PLANETARY GEOLOGY

Lecture 2 – Mars Geology PT2

Prof. Fulvio FRANCHI

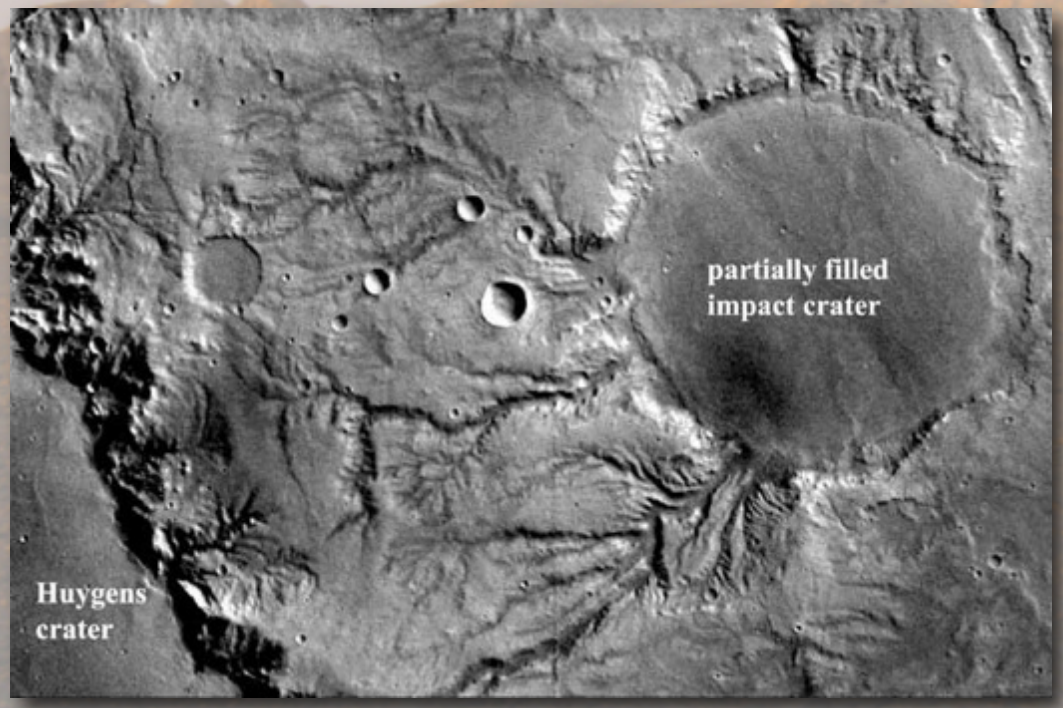
Mars Geology

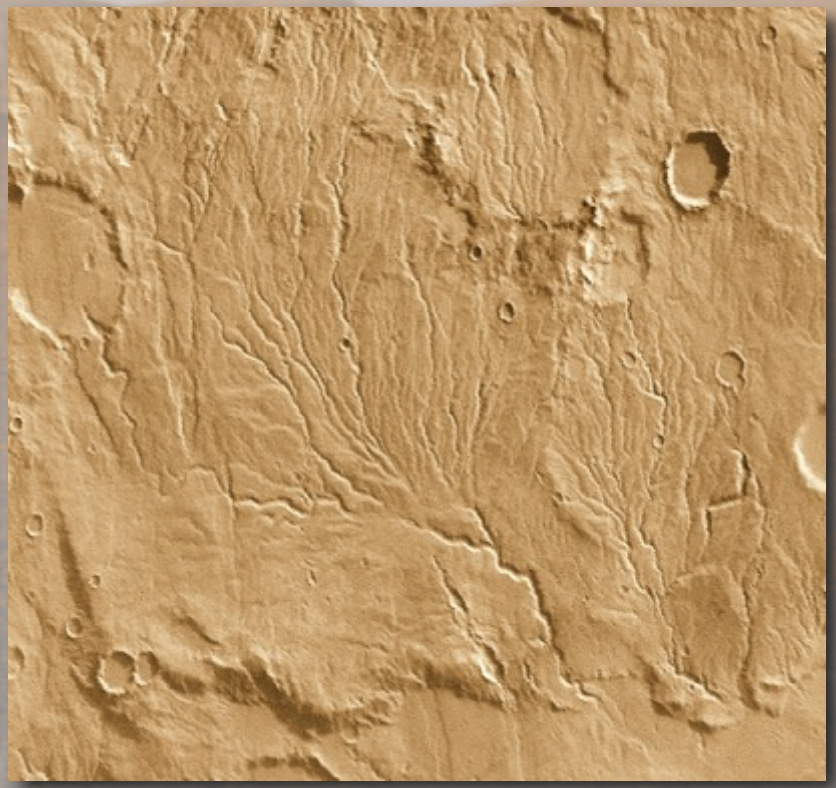
TOPICS TO BE COVERED:

- **Mars Geology (Pt. 2):**
  - **Valley networks**
  - **Alluvial fans and deltas**
  - **Outflow channels**
  - **Chaotic terrains**
  - **Layered deposits**

