What does radar measure?

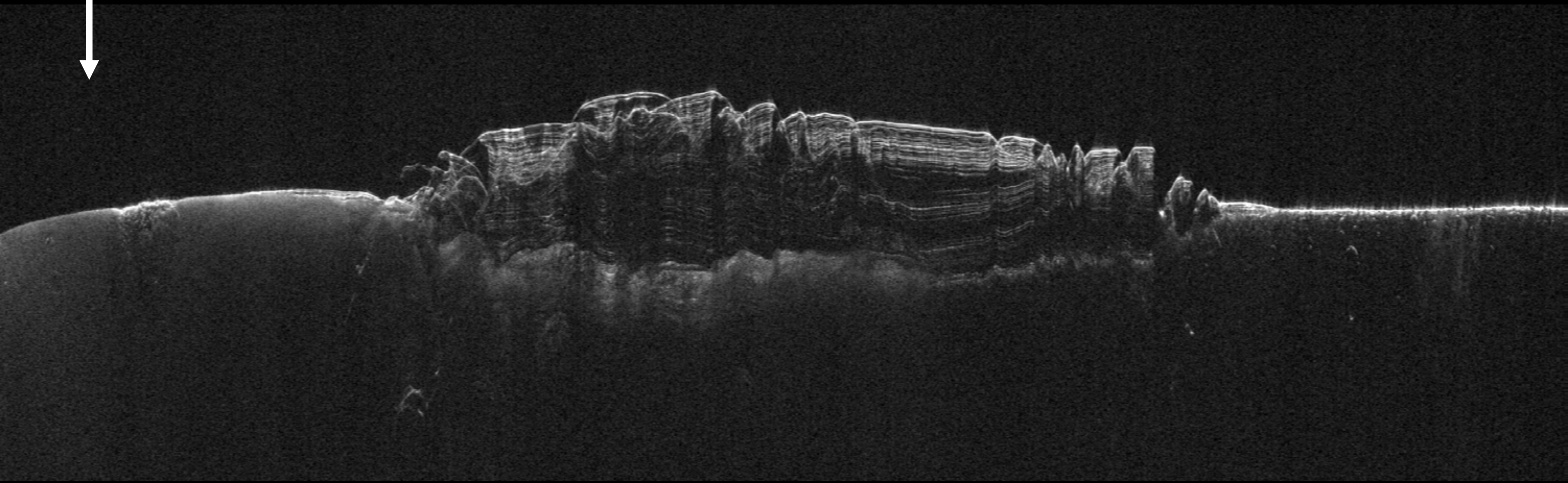
- [Hint: not composition]

- Echo intensity as a function of time, in 2 dimensions
    - "Slow time": along-track spacecraft motion (horizontal)
    - "Fast time": echo delays at ~light-speed (vertical)

    - Result is a 2D radargram:
        - A cross-section, in time, with extreme vertical exaggeration

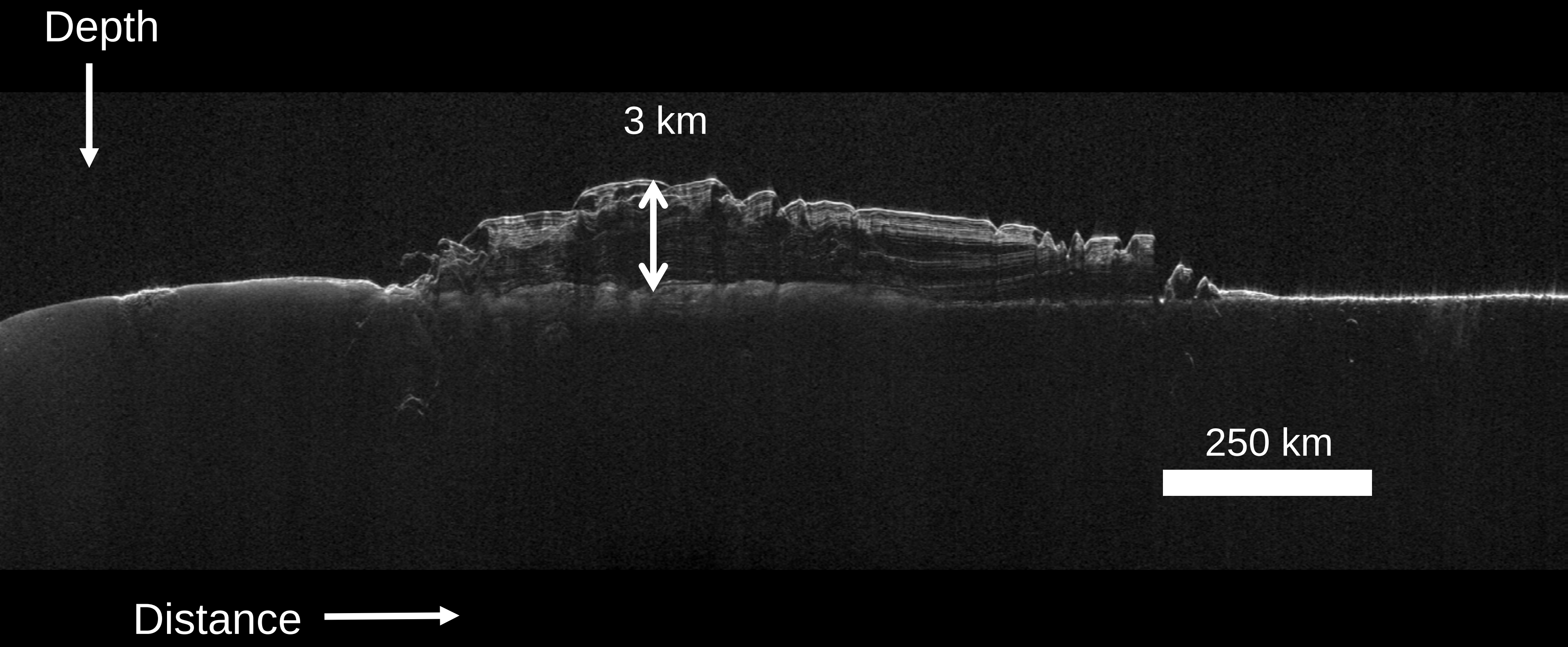
SHARAD NPLD - Time Representation

Fast Time (microseconds)



Slow Time (10s of seconds)

SHARAD NPLD - Depth Representation



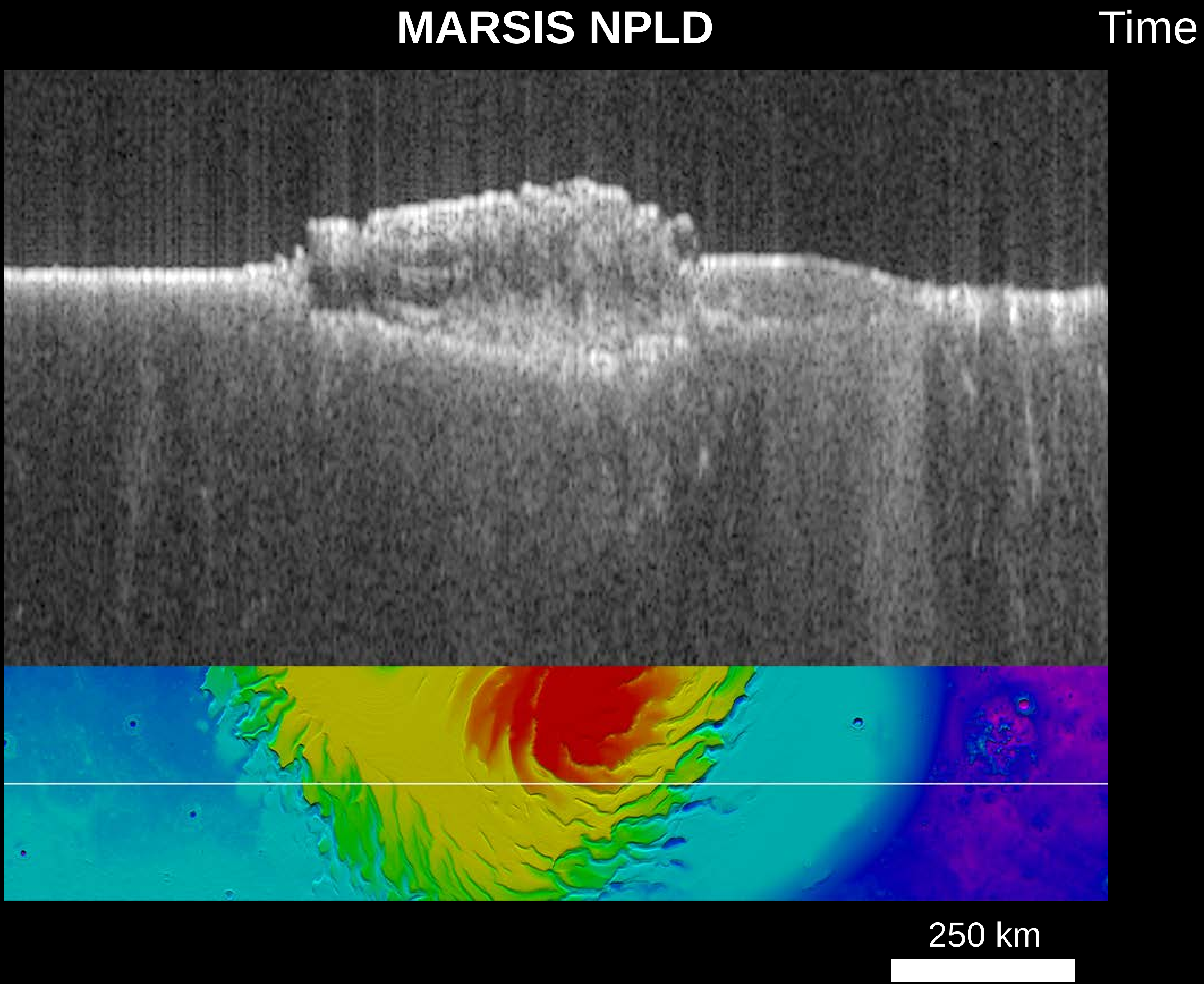
Vertical Exaggeration ~ 100:1

What causes a reflection?

