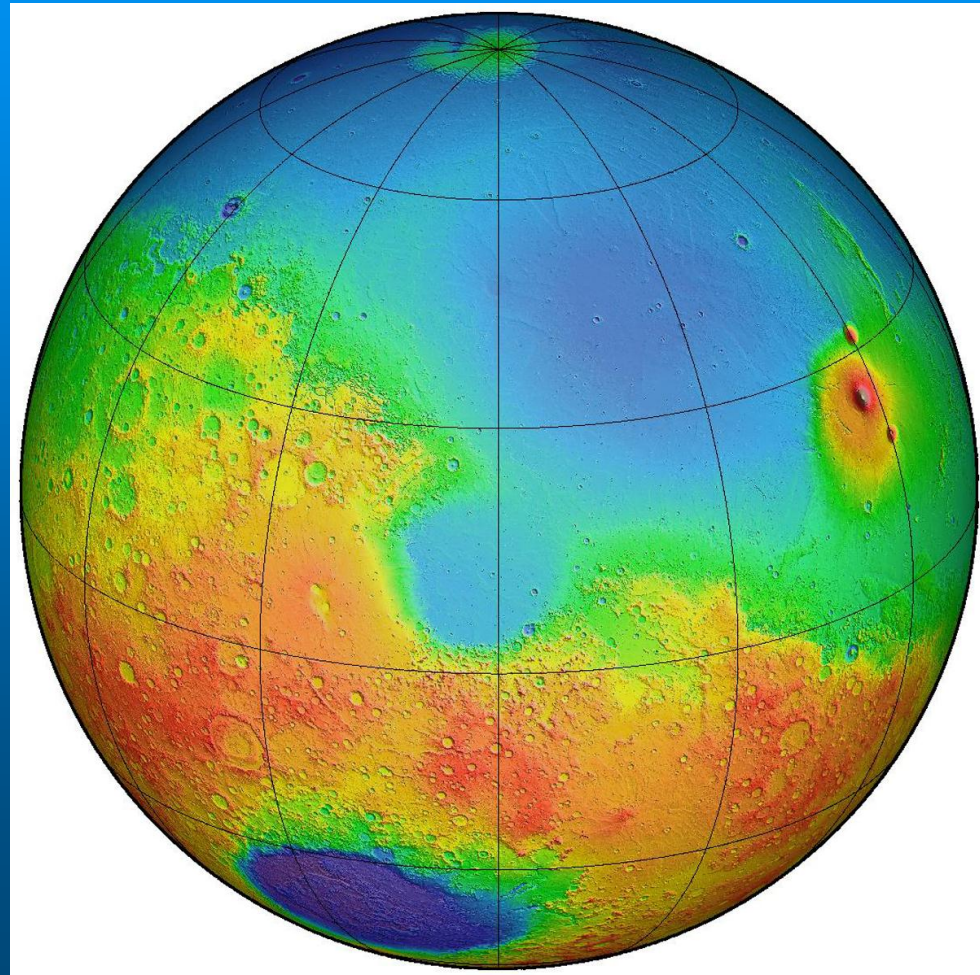


Amenthes Rupes



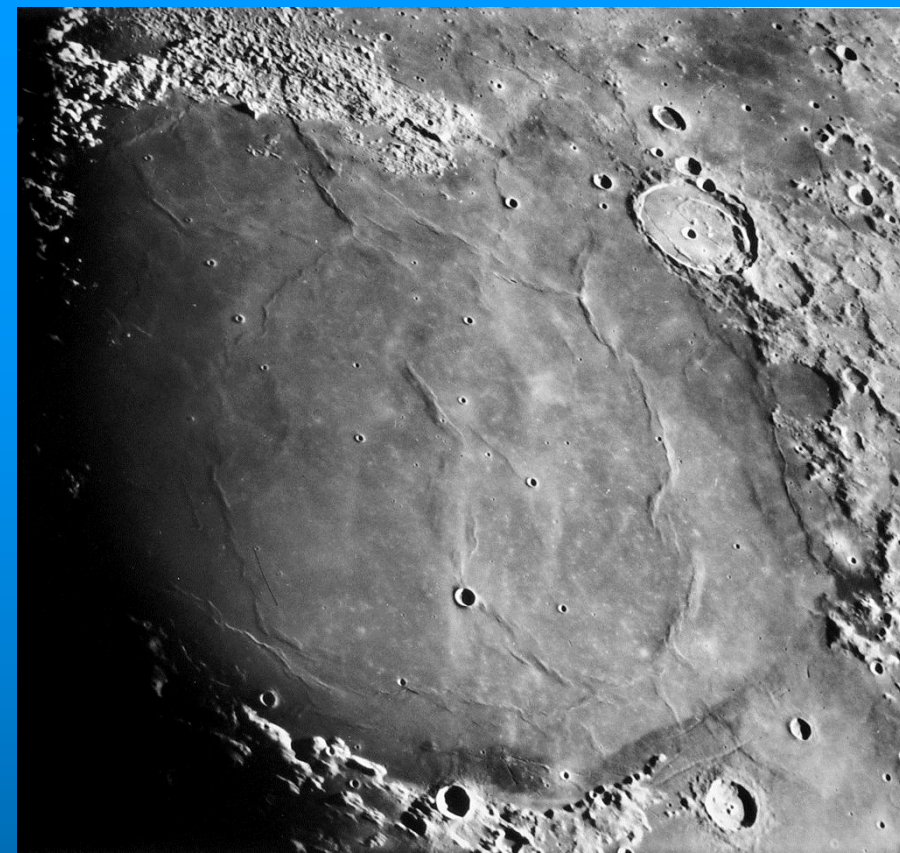
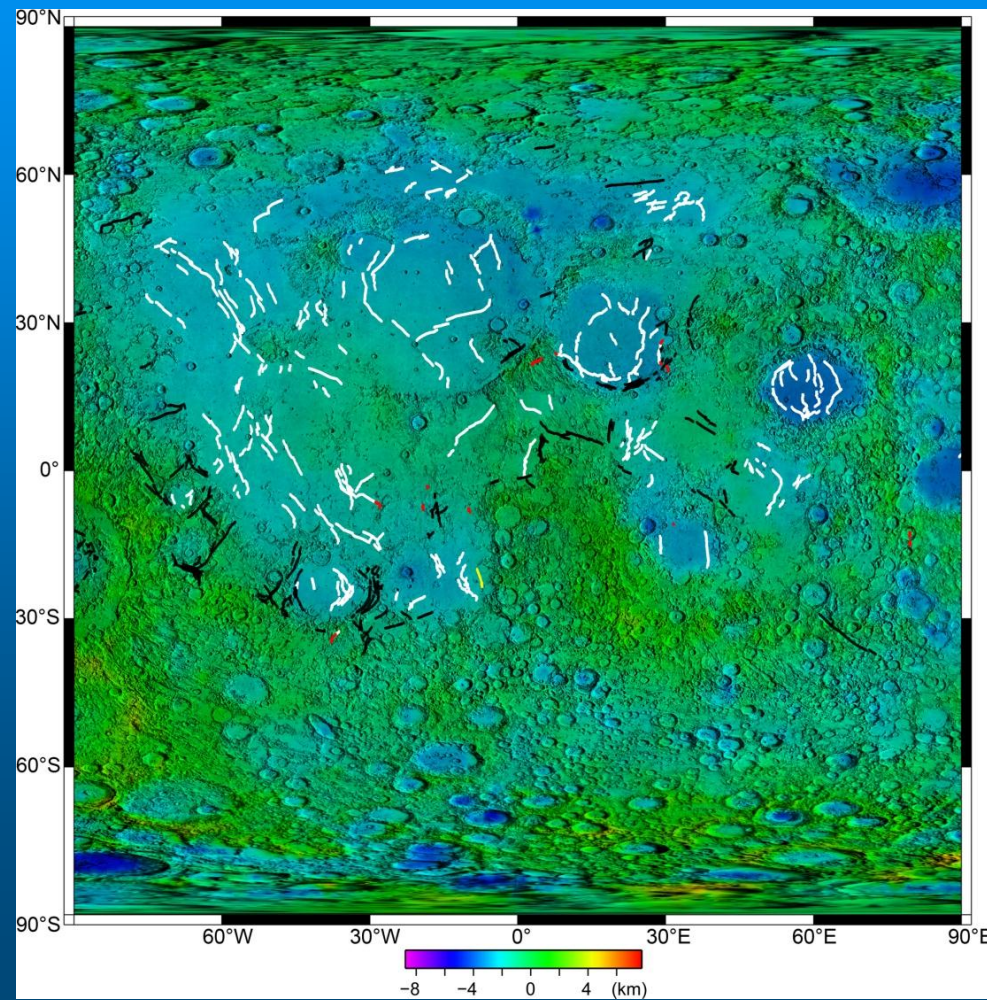
Origin of Crustal Dichotomy?

- Endogenic models for the dichotomy form the lowlands by subcrustal transport through mantle convection or a superplume, the generation of thinner crust by plate tectonics, rapid mantle overturn after formation of a global magma ocean, or an impact induced, local magma ocean.
- Exogenic or externally driven models ballistically remove crust from the northern lowlands by either one giant impact or multiple impacts.

