Impact, fluvial, and lacustrine processes at the Meridiani Hematite site: Possible constraints from MER landing site investigations

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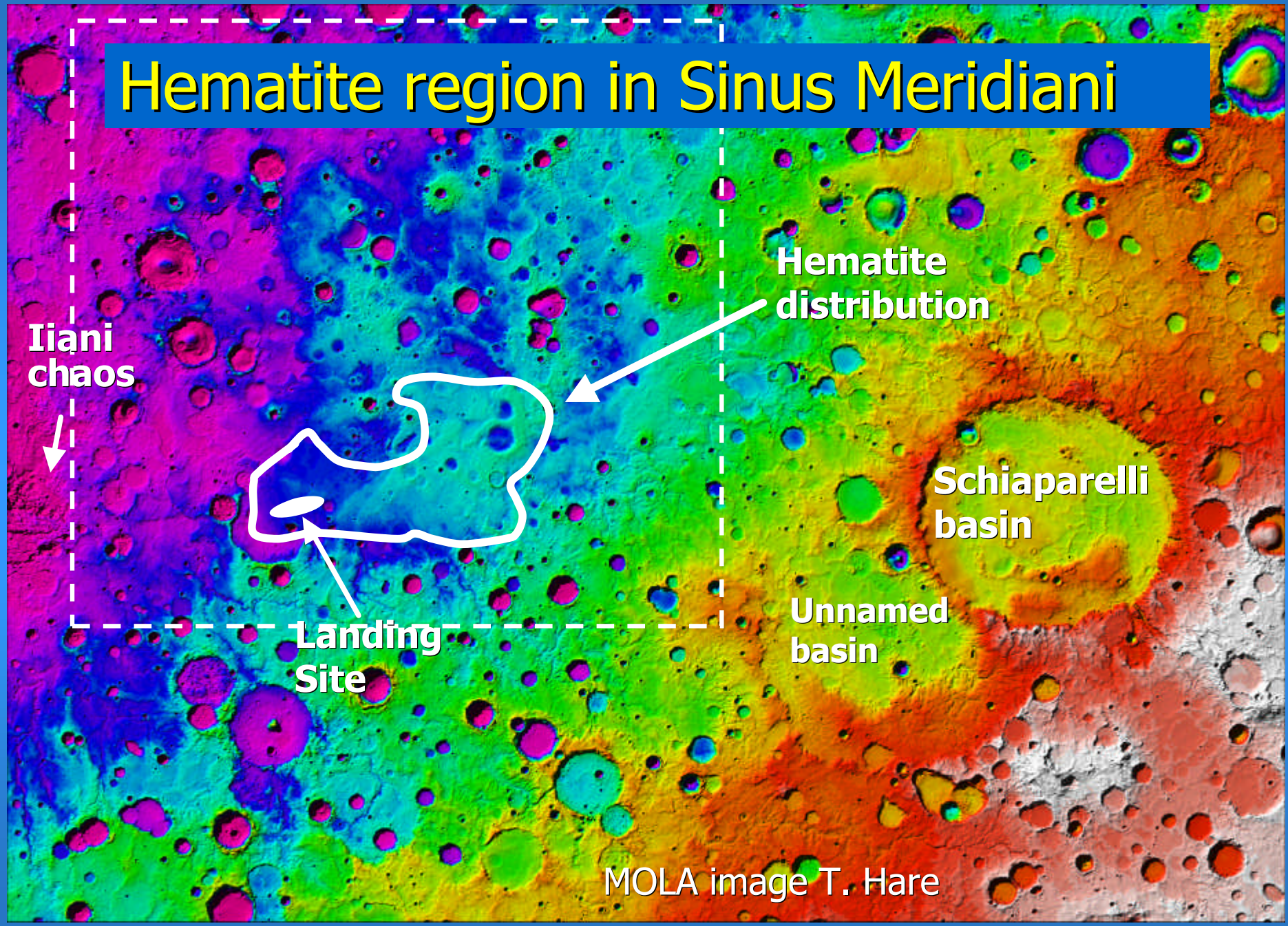
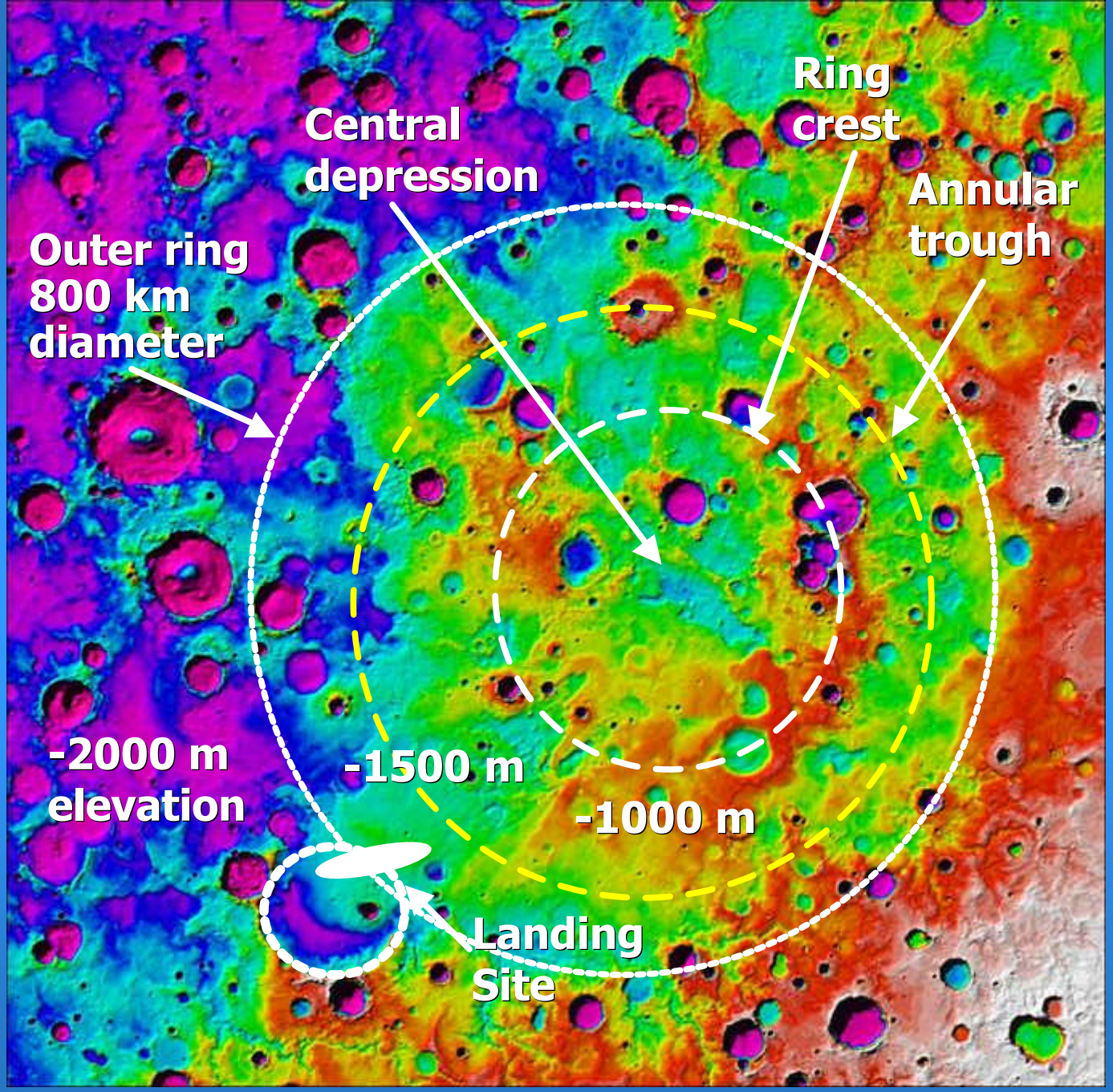
MER hematite site: Outline of topics

