Hot Science Cool Talks

UT Environmental Science Institute

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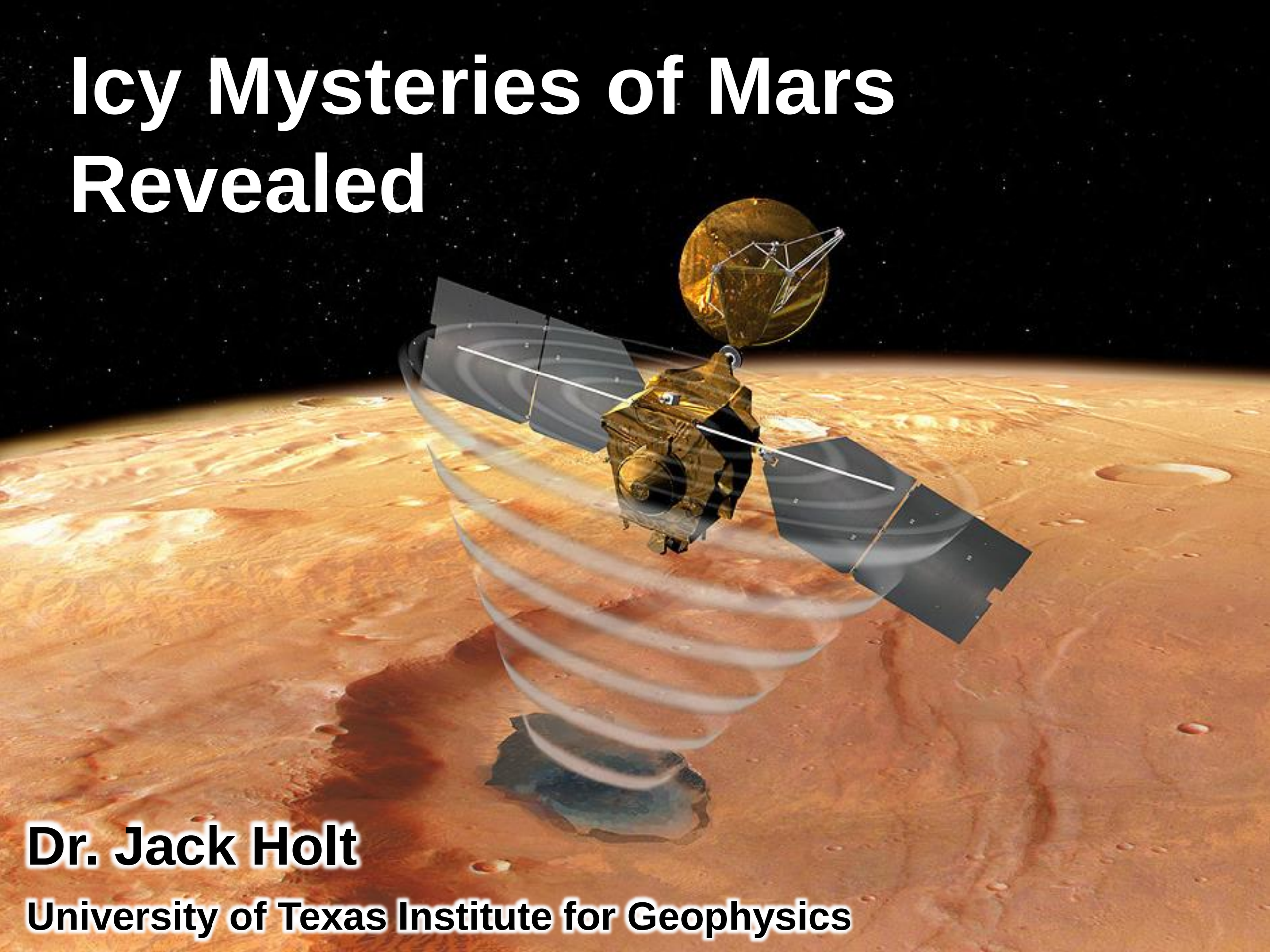
Icy Mysteries of Mars Revealed

Dr. Jack Holt

September 11, 2009

Icy Mysteries of Mars Revealed

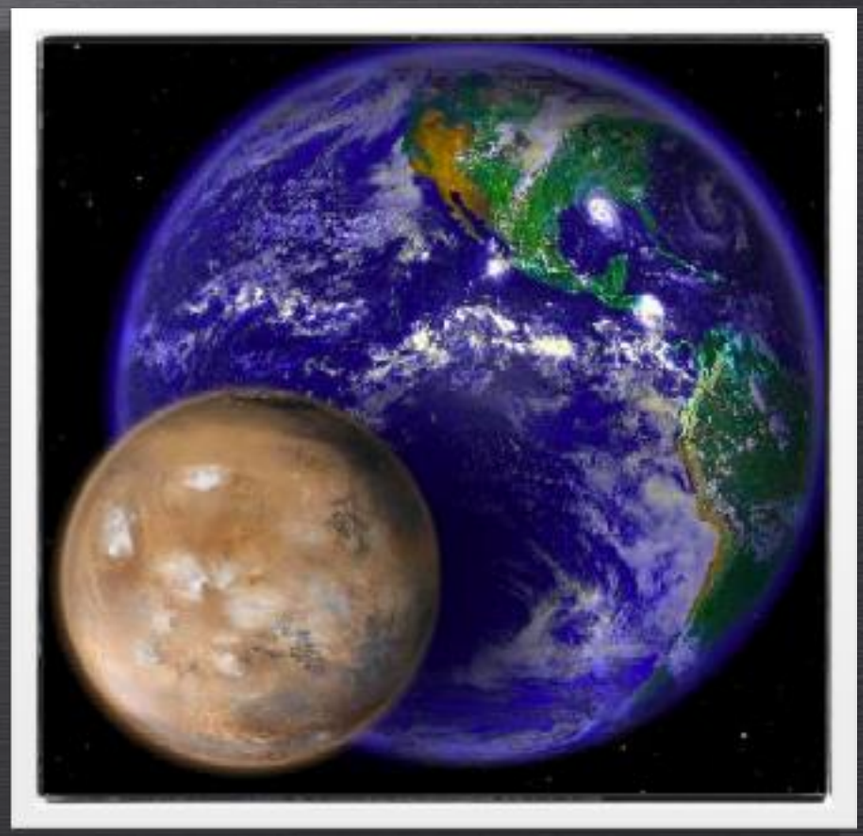


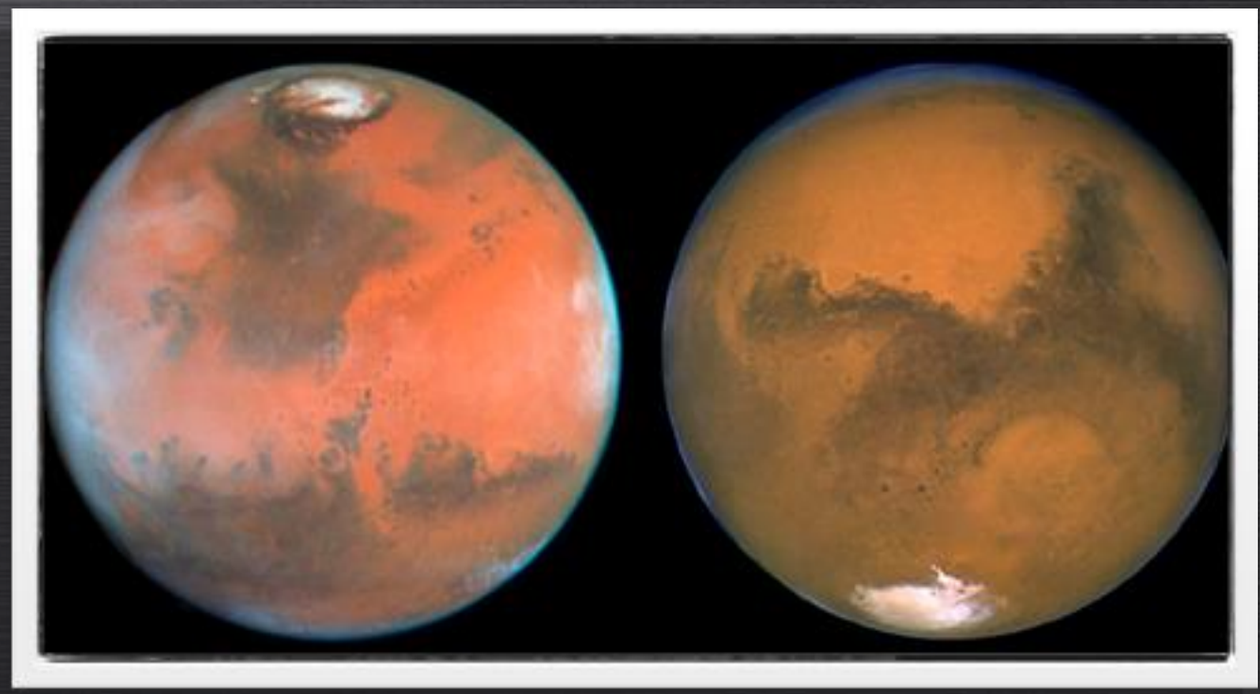
Dr. Jack Holt

University of Texas Institute for Geophysics

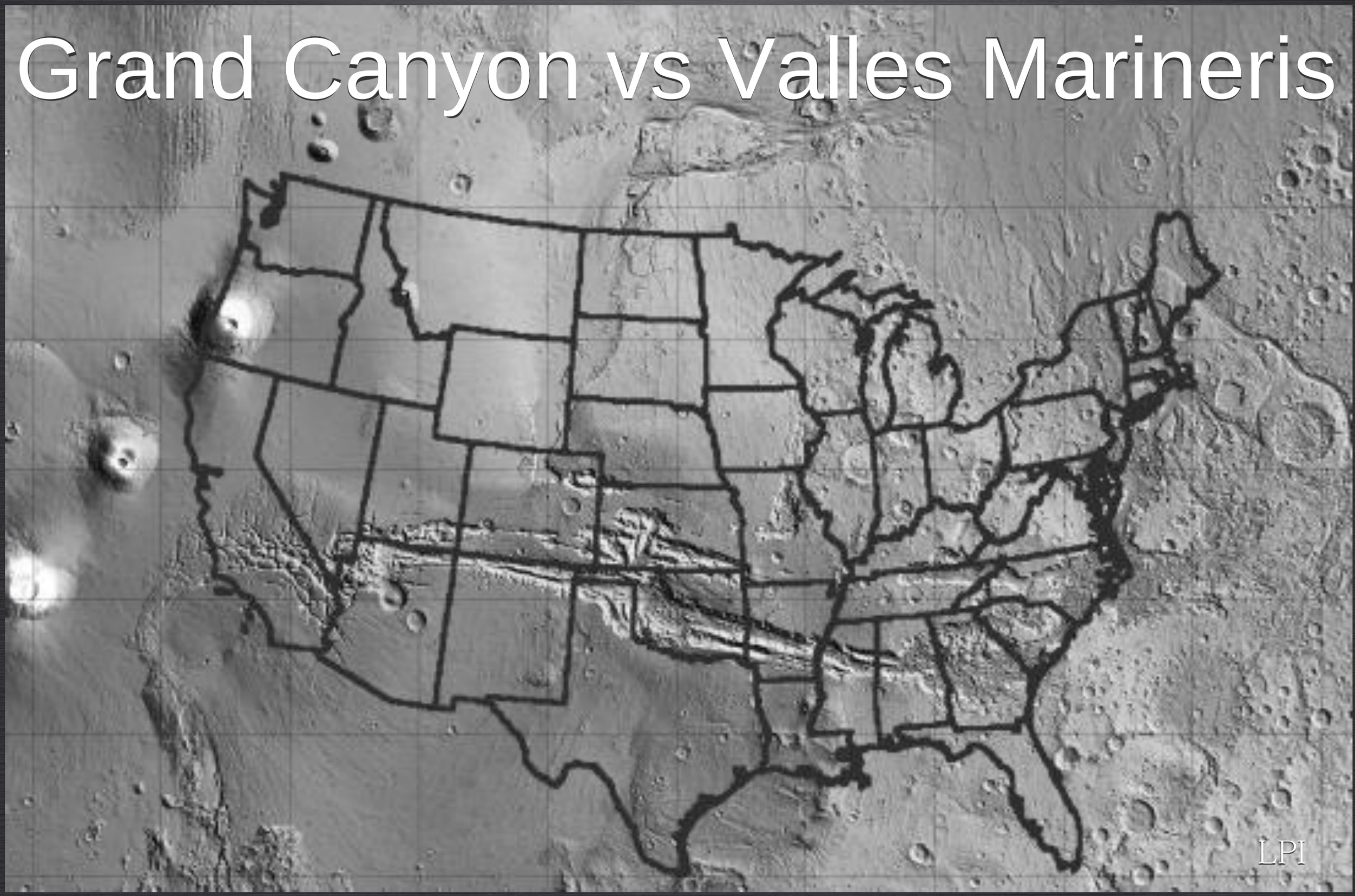
Mars: Earth's Little Sibling

- **About half the diameter of Earth**
- **Density = 0.71 x Earth**
- **Contains largest volcano, deepest/largest canyon in the solar system**
- **Favorite color: red**
- **Atmosphere**
  - **7-10 millibars (~1% of Earth)**
  - **95% CO_2 (Earth is 0.004% CO_2)**





Grand Canyon vs Valles Marineris



Why Ice?

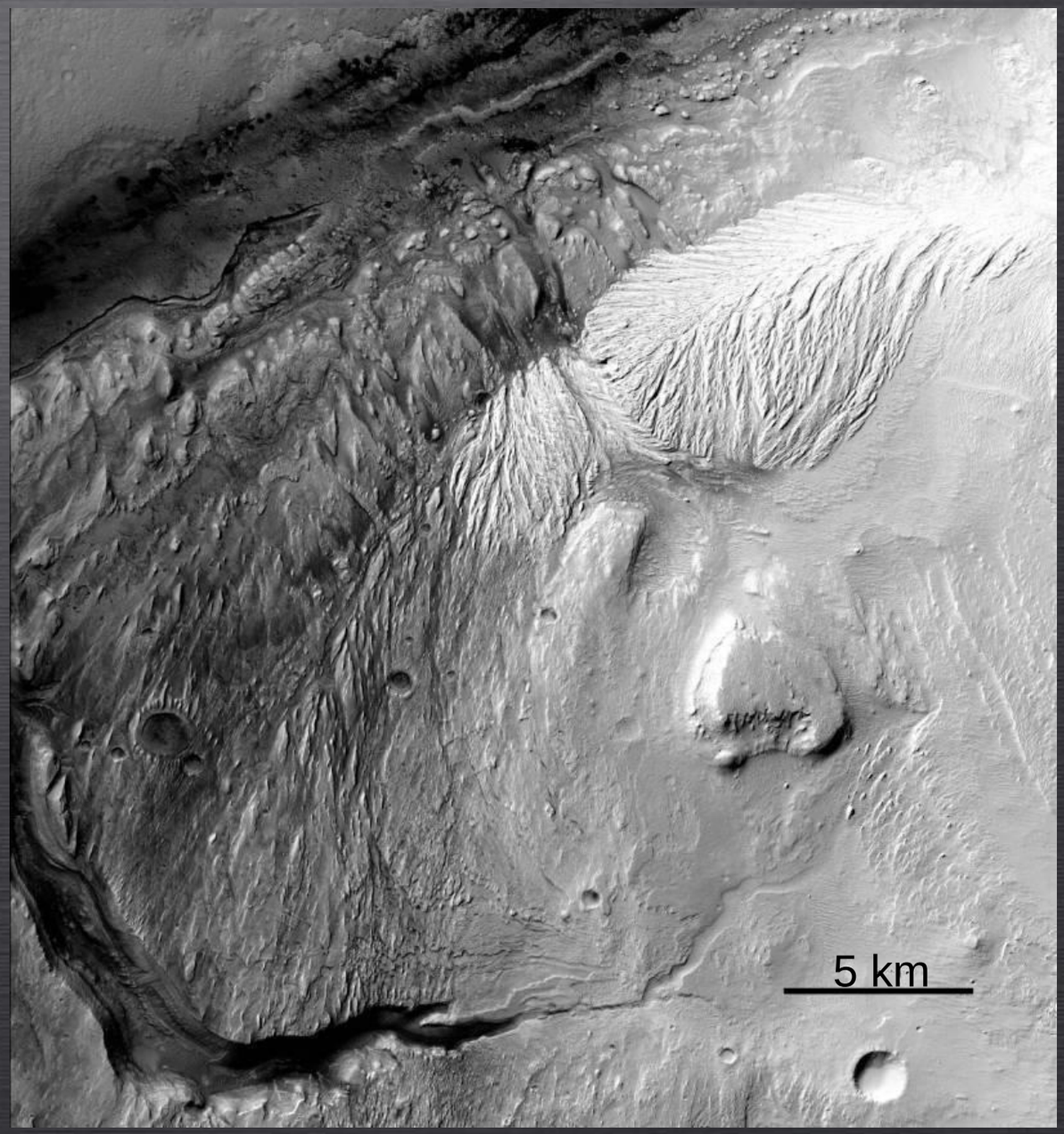
- **Ice = Water**
- **Water = Life?**
  - Possible habitats
- **Life on Mars = Very important**
- **And so COOL!!**

Water on Mars

(old water vs new water)

Old water

- 4.5 to 3.5 billion years ago
- Liquid
  - *River Channels*
  - *Deltas*
  - *Ocean?*



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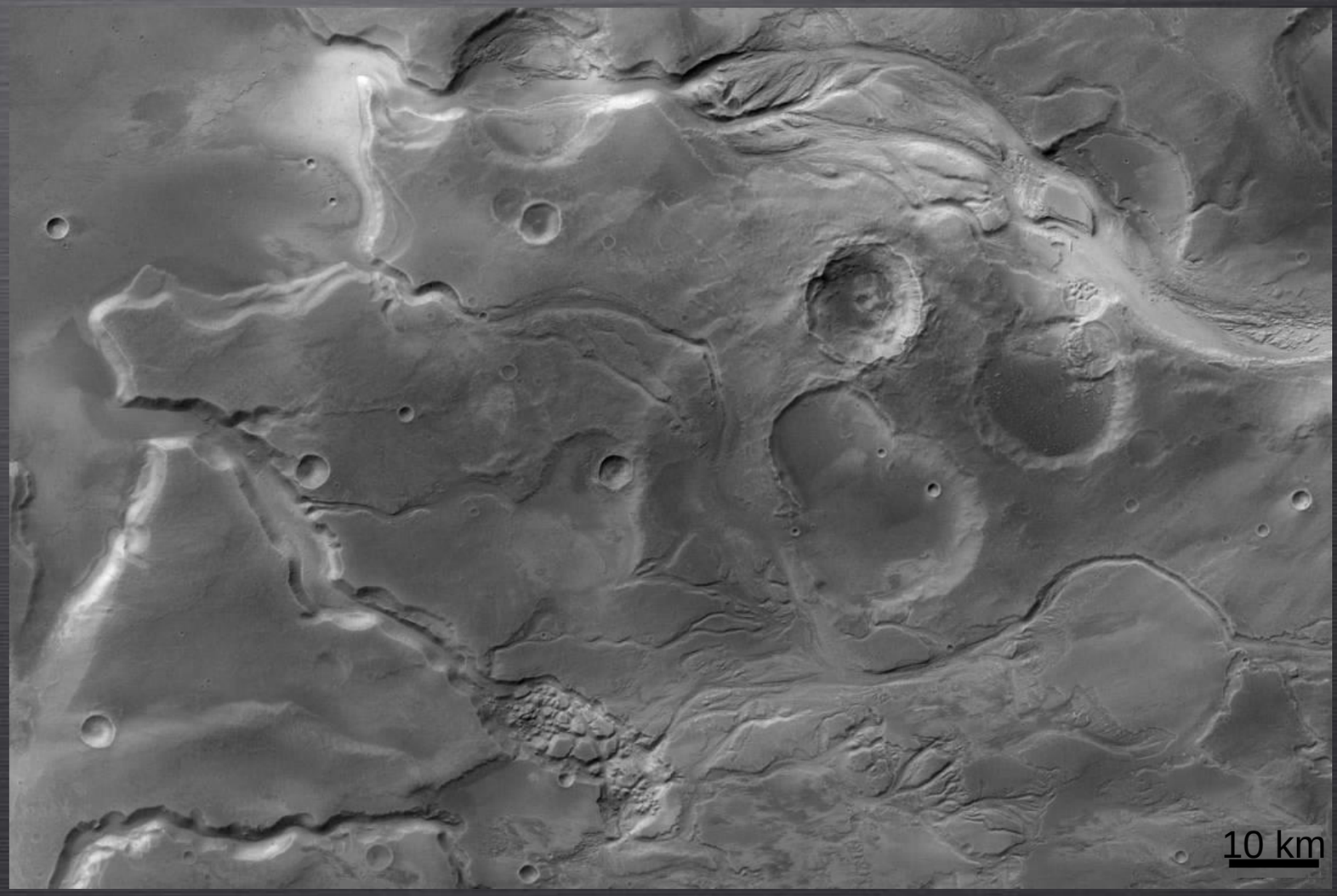

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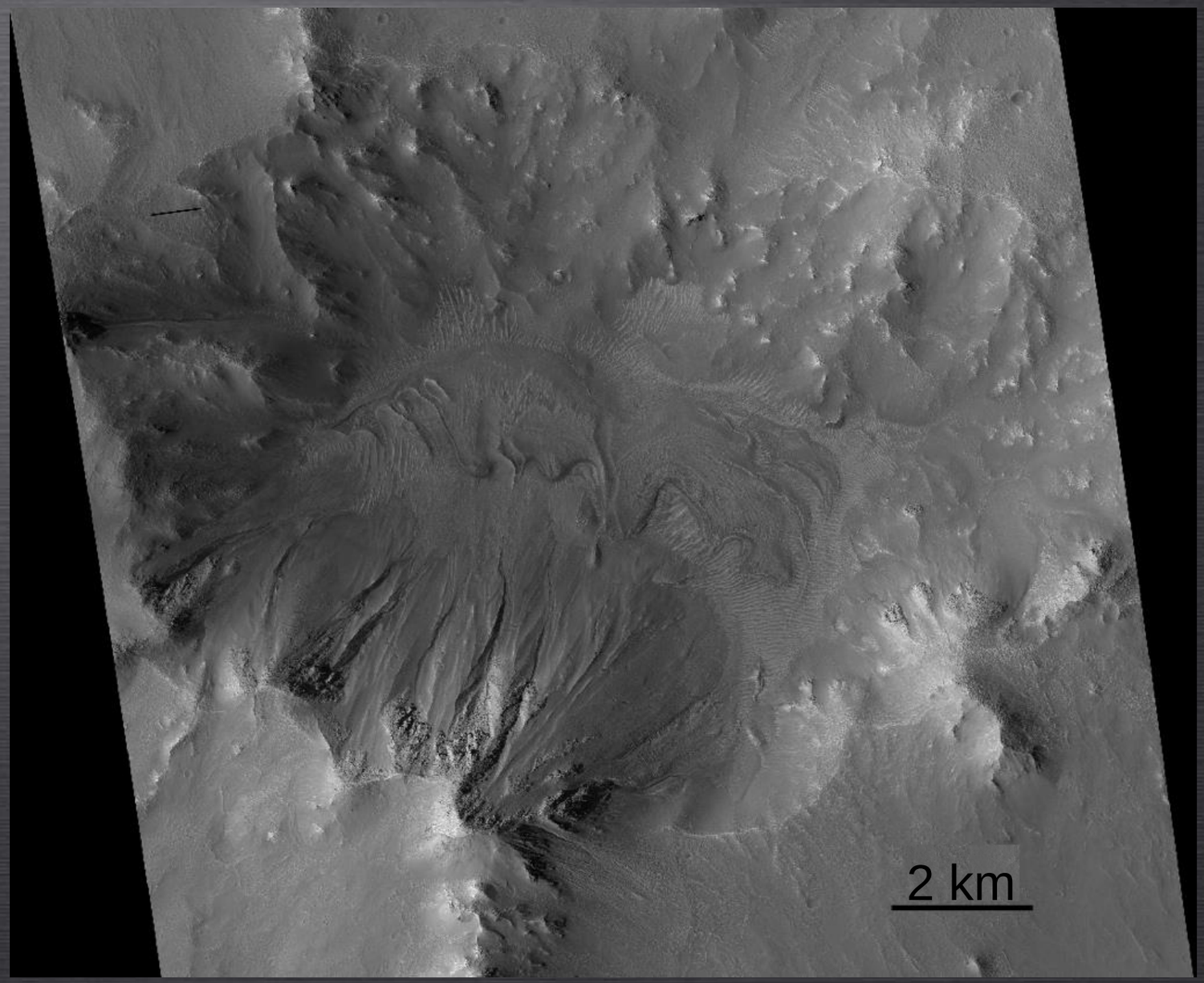