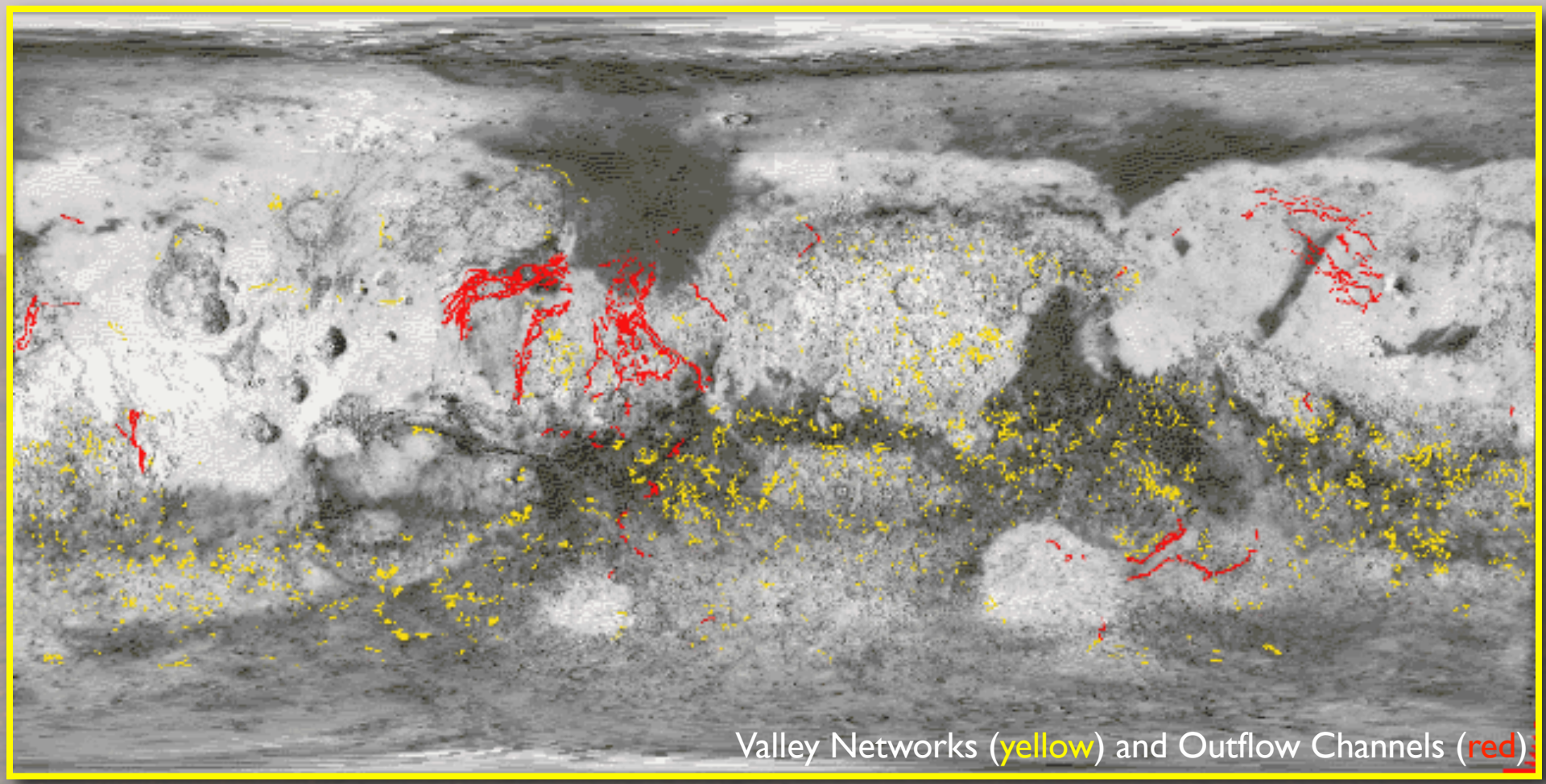
Valley Networks

- Usually very ancient, dating back to Noachian
- Dendritic fluvial systems
- Occurrence mostly in Southern Highlands

