A Survey of Impact Craters in the Inner Solar System: Perspectives from Earth*

William A. Ambrose[1]

Search and Discovery Article #70075 (2010)
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Abstract

The Earth shares a similar history of bombardment by asteroids and comets with other planets in the inner Solar System. Nevertheless, there are significant differences in the number, size, distribution, and degree of preservation of impact craters on Earth versus those on the other planets. Most craters in the Solar System are now widely accepted to be of impact origin. Twentieth-century studies of craters on Earth have documented impact-related structures such as overturned rim strata, hummocky ejecta, shattercones, shocked quartz grains, and diagnostic minerals such as coesite and stishovite that form in intensely overpressured environments. Unfortunately, there are <200 well-preserved impact craters on the Earth, owing to erosion and destruction from tectonic activity.

To fully understand crater size-morphology relationships as well as the history of bombardment in the inner Solar System, it is necessary to observe the crater population on relatively airless bodies such as the Moon and Mercury which preserve a nearly complete record of bombardment. In contrast to the Earth, which has few ancient terranes preserved, >90% of the Moon's surface is older than 3 billion years (Ga). The Moon has several large impact basins older than 3.8 Ga, the result of intense bombardment from large asteroids. Although the Earth is lacking in large craters and impact basins, it is estimated that before 3.8 Ga the Earth had >22,000 craters greater than 20 km in diameter, ~40 basins at 1,000 km across, and may have had some basins up to 5,000 km across. Each of the other planets in the inner solar system - Mercury, Venus, and Mars - feature different crater populations as a result of proximity to the Asteroid Belt, atmospheric attenuation and destruction of small impactors (Venus), or in the case of Mars, crater modification from eolian, periglacial, fluvial, and igneous processes.

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William A. Ambrose

2010 Annual AAPG Convention
New Orleans, LA
April 13, 2010

Bureau of Economic Geology

John A. and Katherine G. Jackson
School of Geosciences
The University of Texas at Austin

Steven Hobbs

Outline

Inner Solar System

Crater-Morphology Continuum

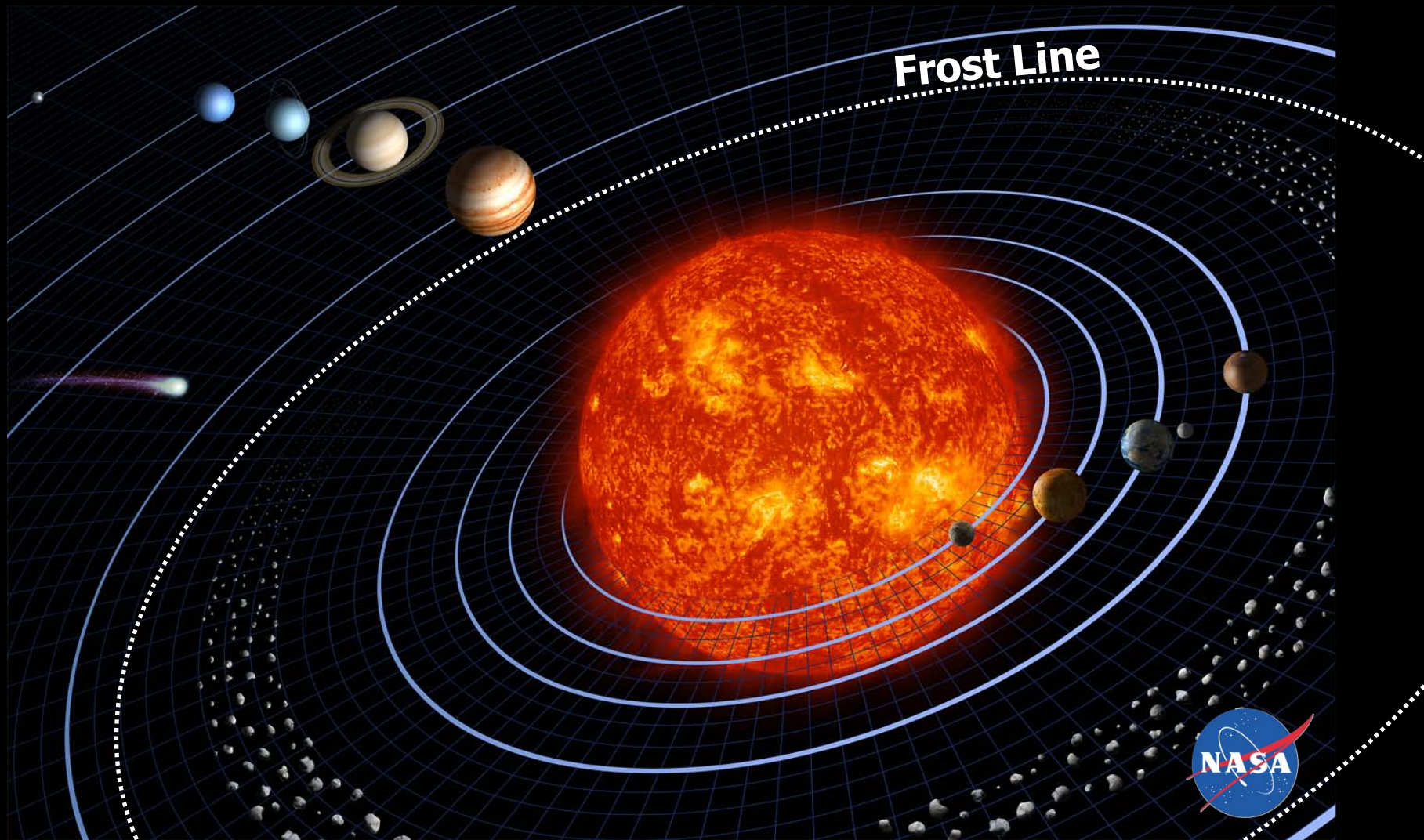
Moon and Mercury

Venus, Earth, and Mars

Basin-Antipodal Effects

Presentation authorized by the Director, Bureau of Economic Geology,
The University of Texas at Austin

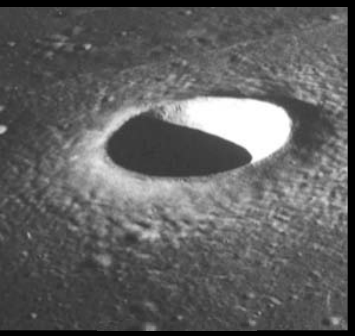
Solar System: Current Configuration



Crater-Morphology Continuum

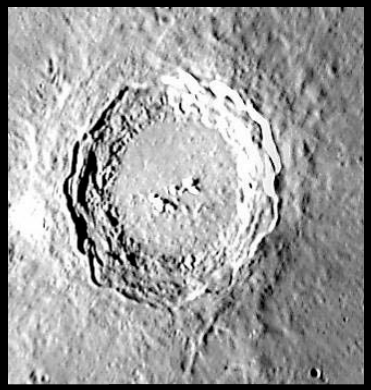
Moon: Diameter in km

Simple	Small Complex	Large Complex	Small Basins	Large Basins
Moltke	Euler	Copernicus	Schrödinger	Orientale Basin