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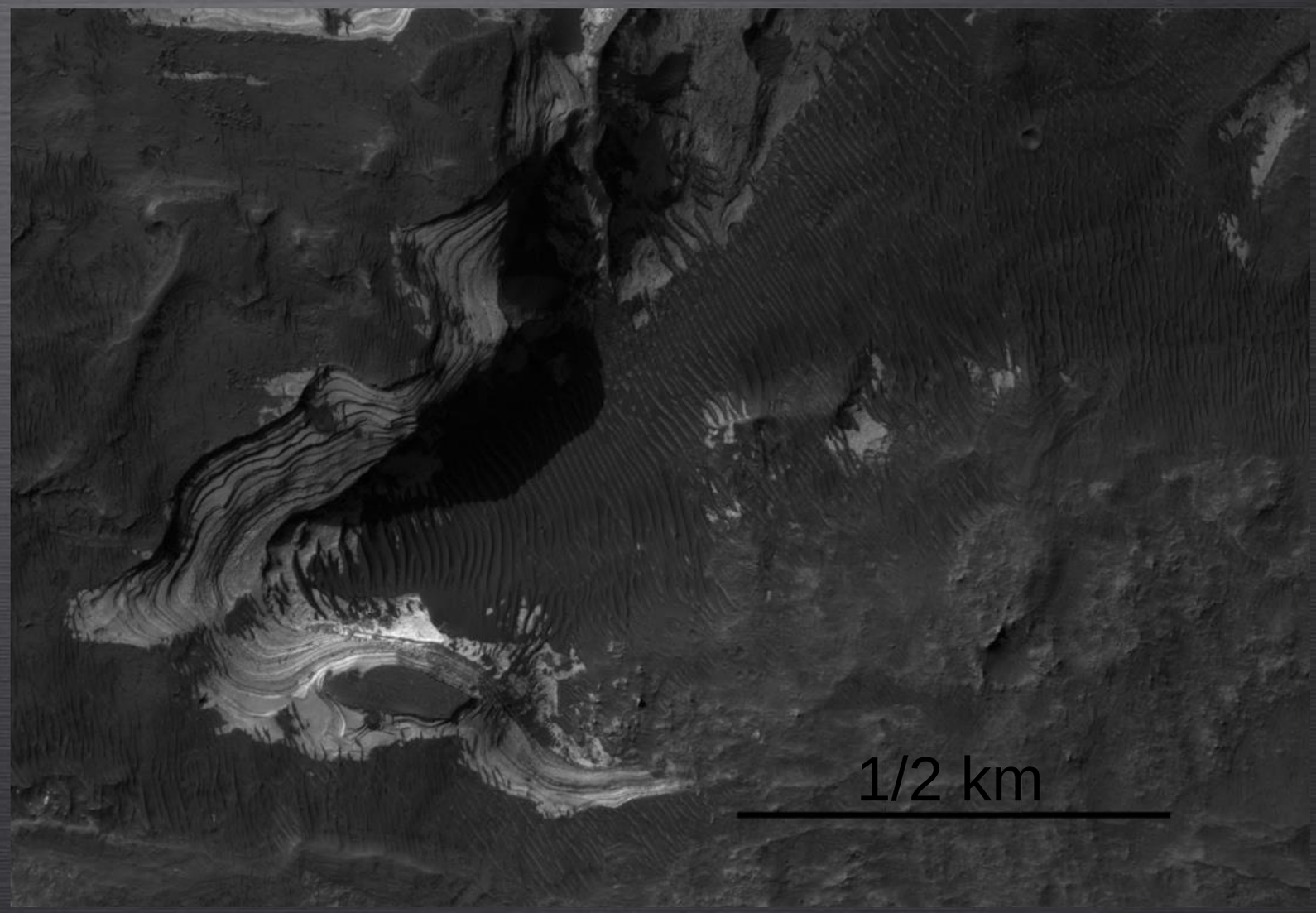

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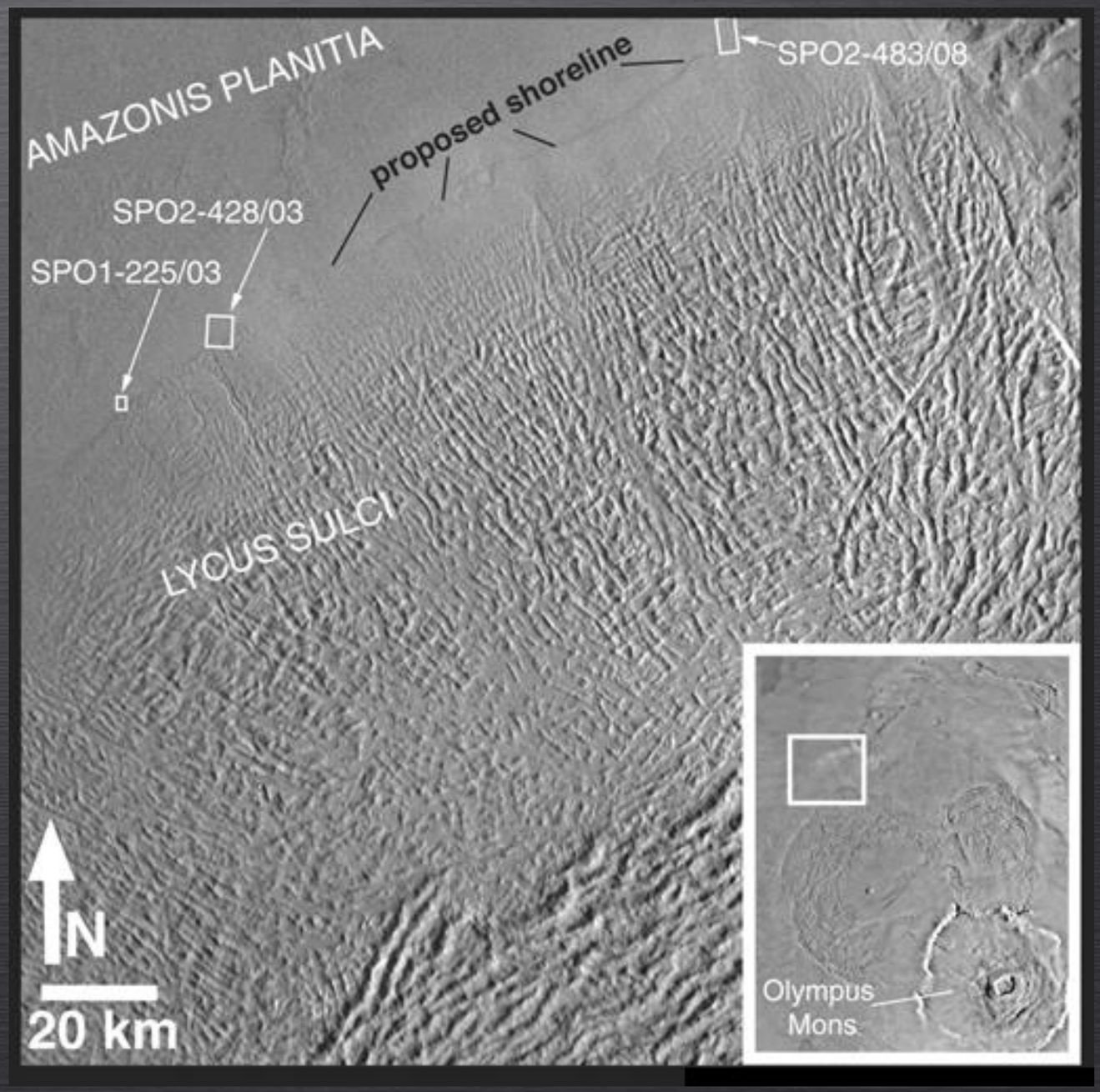
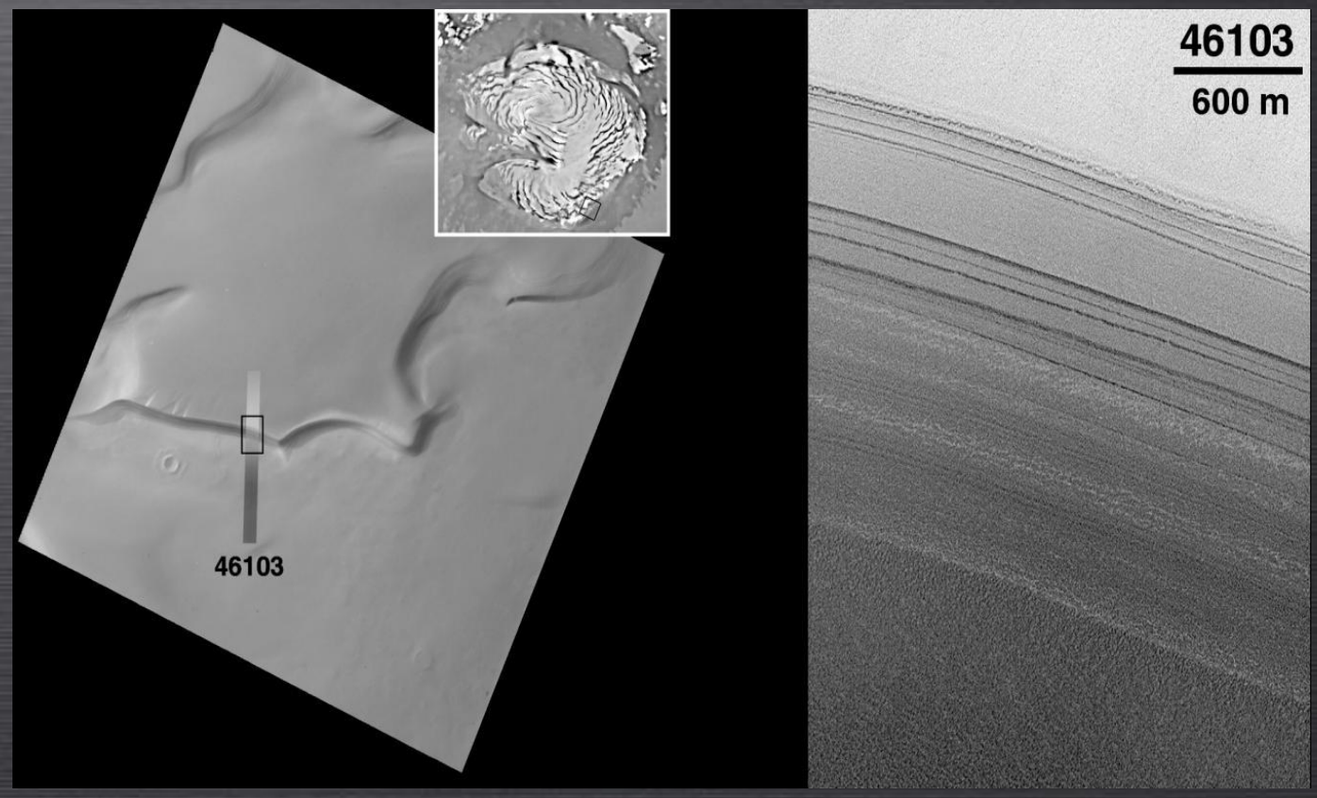


Water on Mars

(old water vs new water)

New water

- **< 2.5 billion years ago**
- **Ice-related**
  - ***Polar deposits***
  - ***Mid-high latitude “mantle”***
  - ***Crater deposits***
  - ***Lobate aprons***
  - ***Lineated valley fill***



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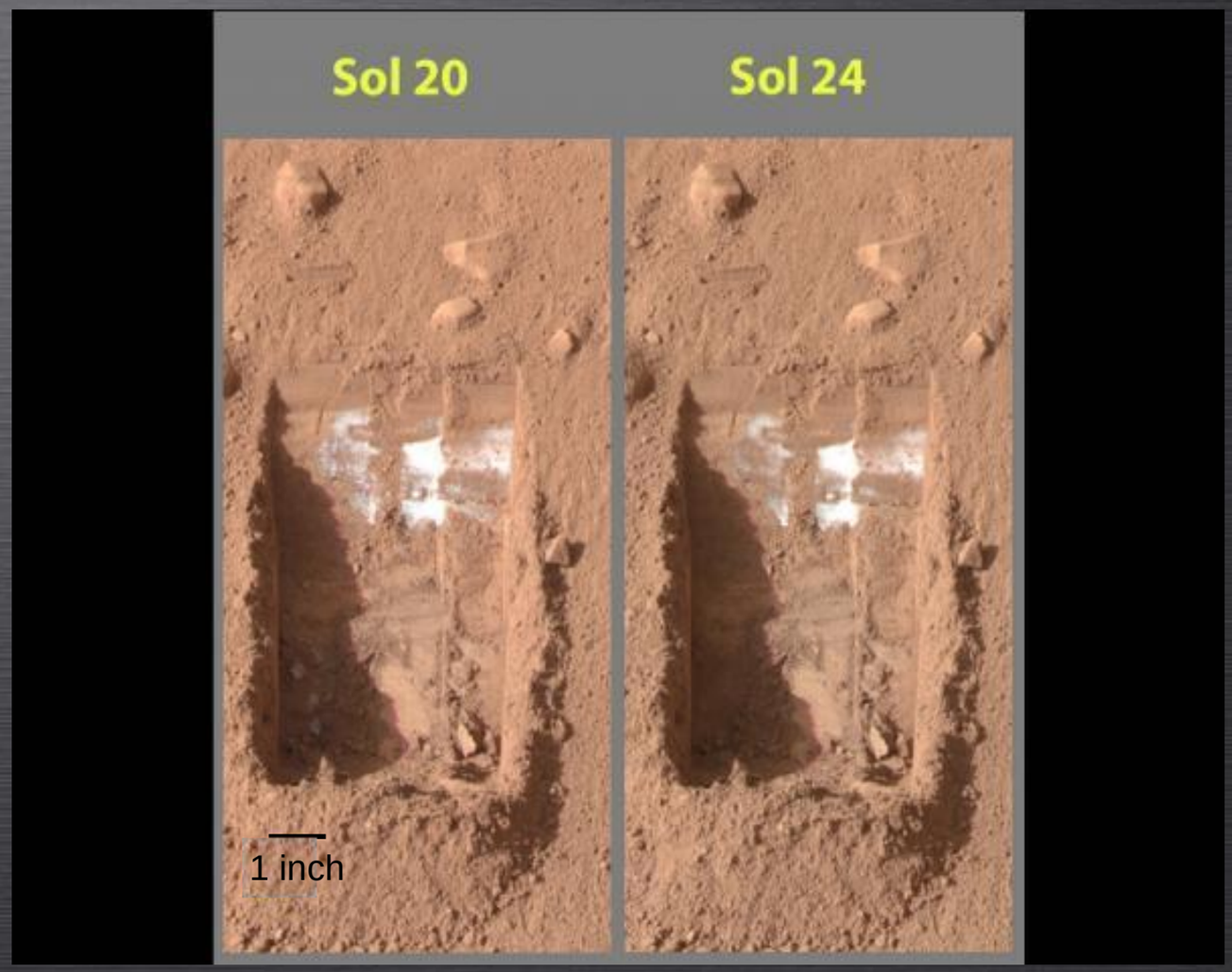

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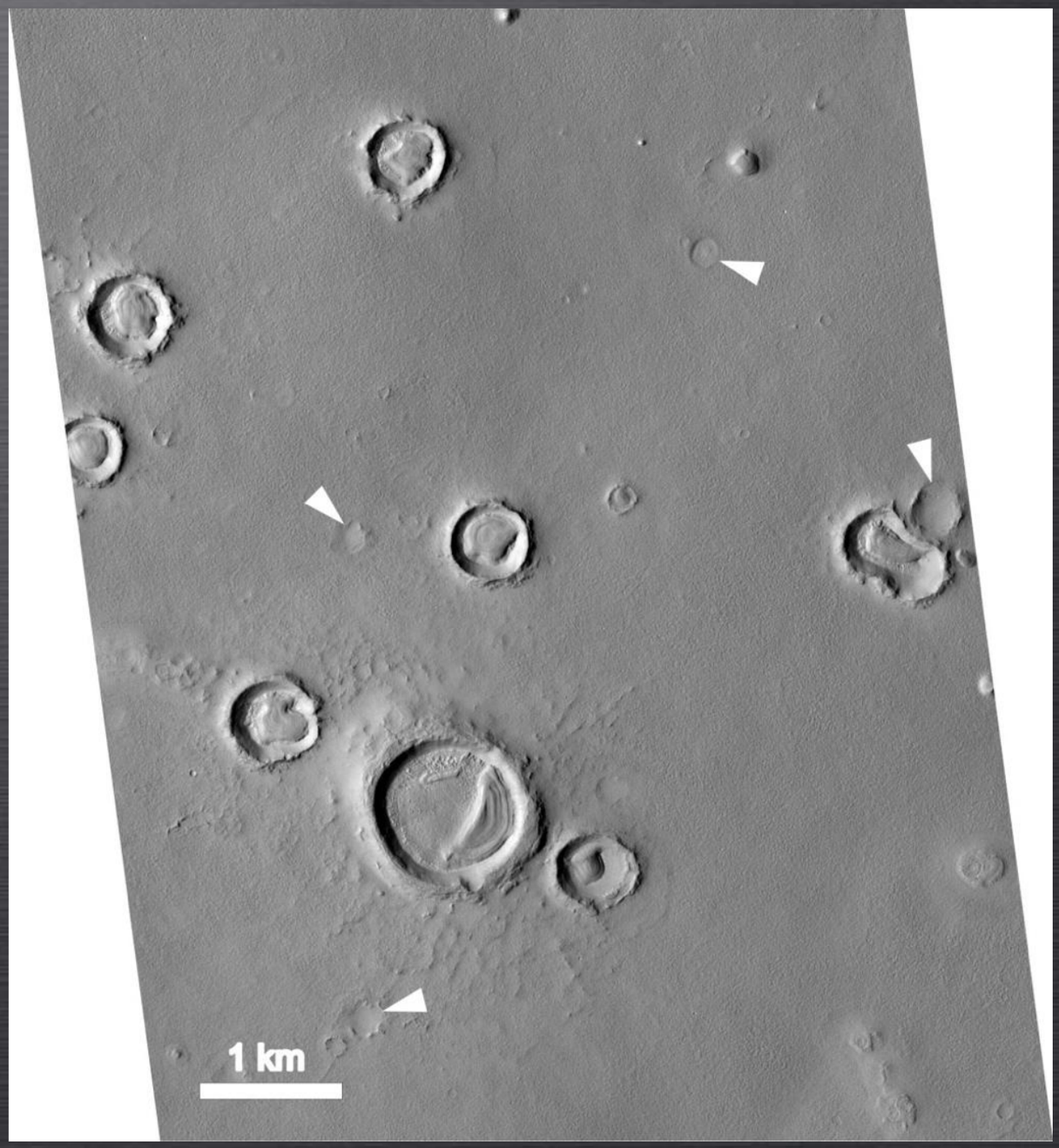

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Water on Mars

(old water vs new water)

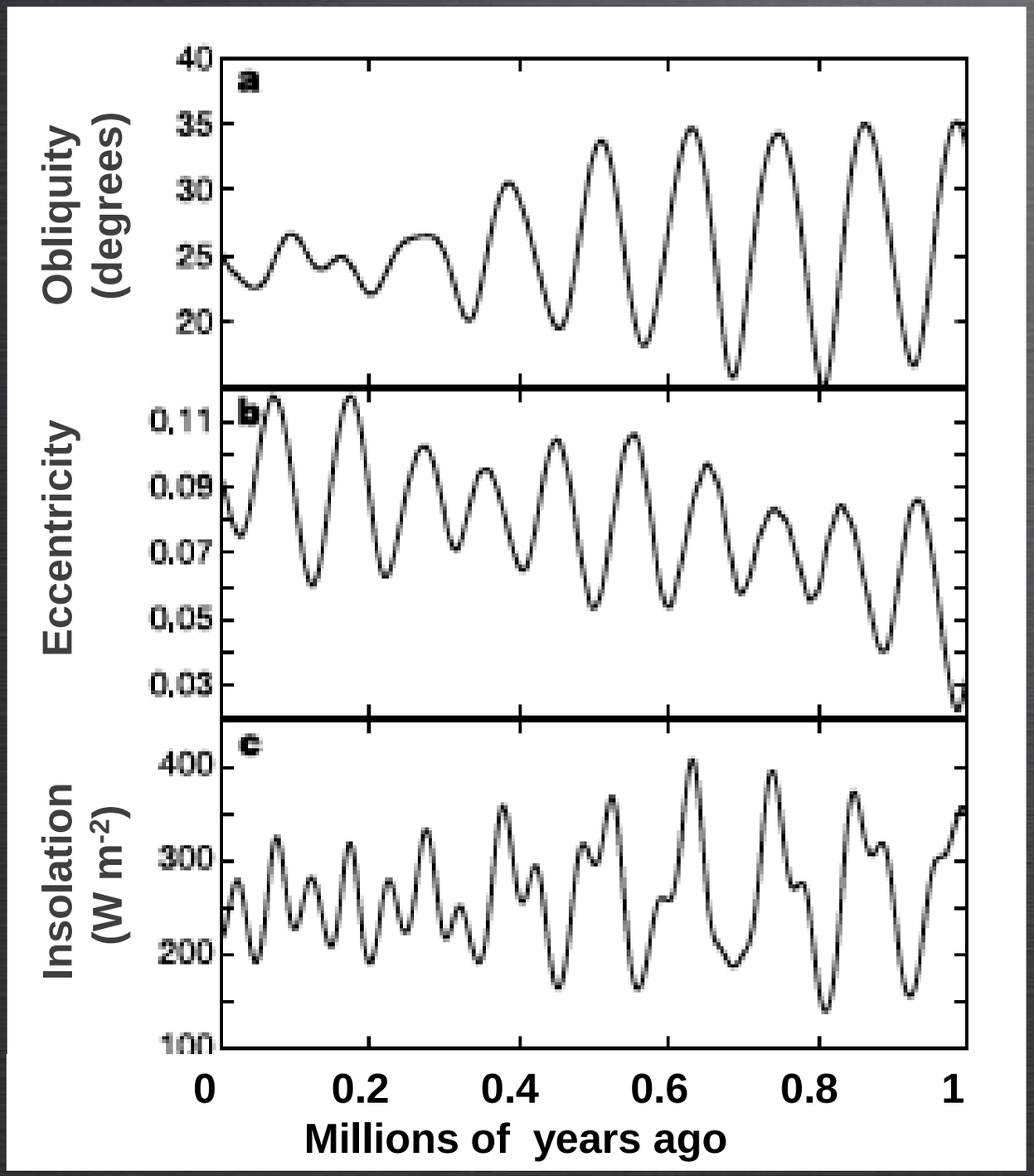
Water on Mars

Questions

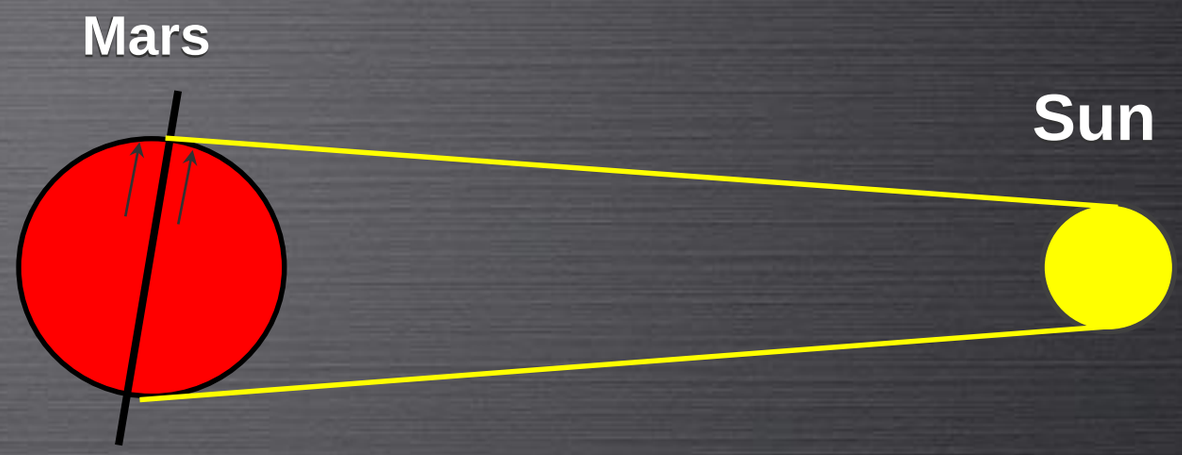
- **Where did the water go?**
  Away (escaped into space)?
  Deep underground aquifers?
  Shallow ice deposits

- **How much ice exists?**
- **How old is the ice?**
- **Where are possible habitats for life?**
- **Is the distribution of ice controlled by changes in the orbit of Mars?**

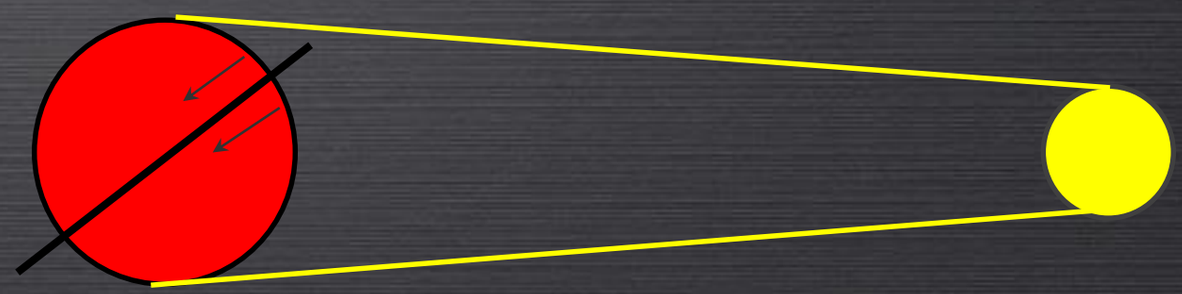
How does Mars' orbit affect its climate and ice?