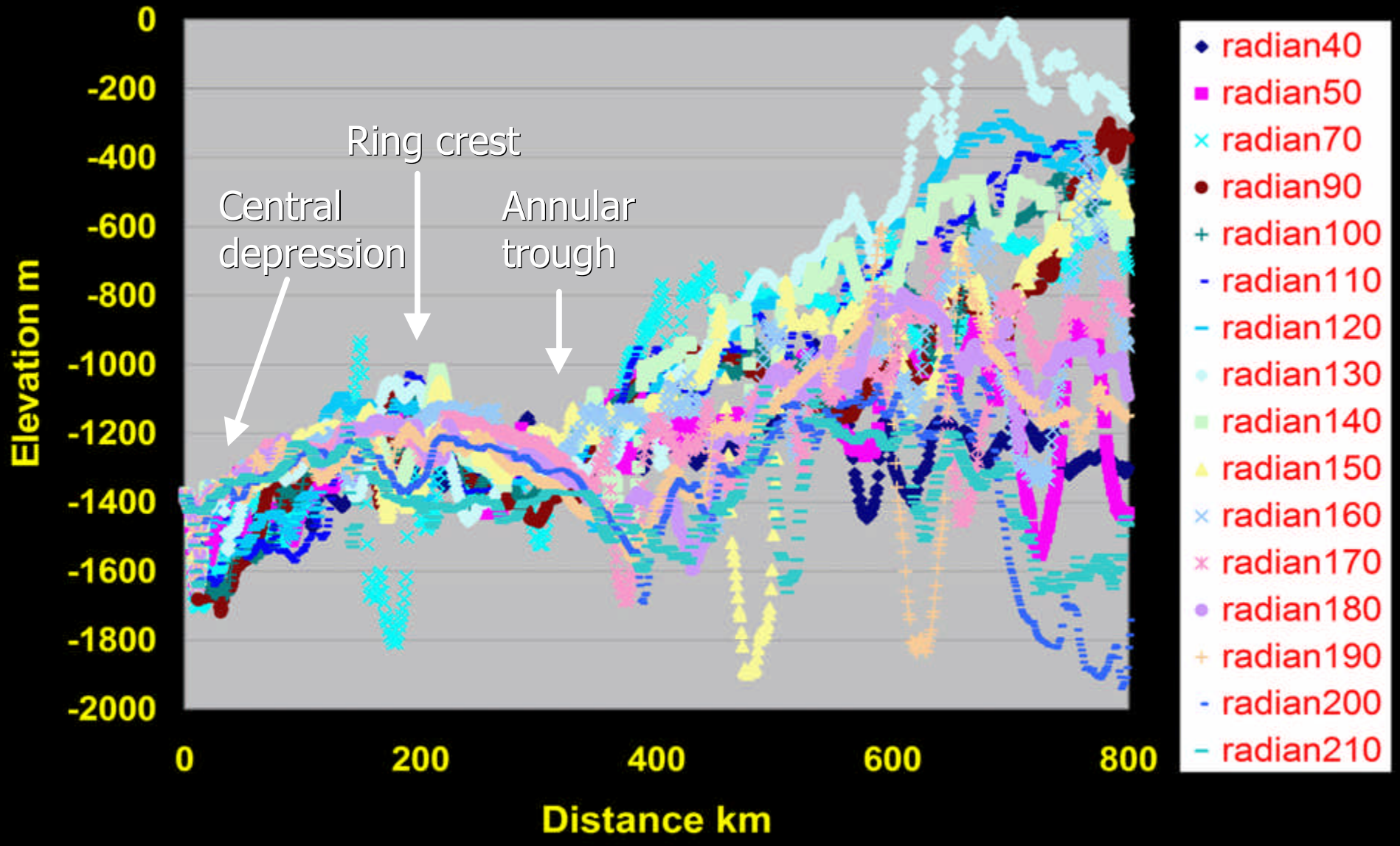
1. The cratering history, including concentric circular features that may represent an 800 km diameter impact structure in the region and a 150 km diameter crater under the site
2. Fluvial and lacustrine activity that was fed by a channeled region the size of Texas
3. The possibility that the hematite deposits are related to impact and/or fluvial processes
4. The possibility that lake deposits and impact melts may be present at the landing site


Hematite region in Sinus Meridiani
Hematite distribution
Iiani chaos
Schiaparelli basin
Unnamed basin
Landing Site
MOLA image T. Hare

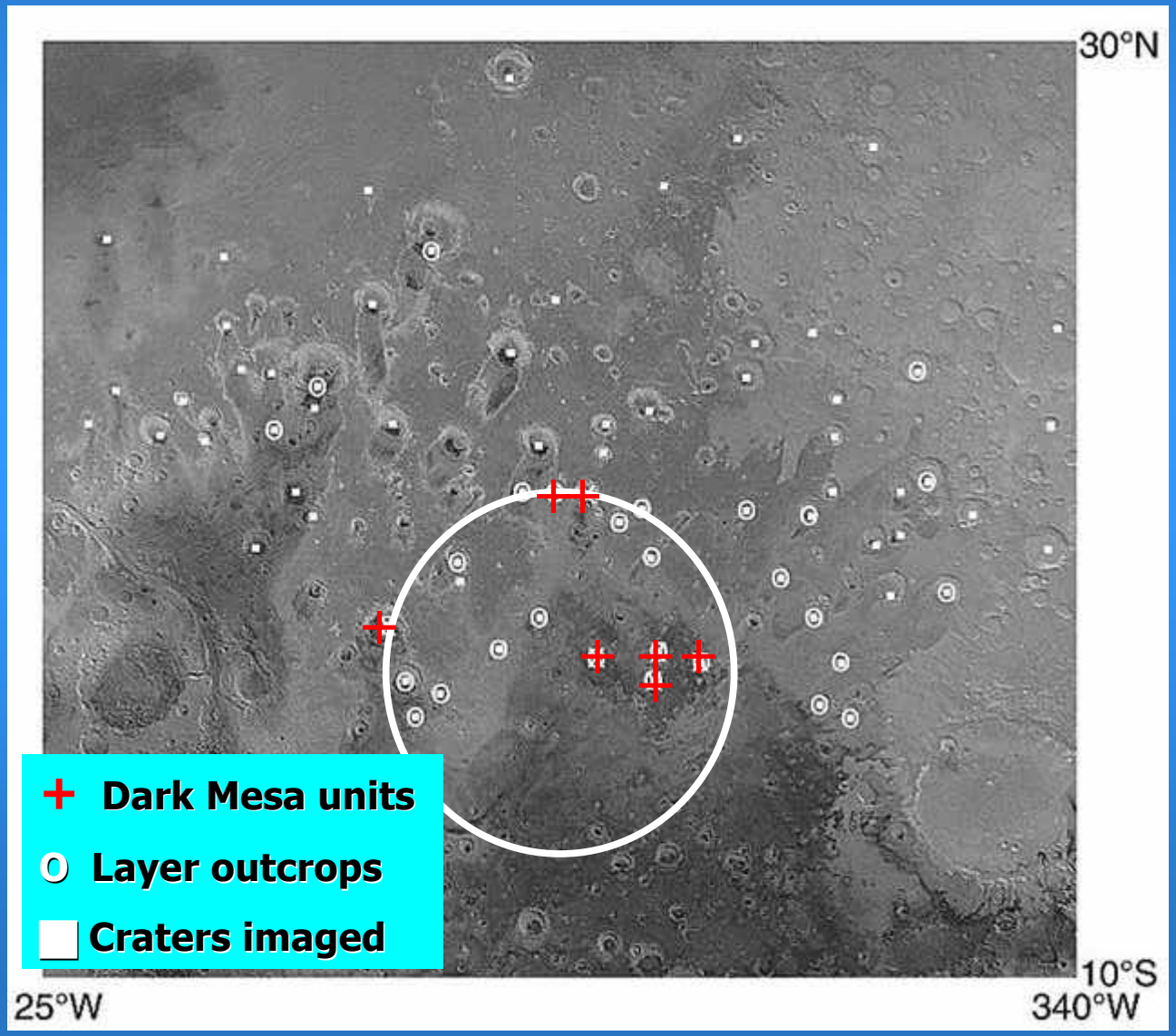
Circular features and craters in Sinus Meridiani