10

25



93

320

930

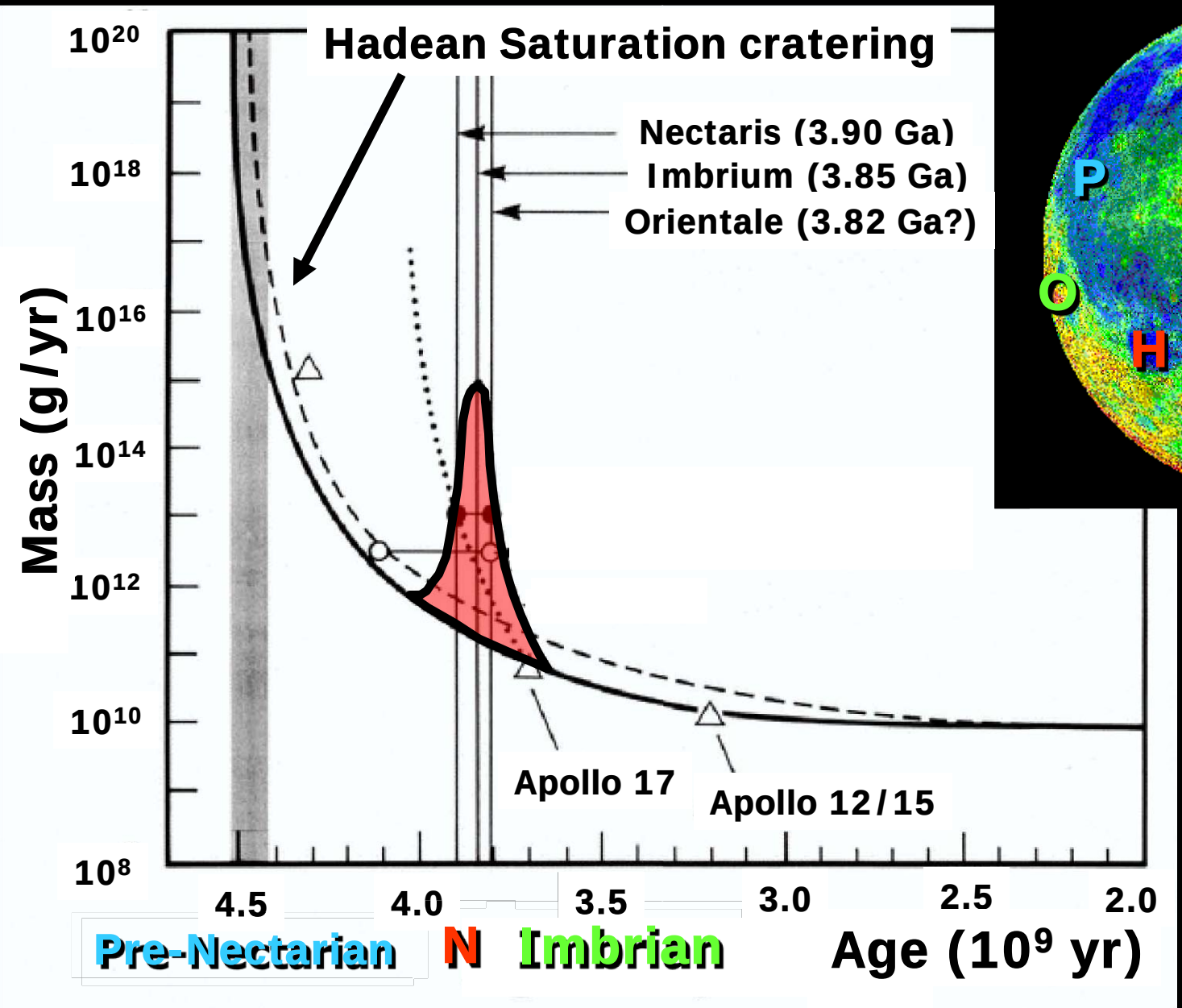
Moon

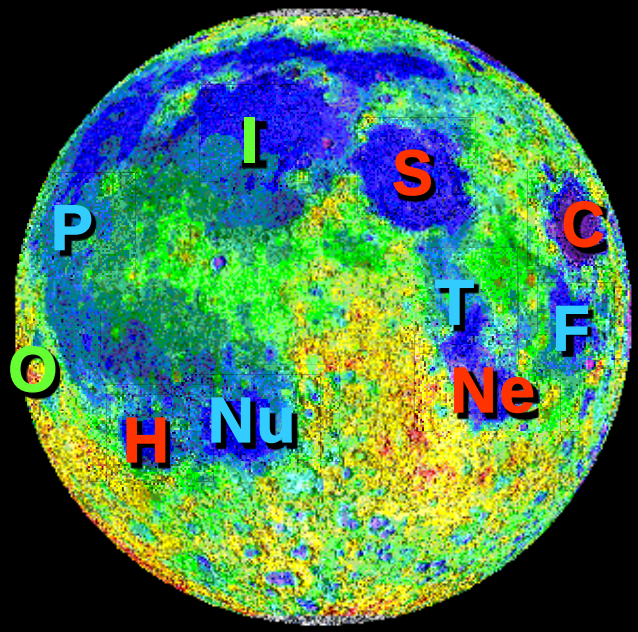
Galileo photograph

Mercury

Mariner 10 photograph

Moon: Late Heavy Bombardment





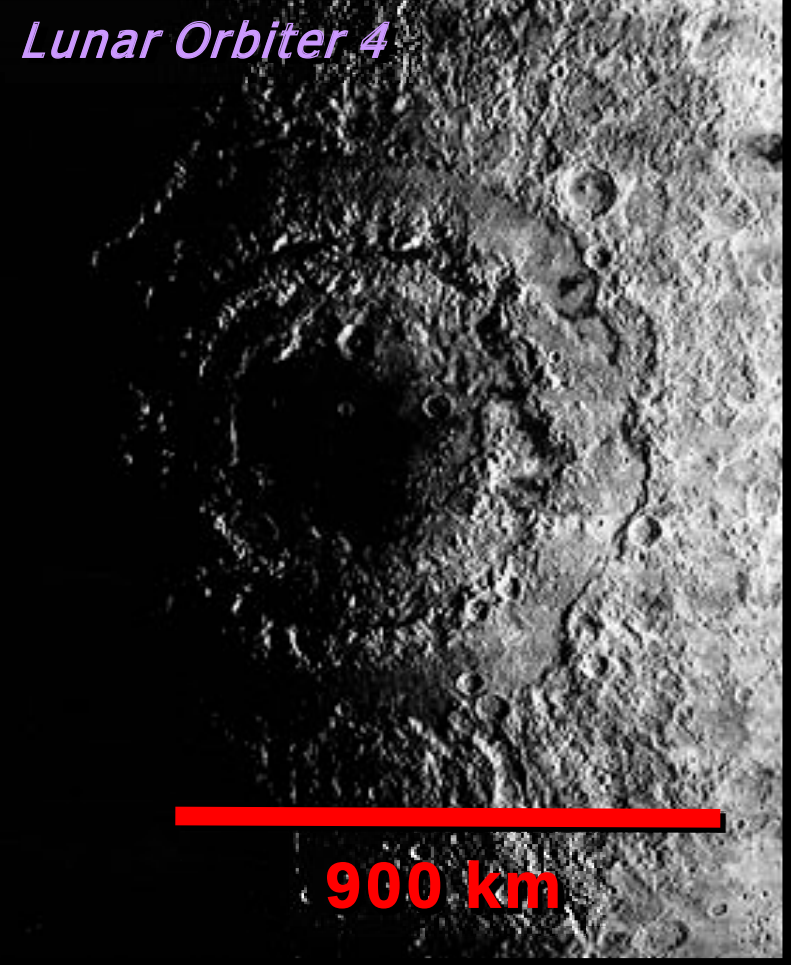
Imbrian

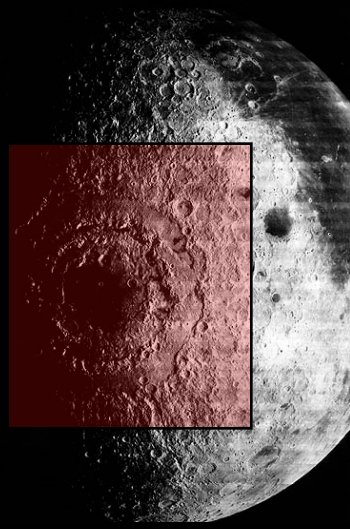
Nectarian

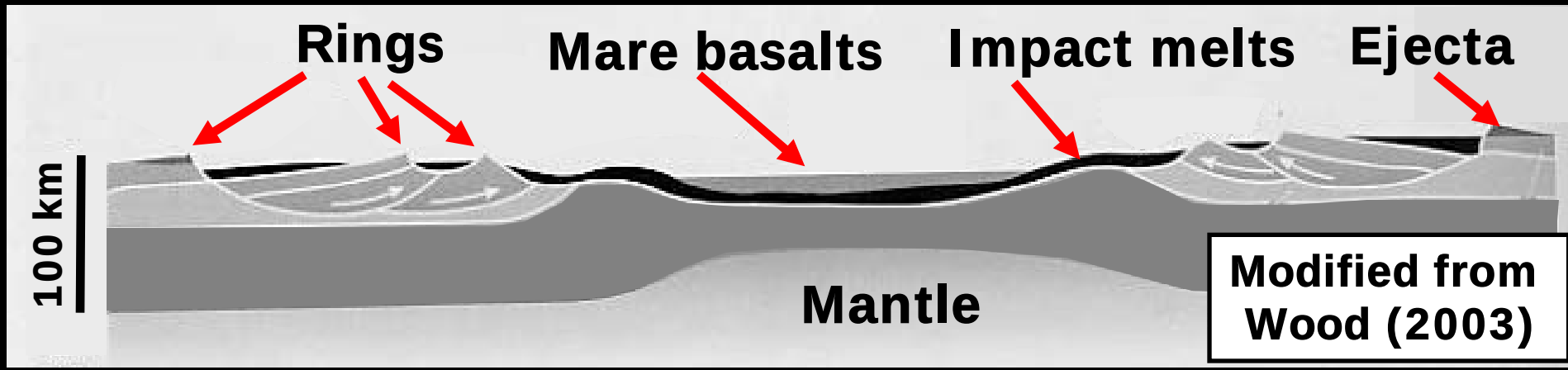
Pre-Nectarian

Haskin, Cohen et al.

Orientale Basin

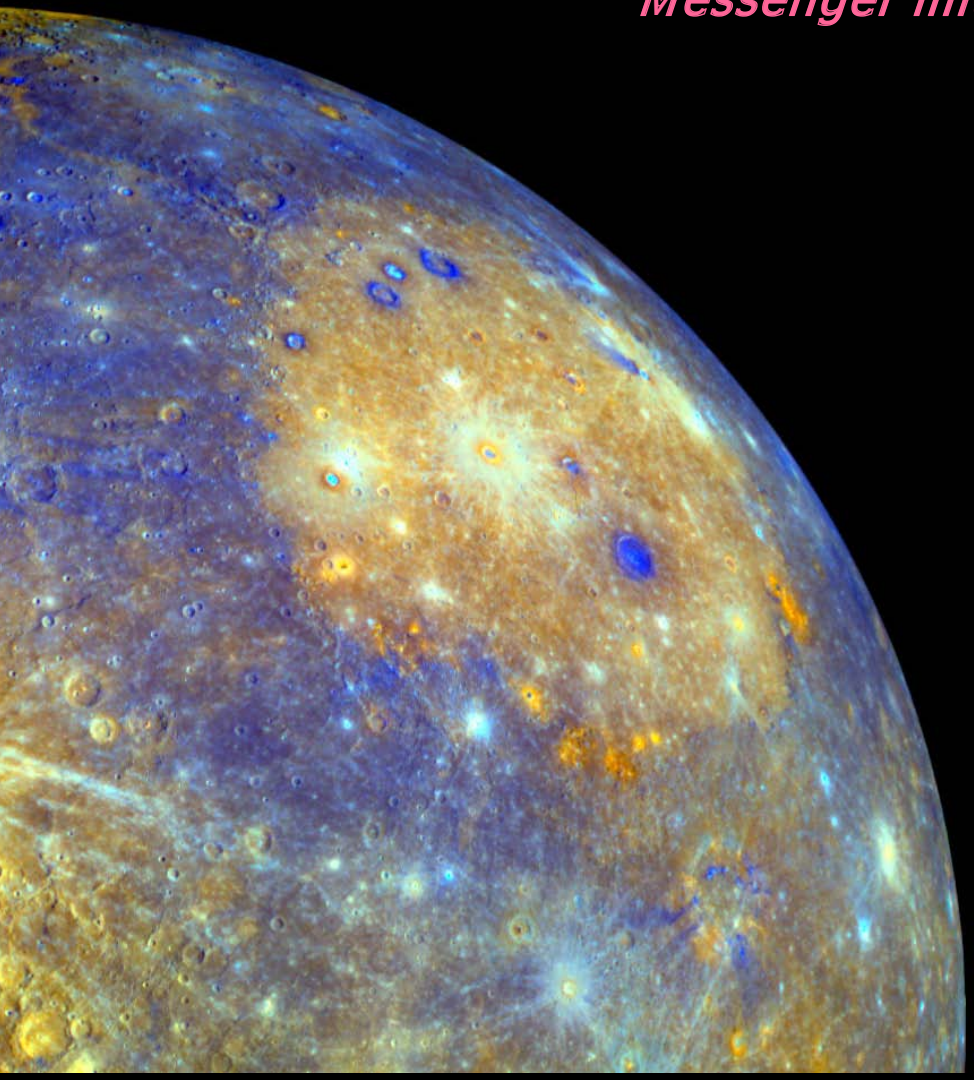




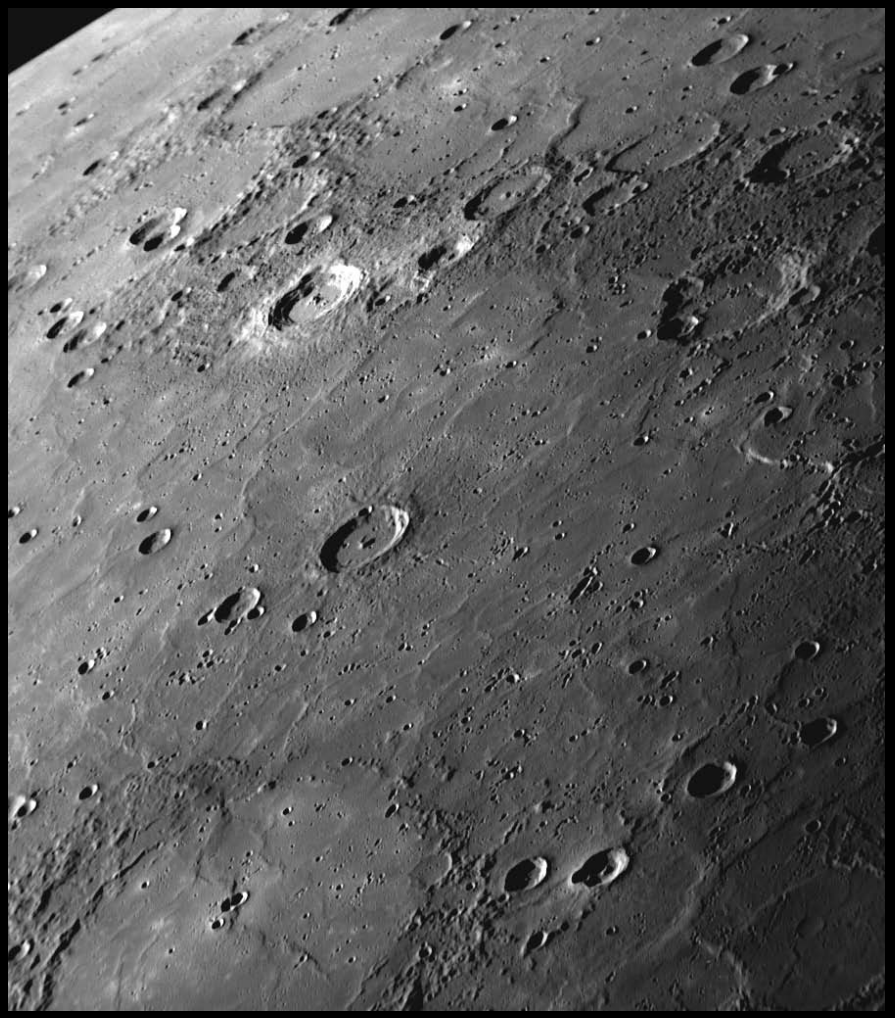


Mercury: Basins and Volcanic Plains

Messenger images



Caloris Basin
(1,550 km diameter)



