Radar Mapping and Water Reservoirs on Mars

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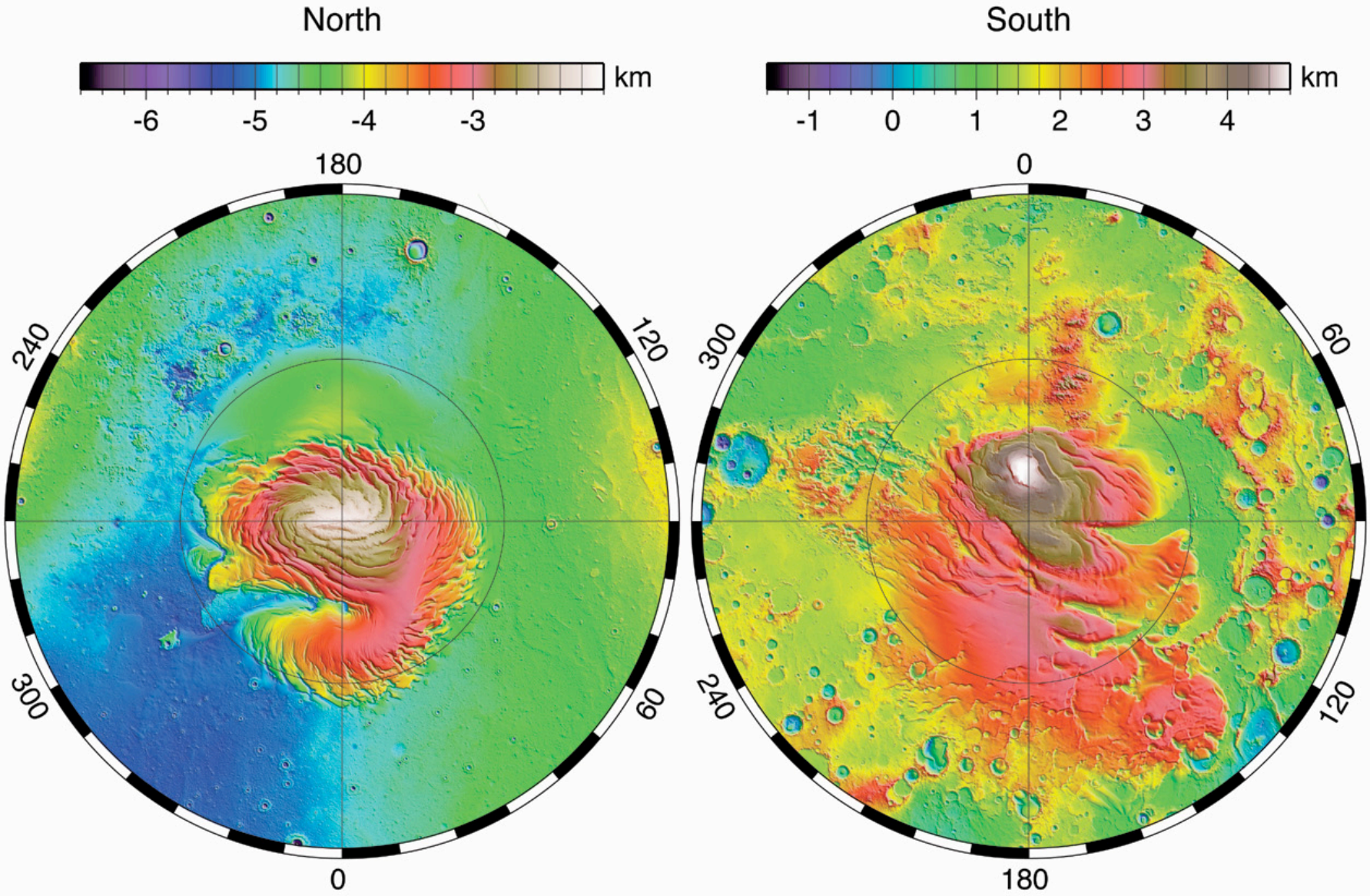
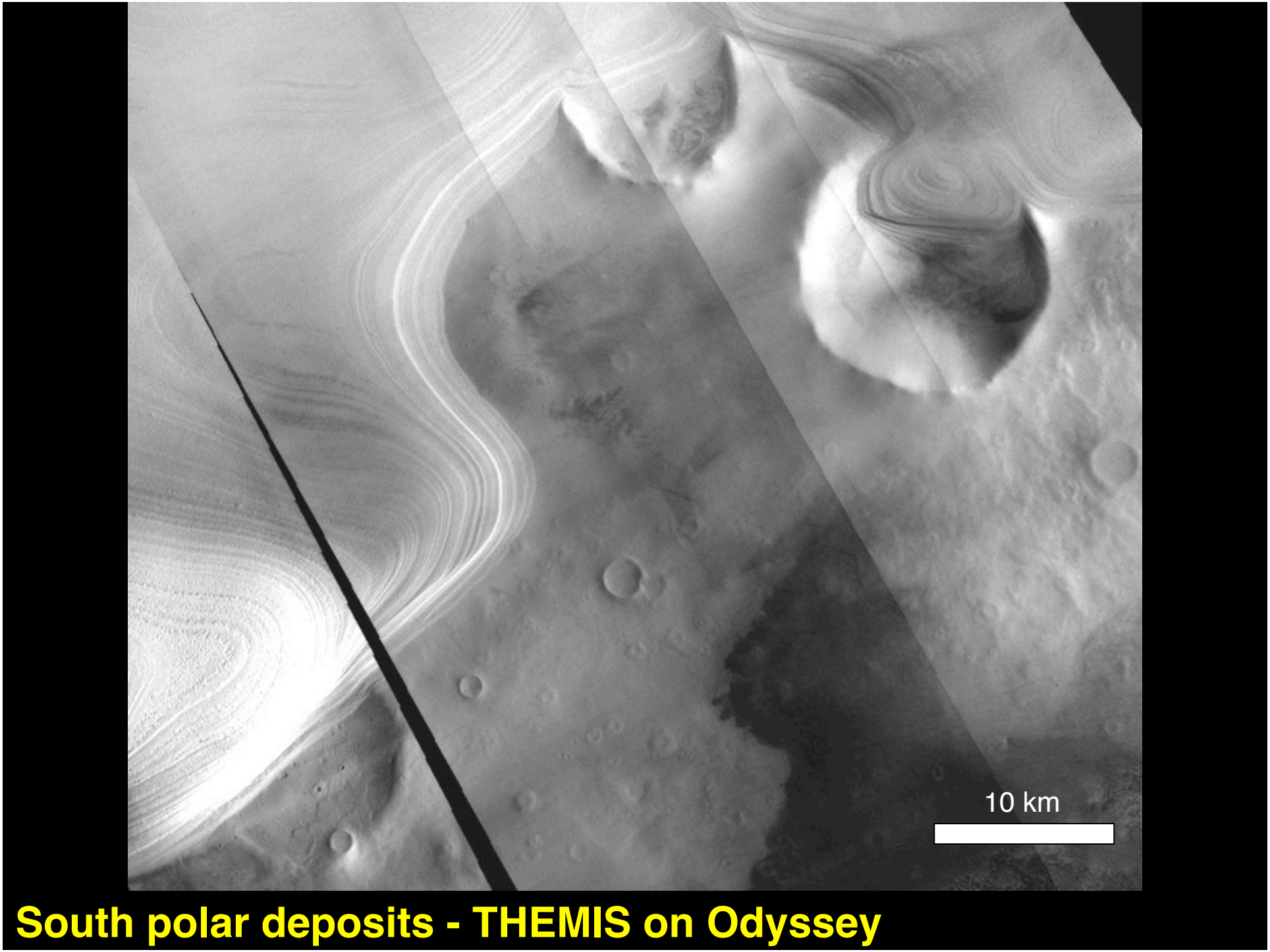
Potential Current Reservoirs of H_2O on Mars

- Polar ice caps ("Layered deposits")
- High-latitude ground ice
- Remnant ice sheets and glaciers from previous climate regimes
- Hydrous minerals
- Groundwater
- The atmosphere

Polar Views - MOLA Topography

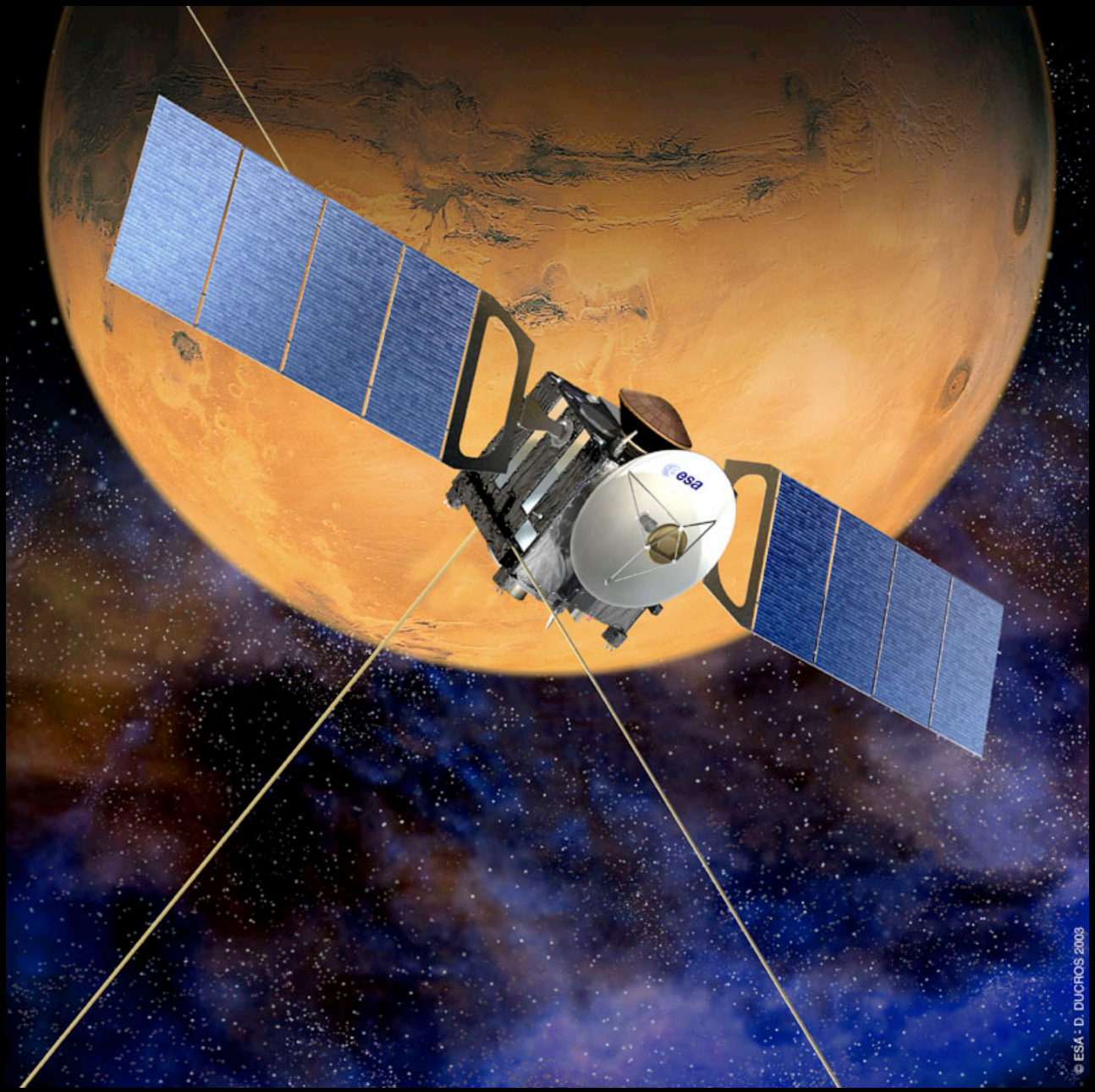


MOLA Team



South polar deposits - THEMIS on Odyssey

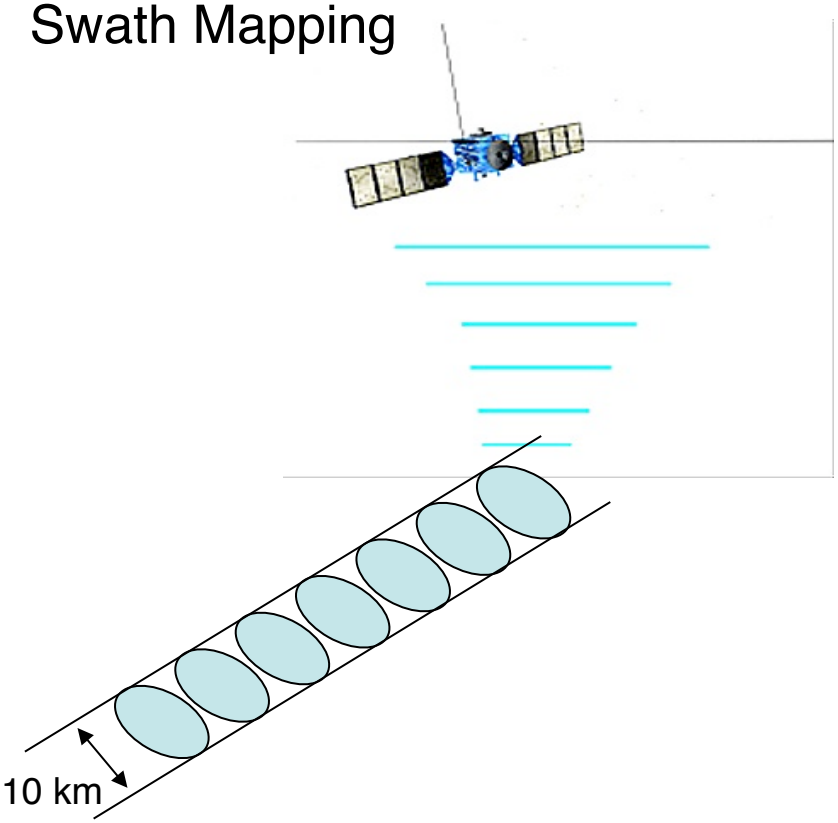
MARSIS on Mars Express



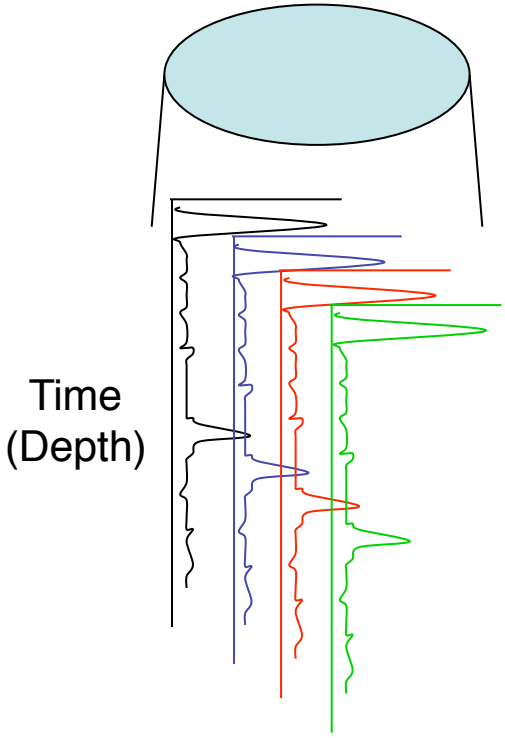
MARSIS
Data Acquisition Scheme

2-5 MHz center frequency
1 MHz bandwidth
Footprint spacing ~4 km
Vertical resolution ~100m (in ice)

Swath Mapping



Single Footprint



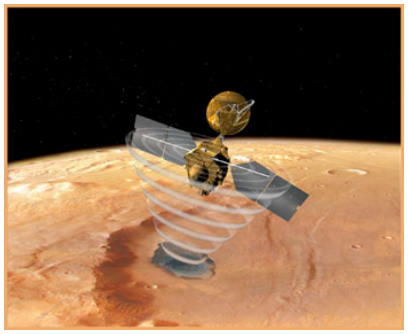
~ 500 contiguous footprints per orbit

Up to 6 profiles for each footprint

agenzia spaziale italiana · INFO-COM Dpt. · ALCATEL ALENIA SPACE · NASA · JPL · Iowa · NORTHROP GRUMMAN Space Technology · esa

SHARAD on MRO

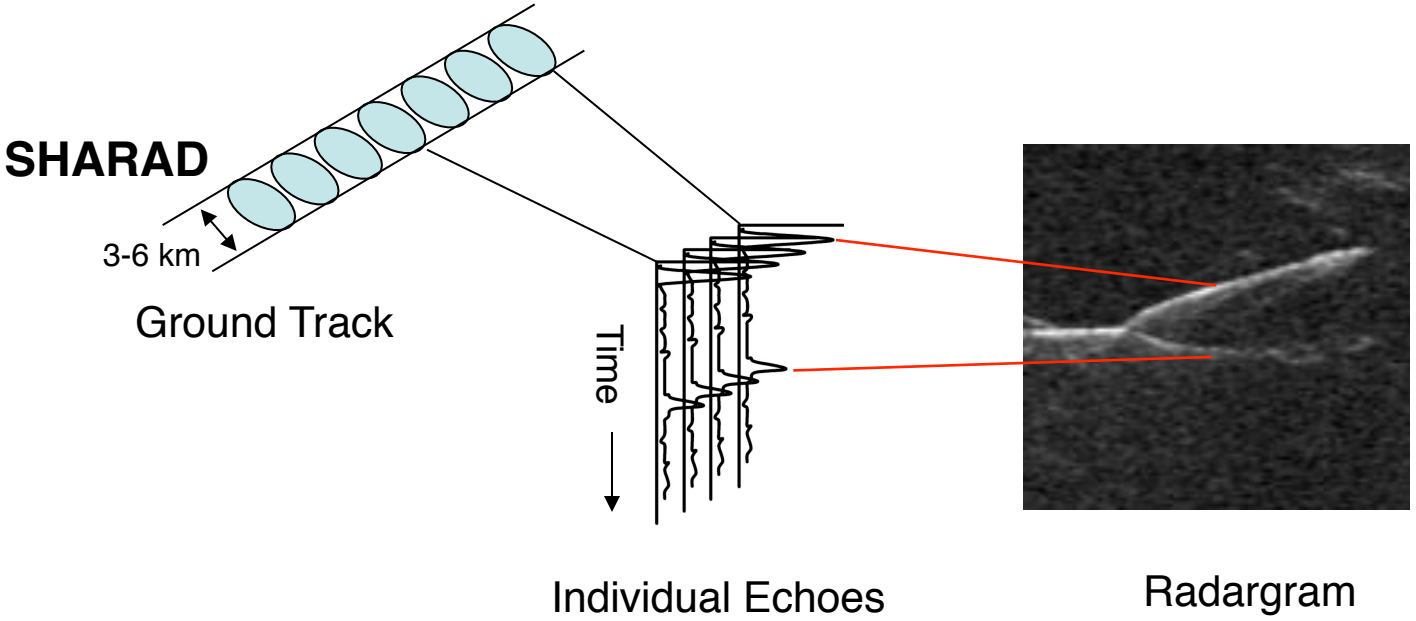
SHARAD Sounding Radar on MRO



20 MHz center frequency
10 MHz bandwidth

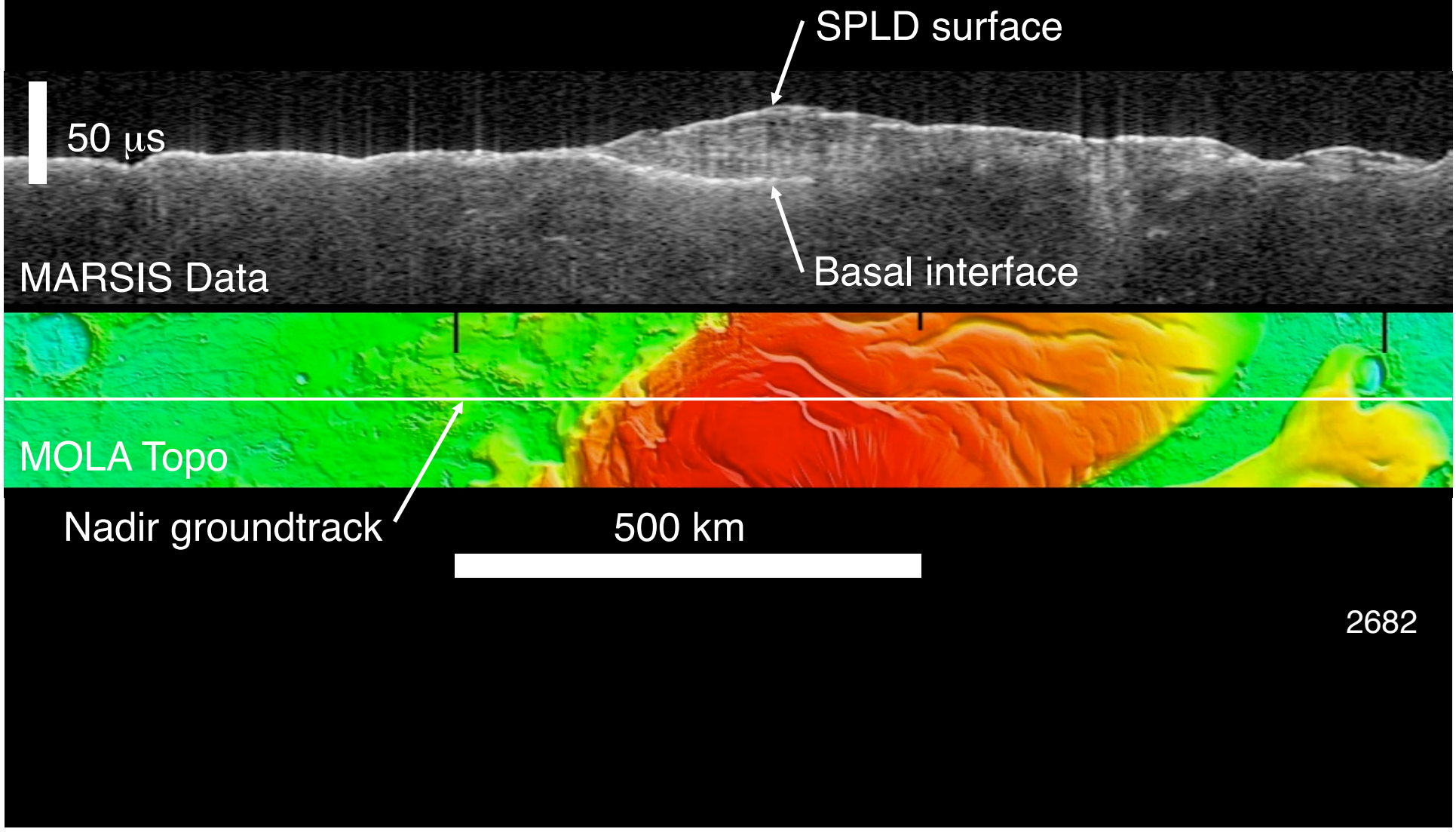
Processed to a footprint spacing ~300 m

Vertical resolution ~5 m (in ice)



Stack individual echo traces along track to build up a radargram

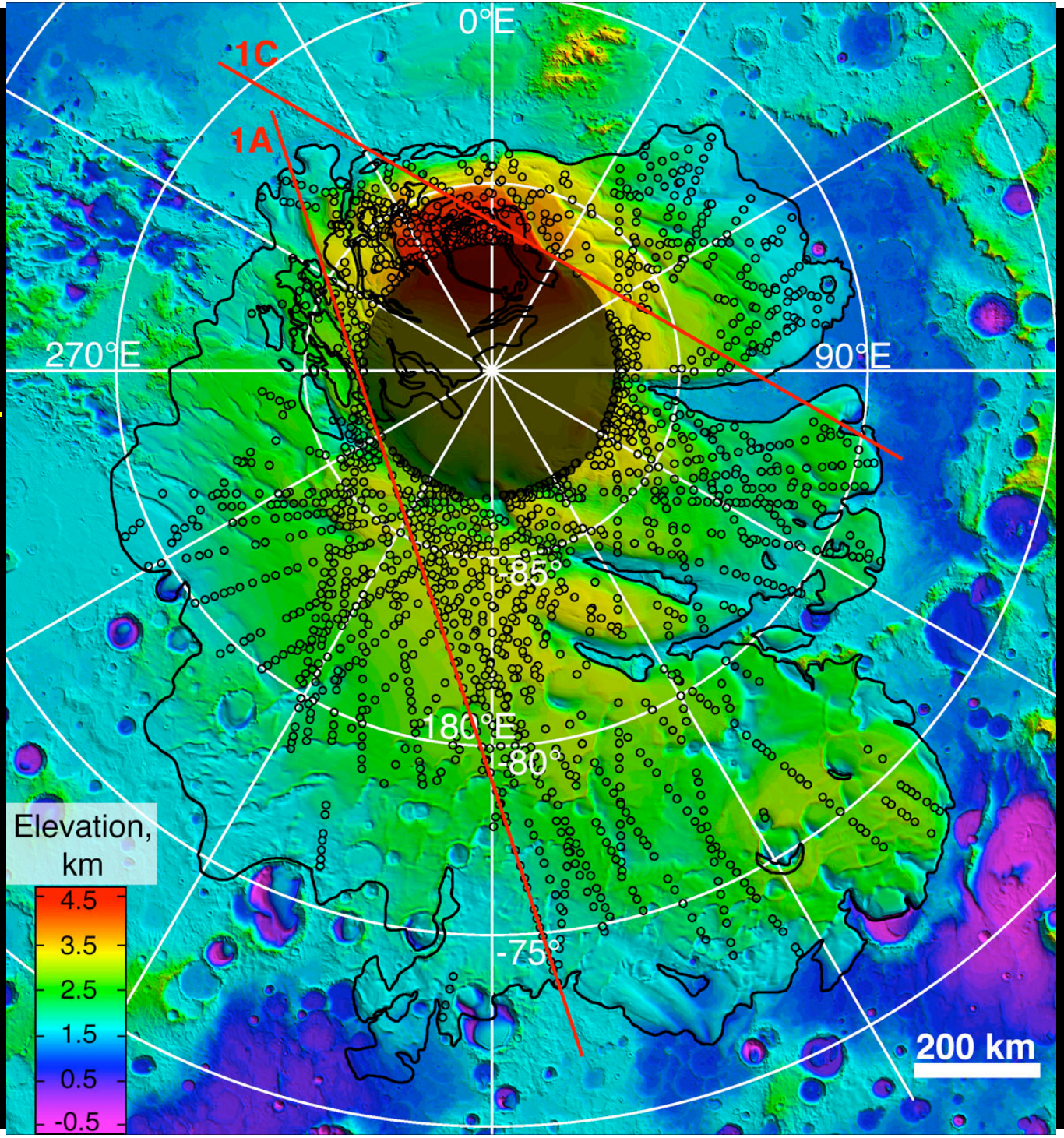
MARSIS Radargram
South Polar Layered Deposits (SPLD)



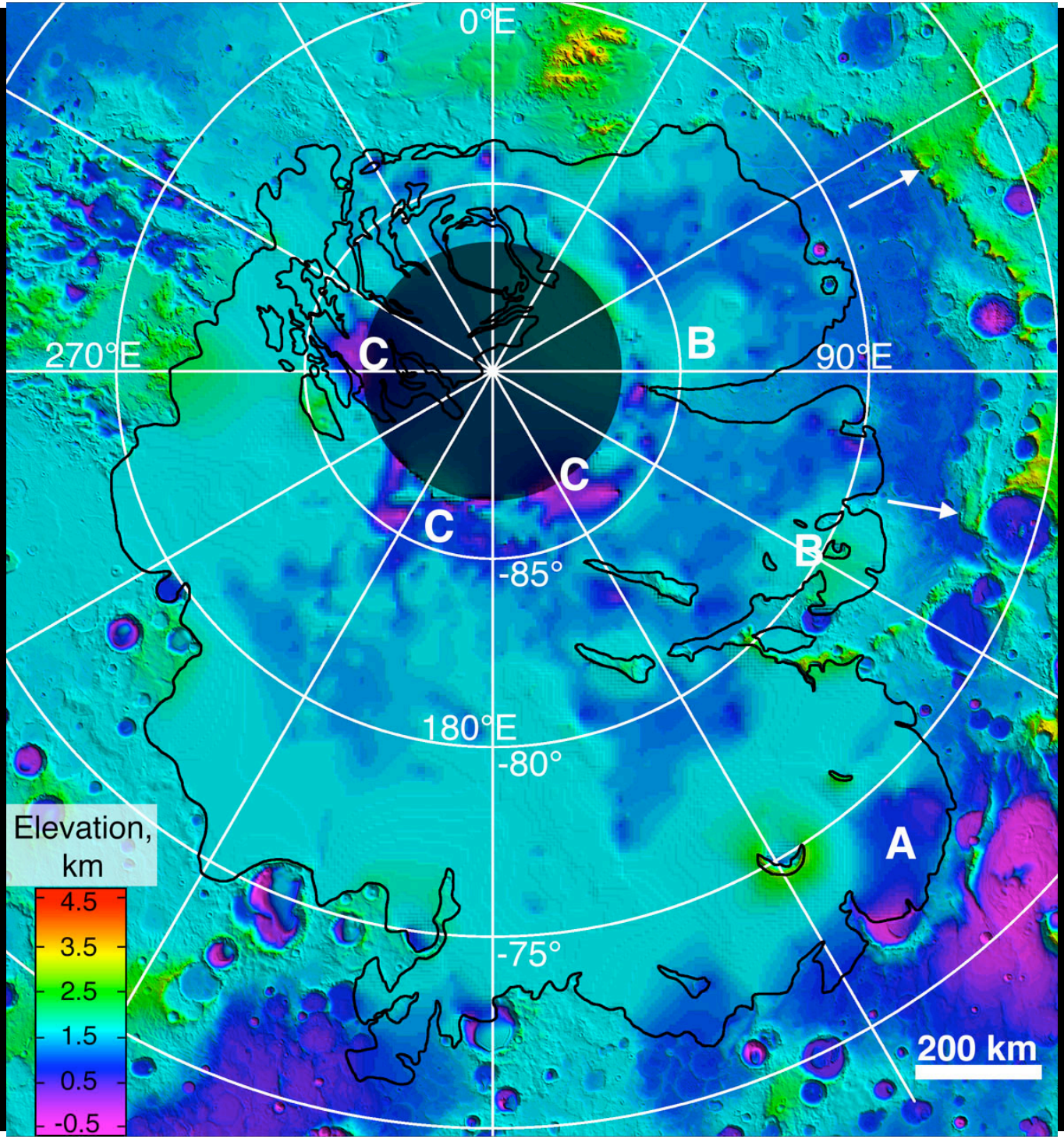
2682

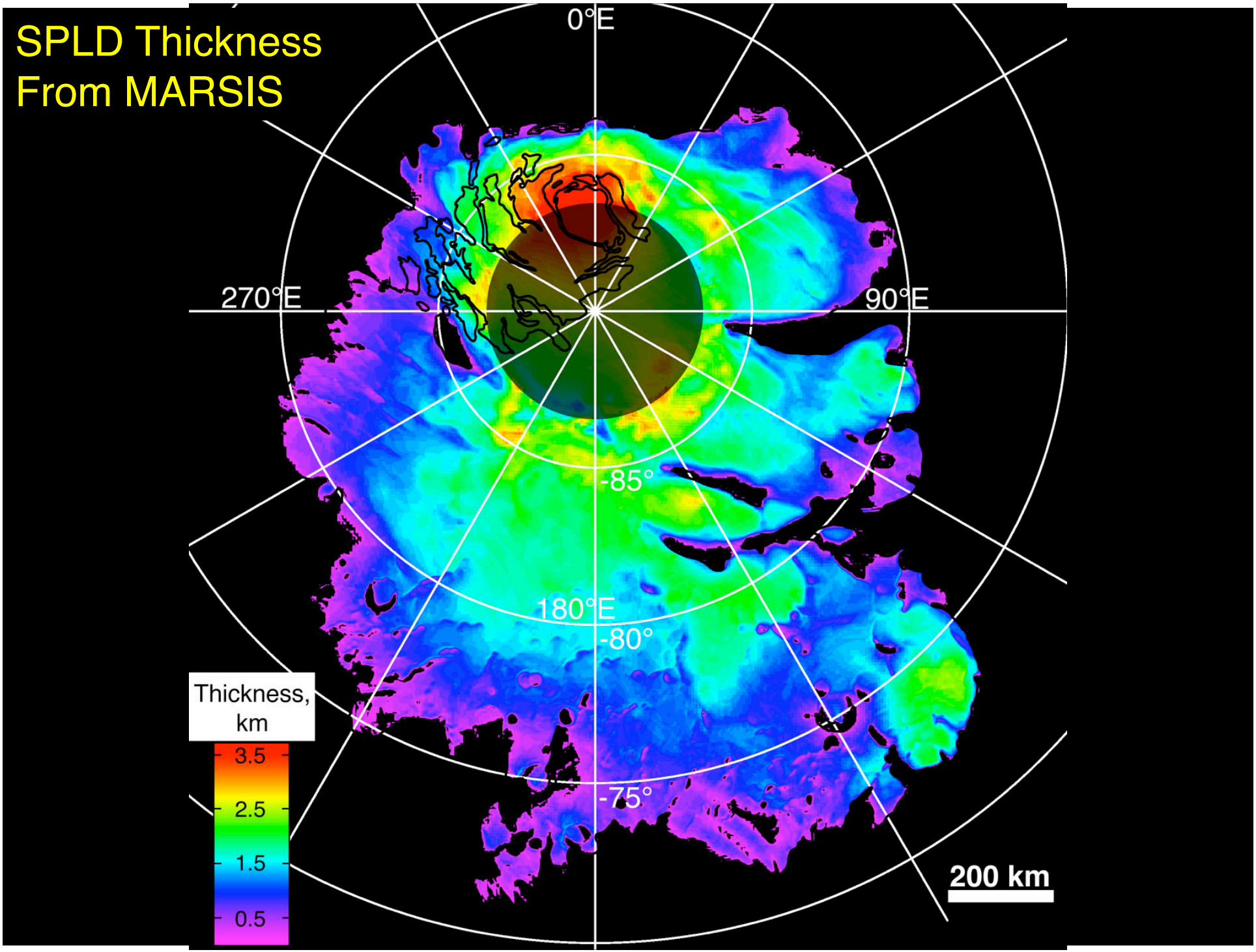
MOLA Topo

MARSIS Bed Measure-ments



Bed Elevation

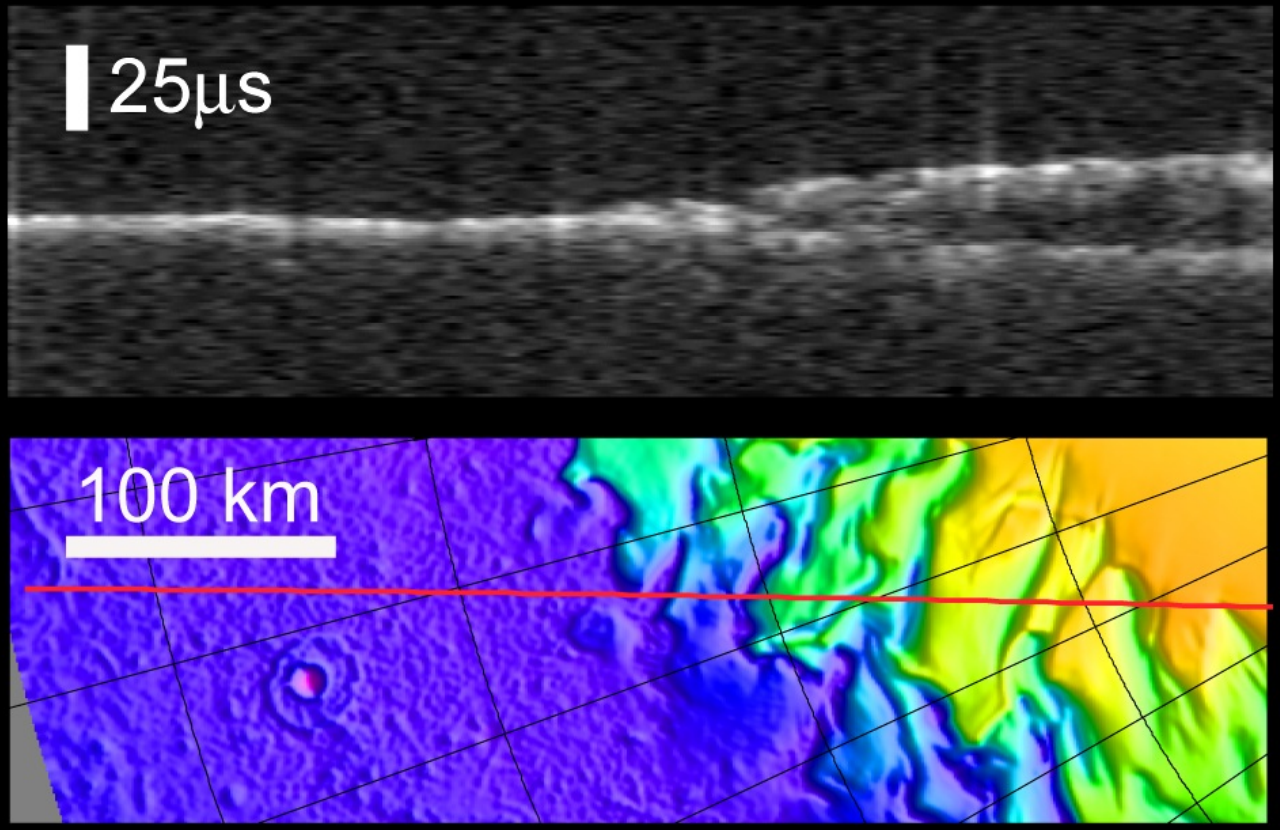



SPLD Thickness
From MARSIS
0°E
270°E
90°E
-85°
180°E
-80°
-75°
Thickness, km
3.5
2.5
1.5
0.5
200 km