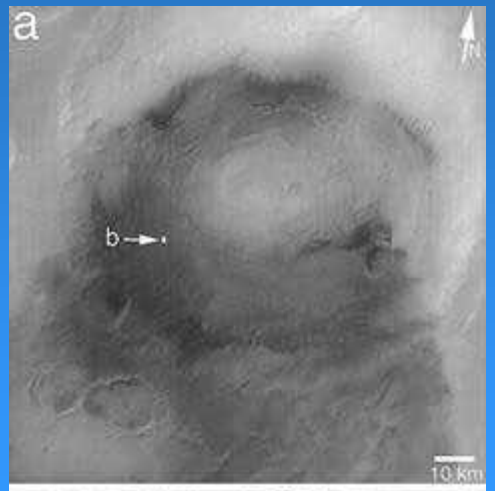


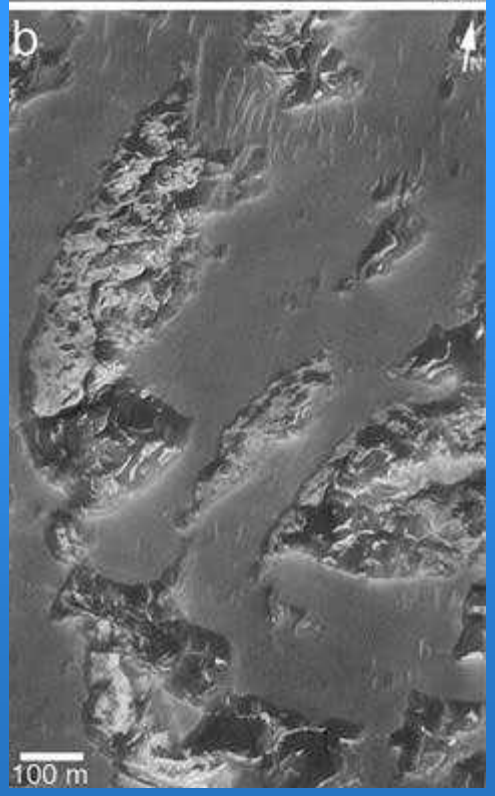
Radial profiles, 40° – 210°



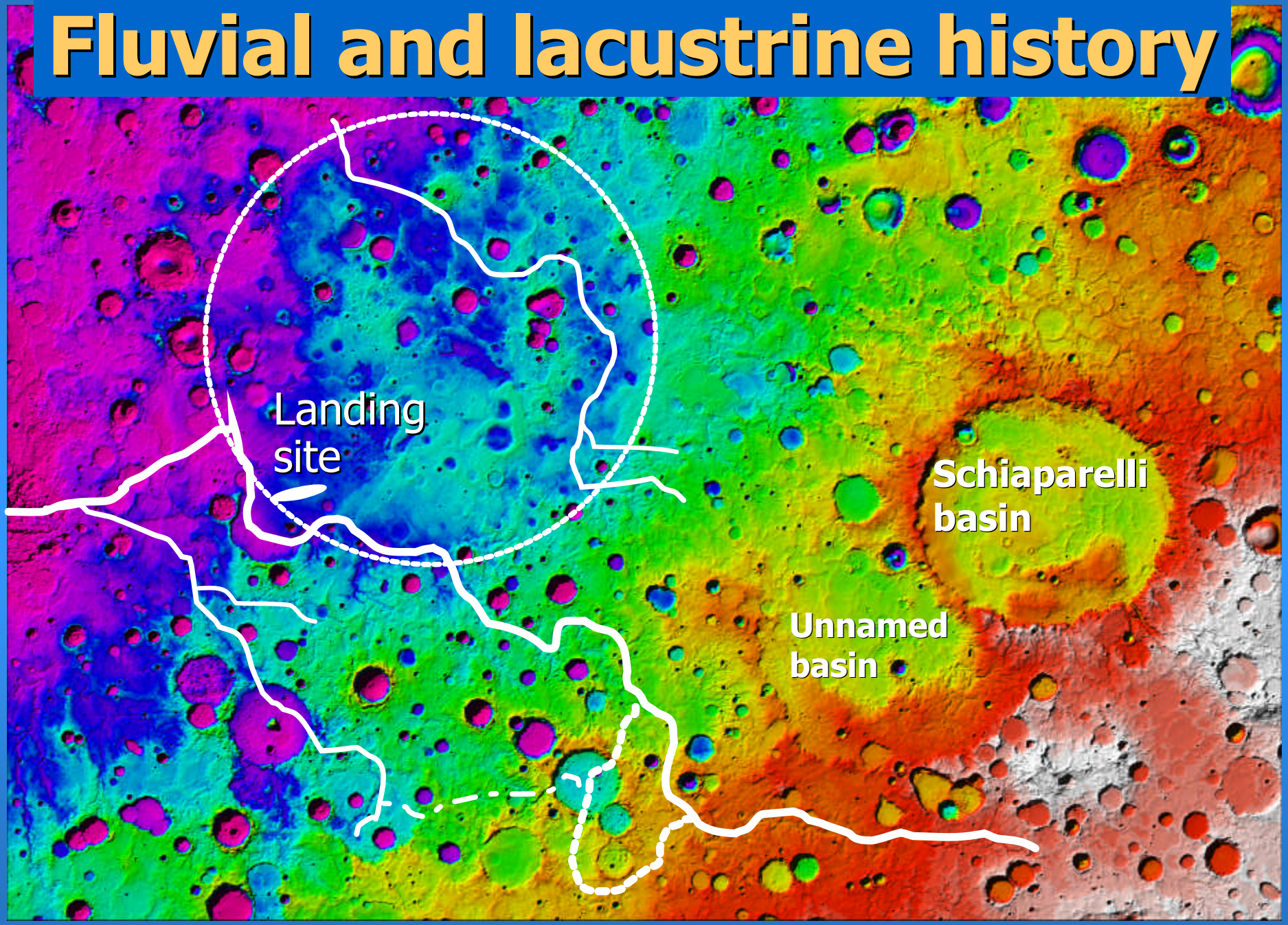
Dark layered material in 800 km diameter structure (from Edgett, 2002)







Fluvial and lacustrine history

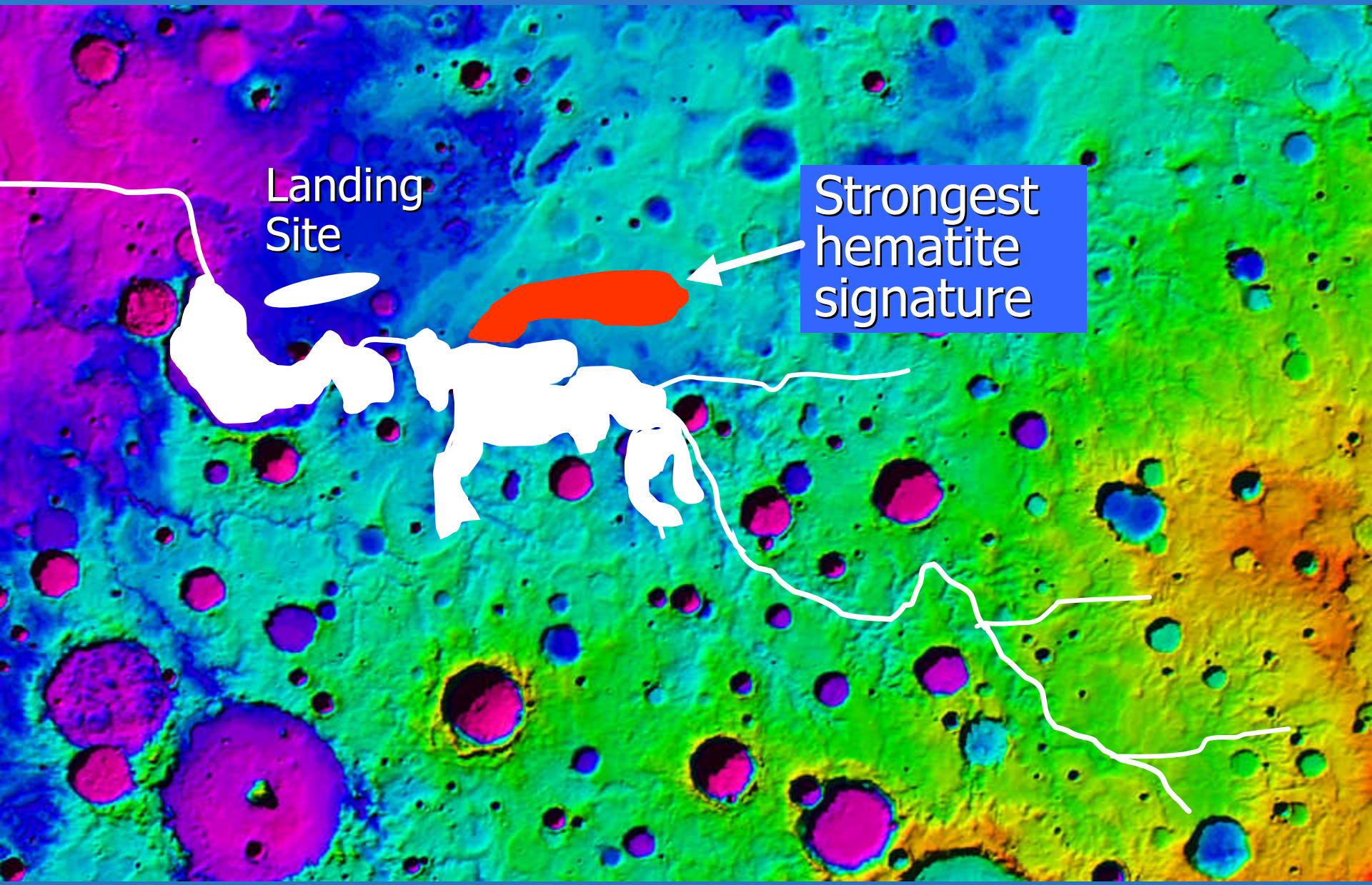


Fluvial history near the landing site - Summary

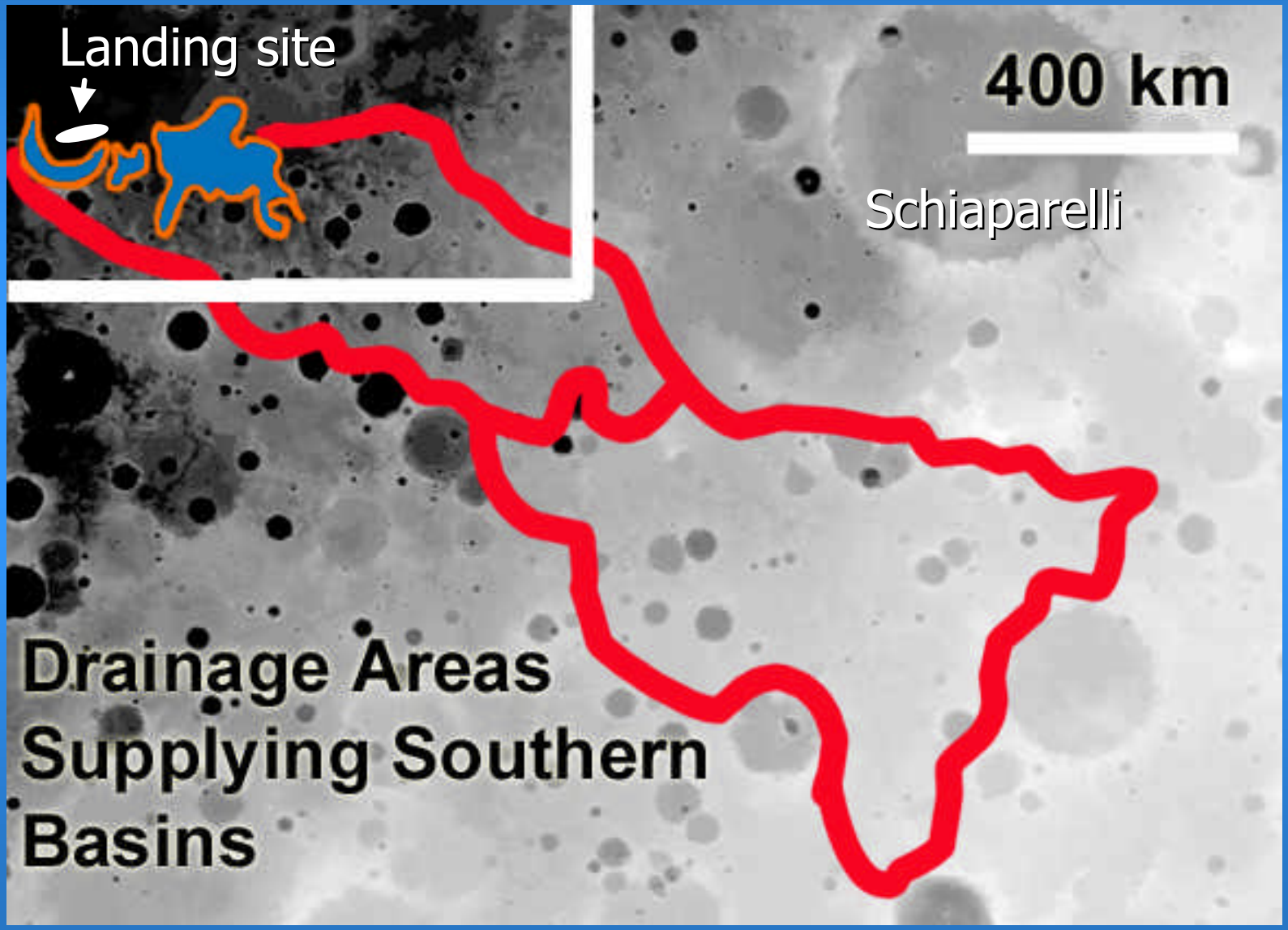
- Widespread flooding throughout geologic history due to low relief in the region and possible ice dams (e.g. 10m annually Canada and Siberia)
- Early deposition of layered materials in the 150 km diameter crater (lower elevation than the rest of the hematite area)
- Formation of the present hematite layer at the landing site
- Burial of the hematite by dark layered material
- Exhumation of hematite by fluvial and aeolian processes
- Recent fluvial activity scouring channels (supported by epithermal neutron data)