Laskar et al., 2002



low tilt = colder polar regions



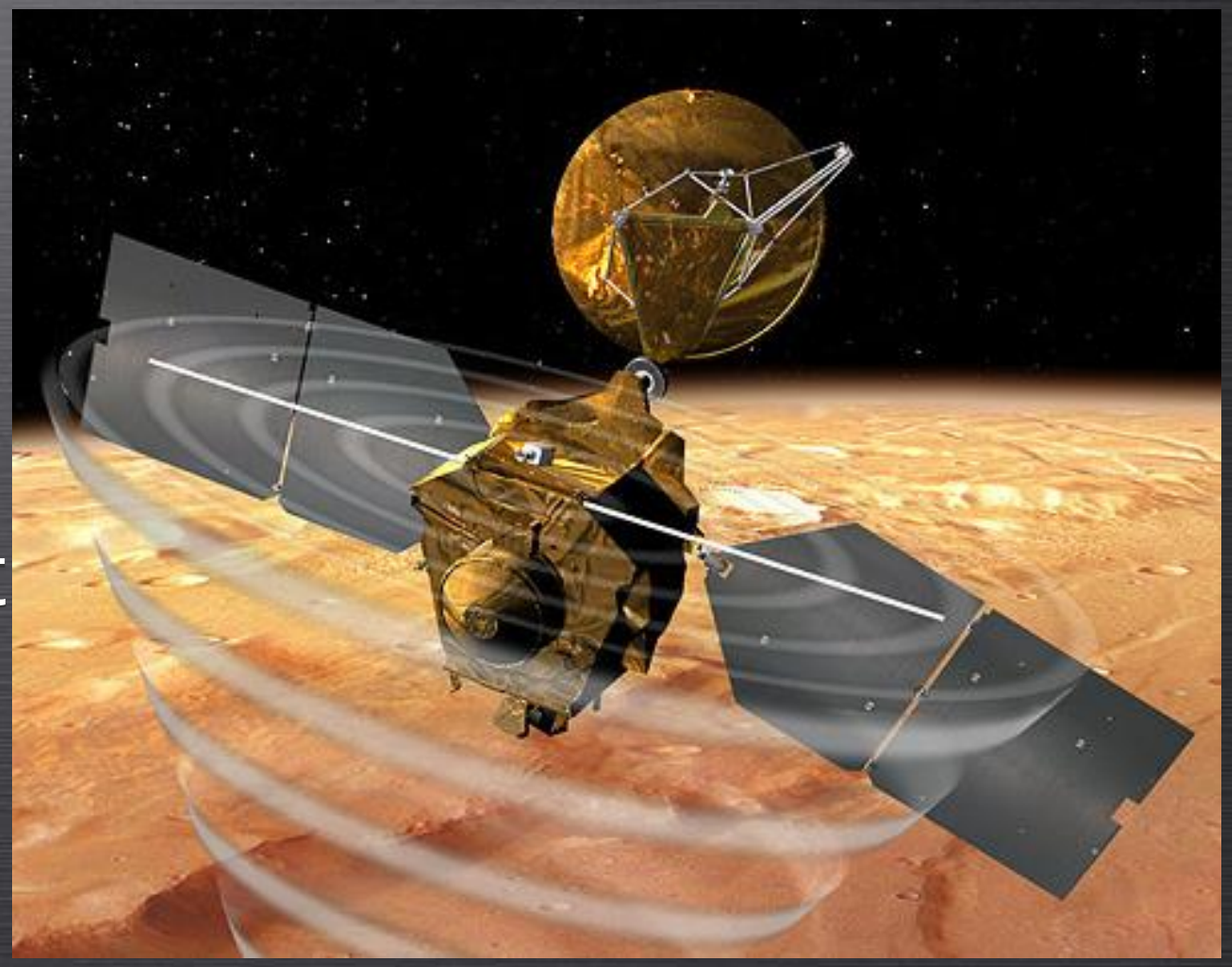
high tilt = warmer polar regions (colder at the equator)

How do we study this?

Landers
Definitive data but limited in extent, can only probe tens of cm

Remote Sensing
Imagery and spectral methods
High resolution, wide areas, but only the top few cm

RADAR
Deep penetration (km’s) but lower resolution



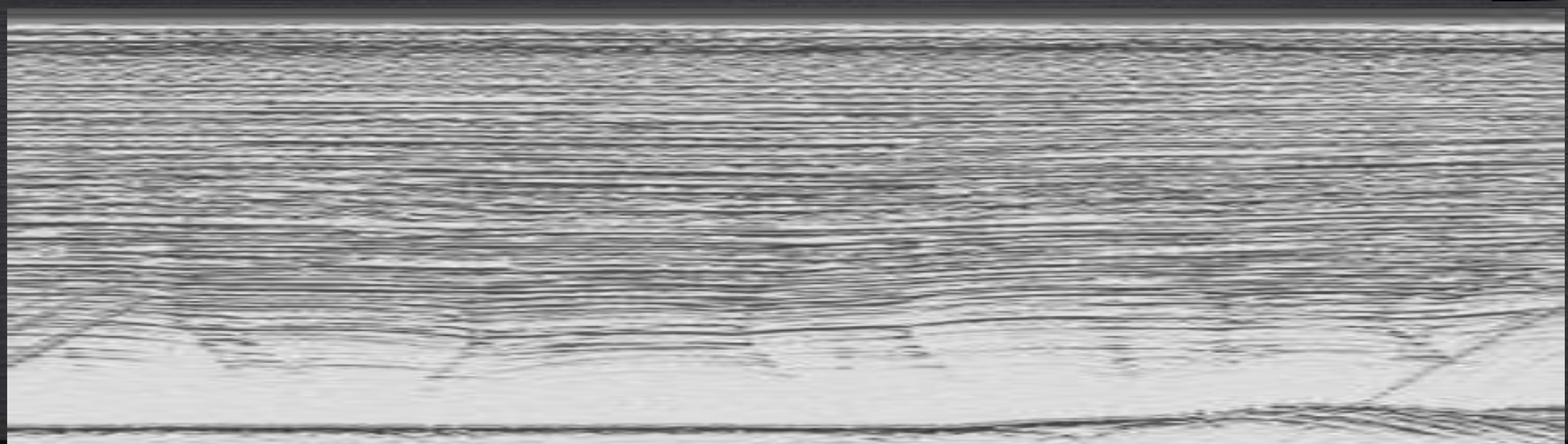
UT Airborne Radar Studies of Antarctica

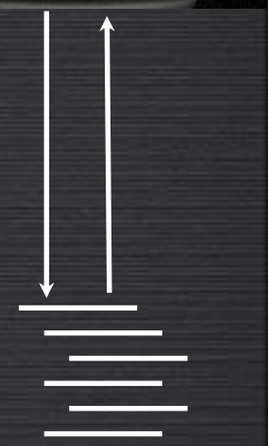
- **Over 300,000 km of acquisition since 1990**
- **Ice-Penetrating radar**

How Does Radar Work?

Sends pulse of energy,
hits interface.
Some reflects,
some goes through

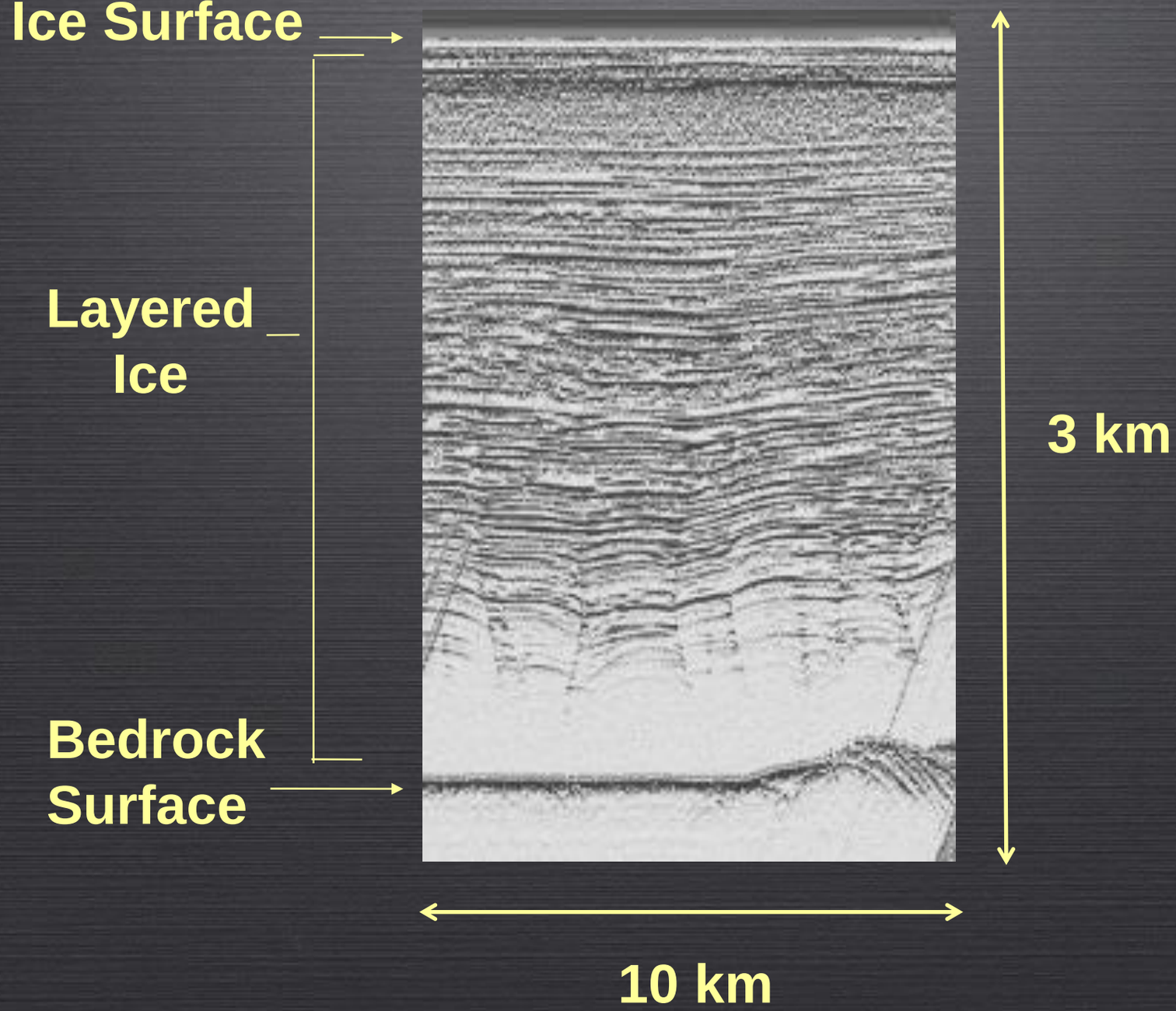
Ice sheets are like cake
(and onions and ogres) -
many layers!



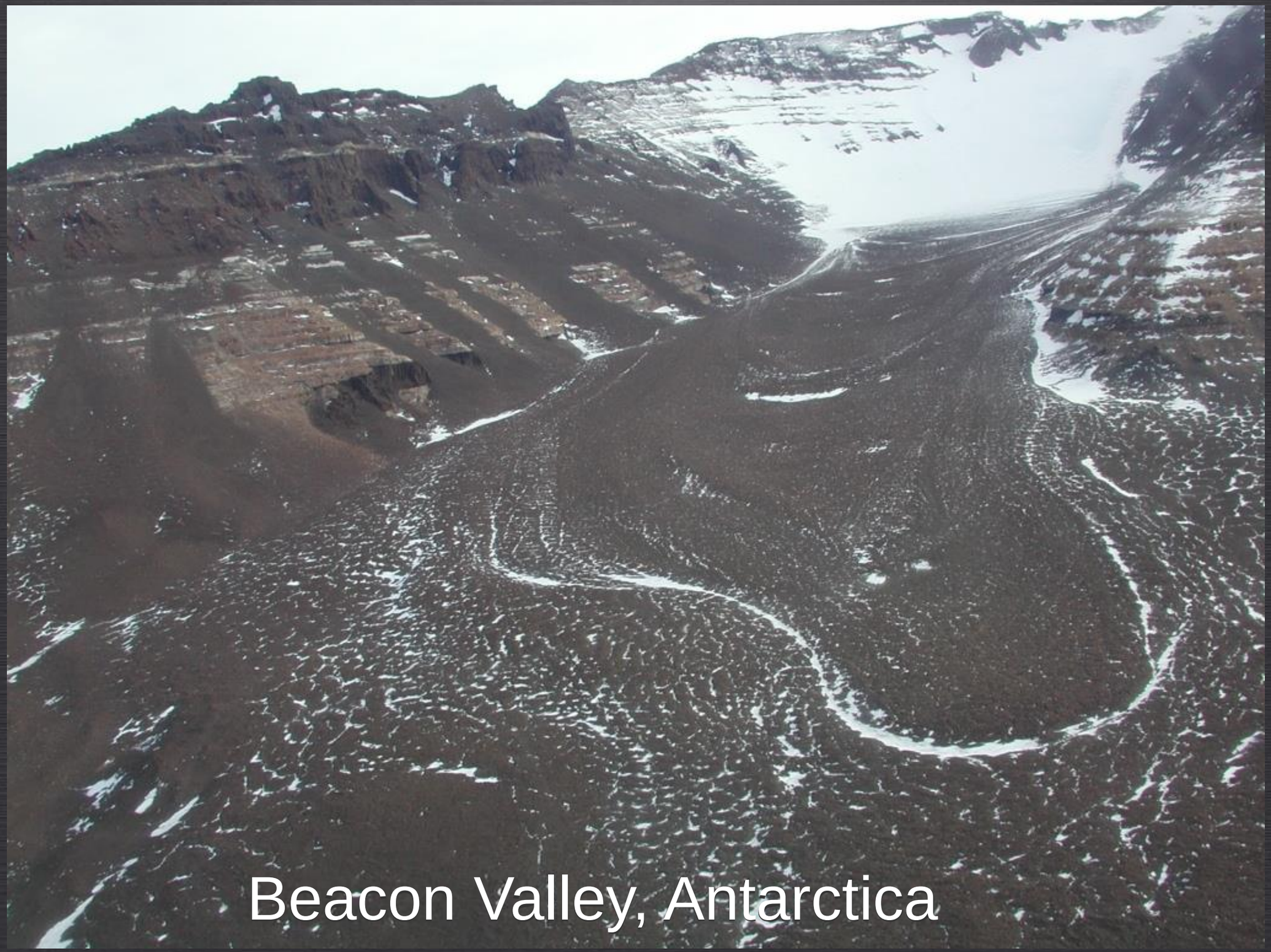


Radar and Ice

Due to the electrical properties of water ice, it is nearly radar transparent



Mars Analog Studies

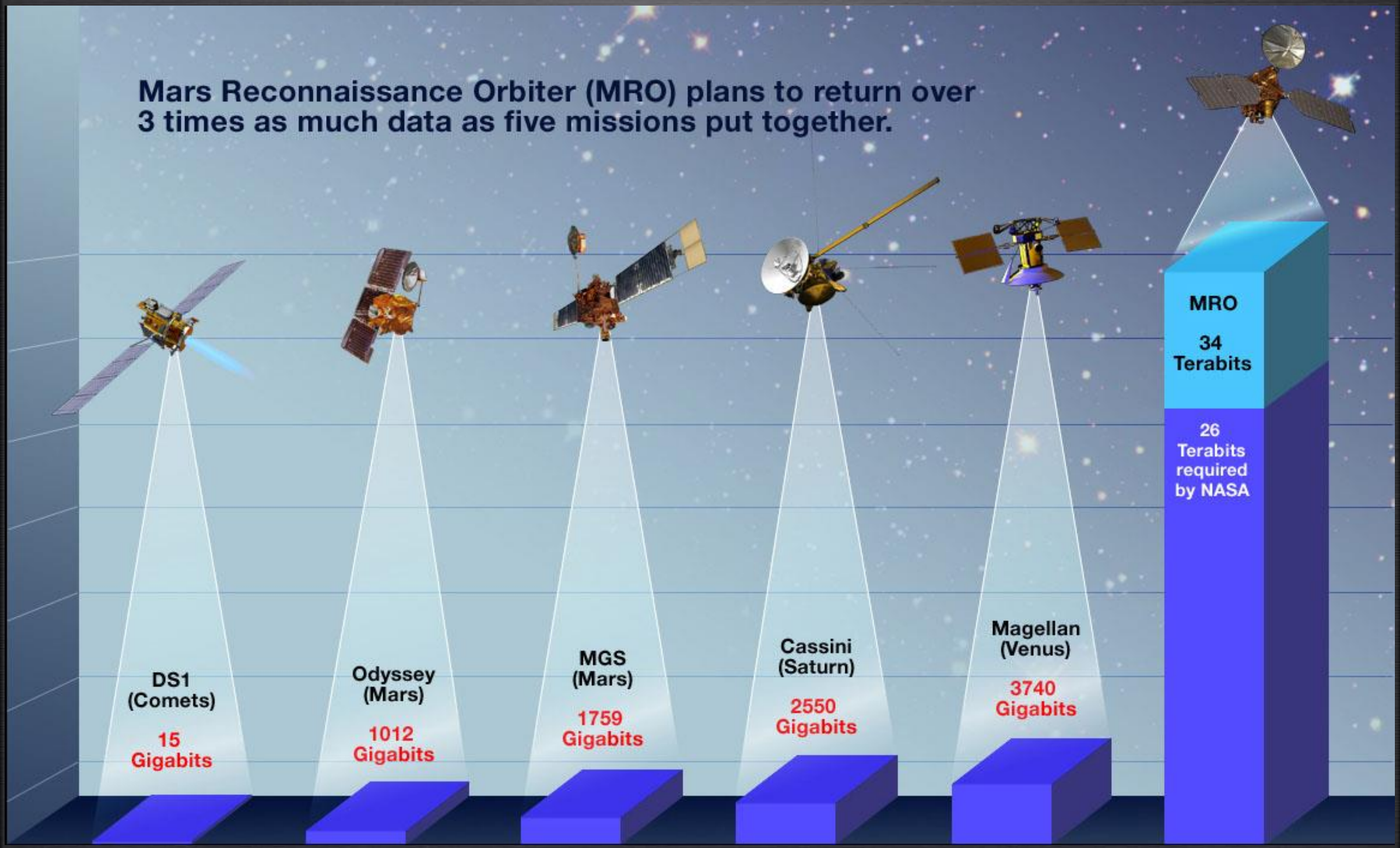


Beacon Valley, Antarctica

Mars Reconnaissance Orbiter (MRO)

Launched August 12, 2005
Orbit insertion March 10, 2006
Aerobraked for 5 months to achieve circular orbit
Primary science phase Nov. 2006 – Nov. 2008
Extended mission approved until Nov. 2010

Building MRO at the Jet Propulsion Lab


Mars Reconnaissance Orbiter (MRO) plans to return over
3 times as much data as five missions put together.
DS1
(Comets)
15
Gigabits
Odyssey
(Mars)
1012
Gigabits
MGS
(Mars)
1759
Gigabits
Cassini
(Saturn)
2550
Gigabits
Magellan
(Venus)
3740
Gigabits
MRO
34
Terabits
26
Terabits
required
by NASA

NASA

MRO Instrument Suite

Hyper-Spectral Imaging Spectrometer
(Johns Hopkins University)

Very High Resolution Imager
(University of Arizona)

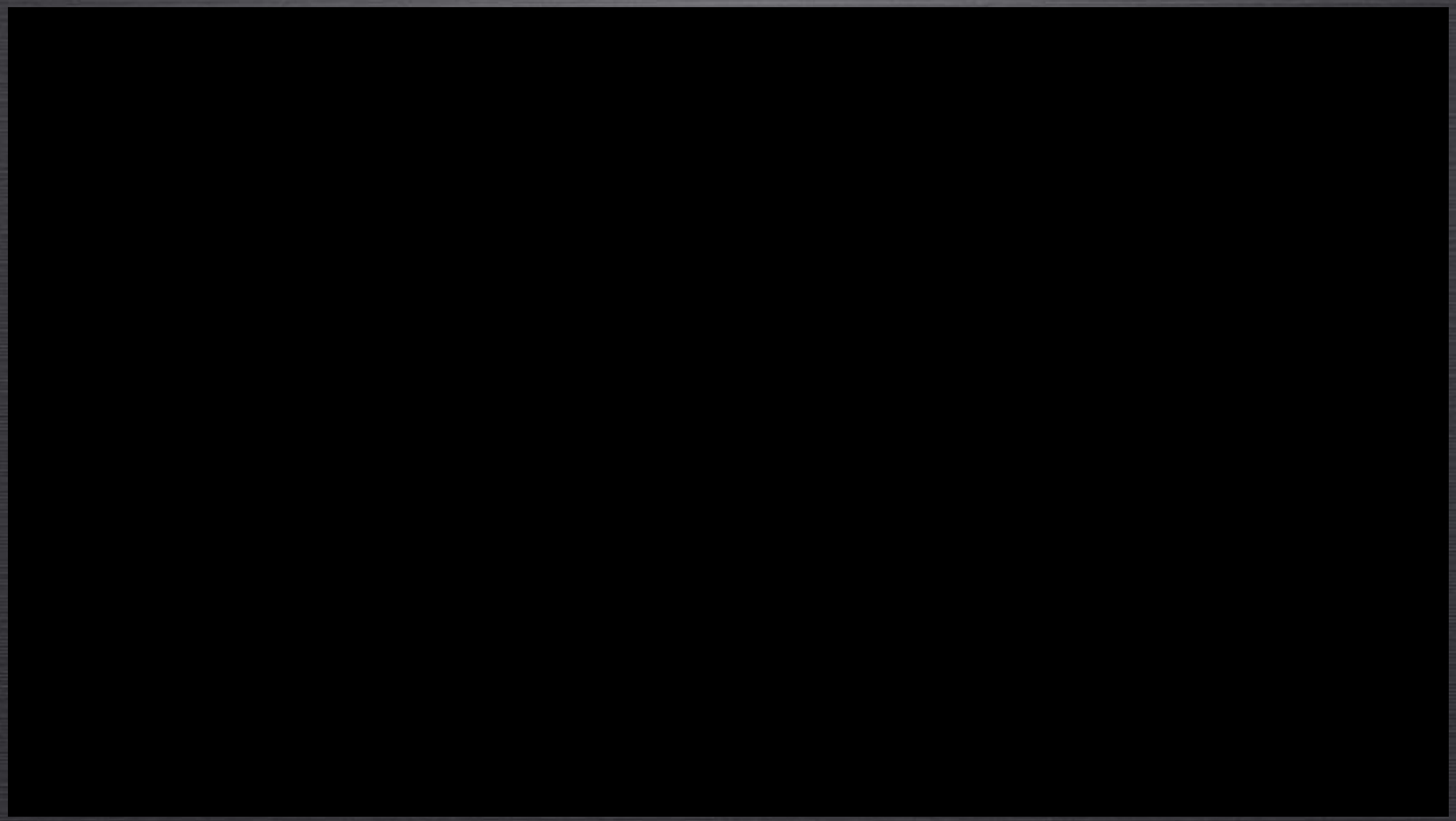
High-Resolution Context Imager
(Malin Space Science Systems)

Shallow Subsurface Sounding Radar
(University of Rome)

Wide Field Multi-band Imager
(Malin Space Science Systems)

Infrared Atmospheric Sounder
(JPL, California Tech)

Orbital Radar at Mars

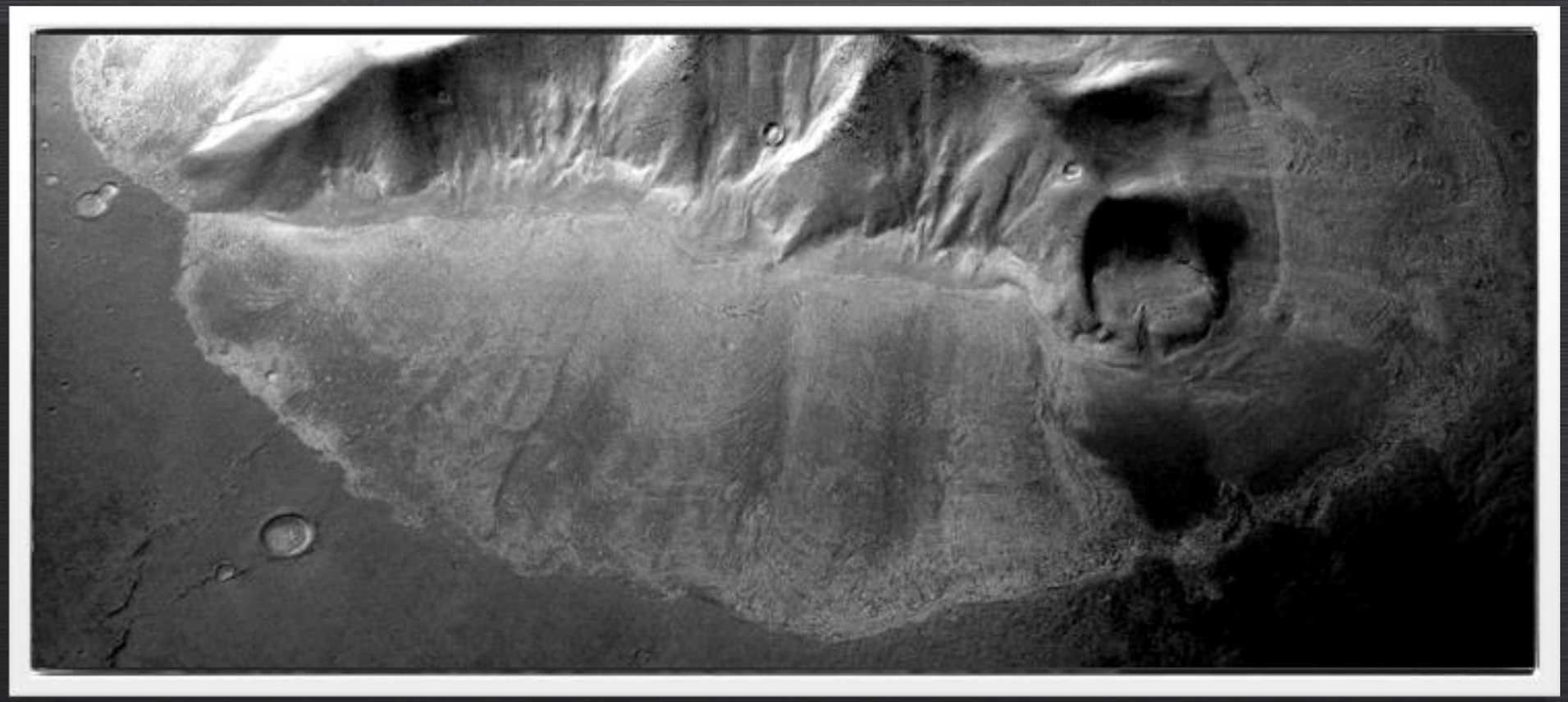


NASA/Caltech/JPL

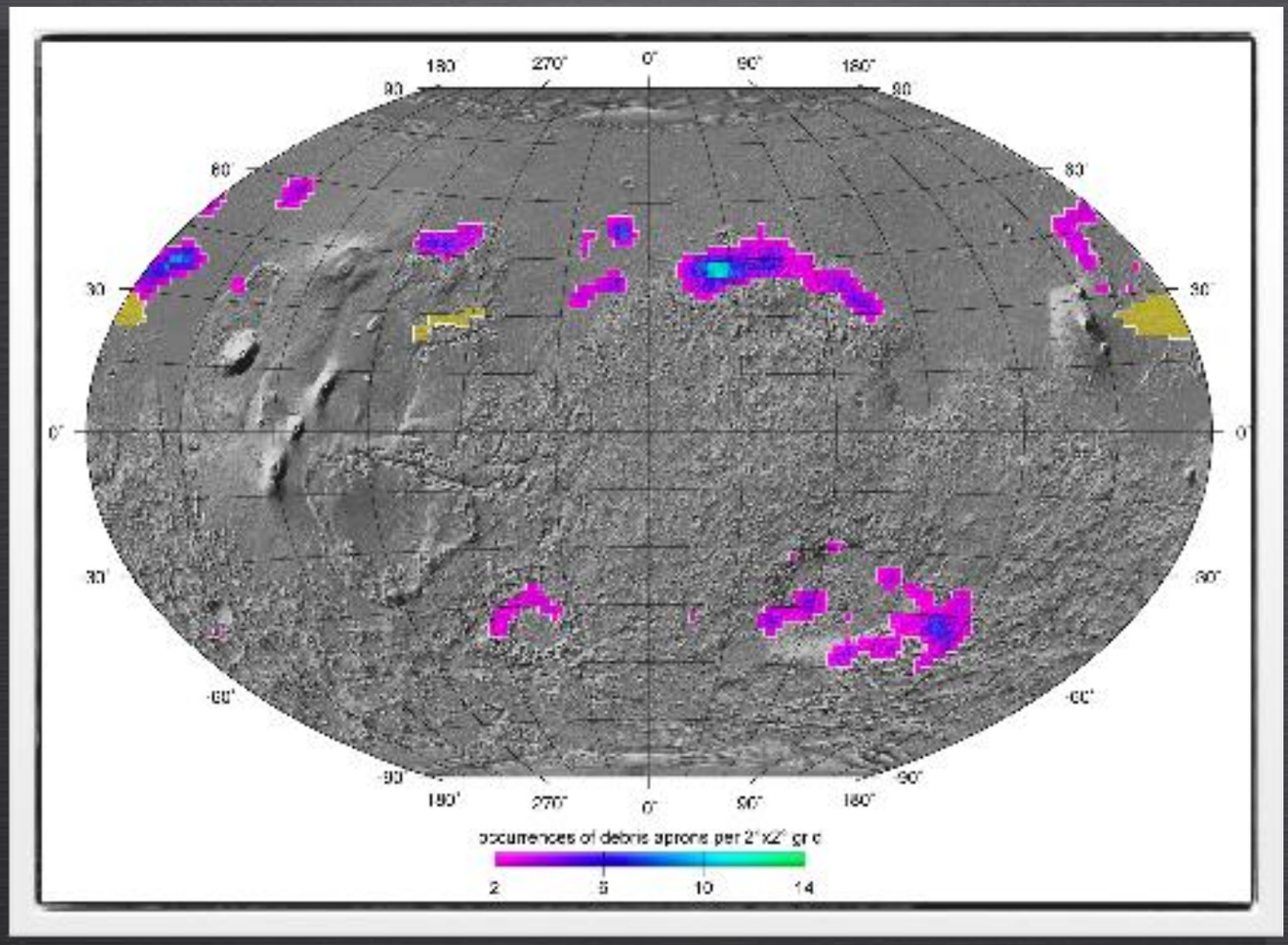
Ice- Lubricated Rock Flows or Rock-Covered Glaciers?