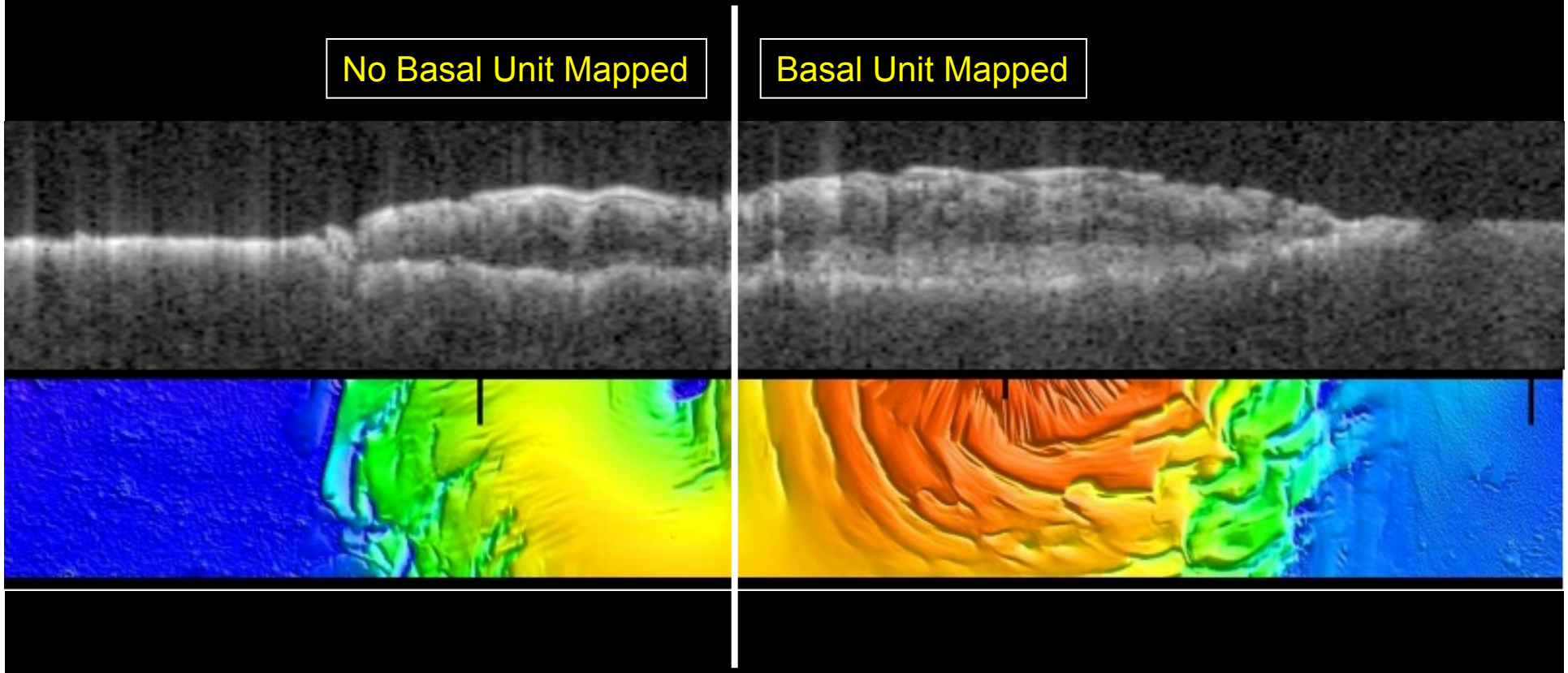
South Polar Layered Deposits
Results

- MARSIS signals penetrate most of the SPLD to their base
- Thickest section: > 3.7 km
- Minimal attenuation of signals implies clean ice (<~5% dust)
- Basal topography:
    - Generally low relief
    - Unexpected depressions in near-polar area
    - No signature of flexural deflection due to load
        Lithosphere elastic thickness >150 km; implies low T gradient
- Thickness:
    - Asymmetry of deposits
    - Anomalous thickness on distal lobes, near-polar area
    - Volume 1.6 x 10^6 km^3 = 11 m global layer
        (best estimate to date, consistent with earlier studies)

MARSIS - North Polar Layered Deposits

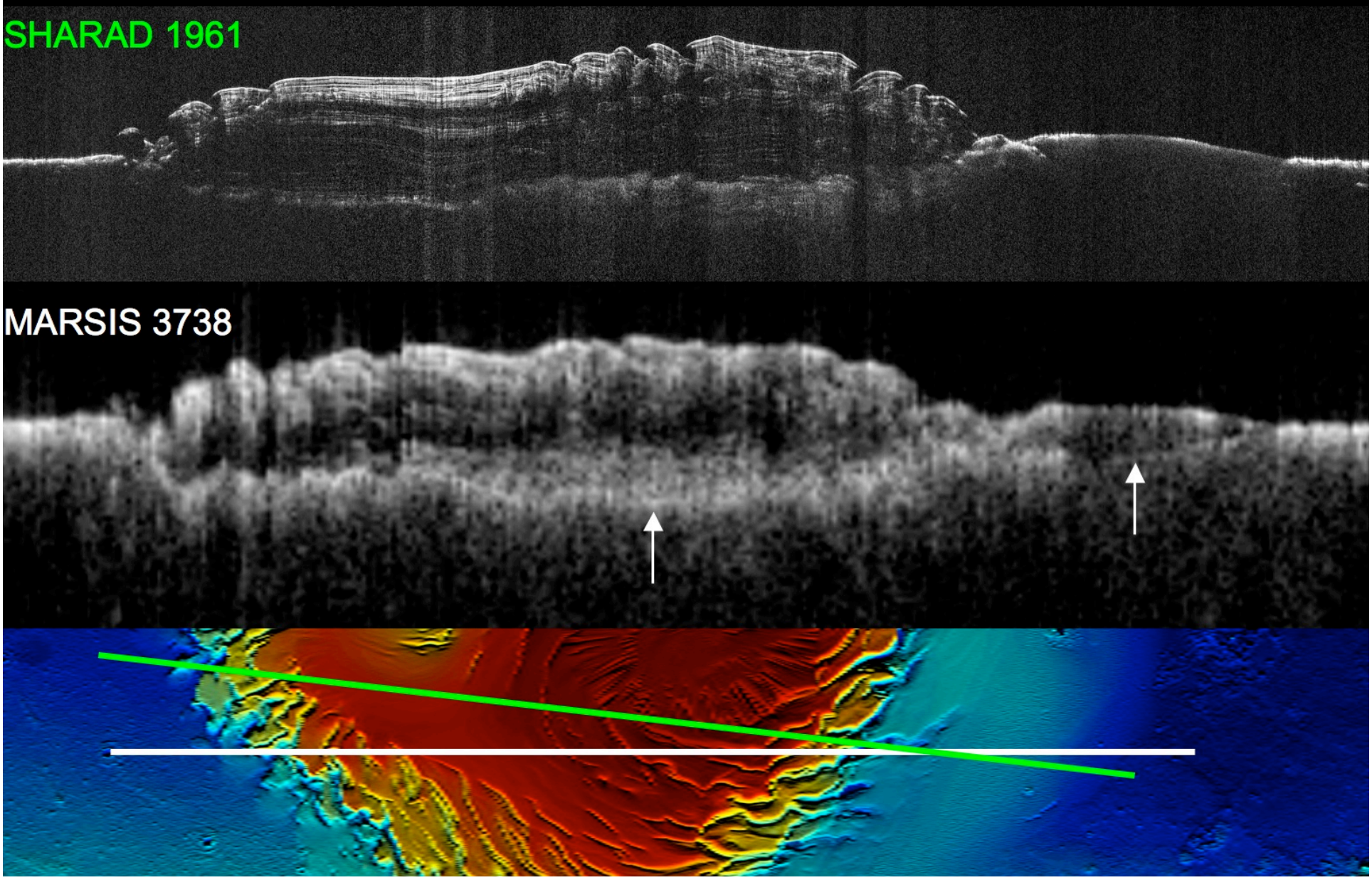


North Polar Layered Deposits - “Basal Unit”

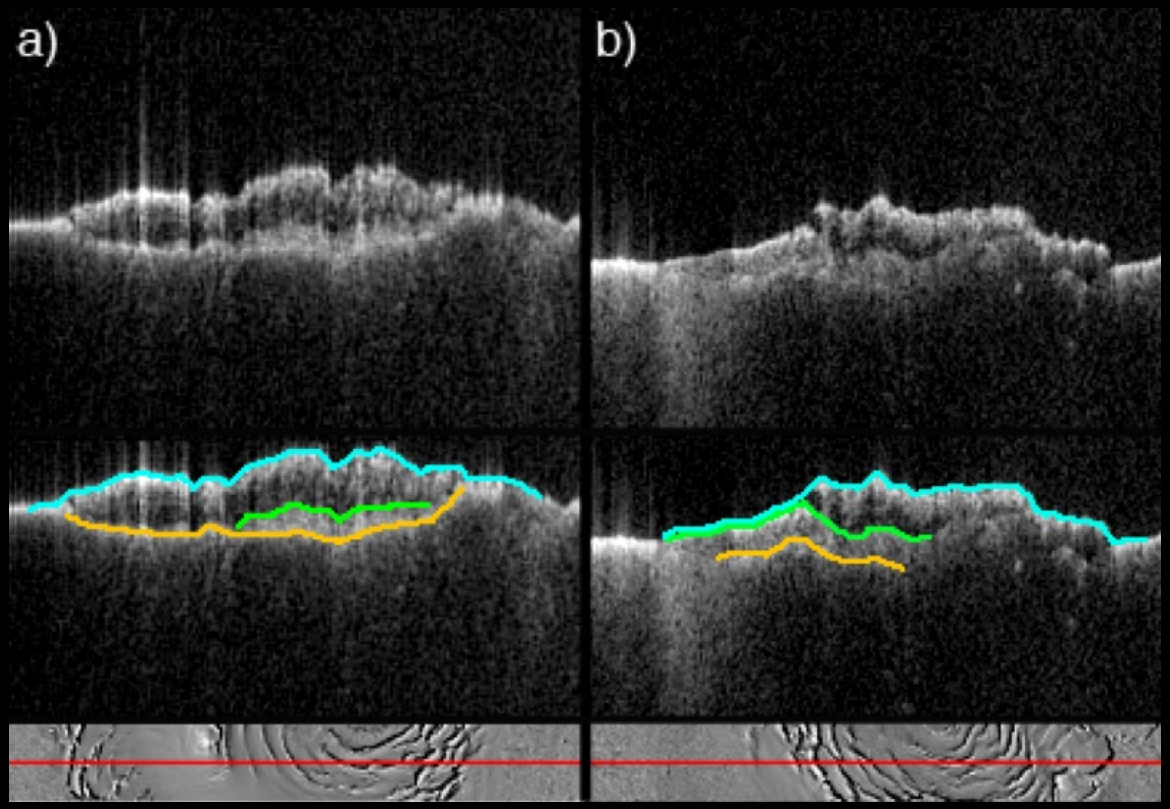


3709

North Polar Layered Deposits: SHARAD and MARSIS

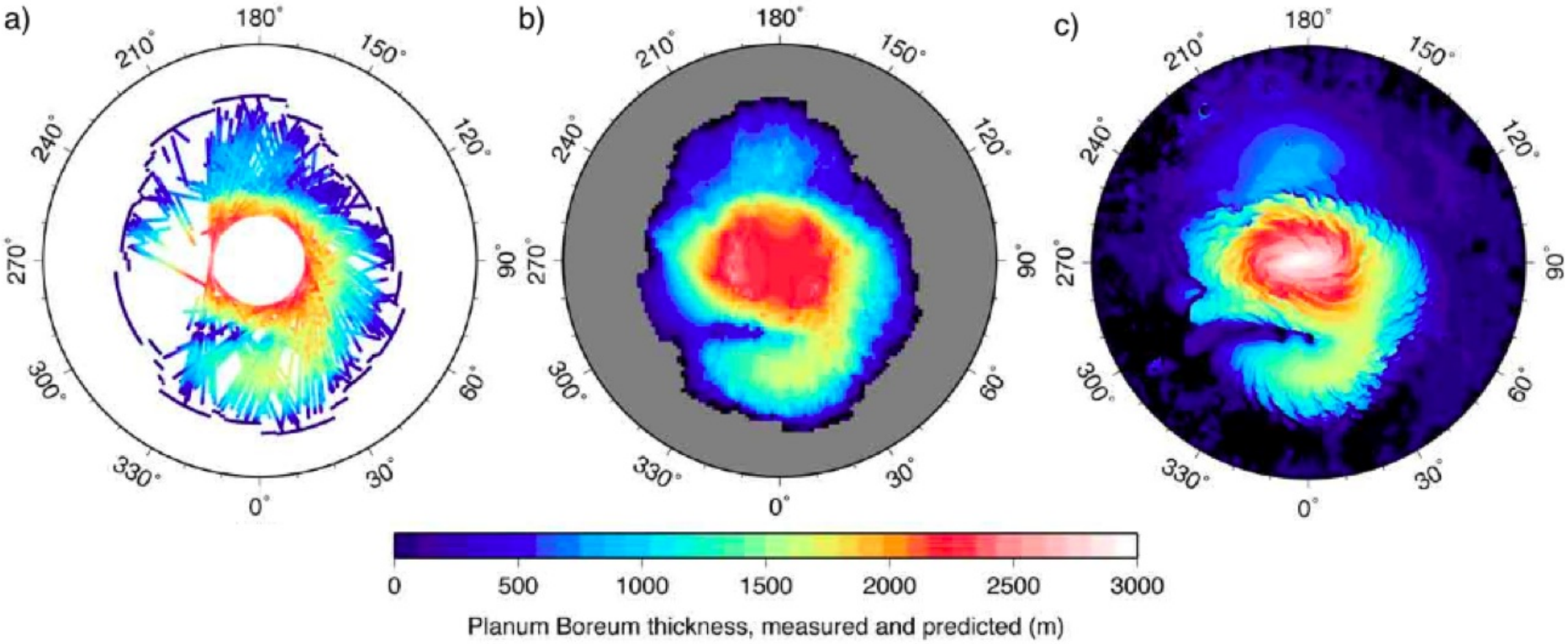


North Polar Radargrams



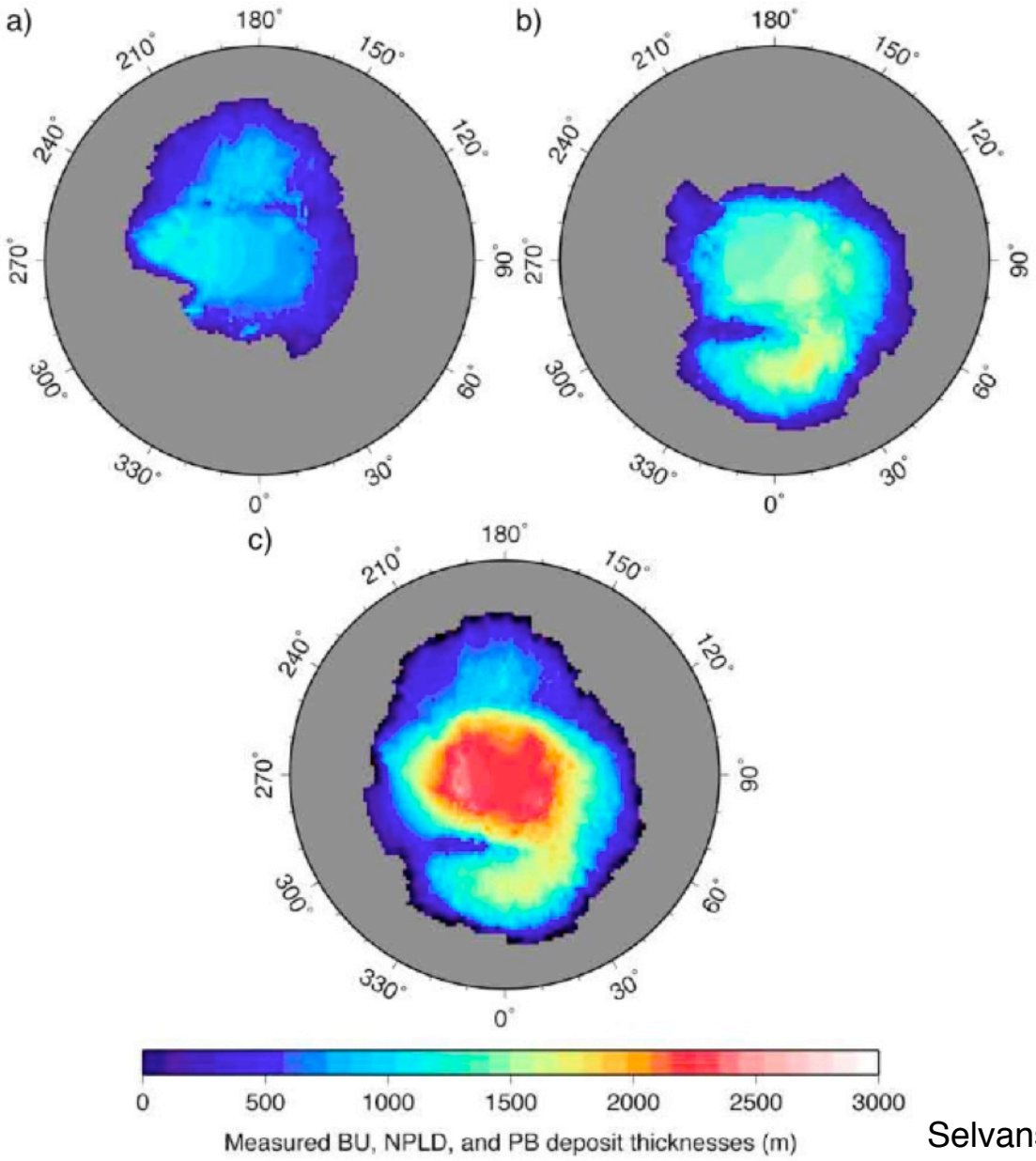
Selvans et al., 2010 in press

Planum Boreum Thickness



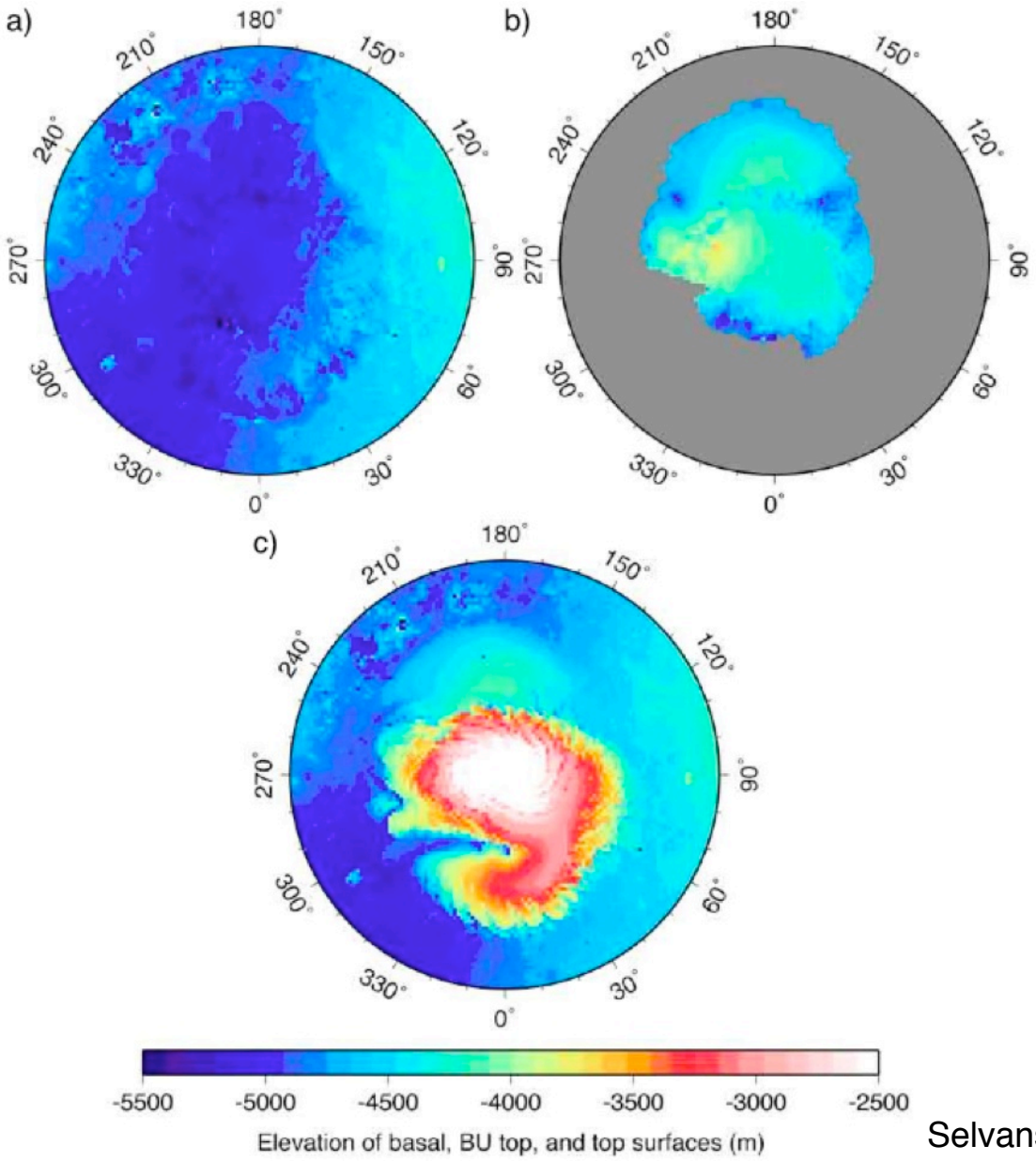
Selvans et al., 2010 in press

Basal Unit, NPLD, Planum Boreum Thickness



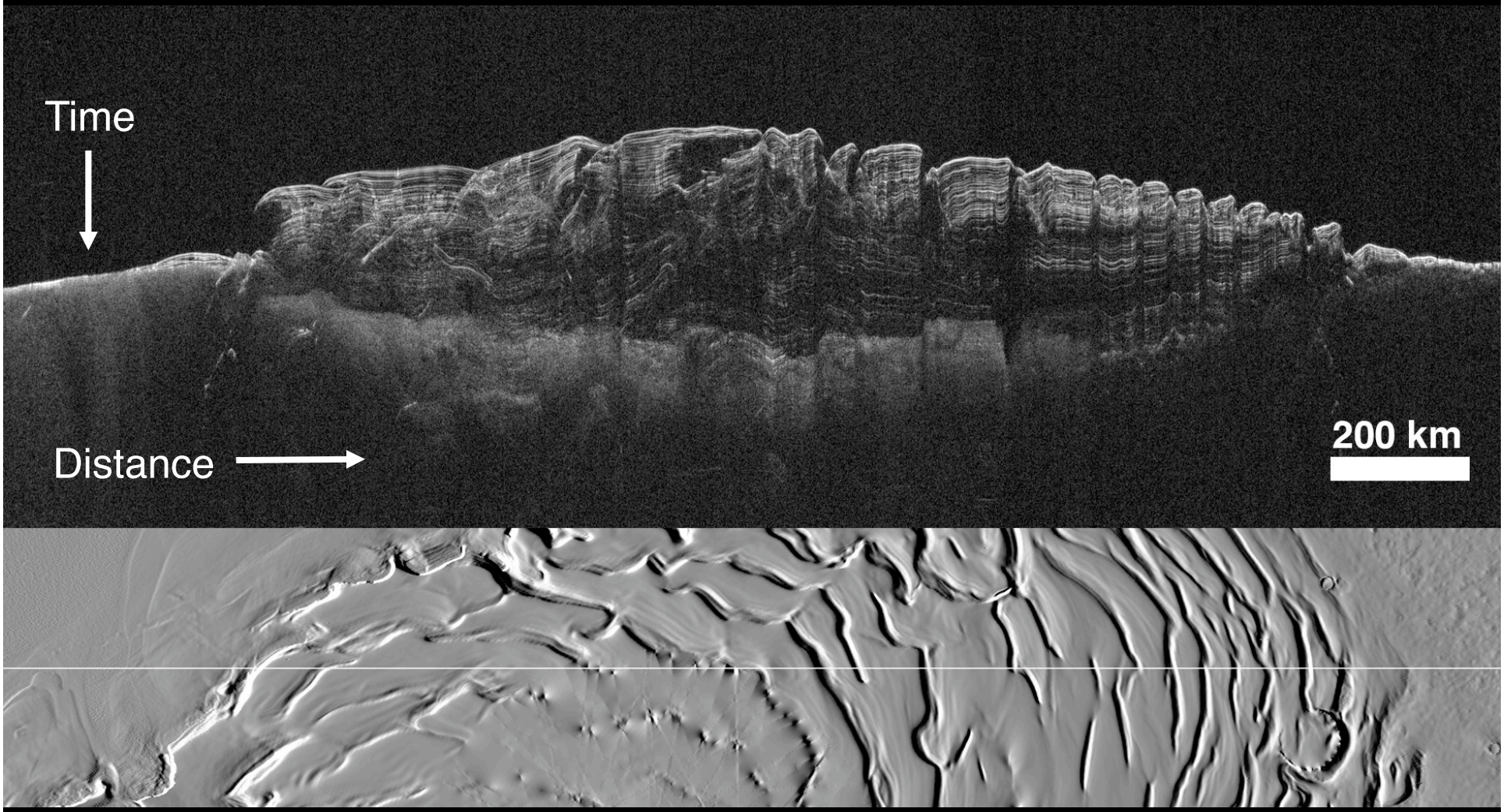
Selvans et al., 2010 in press

Basal Unit Bottom, Top and Planum Boreum Elevation

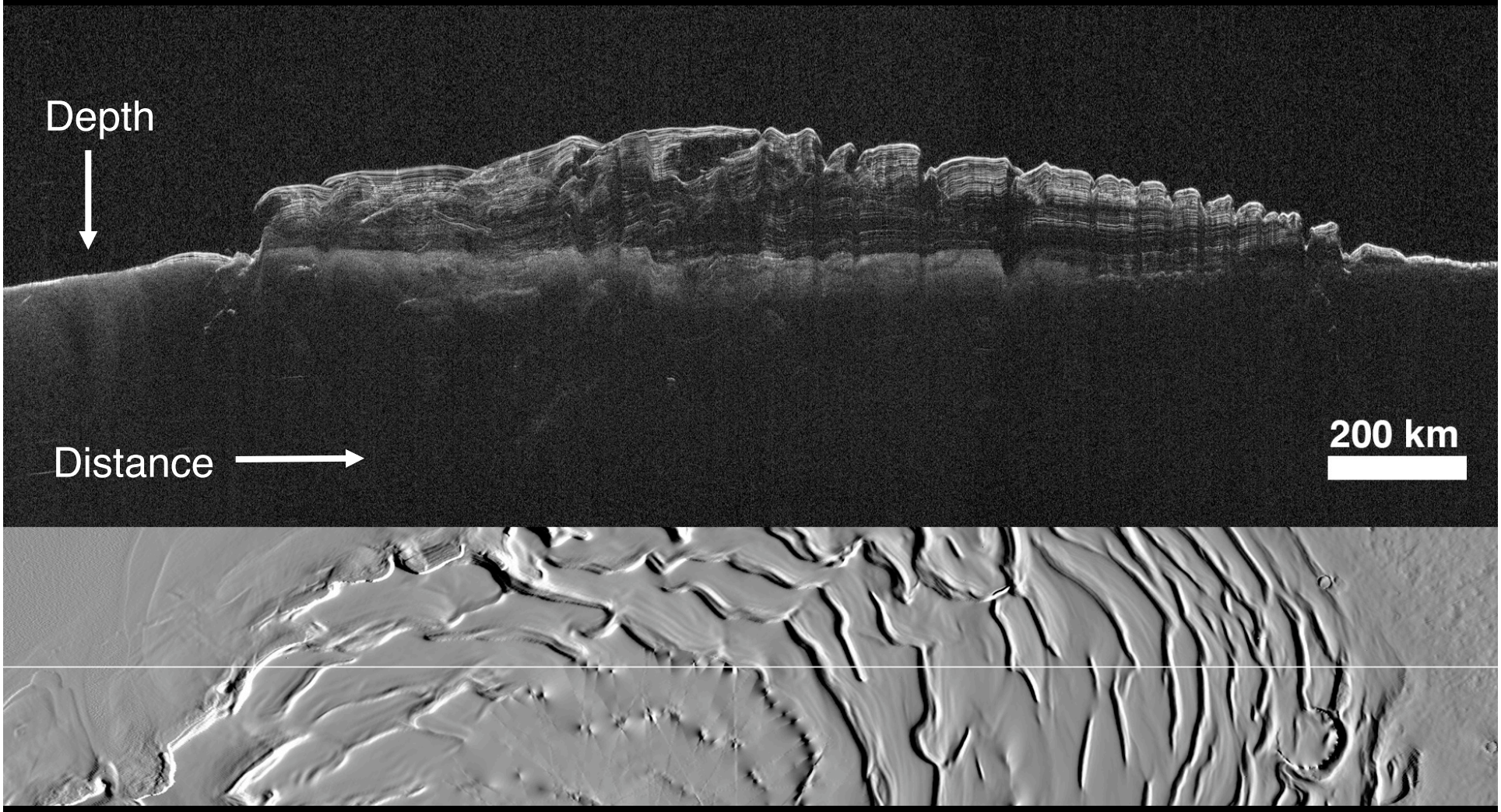


Selvans et al., 2010 in press

SHARAD NPLD - Time Representation



SHARAD NPLD - Depth Representation



Vertical Exaggeration ~ 100:1

MARSIS North Pole Results

• Basal Unit and superimposed NPL deposits are distinct in character, volume and geometry (different depocenters). Implies climate shift, erosional episode(s).

• Volumes:

Basal Unit	0.5 M km^3	
NPLD	0.8 M km^3	
Total Planum Boreum	1.3 M km^3	(South: 1.6 M km^3)

• Topography below BU is flat
  - Confirms lack of deflection
  - Consistent with cold, thick lithosphere

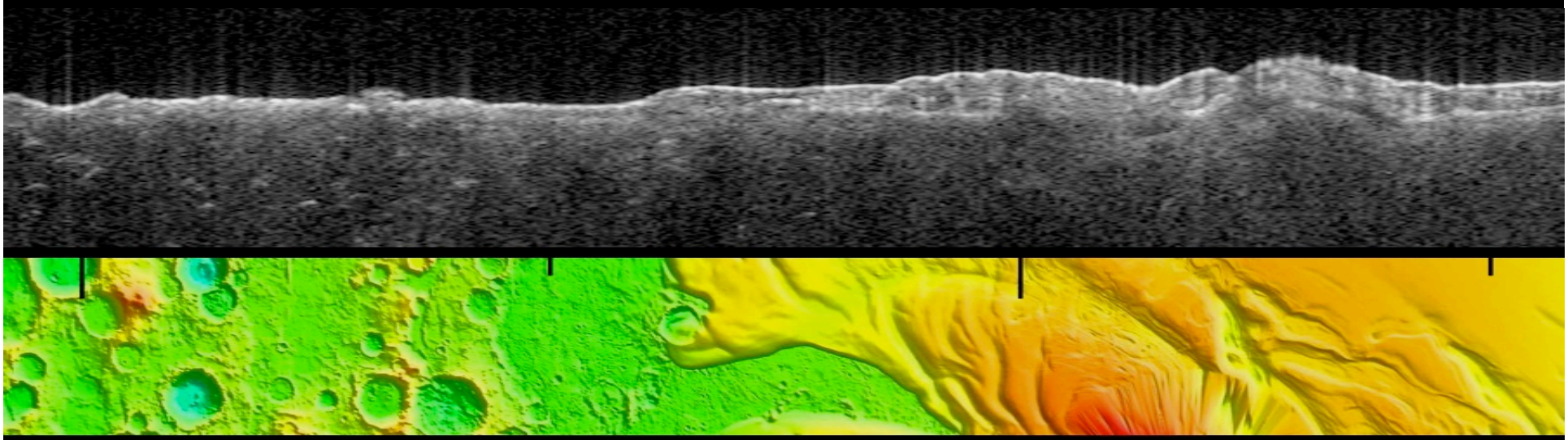
Selvans et al., 2010 in pres

South Polar Plains

- MARSIS detects a boundary 100s of m to ~ 1 km deep in many areas of plains off of the SPLD.

- The locations of these subsurface interfaces closely match the Hesperian Dorsa Argentea Formation (DAF).