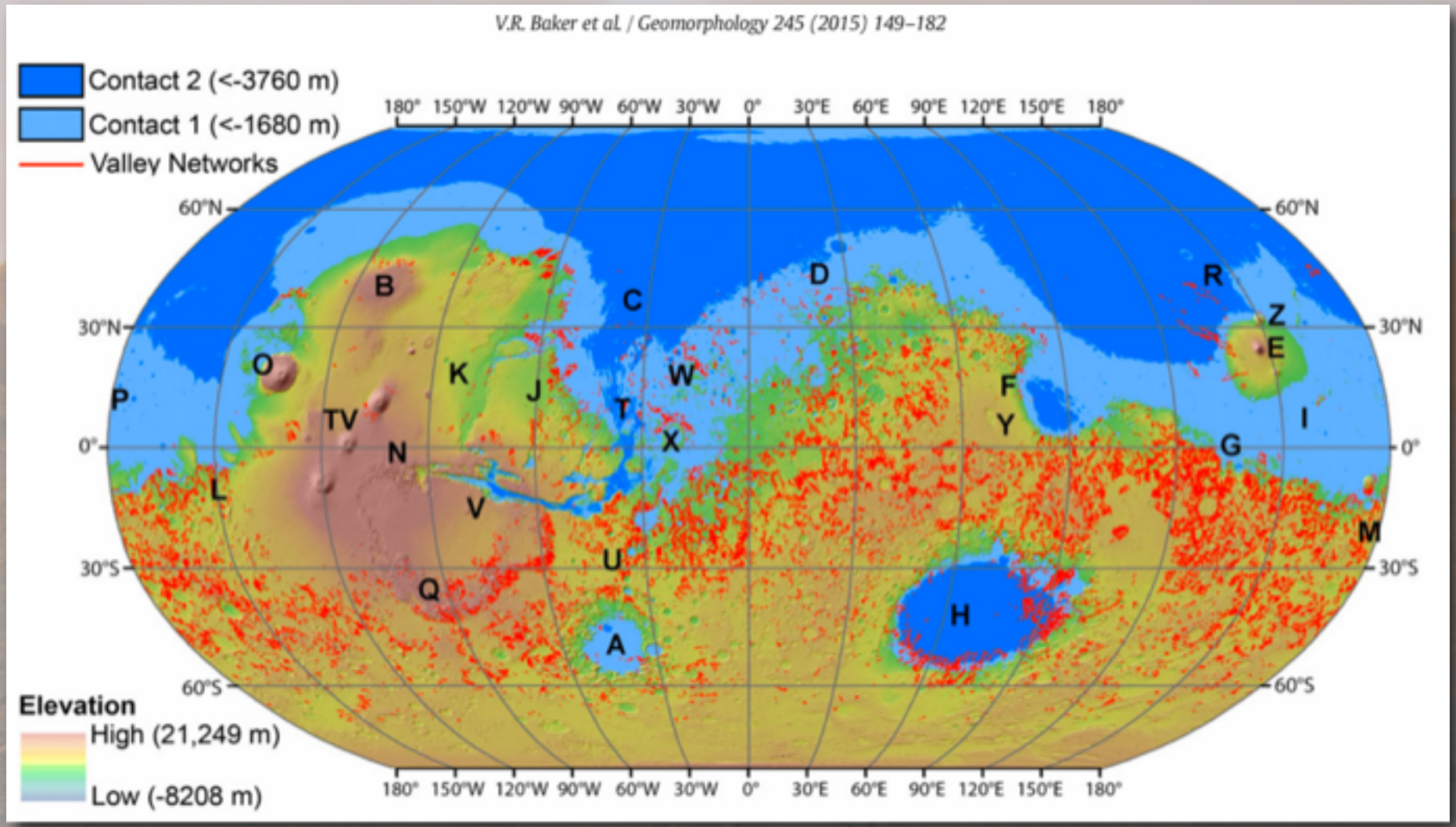




Valley Networks



Valley Networks

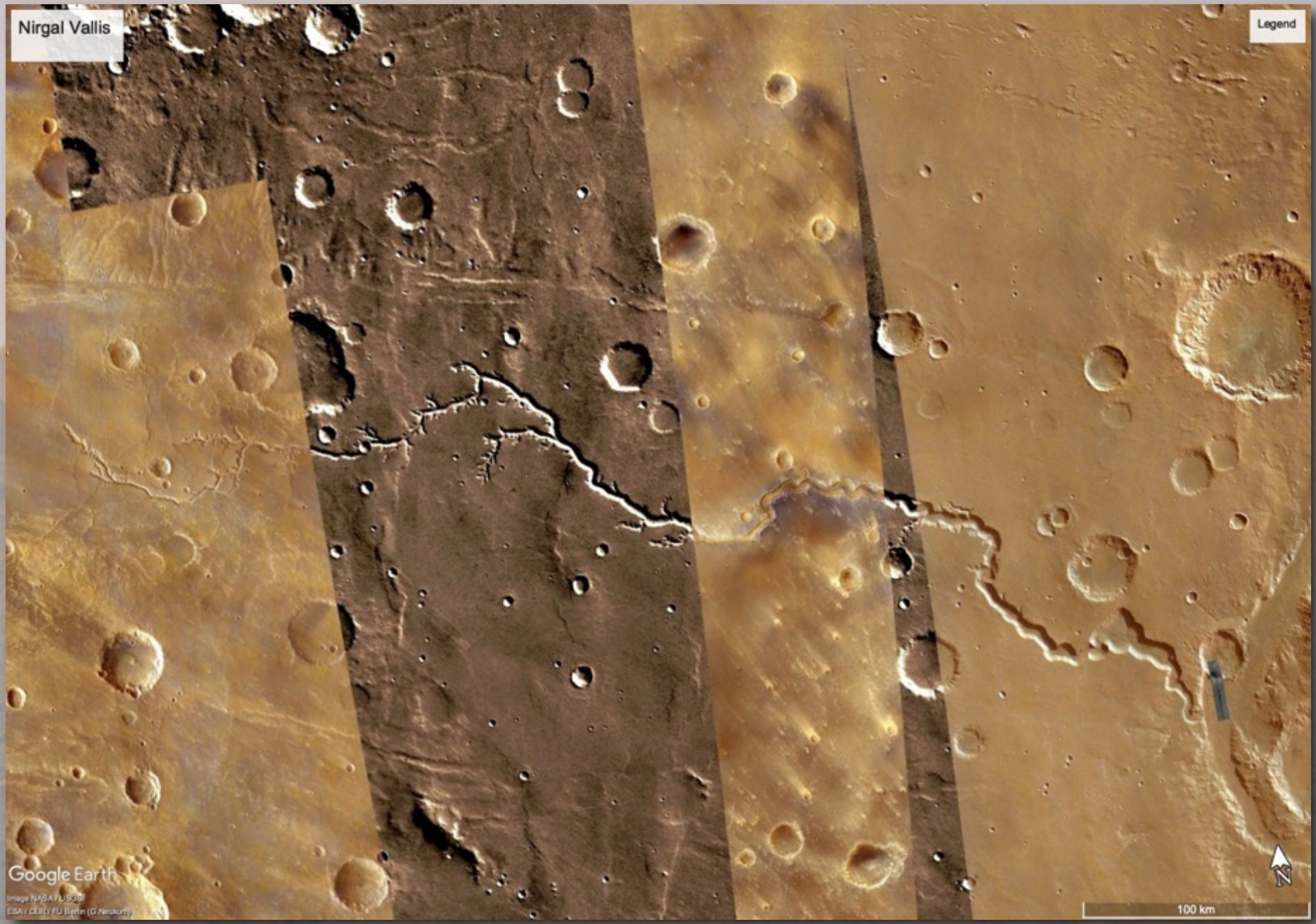


Valley Networks

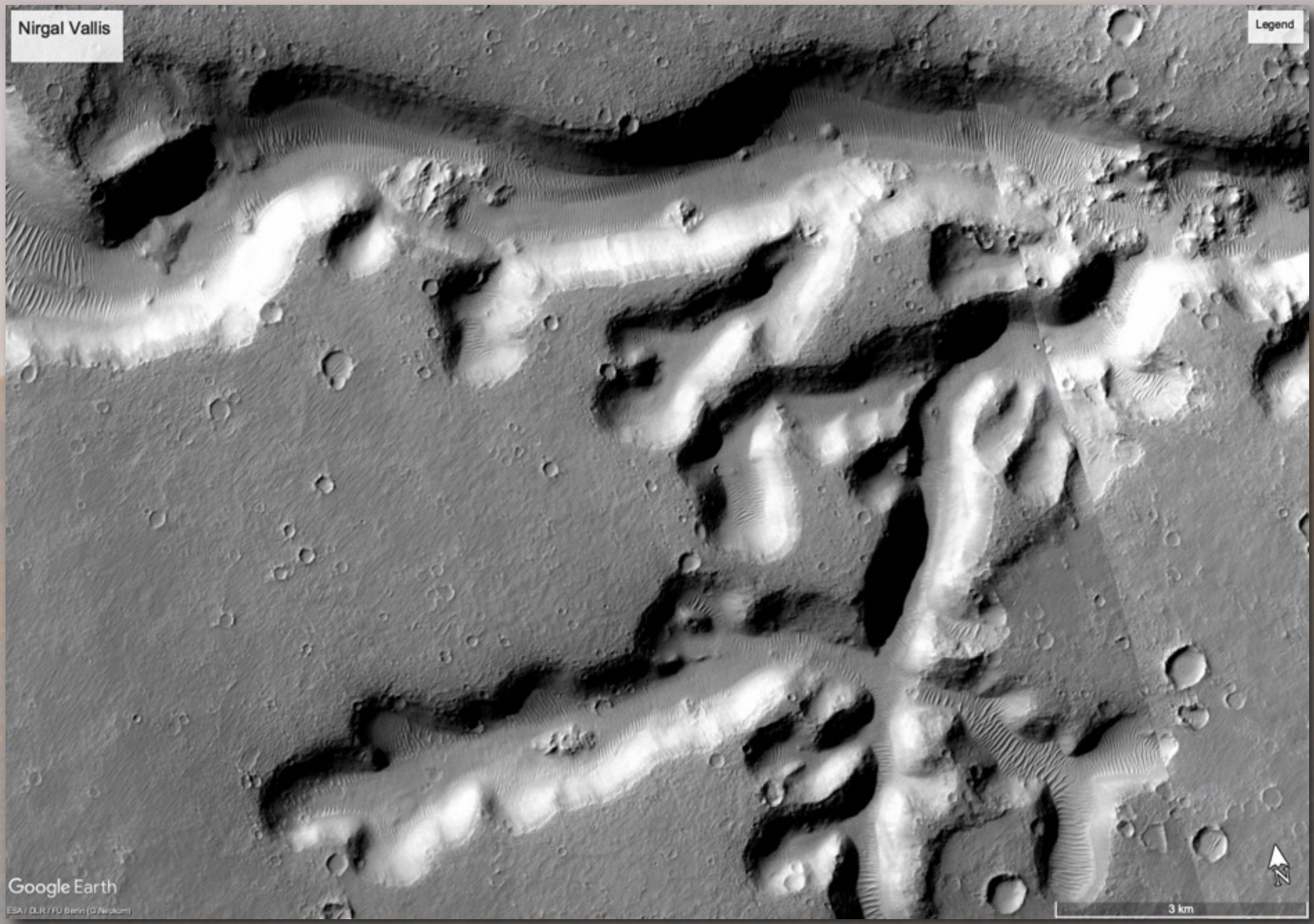
- Valley networks are (often) dendritic drainage systems on Mars
- Very old age usually, in most cases Noachian - early Hesperian (exceptions for some networks on volcano flanks)
- Relative role of ancient rainfall or sapping (groundwater) still debated (possibly hydrothermally driven)
- Formed, in any case, during a period when Mars had much more water availability, both in the atmosphere, surface and subsurface