Layered materials above and below hematite

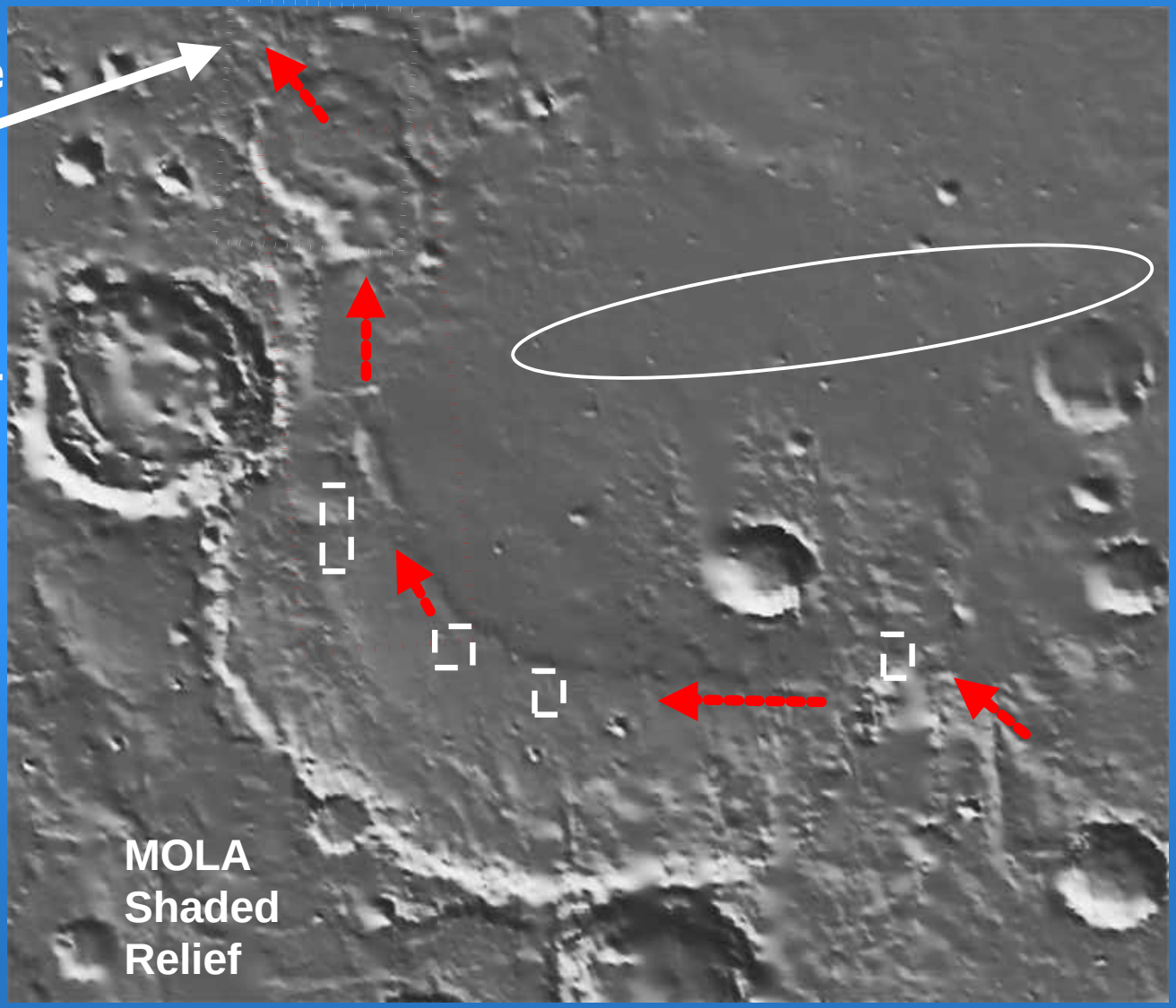
Channels and basins near landing site

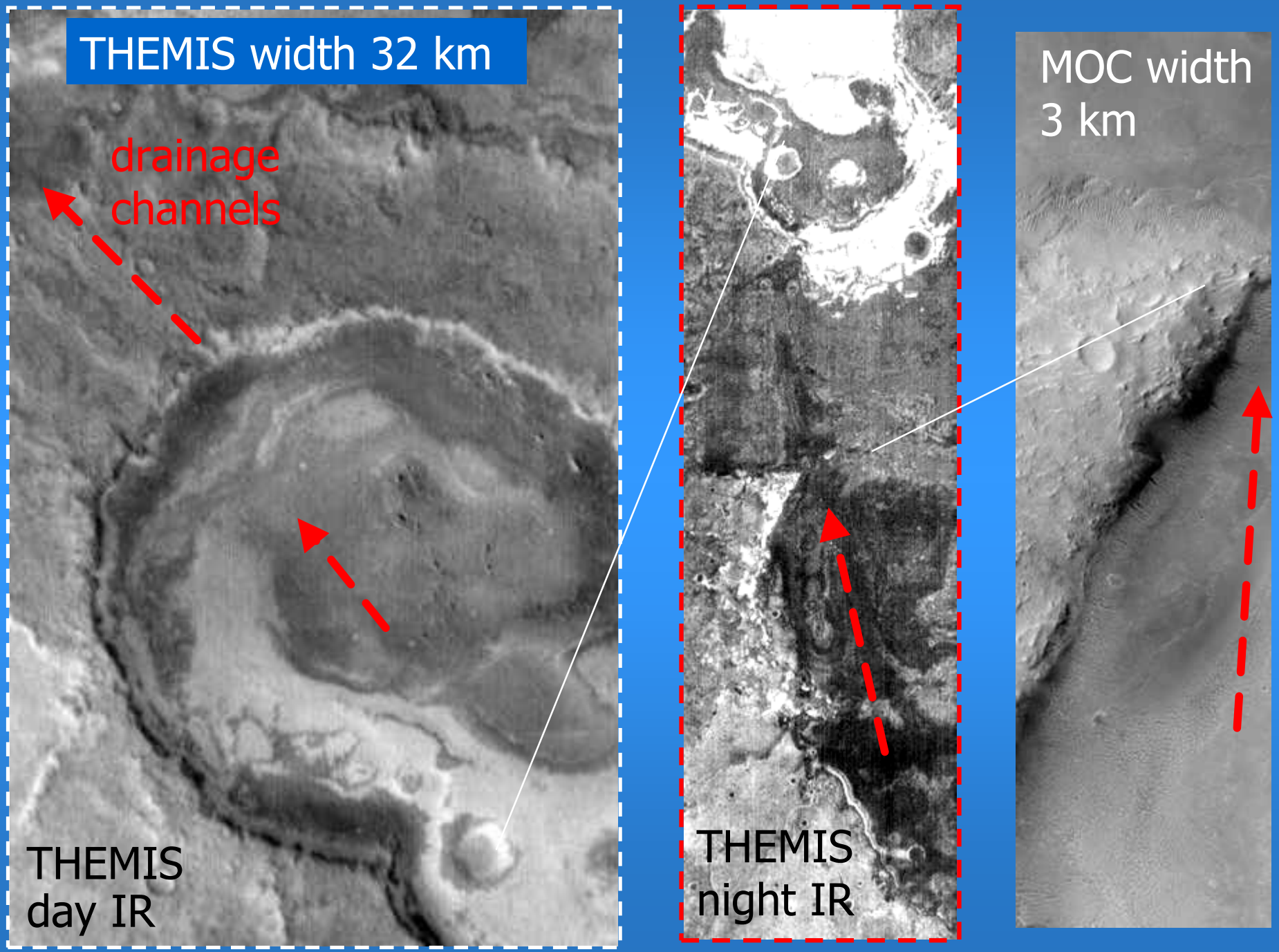


Southern basin "watershed" with an area the size of Texas

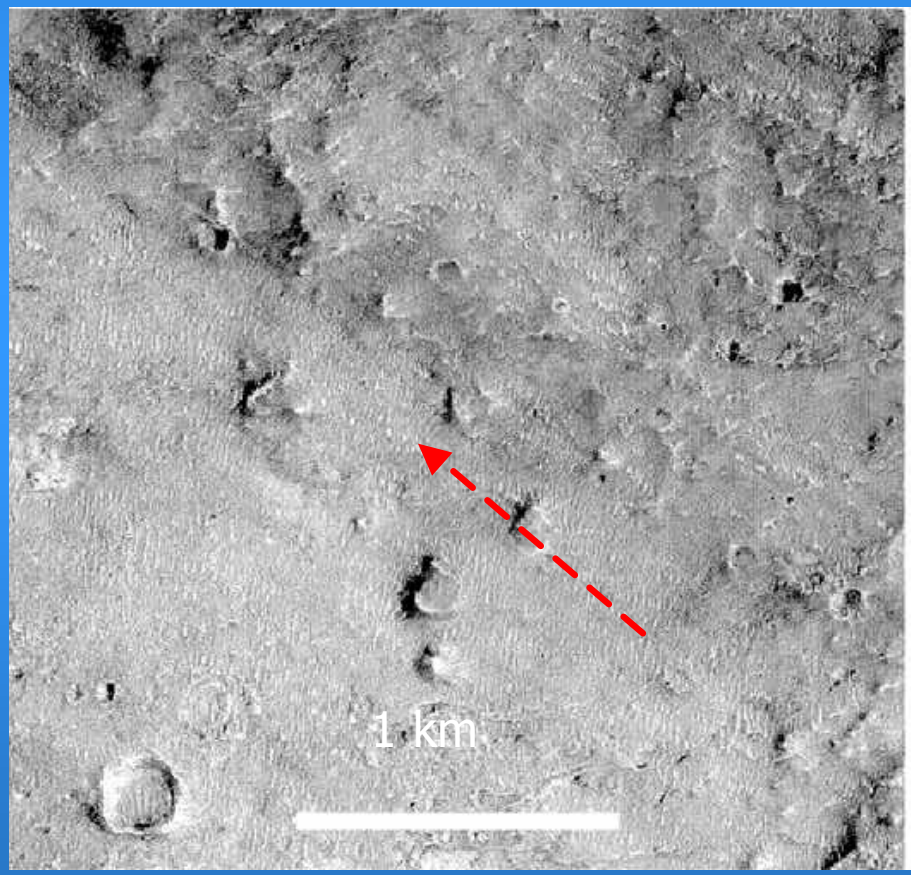


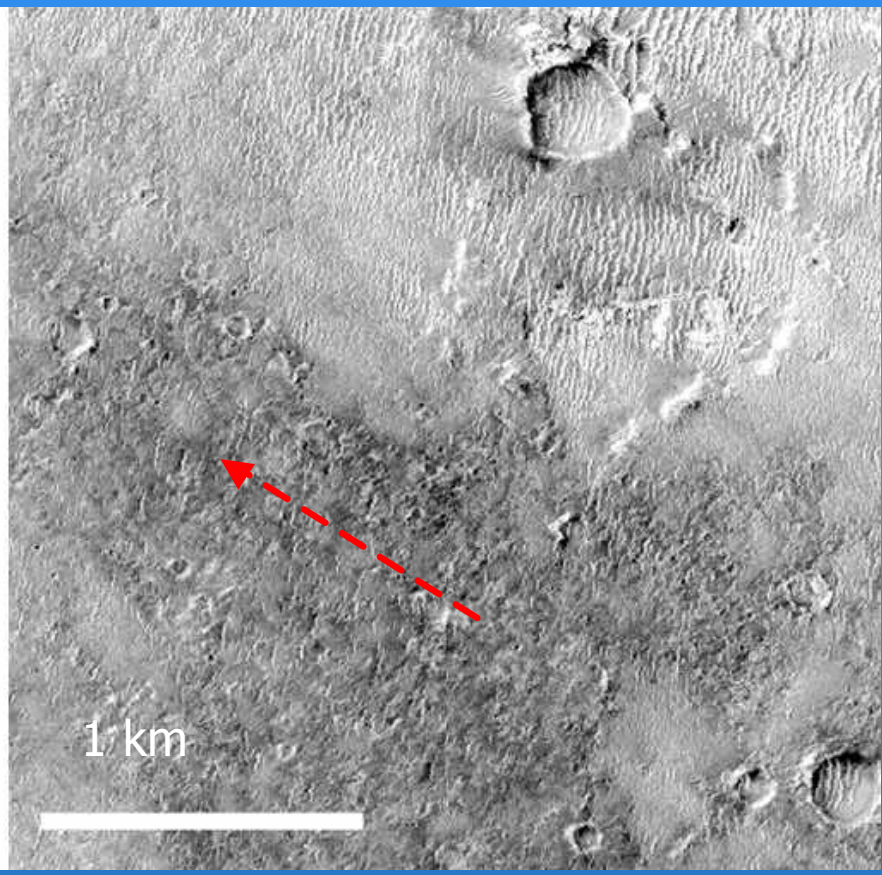