Thin Layers Off the Layered Deposits

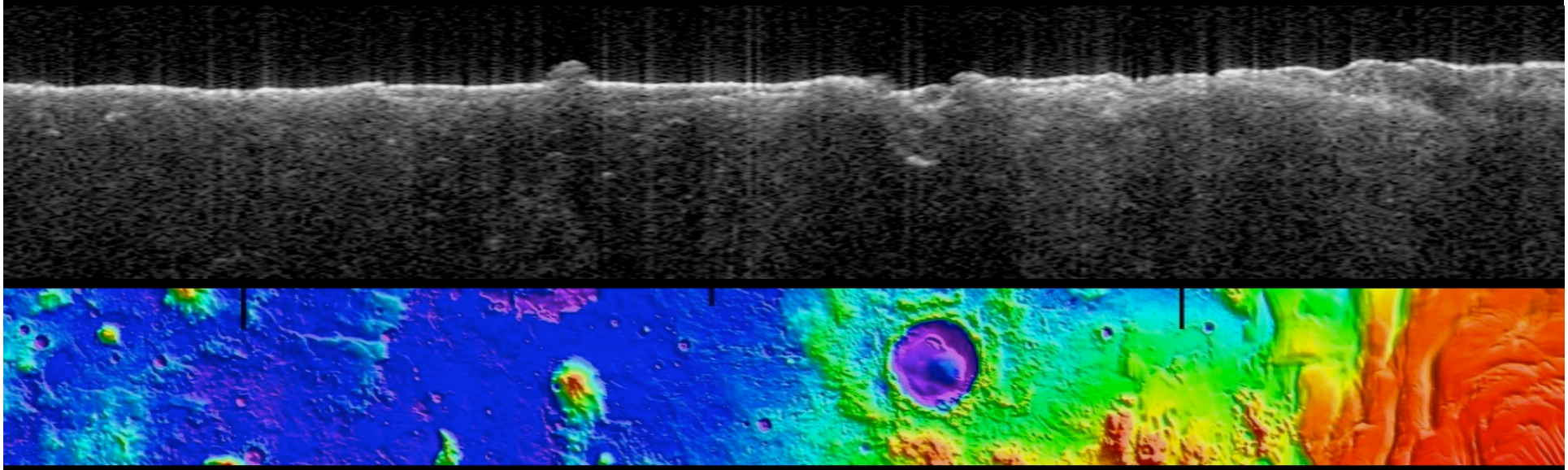


500 km

2655

Prometheus basin floor
Max depth ~ 600 m

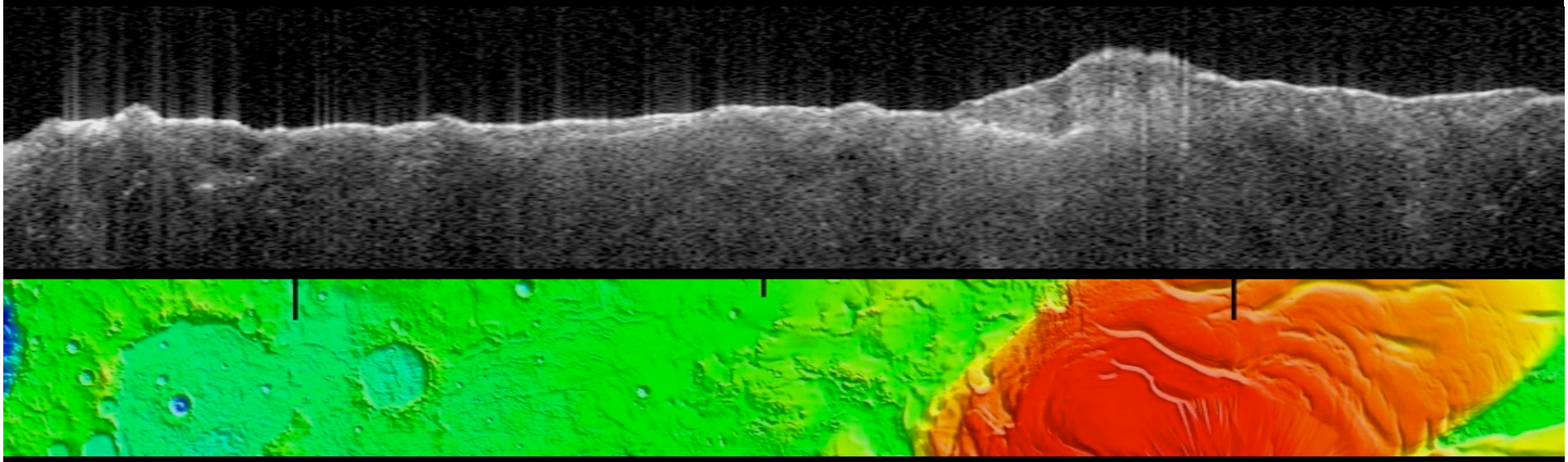
Thin Layers Off the Layered Deposits



2685

Sisyphi Planum, South Crater
Max depth ~ 800 m

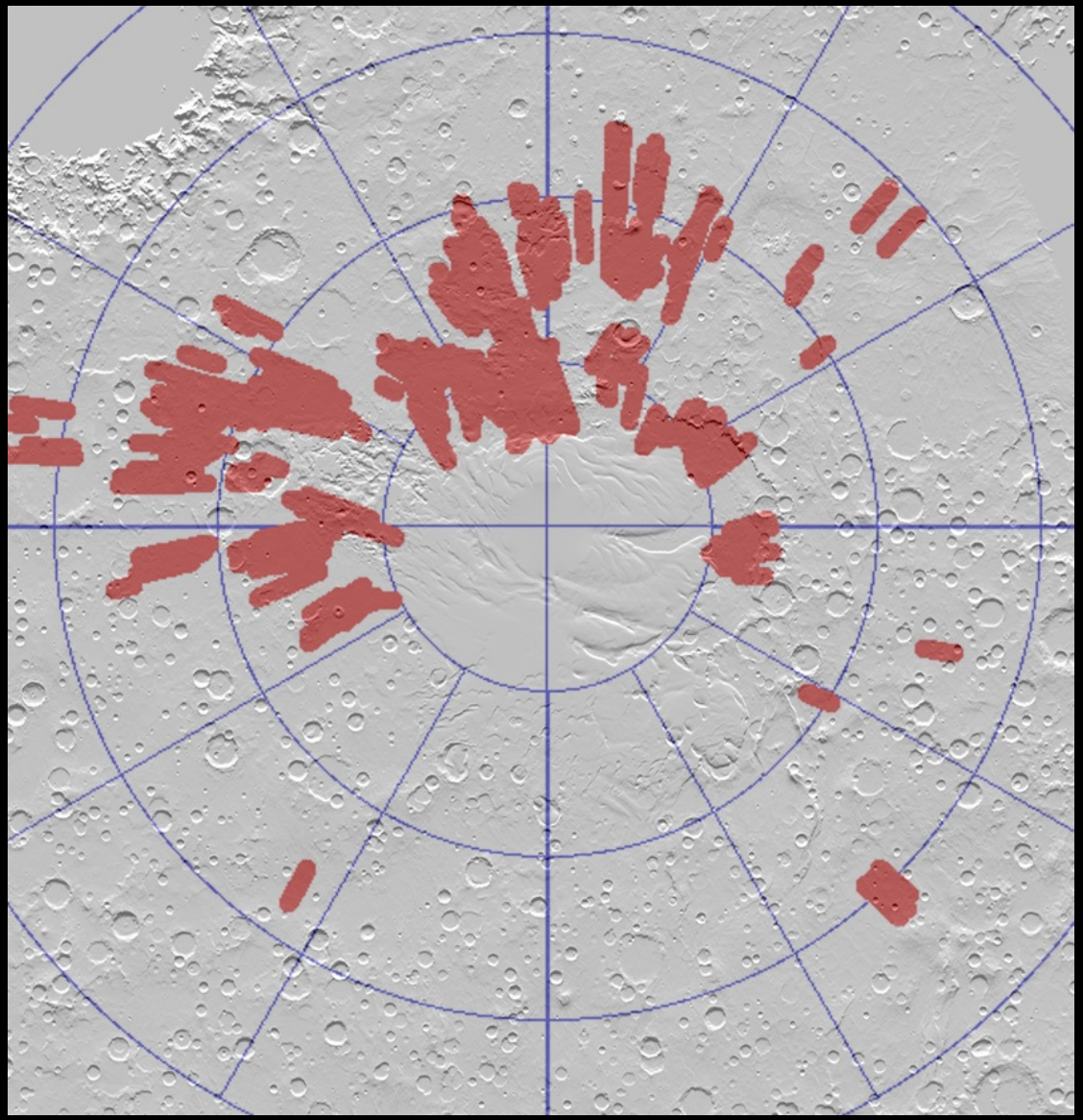
Thin Layers Off the Layered Deposits



2638

Dorsa Argentea ridge area
Max depth ~ 700 m

All MARSIS Subsurface Detections Off the SPLD

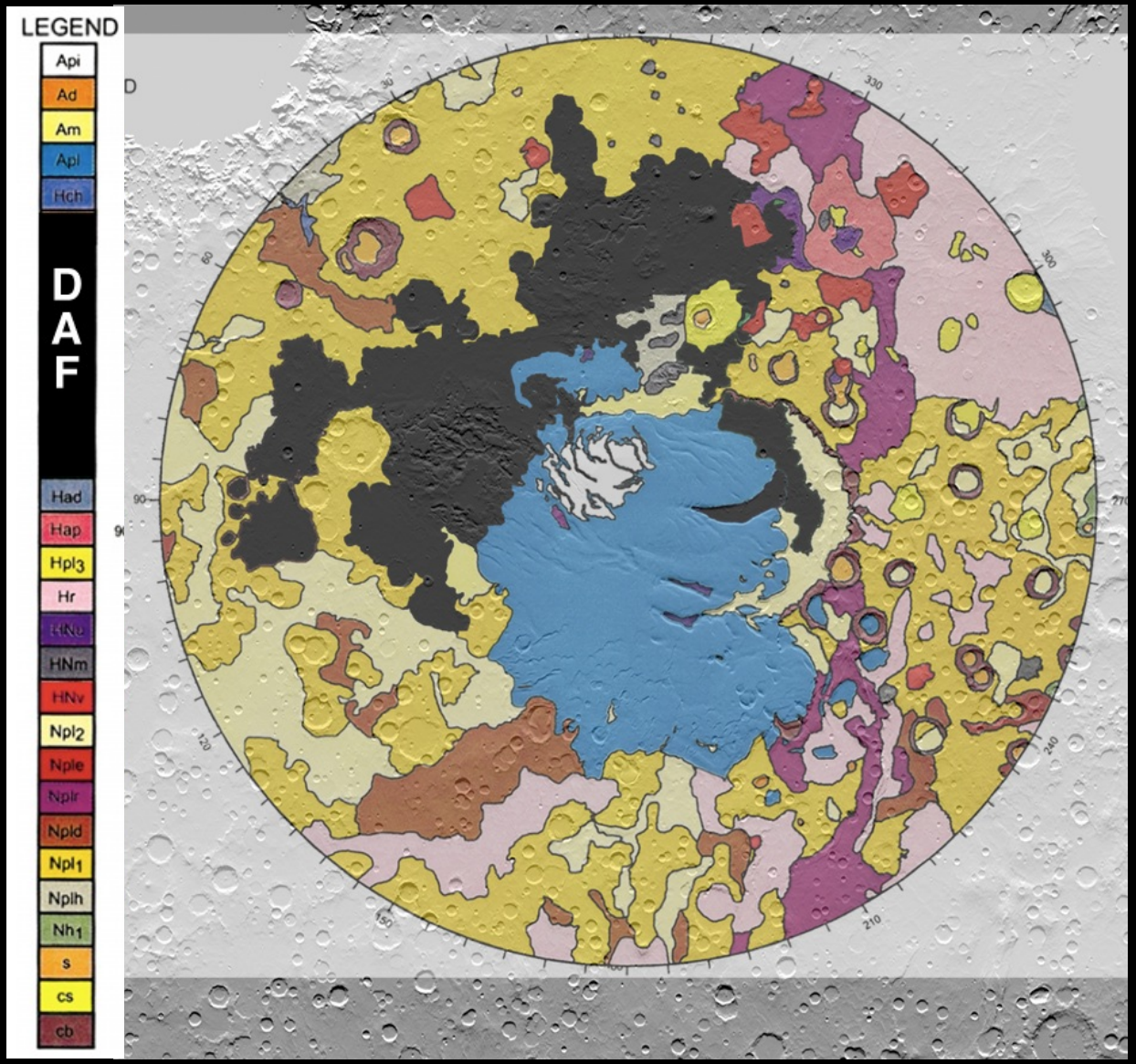


HRSC
Dorsa Argentea Sinuous Ridges

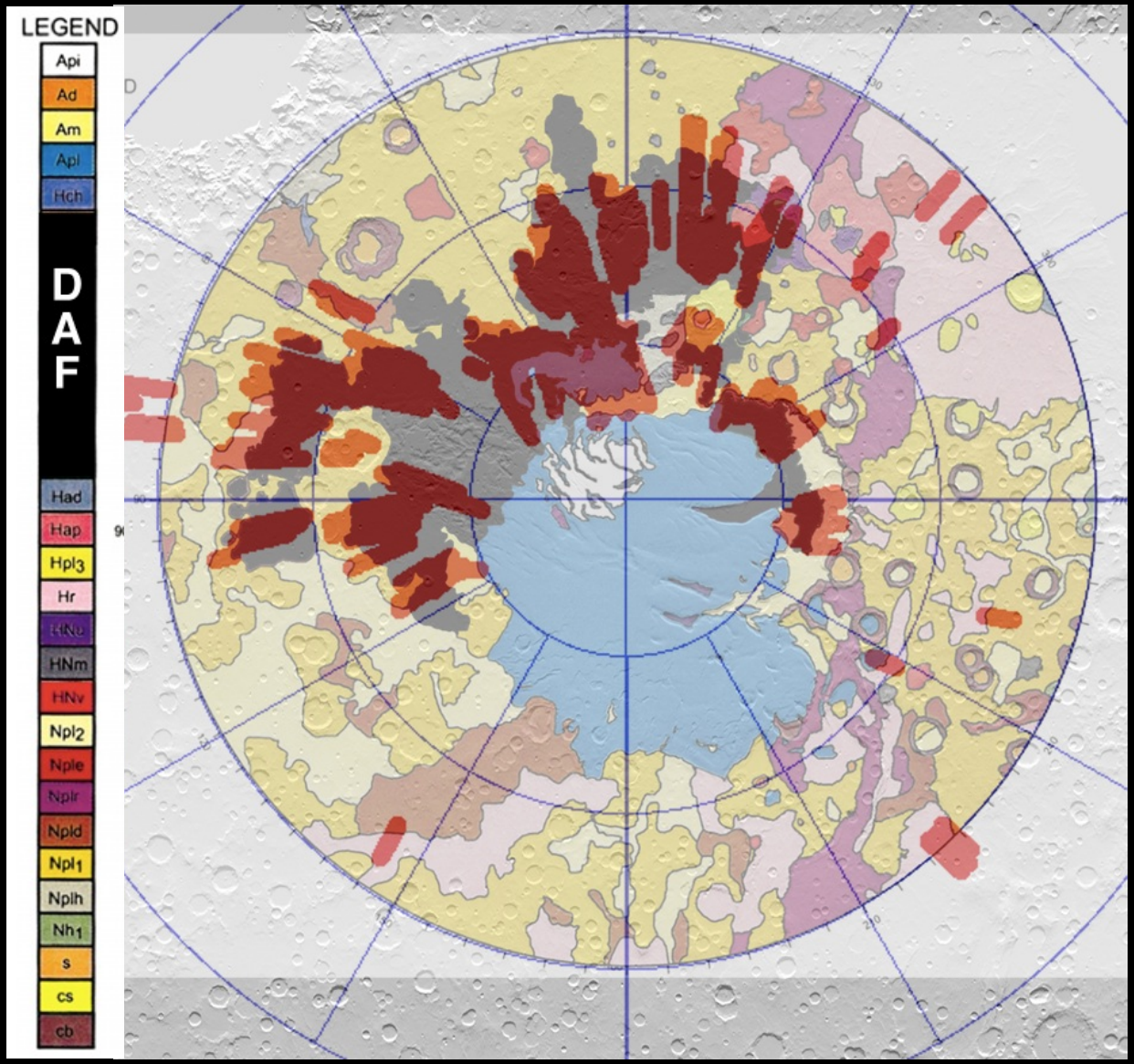
10 km

Orbit 2416

Geologic Map - Kolb and Tanaka 2001



Geologic Map - Kolb and Tanaka 2001



Dorsa Argentea Formation
Summary

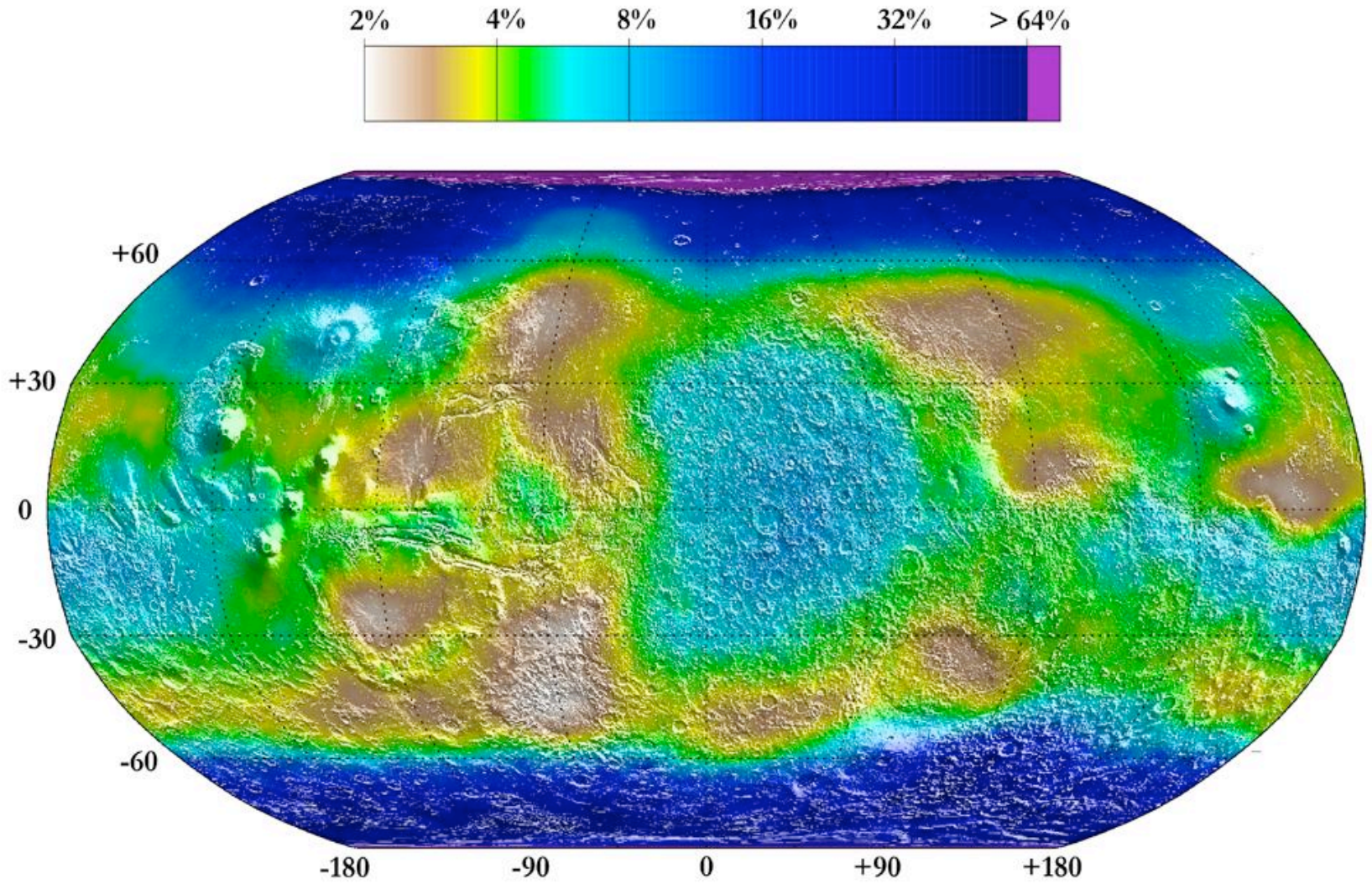
- MARSIS detects lower boundary of a unit off the SPLD, covers an area ~1 M km^2 - comparable to SPLD area.

- Depth to interface 100s of m to > 1 km.

- Strong association with Hesperian Dorsa Argentea Formation. In places MARSIS may see the lower contact of the DAF.

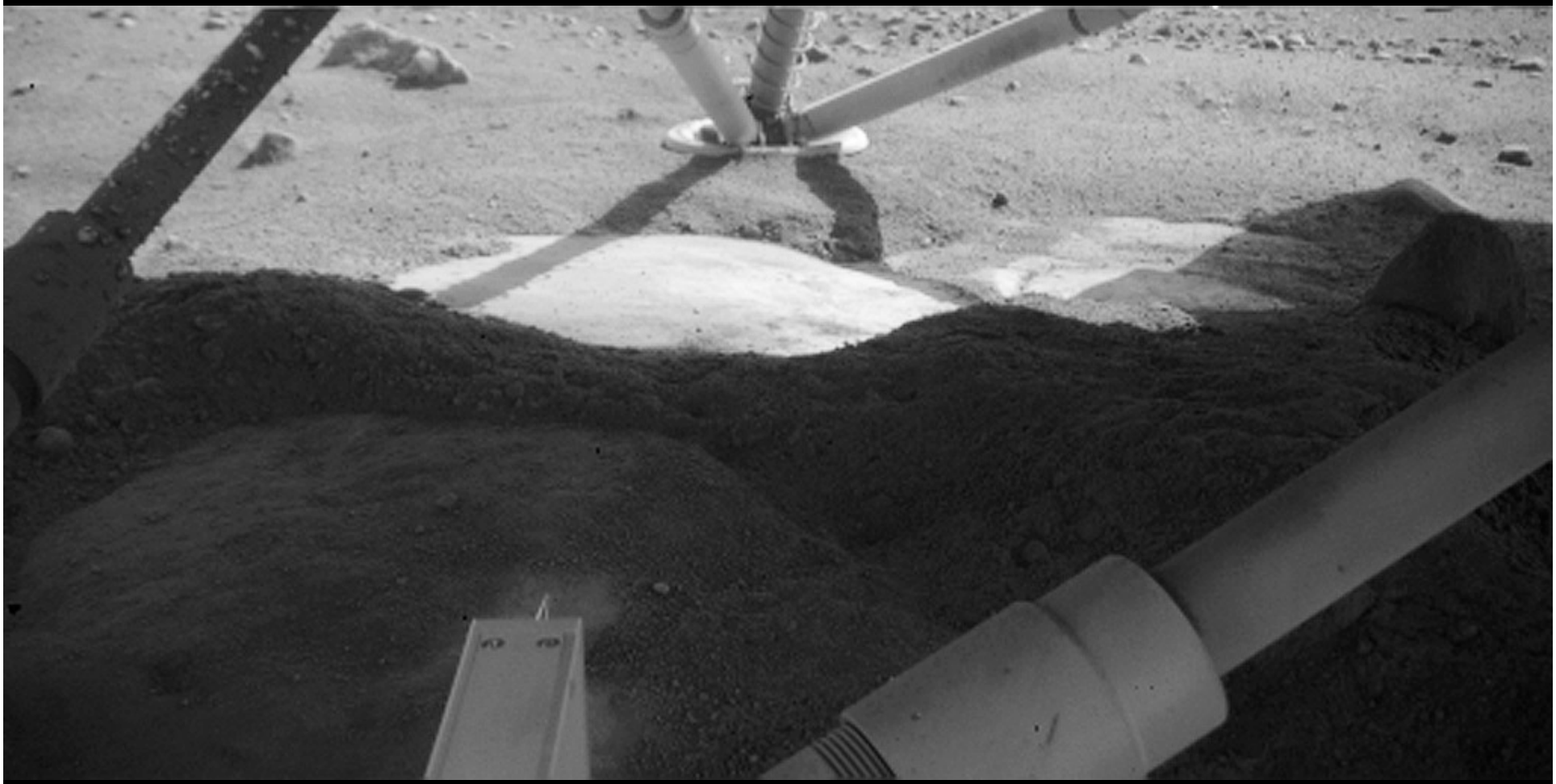
Mars Odyssey GRS Neutron Spectrometer

Lower-Limit of Water Mass Fraction on Mars

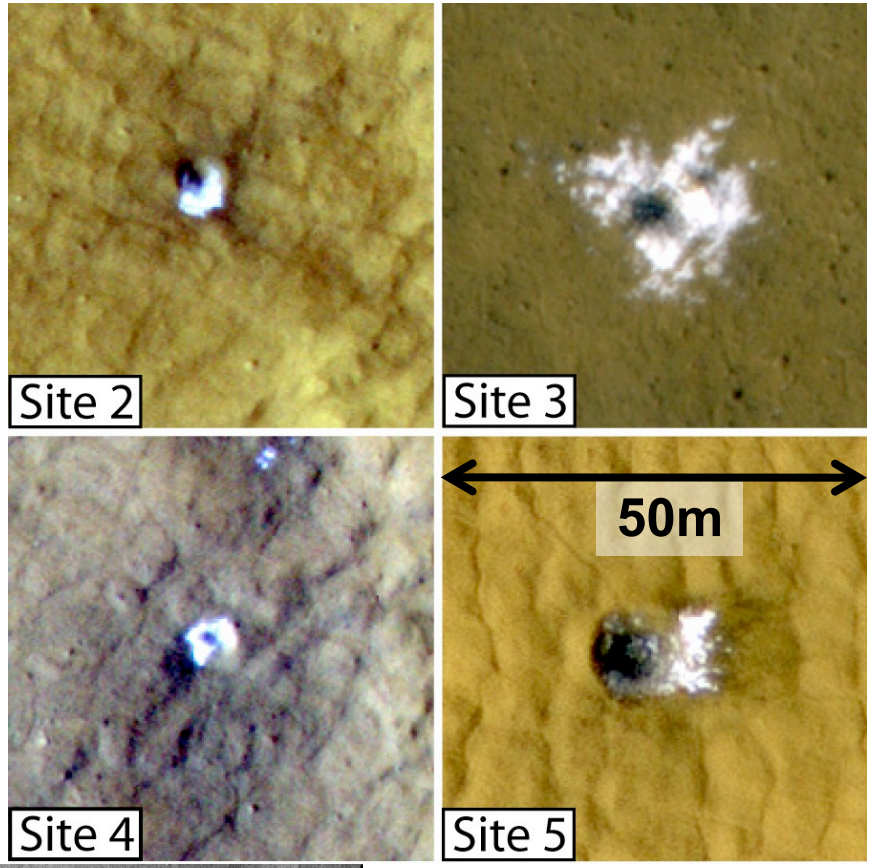


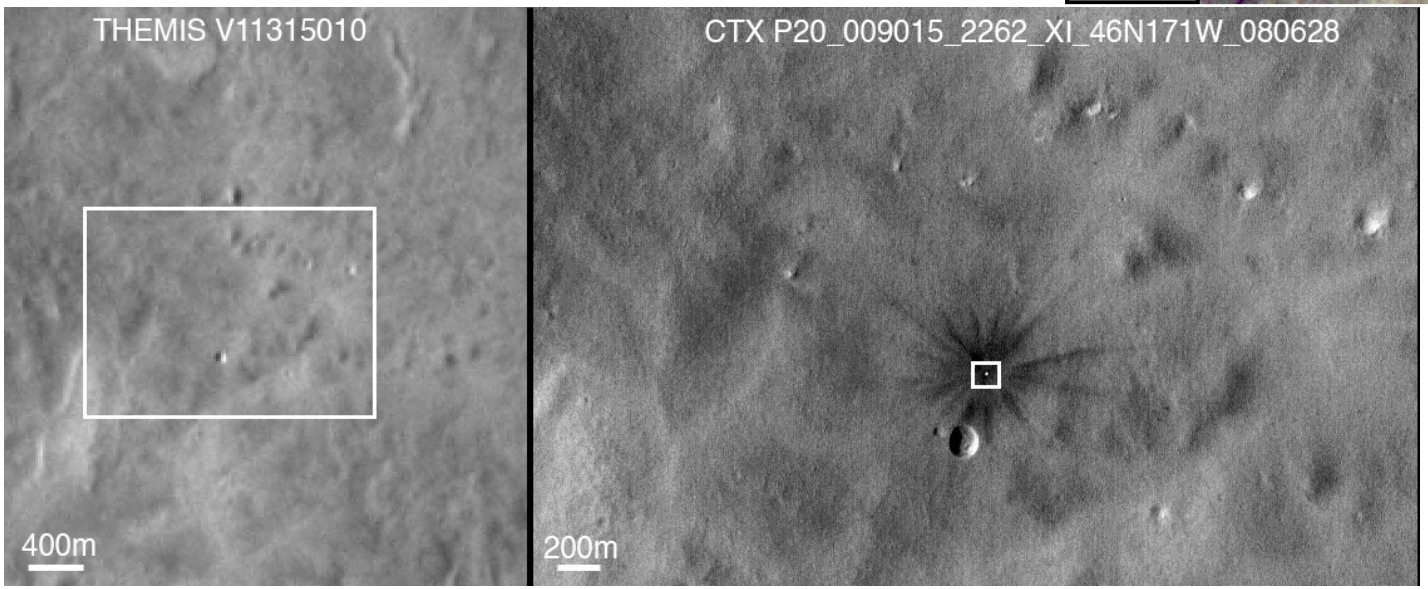
W. Feldman - GRS

“Clean” Ground Ice Under the Phoenix Lander



- CTX continuously discovers more high-lat. impacts
- HiRISE follow-ups show more craters with associated ice
- 5 sites in total
- All new impacts poleward of 41N have associated ice
- All a few meters across





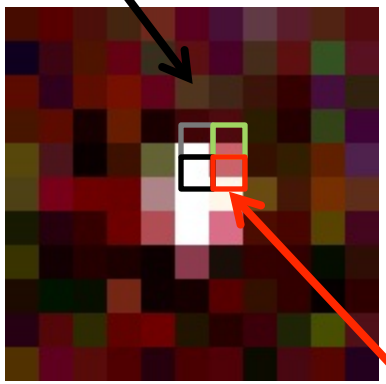
S. Byrne, C.M. Dundas, M.R. Kennedy, M. Mellon, D. Shean, I. Daubar, S. Cull, K.D. Seelos, S. Murchie, B. Cantor, R.E. Arvidson, K. Edgett, A. McEwen, T. Harrison, L. Posiolova, F.P. Seelos

HiRISE, CTX and CRISM teams

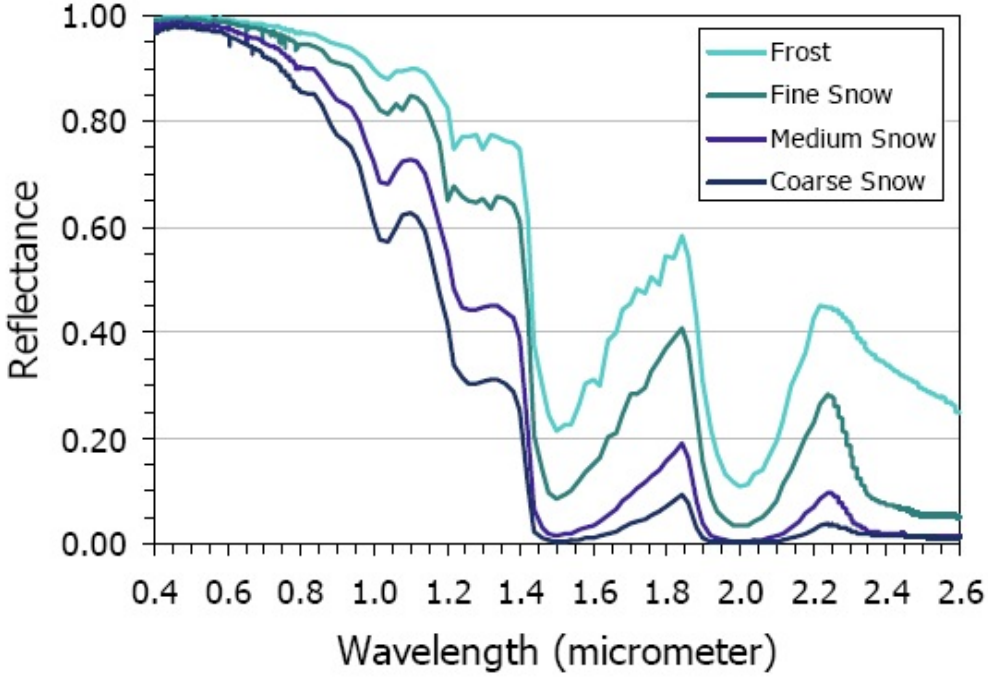
CRISM Findings:

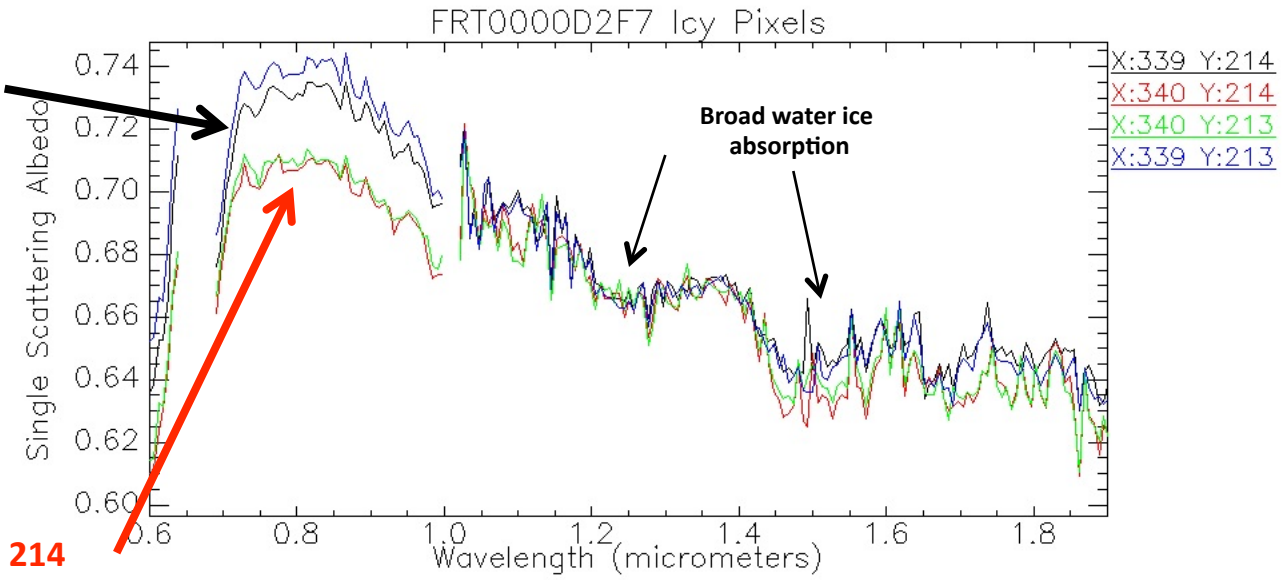
- Detected water ice
- Spread over a few pixels