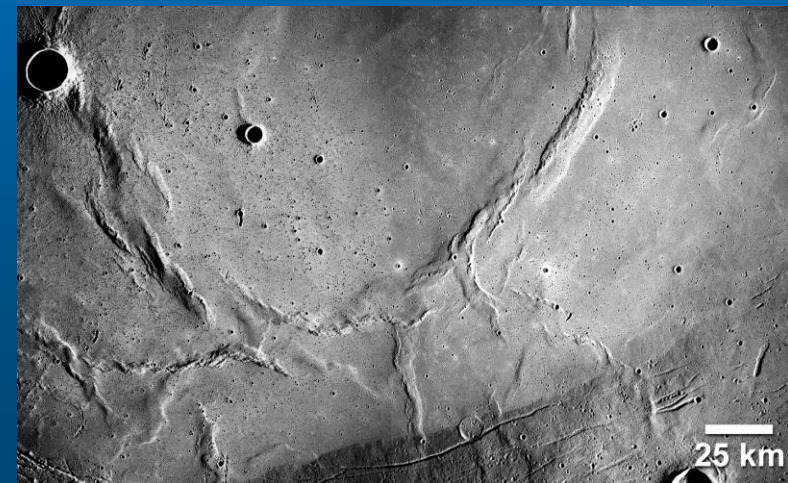


Tectonics of the Moon

- The vast majority of tectonic landforms are on the nearside and are basin localized.

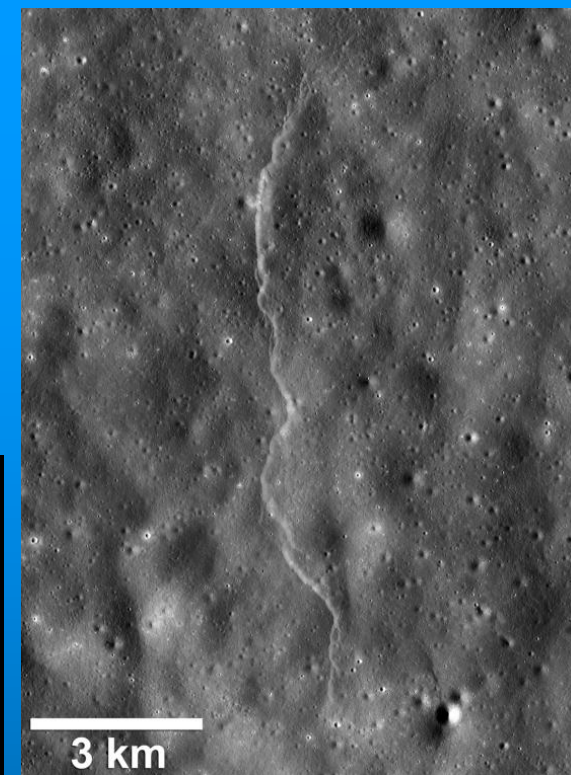
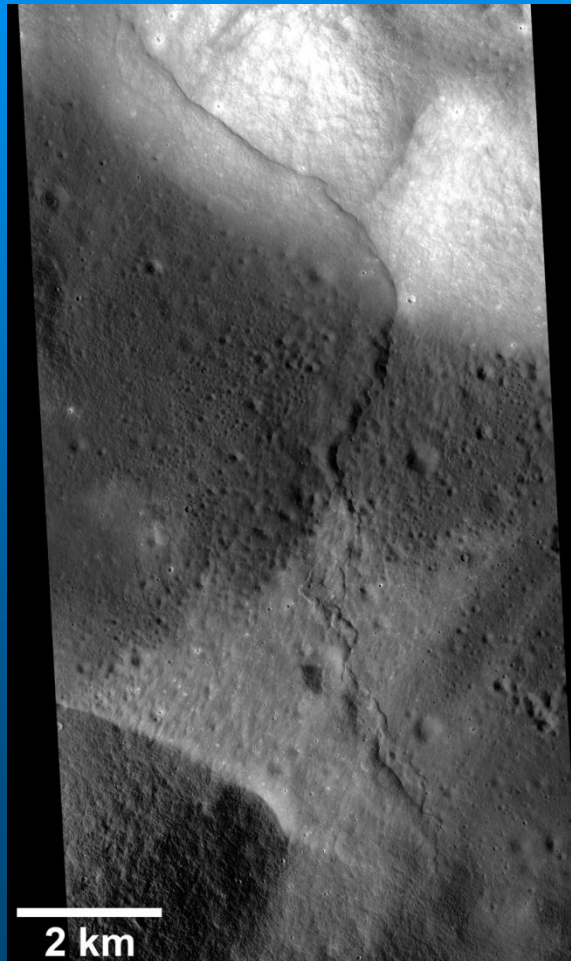
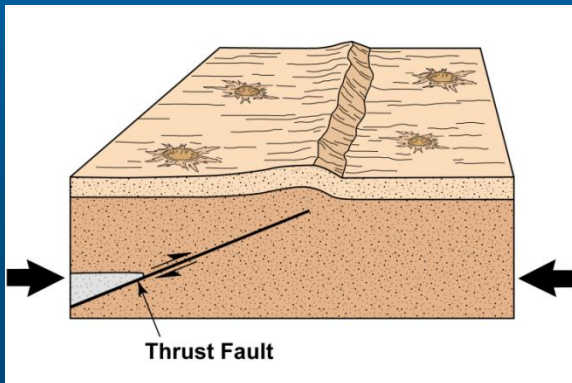