200 km

Outline

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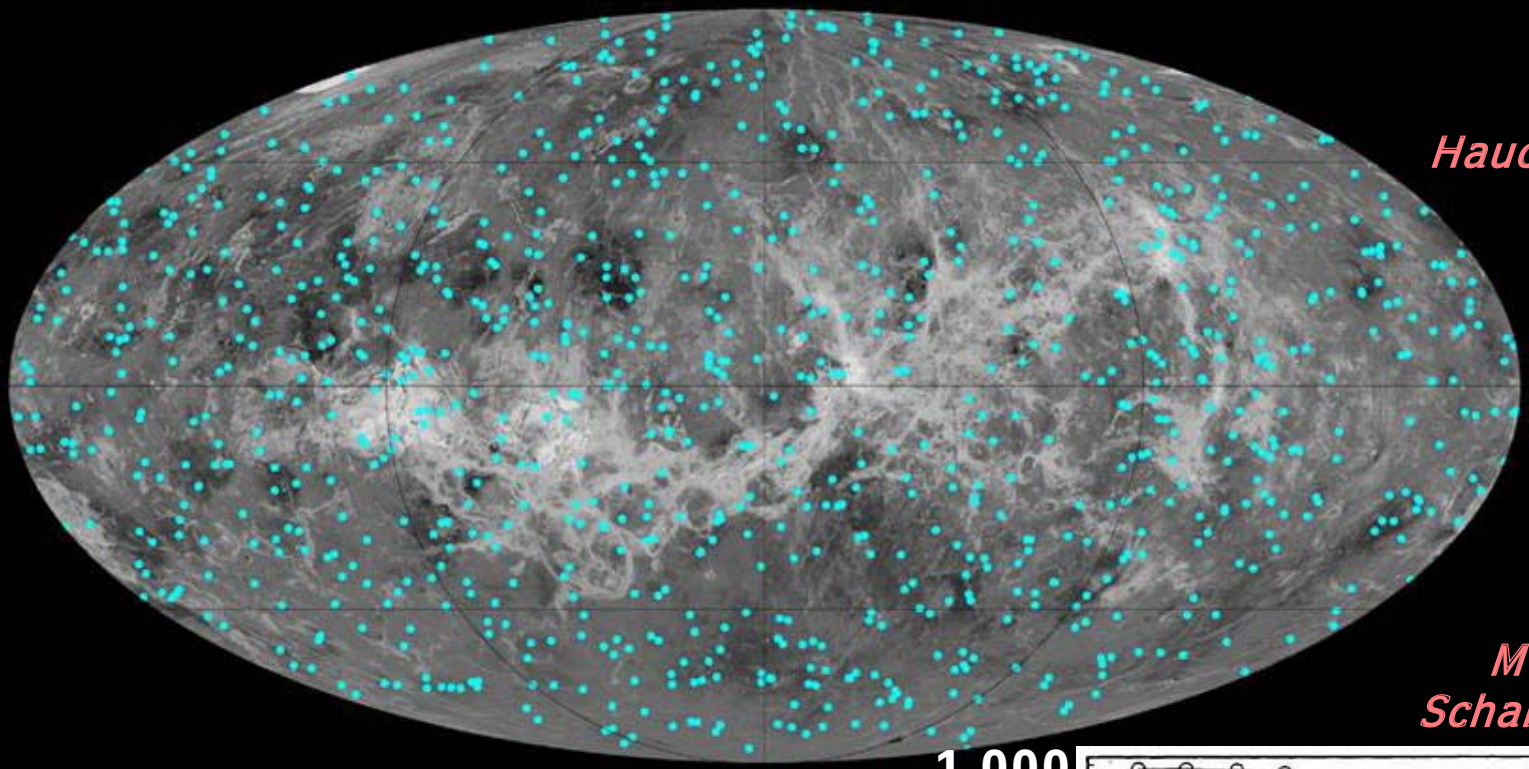
Basin-Antipodal Effects

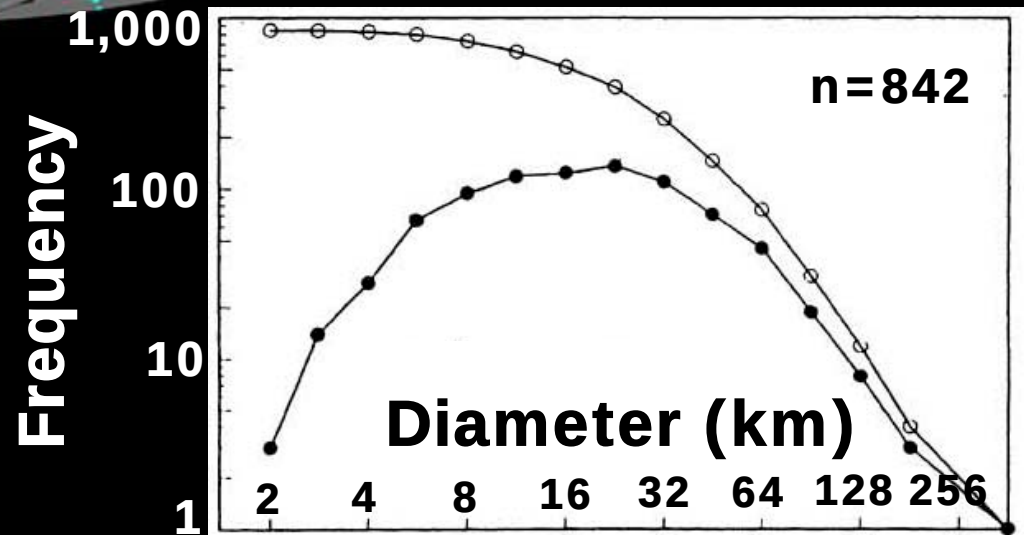
Venus: Impact Craters



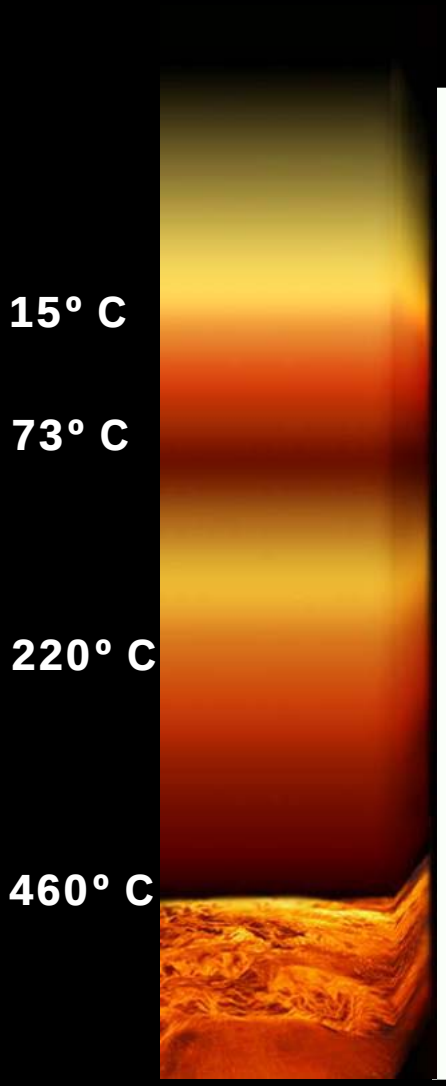
Hauck (1998)

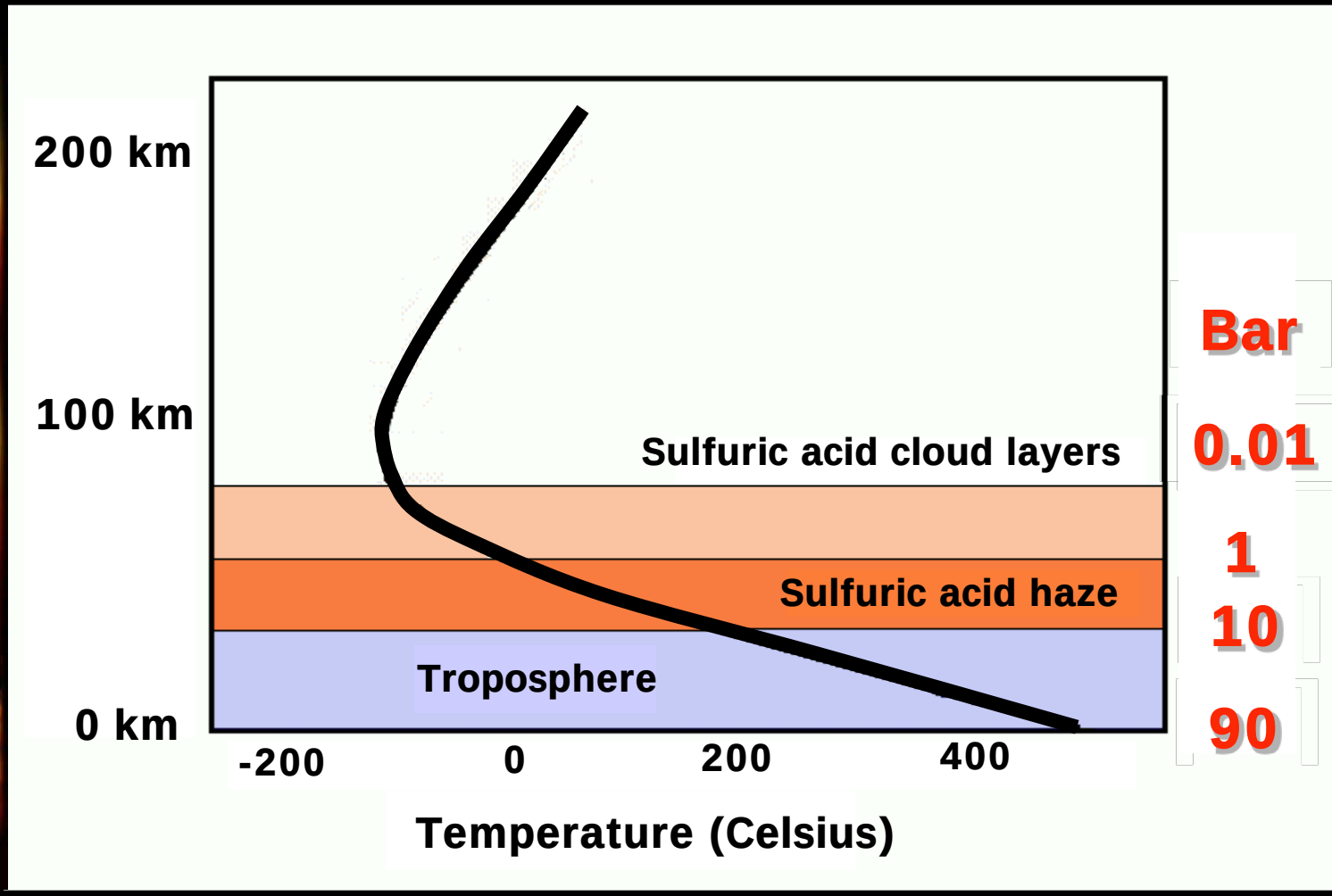
Modified from Schaber et al. (1992)