X:339 Y:213 and 214

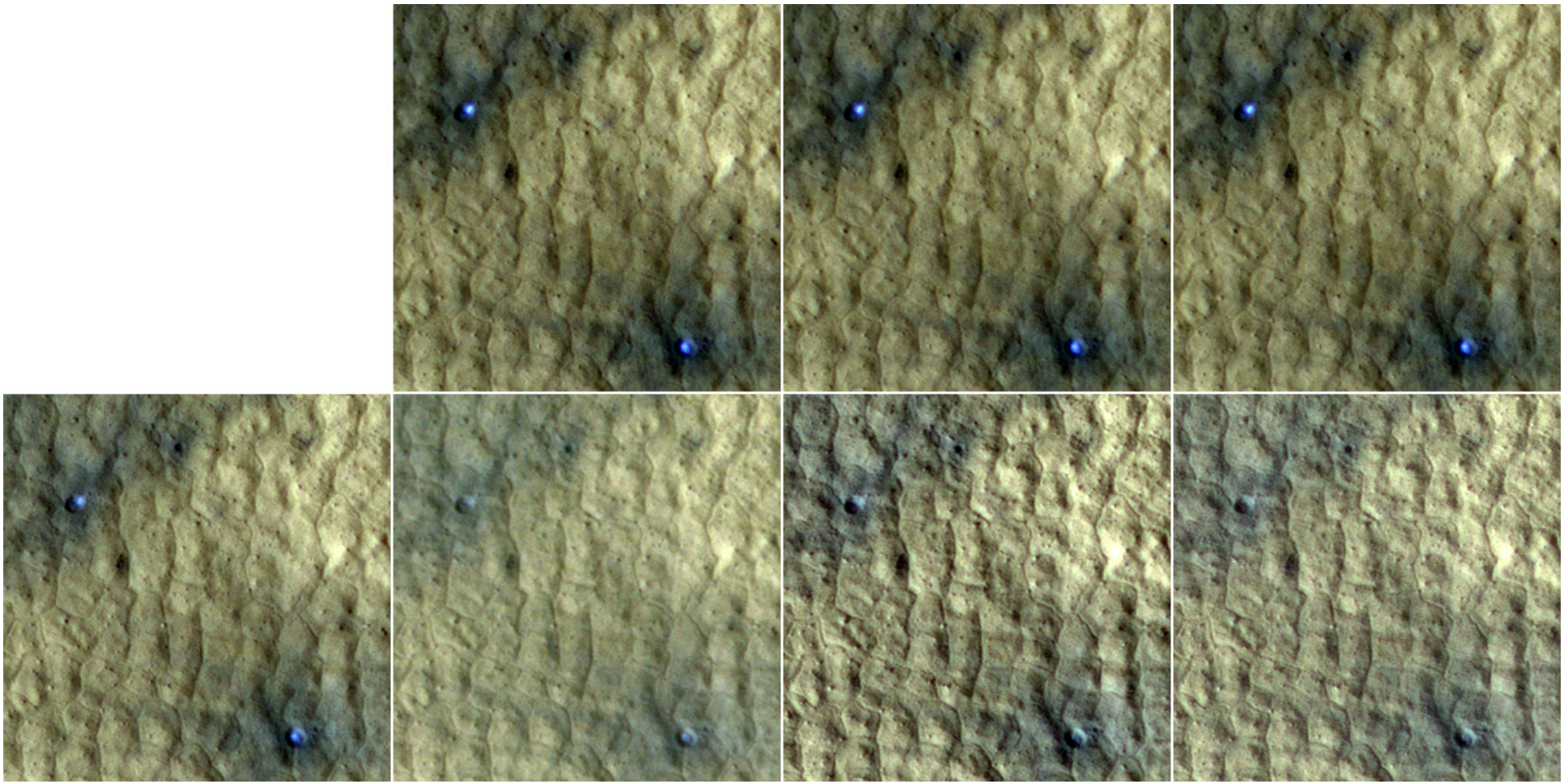


X:340 Y:213 and 214

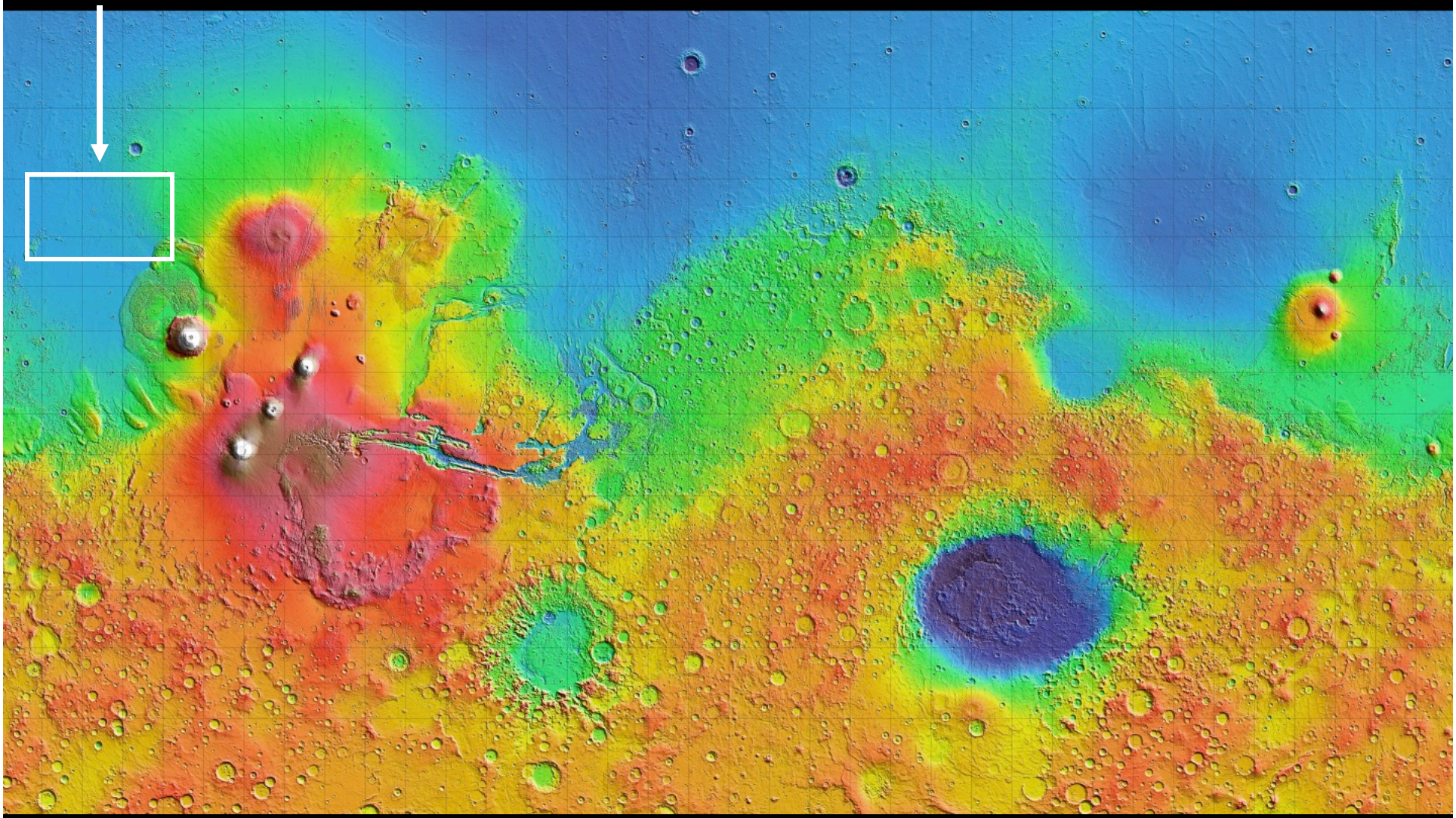


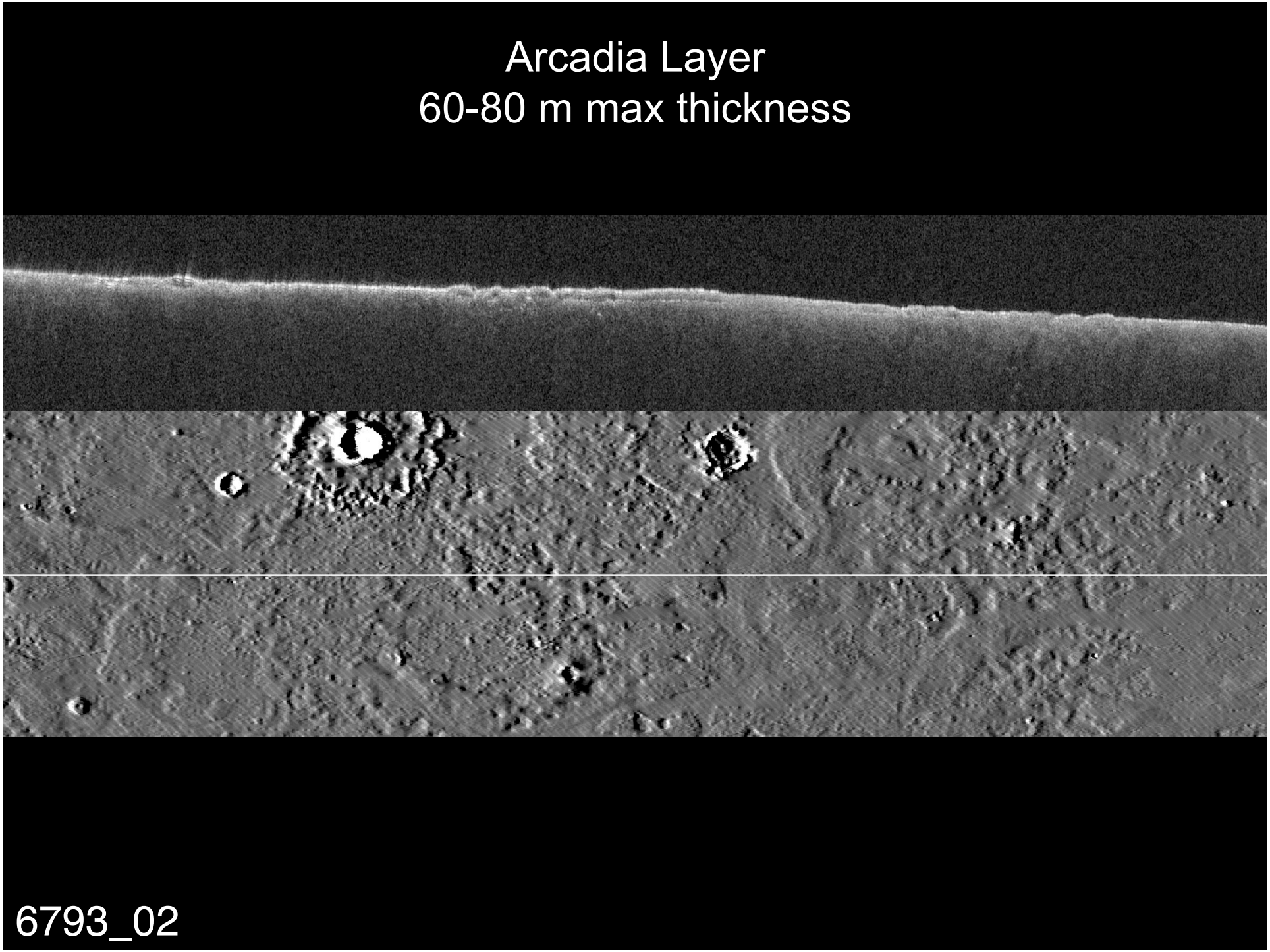


Ice patches faded away over ~100 days

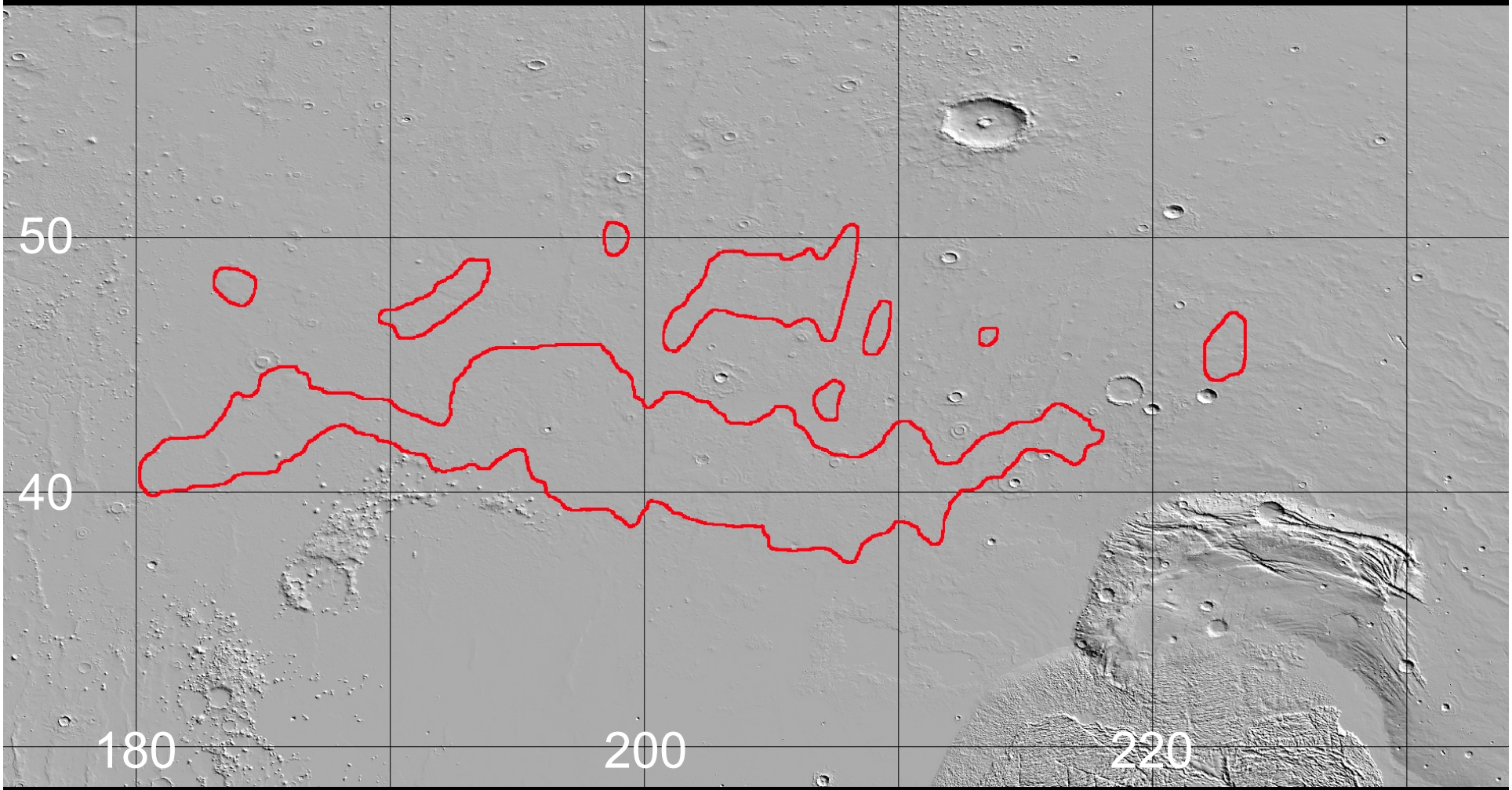


Arcadia Planitia

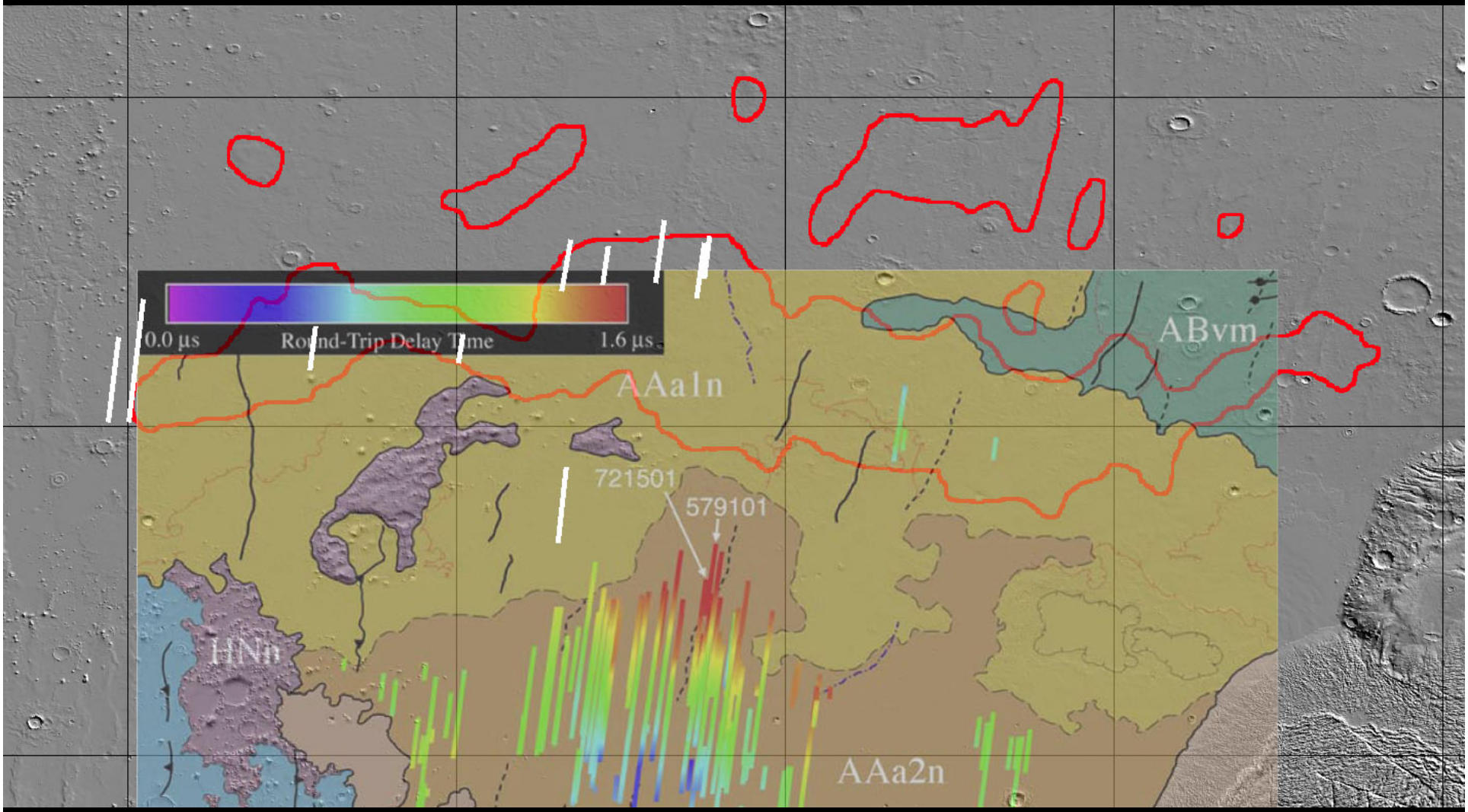



Arcadia Layer
60-80 m max thickness
6793_02

Arcadia Layer
SHARAD Detections

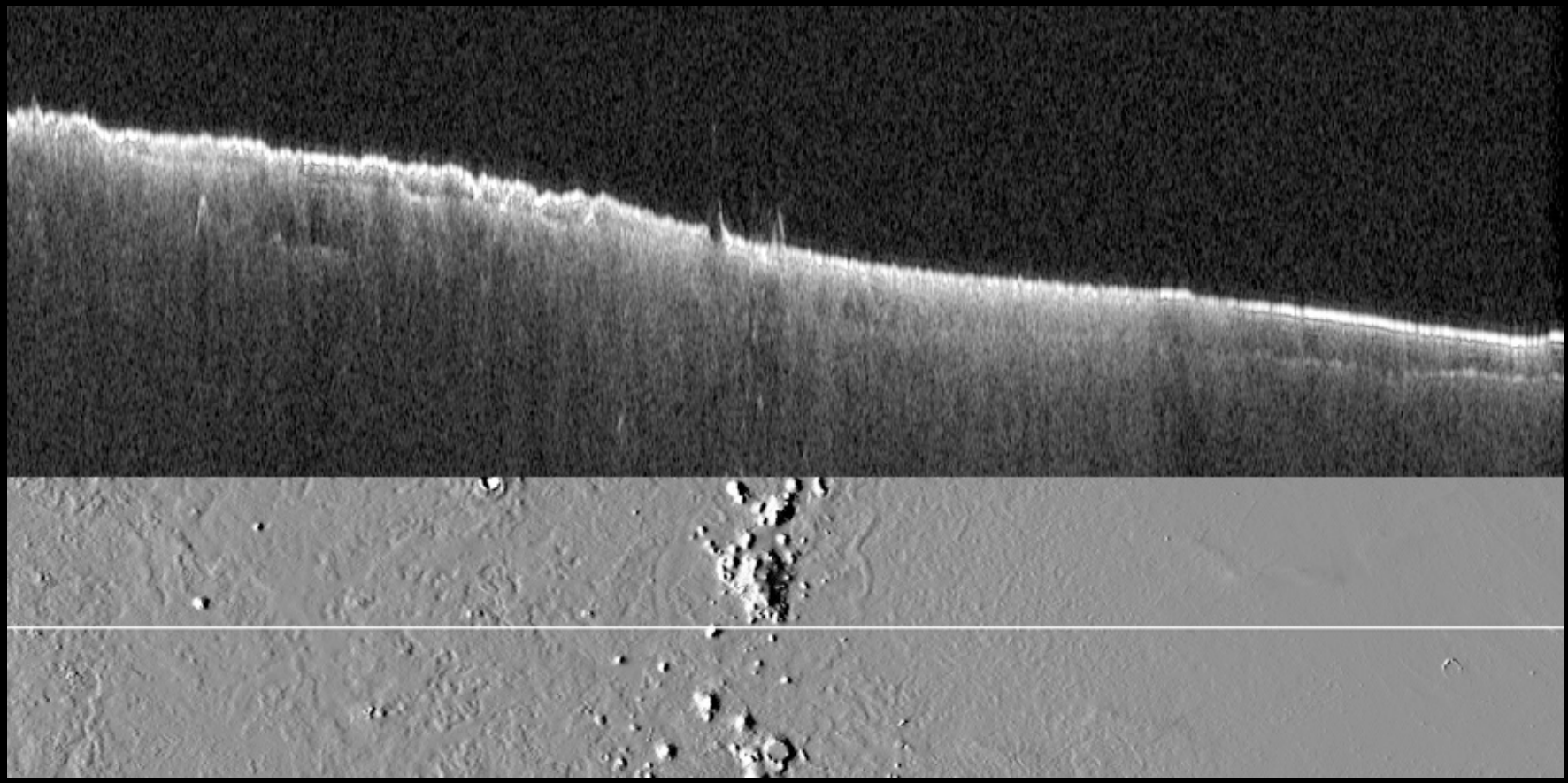


Arcadia and Amazonis Subsurface Units

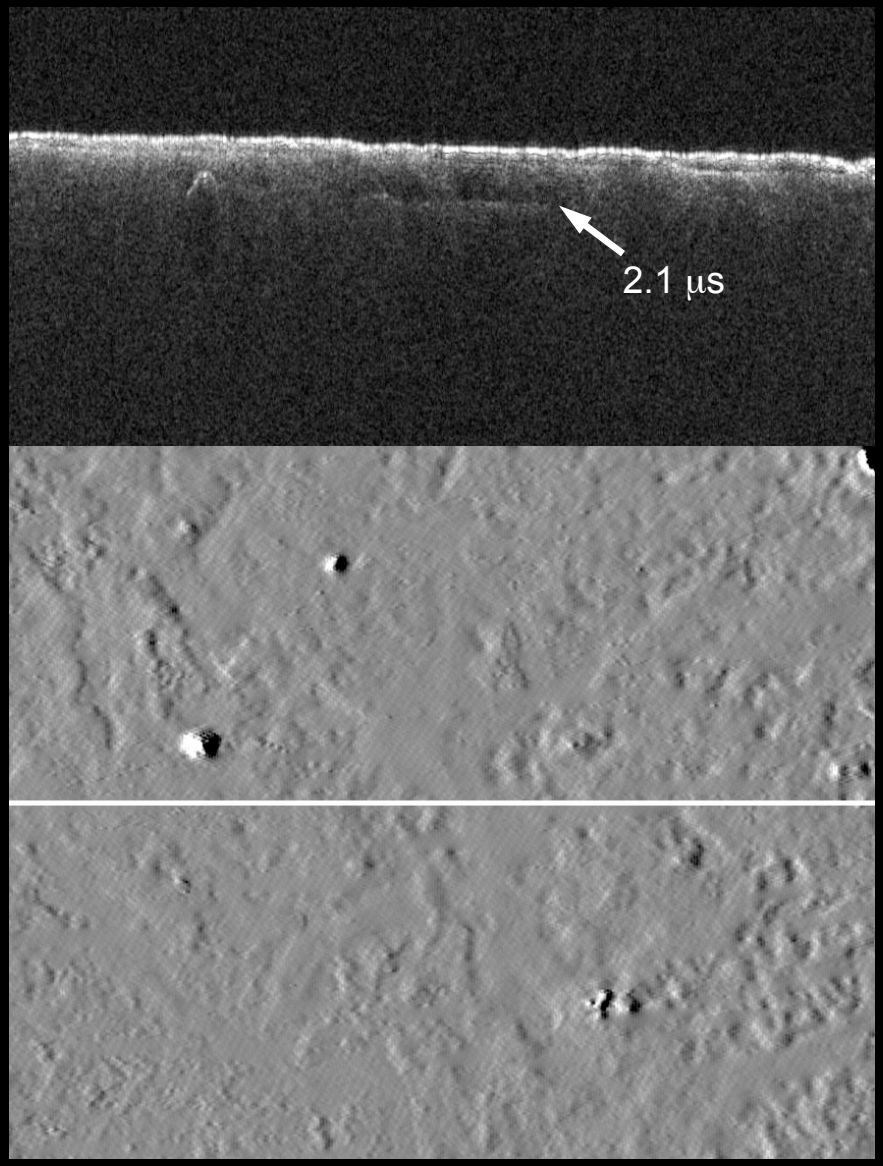


Amazonis map from Campbell et al., 2008

Arcadia to Amazonis - 9496_01



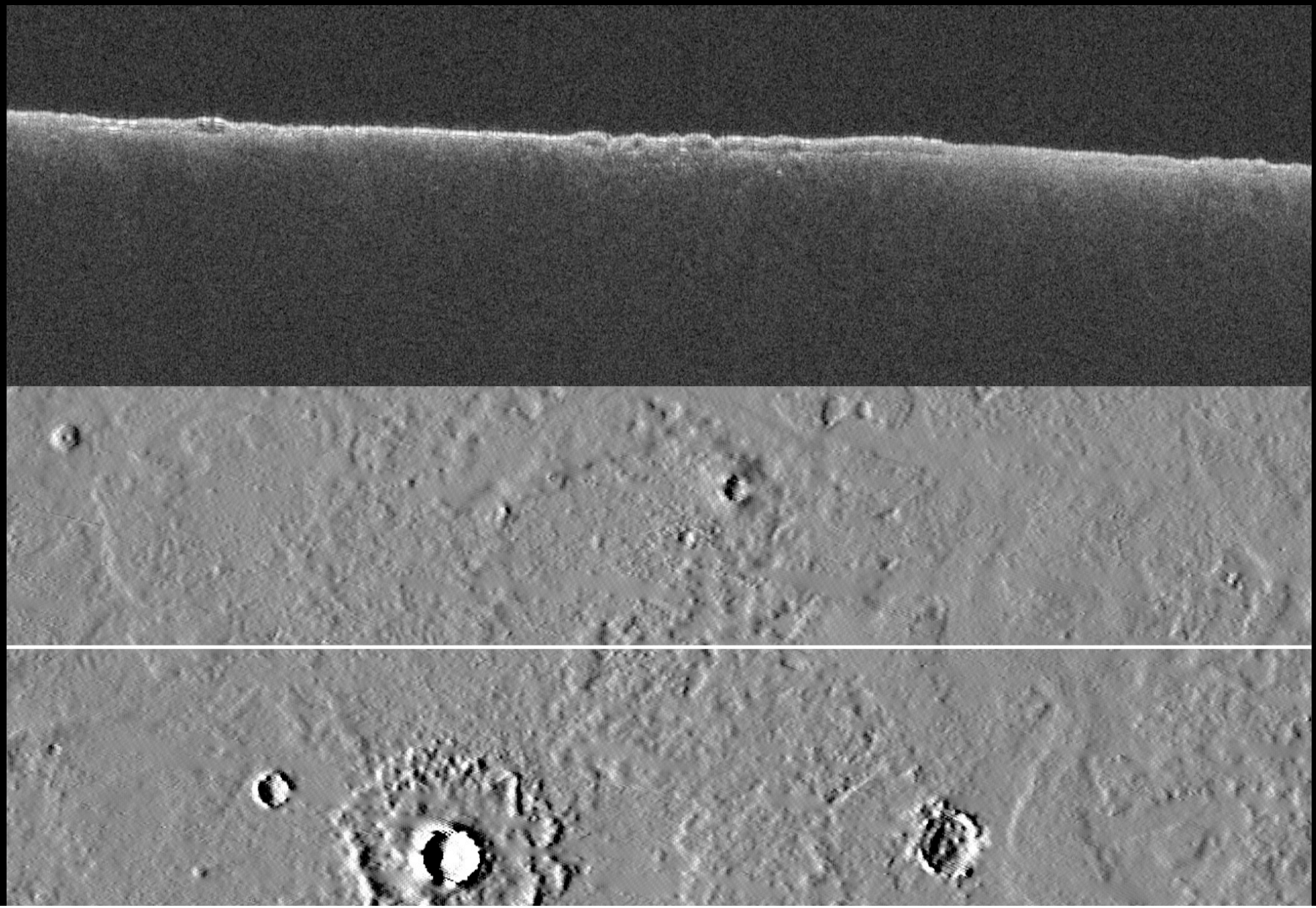
Arcadia to Amazonis - 9496_01



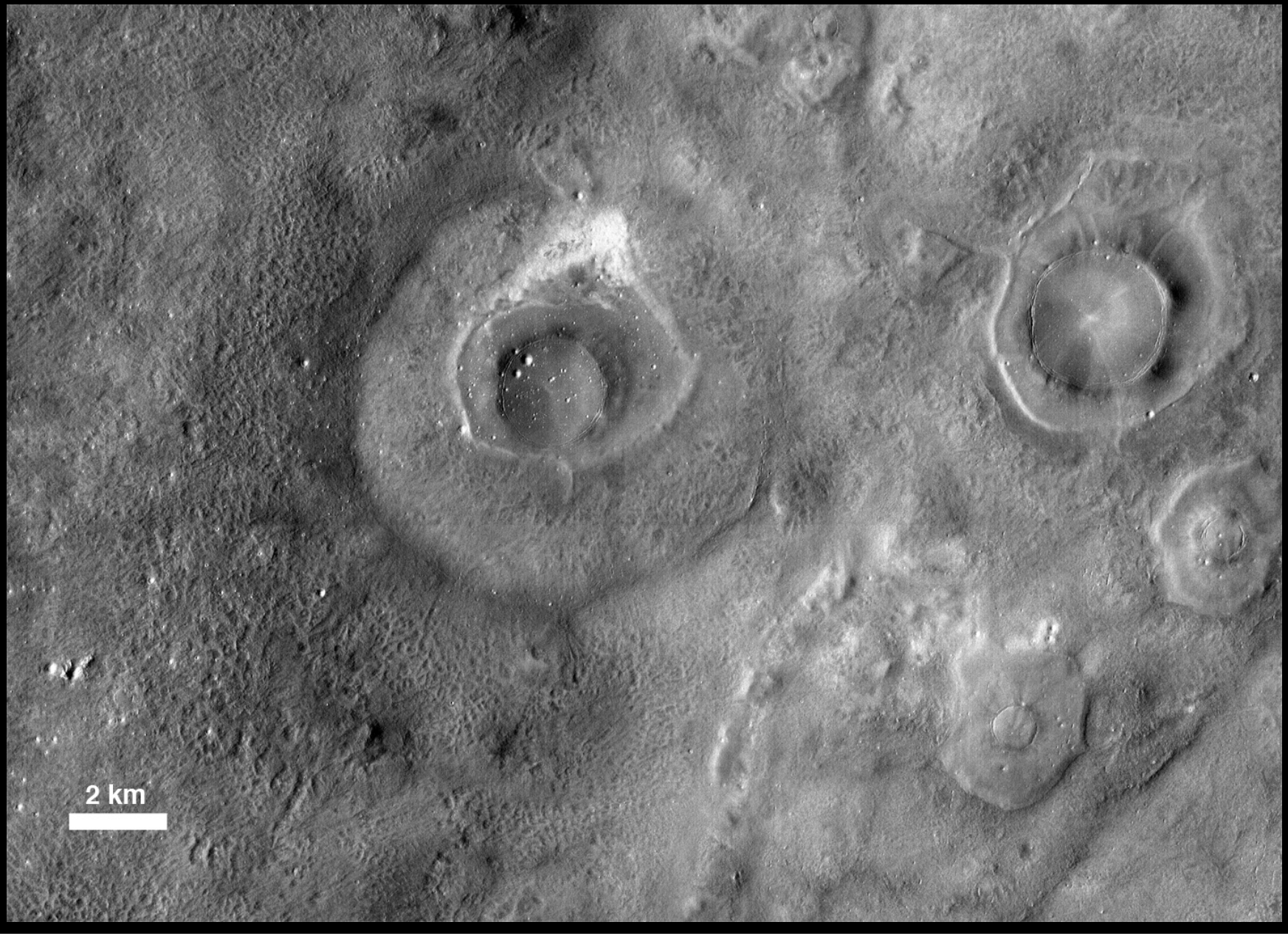
2 μs =
100 - 150 m

Estimating thickness to get ε

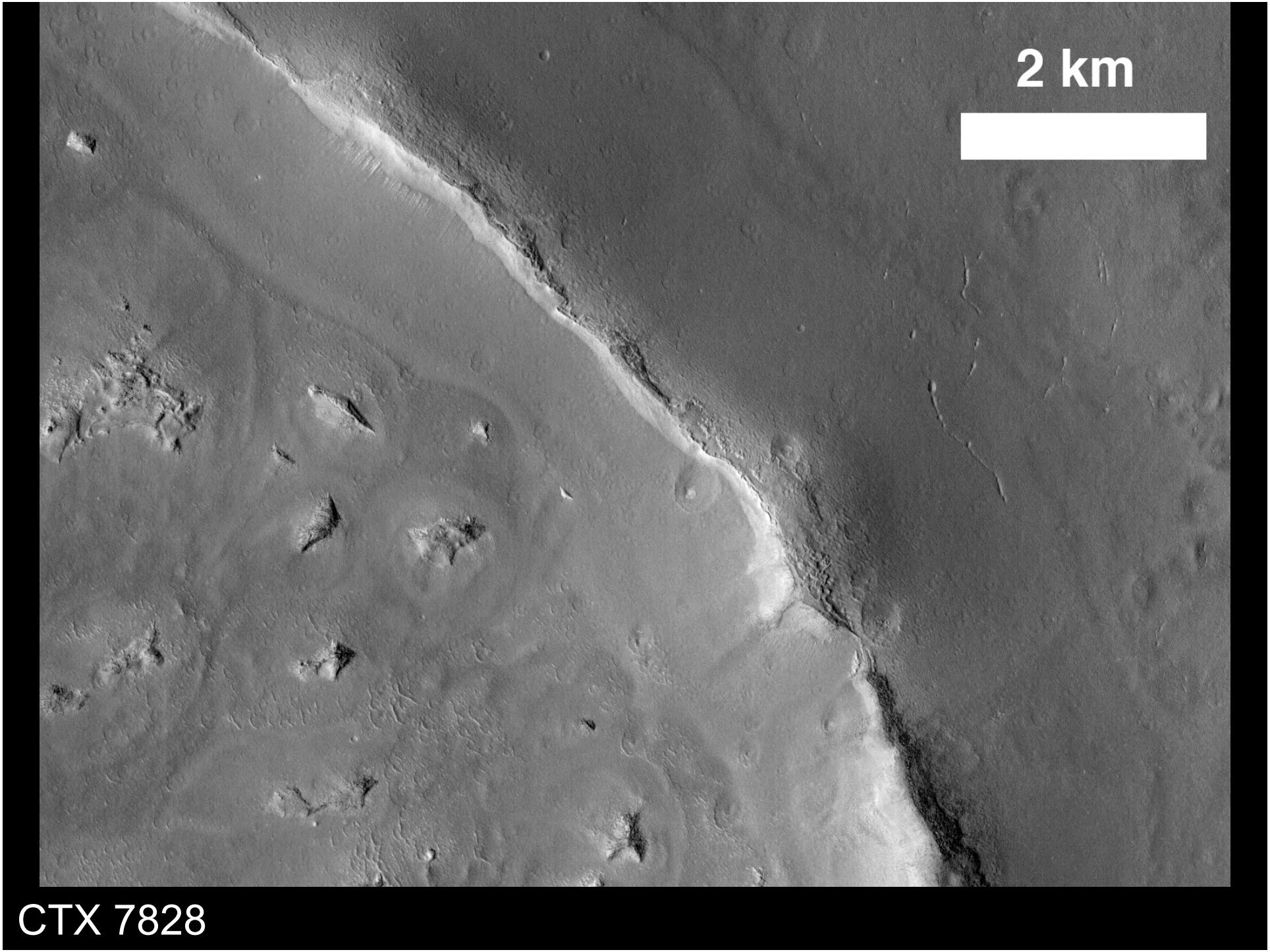
8441_01