- Reflections occur a boundaries of packets of material of differing dielectric constant (refractive index)

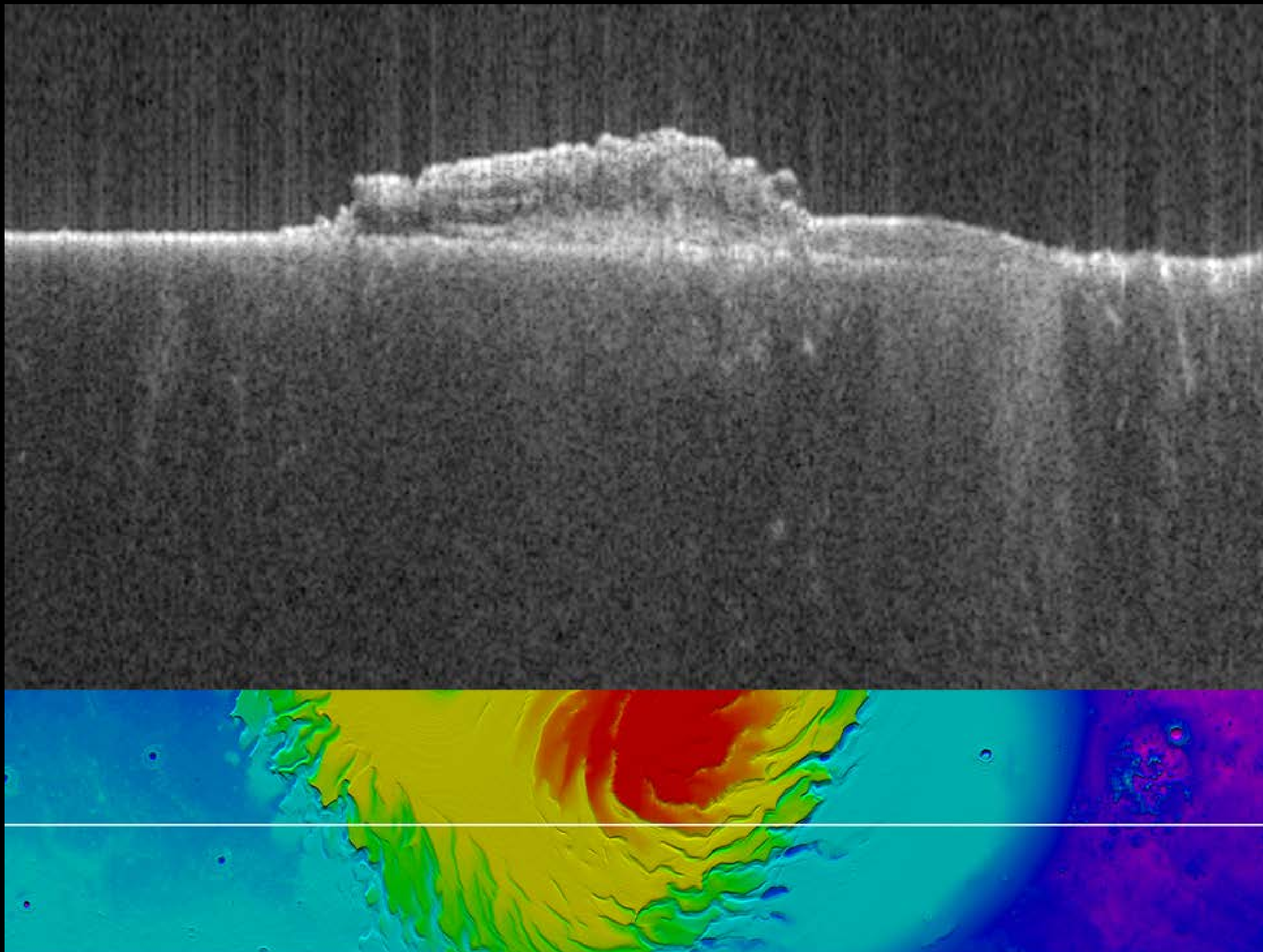
- Examples:
  - Atmosphere over regolith (always see this)
  - Ice over rock (base of polar ice, a glacier's bed)
  - Ice over water (Lake Vostok)
  - Clean ice against dirty ice (polar layered deposits, NPLD over basal unit)
  - Various contacts of rock units (lava flows, sediments, paleo-regolith)