THEMIS and MOC evidence for drainage from the 150 km diameter crater




THEMIS width 32 km
drainage channels
THEMIS day IR
THEMIS night IR
MOC width 3 km

Channel flow features on the floor of the 150 km diameter crater.





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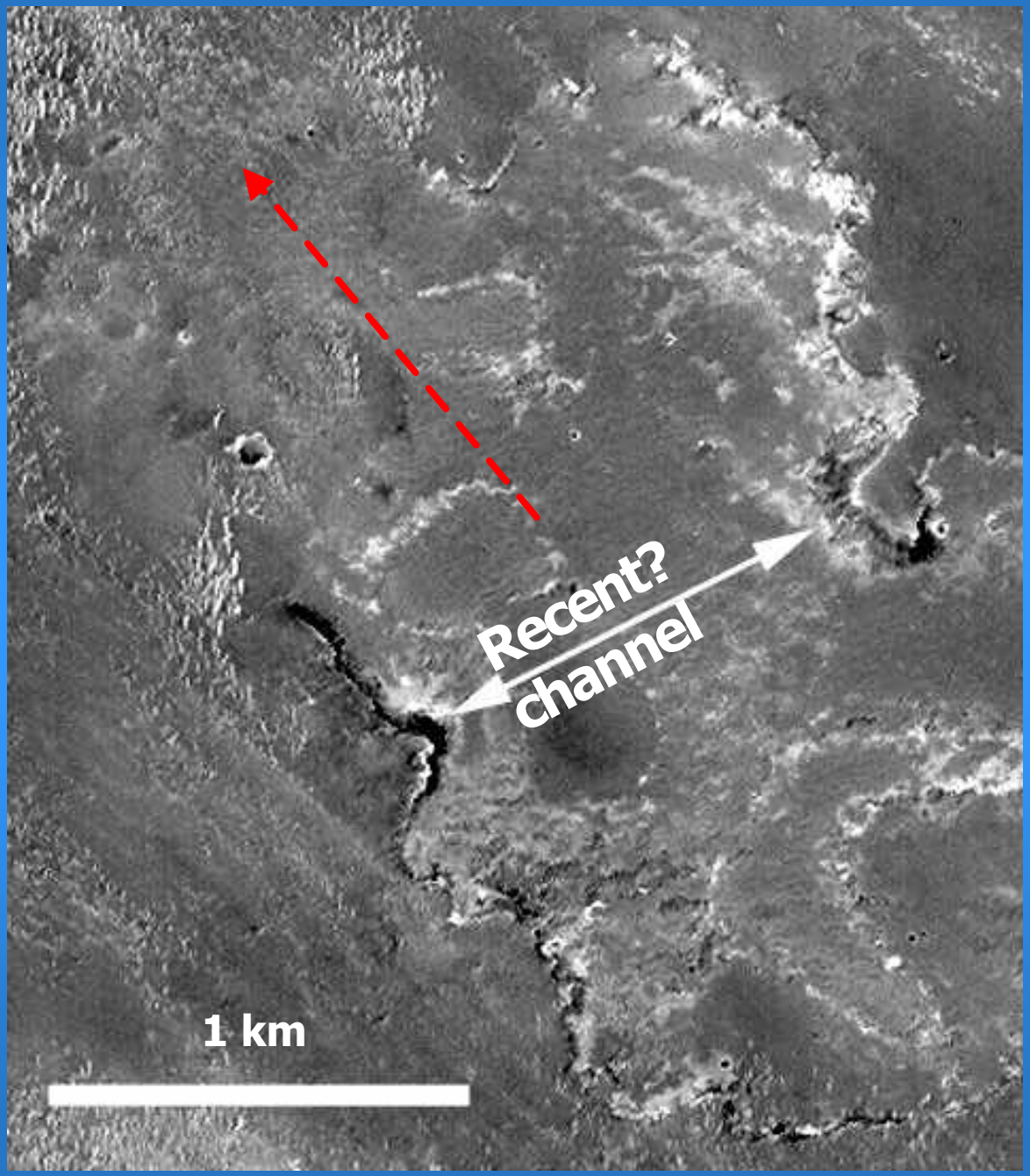
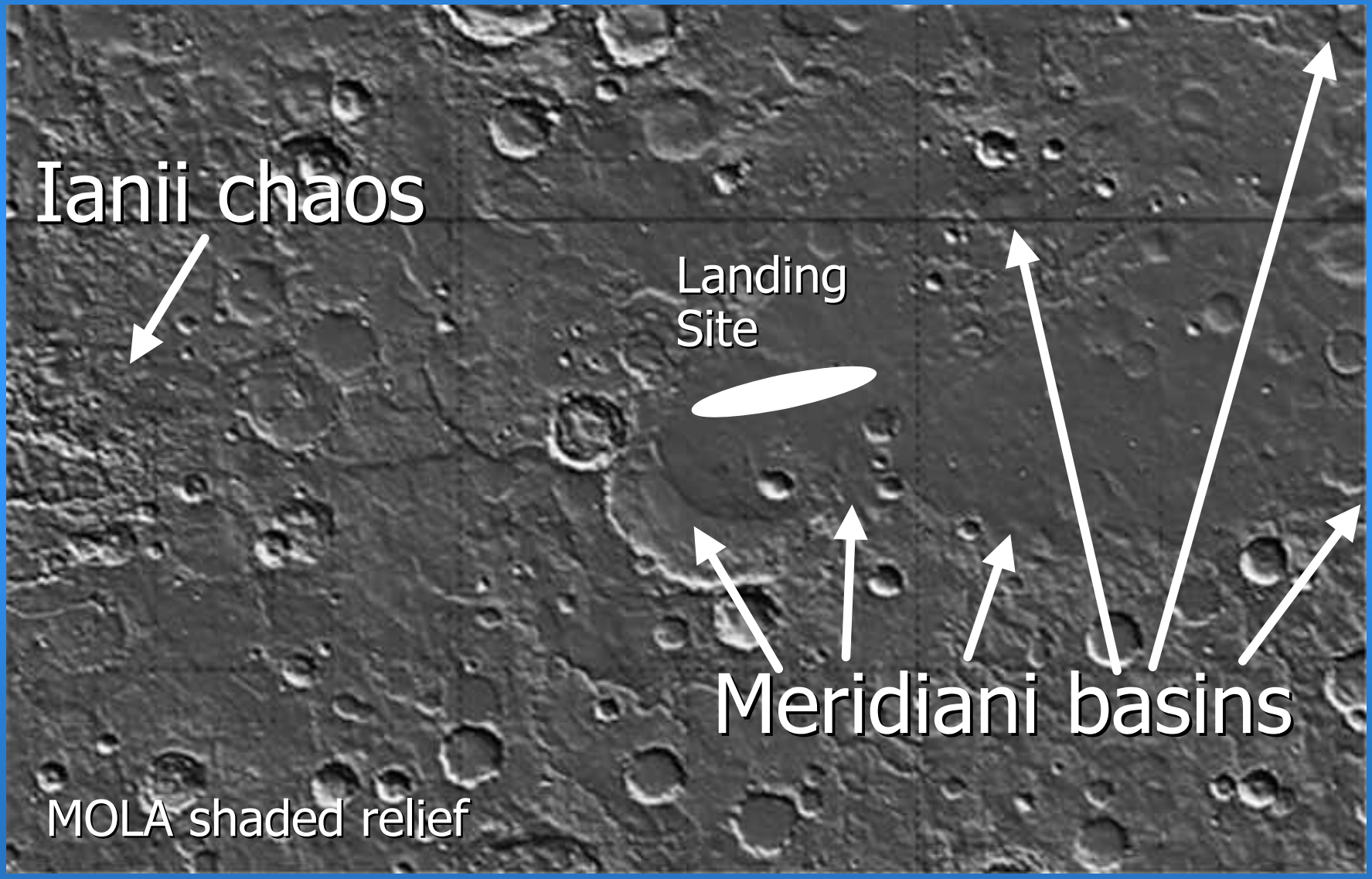