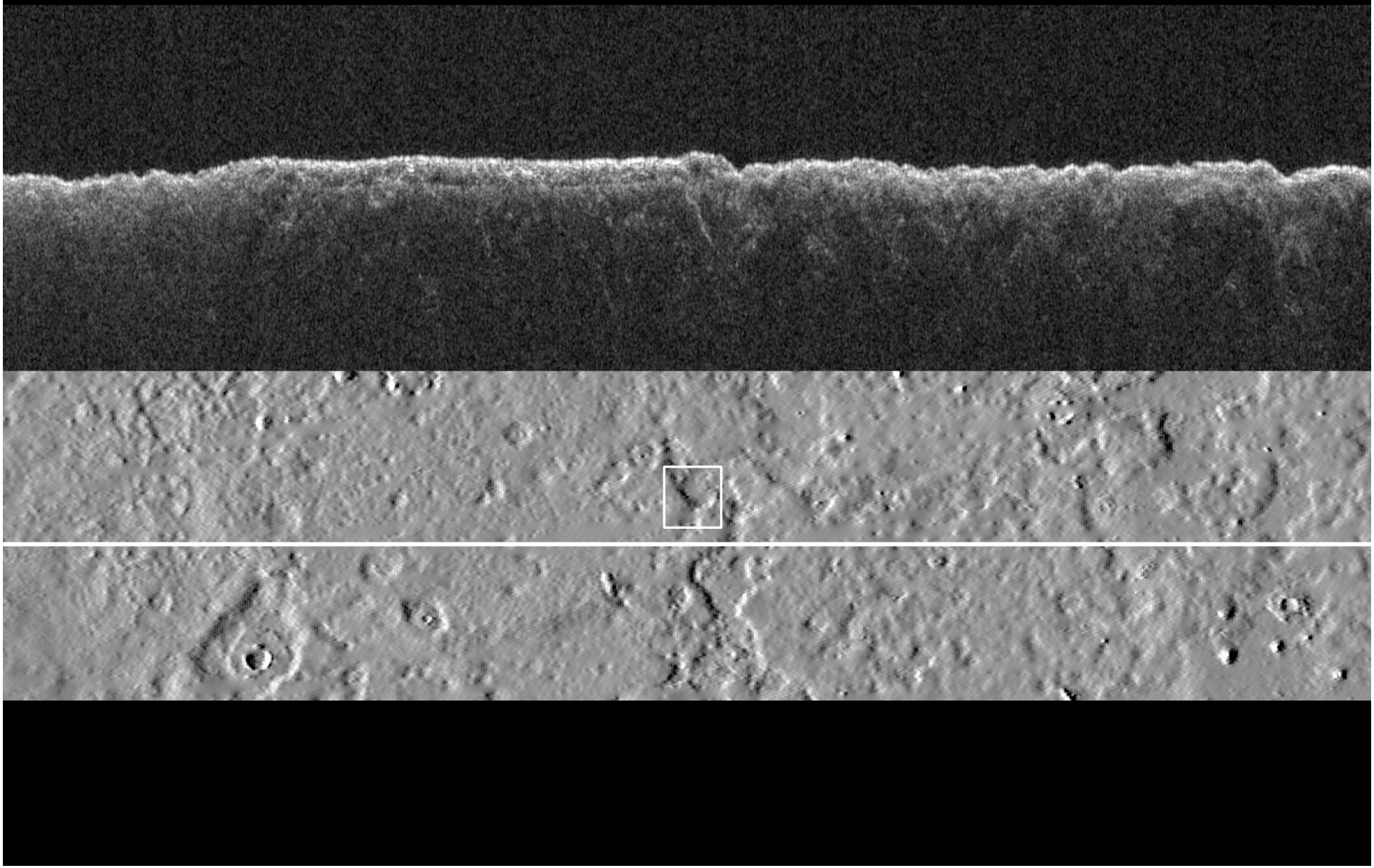
CTX 8408 North Outlier



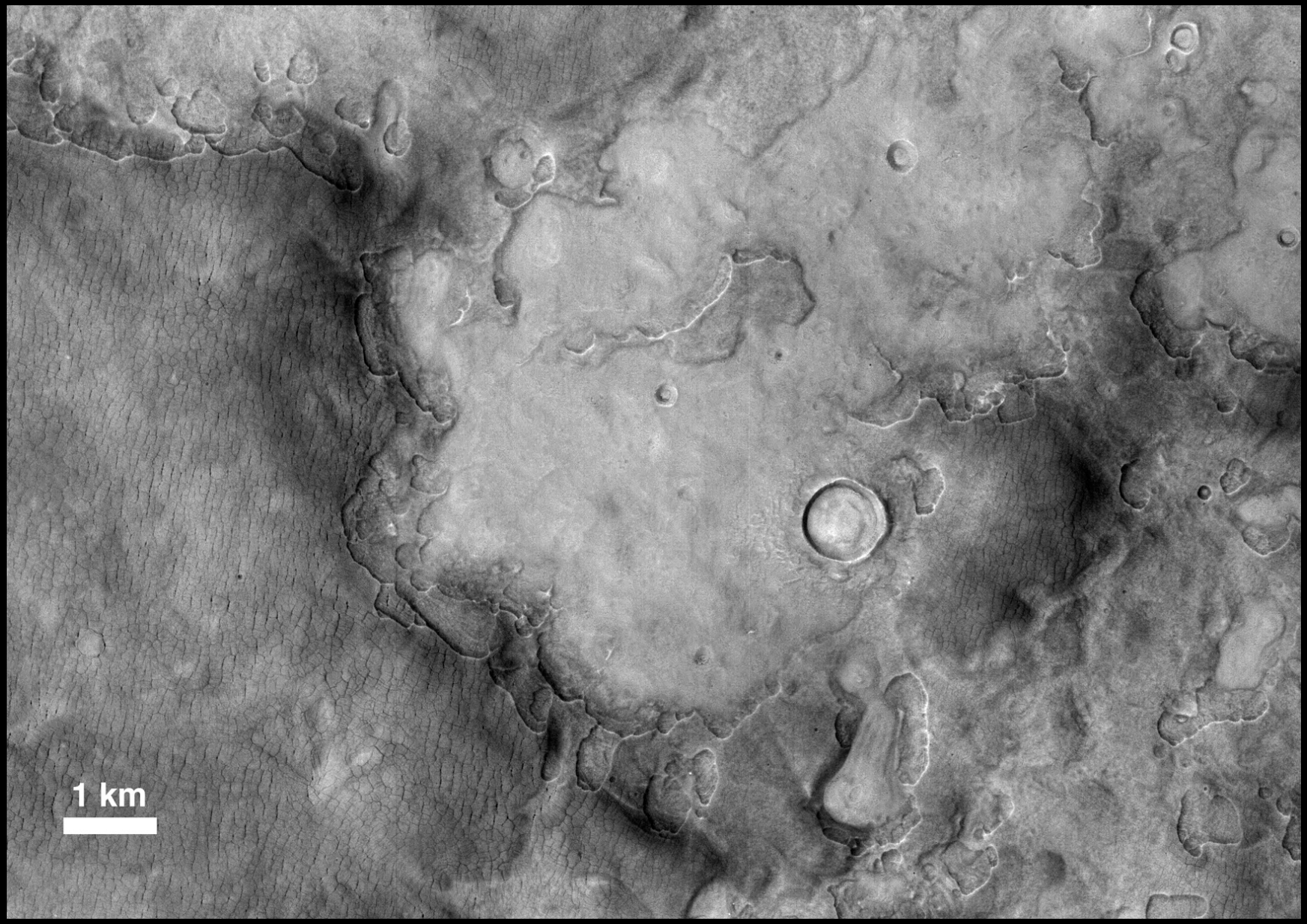
CTX 7828


2 km
CTX 7828

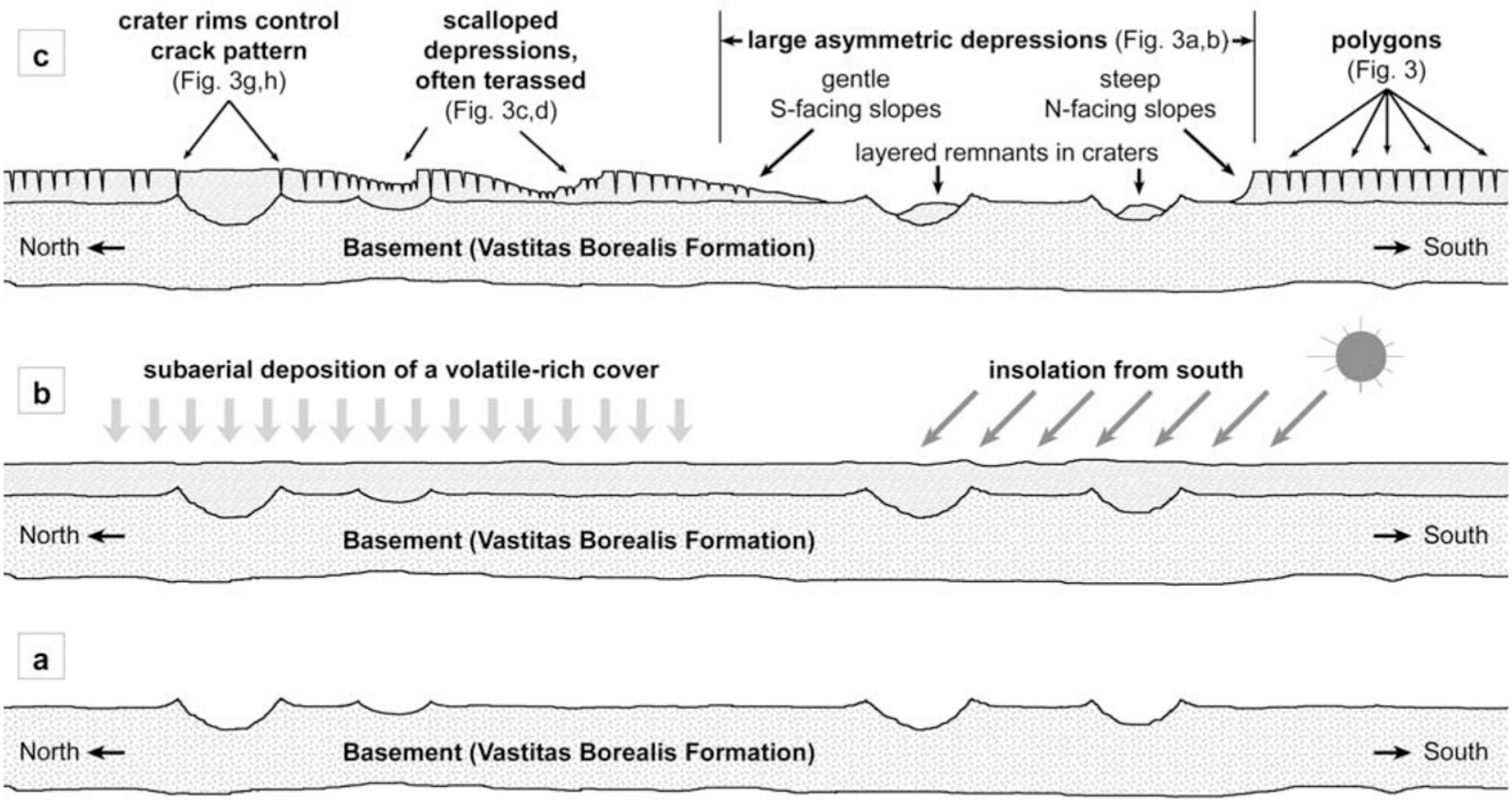
Utopia Planitia 6283_02

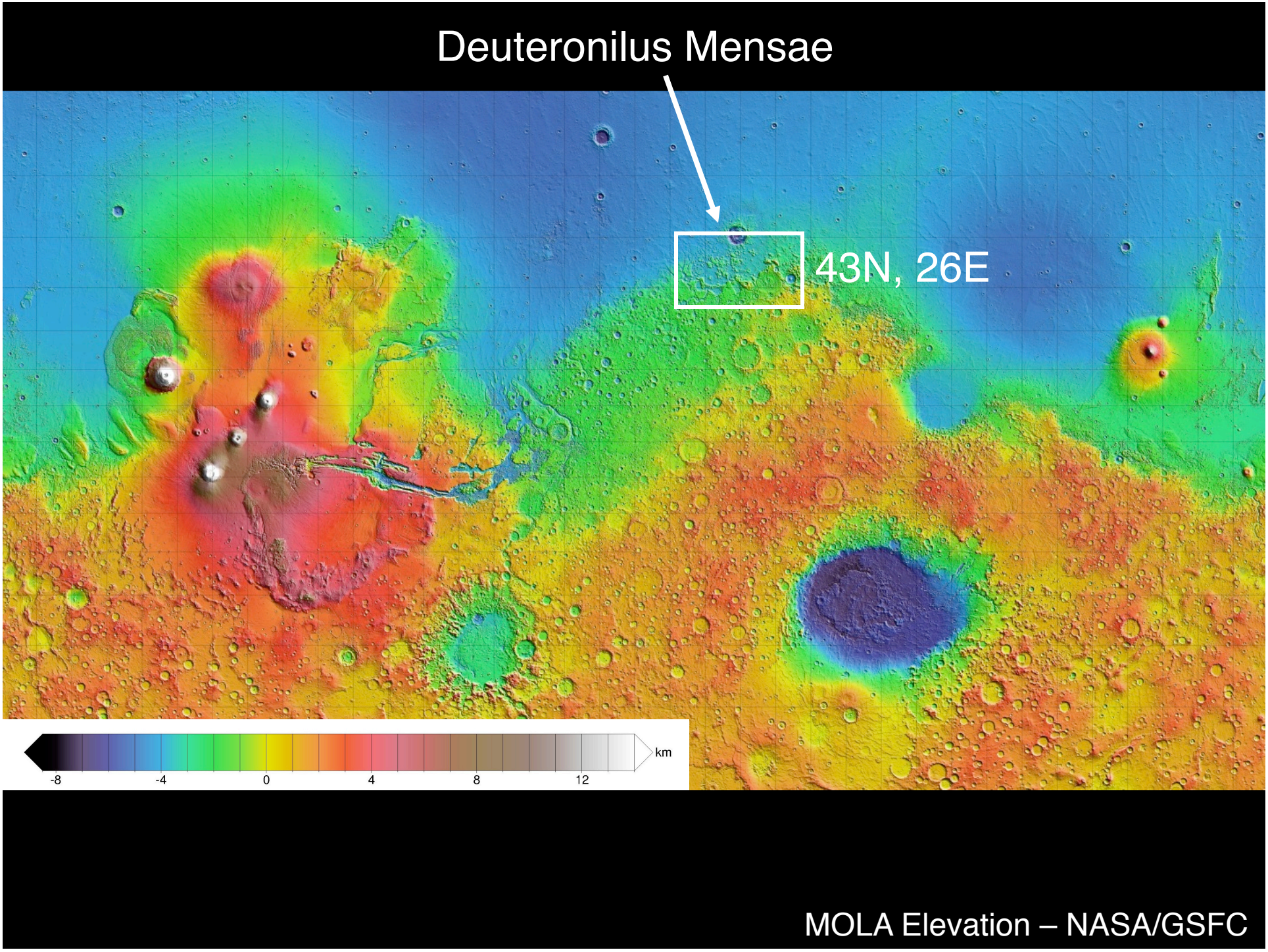


Utopia Planitia CTX 7384

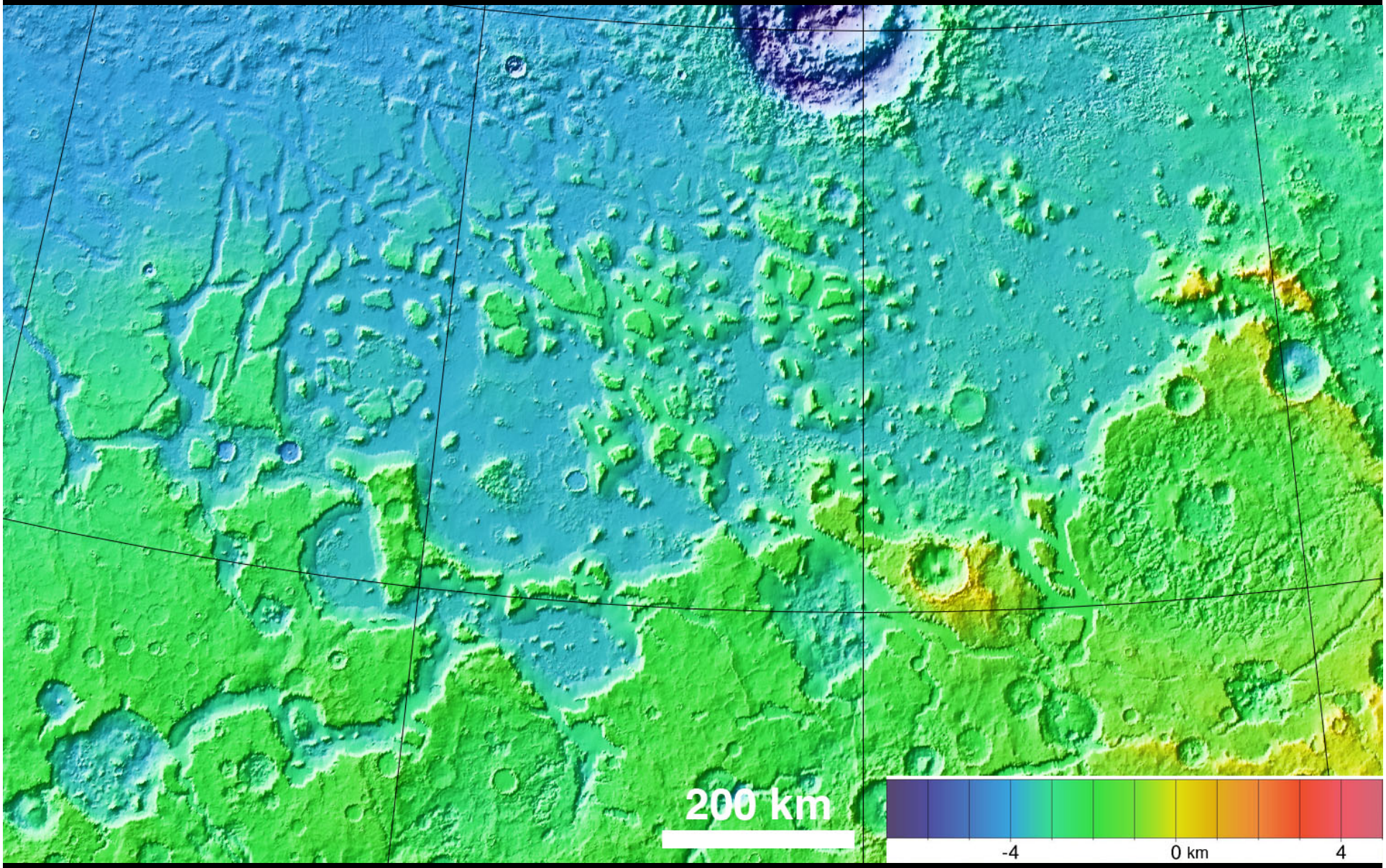


Utopia Planitia 40-50N 80-85E
Morgenstern et al., 2007



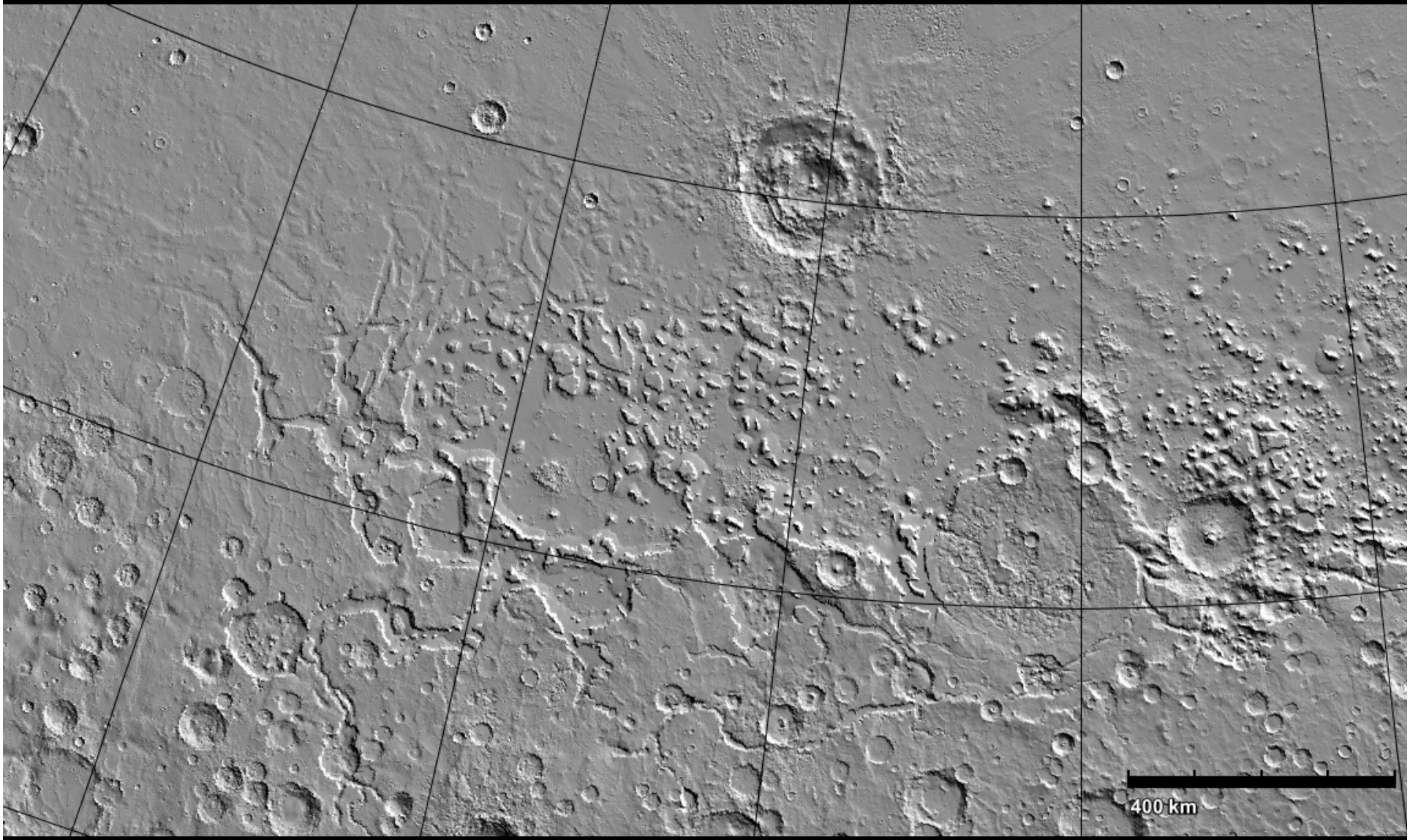

Deuteronilus Mensae
43N, 26E
km
-8
-4
0
4
8
12
MOLA Elevation – NASA/GSFC

Deuteronilus Mensae

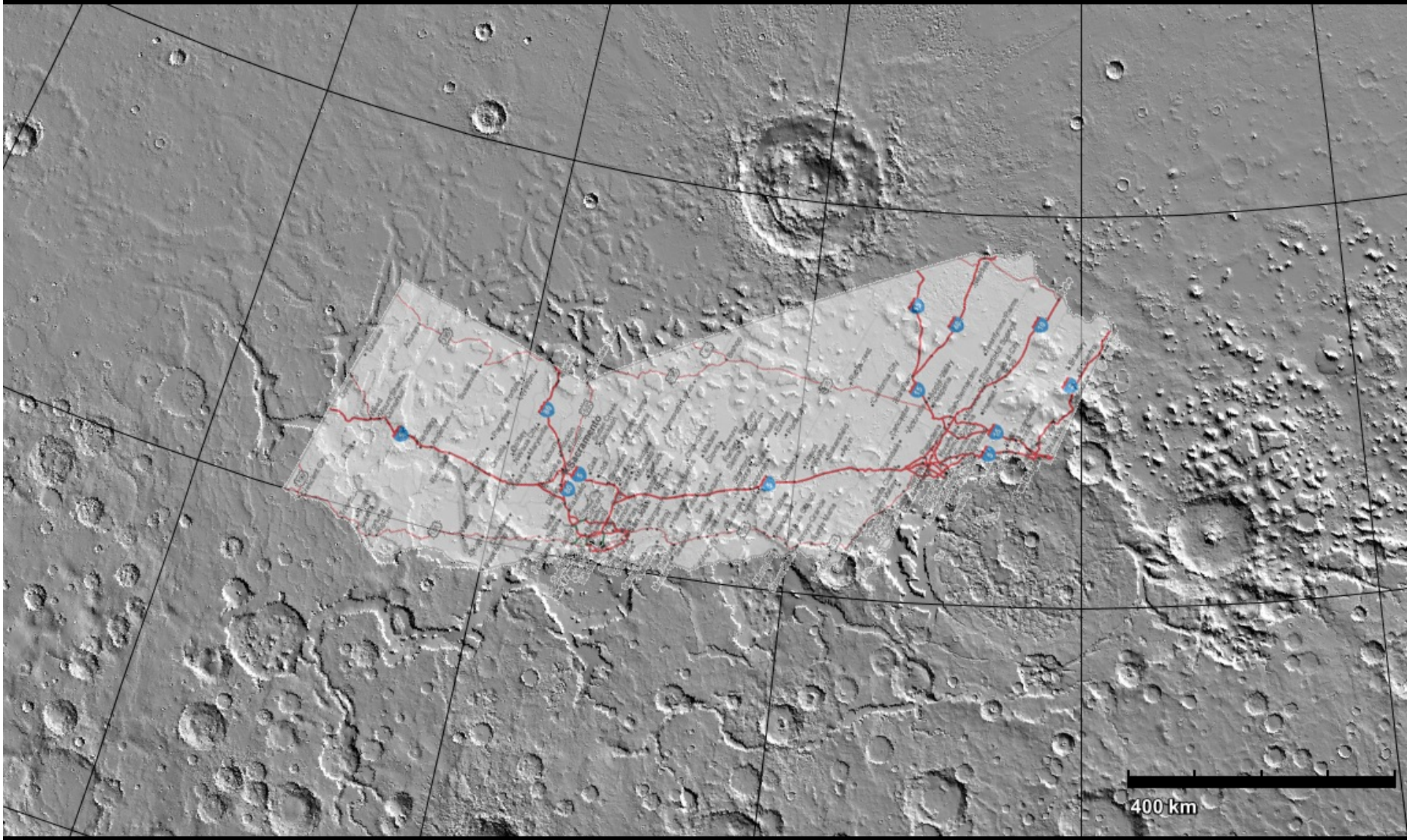


MOLA Team

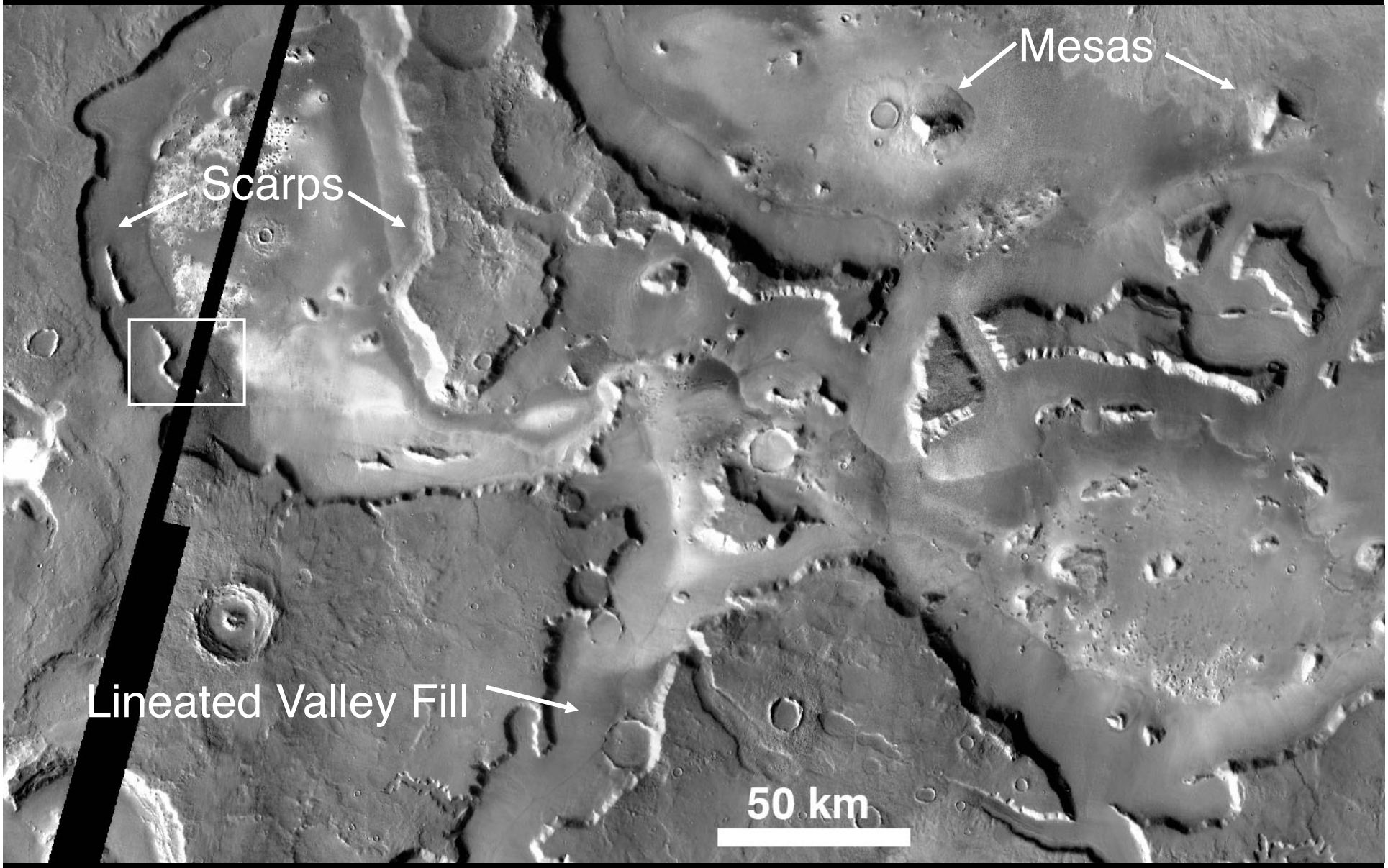
A Big Place



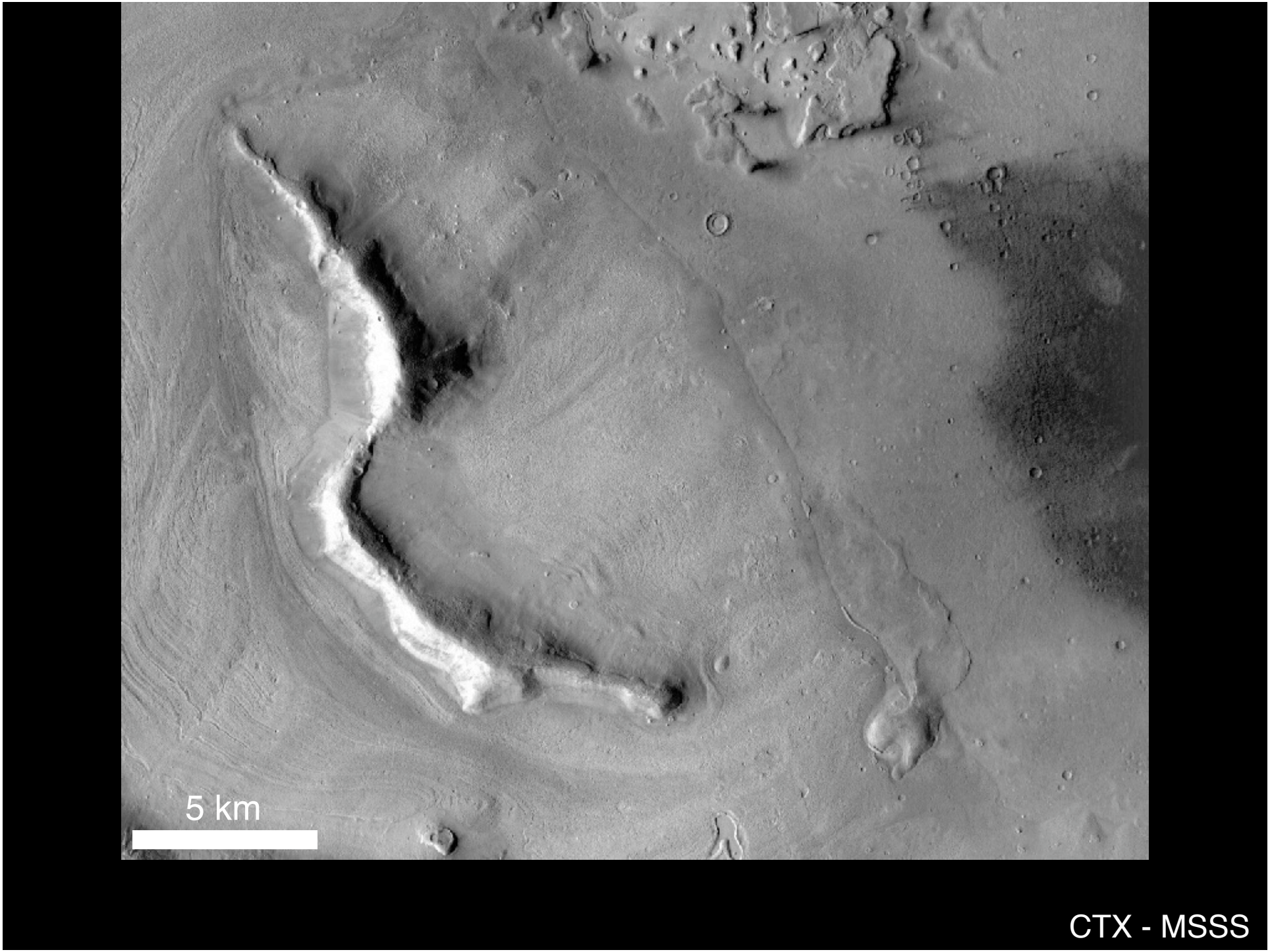
A Big Place

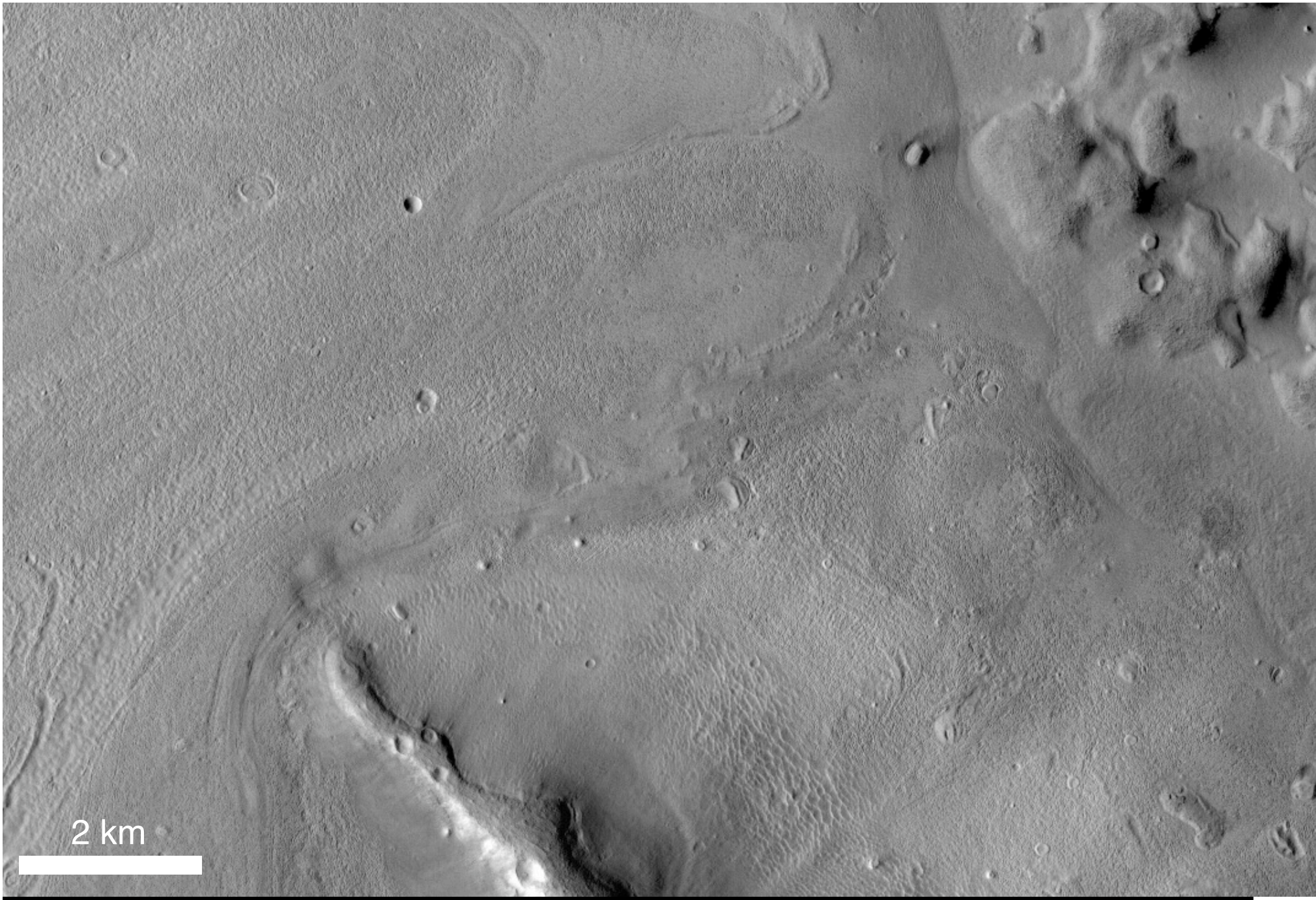


Geomorphic Settings of Lobate Aprons



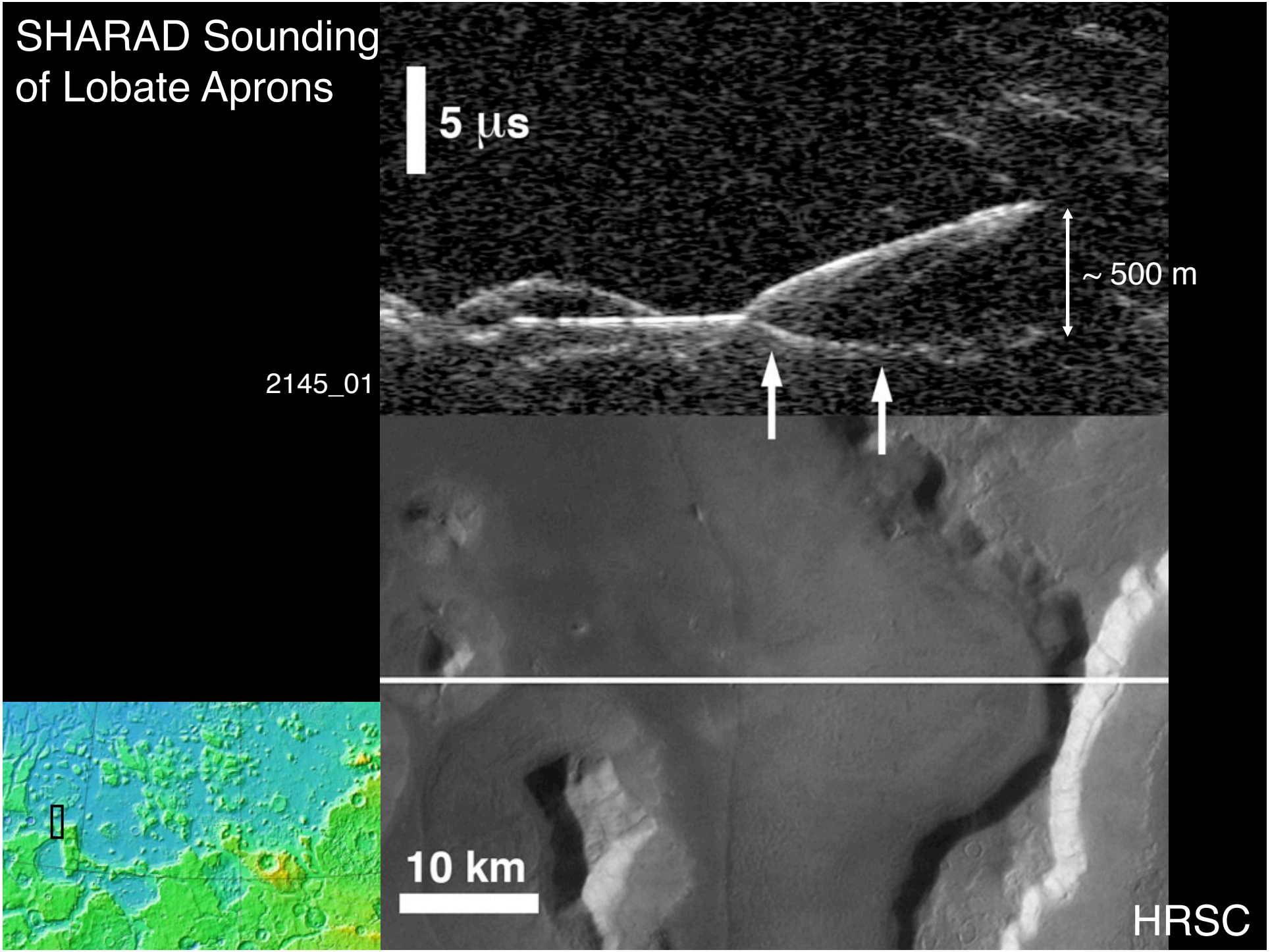