MARSIS NPLD



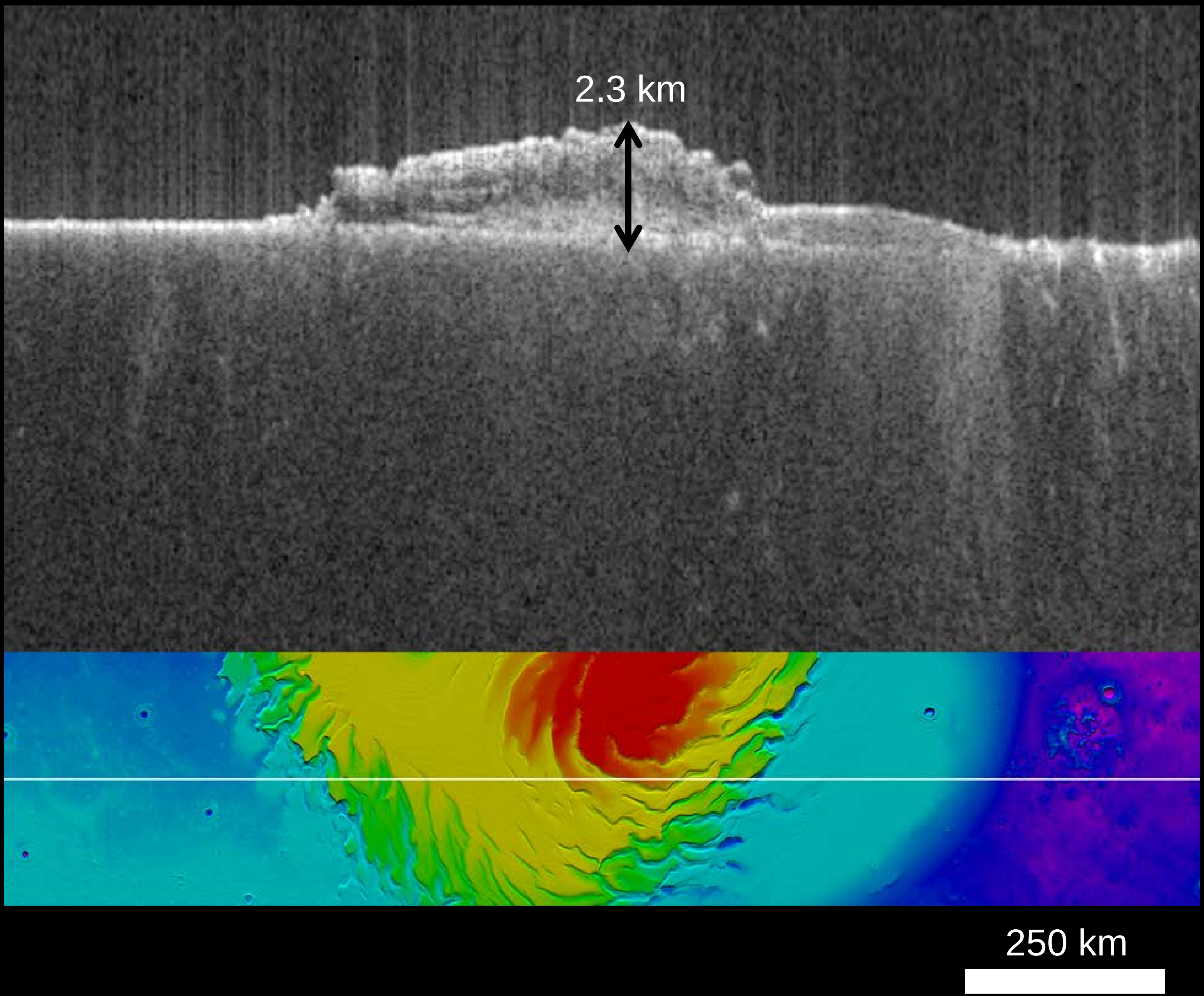
MARSIS NPLD

Depth

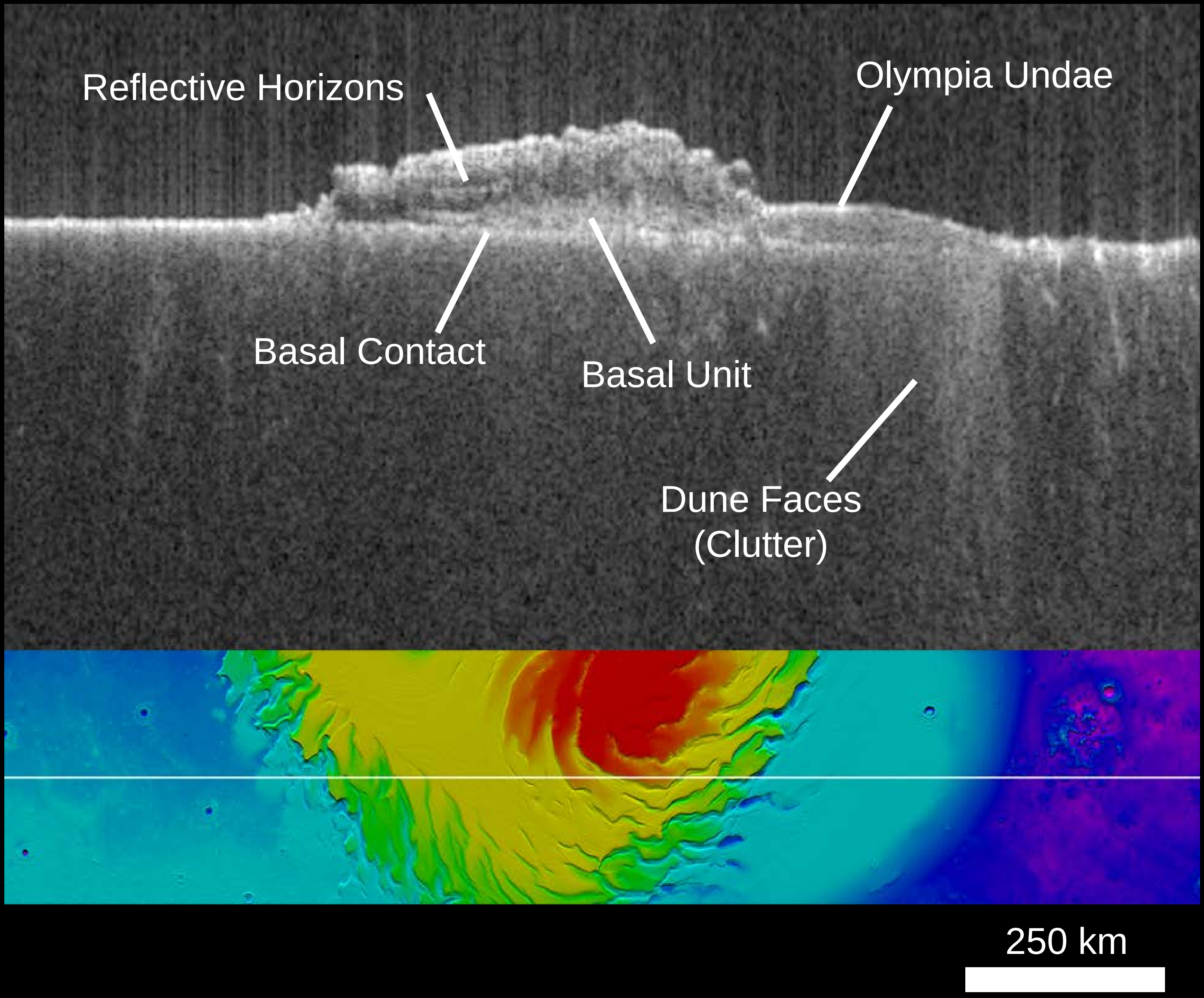


250 km

MARSIS NPLD



MARSIS NPLD



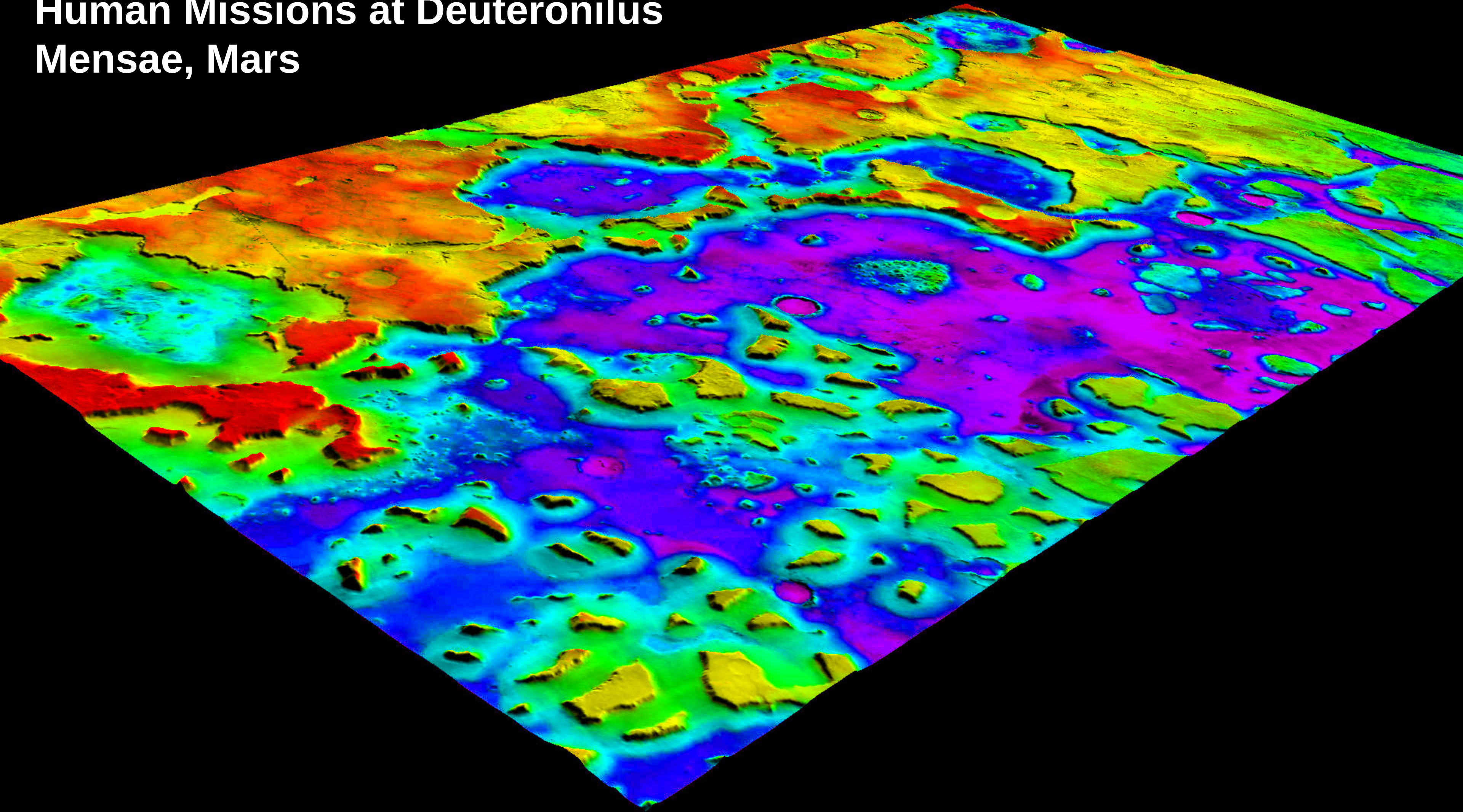
Reflective Horizons
Olympia Undae
Basal Contact
Basal Unit
Dune Faces
(Clutter)
250 km

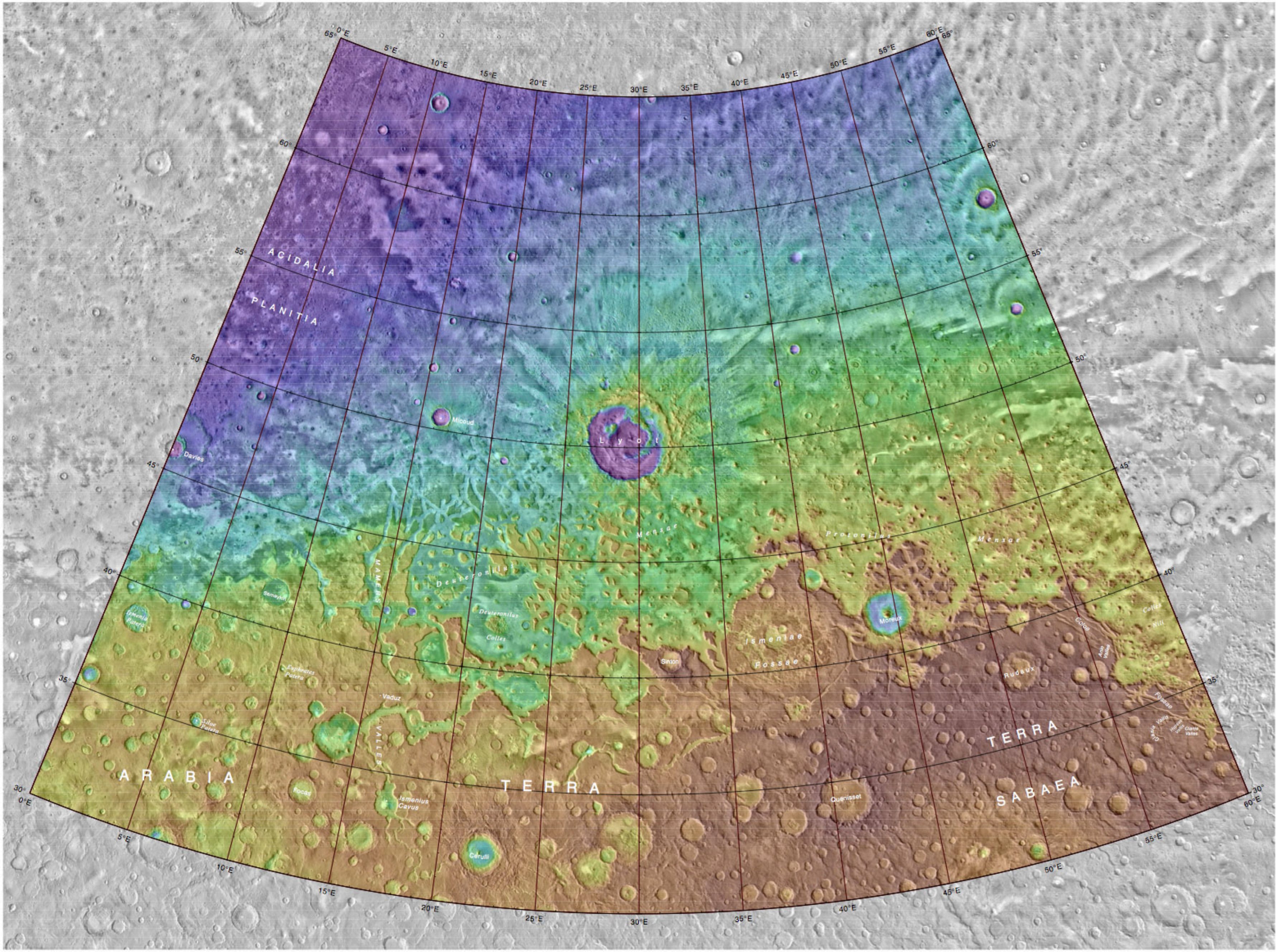
How do we "know" it's ice?

- Radar does not uniquely determine composition
- Waves are affected by the complex dielectic constant
  - Real part (reflectivity at interface, speed of wave in volume)
  - Imaginary part (loss across a volume)
- Ice and sedimentary rock may have the same real dielectric
- But clean ice has very low loss; lithics much higher

- Best indications of ice:
  - Speed of the wave (geometry)
  - Strong reflection at basal interface indicates low loss on round trip
  - Supporting evidence from other sources: morphology from images, thermal environment

A Resource-rich, Scientifically Compelling Exploration Zone for Human Missions at Deuteronilus Mensae, Mars





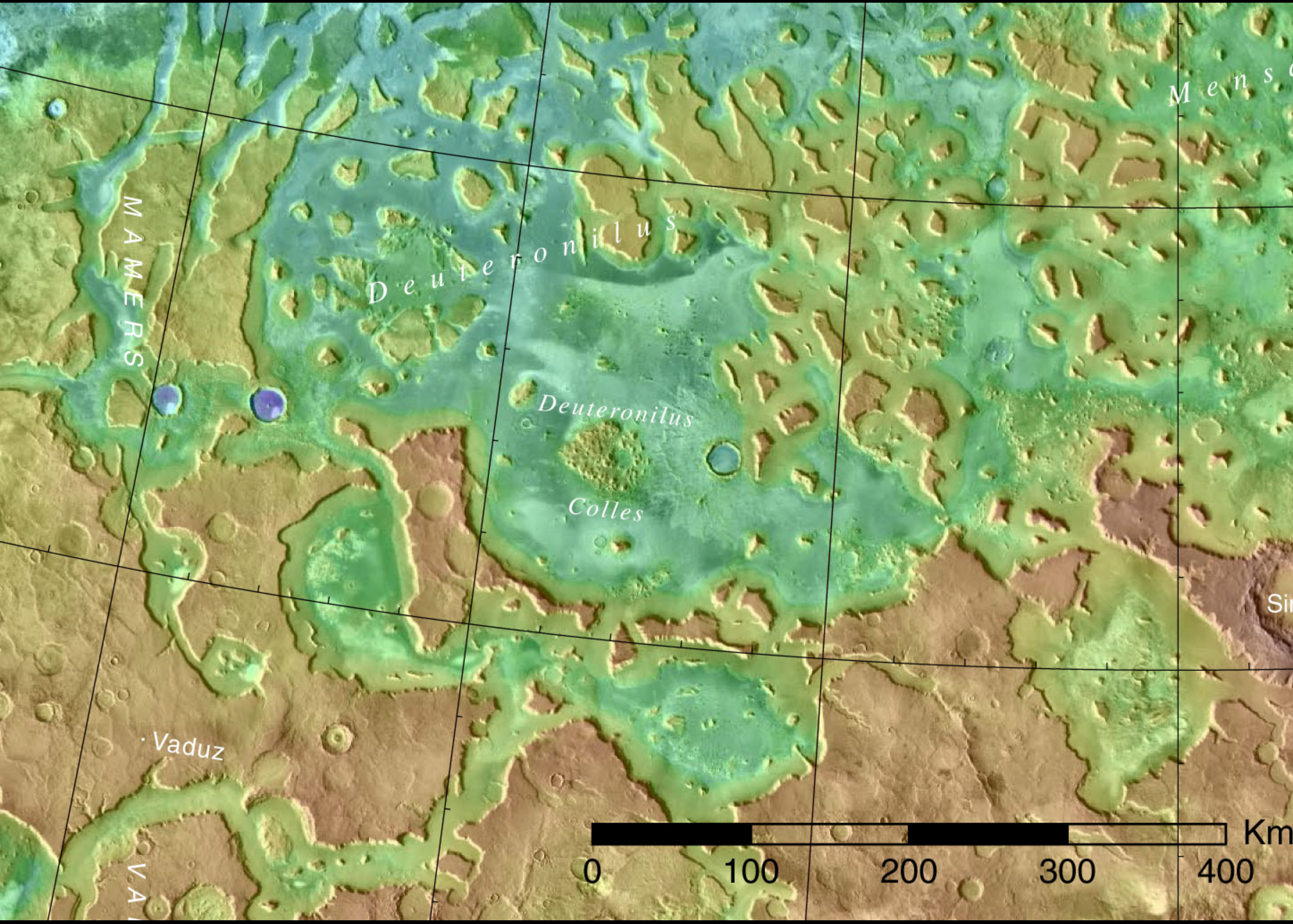
Projection: Lambert Conformal Conic
Datum: Mars 2000 Sphere
Central Meridian: 30.0
Standard Parallel 1: 36.2
Standard Parallel 2: 59.5
Scale Factor: 1.0
Latitude of Origin: 0.0