Many features at middle and low latitudes suggest past or present ice

- **Lobate deposits with flow textures abut steep topography and fill some craters**
- **Originally thought to be ice-lubricated rock flows**
- **Alternative hypothesis: rock-covered glaciers**
- **Ice content could range from 10% - 90%**



Distribution of these Features

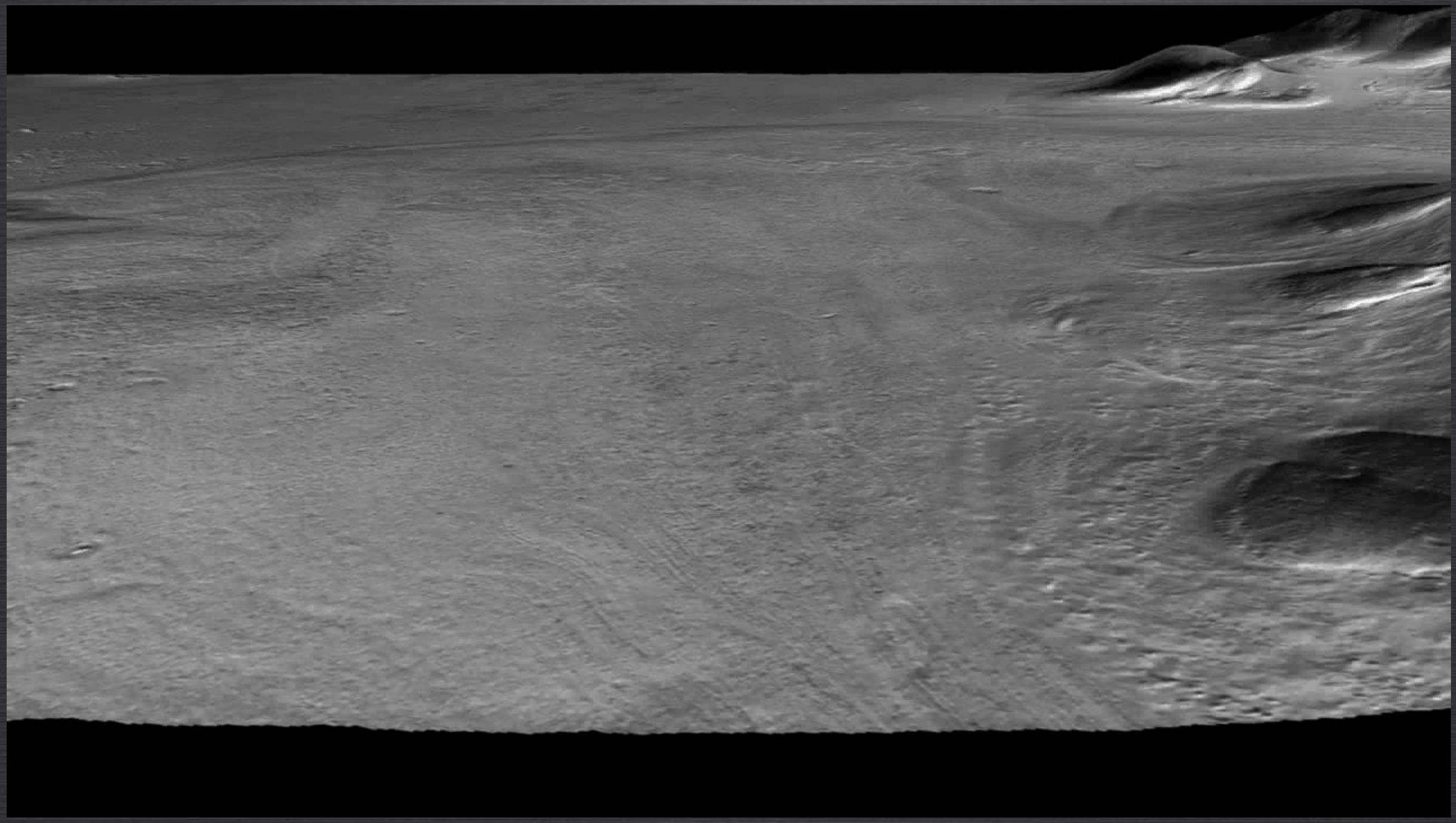


Haubeck (2010)

- If they contain ice, how can they exist?
  - **Water ice is unstable at the surface below ~60° latitude.**
- Rotational axis tilt variations and climate models support the hypothesis of past mid-latitude glaciations and localized, low-latitude mountain glaciers.
  - **How much ice remains at these latitudes?**
  - **How extensive are such events, how frequent and what is the duration?**

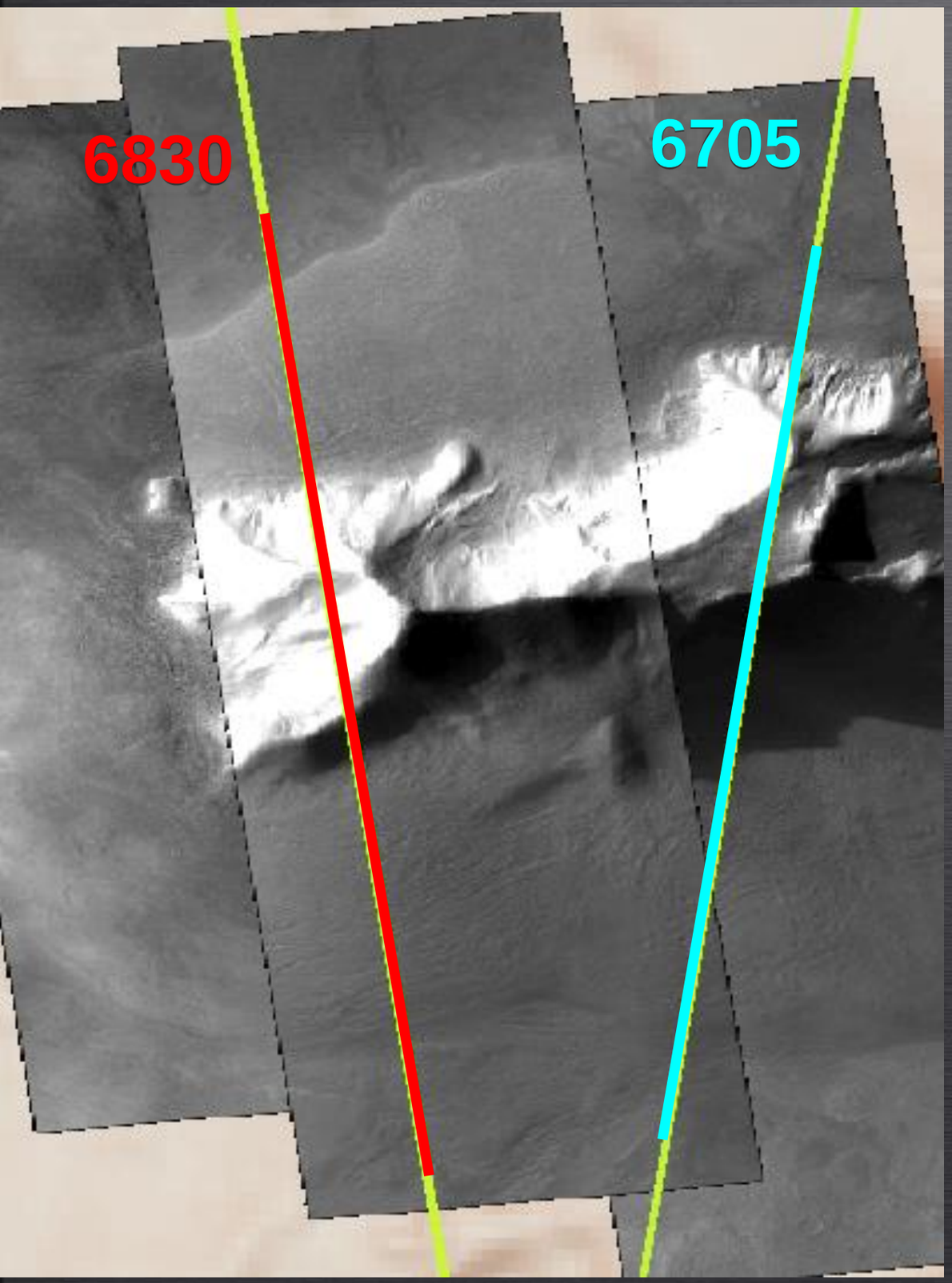
30 km

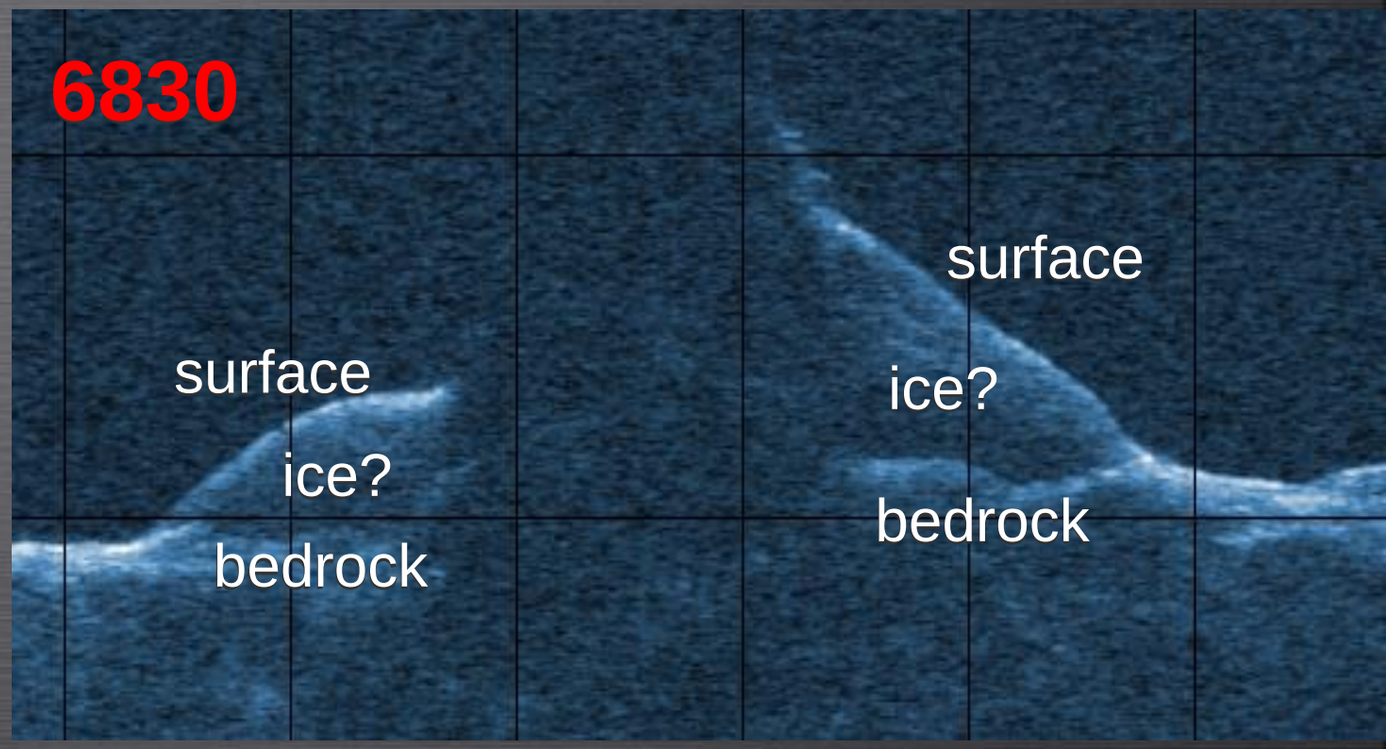
Simulated Overflight

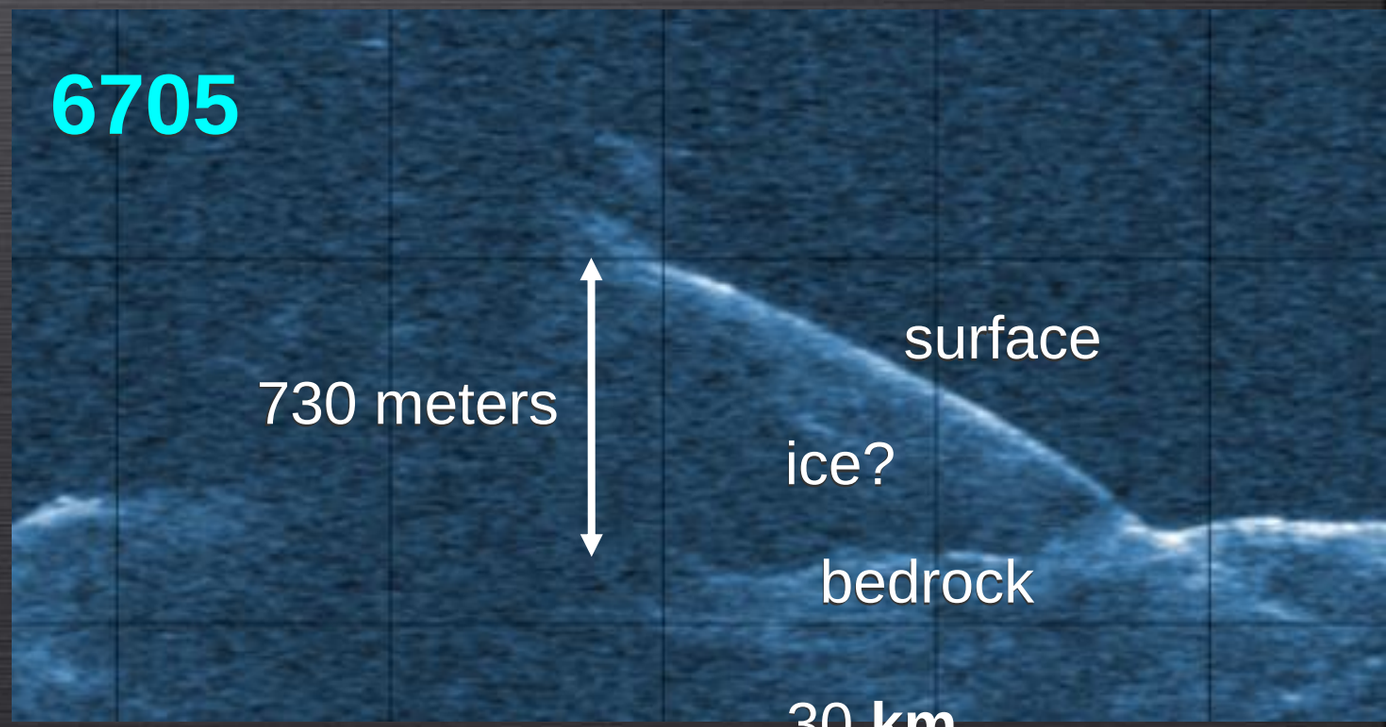


NASA/Caltech/JPL

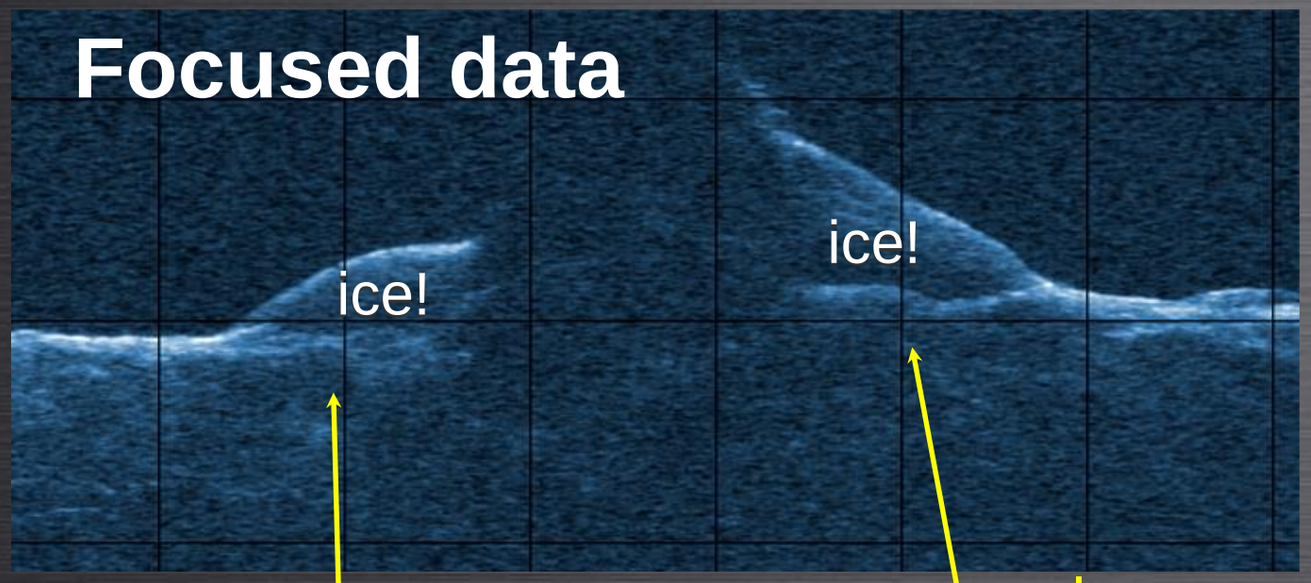
Two Radar Profiles Crossing These Features

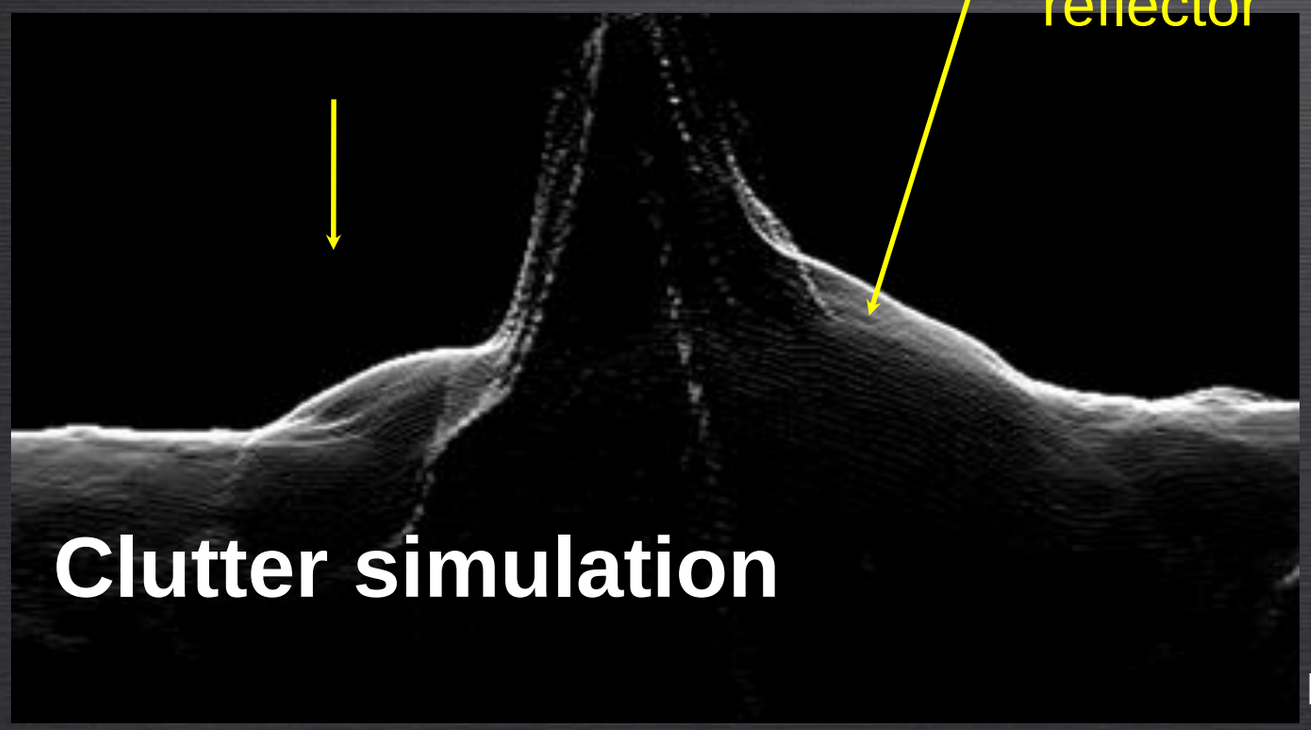






Check Against Surface Clutter Simulation





Simulated surface clutter
(surface echoes ONLY)

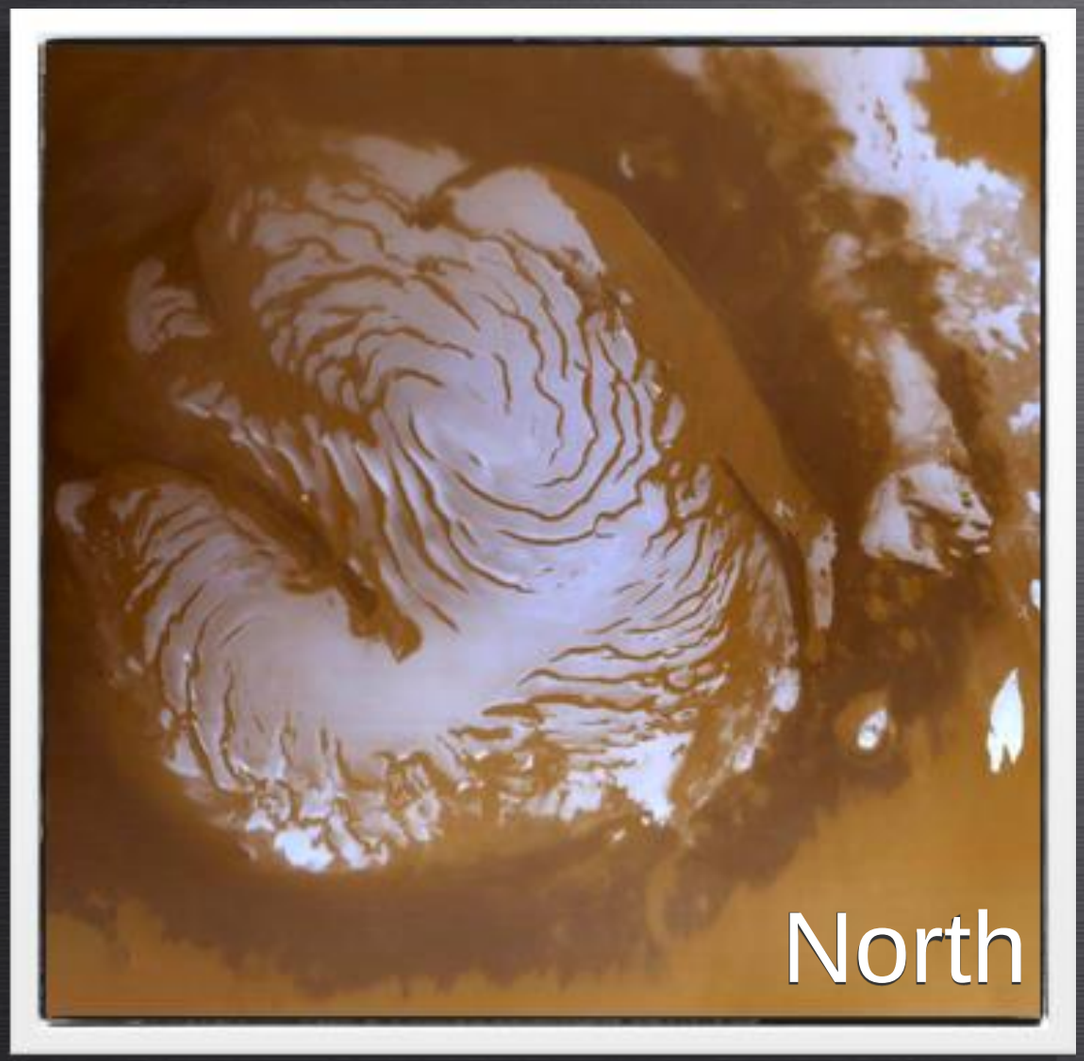
- No layering
  - –Homogeneous material
  - –Contrasts with polar caps where layering is pervasive
- Low volume scattering
  - –Indicates lack of large rock component