Sapping channels

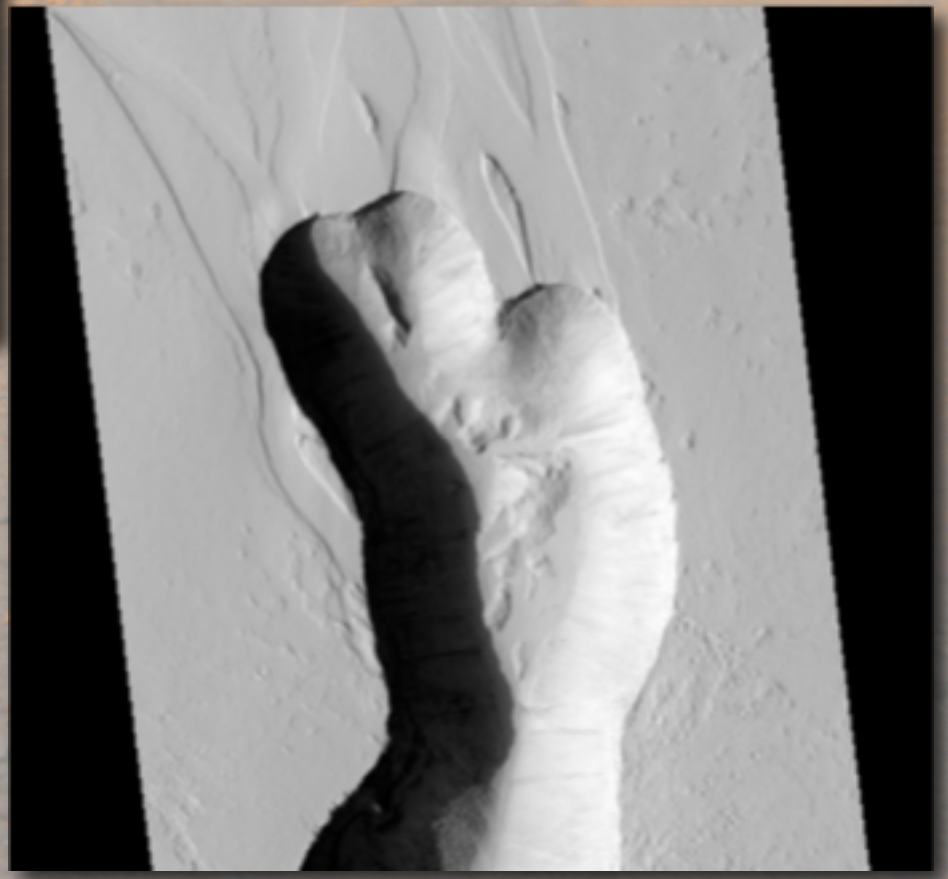
- Sapping channels are formed by the erosion of groundwater
- Amphitheater-shaped head
- Several features on Mars interpreted as related to sapping