Impact Crater Size Distribution



Venus: Atmospheric Profile

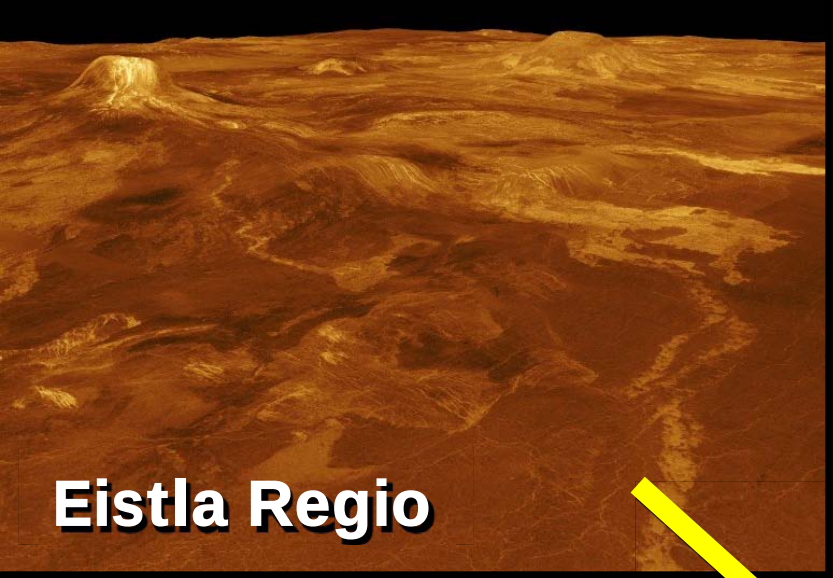




UCAR and Wikipedia

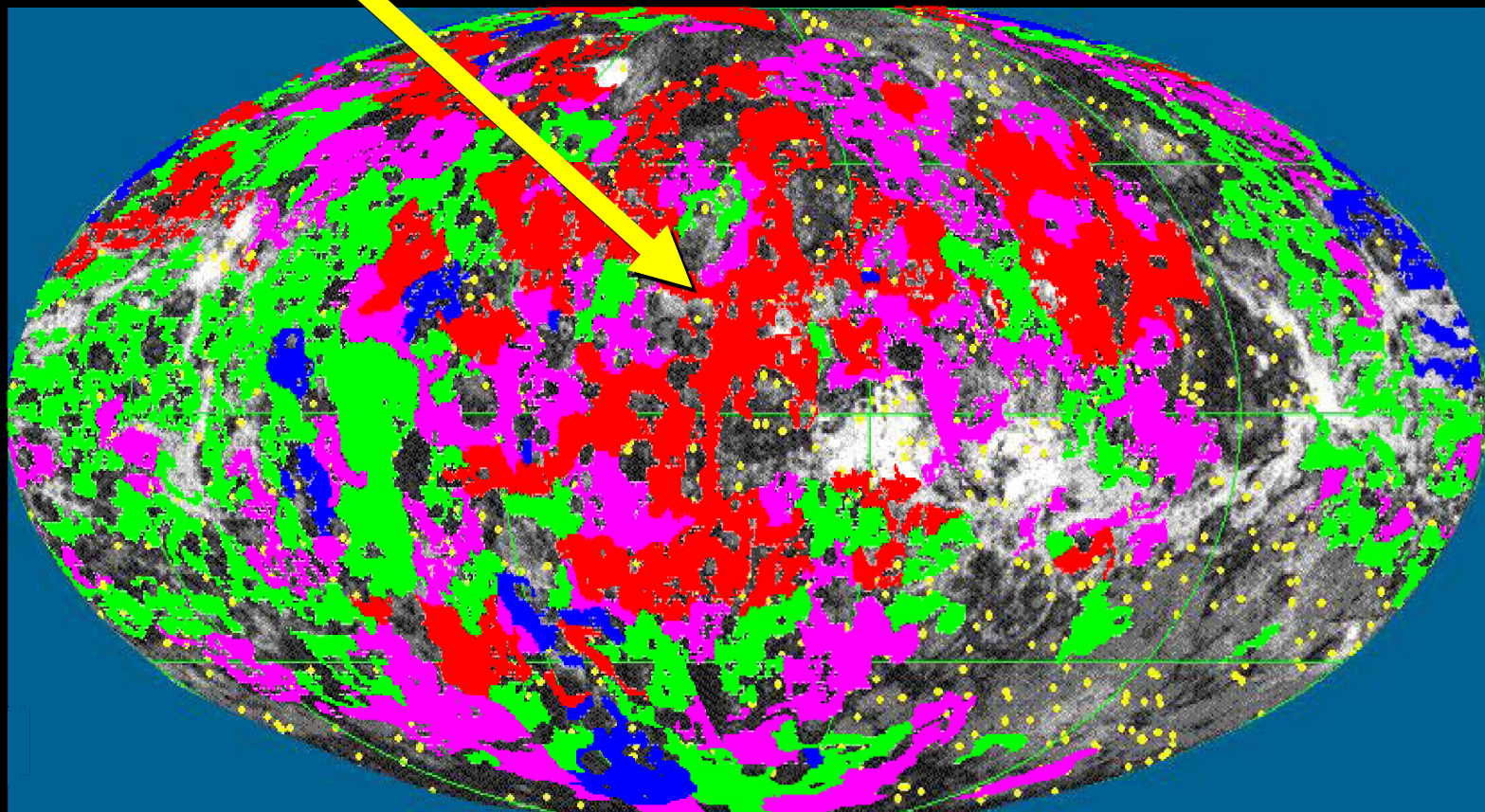
Venus: Plains Units

Ages: 590 to 980 Ma



Eistla Regio

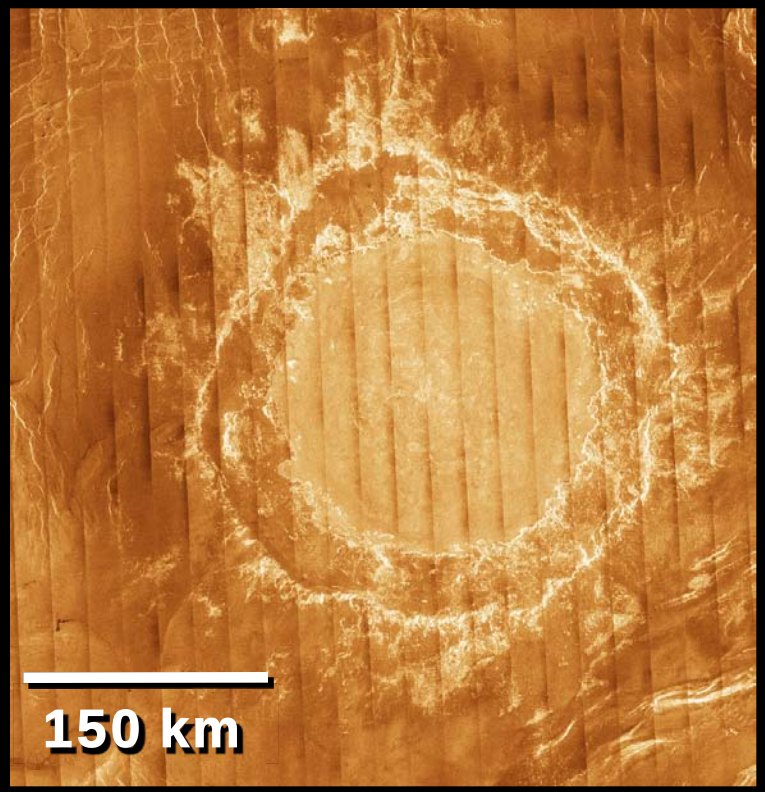
● **Impact Crater**

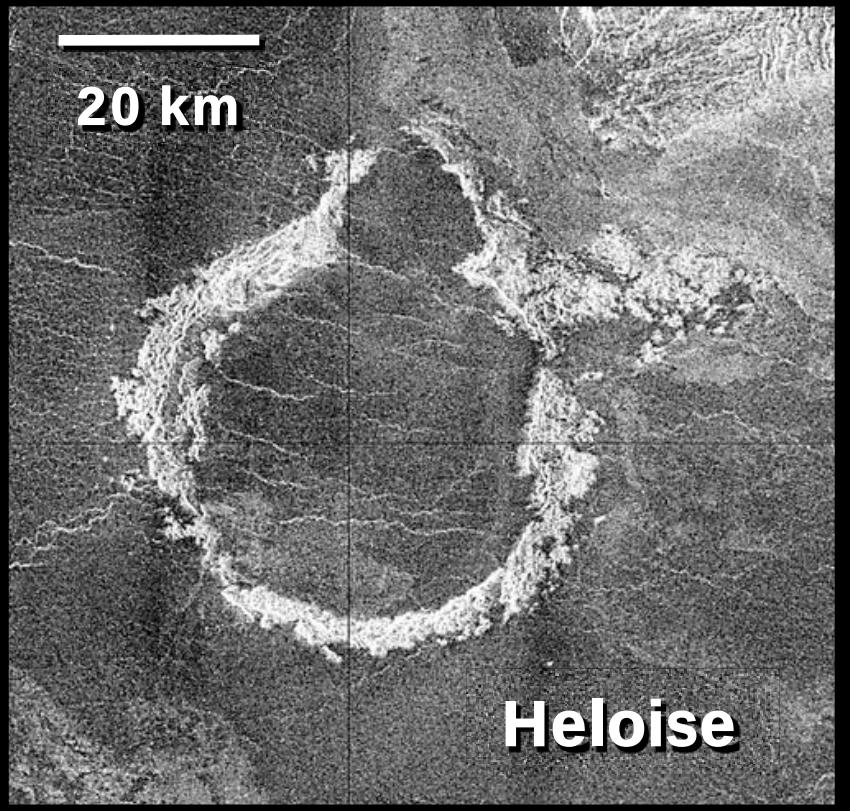


Hauck (1998)

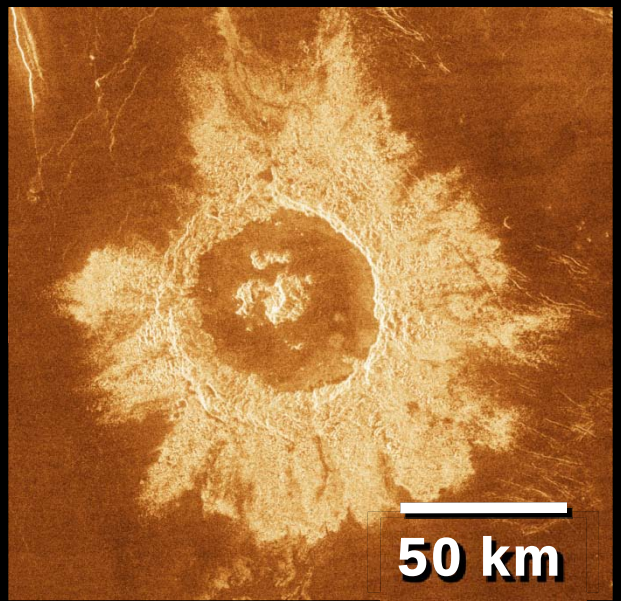
Venus: Impact Craters

Mead





Danilova



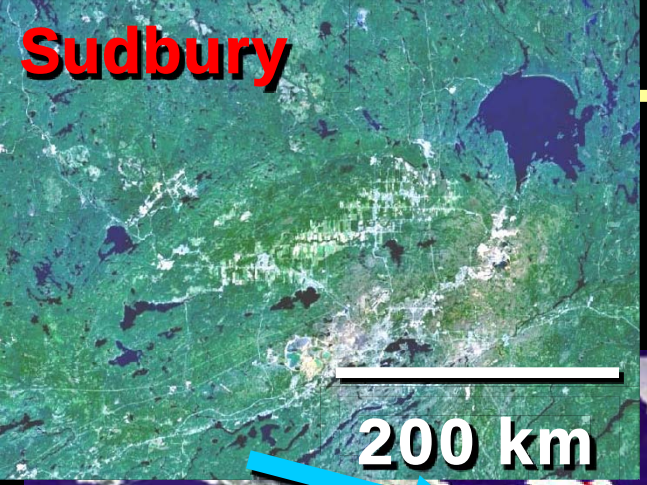
Magellan radar images

Earth's Hadean Eon: 3.8 – 4.56 Ga

Steven Hobbs

- *Early bombardment phase*
- *Saturation cratering*
  - *>22,000 craters >20 km*
  - *~40 basins at 1,000 km*
  - *some basins: 5,000 km*
- *Earth crustal formation*
  - *possible water, clays*
- *3.8 Ga: end of late bombardment phase: earliest recorded life*

th Impact Sites



Space Imagery Center: *http://www.lpl.arizona.edu/SIC/*

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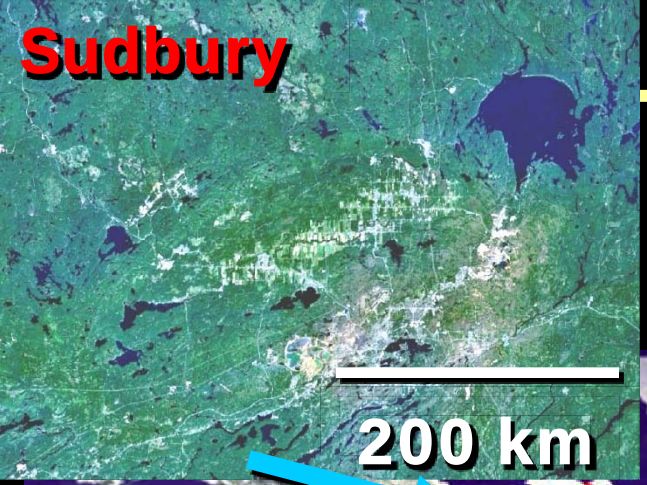