MOLA Elevation (m)
High : 1205
Low : -7013

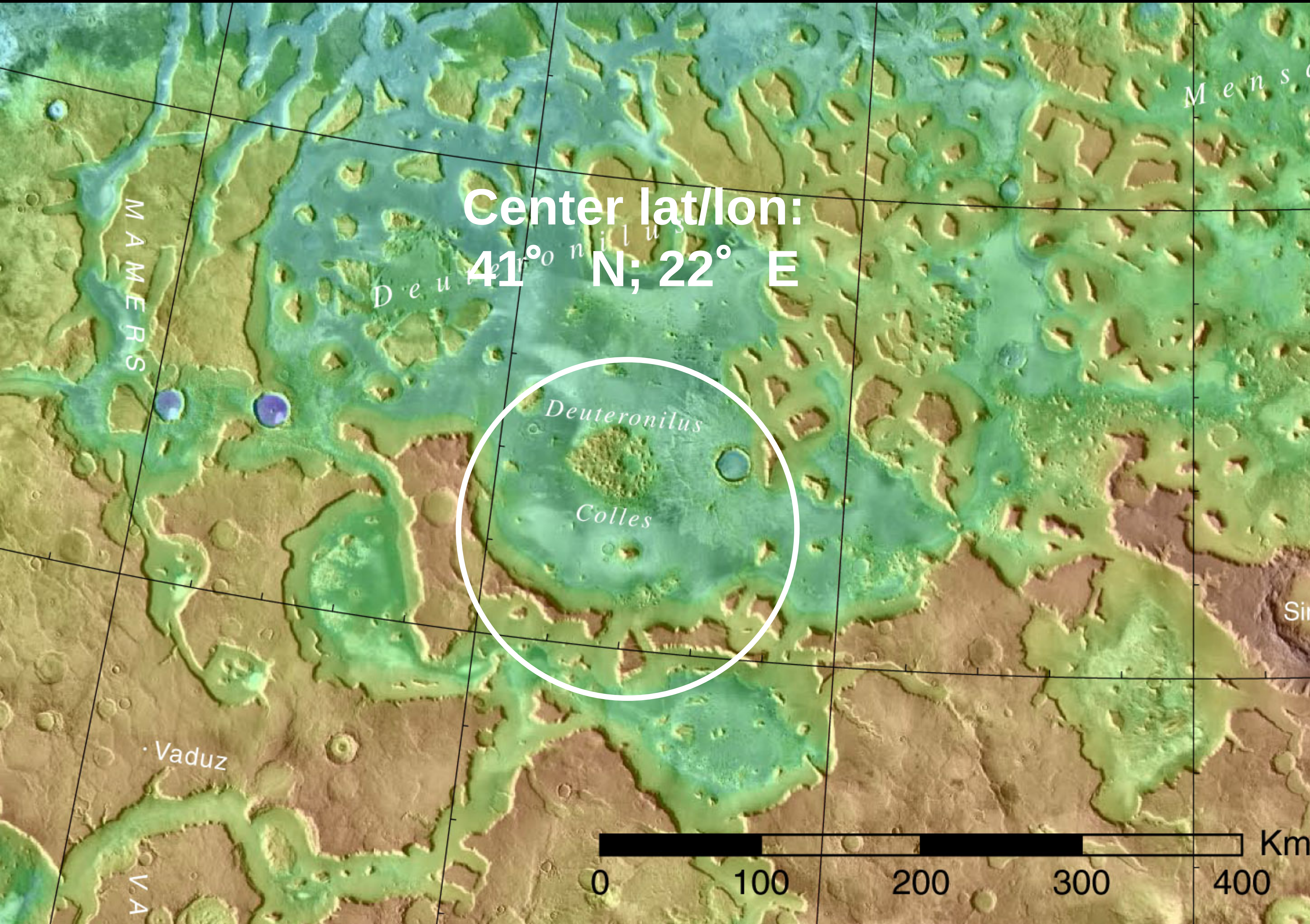
Km
0 100 200 300 400
Scale 1:5,000,000 at standard parallel

Ismenius Lacus, MC-5

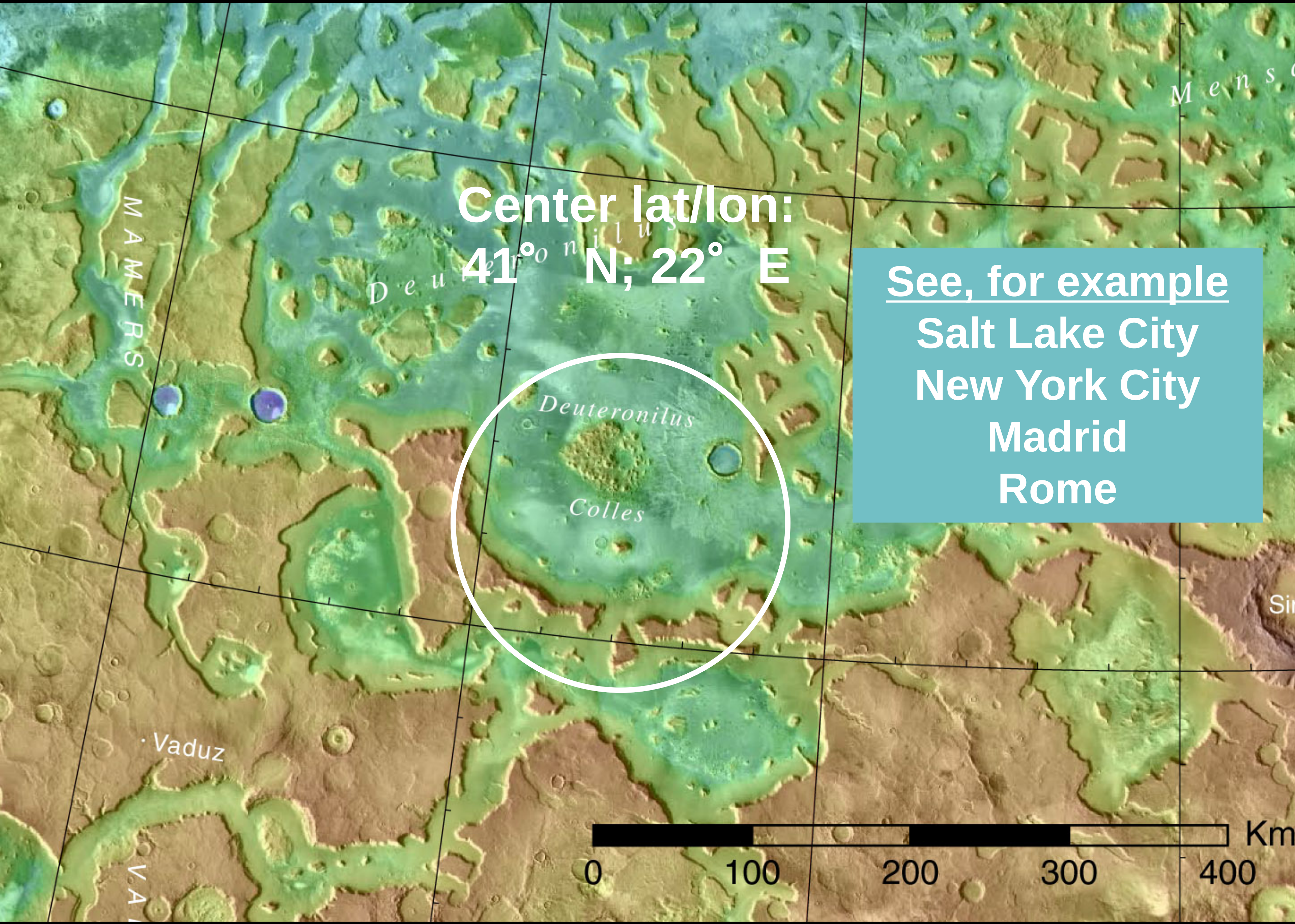
Base image: THEMIS IR Day mosaic by ASU
Margin image: THEMIS IR Global Mosaic v11.6, ASU
Colorized Topography: MOLA Elevation Model, GSFC