Nirgal Vallis
Legend
Google Earth
100 km
N

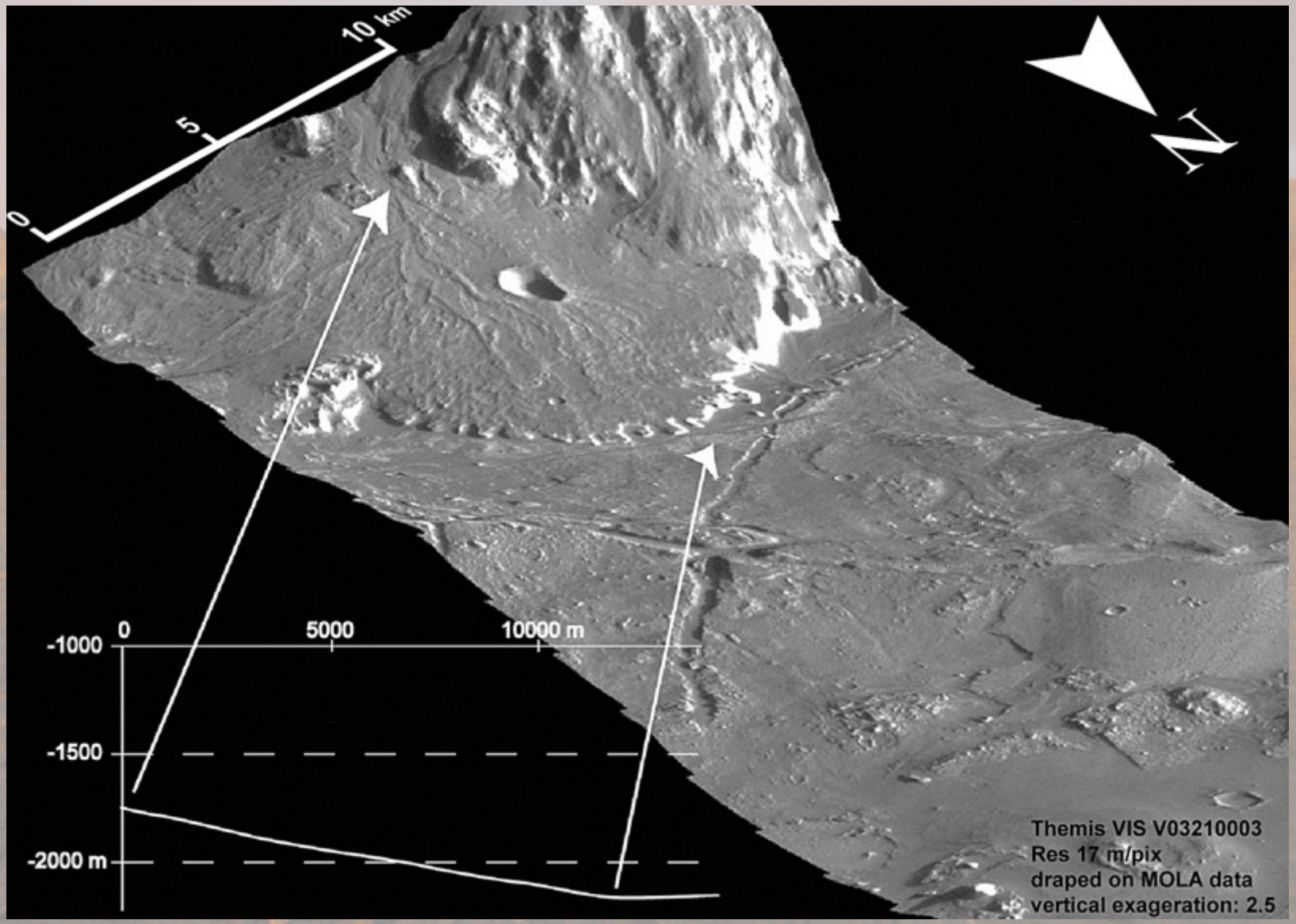

Nirgal Vallis
Legend
Google Earth
1 km


Nirgal Vallis
Legend
Google Earth
3 km