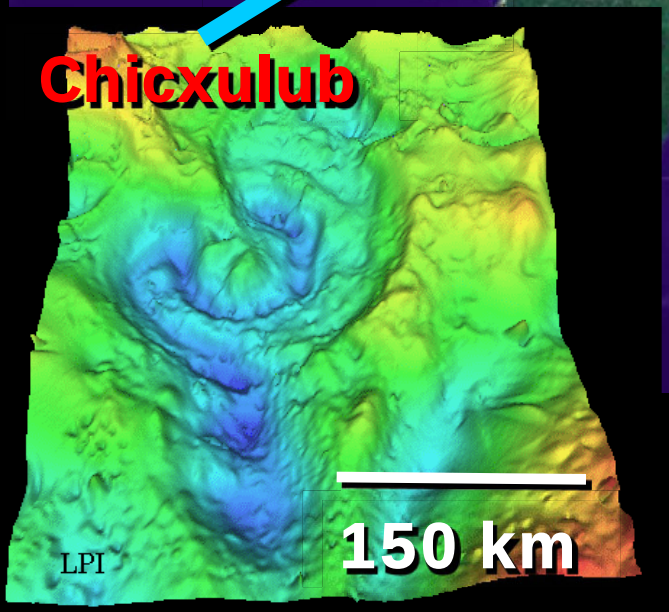

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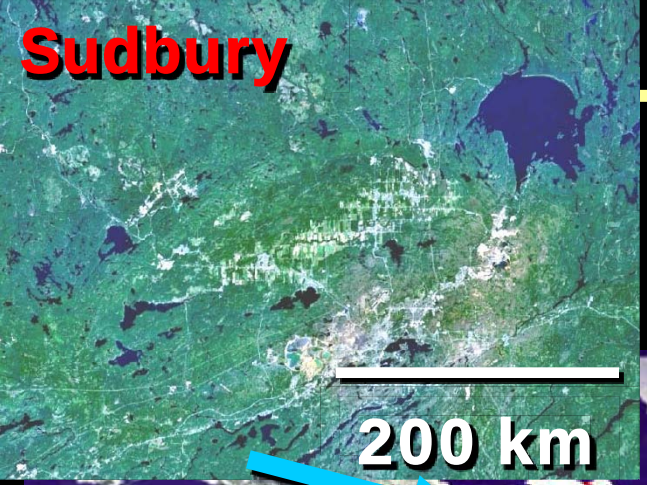
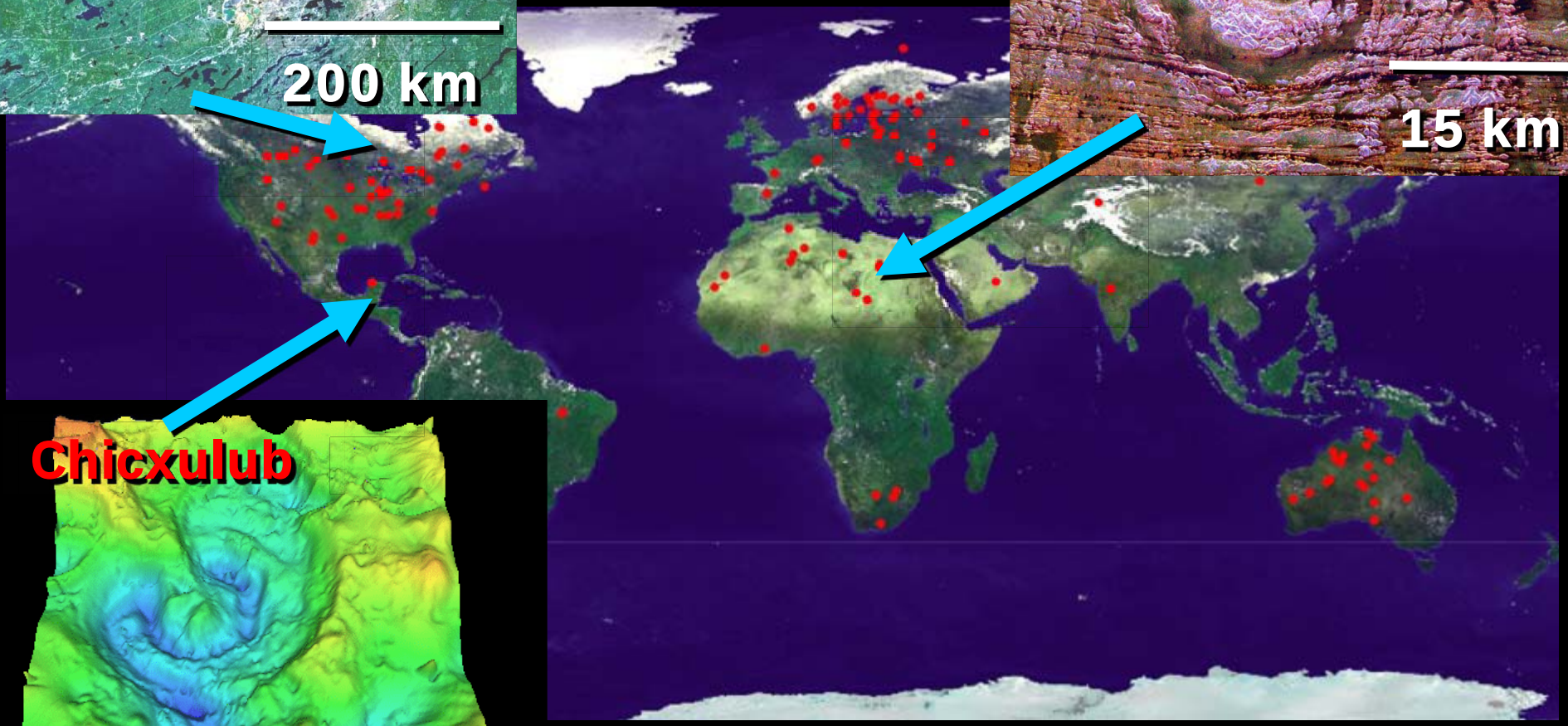
th Impact S





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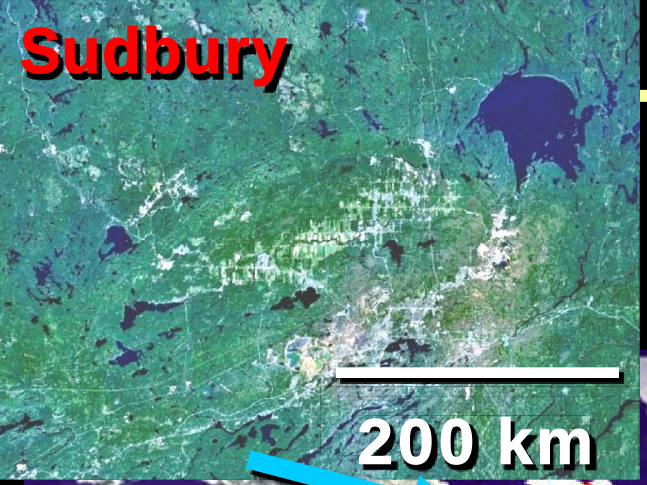
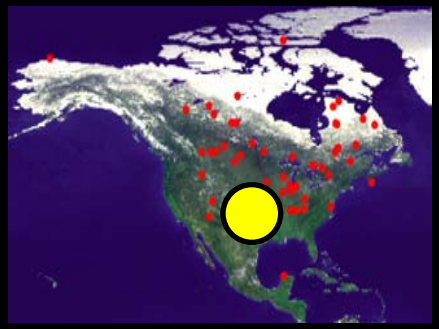
th Impact S