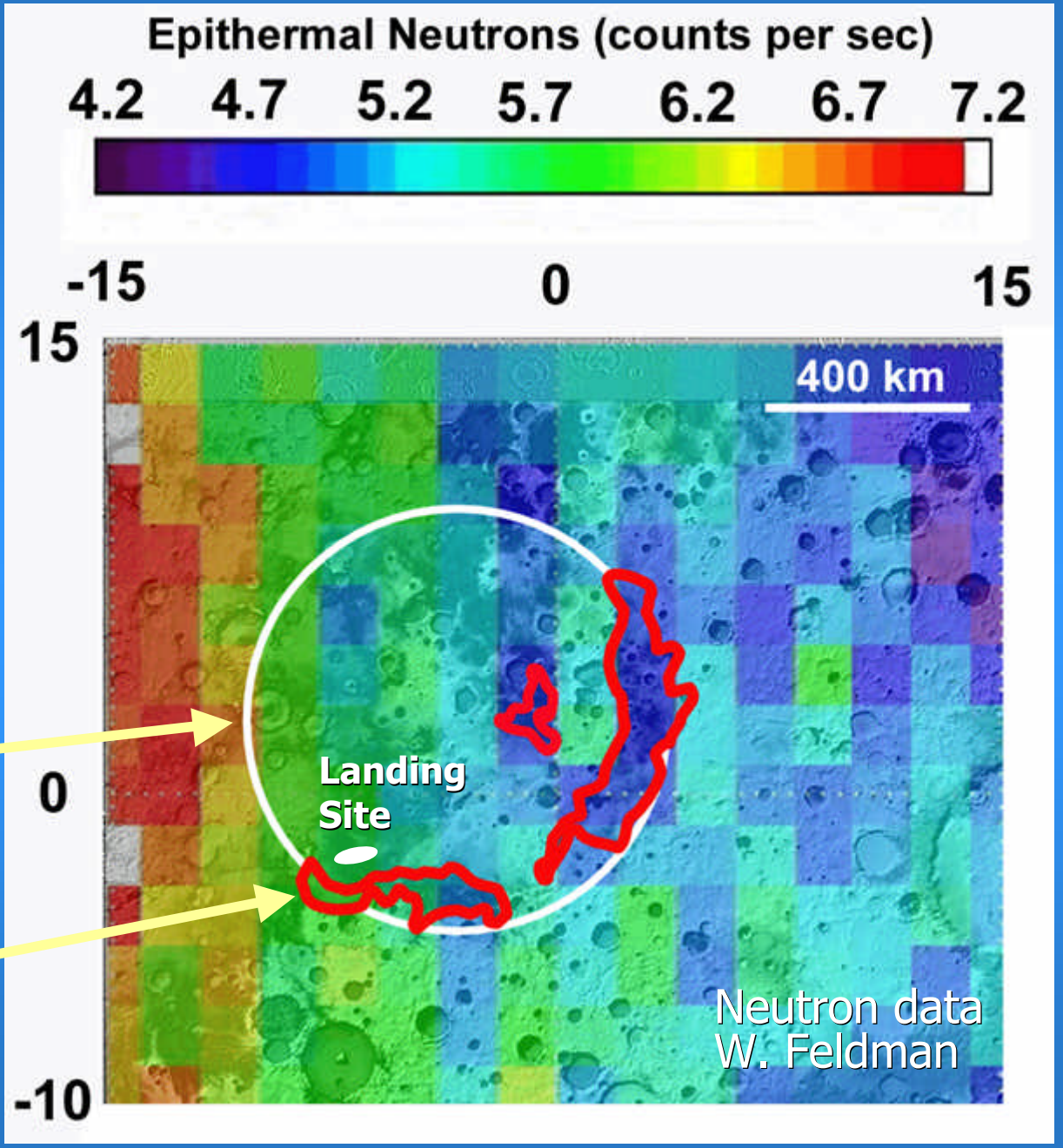
Ianii chaos formation is consistent with ground water flow from Meridiani basins



Epithermal neutron map of bound water (H) in basins

800 km diam. structure

Basins and lowlands outlined in red



Origin of the hematite: Hydrothermal precipitation or ambient temp. coatings?

- Hydrothermal fluids
  - In lakes
  - In impact melts
- Ambient temperature coatings formed in-situ
  - Dissolution of Si, oxidation of iron oxides, and/or effects of repeated wetting

Hydrothermal precipitation, connection with the 800 km diameter structure?

- The 800 km impact could produce a huge long-lived hydrothermal system at or near the landing site
- Iron oxides could be precipitated in a basin or in the impact melt rocks
- The other large hematite deposit is also located in a large basin (Aram, 500 km diameter)
- There is limited evidence for volcanic constructs in the area
- However, the hematite does not occur in any other large basins

Banded iron formation, Carajas formation, Brazil

Hydrothermal precipitation: possible deposits at the landing site?

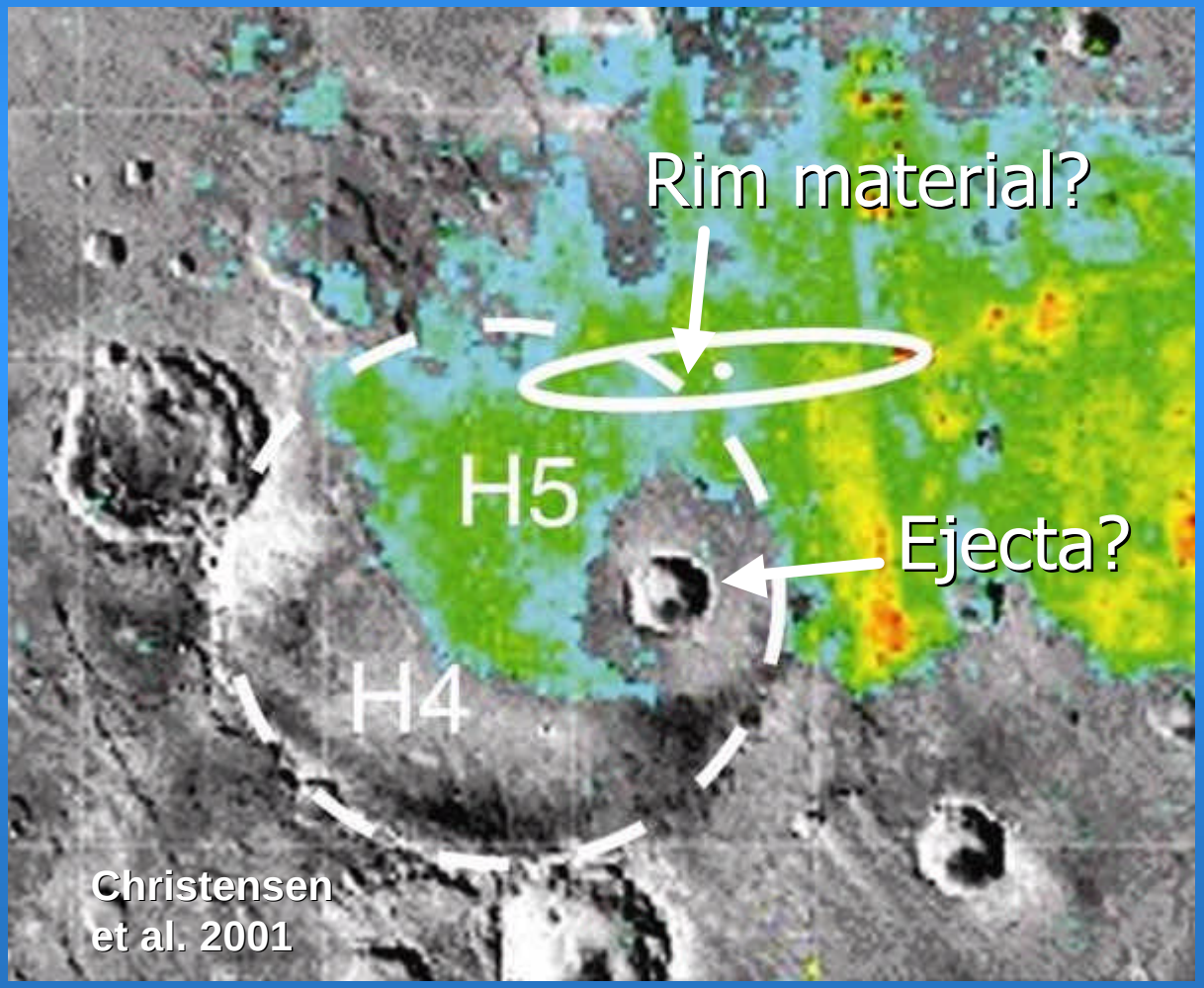
- Precipitation from hydrothermal fluids in a lake or lakes (similar to banded iron formation)?
  - Presence of layered deposits, iron oxide and carbonates
  - Erosion, re-deposition and oxidation in landing site environment due to later fluvial and lacustrine processes are needed if iron oxides formed prior to the 150 km diameter crater under the landing site.
- Precipitation near the hydrothermal fluid source in impact melts (analogous to Olympic Dam Fe-oxides and porphyry-Cu hydrothermal deposits)?
  - Massive iron oxides and extreme incompatible element enrichments (e.g. REE = 0.5 wt%)
  - Erosion, re-deposition and oxidation in landing site environment may be needed

Ambient temperature coatings?