Mare Serenitatis



Lunar Lobate Scarps

- These are small-scale tectonic landforms and like their larger cousins on Mercury and Mars interpreted to be the surface expression of thrust faults.
- Their distribution is unknown because previously known examples could only be identified in Apollo Panoramic Camera images.

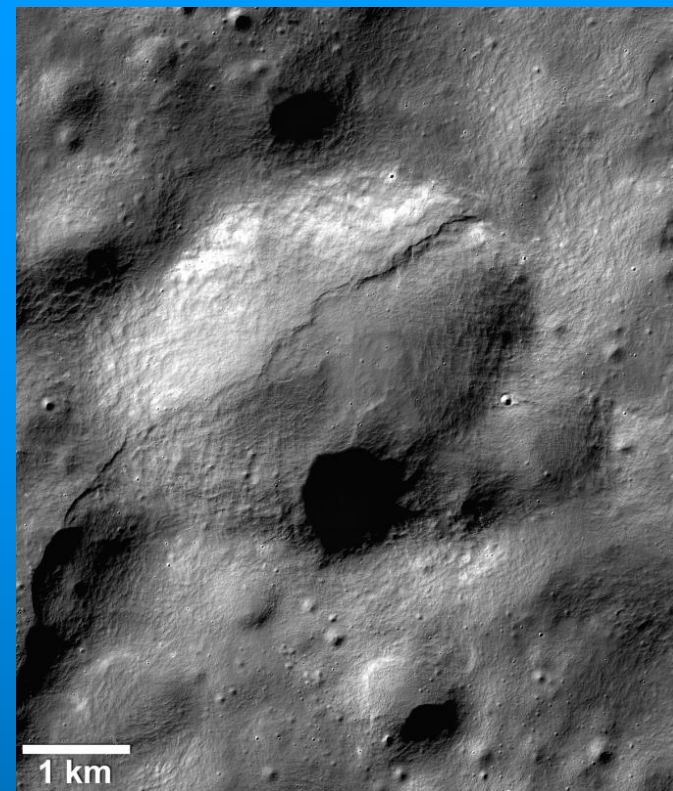
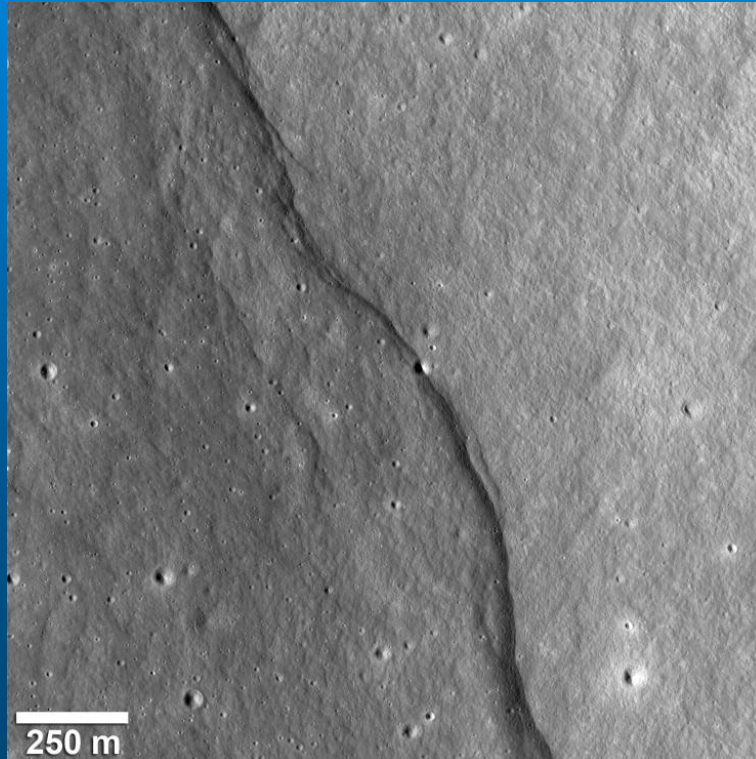