THEMIS Day IR - ASU


5 km
CTX - MSSS

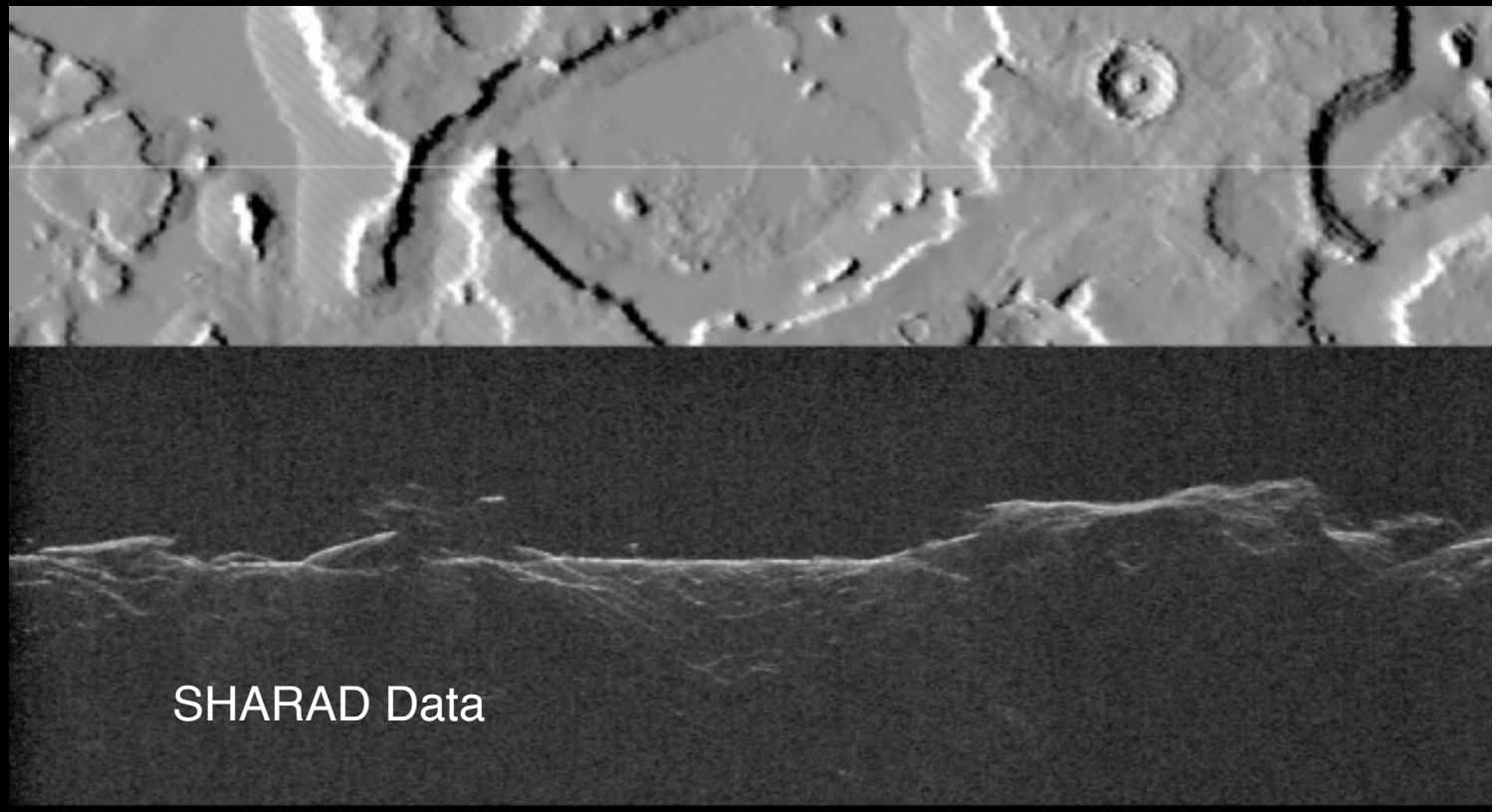


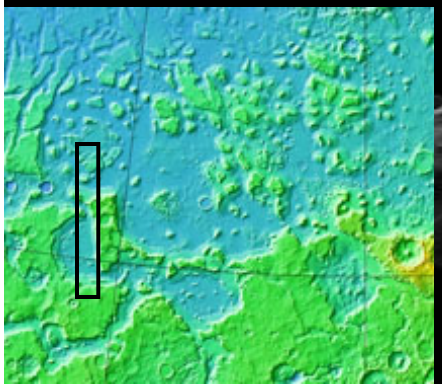
CTX - MSSS

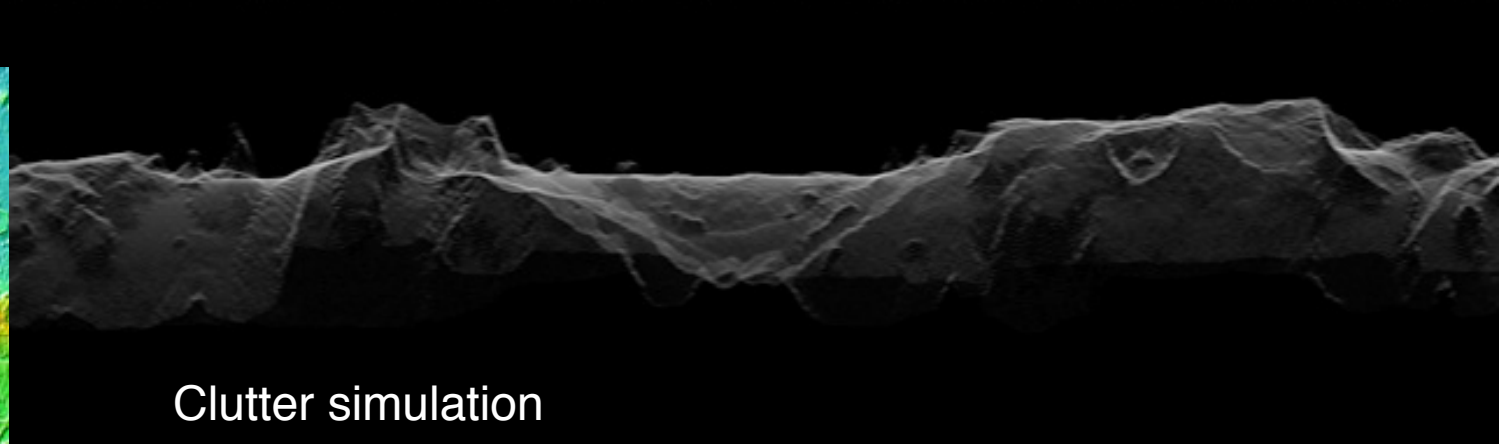
SHARAD Sounding of Lobate Aprons

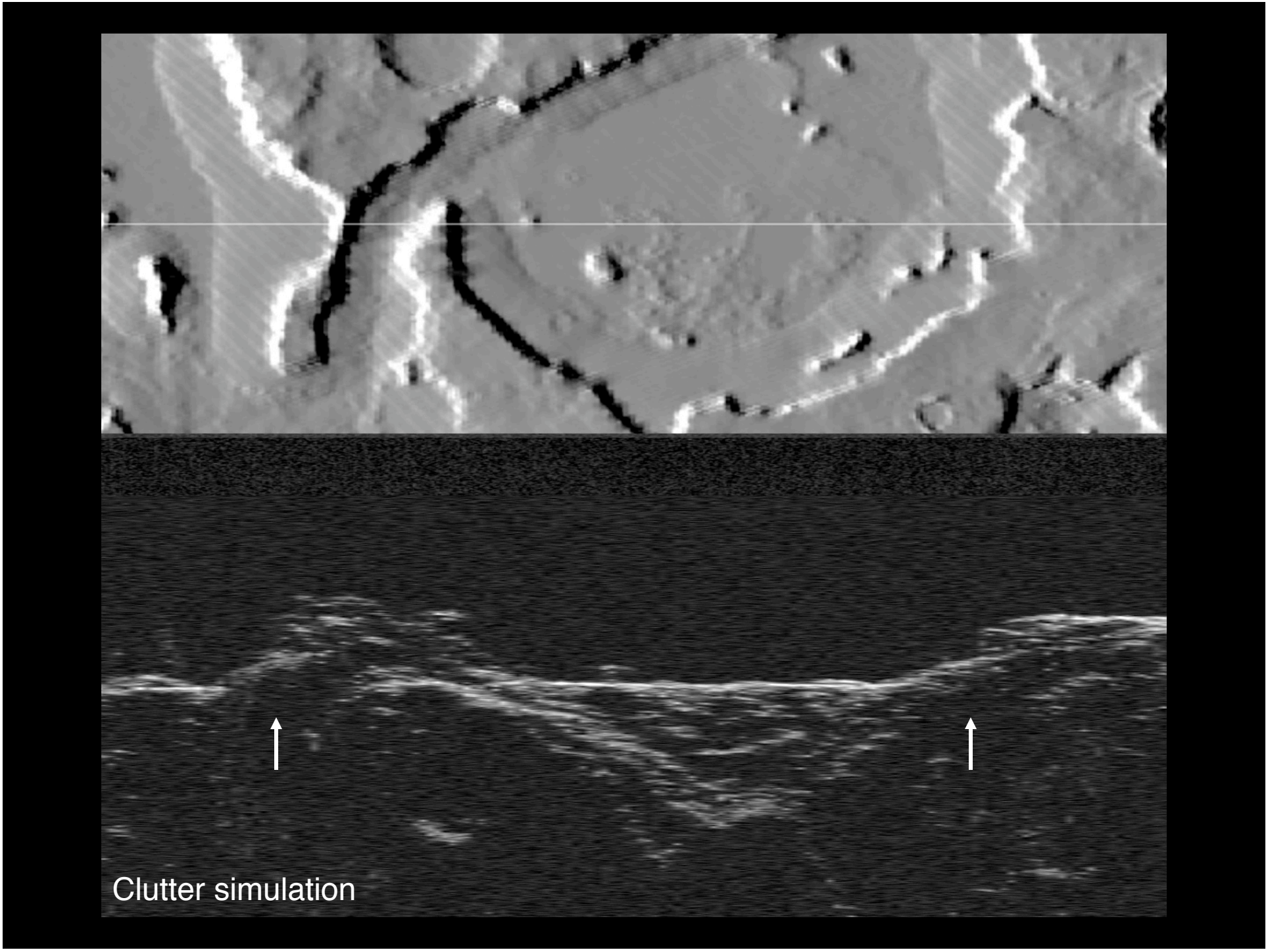


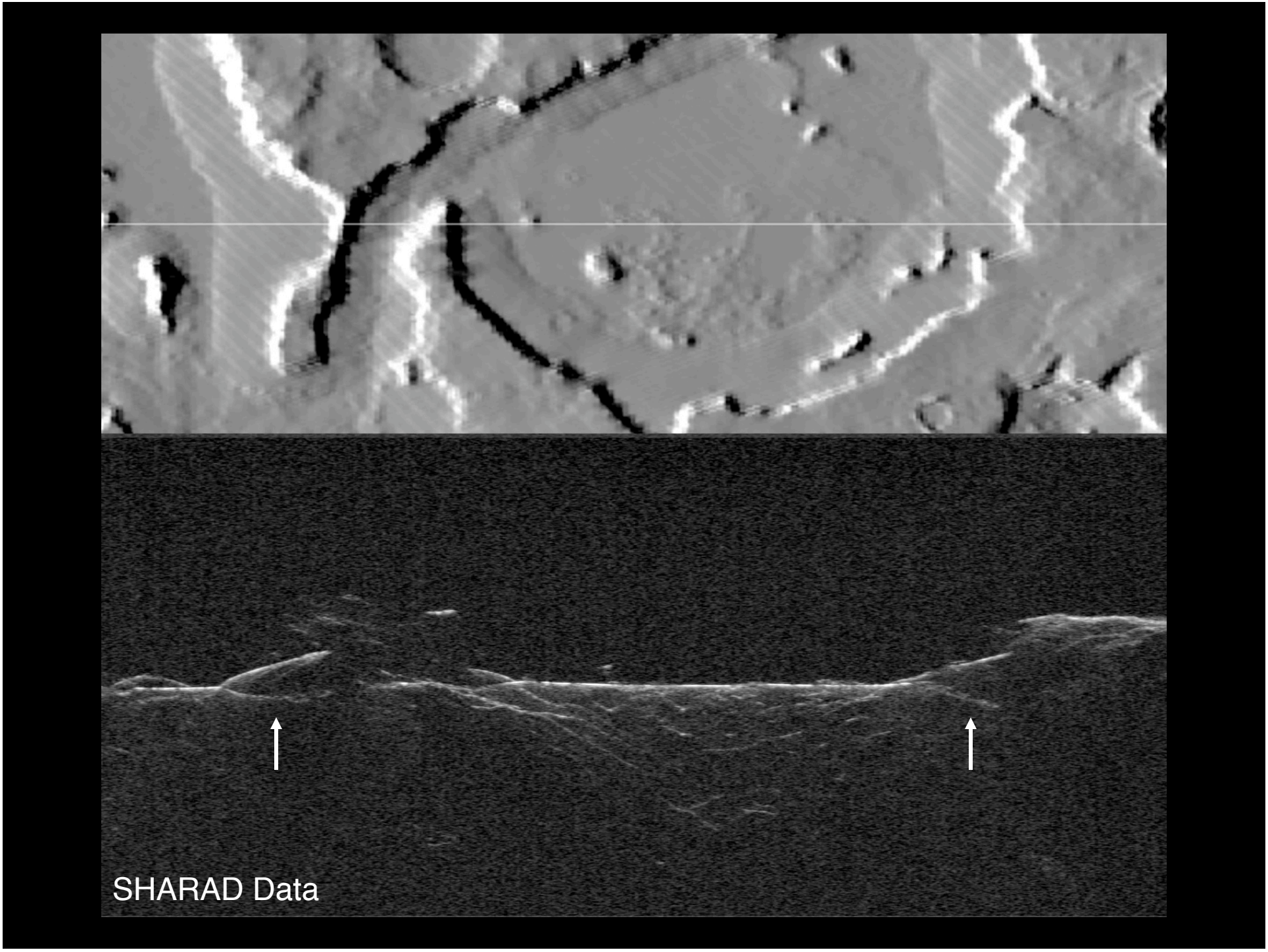
Subsurface, not Clutter





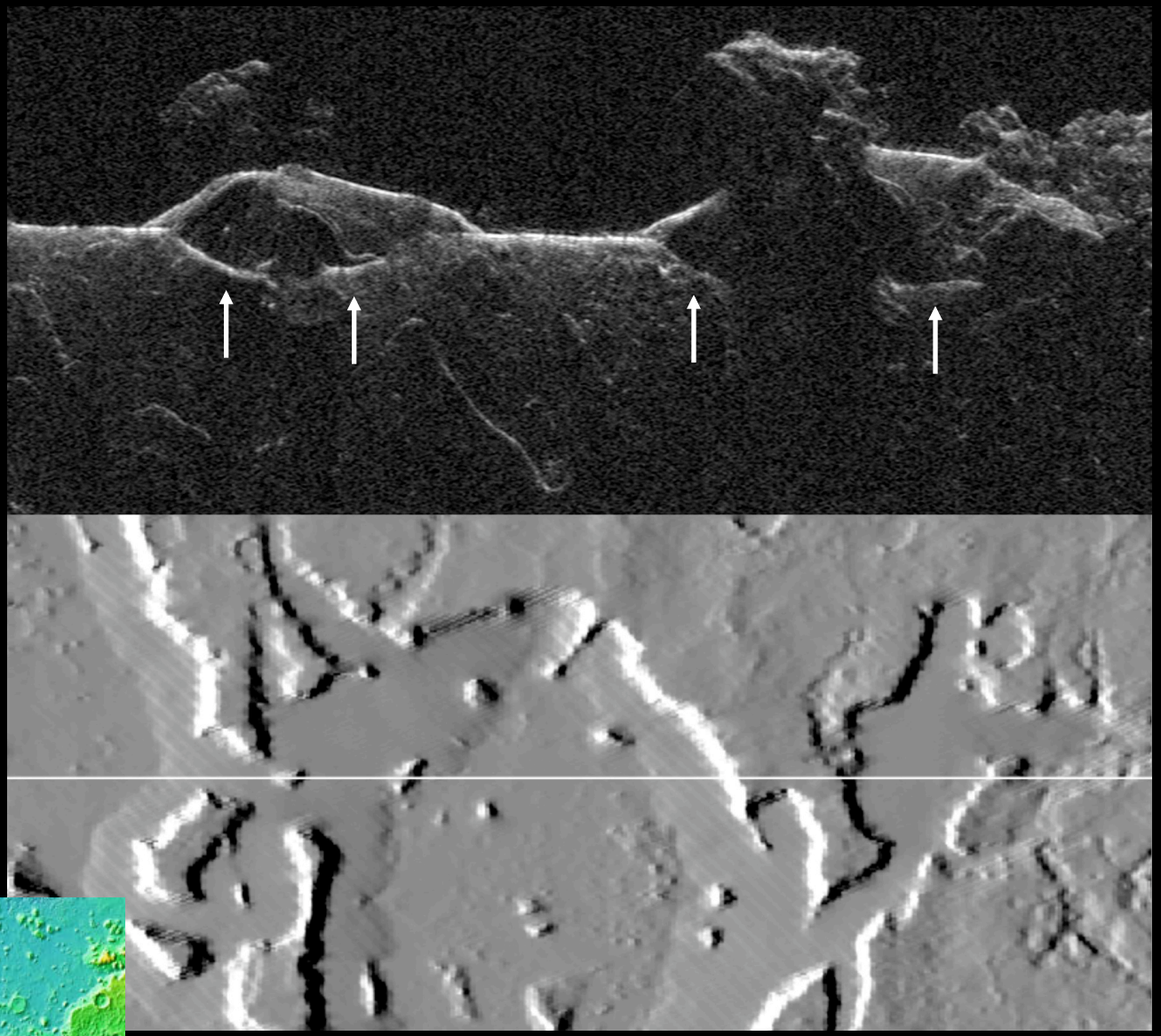


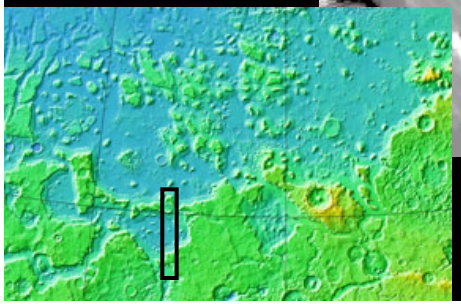

Clutter simulation


SHARAD Data

Converting Time to Depth

Time

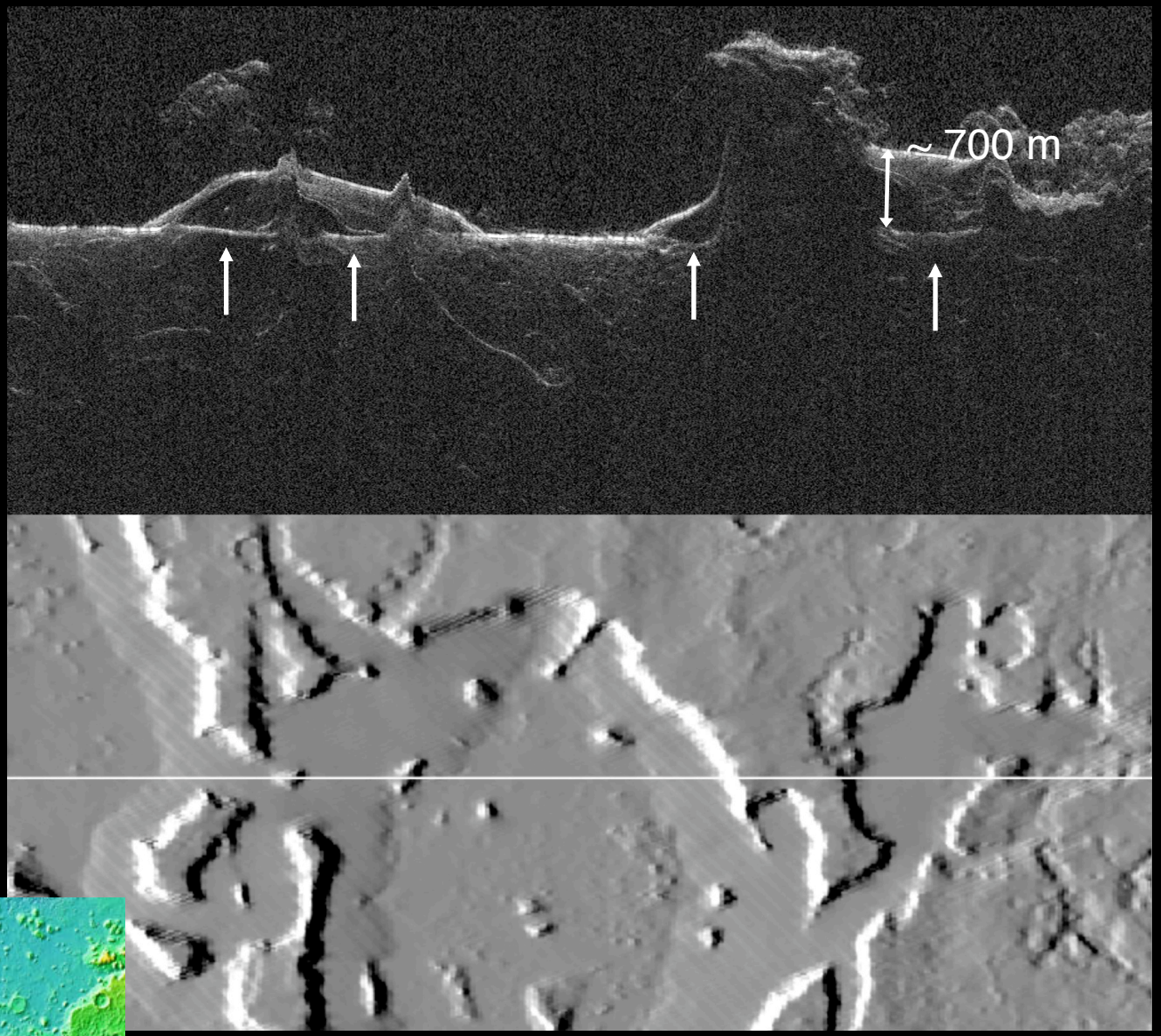




50 km

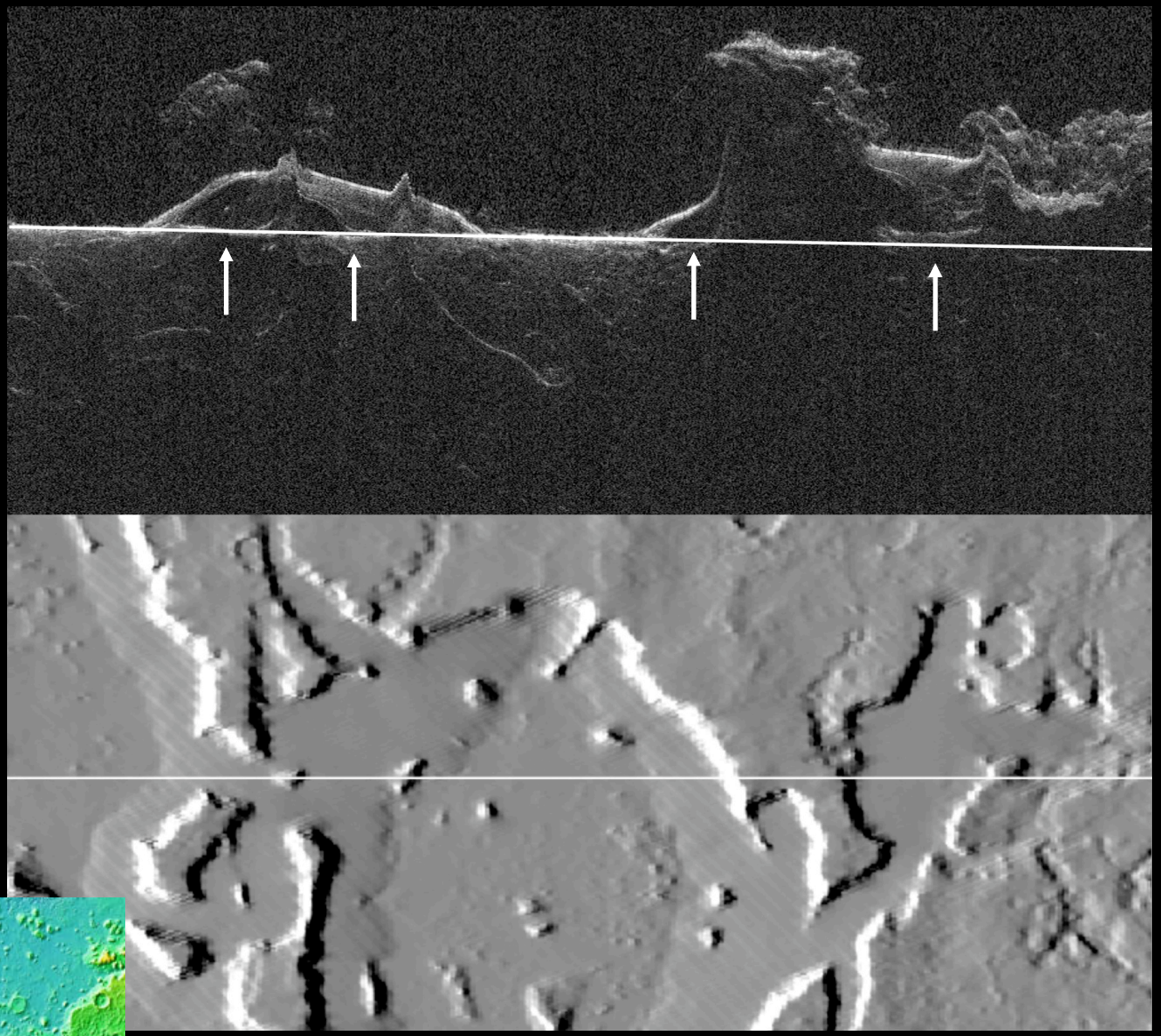
Converting Time to Depth

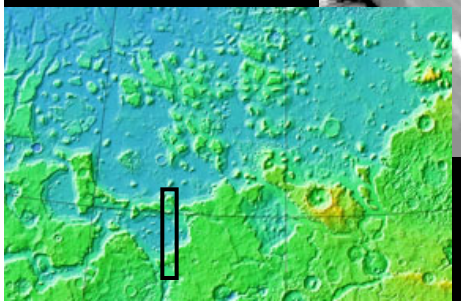
Depth



Converting Time to Depth

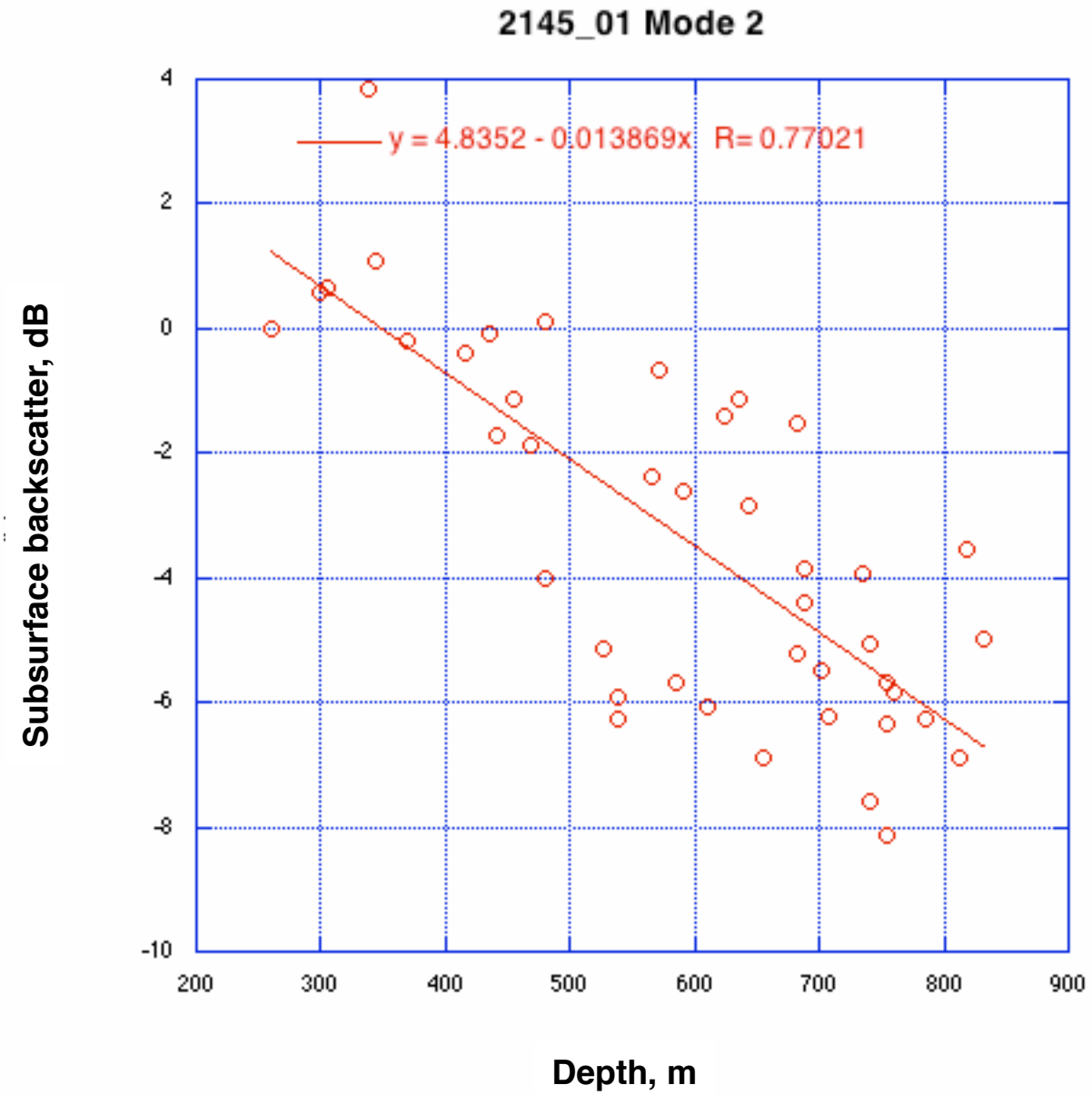
Depth





50 km

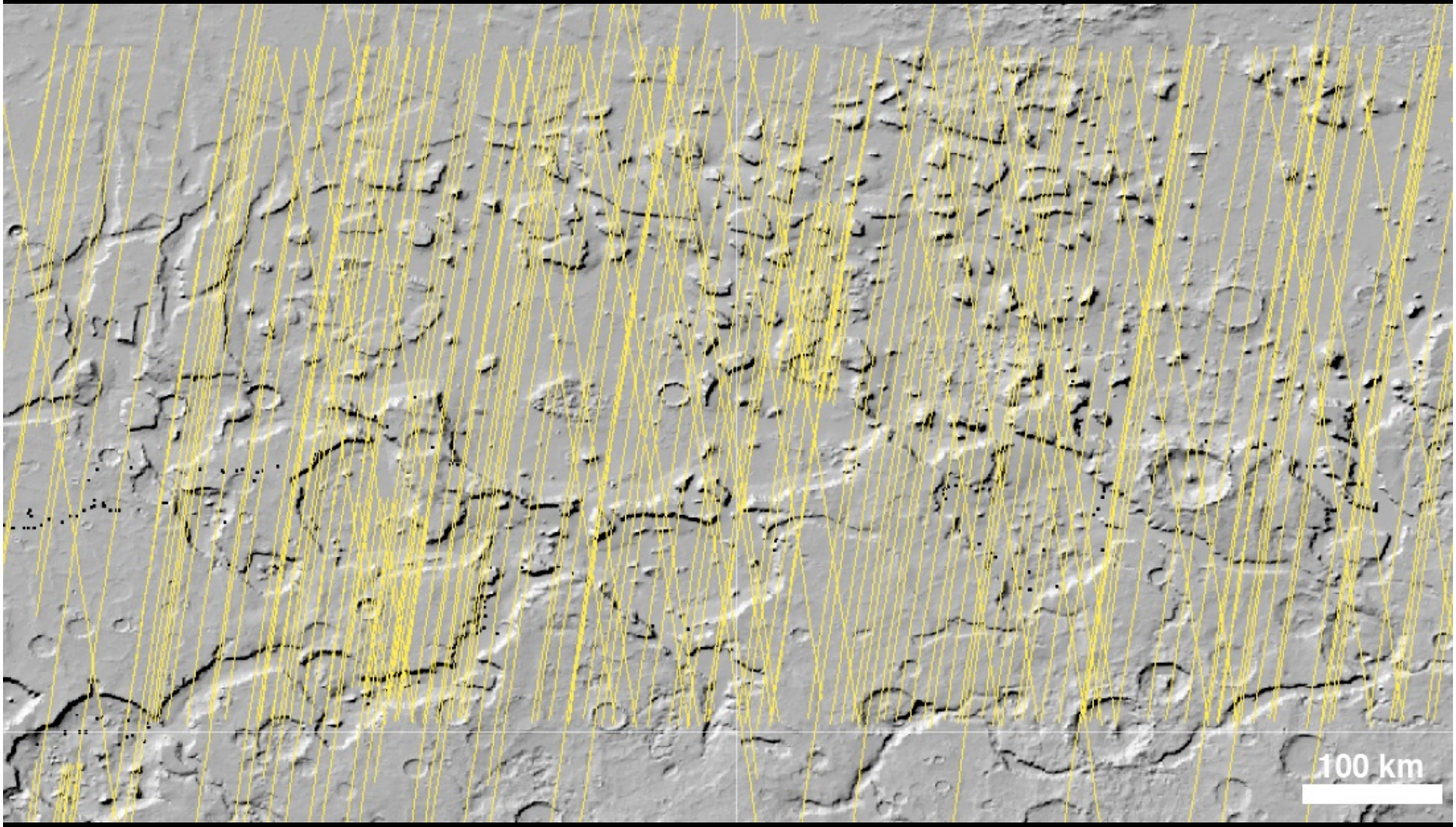
Attenuation of the Subsurface Reflection