N

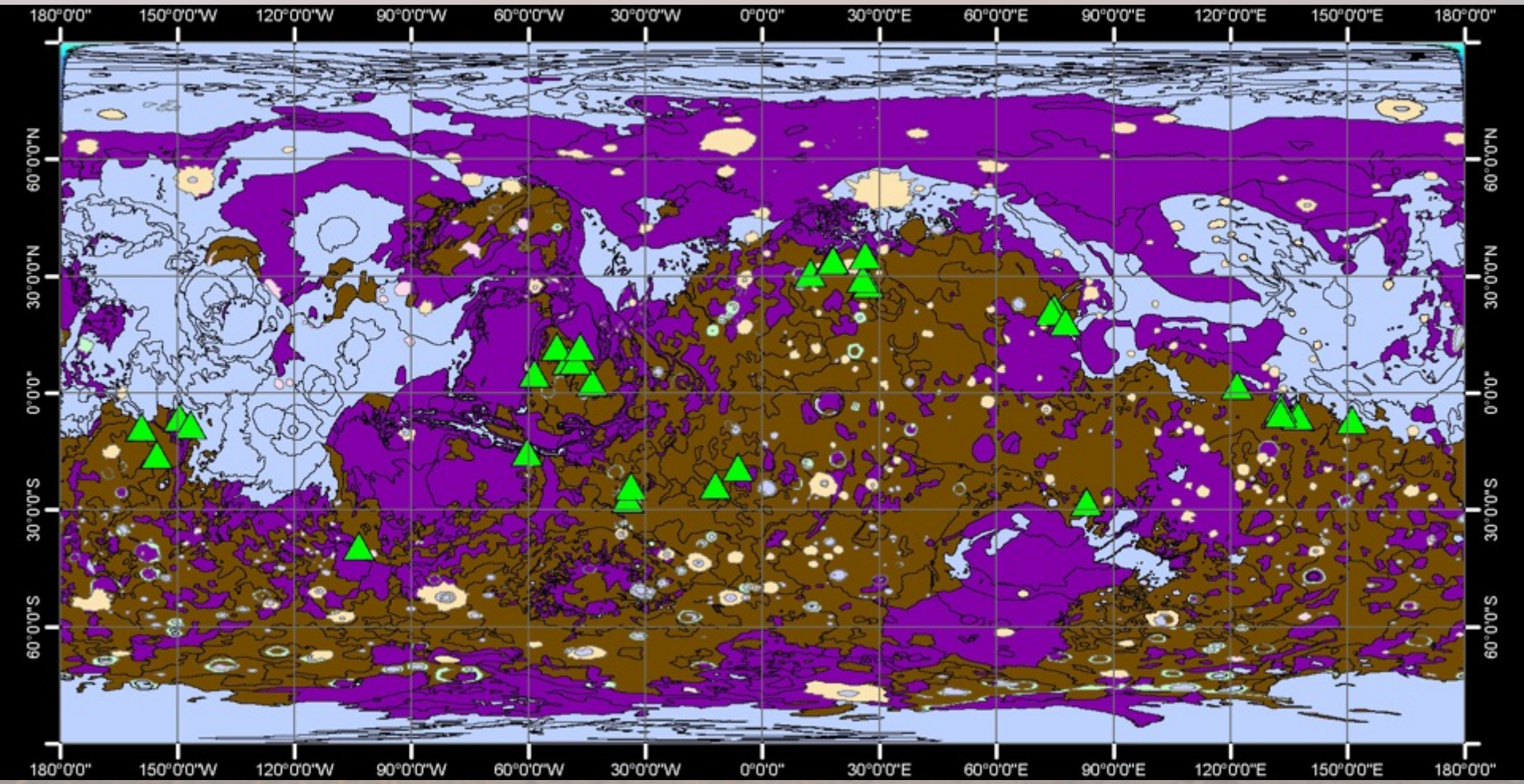

0
200
Meters



Alluvial fan:
Holden crater



Deltas on Mars



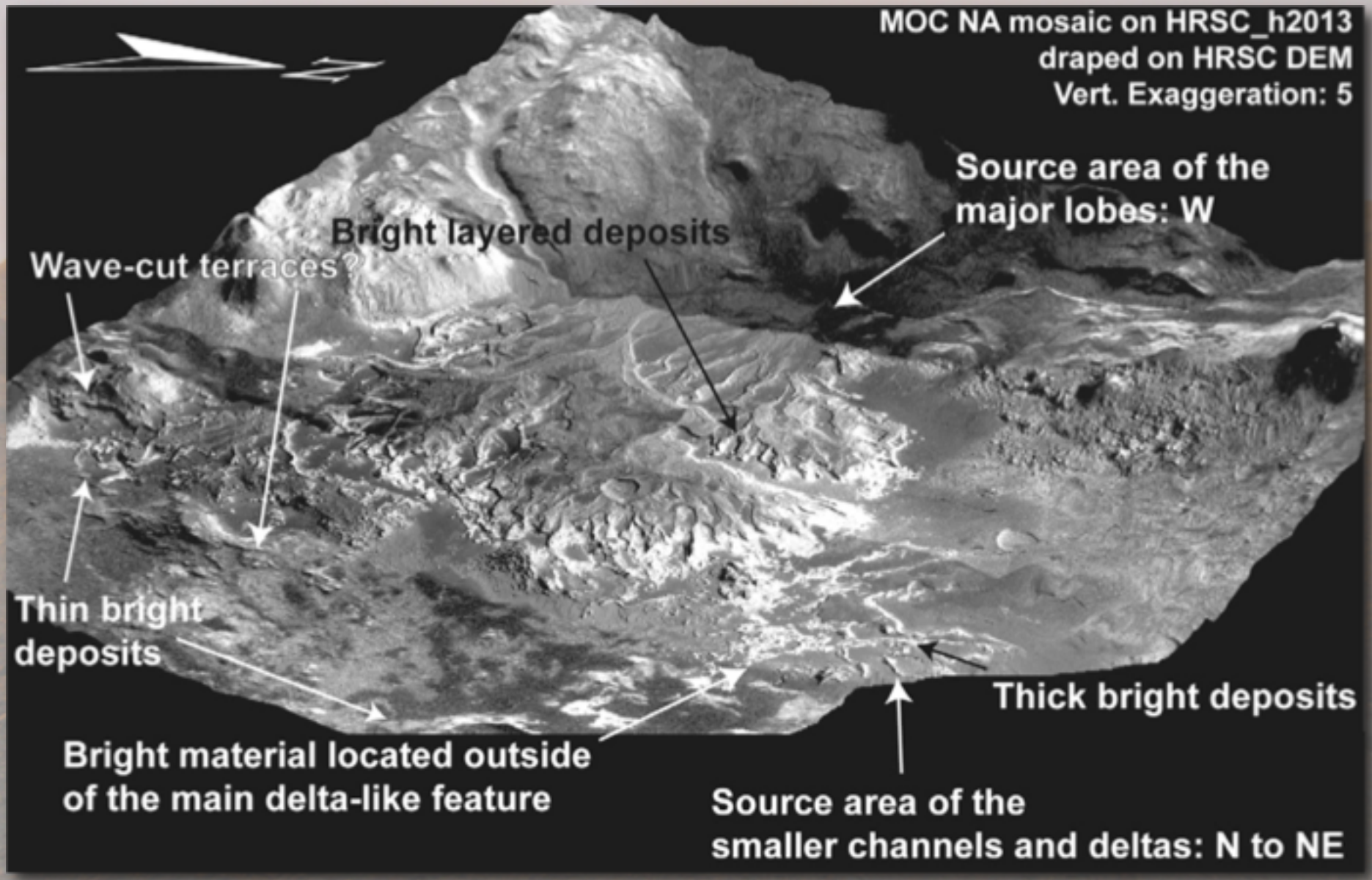
Delta

Noachian