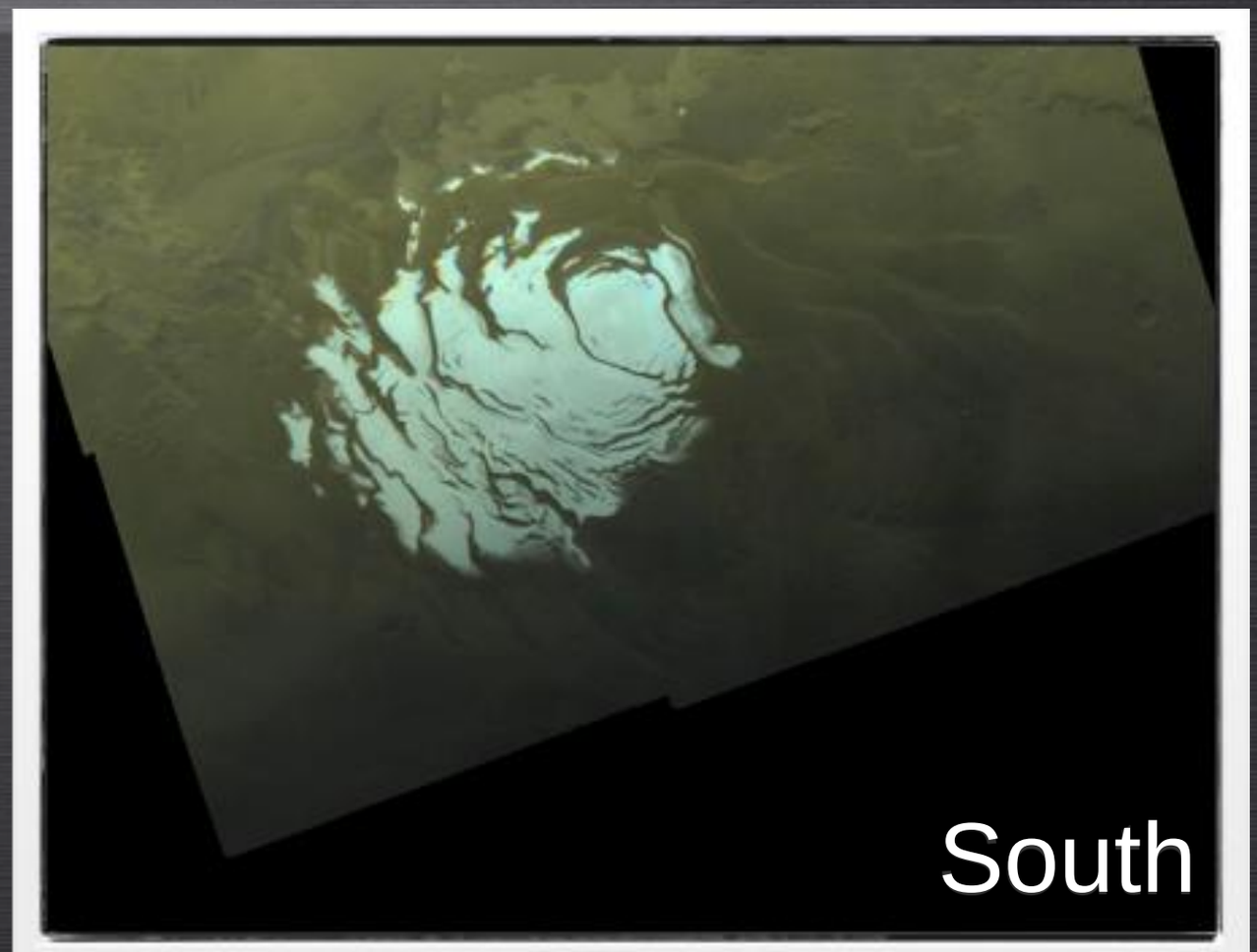
Holt et al., *Science* 2008

Conclusions for these features

- Radar properties of these lobate apron features are consistent with the rock-covered glacier hypothesis, rather than an ice-lubricated rock flow.
  - Subsurface echoes consistent with a sharp basal contact
  - Attenuation consistent with clean ice
  - Lack of layering or structure indicates massive ice
- They are remnants of a past climate favorable to glaciation at mid latitudes.
  - Atmospheric circulation model of Forget et al. (2006) shows preferential deposition of ice in Eastern Hellas region during periods of high spin-axis obliquity
- Proves that a thin protective layer can preserve shallow ice at middle latitudes!

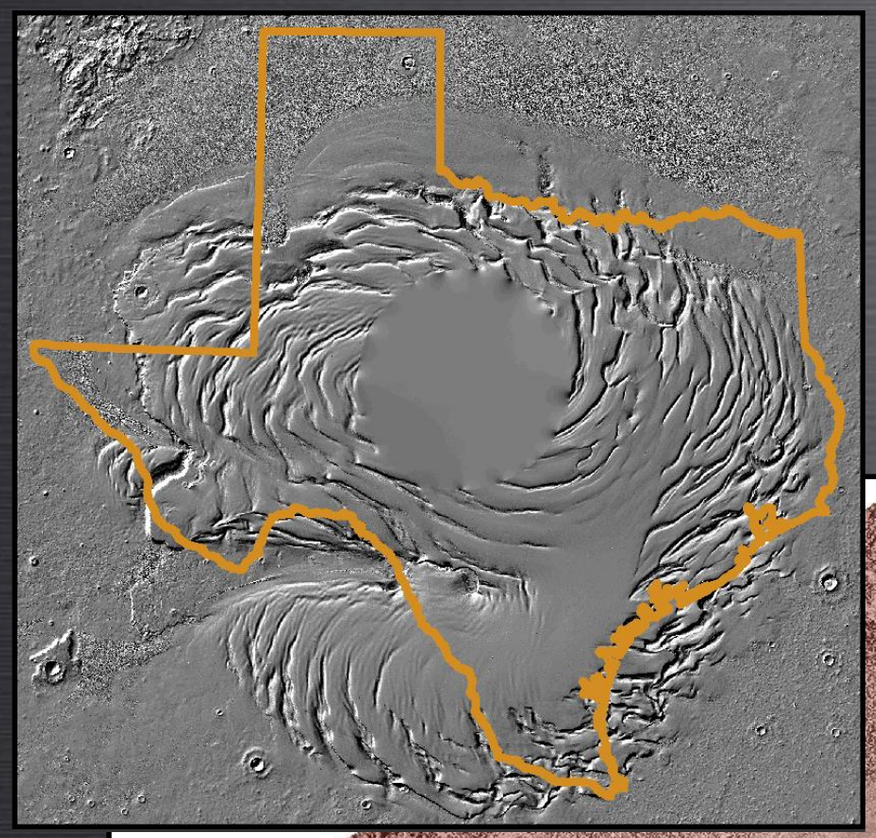
Polar Layered Deposits (PLD)

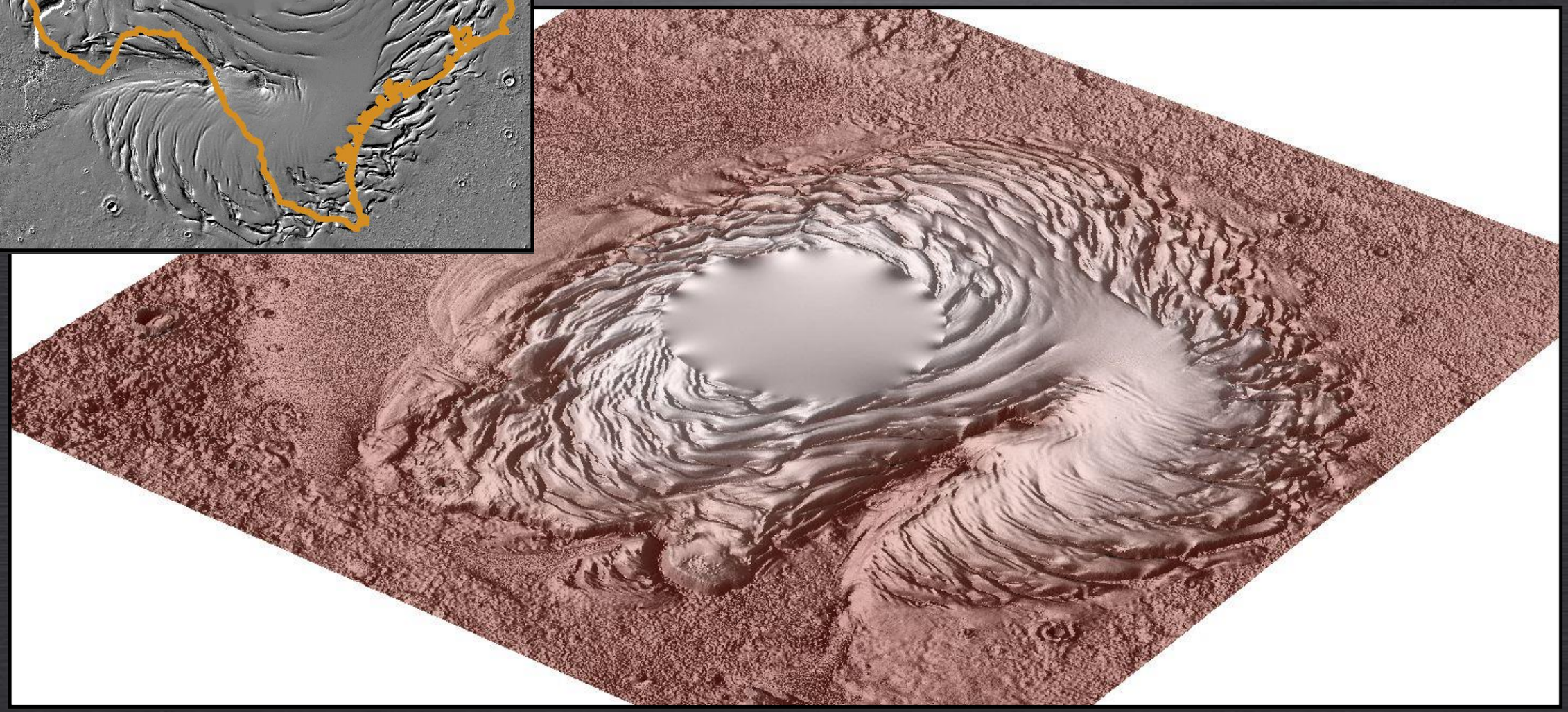




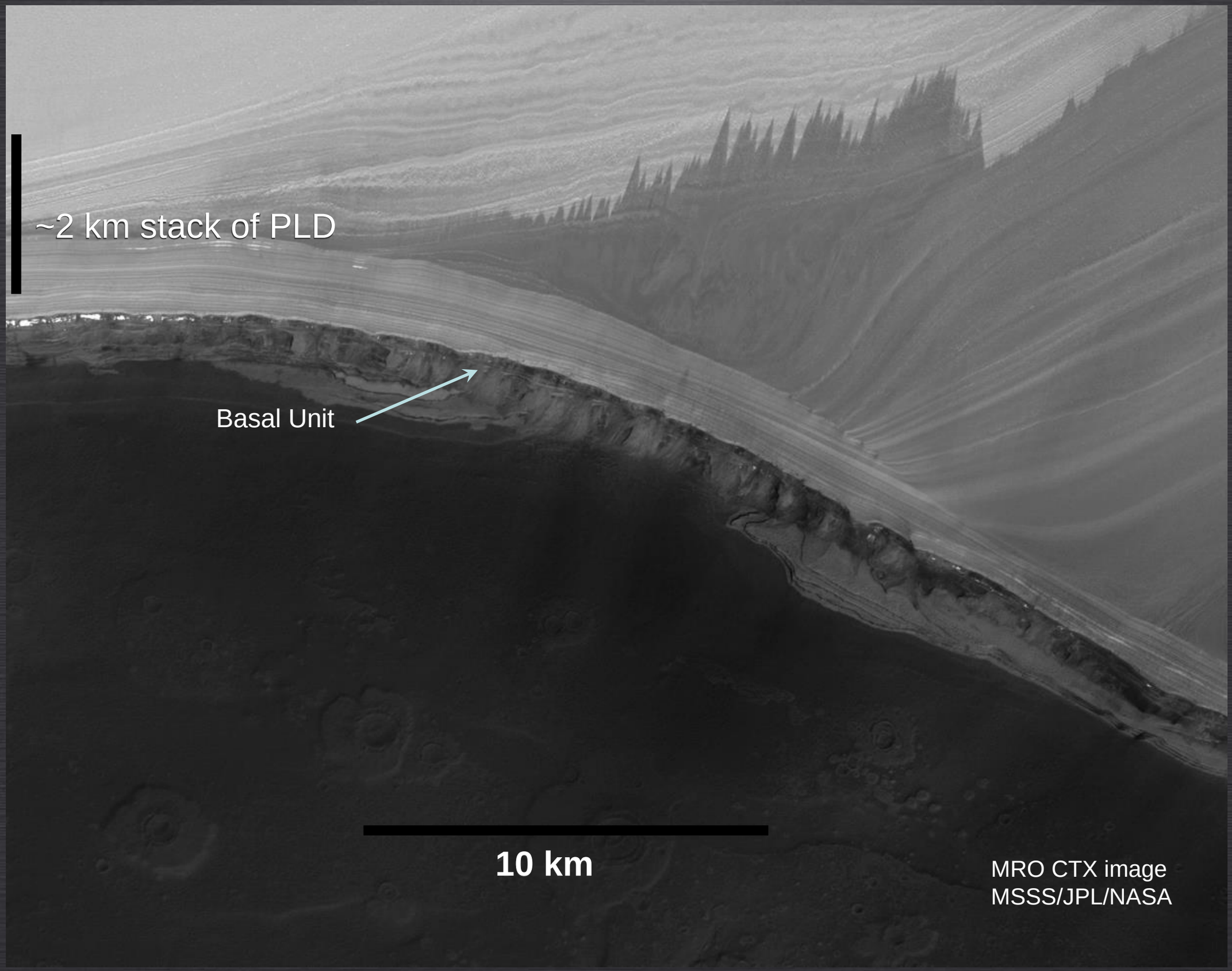
- Layers of dust and ice
- Seasonal CO_2 cover
- North and South are quite different
  - North considered to be much younger based on crater counts

Polar Caps: Perspectives





Oblique View of Polar Cap Edge

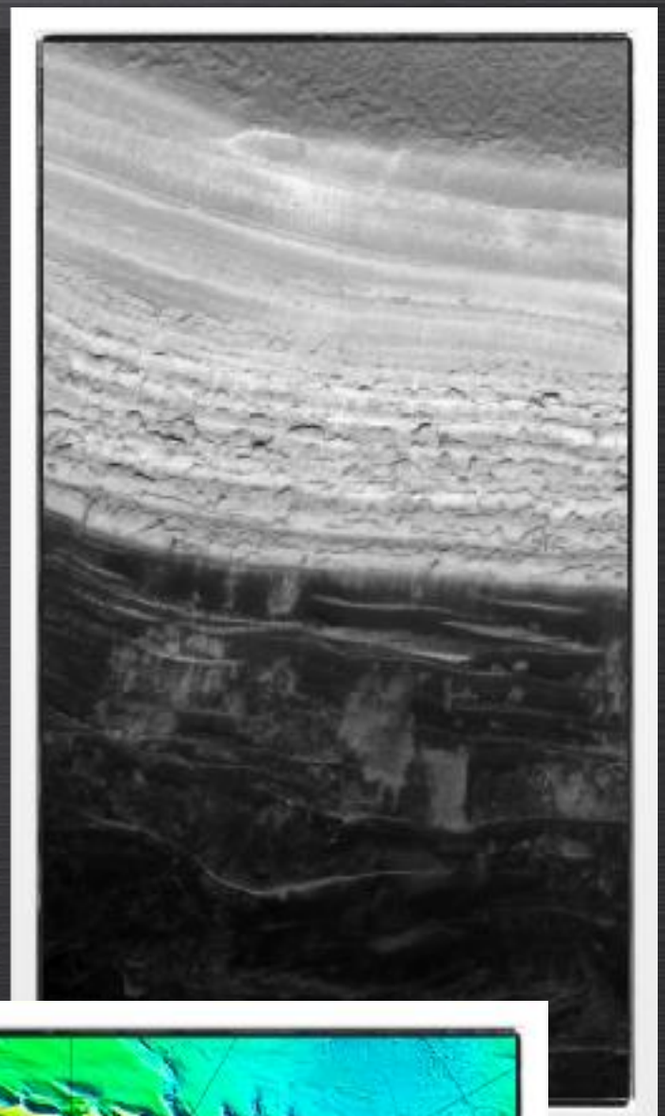


Questions Regarding the Polar Cap

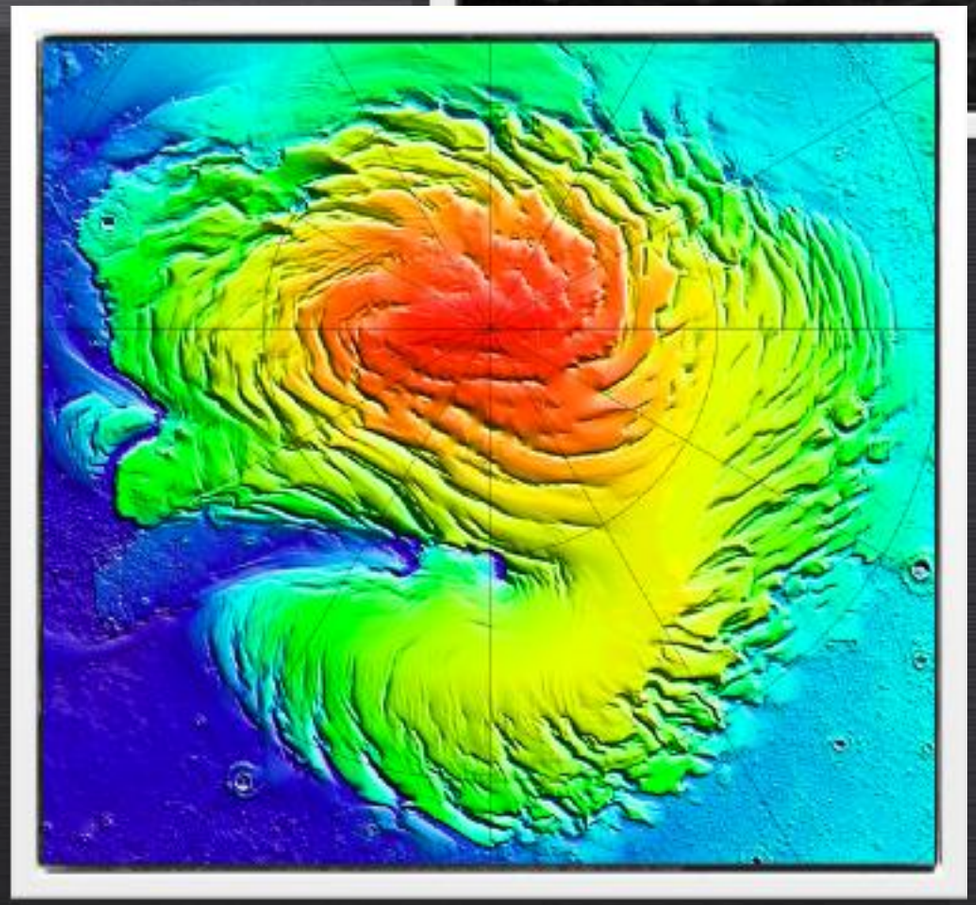
What is its history of construction and modification?

- **Chasma Boreale?**
- **Spiral troughs?**

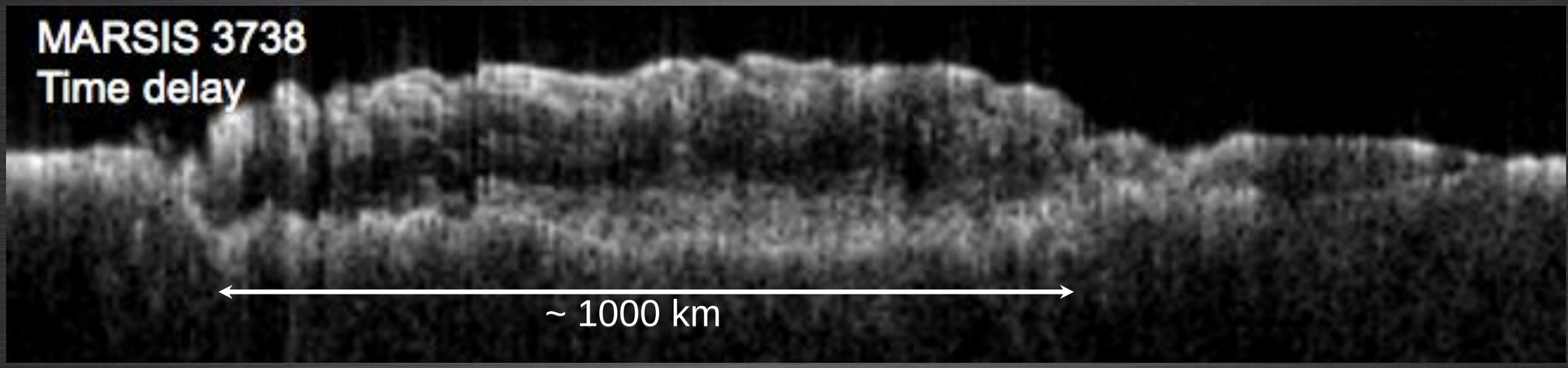
Layers are assumed to result from changes in ice/dust ratio, related to climate and possibly forced by orbital variations

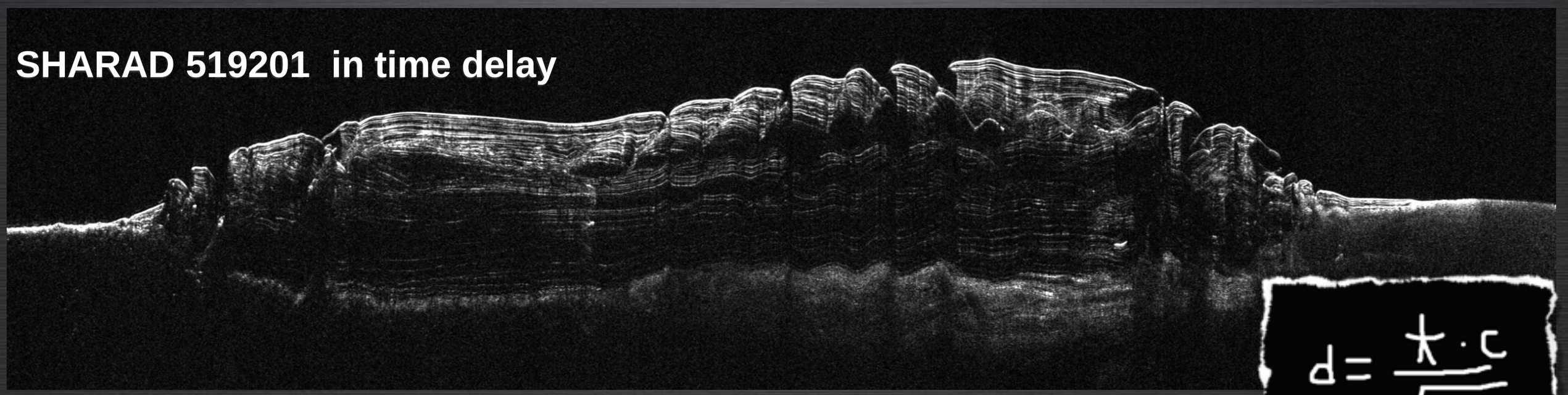


- Many people attempt to correlate layers to orbital parameters
  - **but how old are the deposits??**
    - *10 million years?*
    - *100 million years?*
    - *1 billion years?*
  - **and how continuous is the depositional record?**

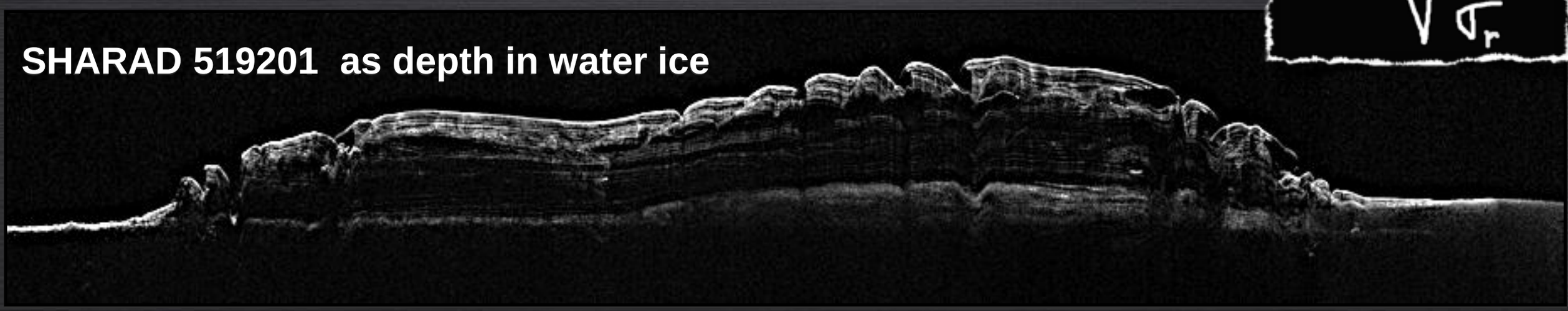


Data: MARSIS vs SHARAD



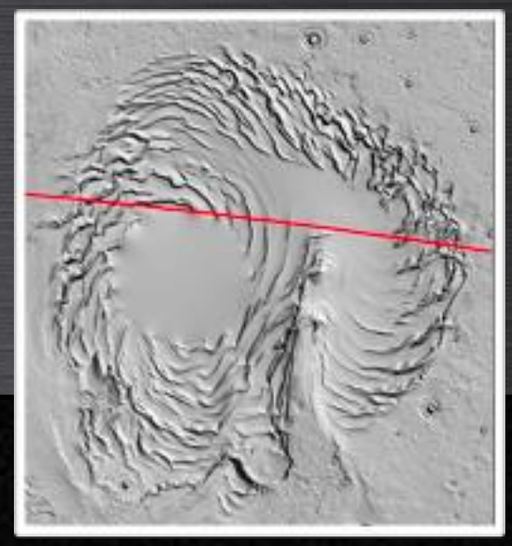


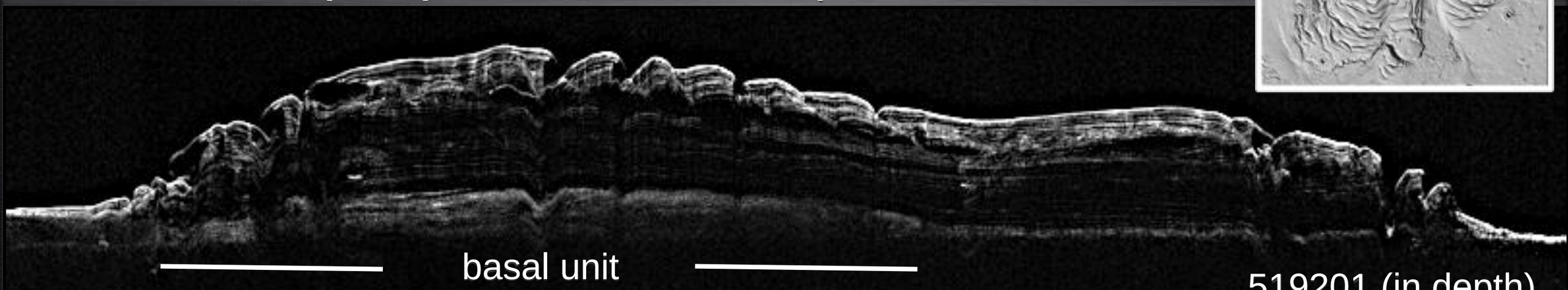
$$d = \frac{t \cdot c}{\sqrt{\varepsilon_r}}$$