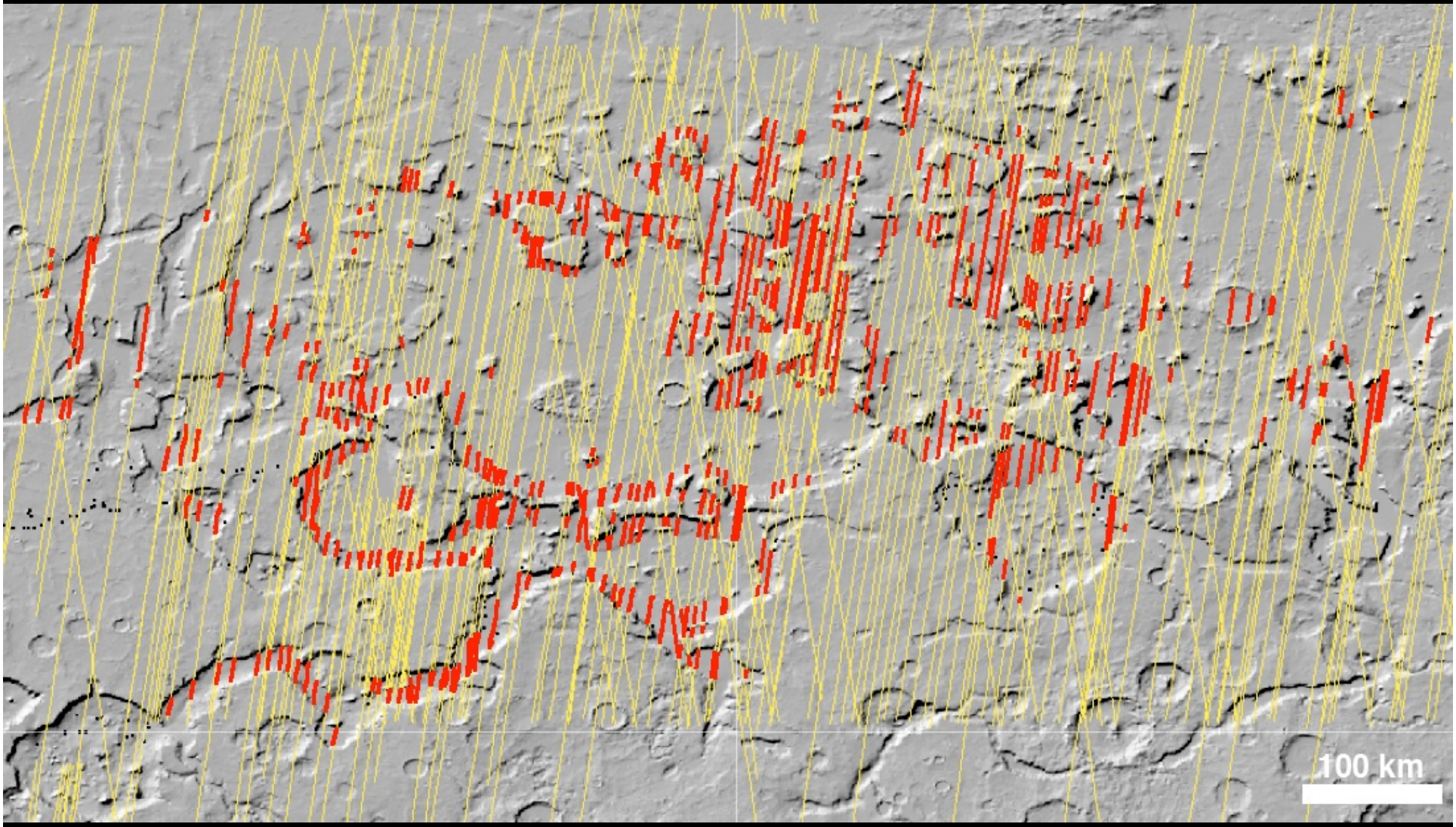
Atten =
~ 7 dB/km

Loss tangent
tanδ = .004

SHARAD Coverage – January 2010

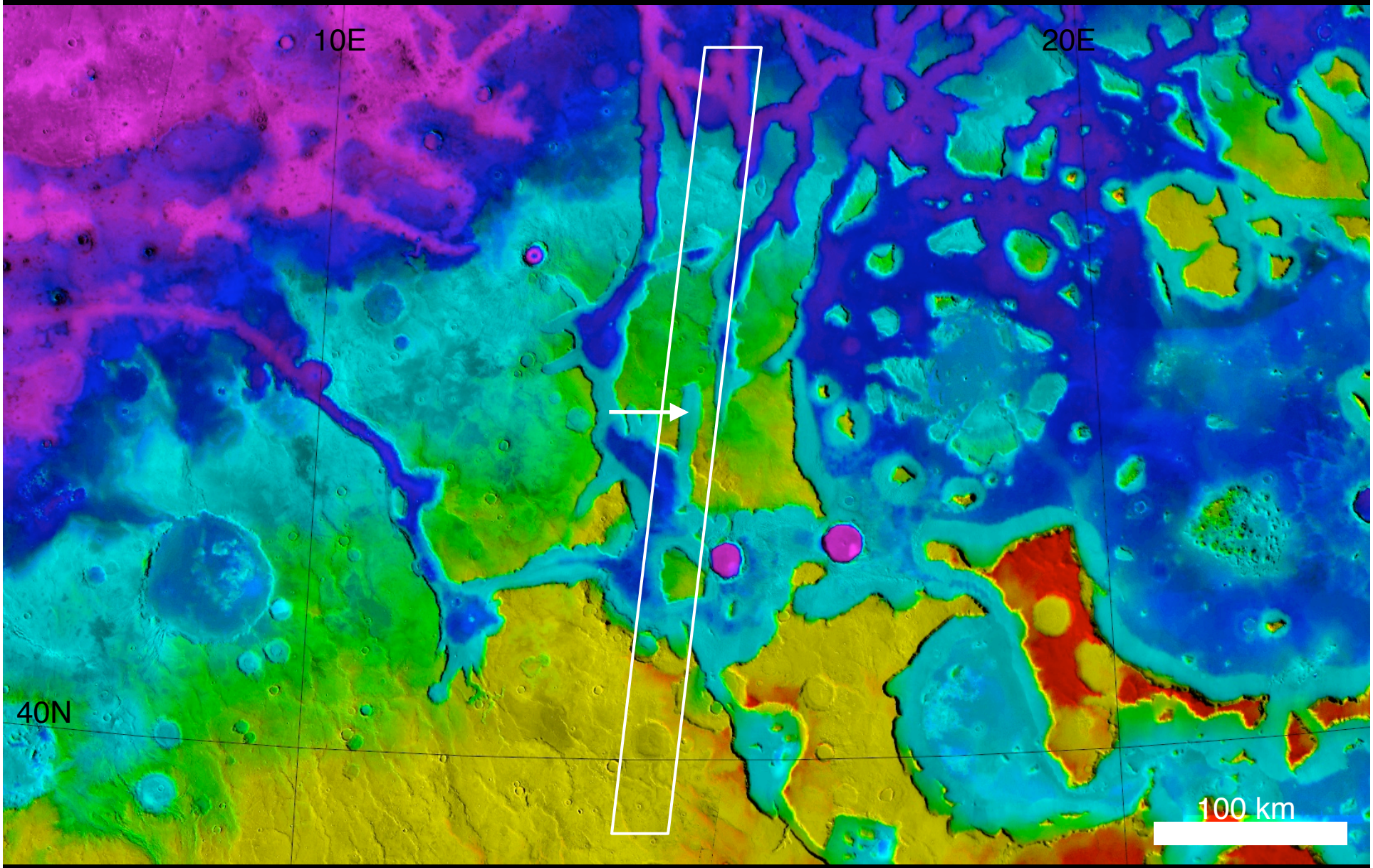


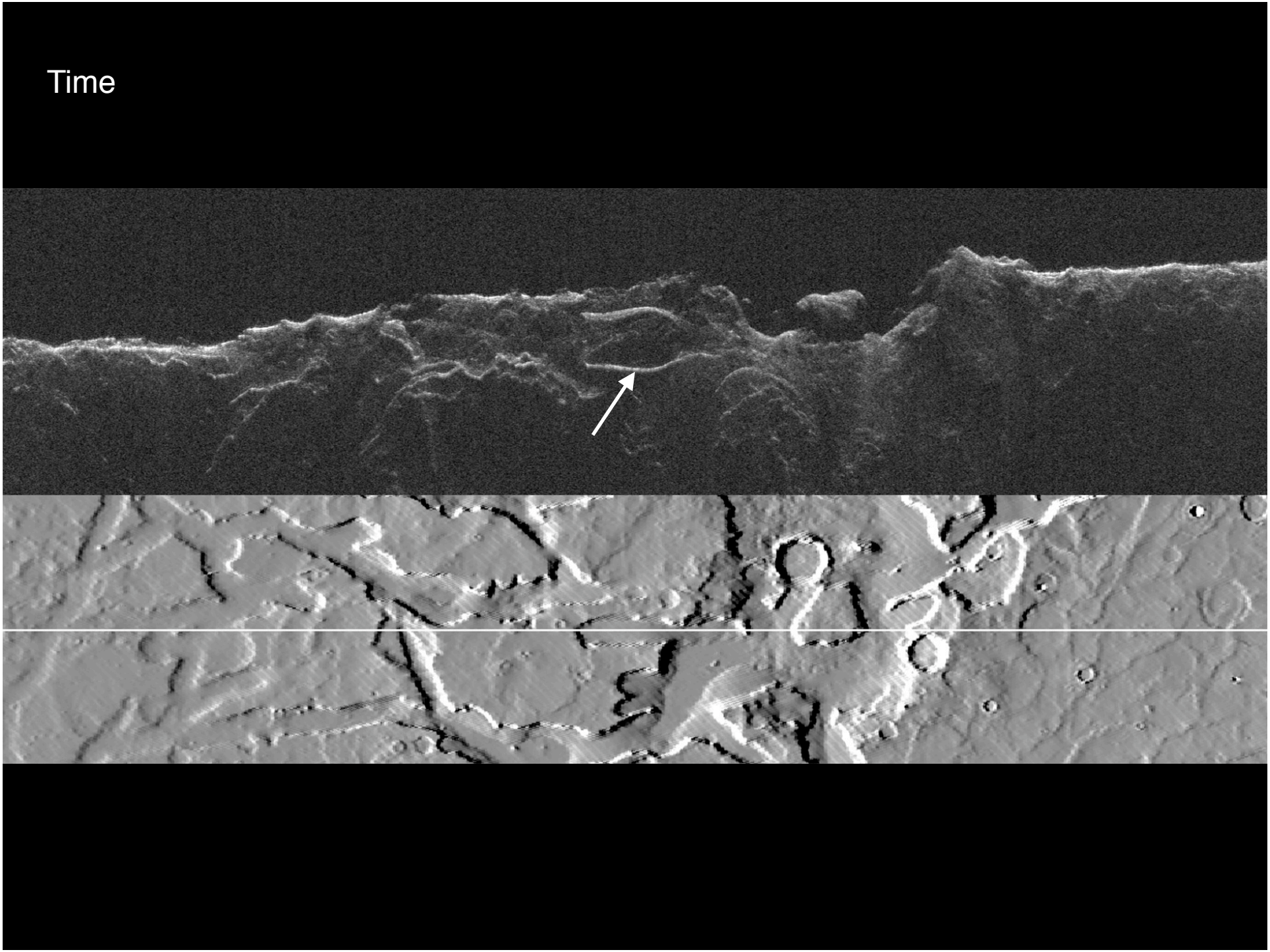
Detected Interfaces



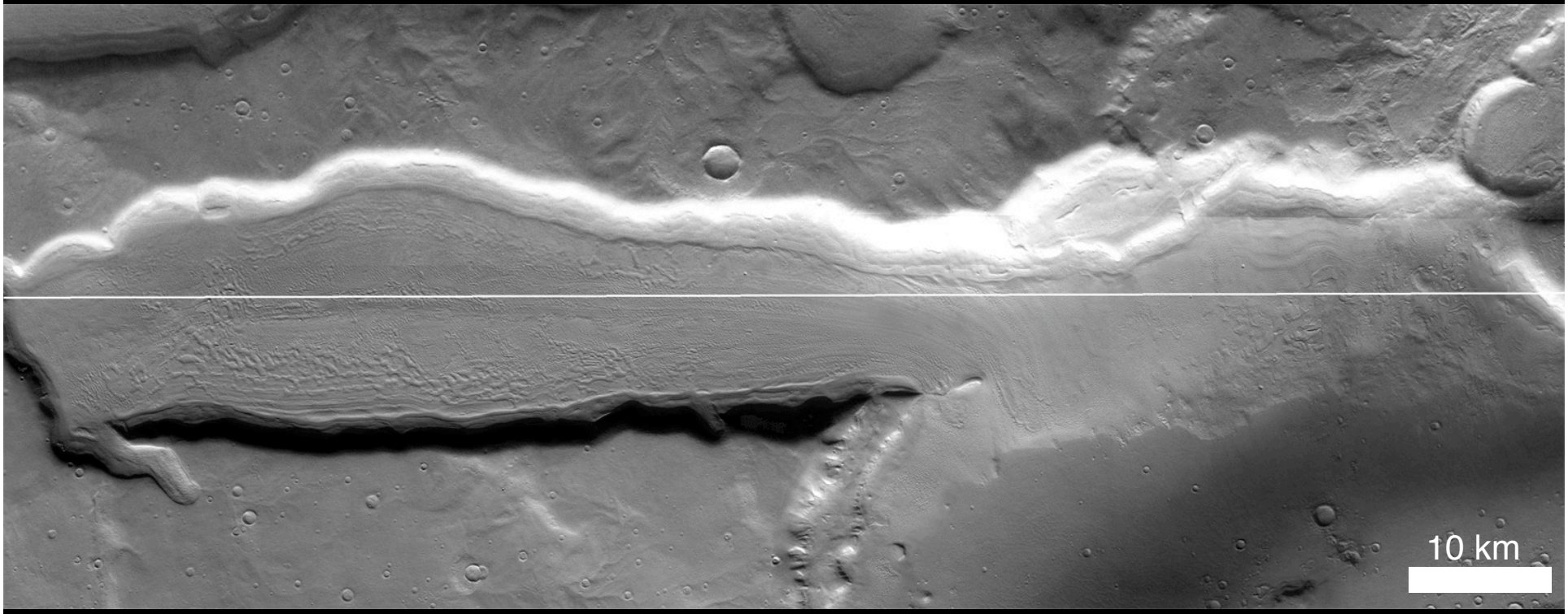
Valley in West Deuteronilus

MOLA Elevation on THEMIS Day IR

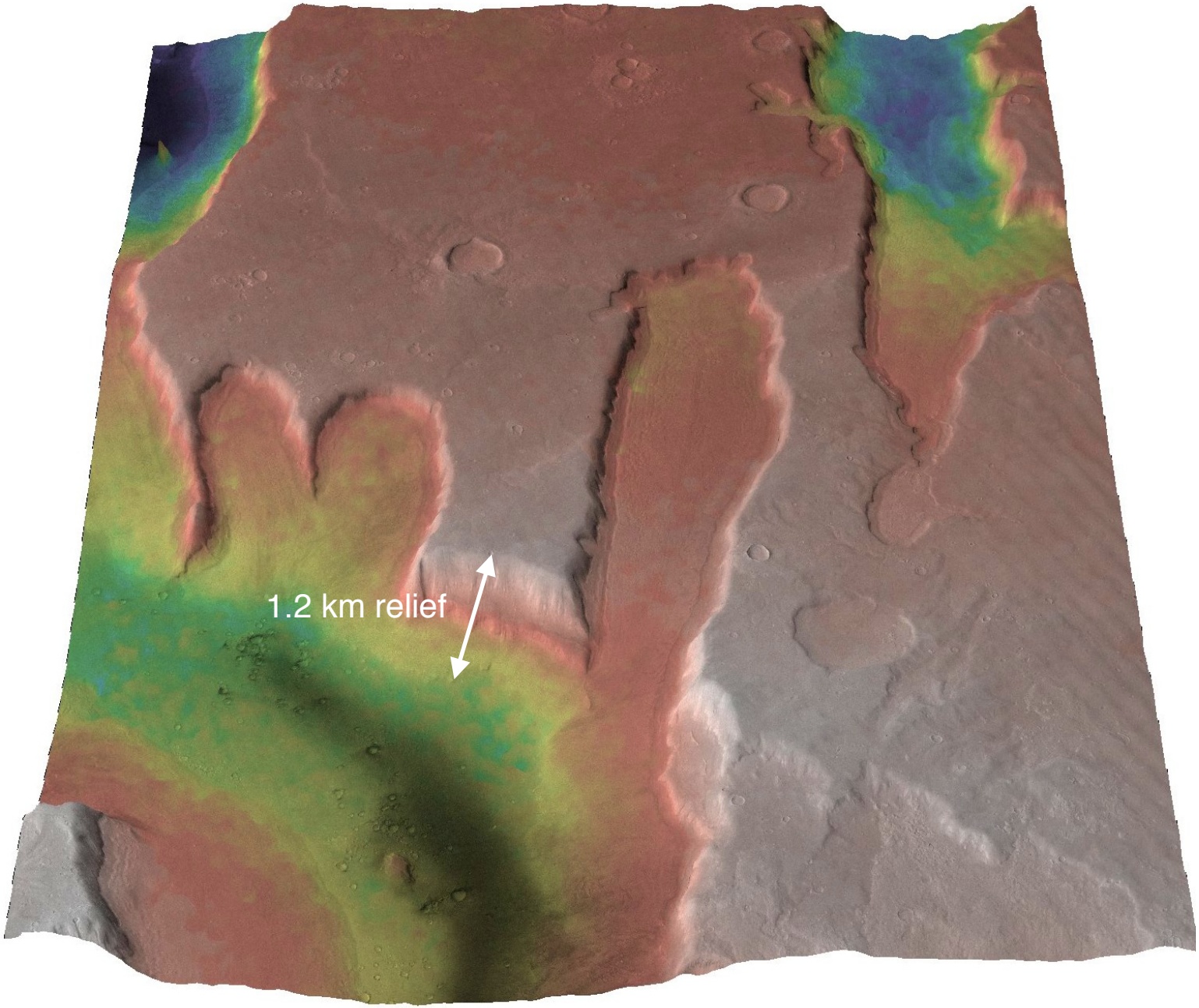


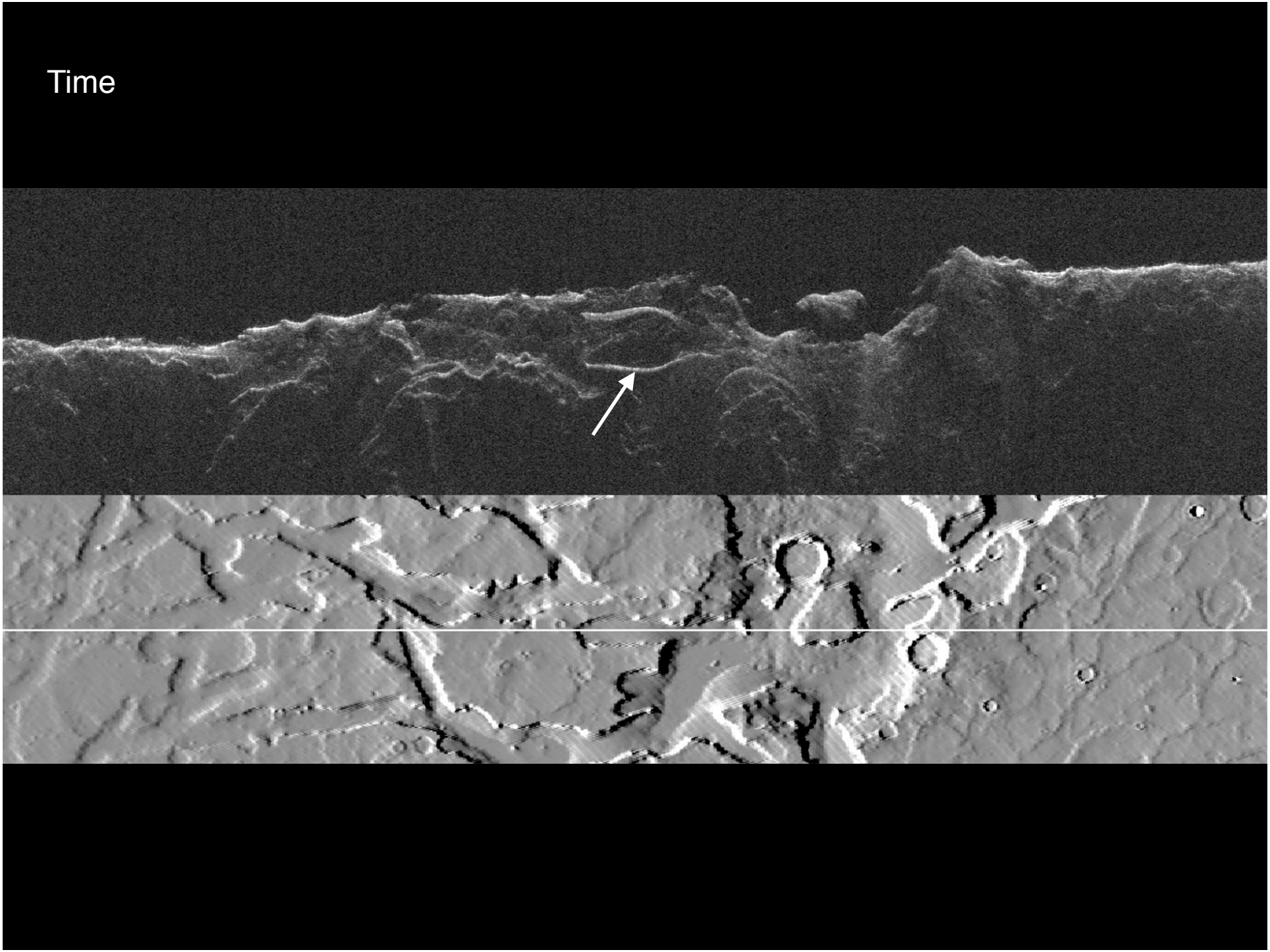

Time

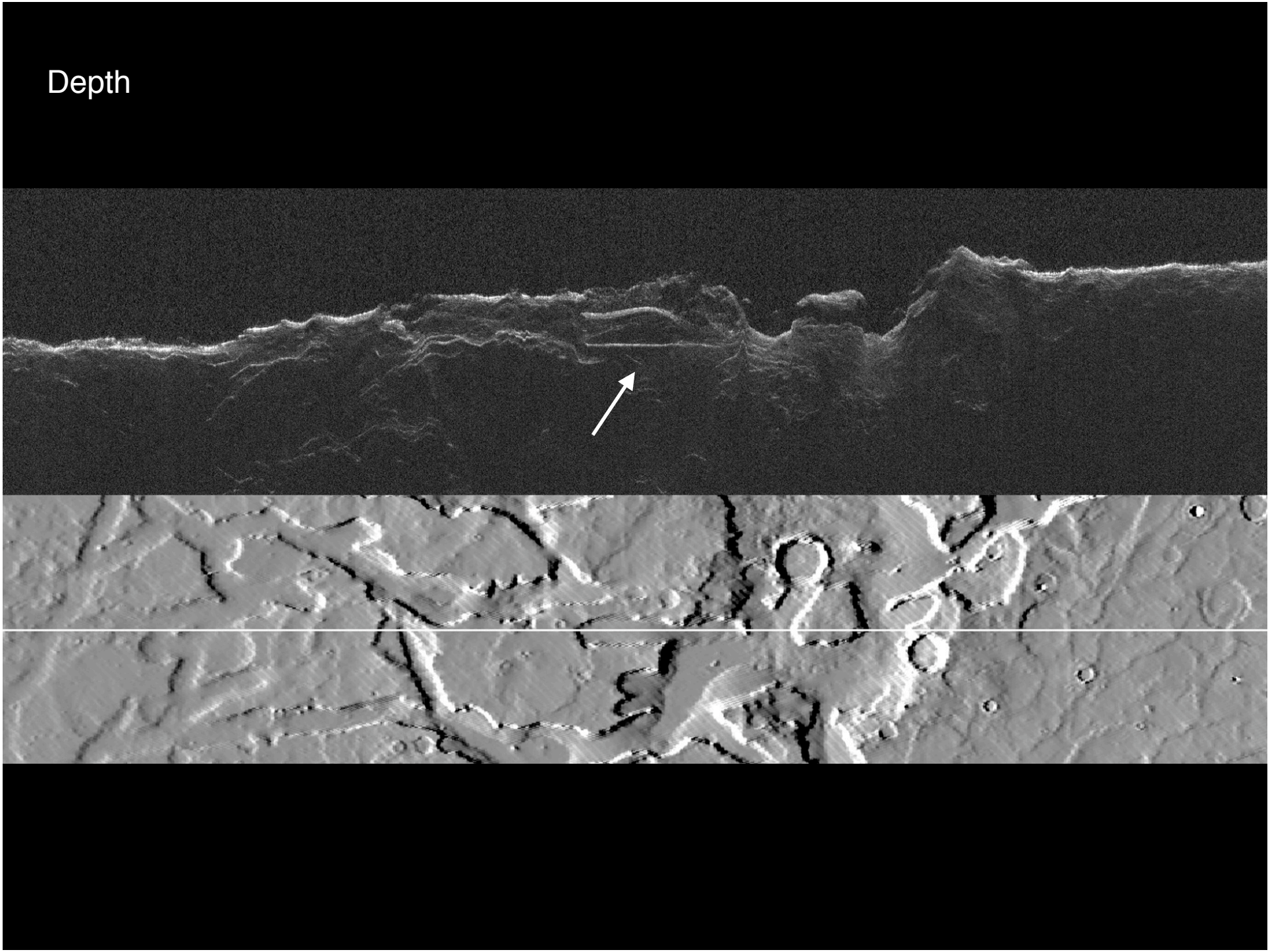
THEMIS VIS

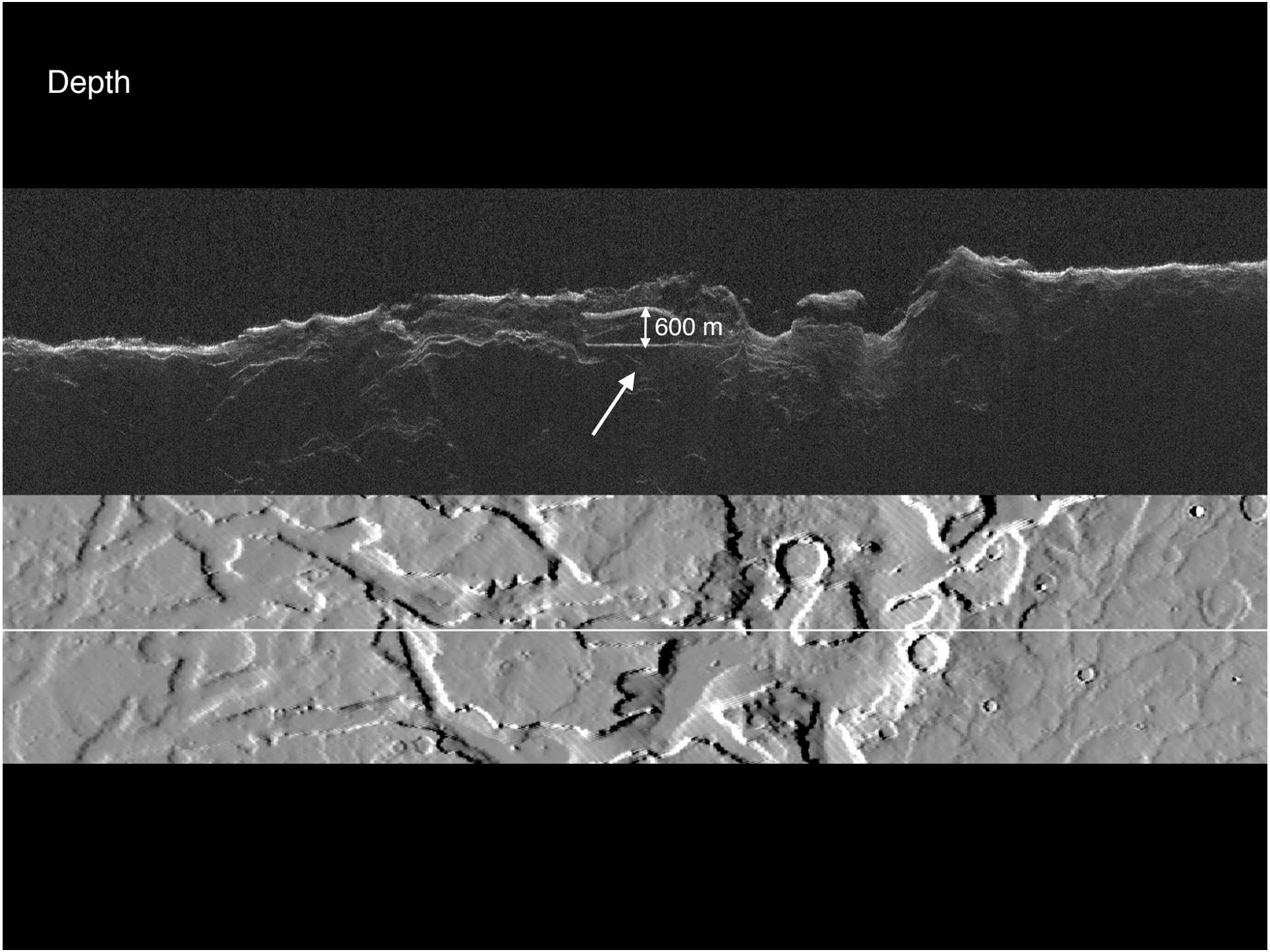


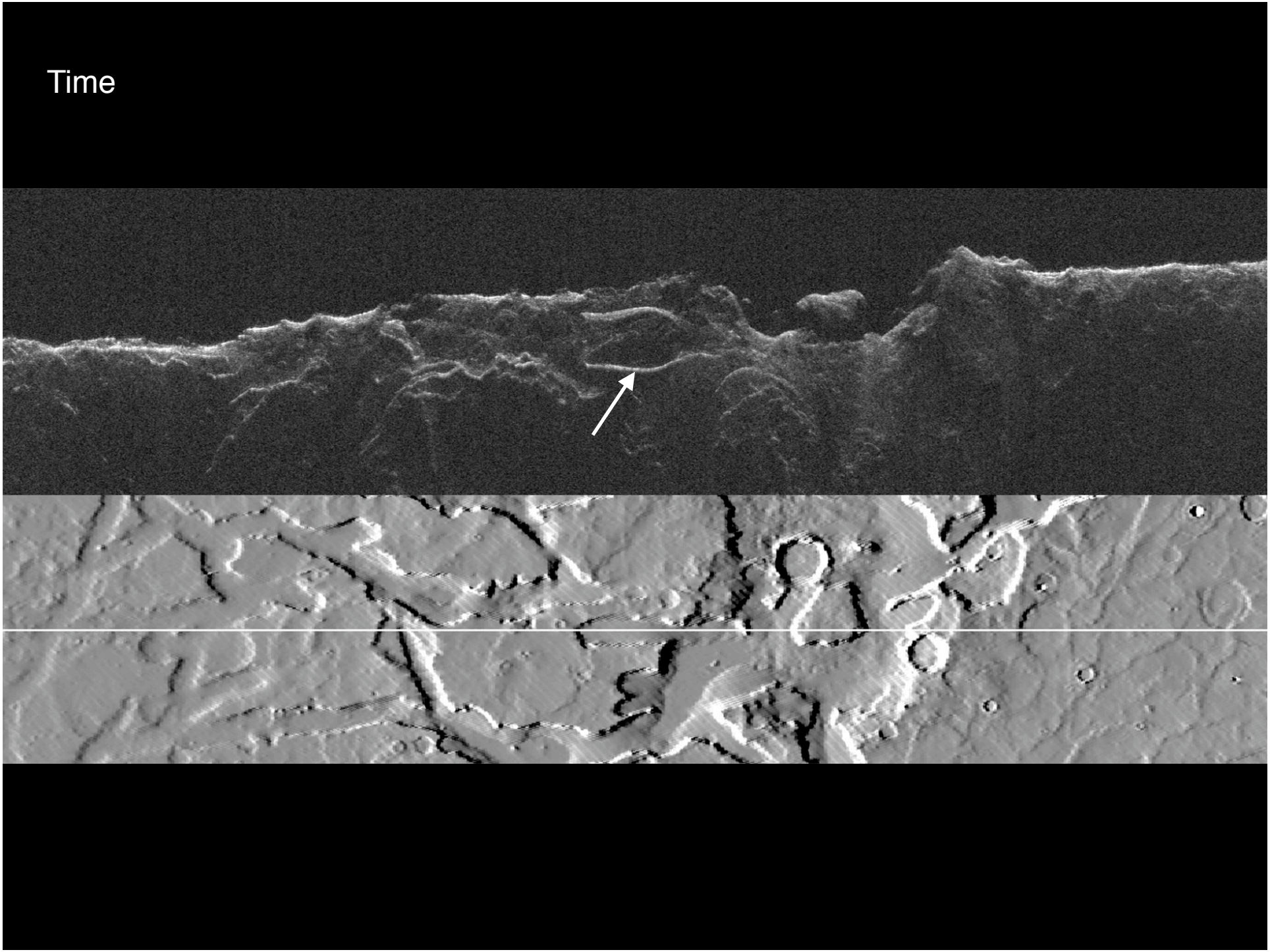
HRSC
Topo

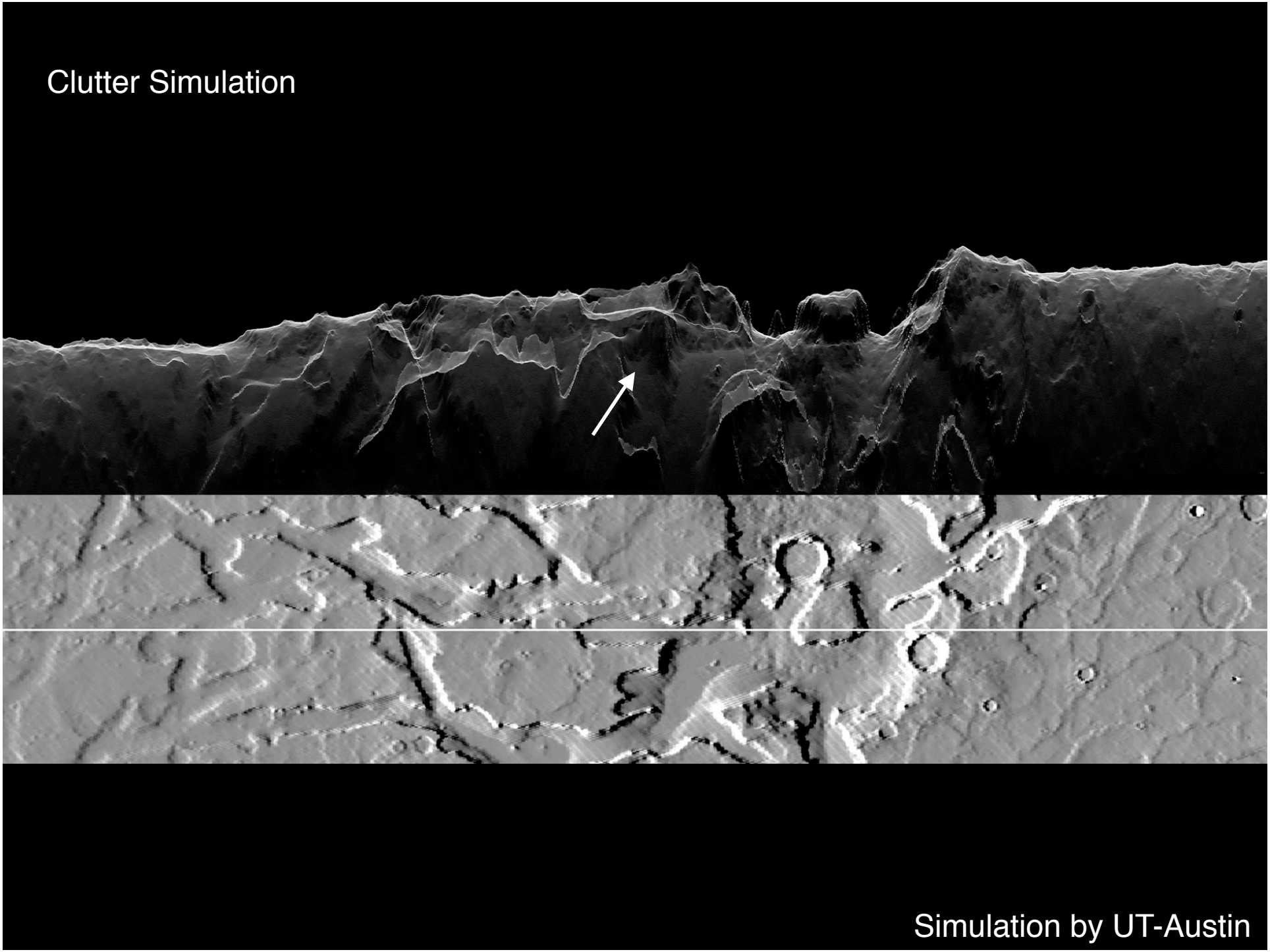


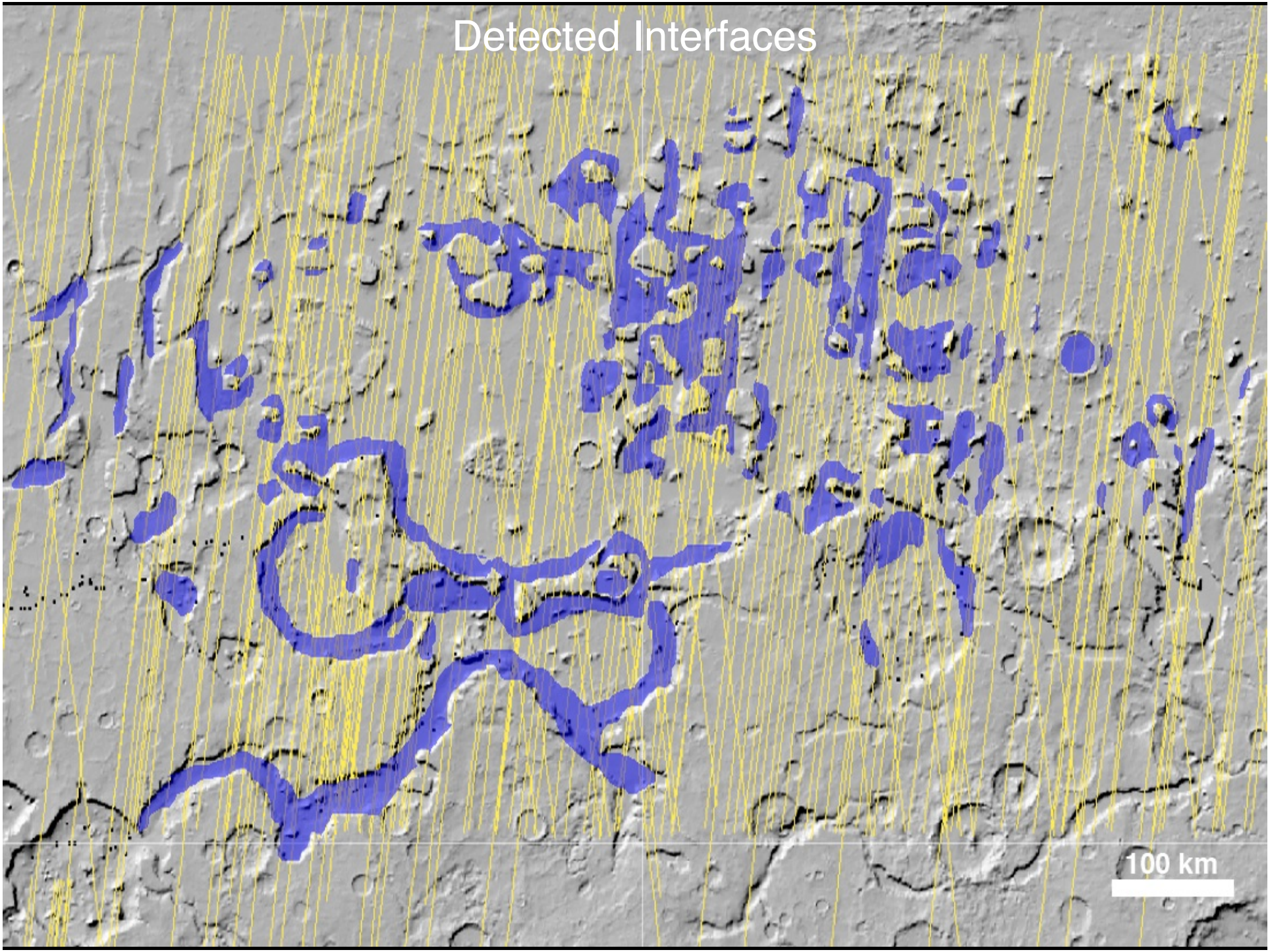

Time


Depth


Depth
600 m

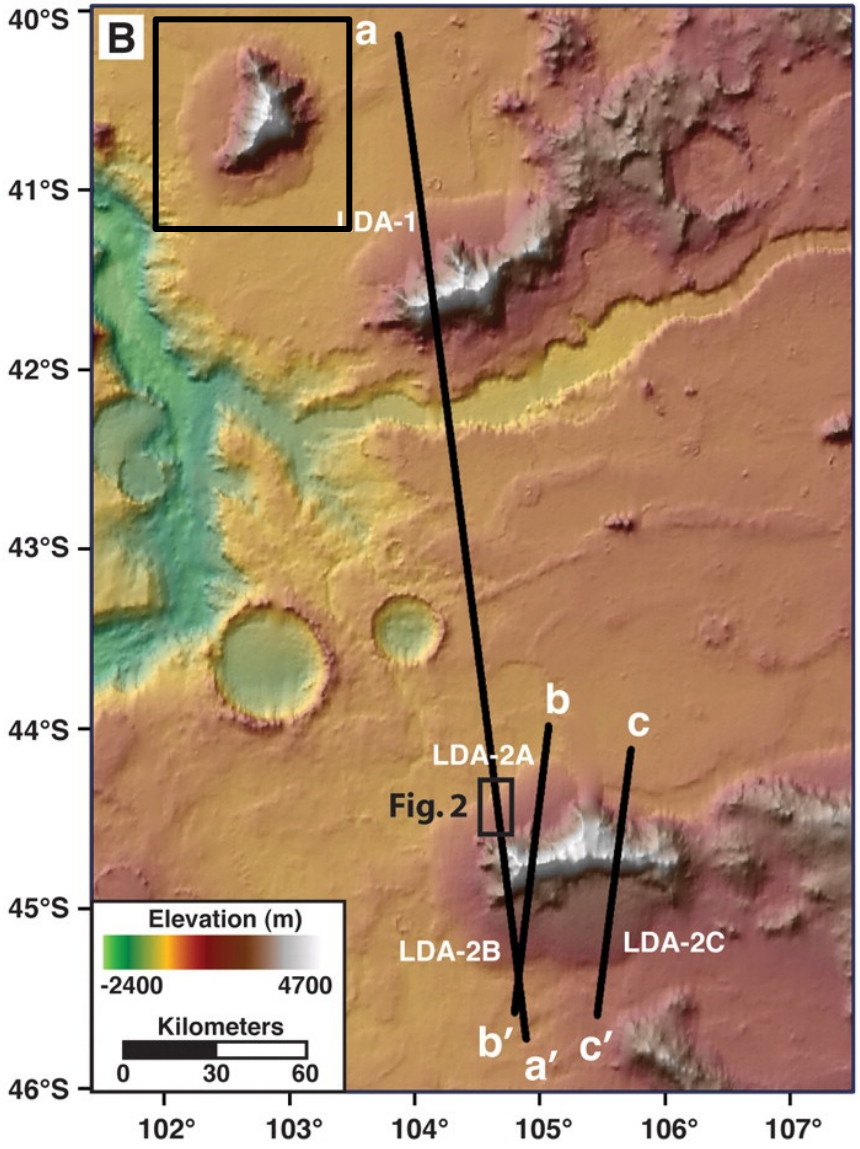

Time


Clutter Simulation
Simulation by UT-Austin

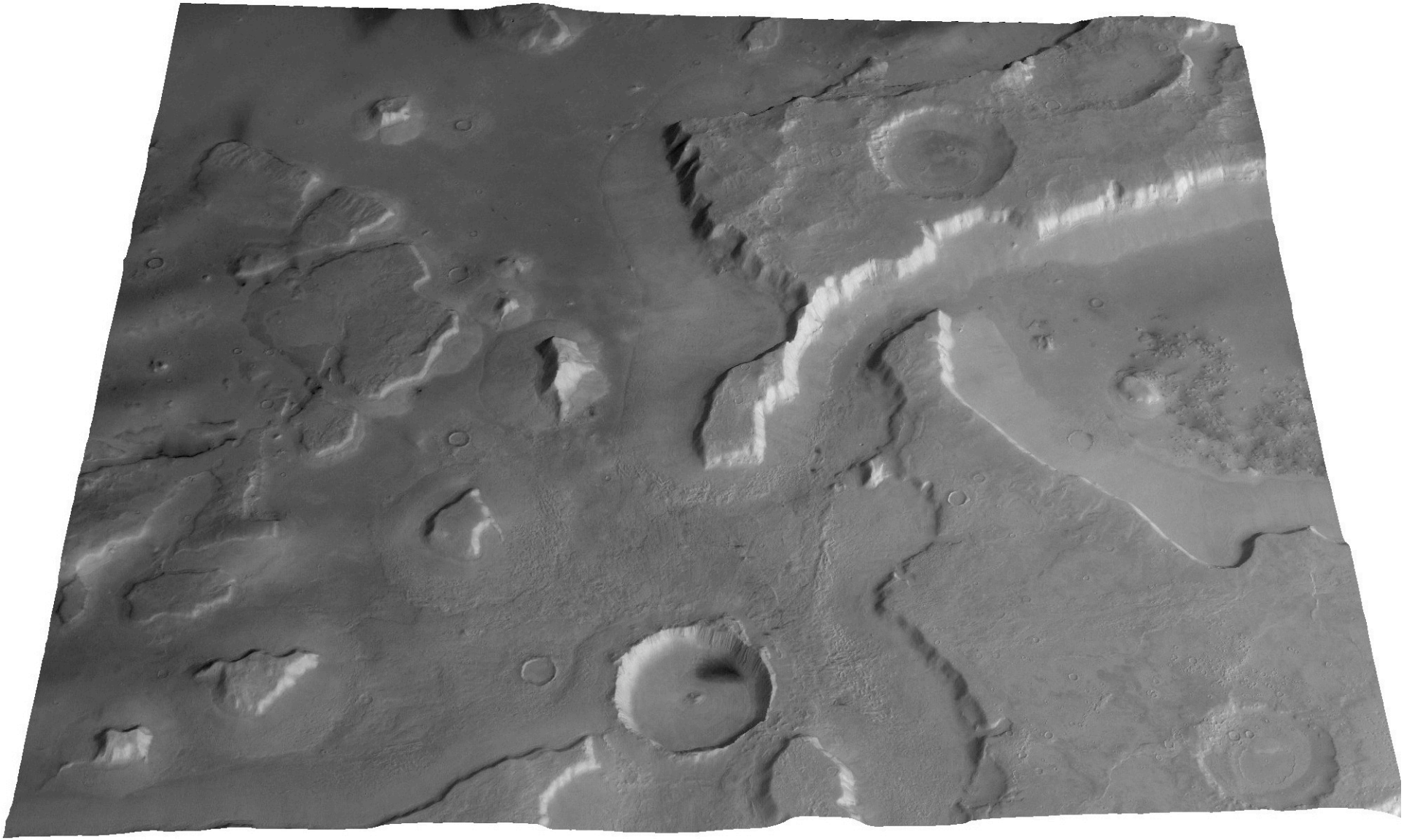

Detected Interfaces
100 km

Radar Sounding Evidence for Buried Glaciers in the Southern Mid-Latitudes of Mars

John W. Holt,[1]* Ali Safaeinili,[2] Jeffrey J. Plaut,[2] James W. Head,[3] Roger J. Phillips,[4] Roberto Seu,[5] Scott D. Kempf,[1] Prateek Choudhary,[1] Duncan A. Young,[1] Nathaniel E. Putzig,[4] Daniela Biccari,[5] Yonggyu Gim[2]

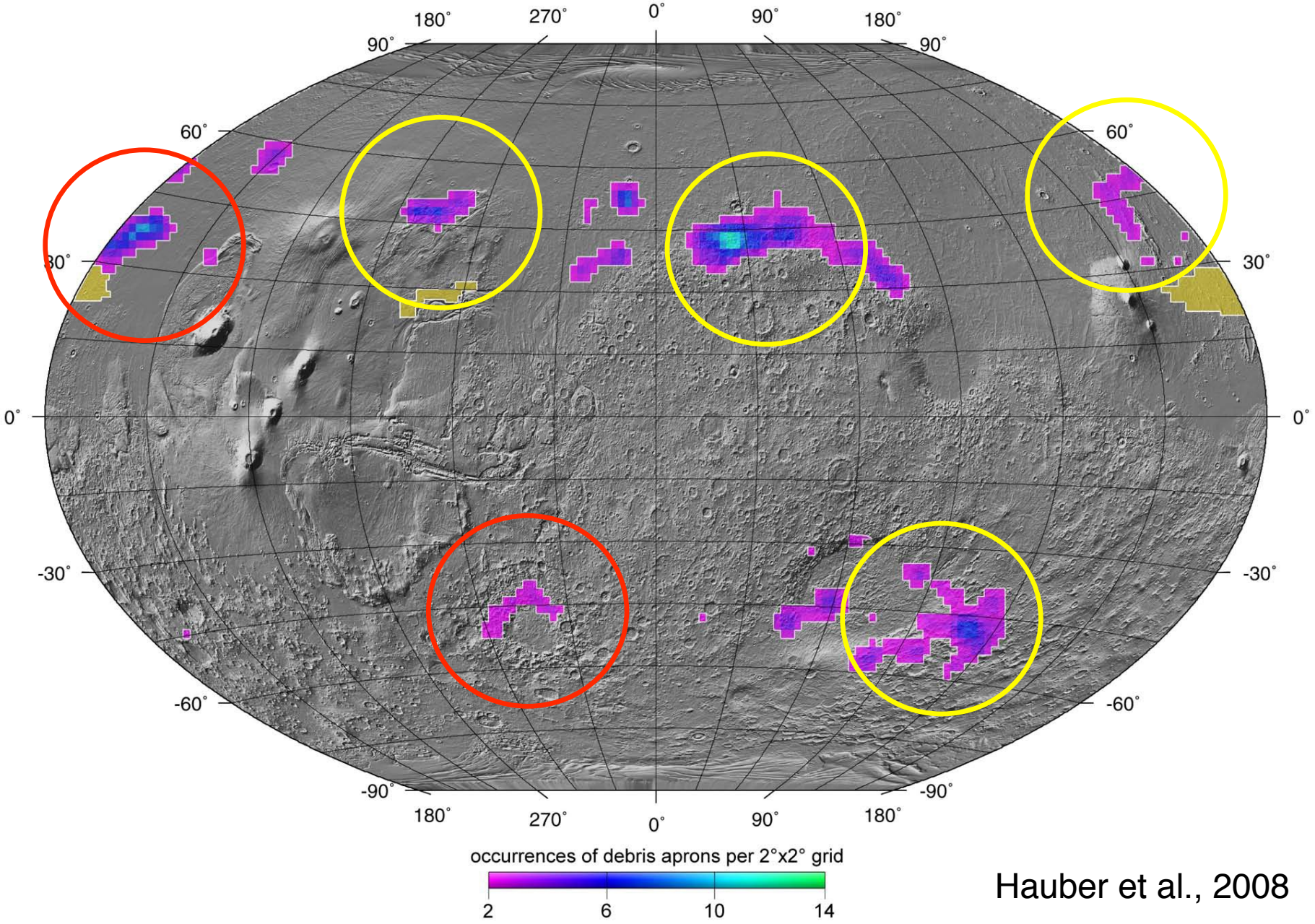


Science
AAAS
Published by AAAS



HRSC perspective

LDA Distribution and SHARAD Detections