Space Imagery Center: *http://v*

Ames Crater



3-D subsurface view

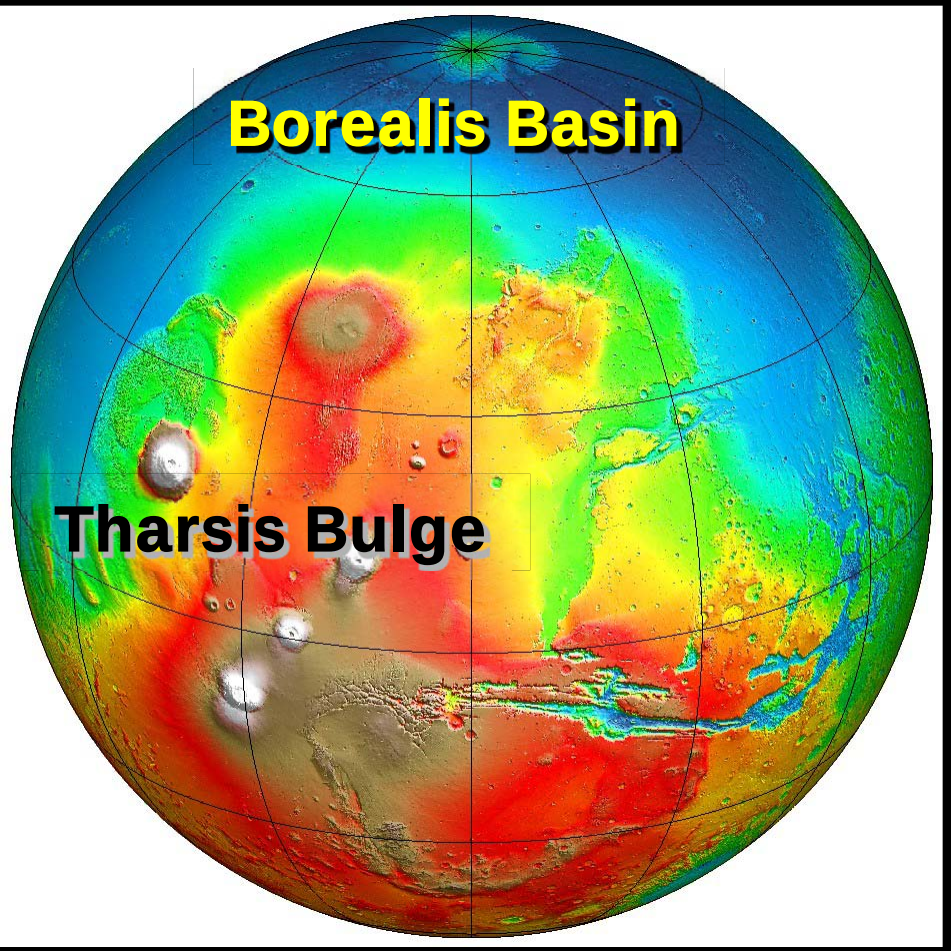
US oil-producing crater

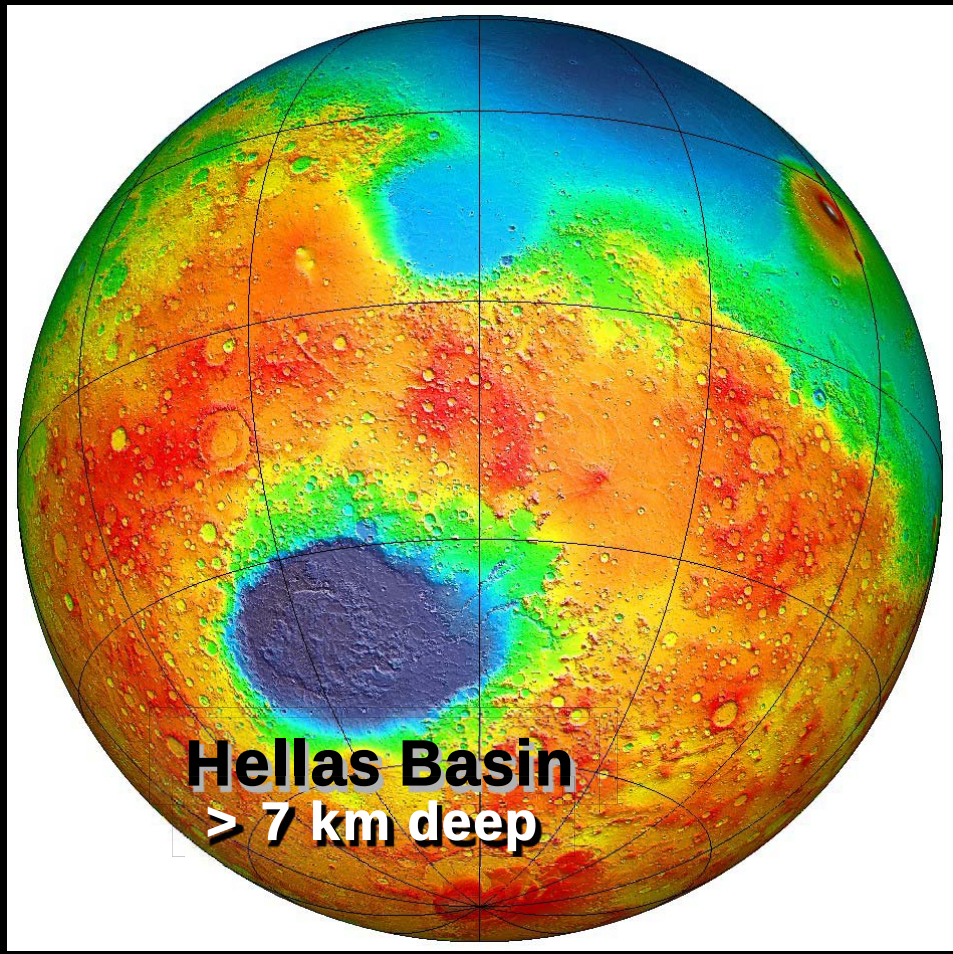
Discovered in 1991

Cumulative production
~11 MMBO
~12 BCFG

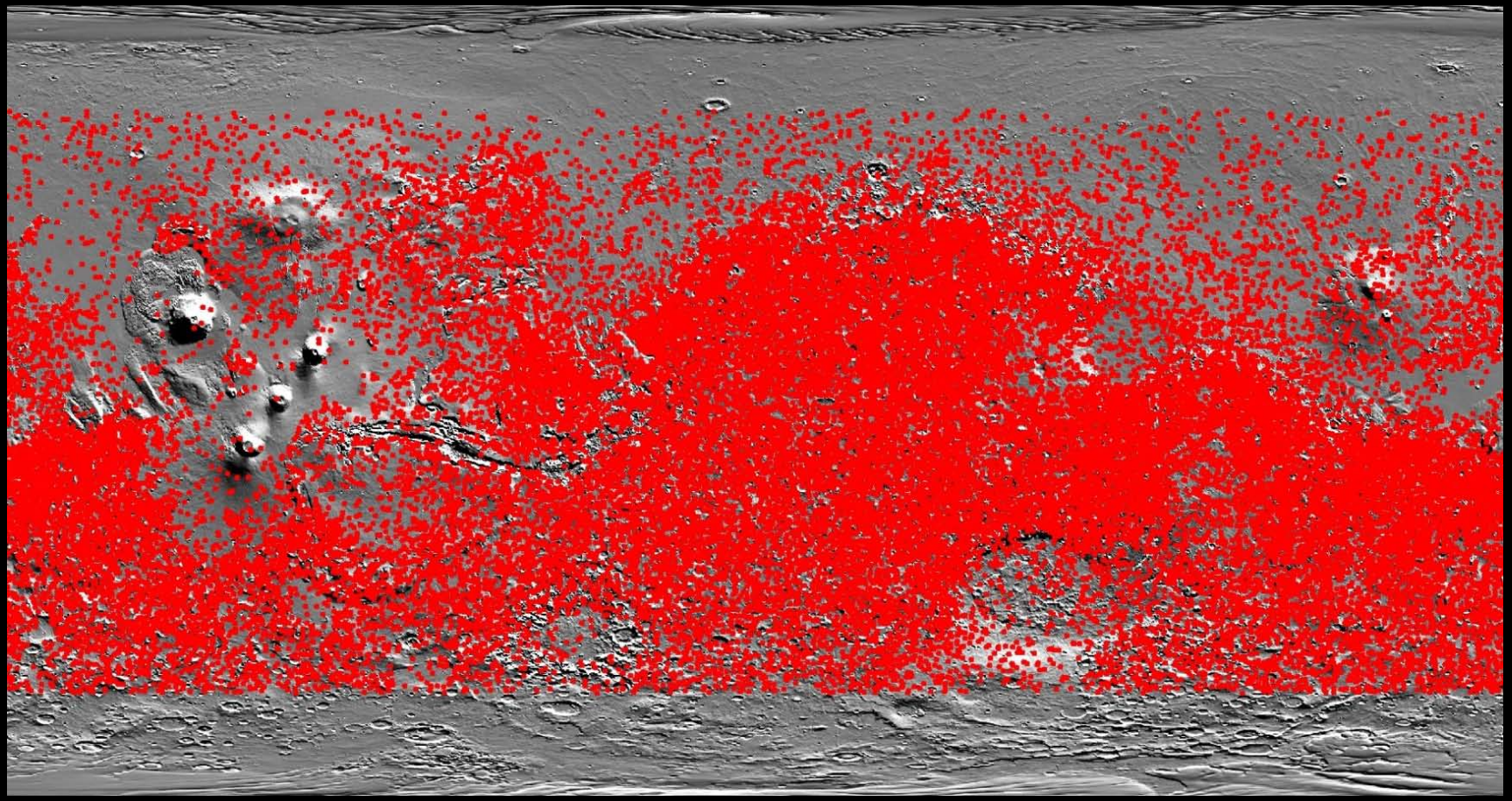
Most production from fractured and brecciated granite in central uplift

Mars: Topography



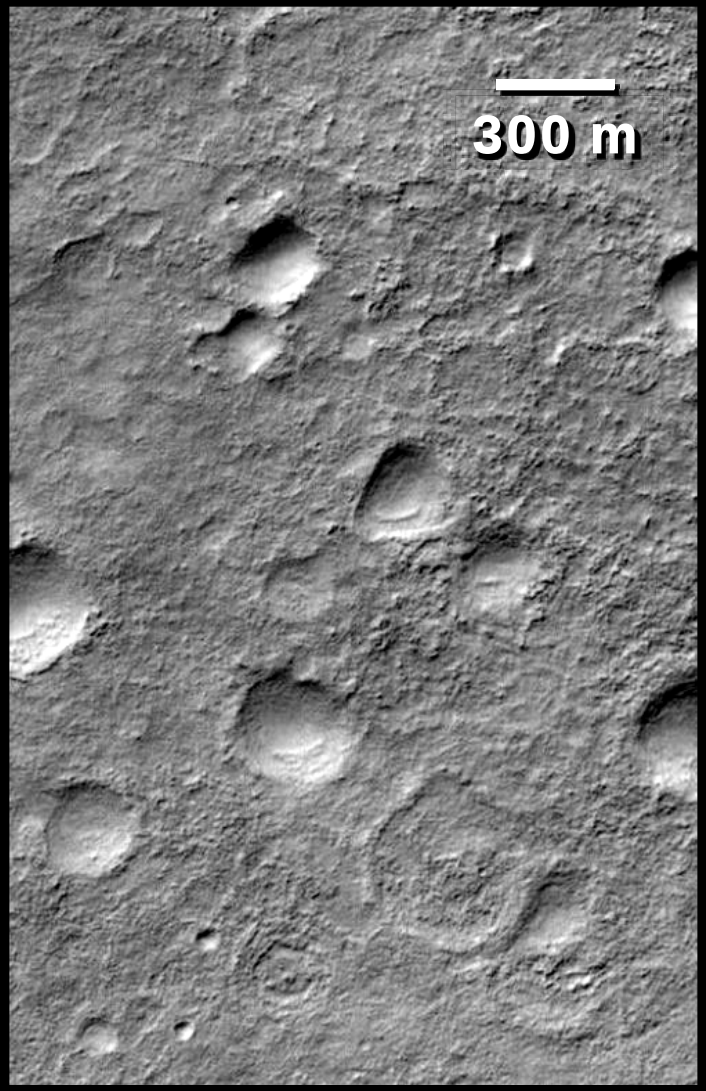


Martian Impact Craters



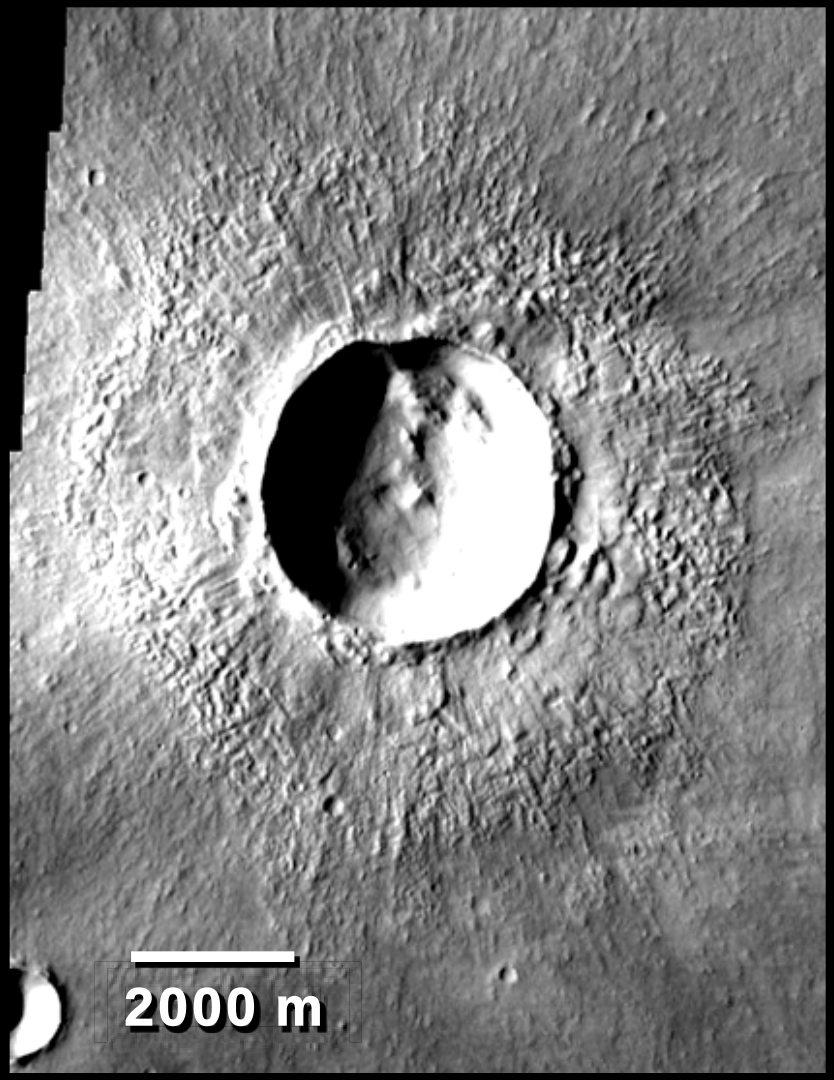
Craters > 4 km from *Barlow* database
Large basins excluded