Lee-Lincoln

Lunar Lobate Scarps

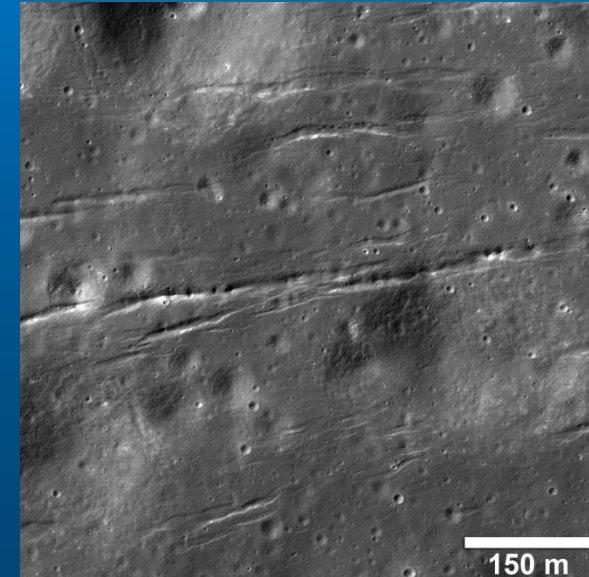
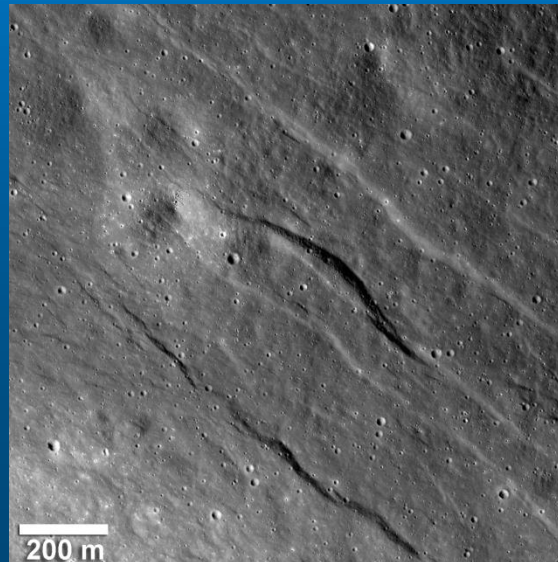
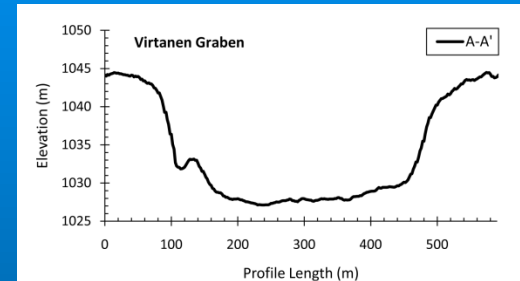
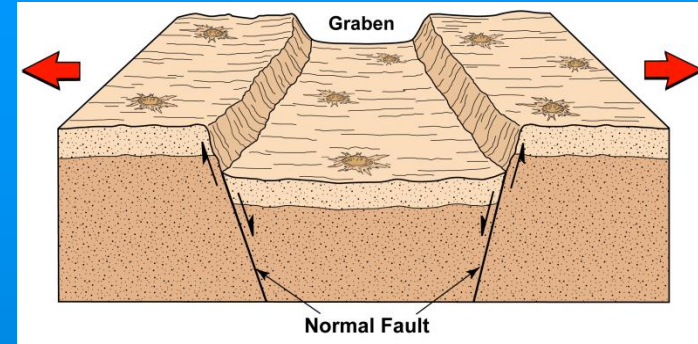
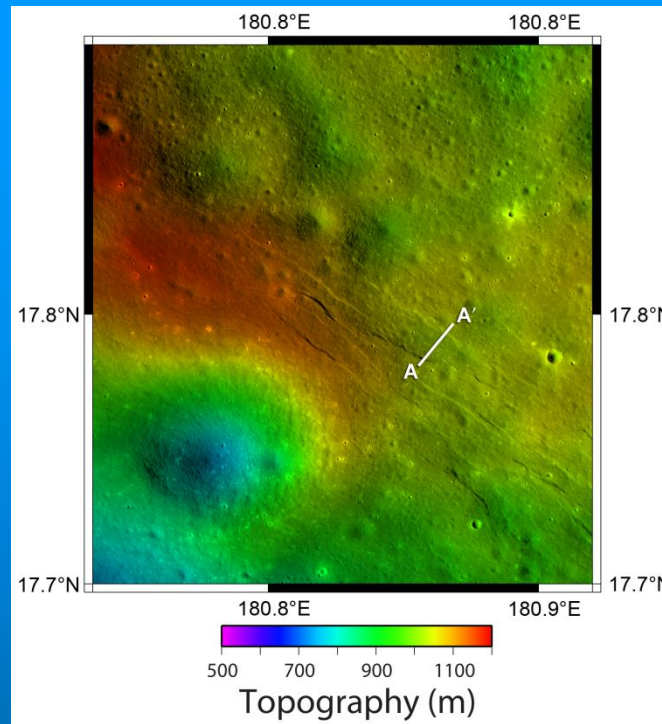
- To date more than 300 new lobate scarps and scarp clusters have been identified.