First-Order Results for SHARAD Over the Polar Caps

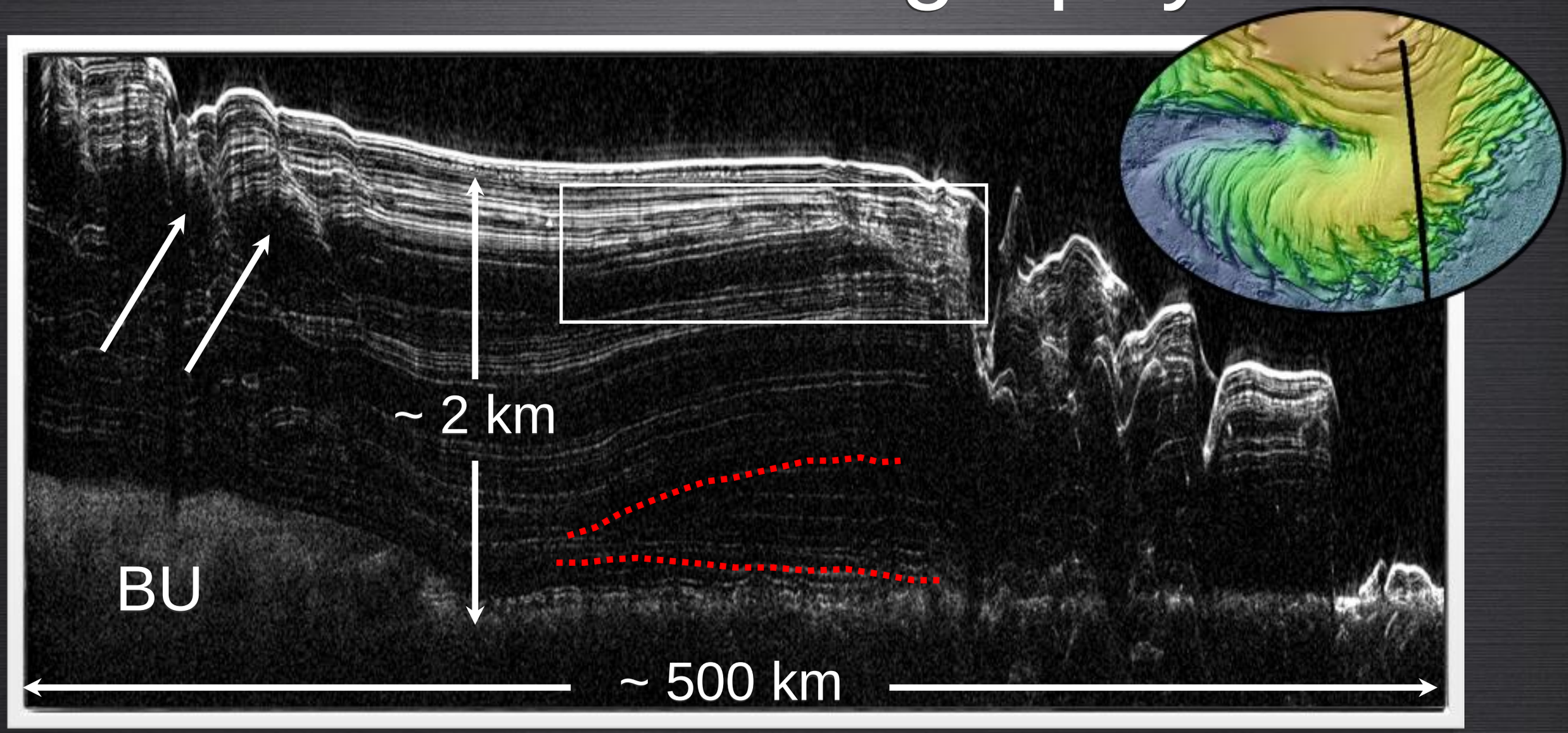
(Phillips et al., Science, 2008)





- Composition must be nearly pure (~ 95%) water ice
  - **Volume equivalent to a global water layer ~ 9 m thick**
  - **Confirmed by independent gravity results**
- Lithosphere is not depressed from load
  - **Colder, thicker than expected (~ 300 km)**
- Reflectors are largely continuous across polar cap
  - **Mostly uniform thickness, but significant deviations observed**

Detailed Stratigraphy



529701 (depth) - Phillips et al., 2008

Lateral discontinuities

- **Most appear to be related to troughs in upper layers**

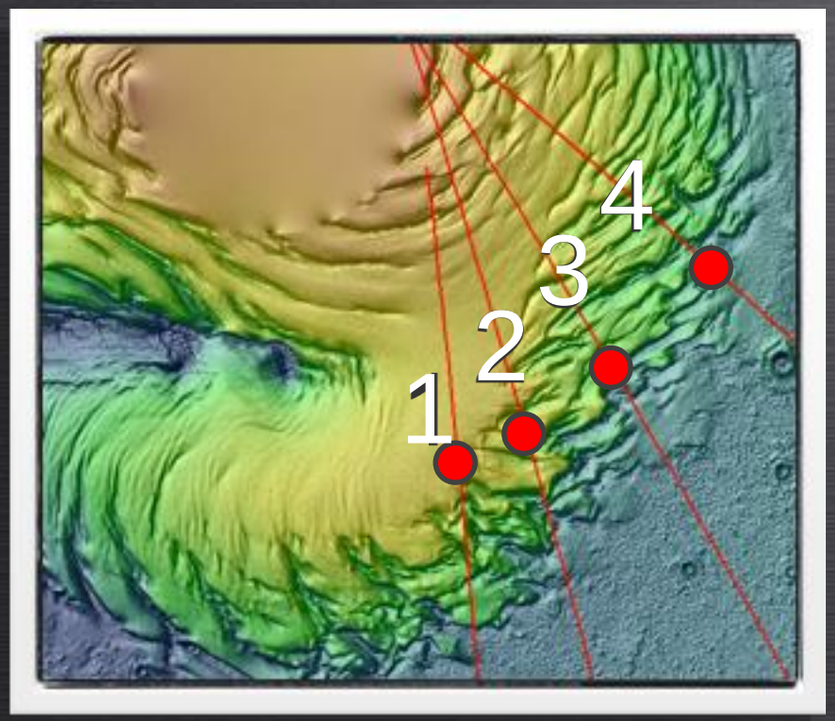
Thickness changes

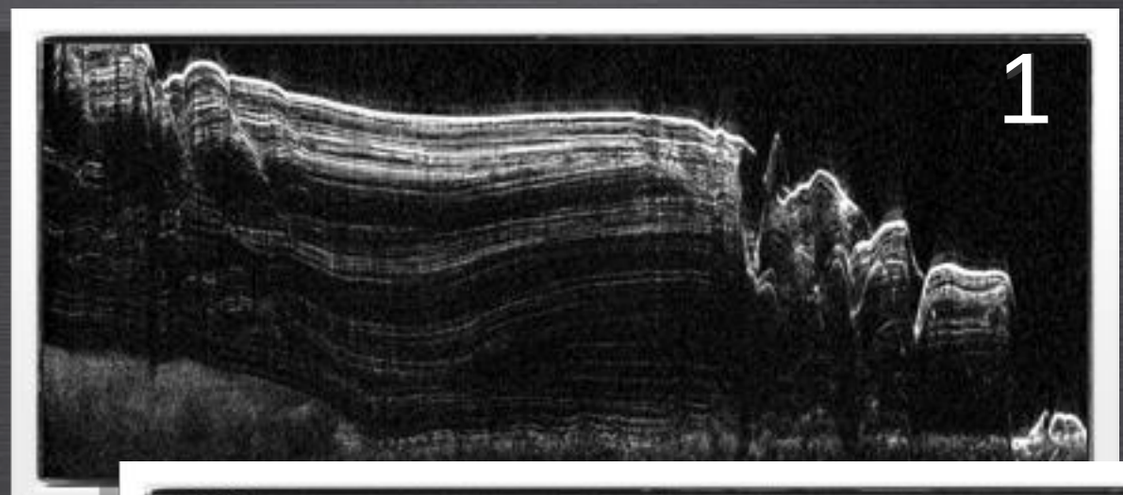
- **Layers that are truncated or pinch out laterally**

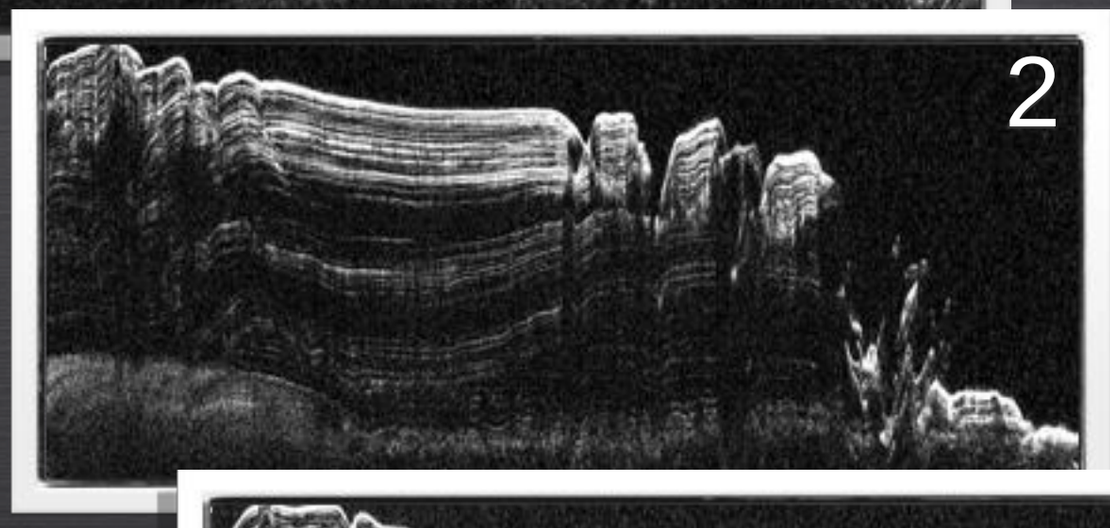
Angular unconformities

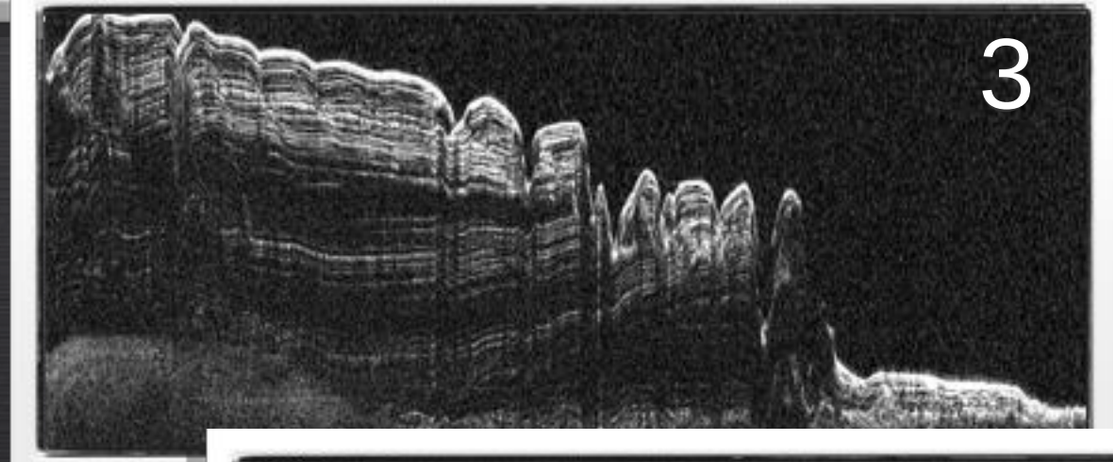
- **and disconformity**

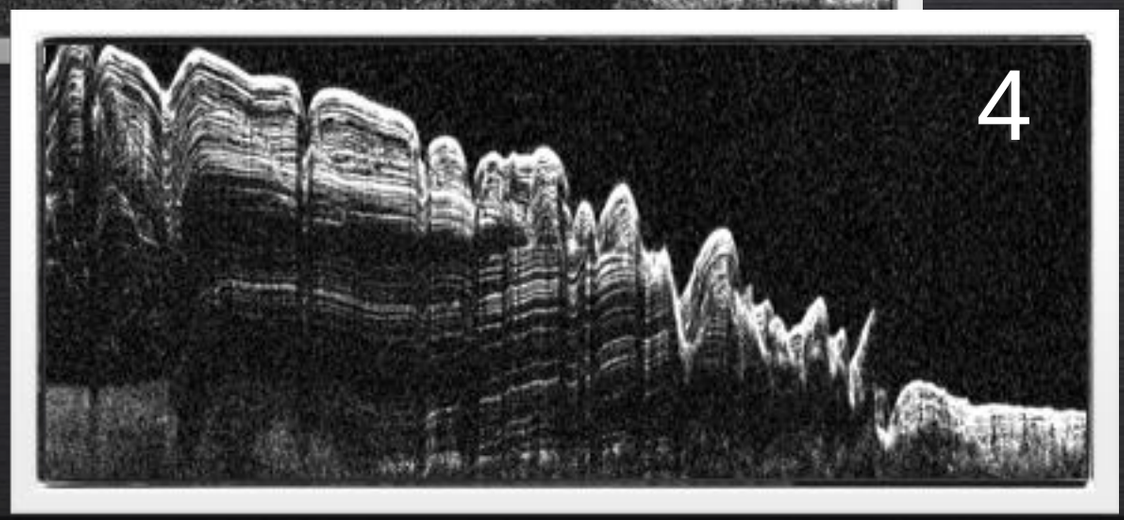
Building 3-D Stratigraphy











Spiral Troughs

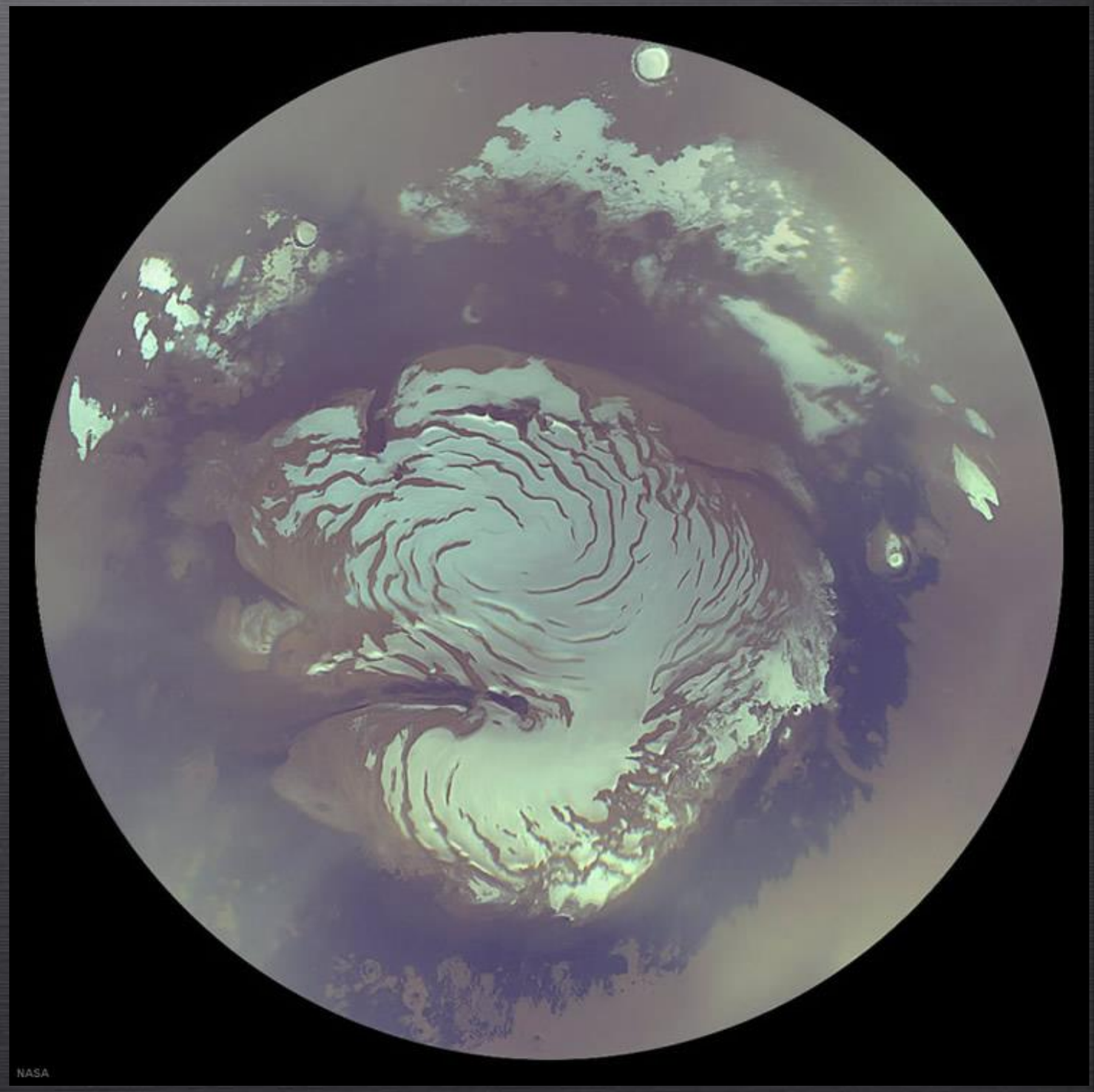
How did they form?

Are they old or young?

Why are the troughs spiral shaped?

Were they cut into the polar deposits, or grow with them?

Have they moved?



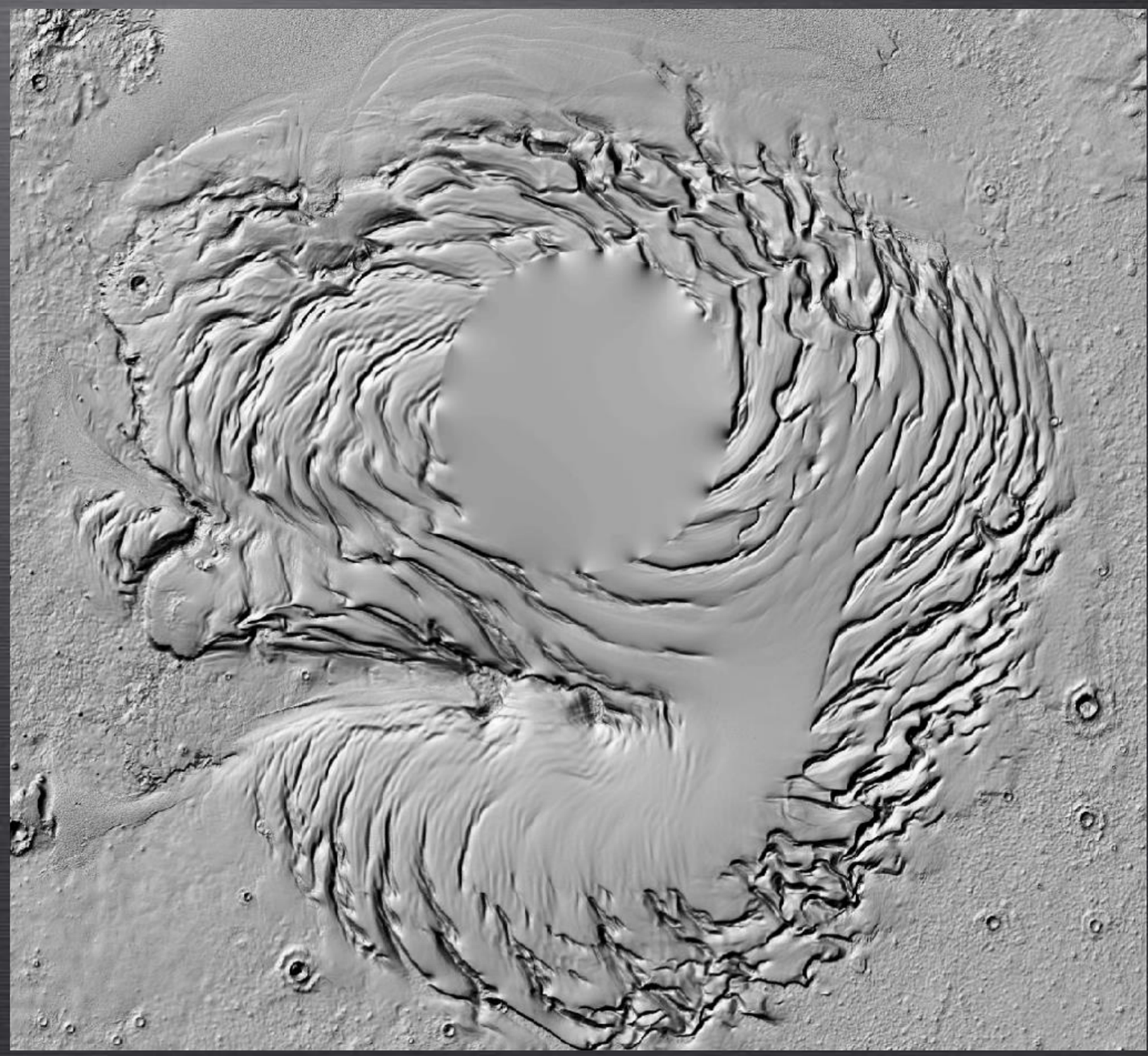
- Context Camera (CTX) images show layers on south facing slopes

- North-facing slopes tend to be blanketed with deposits

Could wind be involved?