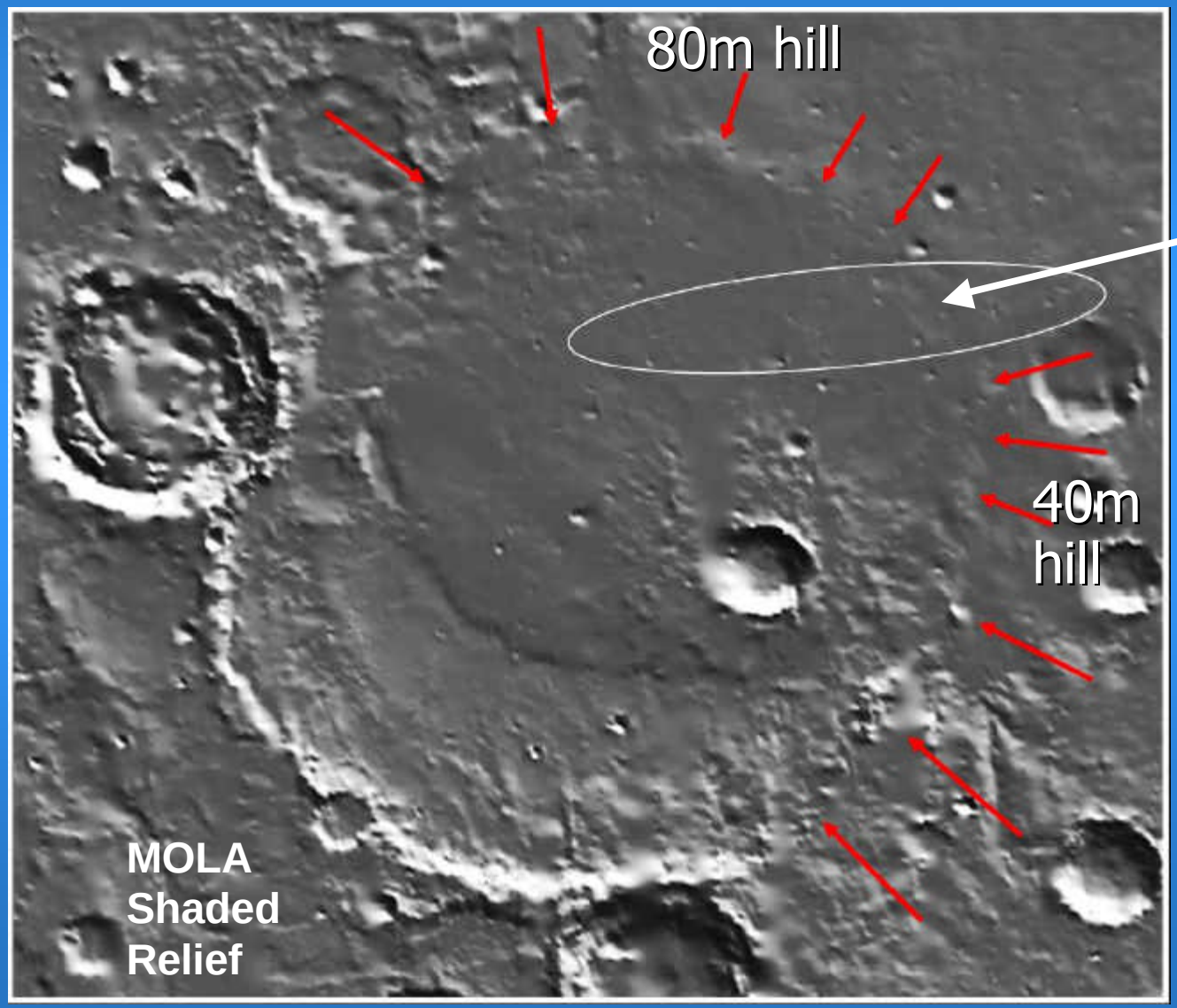
- Coatings similar to desert varnish?
- Leaching of silica due to repeated wetting in a near shore or vadose zone environment?
  - Fe-rich coatings
  - Dissolution and oxidation textures
  - Evidence for repeated flooding at landing site (sediments, shorelines, playa lake deposits)

Black hematite-rich coatings from near-shore environment of Shark Bay, Australia

Presence of lake deposits or hydrothermal materials at the landing site from the 150 km crater?



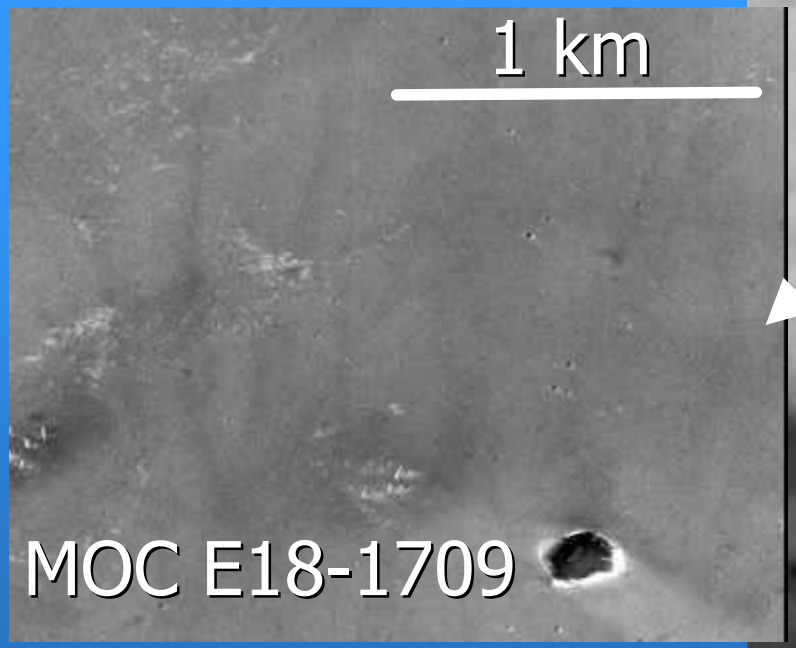
Rim material from the 150 km diameter crater?



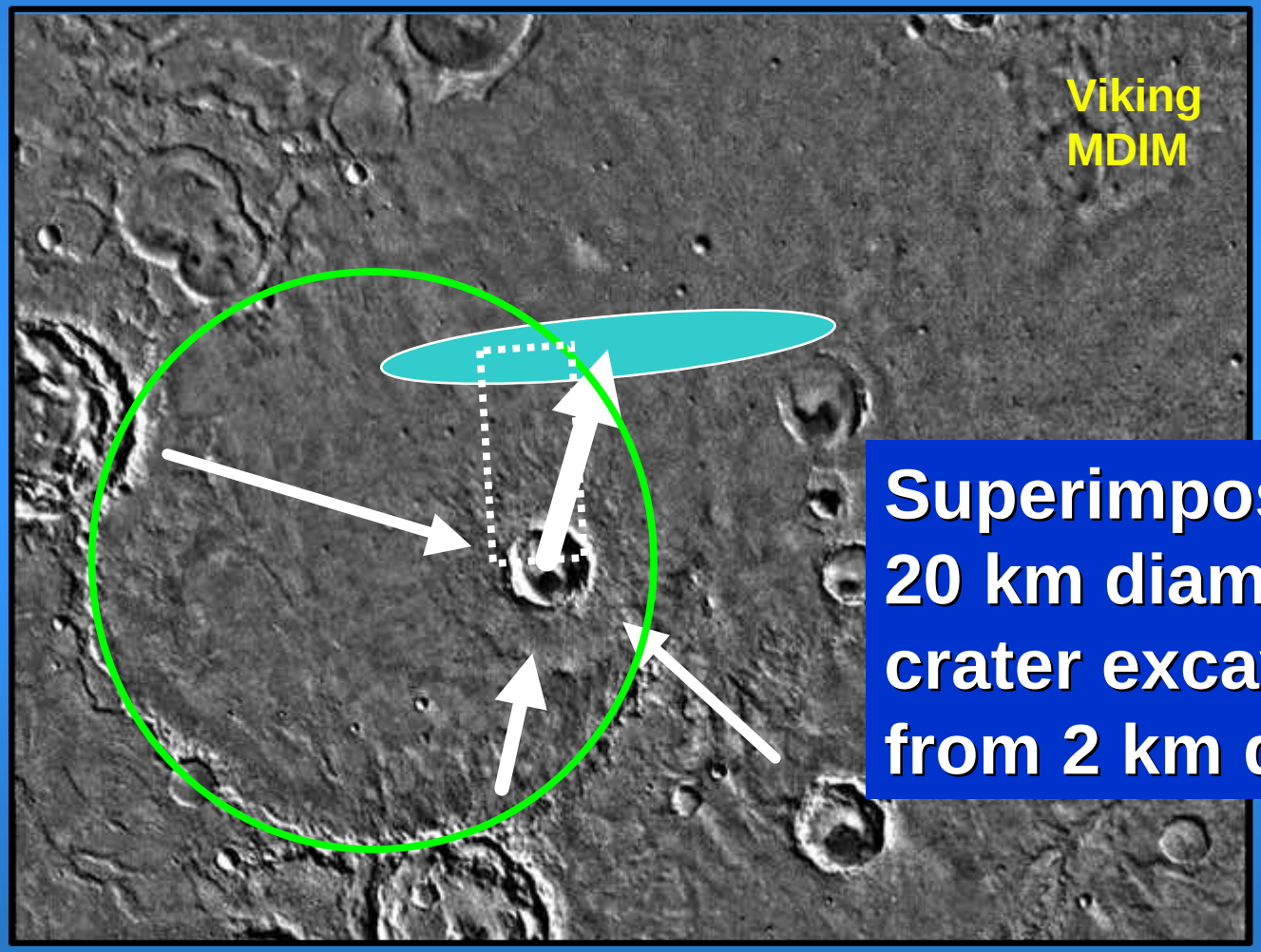
Possible MOLA evidence for low rim, but less than 40m in height

Rim material from the 150 km diameter crater?