MAMERS
Deuteronilus
Deuteronilus
Colles
Vaduz
Km
0
100
200
300
400



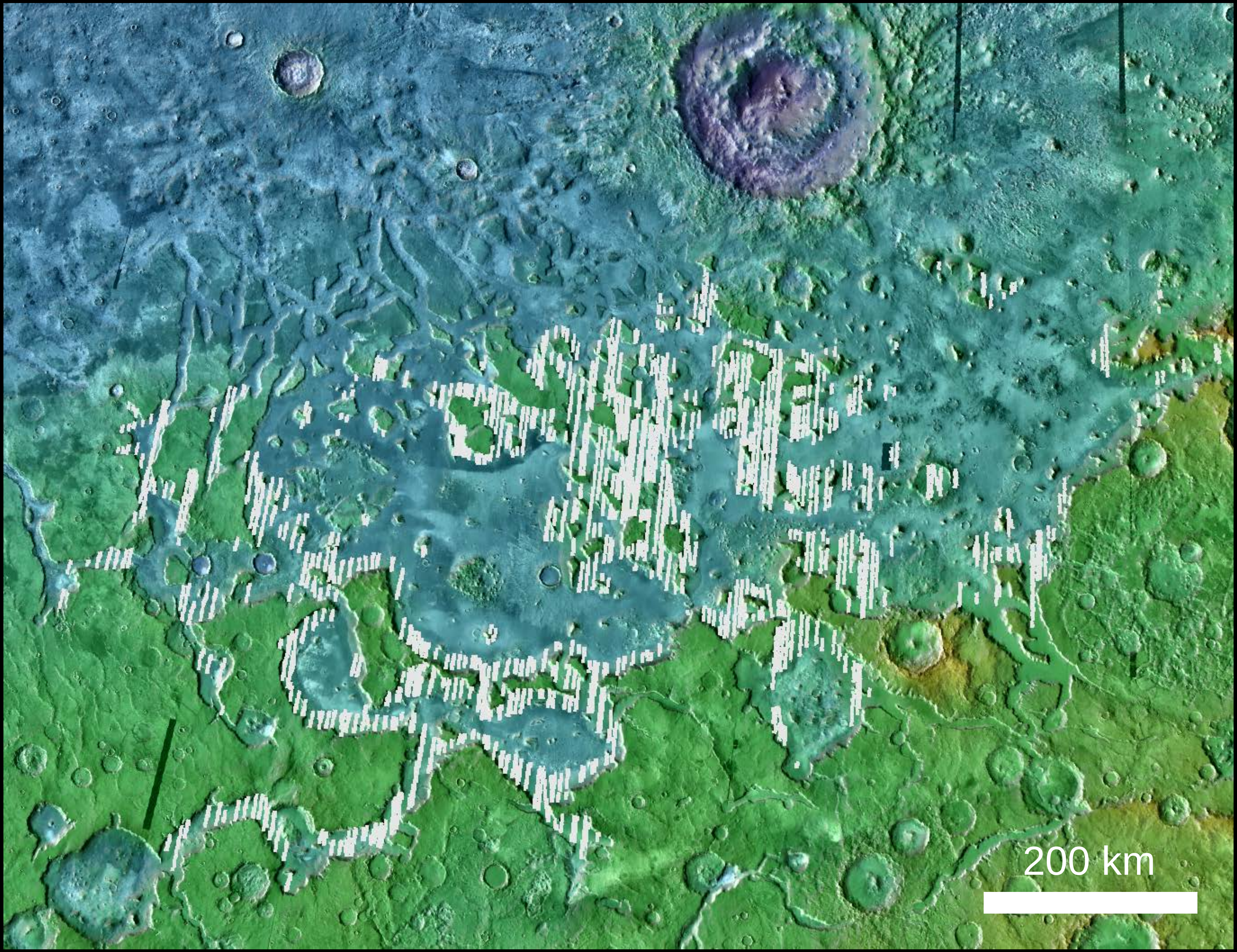
Center lat/lon:
41° N; 22° E
MAMERS
Deuteronilus
Deuteronilus Colles
Vaduz
0 100 200 300 400 Km