Coriolis Force deflects winds similar to hurricane on earth, but opposite direction

On Mars winds push out from cap, on earth winds move inward to low pressure



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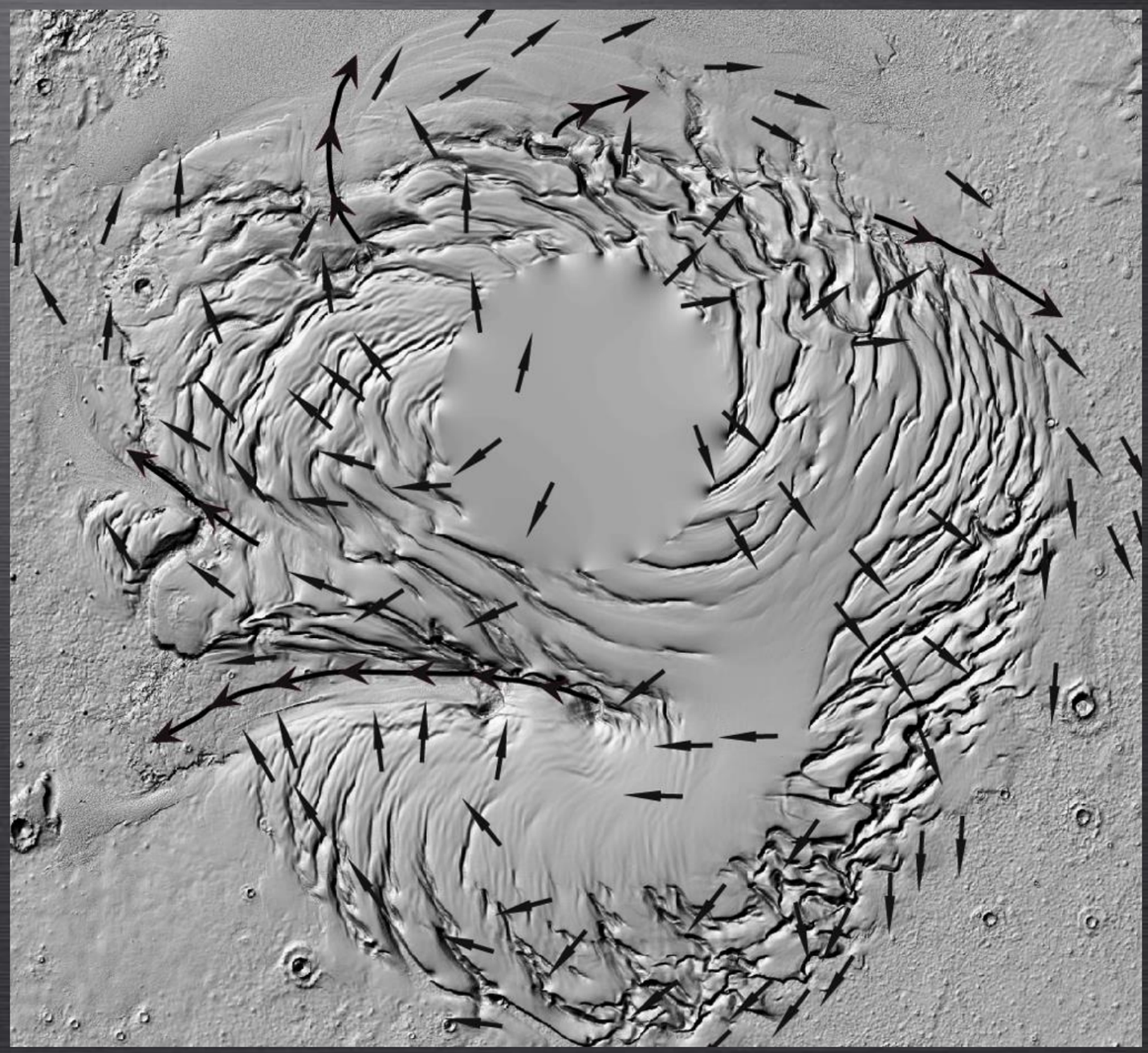
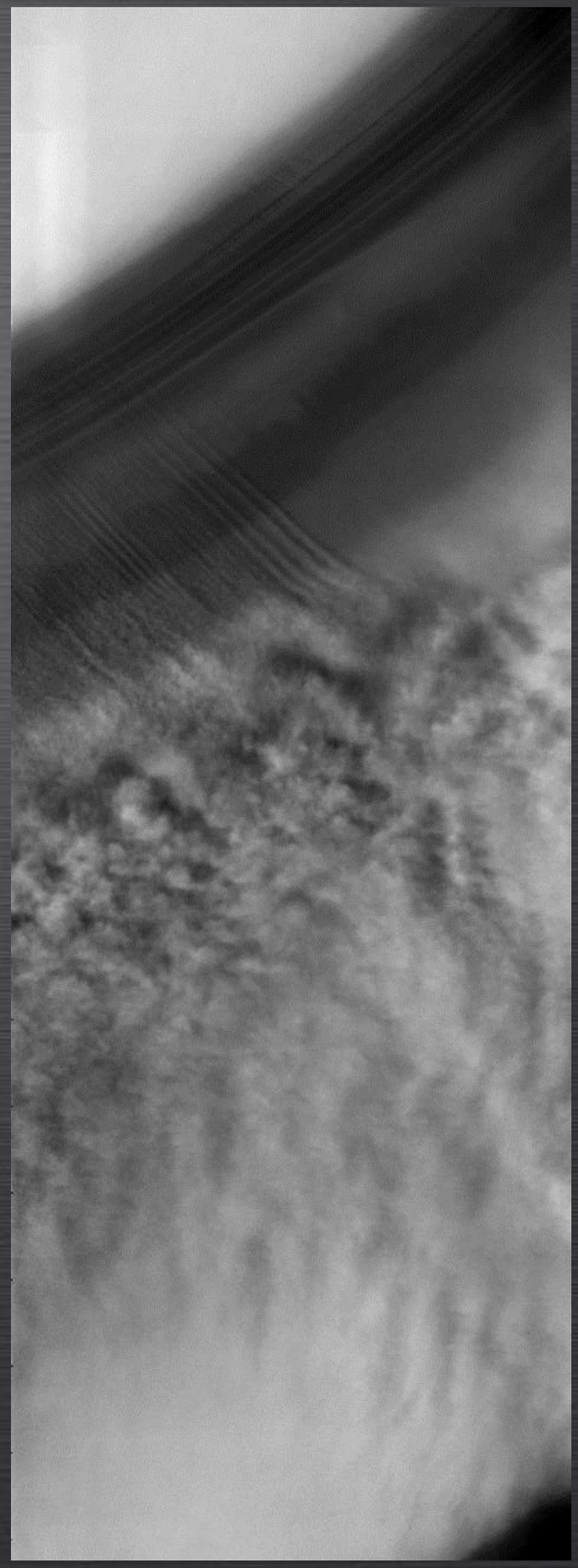


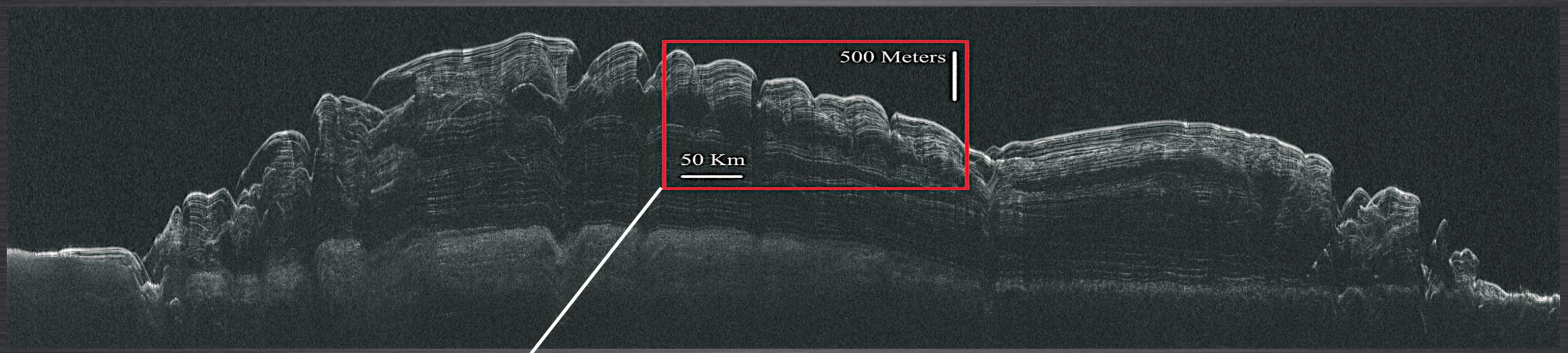
Wind in Action

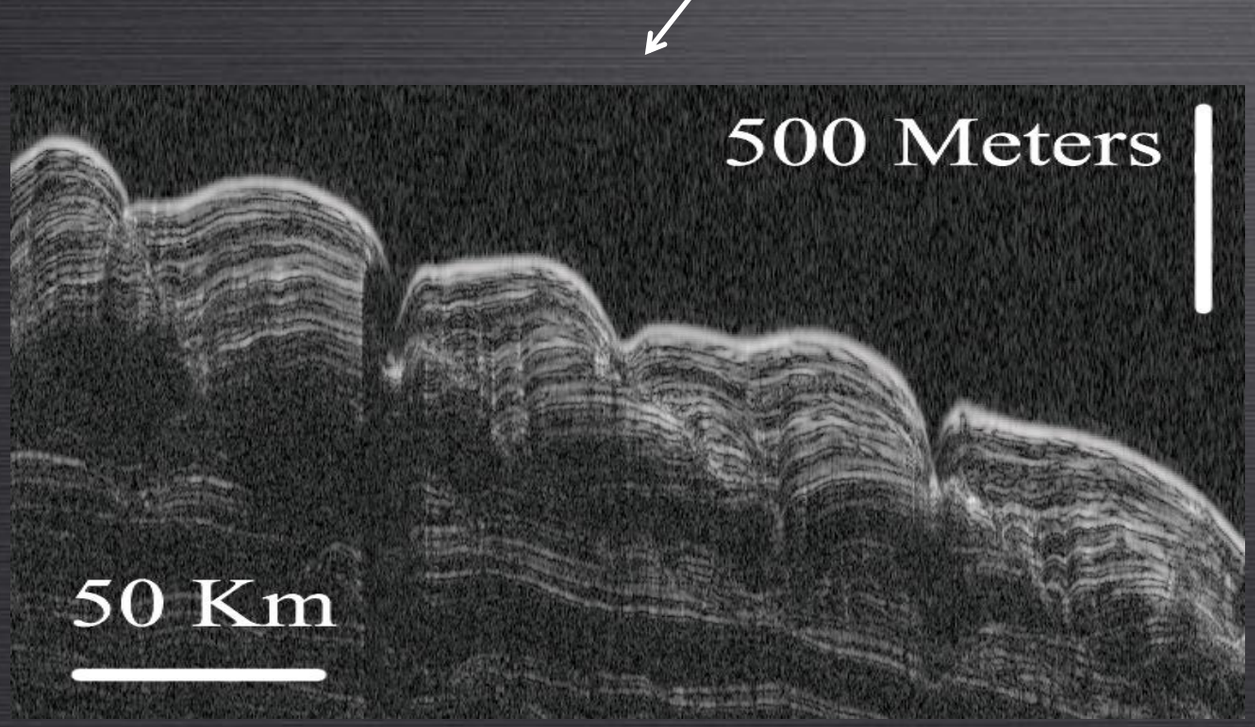
- Down-slope winds imaged by the THEMIS instrument on Mars Global Surveyor

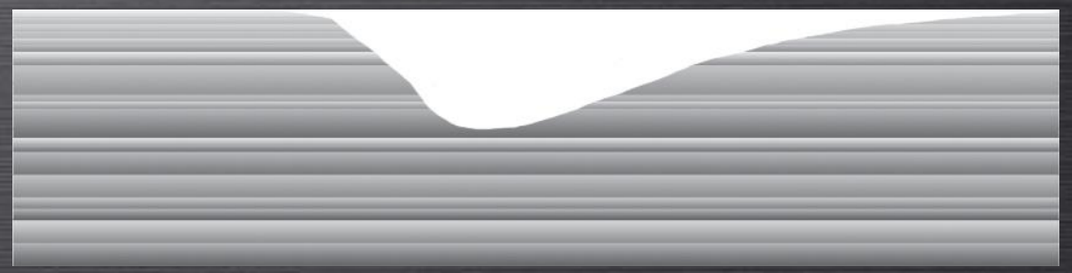
- Dust and loose ice crystals are removed from the steep slope, and deposited on the opposite, shallow slope



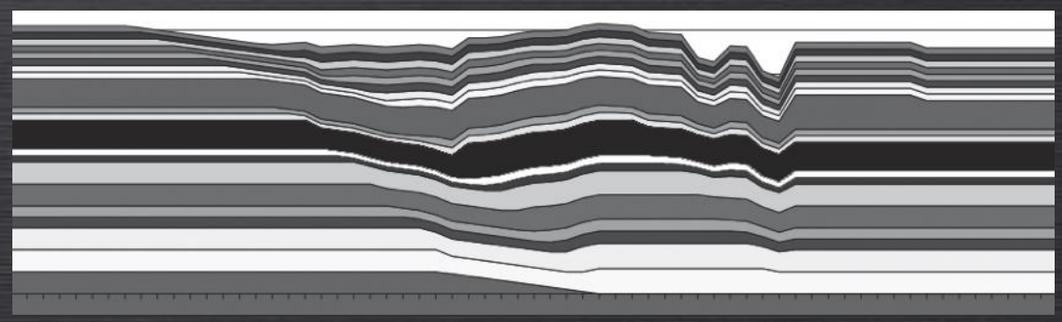
Let’s look at the radar data







Downcutting Model



Deposition + Wind Model

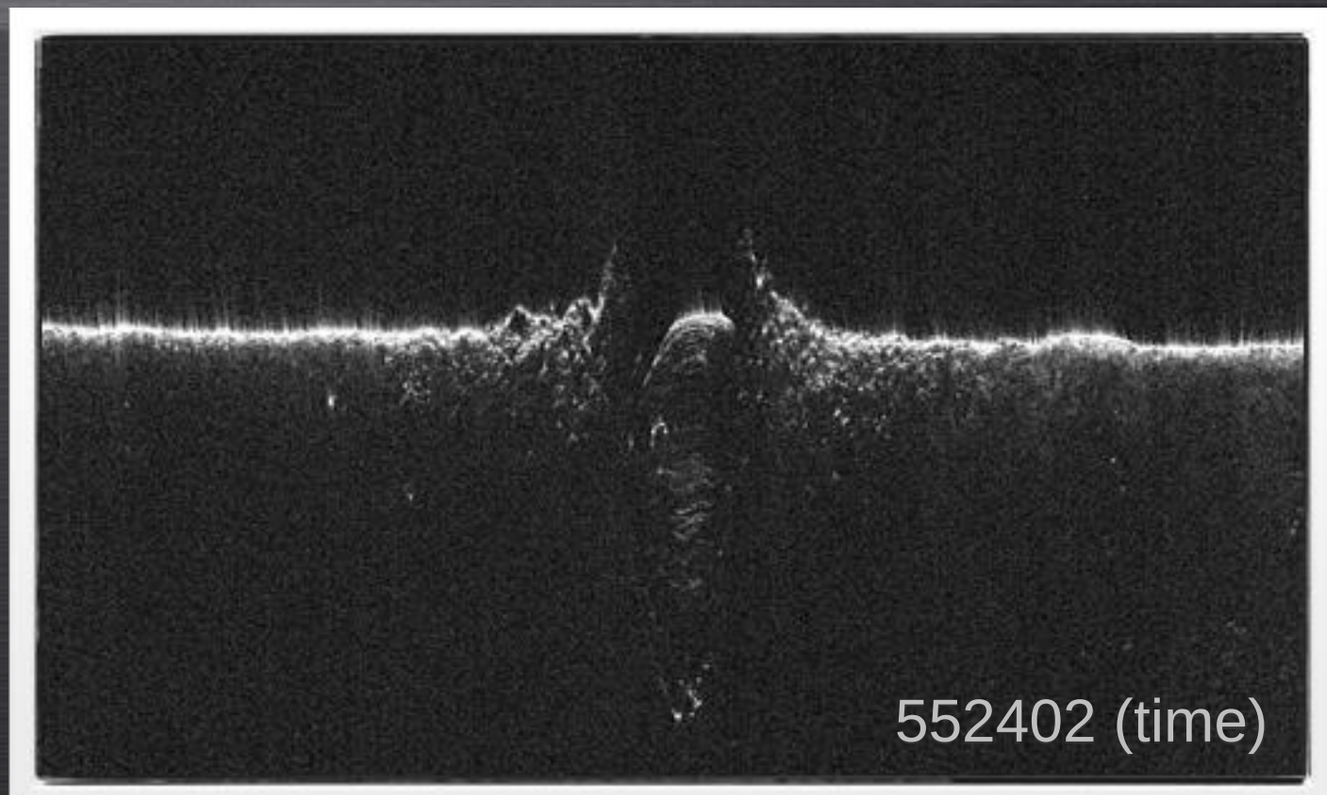
They are not recent!

Korolev Crater

(This One)

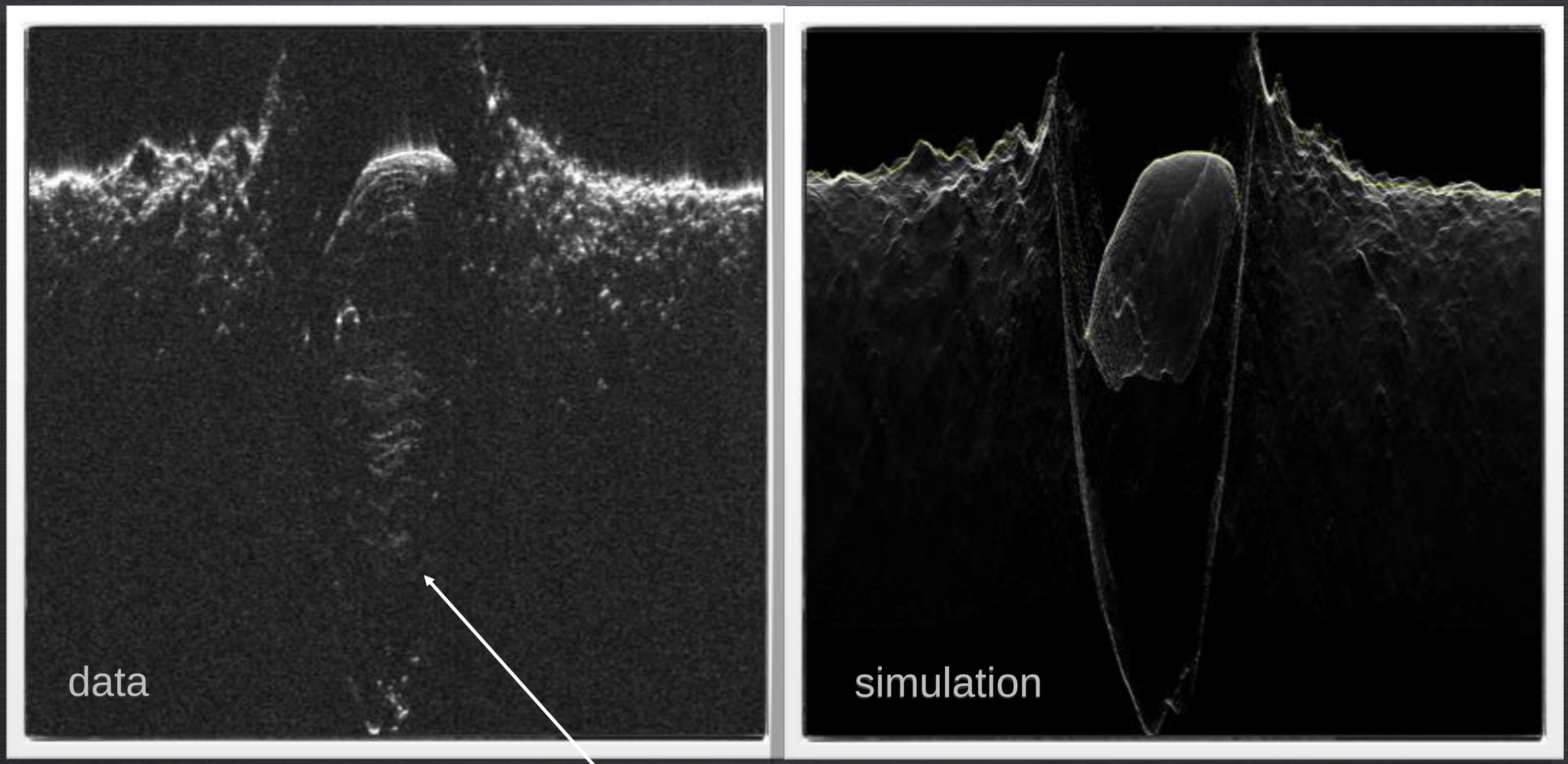
CTX P22_009754_2529_XN_72N195W

SHARAD data crossing Korolev Crater



Armstrong and others concluded based on THEMIS and TES observations that the interior deposits contain several meters of water ice or ice-rich regolith

Korolev Crater



1.78 km
in ice!!

The Future

- Still much to learn on Mars
  - Have barely scratched the surface with SHARAD
  - Still acquiring new data!
  - An imaging SAR with shallow depth penetration capability (~ 400 MHz for a few meters) would be great!
- Earth analogs can be even more useful now that we have Mars data
  - Adding a SHARAD emulator to the UTIG airborne platform for the 2009-10 Season
- Europa!
- Life on Mars?

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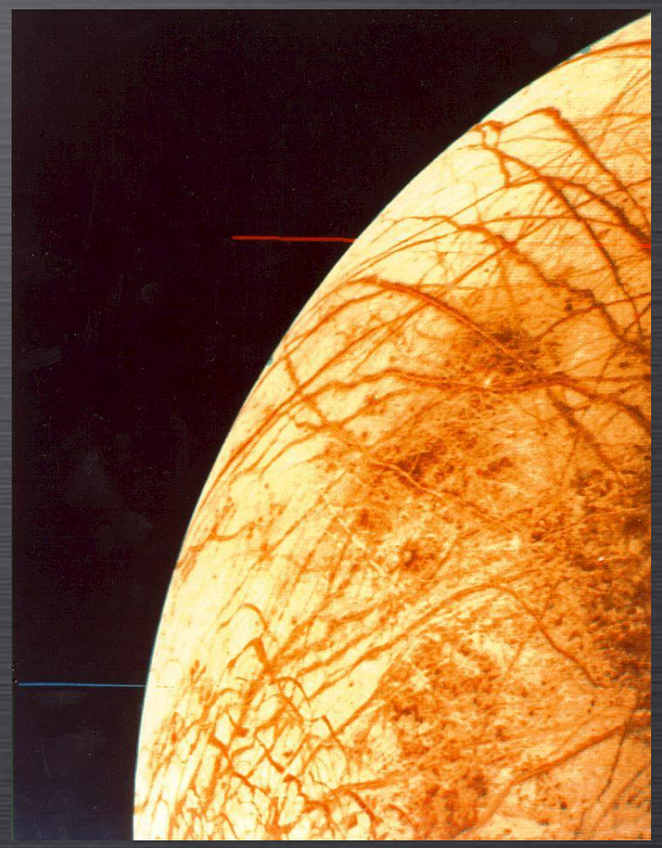
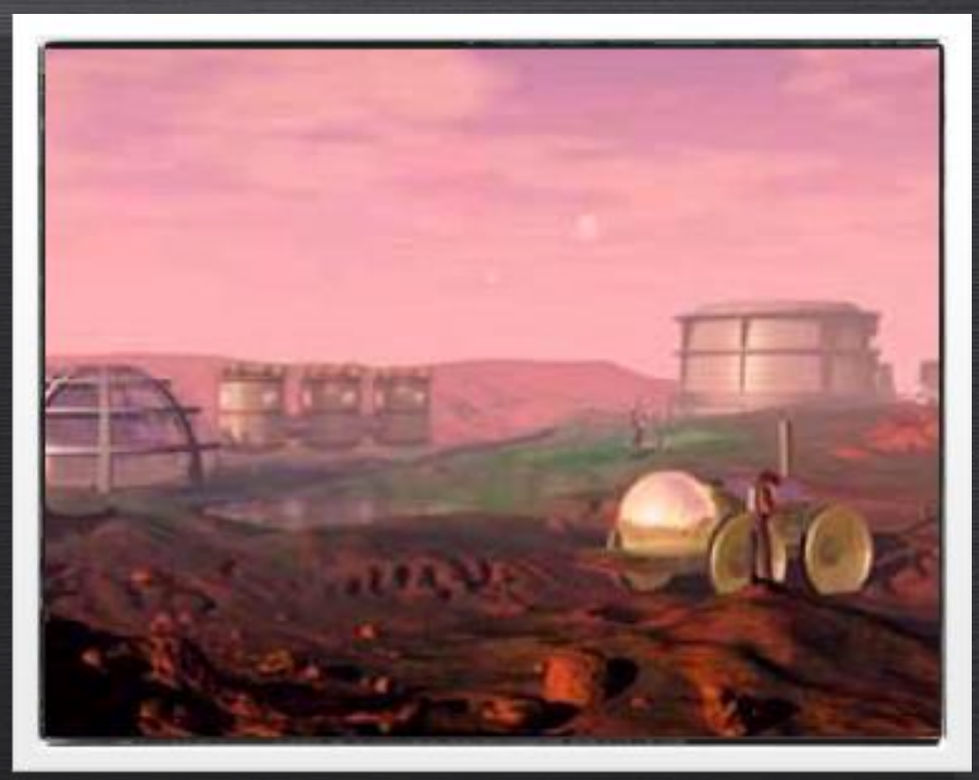


Man on Mars?