Mars: Impacts into Icy Substrates



MOLA M20-00860

Mars: Impacts into Icy Substrates



Themis SP2-43704

Outline

Inner Solar System

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Moon and Mercury

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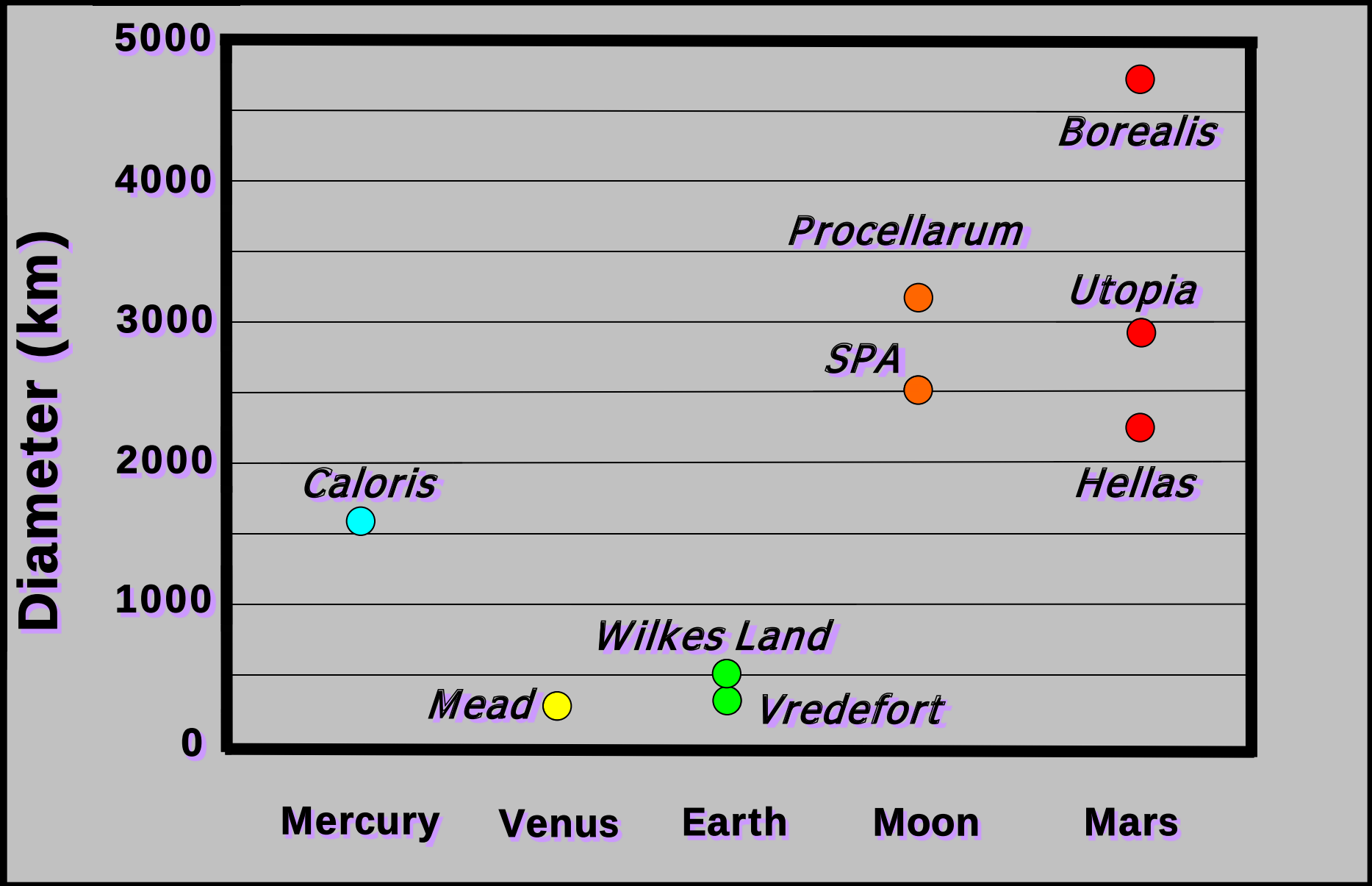
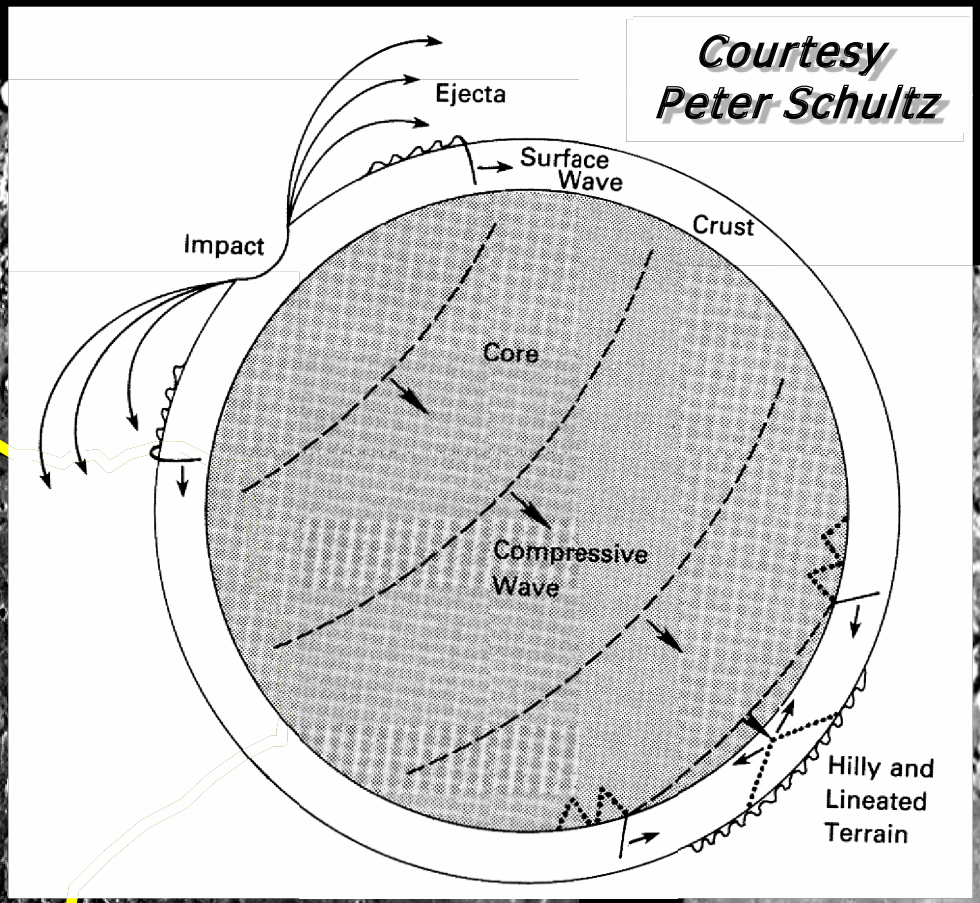
Basin-Antipodal Effects