No evidence from MOC or THEMIS

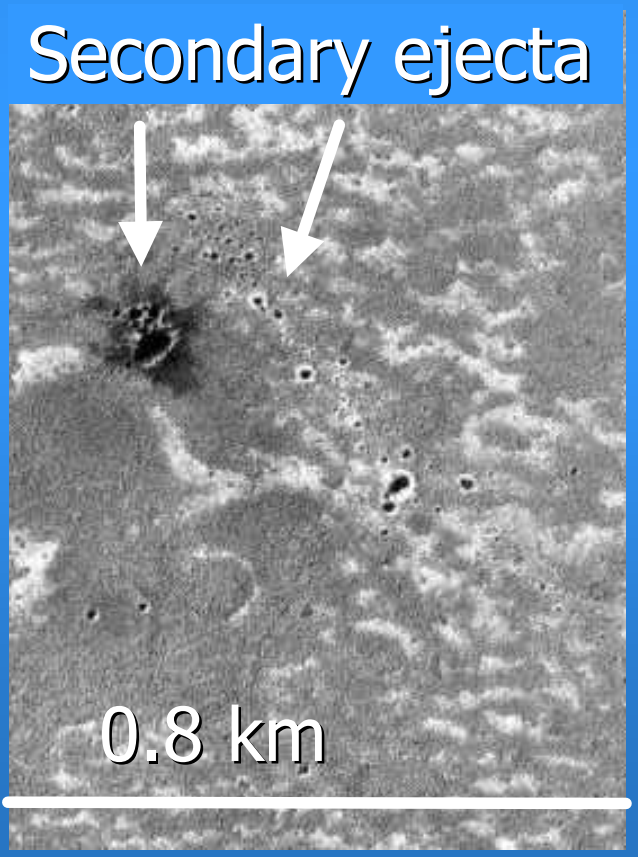


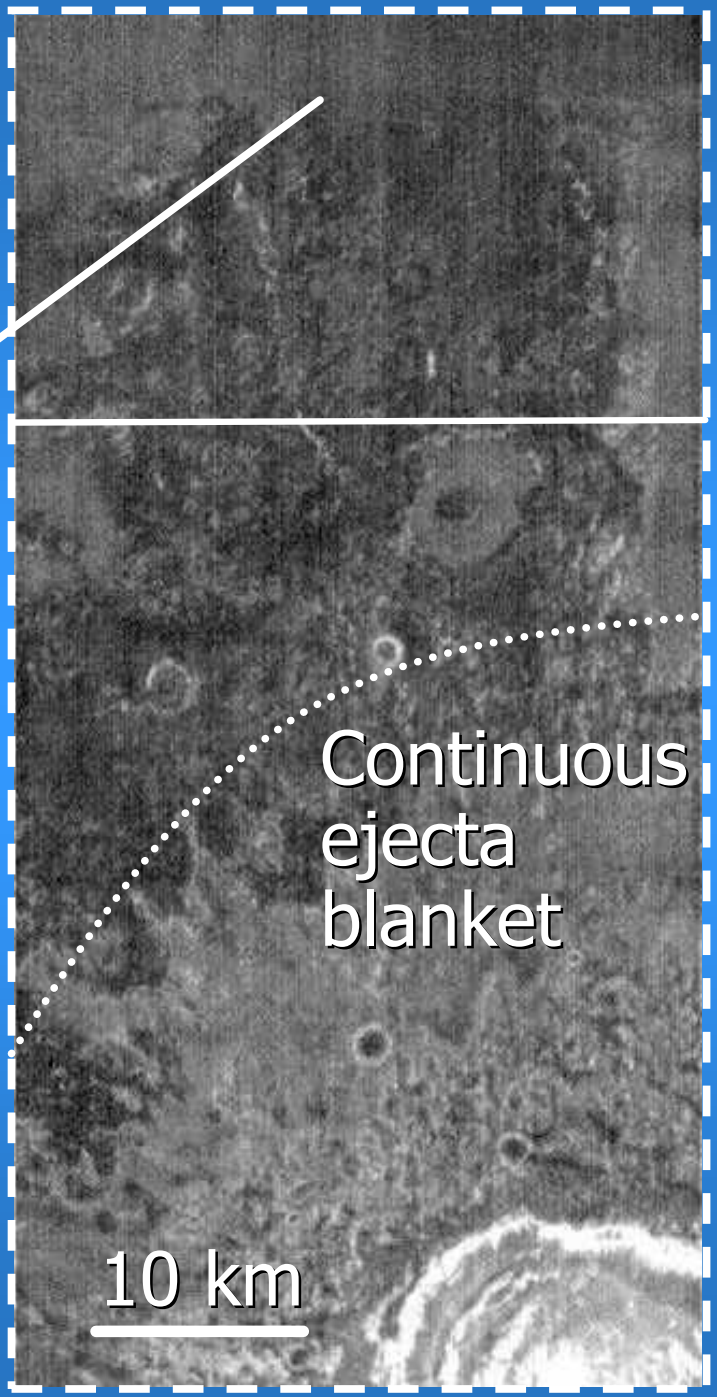
Excavation and transport of rim and basin fill materials as ejecta?



Superimposed 20 km diam. crater excavates from 2 km depth

Evidence for secondary ejecta from 20 km crater near landing site?

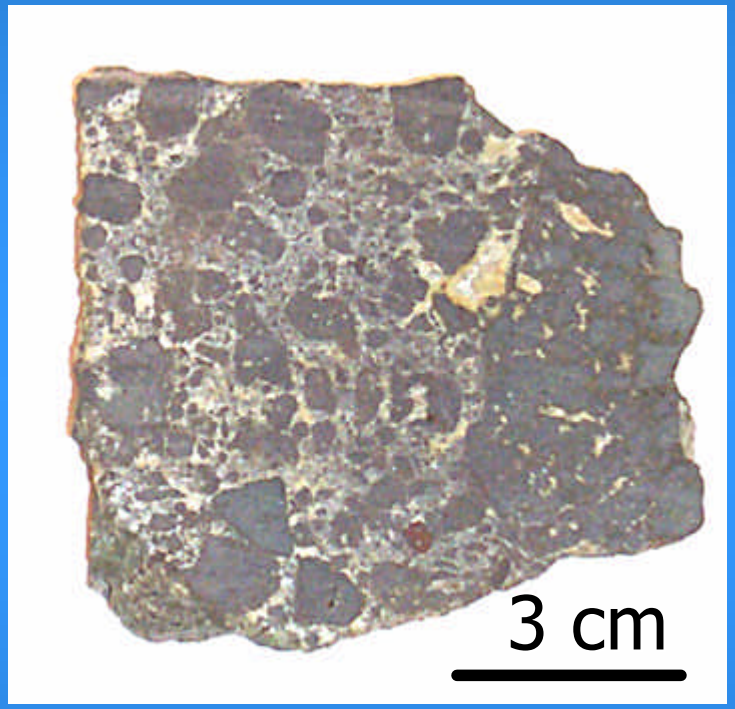




THEMIS I00993002

Tests for excavation and transport of rim and basin fill materials?

- Center of ellipse may contain 20 to 40 cm of ejecta from superimposed 20 km diam. crater including:
  - Rim material from 150 km crater (transported by superimposed craters)
  - Lake or other deposits in crater (negative gravity anomaly: -75 mgal)
  - Buried impact melt from floor of 150 km diameter crater (too deep?)



Basaltic impact breccia, Lonar crater, India

Conclusions – New observations

- The hematite area is located on the southern portion of a circular highland area (400 km in diameter) surrounded by a shallow circular annulus (800 km in diameter) that may represent an early large impact structure
- The basins adjacent to the hematite are fed by channels from a region the size of Texas
- The basins are up gradient from the Ianii chaos, supporting the early presence of lakes
- Epithermal neutron data confirms the presence of buried hydrogen in the basins, probably as bound water, supporting the presence of lakes, possibly in the more recent past

Summary – MER Science Questions

- Origin of 800 km diameter structure?
  - Presence of impact and lacustrine materials
- Extent and history of fluvial processes
  - Sedimentary and playa lake deposits
  - Shorelines and channels
- Origin of layered materials?
  - Sedimentary and aeolian deposits
  - Stratigraphic evidence for timing of deposition and exhumation
- Origin of the hematite?
  - Iron oxide bearing materials from the 800 km basin
  - Near shore coatings as at Shark Bay
  - Volcanic processes
- Materials transported as ejecta to the site?
  - Lake sediments and impact melts excavated by the 20 km diam. crater near the landing site