- What would we need?
  - ***National commitment***
  - ***A 20-year presidency?***

- Water (on Mars)
  - ***for people to drink and grow food***
  - ***for fuel***



NASA

Acknowledgments

- Students
  - **Isaac Smith (Ph.D. candidate, Geophysics)**
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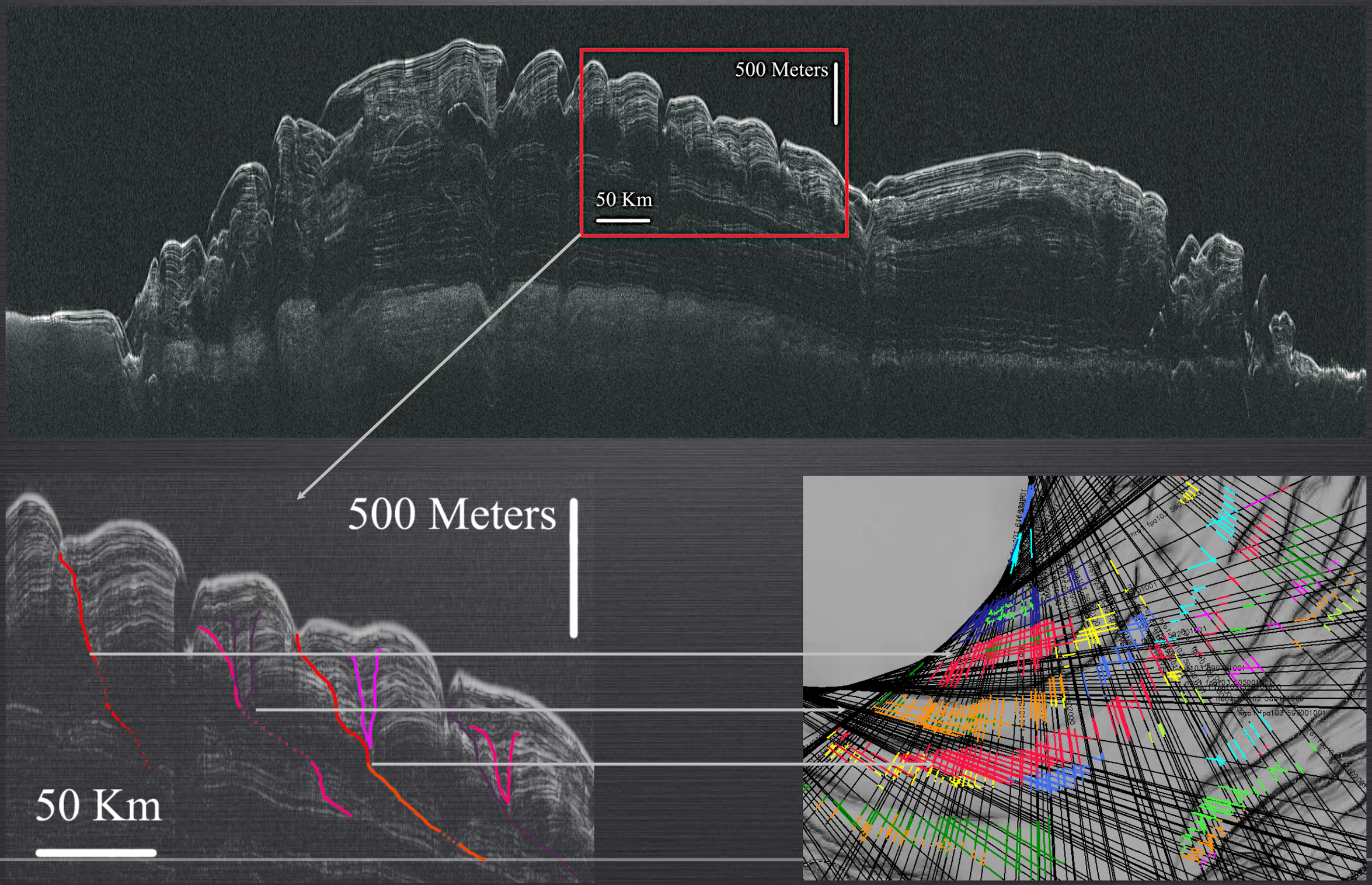
  - **Sarah Christian (Undergraduate, Geology, Bryn Mawr)**
  - **Charles Brothers (Ph.D. candidate, Geology)**
- Technical/Research Staff
  - **Scott Kempf**
  - **Dr. Duncan Young**
- NASA Grants NAG5-12693 and NNX08AR34G
- The SHARAD Team
- SHARAD OPERATIONS CENTER, ROME

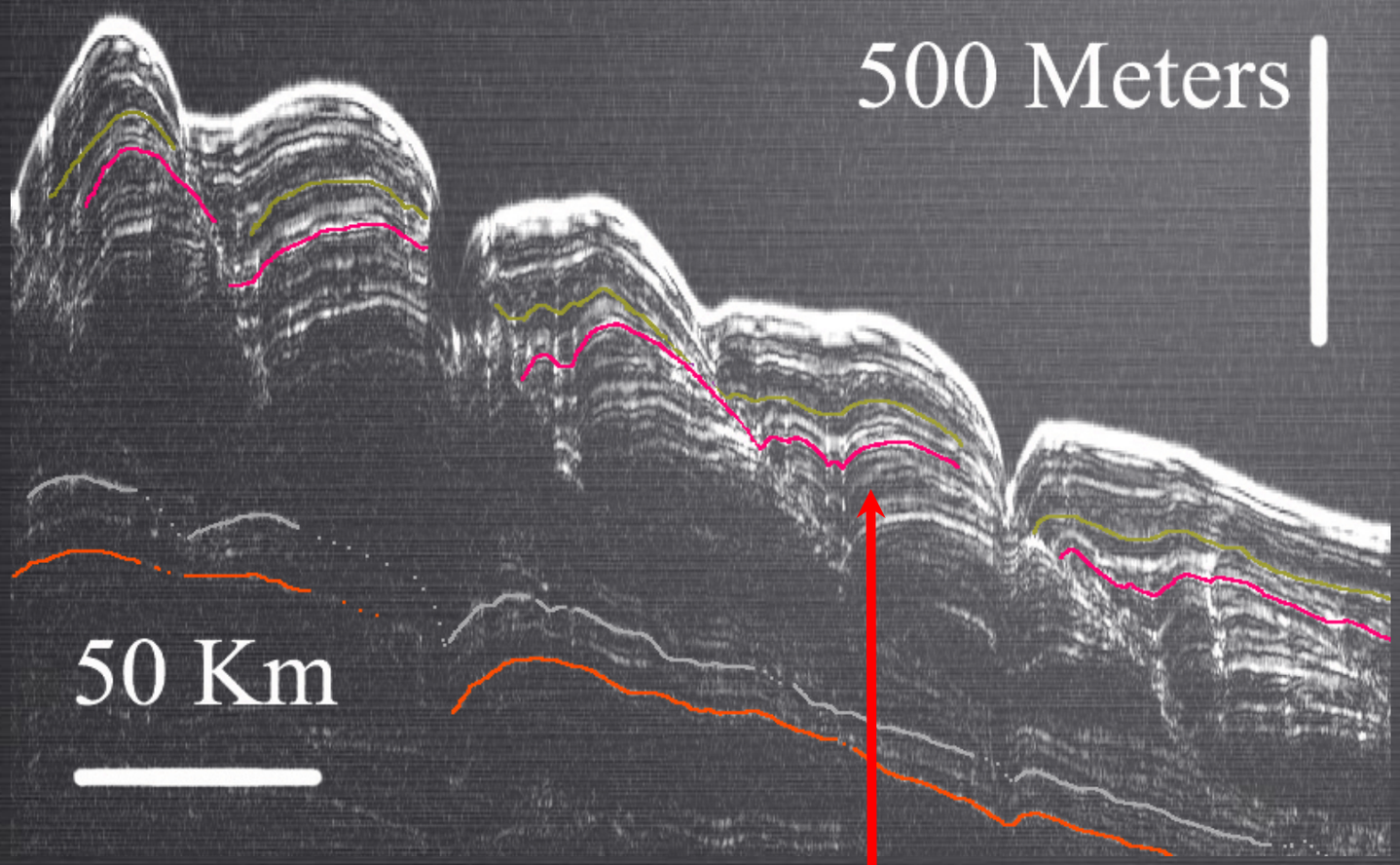
This talk is dedicated to the memory of my friend and colleague Ali Safaeinili.

Without his brilliant work in helping to design SHARAD and transform the data from raw numbers to beautiful pictures of the subsurface, this work would not have been possible.

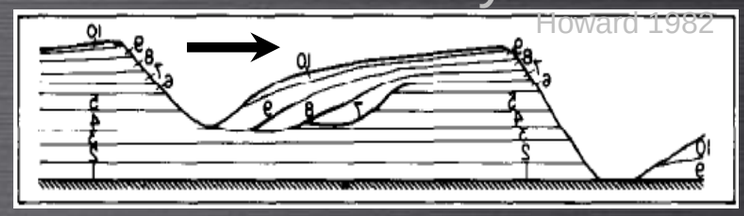
Let’s look at the radar data



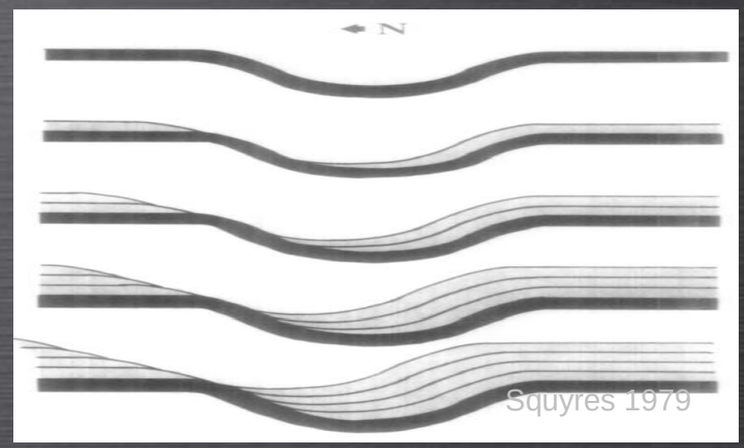
What processes are at work?



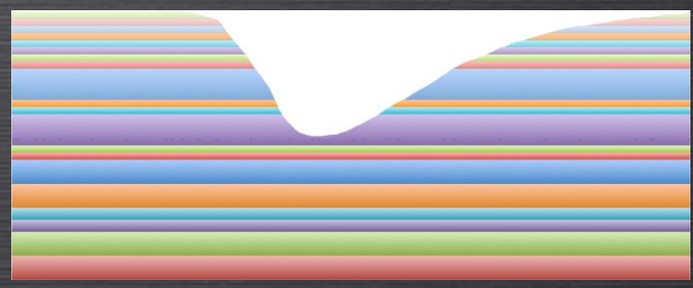
Predicted layers



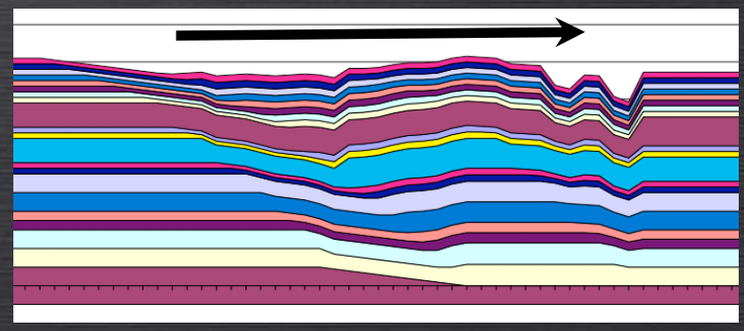
Erosion + Wind



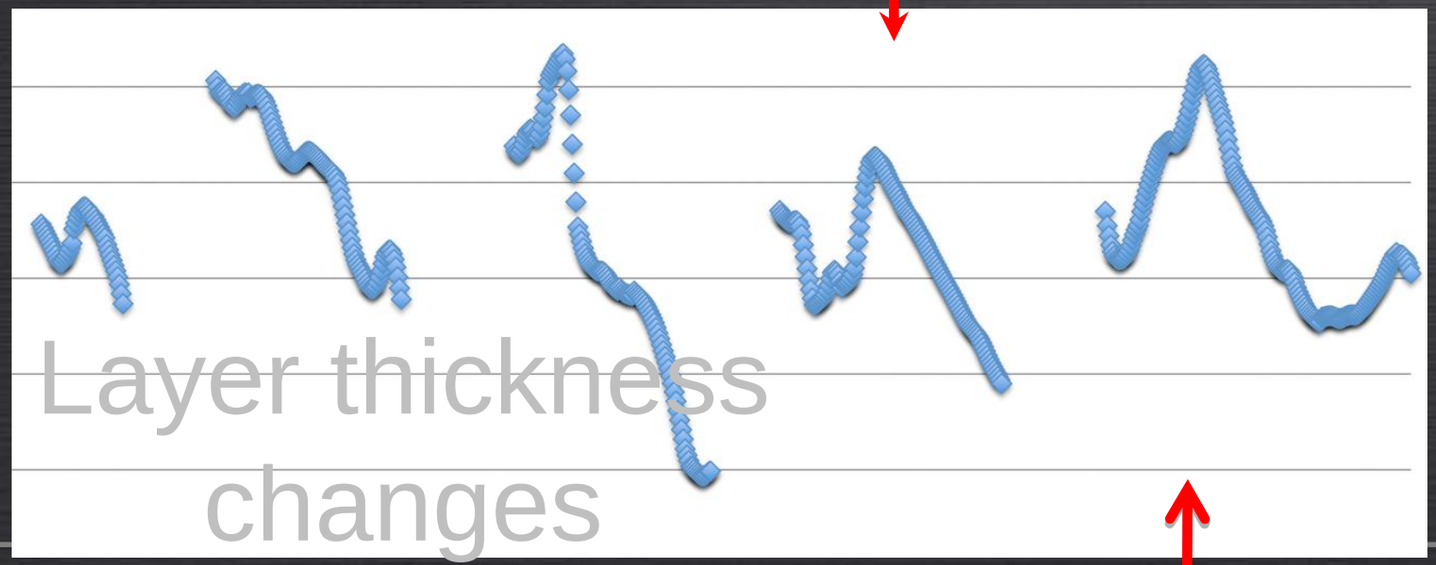
Solar Ablation



No Migration



Wind with Deposition



Hypothesized Process of Trough Migration

Howard et al. (1978), Squyres (1979)

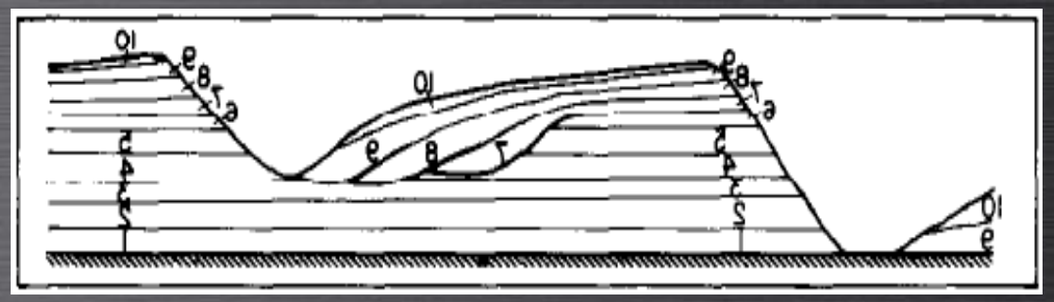
1. Initiation of a surface depression (unknown process)

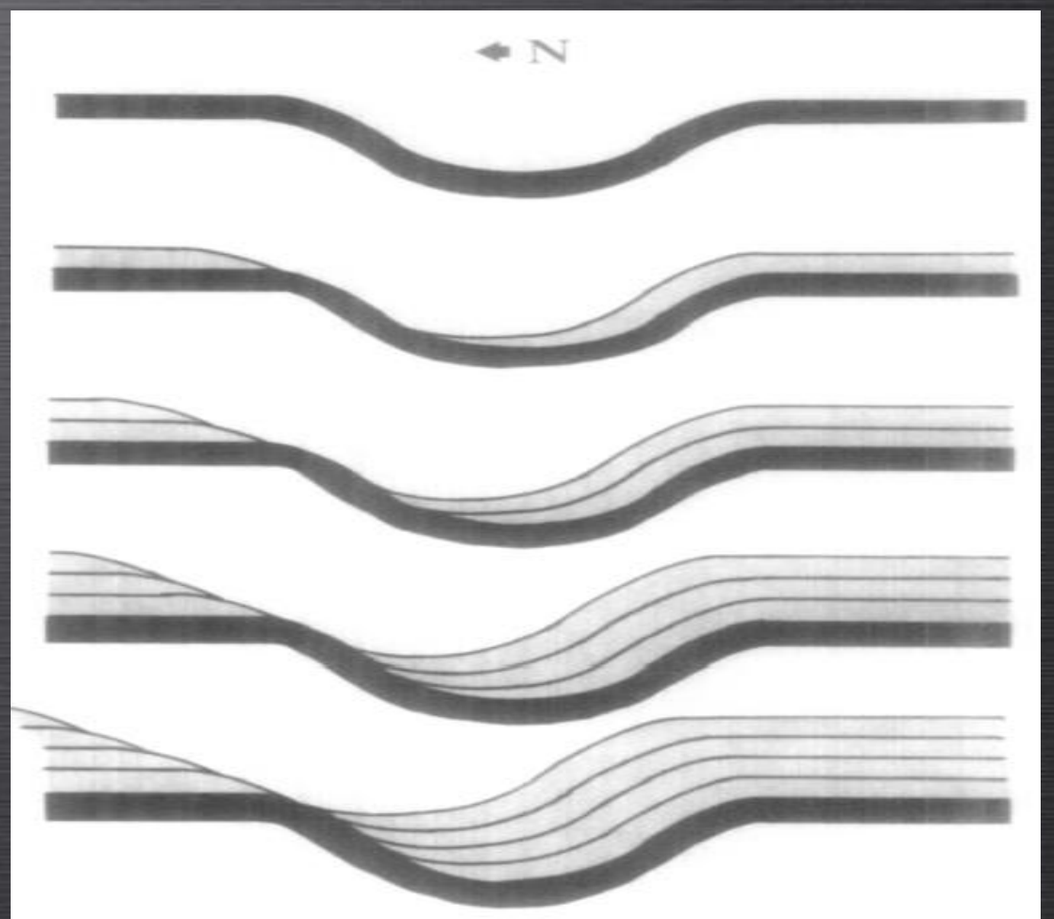
2. Solar-induced ablation and down-slope winds remove material from equator-facing slopes, exposing internal layers

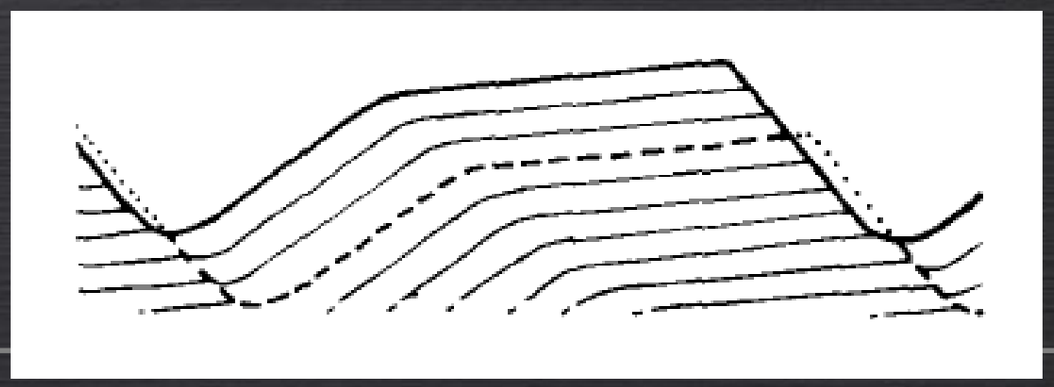
3. Winds deposit material downstream on north-facing slope.

4. Both slopes migrate northward

5. Continued deposition raises elevation of all surfaces.



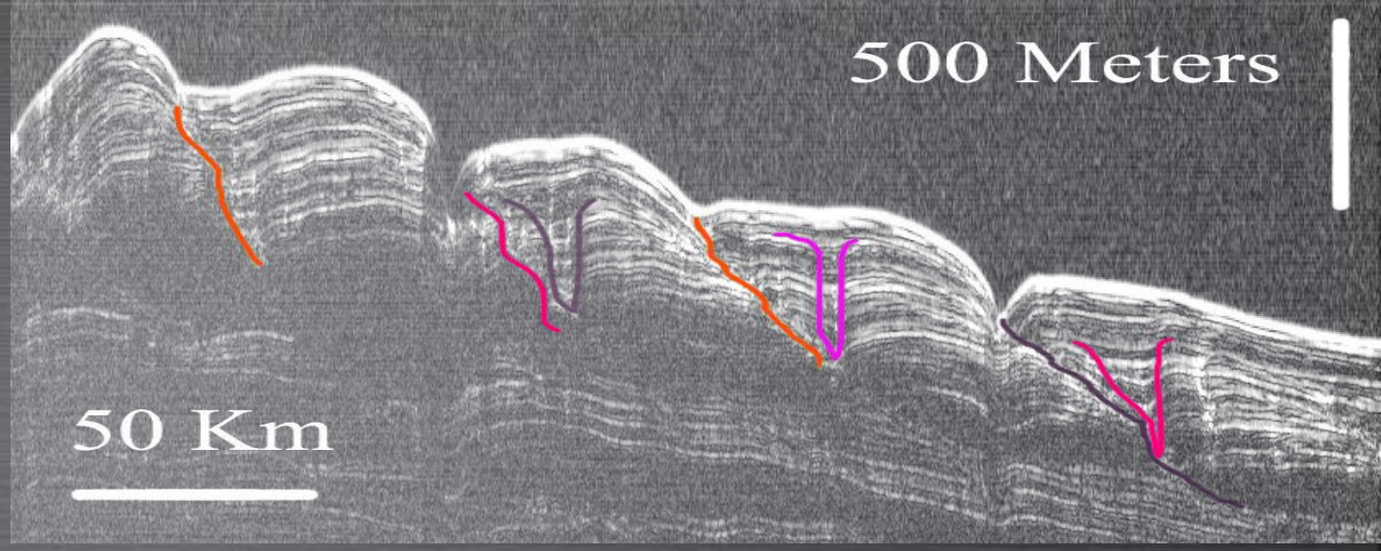


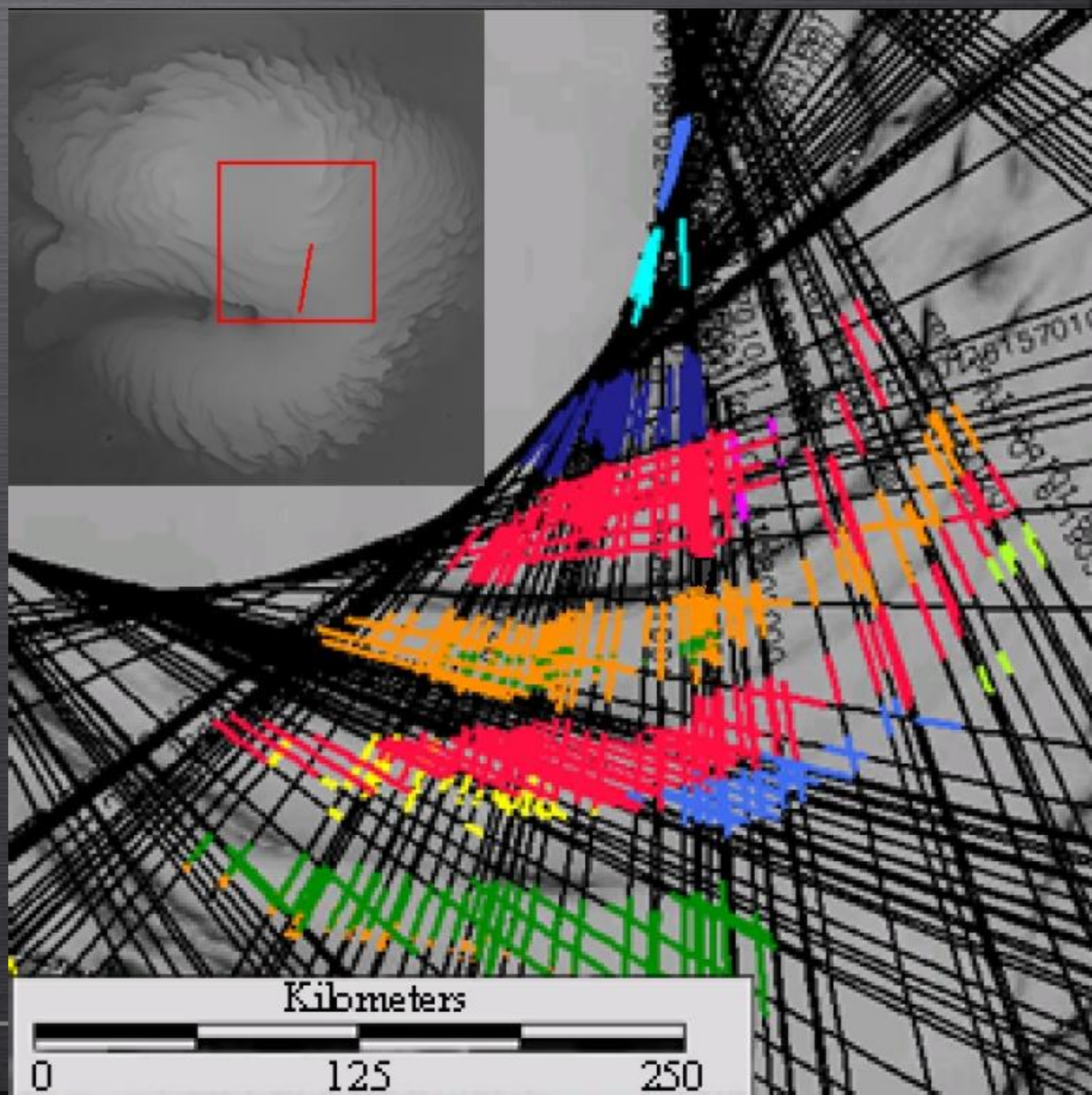


S.W. Squyres Icarus 40 1979

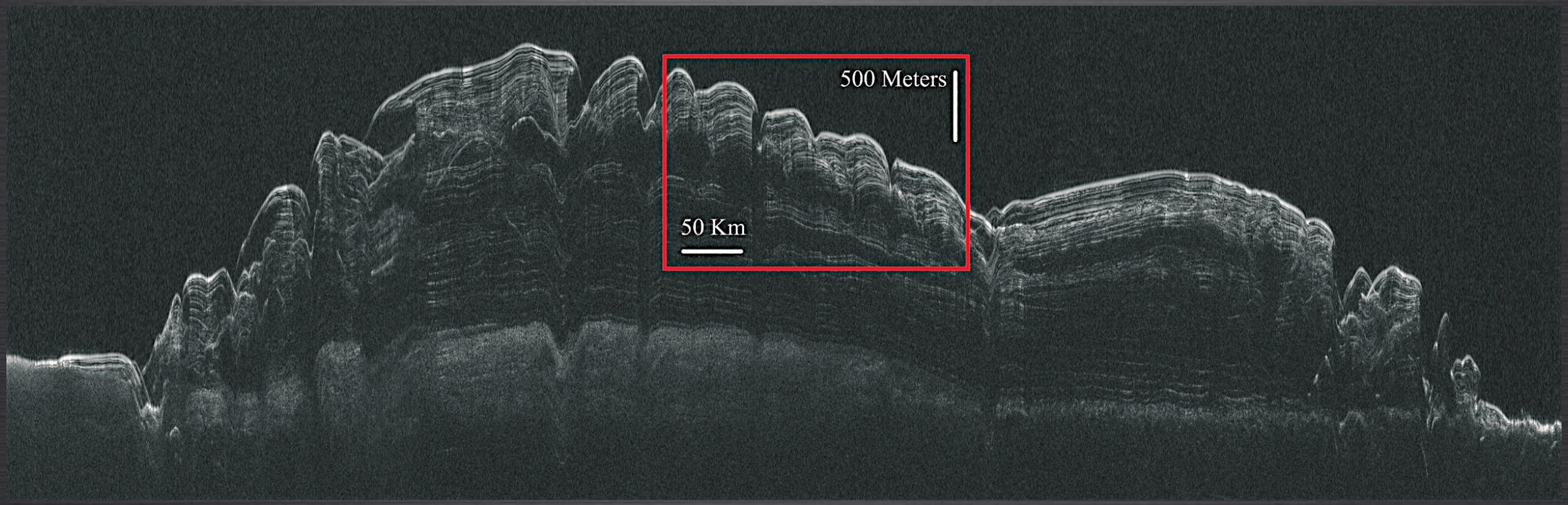
Conclusions Regarding Spiral Troughs

- Troughs have persisted throughout deposition of uppermost layers.
- Troughs have migrated both north and up as predicted by Howard and Squyres.
- Lateral transport (wind) is an important part of the process.





Remaining Questions about Troughs



- Why did troughs begin to grow at a certain time?
- Are they all the same?
- How do they compare in the south?

Dr. Jack Holt

Dr. Jack Holt employs airborne geophysical techniques to study ice-covered regions of Earth and Mars. He has led five field expeditions to Antarctica since 1998 to map the ice and features buried beneath the ice.

In early 2007 Holt was selected as a Participating Scientist on the SHARAD (Shallow Subsurface Radar)instrument team of the Mars Reconnaissance Orbiter. SHARAD looks for liquid or frozen water in the upper part of Mars' crust. This effort to find subsurface water on Mars is important for evaluating the possibility of life on the red planet and plays a role in planning any future human exploration of Mars.