Large Impacts: Inner Solar System



Mercury: Caloris Basin

Mariner 10 photographs



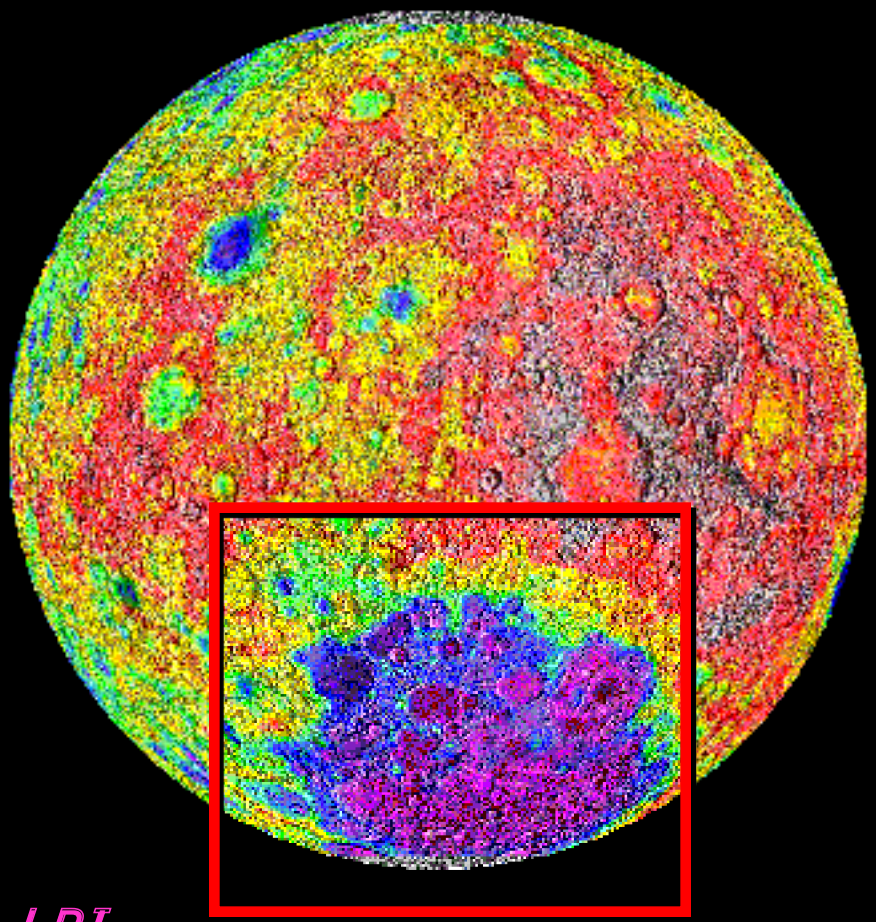
Antipodal point

650 km

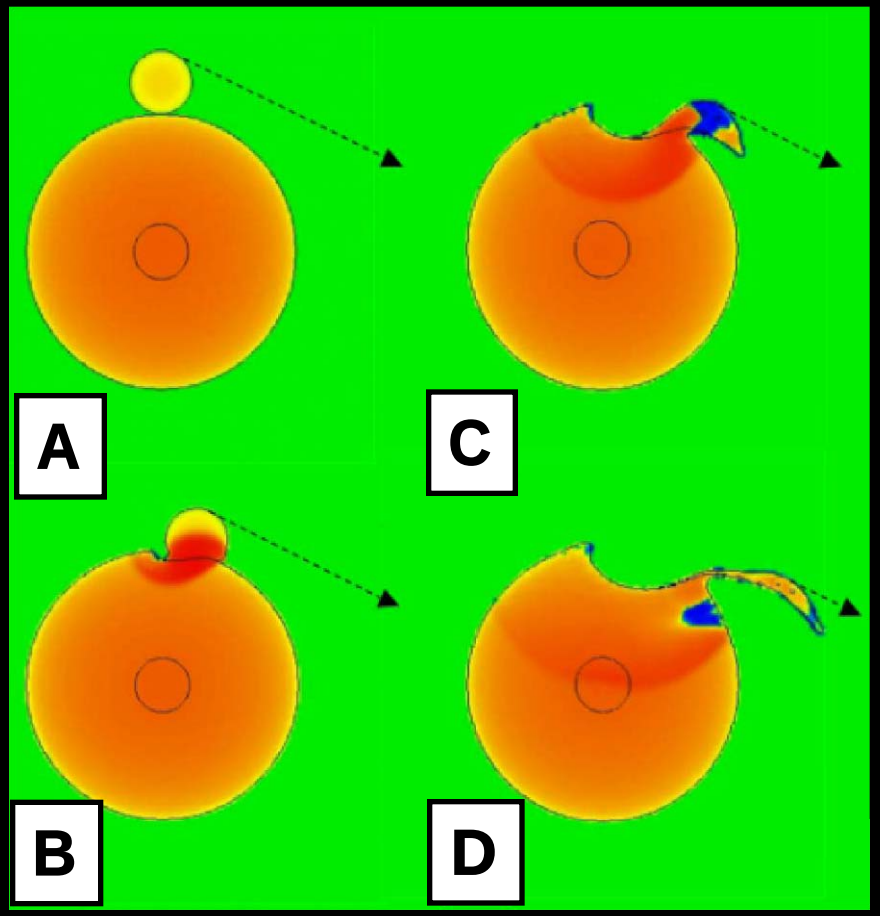
~50 km

Moon: South Pole–Aitken Basin

Laser altimetry



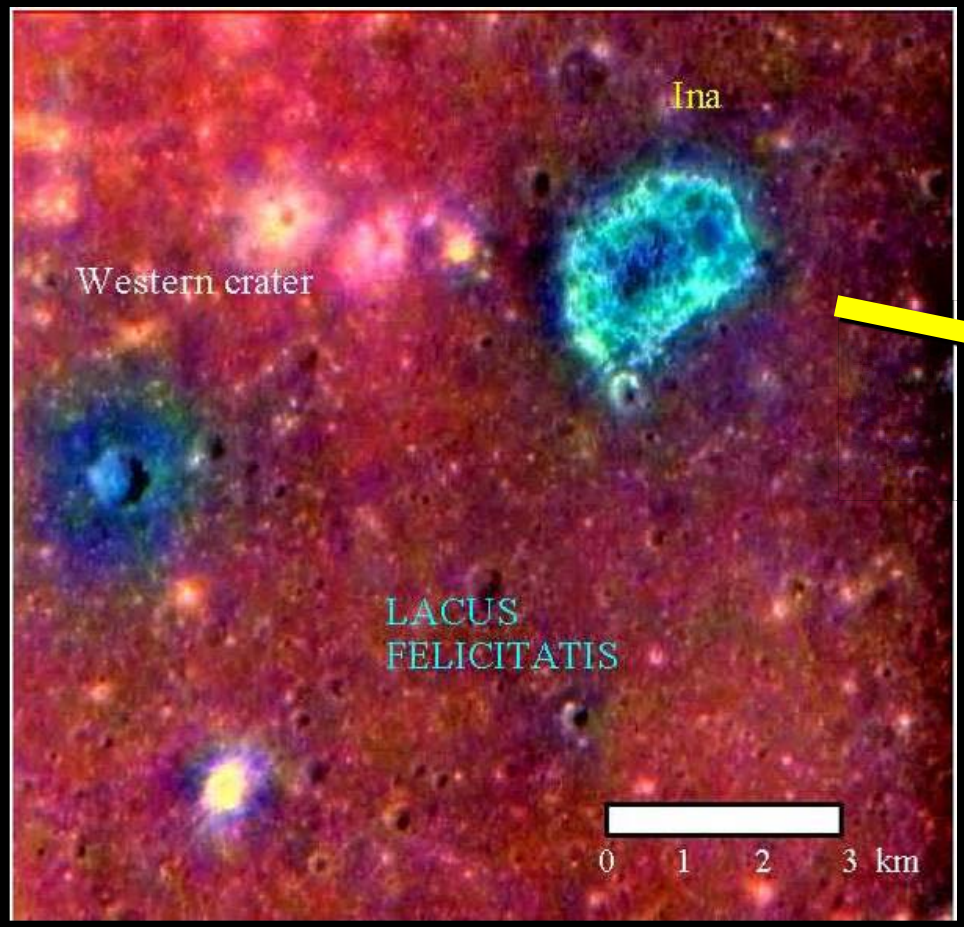
Collision model



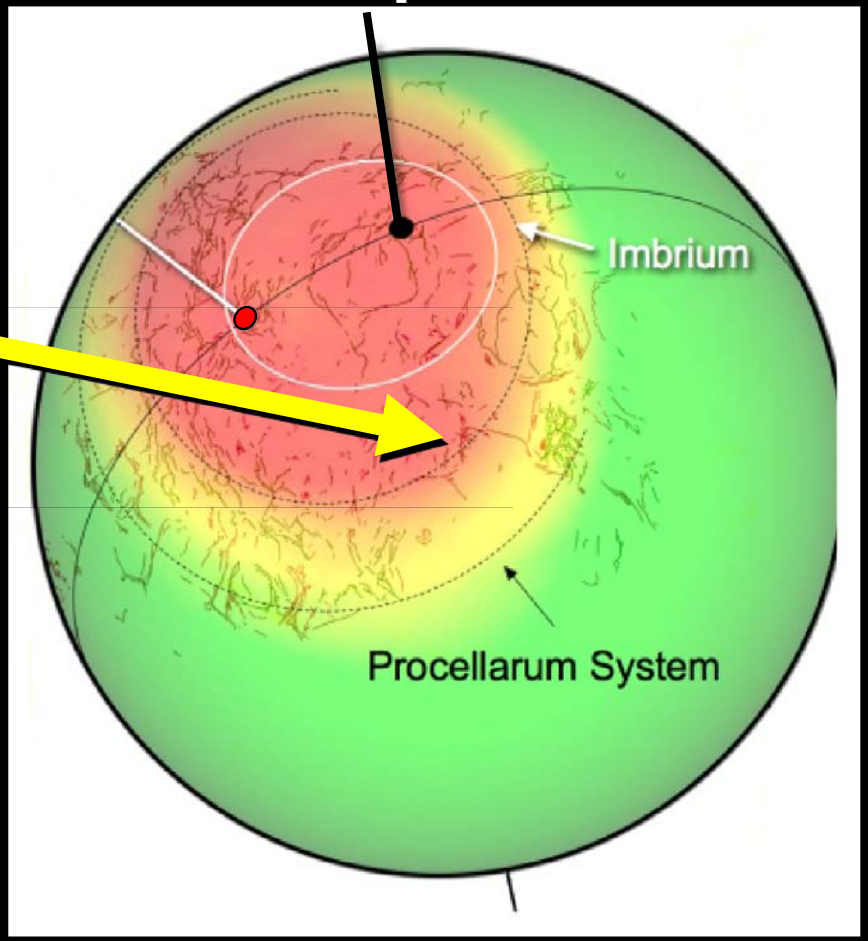
LPI

Modified from Schultz and Crawford (2008)

Moon–Ina Volatiles

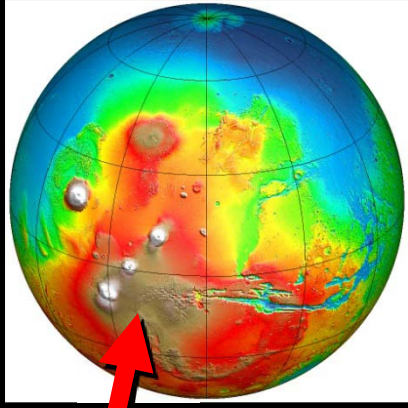


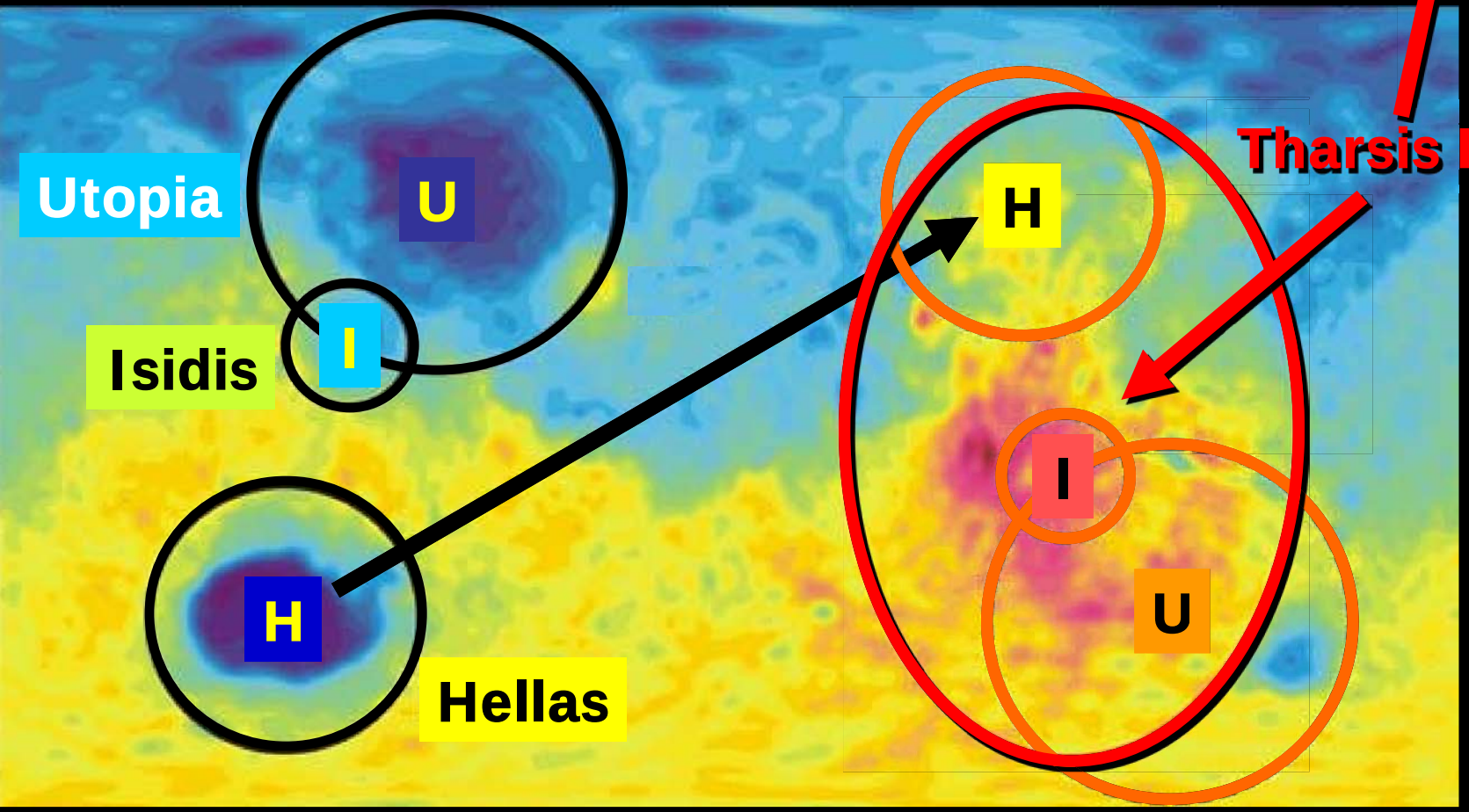
SPA antipode



Schultz et al. (2006)
Schultz and Crawford (2008)

Mars–Basins and Volcanic Terrains





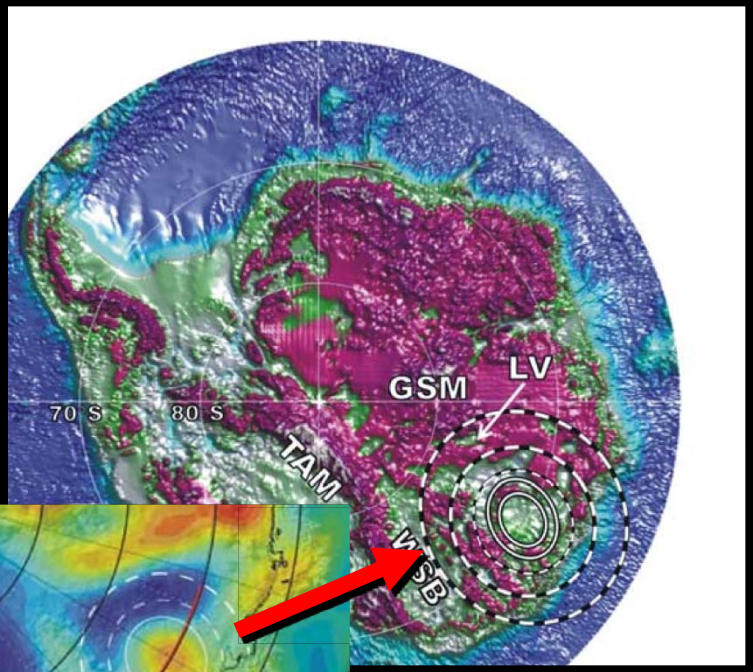
Modified from Frese et al. (2009), after Neumann (2004)

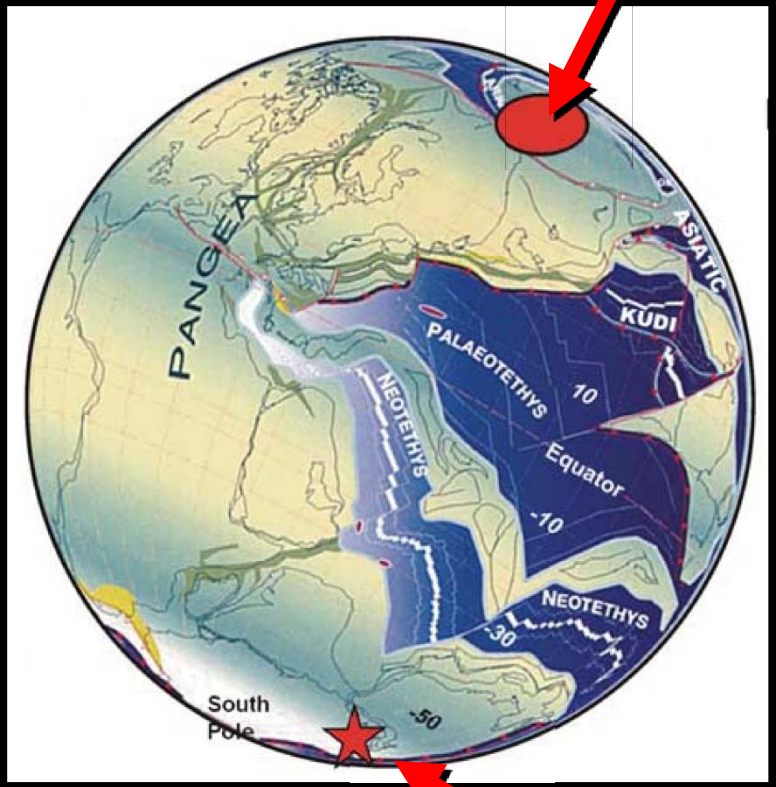
Earth–Wilkes Land and Siberian Traps

Frese et al. (2009)
after Stampfli and Borel (2002)

Late Permian (~250 Ma)

Siberian Traps





Wilkes Land

GRACE free-air gravity anomalies

Summary

Inner Solar System preserves a record of ancient impacts

Moon>Mercury>Mars>Earth>Venus

Moon and Mercury

Large, flooded basins: impact degradation

Mars: *Large basins: many degradational processes*

Earth: *Few large basins: tectonics, weathering*

Venus: *Narrow impact range: resurfacing, thick atm.*

Basin-Antipodal Events: *Shocked, volcanic terrains*

AAPG Special Publication

Astrogeology Committee

Energy Resources for Human Settlement in the Solar System And Earth's Future in Space