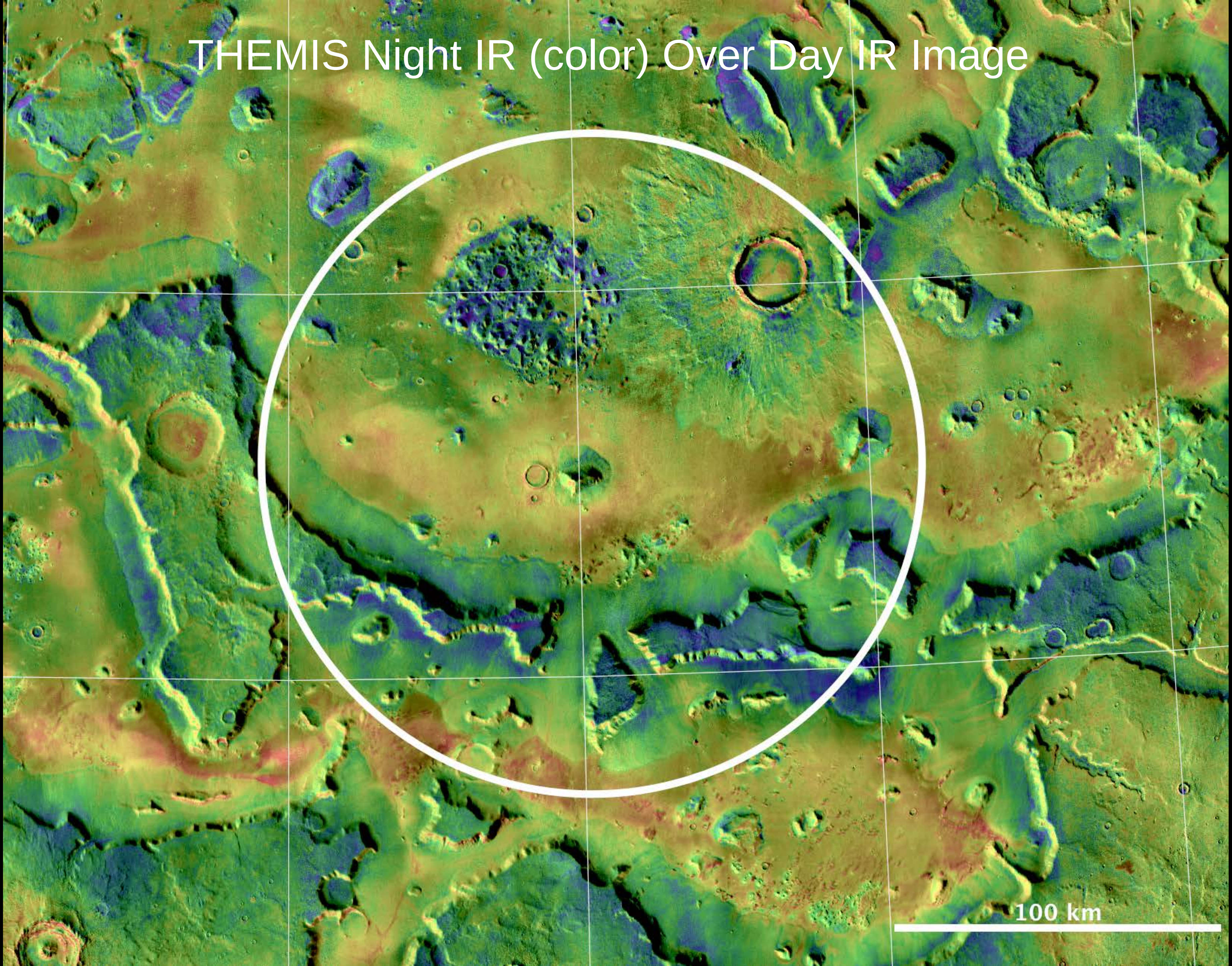


Center lat/lon:
41° N; 22° E

See, for example
Salt Lake City
New York City
Madrid
Rome

Detections of Thick Ice in Deuteronilus



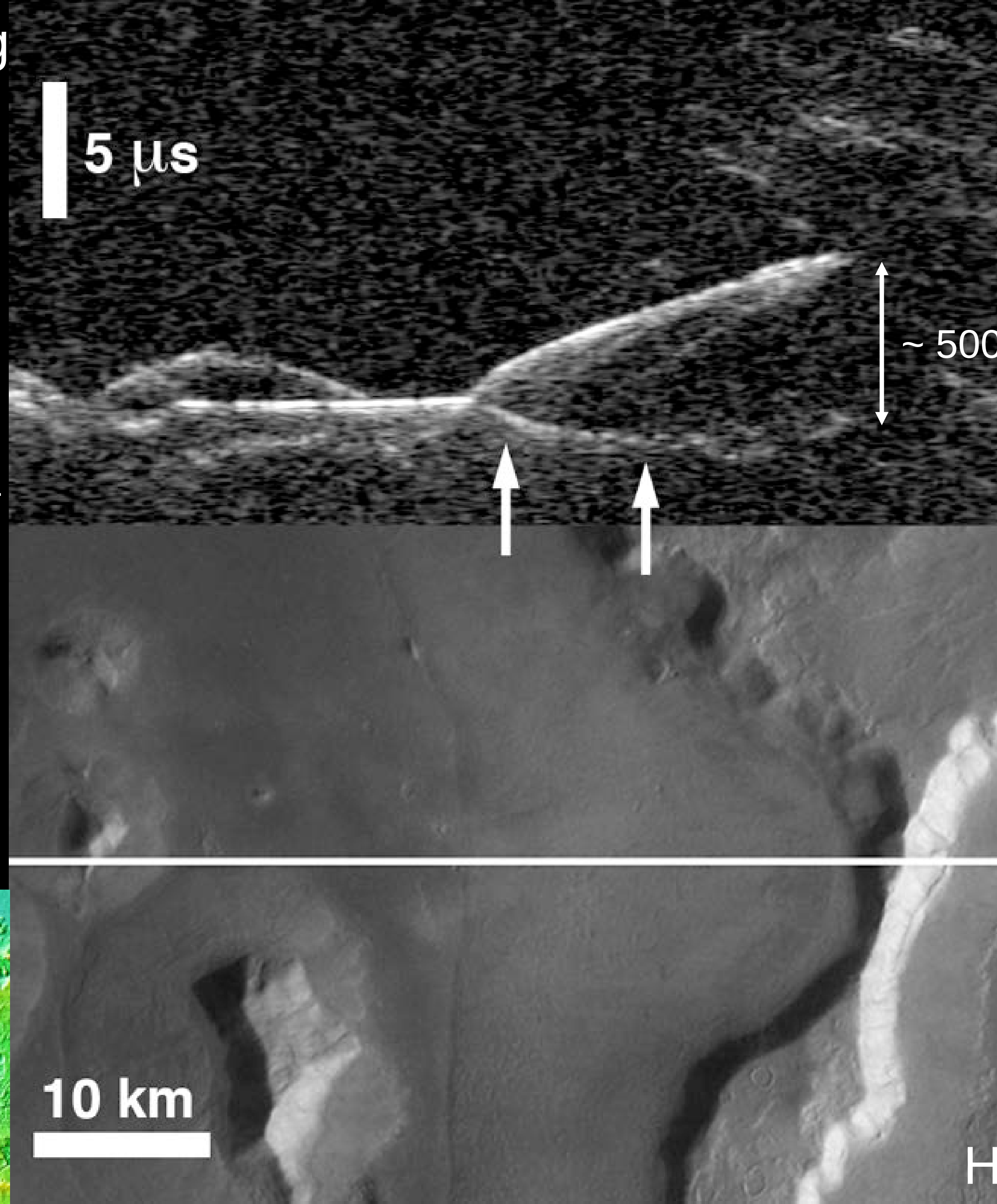

THEMIS Night IR (color) Over Day IR Image
100 km

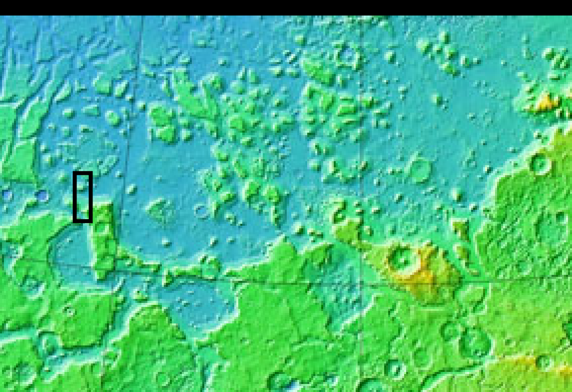
Resource ROI 1 – Margin of Apron

Resource ROI 1 – Margin of Apron

SHARAD Sounding of Lobate Debris Aprons

2145_01

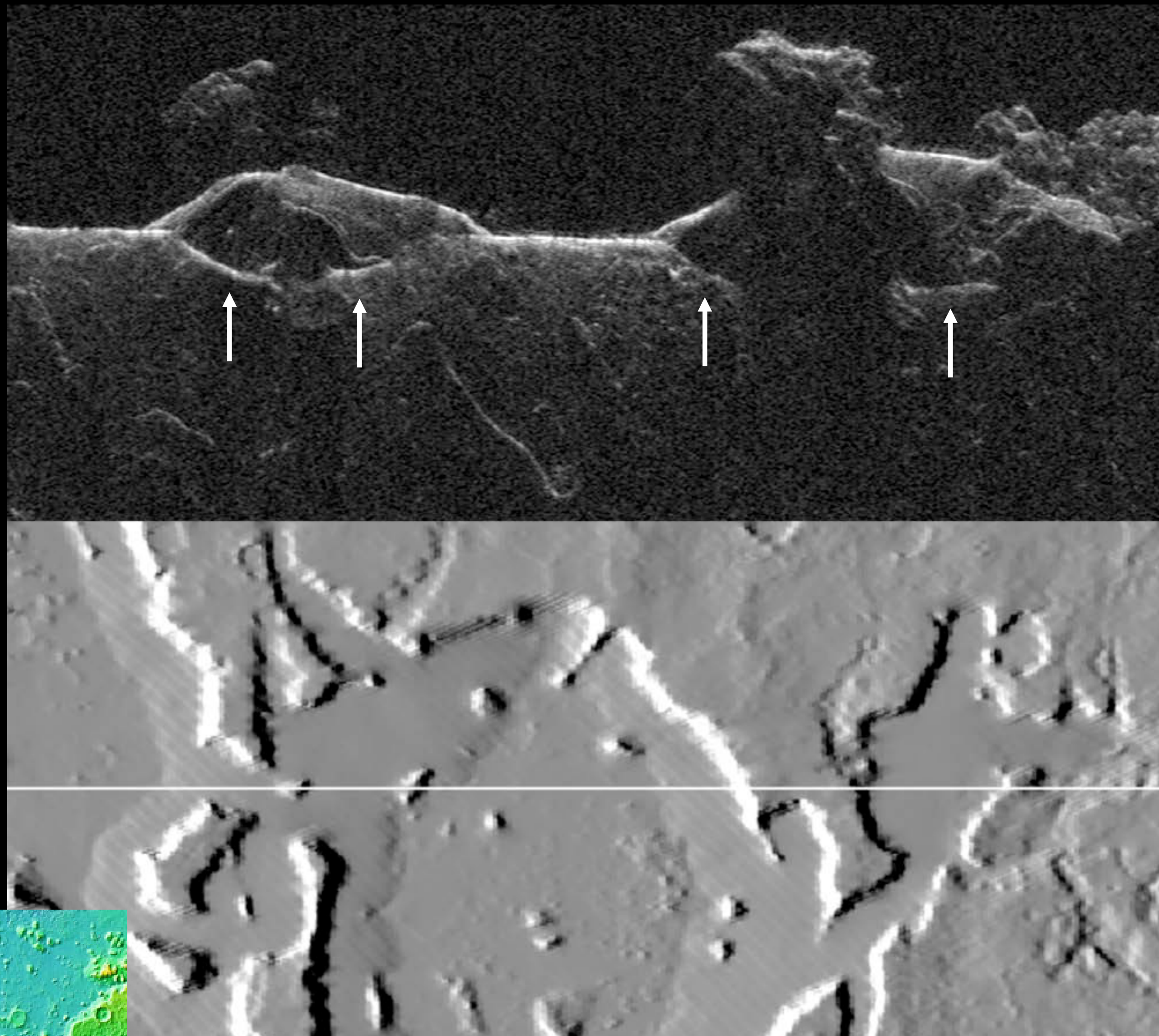


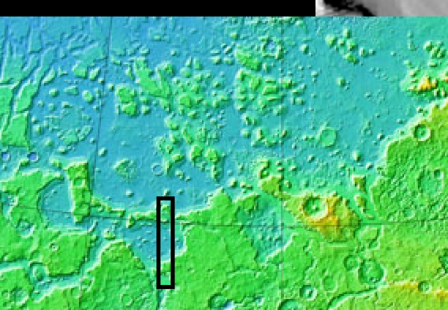


HRSC

Converting Time to Depth

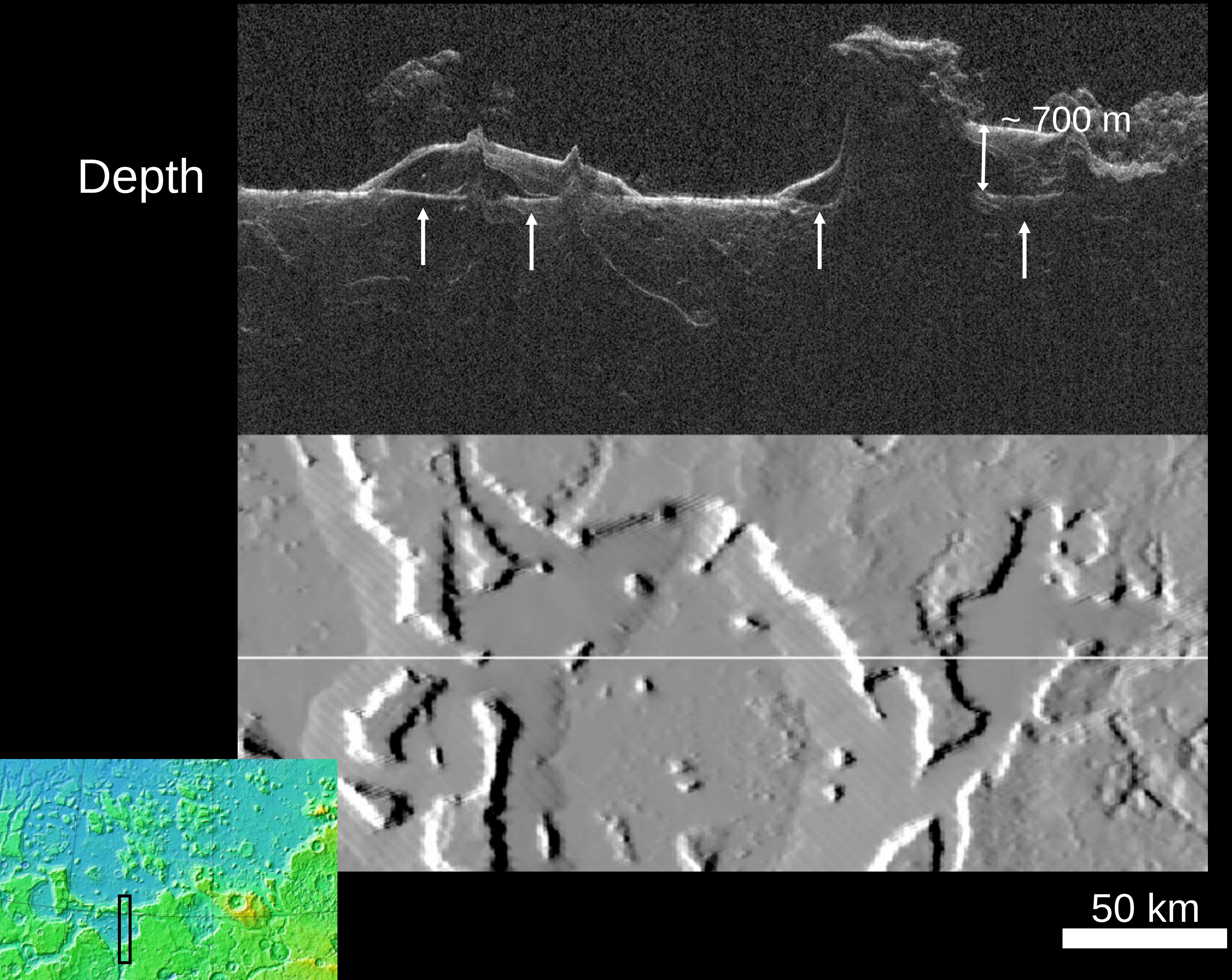
Time





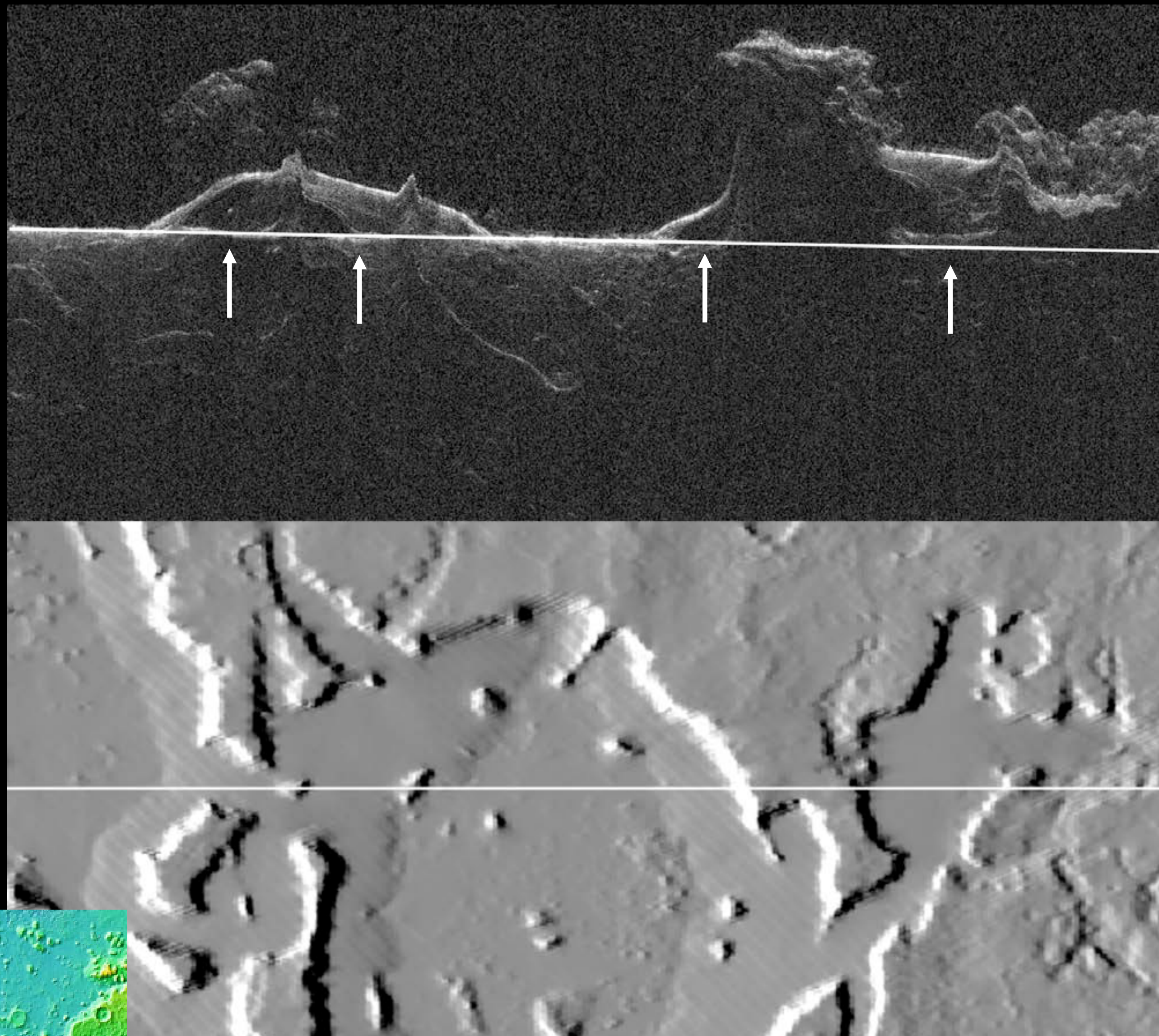
50 km

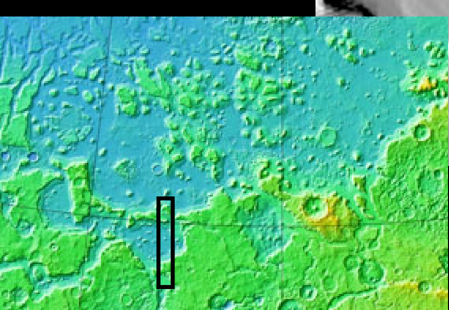
Converting Time to Depth



Converting Time to Depth

Depth





50 km

Constraining the thickness of overburden (How deep is the top of the ice?)