- These scarps are being found at all latitudes, on both the nearside and farside, and appear to be globally distributed.



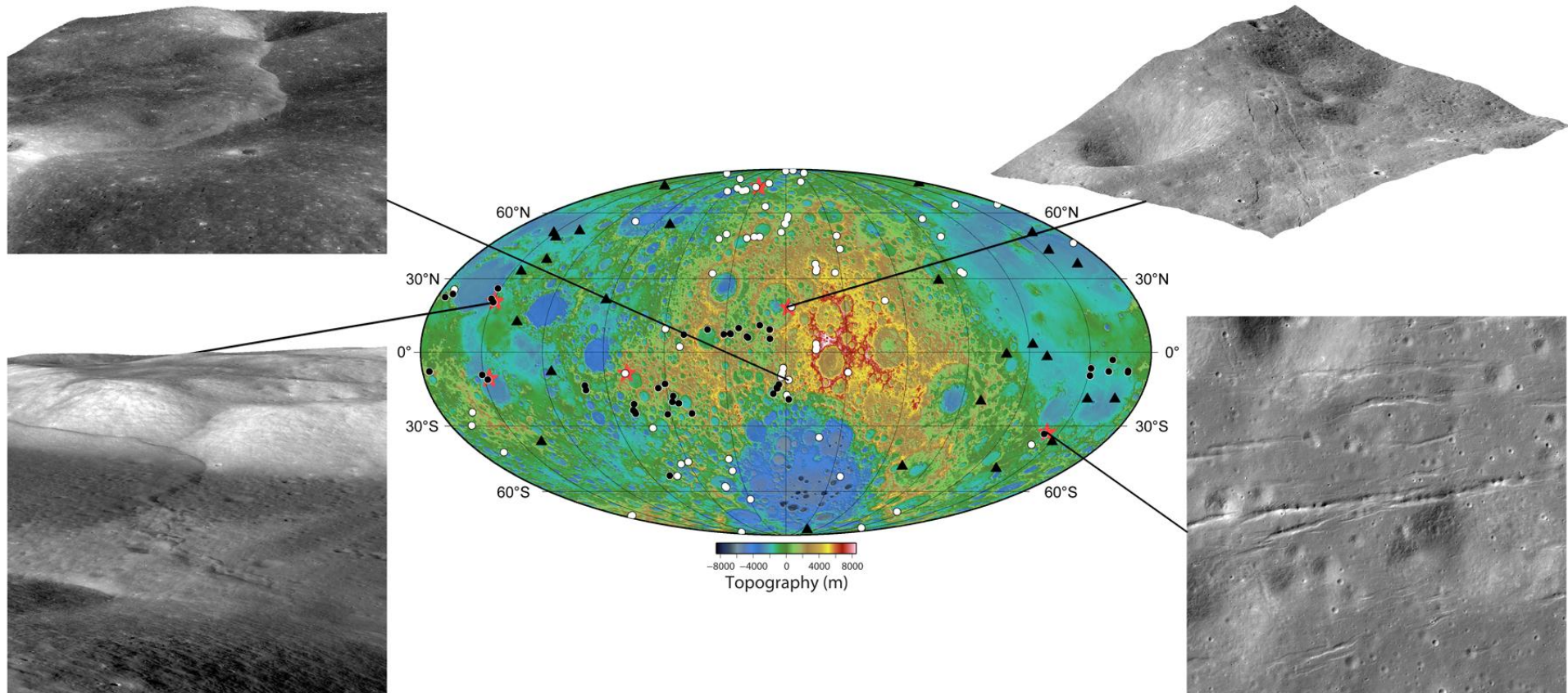
Young Lunar Graben

- Small-scale graben are also being found on the Moon.
- These are pristine appearing graben are estimated to be <50 Ma.
- Young thrust fault scarps and graben indicate recent tectonic activity on the Moon.