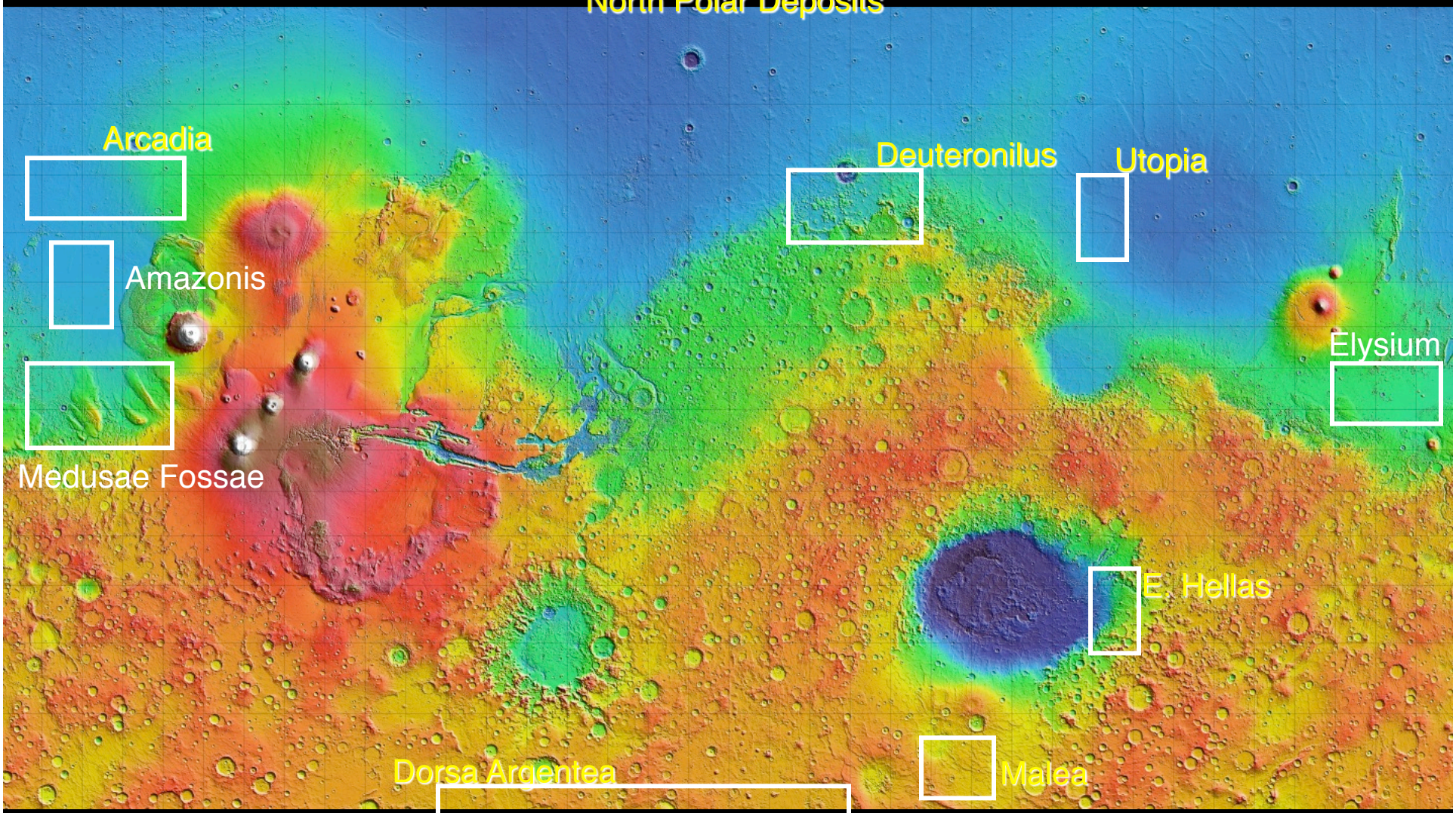


Hauber et al., 2008

Summary – Lobate Aprons

- SHARAD signals penetrate lobate debris aprons to ~1 km depth.
- Time-to-depth conversion using an ice dielectric (~3) brings reflectors in line with surrounding valley floors.
- Low attenuation of signals is consistent with predominantly ice composition: probably > 80% ice, could be more.
- Radar evidence is consistent with the vast body of evidence for ice-rich lobate debris aprons.
- Implications: In the mid-latitudes of Mars,
  - Large volumes of ice were deforming during Amazonian time;
  - Much of this ice is preserved today;
  - These are intriguing targets for *in situ* exploration.

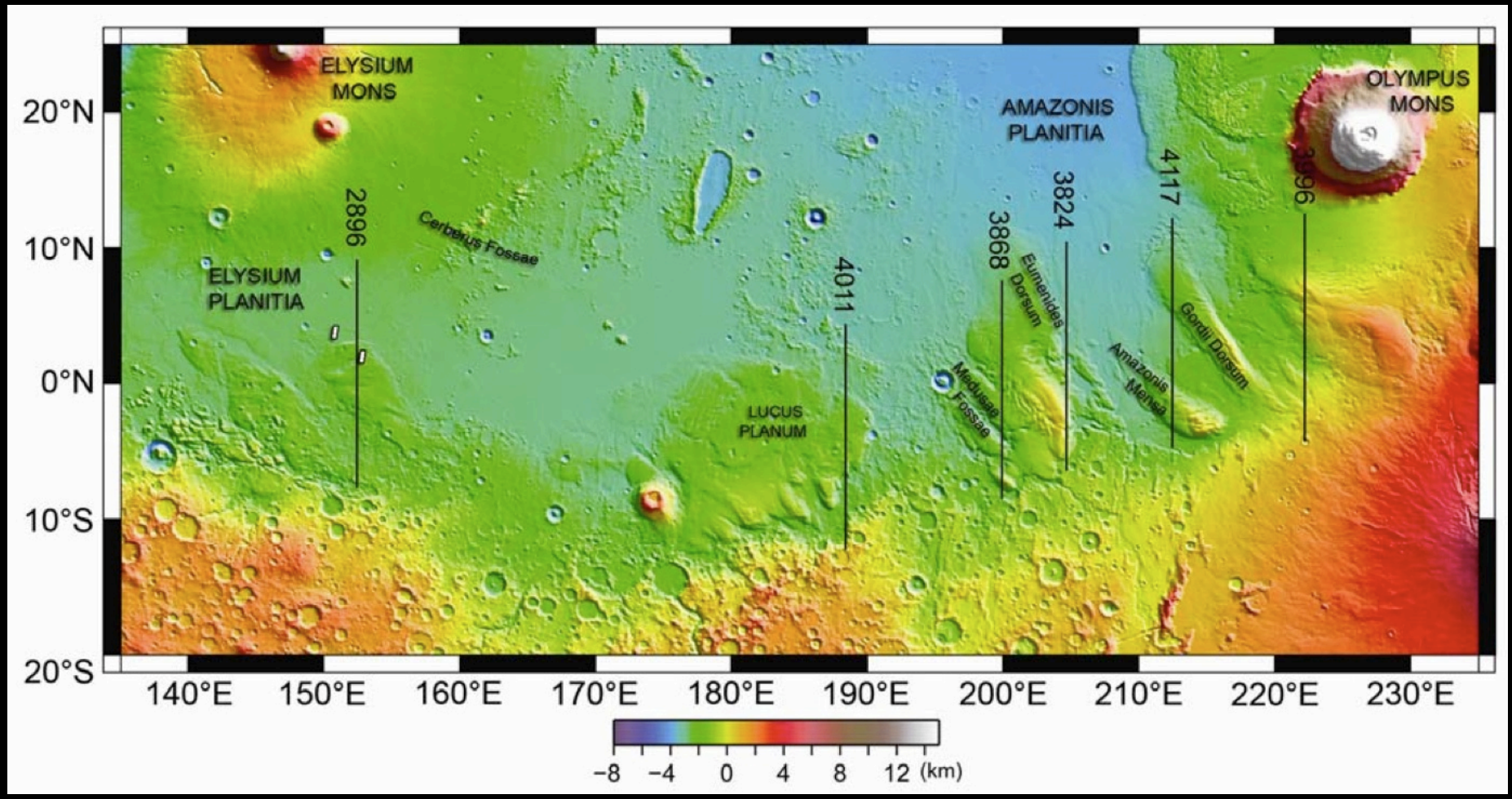
MARSIS and SHARAD Subsurface Detections



Mars Global H_2O Inventory

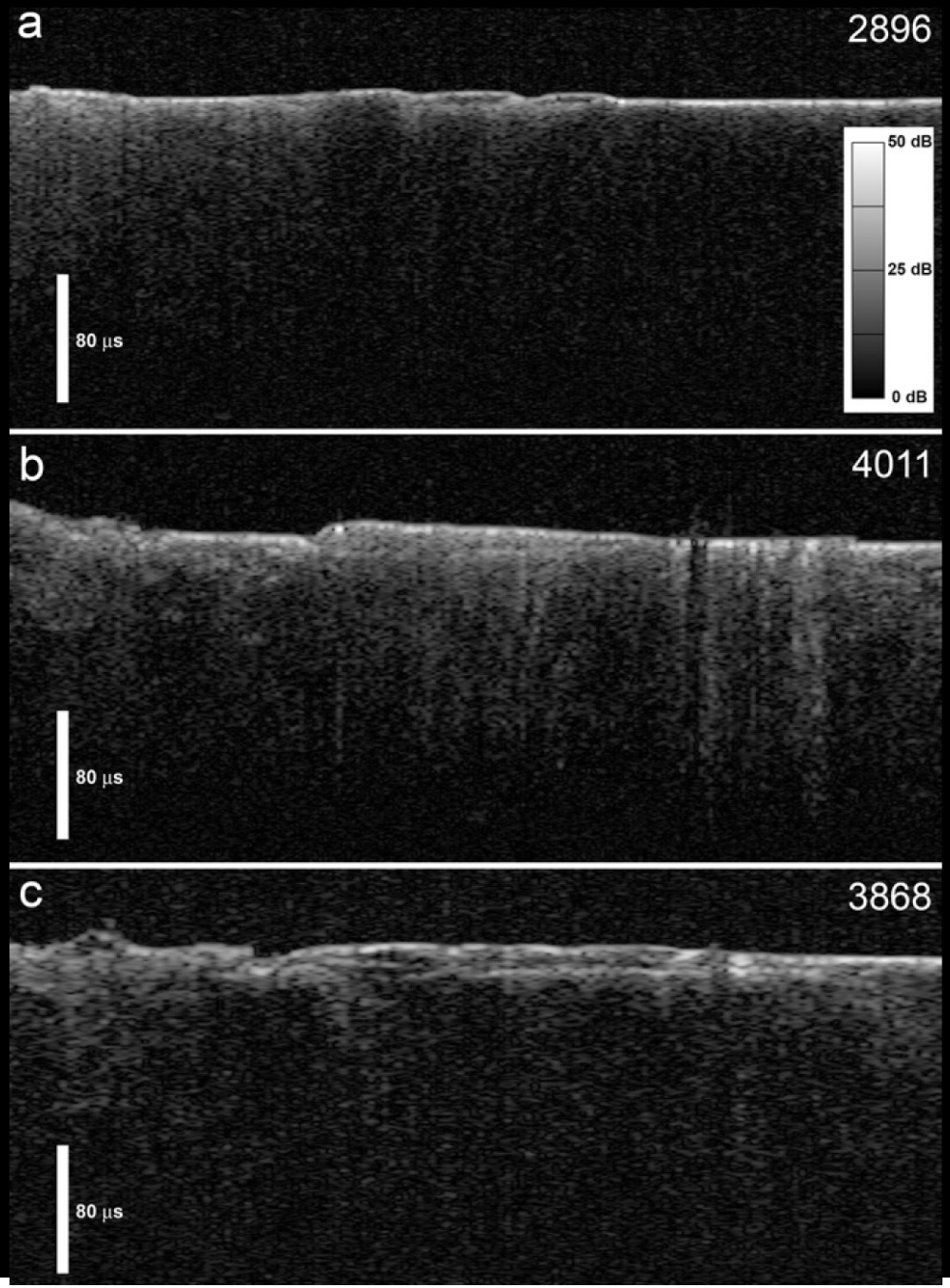
Reservoir	Global Layer Thickness
Atmosphere	< 50 microns
Ground Ice (Neutron and Gamma Rays)	> 14 cm
Polar Layered Deposits	20-25 m (MARSIS and SHARAD)
Circum-polar units	< 10 m (MARSIS)
Lobate Debris Aprons Lineated Valley Fill	~ 10-100s cm (SHARAD)

Subsurface Sounding of Medusae Fossae Formation



Watters et al., 2007

Subsurface Sounding of Medusae Fossae Formation



Watters et al., 2007

Subsurface Sounding of Medusae Fossae Formation