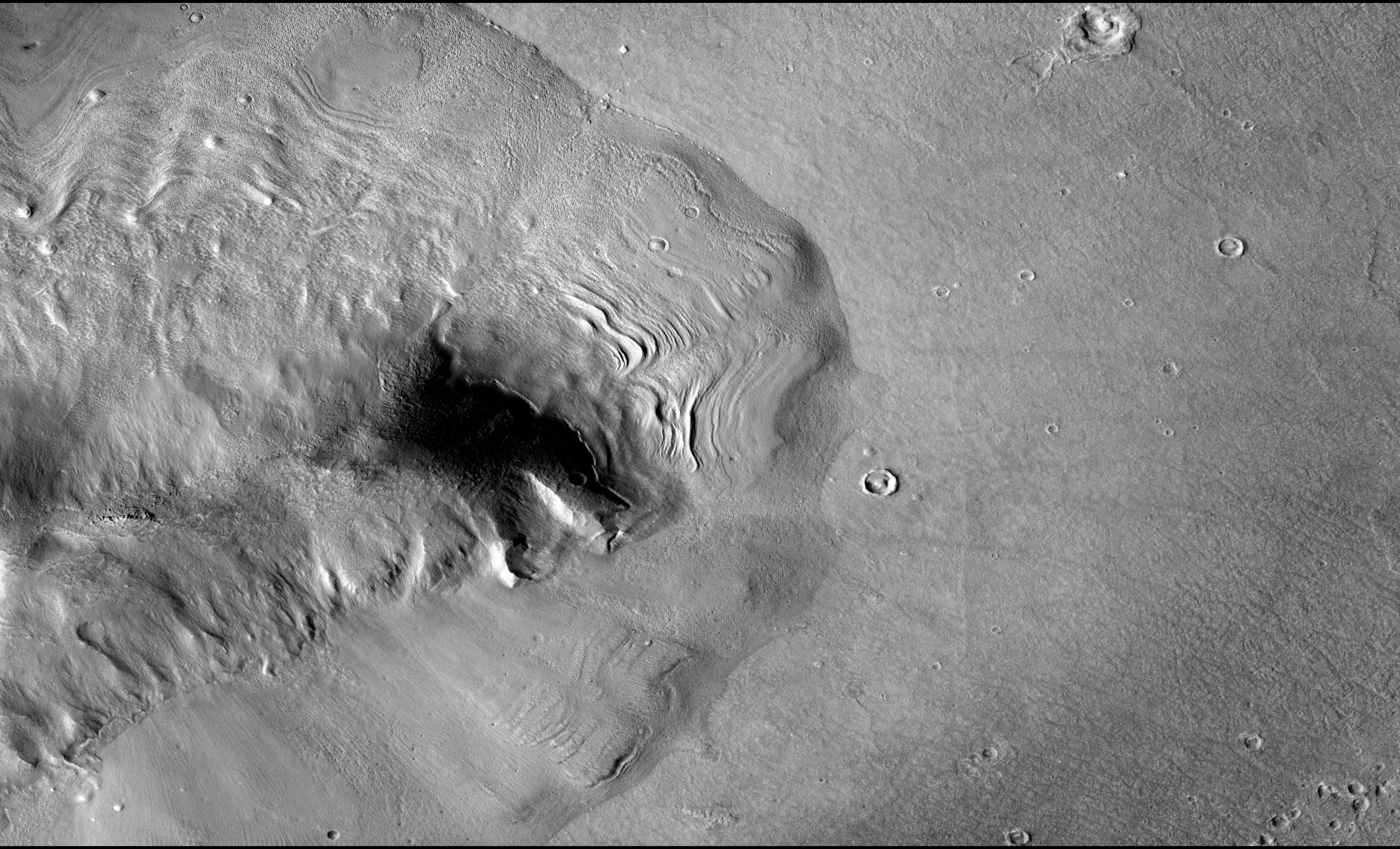
- No enhancement in H content is seen in Odyssey GRS or Neutron data.
  - Implies that the upper 0.5-1.0 m is “dry”.

- No shallow boundary between dry overburden and massive ice is seen in SHARAD data. Implies either:
  - a) boundary is in the near-surface blind zone (~10m), or
  - b) boundary does not provide sufficient dielectric contrast to produce an echo.

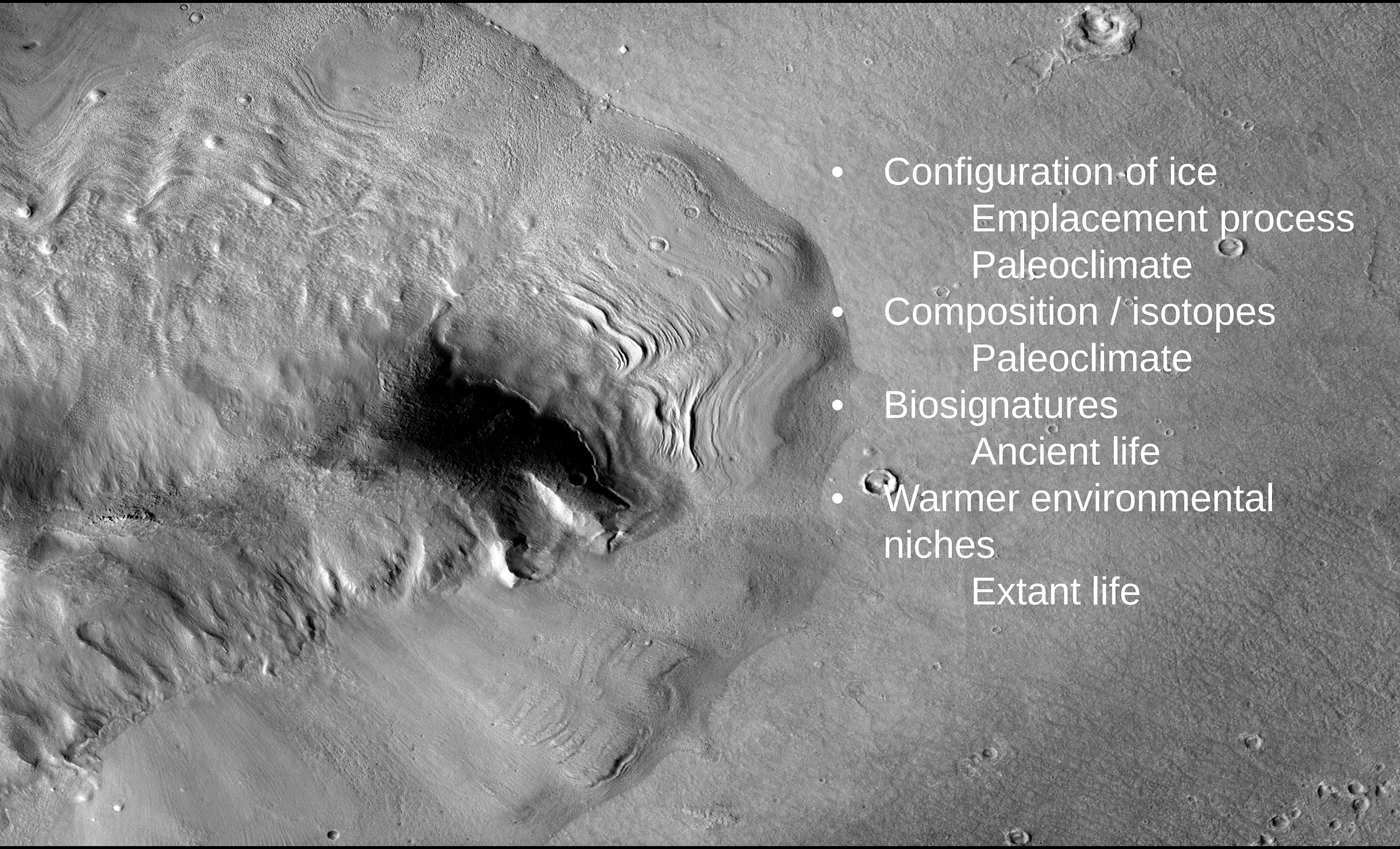
- Preferred interpretation is a) above, because a thick debris layer is unlikely to be low enough in density (source is mass wasted bedrock; compaction of thick layer will increase density).

- Best current estimate of overburden thickness is 1-10 m.