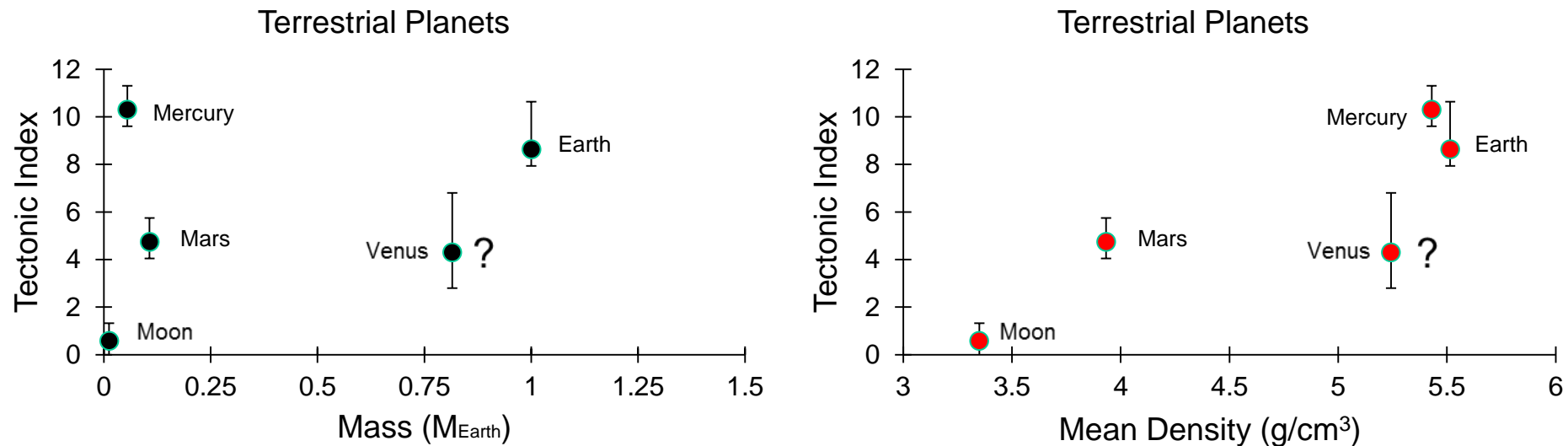
Young Tectonics on the Moon

- A globally distributed population of young thrust faults suggests a small amount of late-stage lunar contraction.
- A small amount of radial contraction does not support a thermal history involving total or nearly total melting of the early Moon.



Is plate tectonics an end member or outlier process?

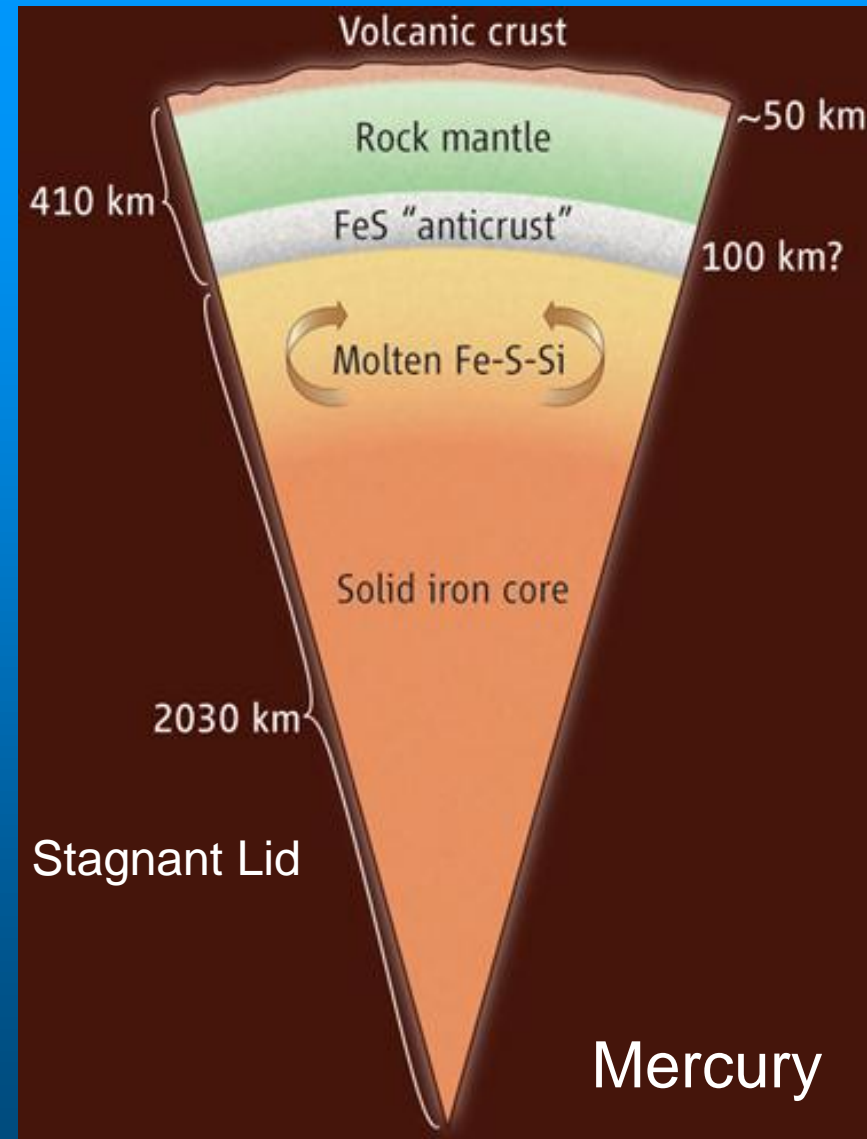
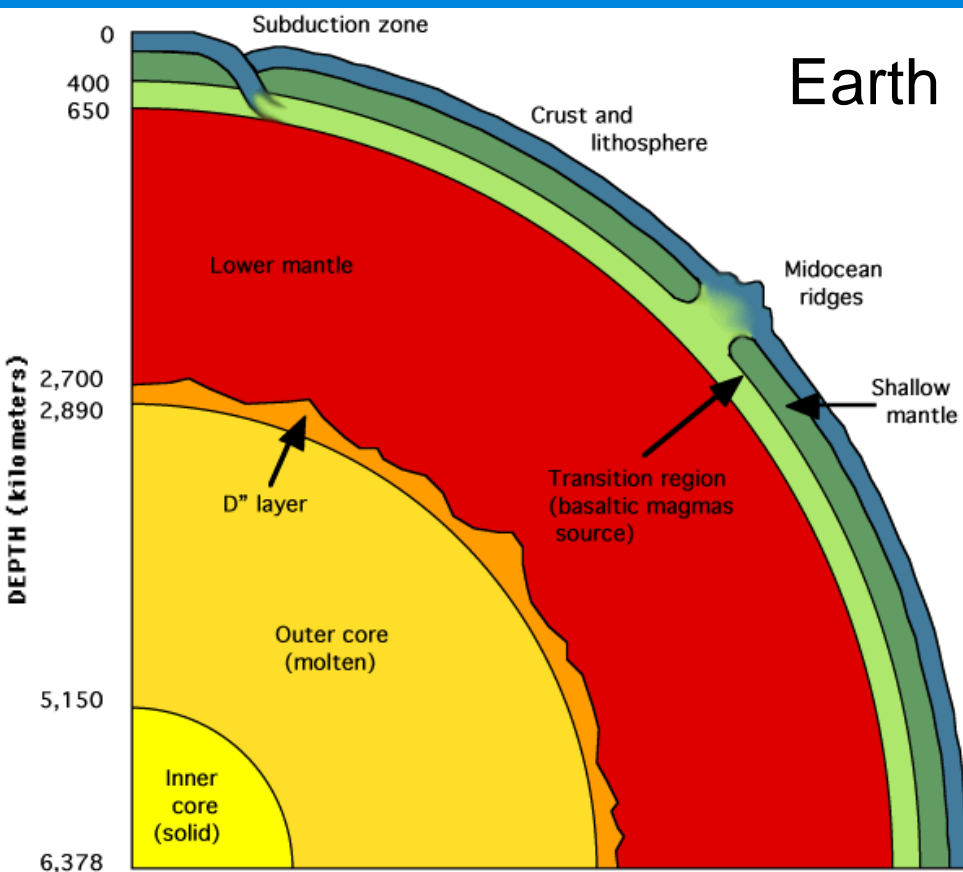
- The picture that has emerged is that each terrestrial planet in our solar system has a unique tectonic evolution.
- Tectonic systems on the terrestrial planets do not represent a spectrum with plate tectonics as a clear end member.
- The best case for end members may be the Moon and Mercury.



Plots show the ratio of estimated total lengths of major contractional tectonic landforms to mean radius as a function of mass and density.

Internal Structure of Earth and Mercury

- Stagnant lid versus plate tectonics.
- Range of models for Mercury's interior have the mantle not thicker than ~300 km. Challenge for mantle convection?





Questions to be considered

- Does plate tectonics scale to super Earths?
- How does rate of seismicity scale to super Earths?
- How do tidal force influence the evolution of super Earths?