Science ROI 1 – Margin of Apron

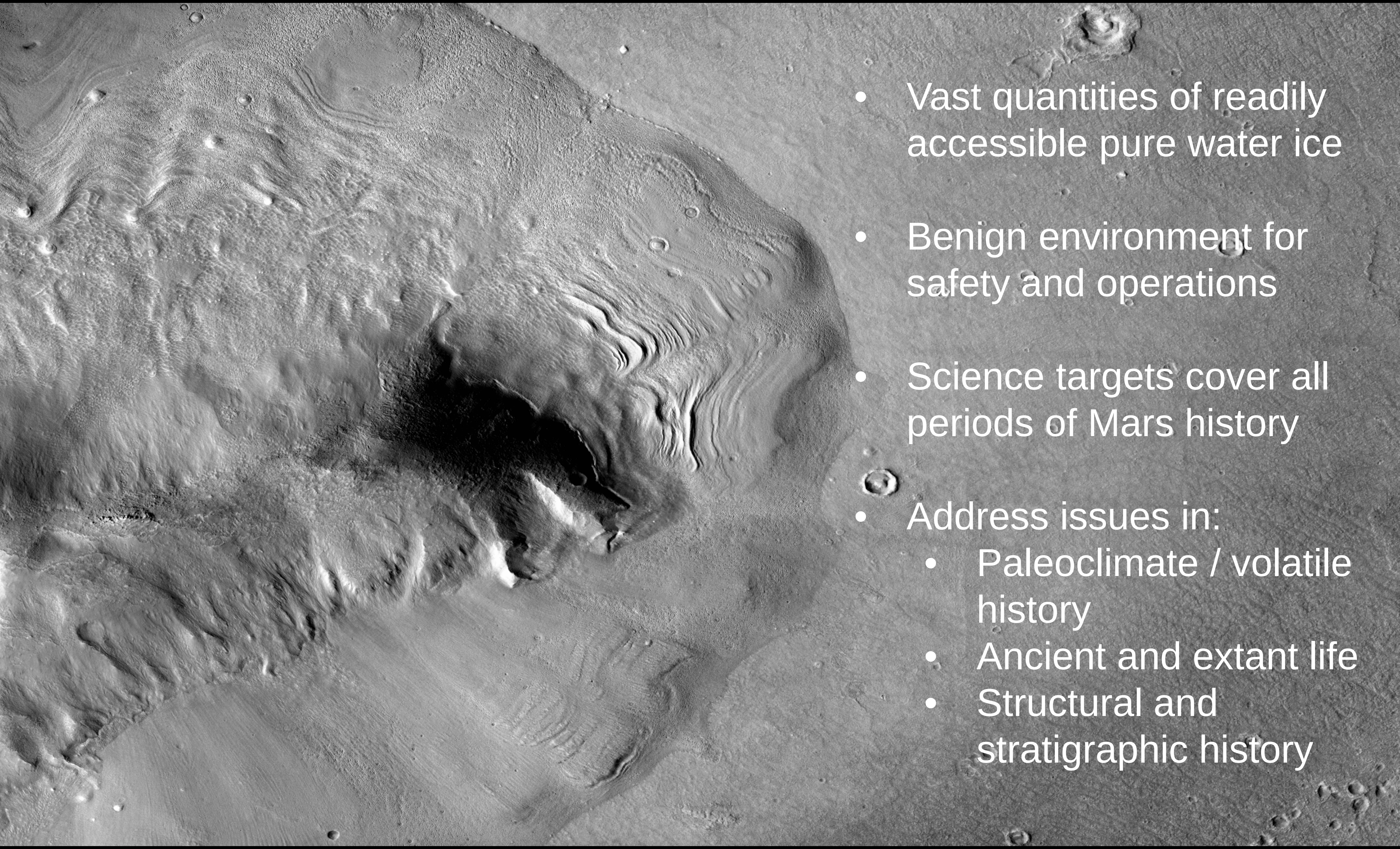


Science ROI 1 – Margin of Apron

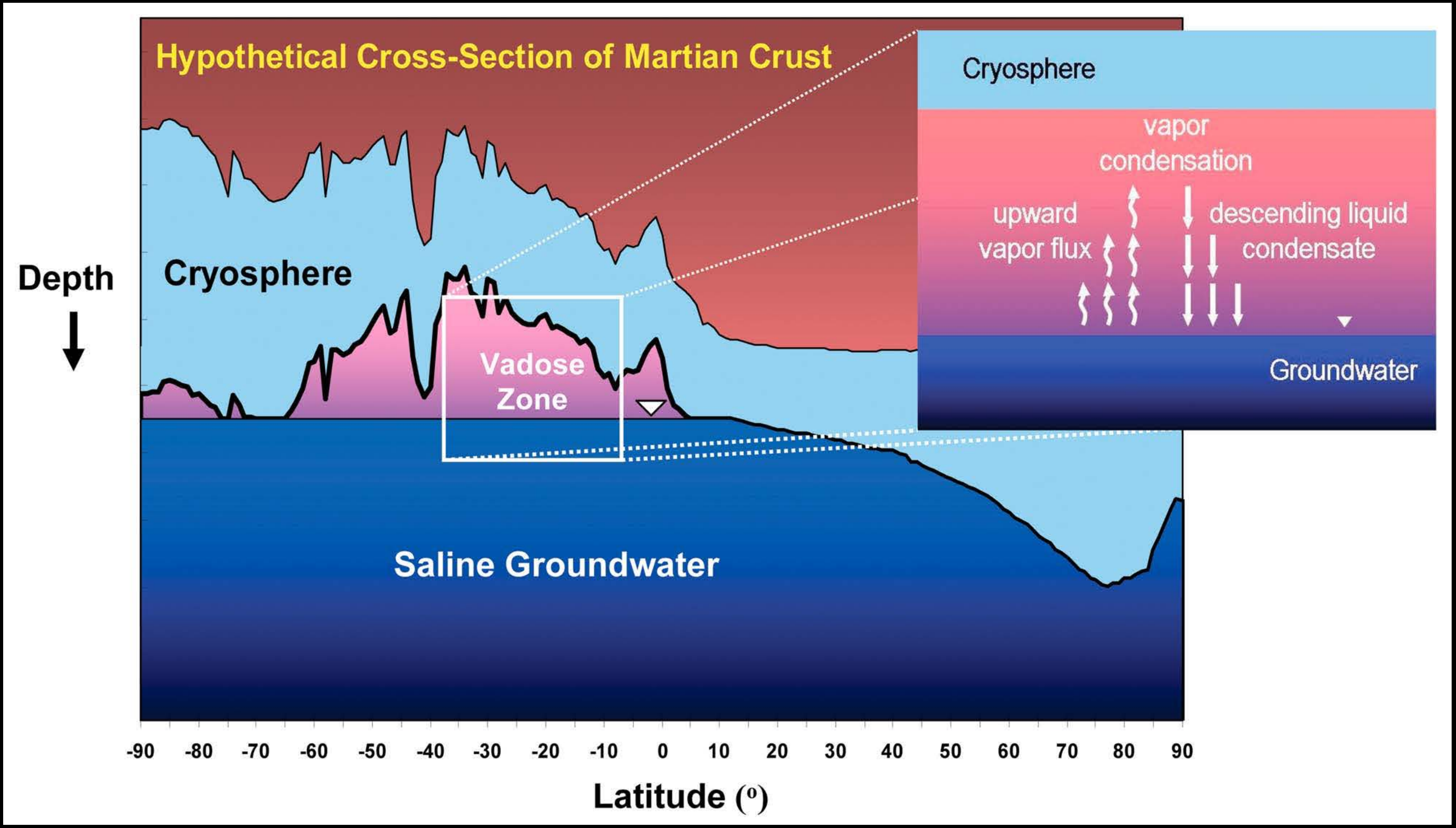


- Configuration of ice
  - Emplacement process
  - Paleoclimate
- Composition / isotopes
  - Paleoclimate
- Biosignatures
  - Ancient life
- Warmer environmental niches
  - Extant life

Summary



- Vast quantities of readily accessible pure water ice
- Benign environment for safety and operations
- Science targets cover all periods of Mars history
- Address issues in:
  - Paleoclimate / volatile history
  - Ancient and extant life
  - Structural and stratigraphic history



Clifford et al., 2010

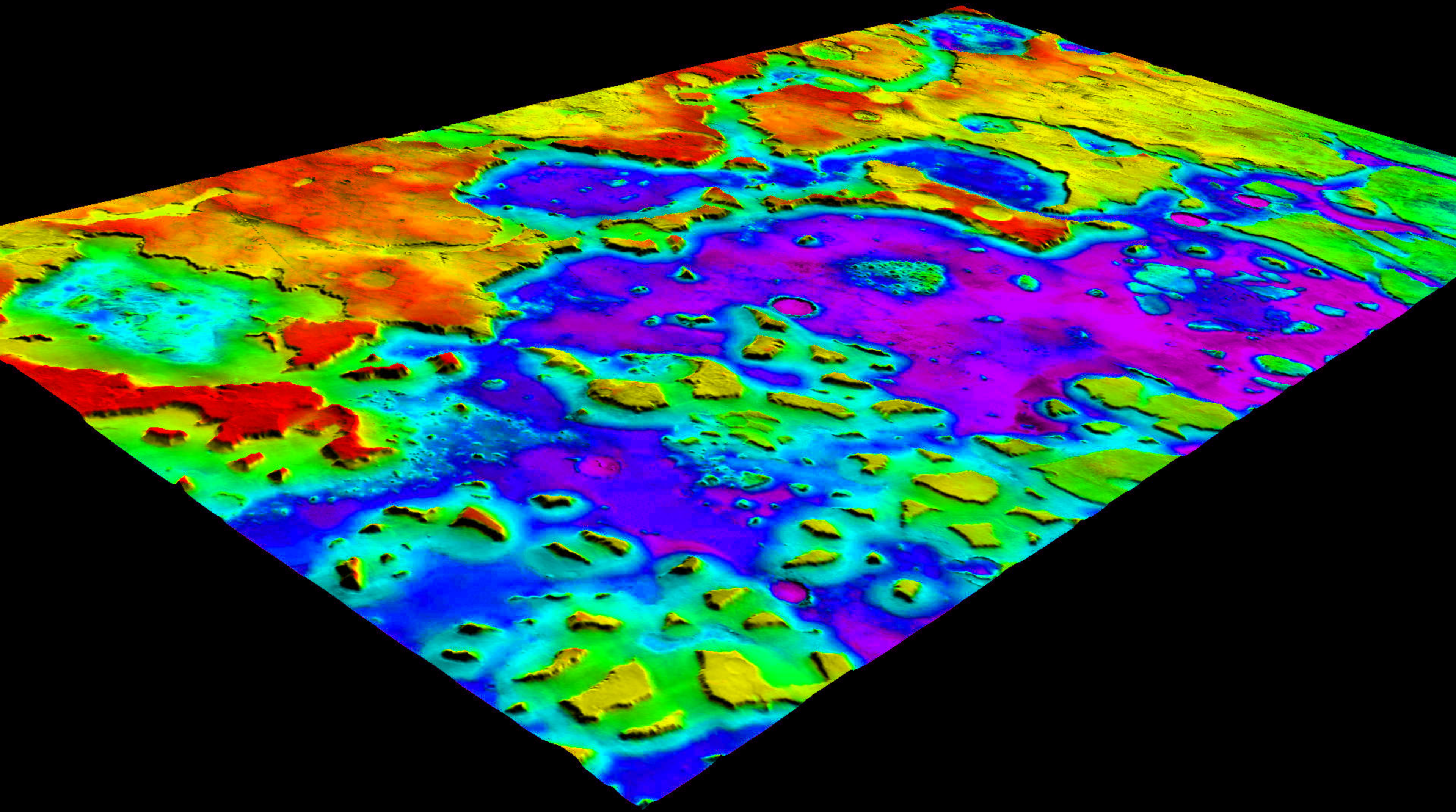
Possible Explanations for the Absence of Subsurface Reflections Indicative of Groundwater

1. **Subpermafrost groundwater may no longer survive on Mars**, having been cold-trapped into the pore volume of the thickening cryosphere or lost by other processes (e.g., chemical weathering).

2. **Groundwater is present but the cryosphere is deeper than previously believed**, placing it beyond the maximum sounding depth of MARSIS.

3. **Gradients of unfrozen water in the lower cryosphere, or above a subpermafrost groundwater table, have reduced the dielectric contrast necessary to obtain a reflection**.

4. **The dielectric loss and scattering properties of subsurface may be greater than previously thought**, resulting in lower than expected MARSIS sounding depths.



Resource ROI 1 – Margin of Apron