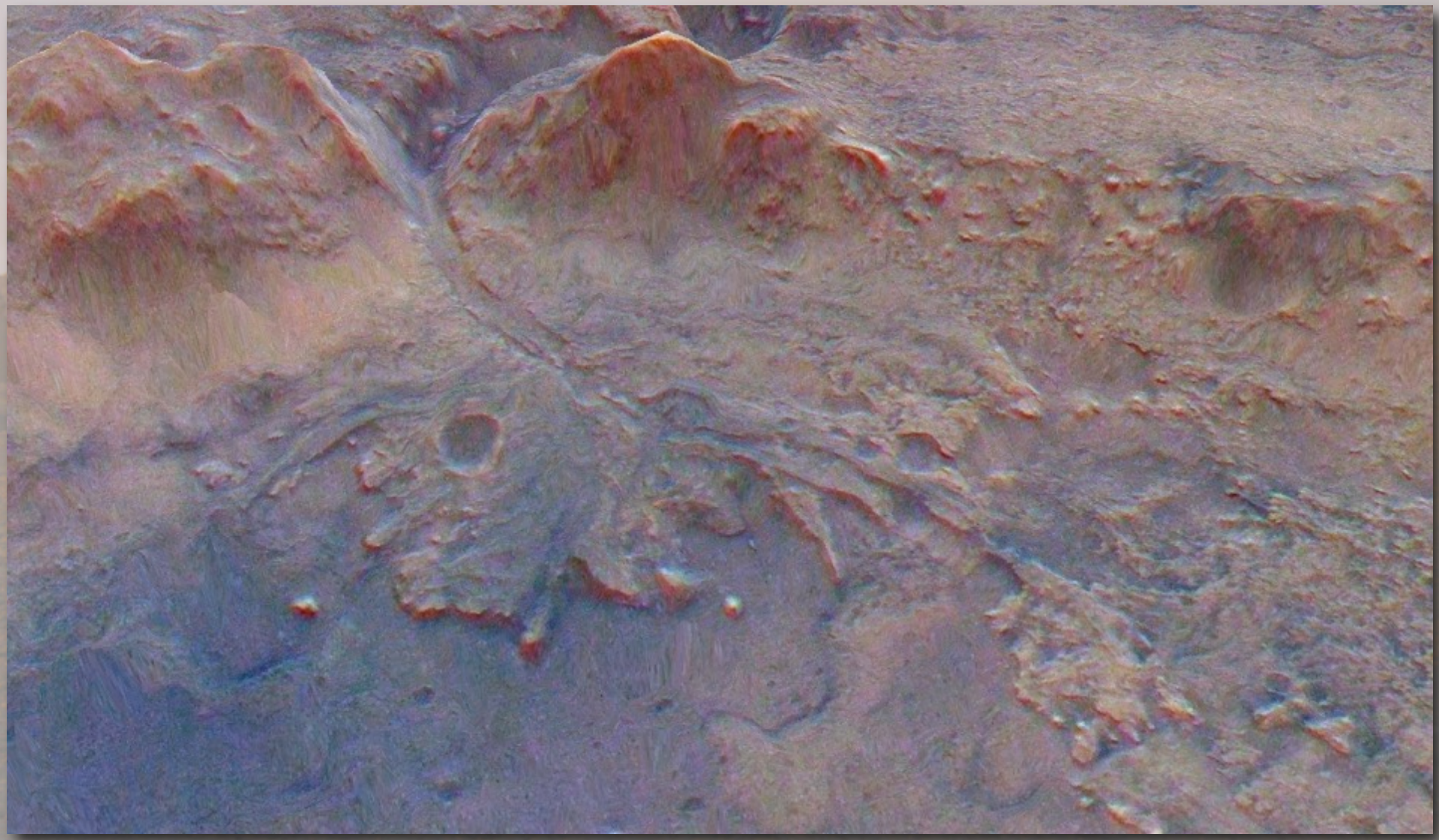
Hesperian

Amazonian

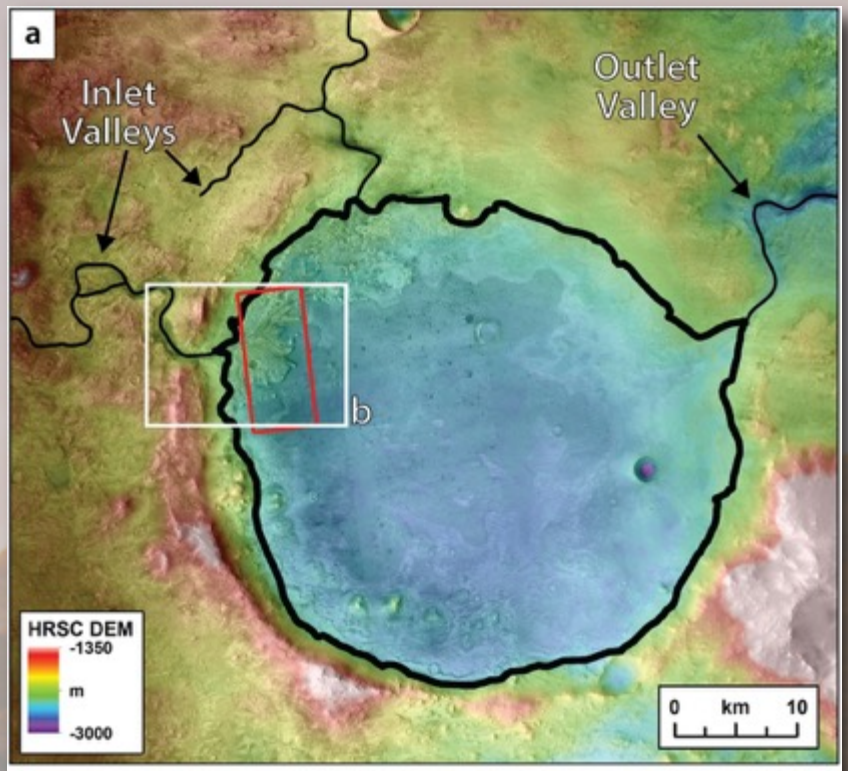
Eberswalde delta

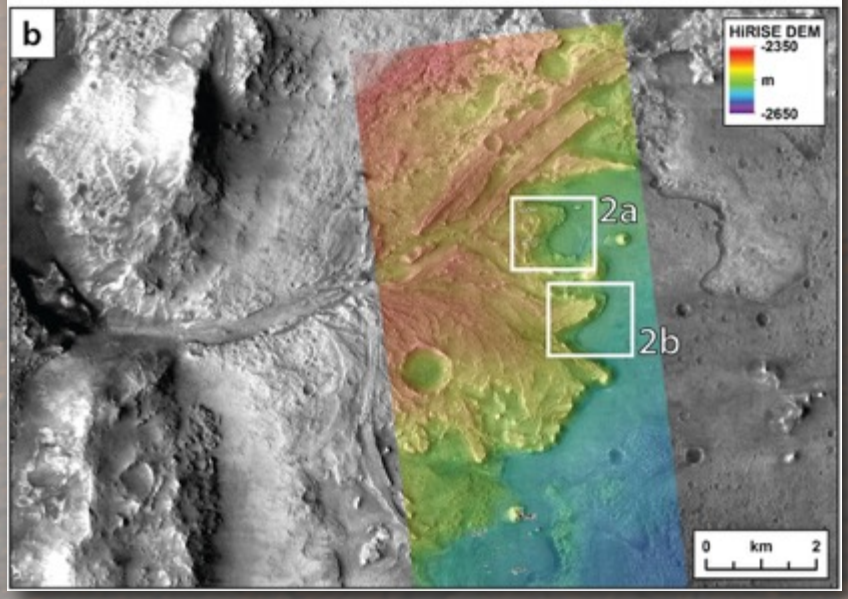


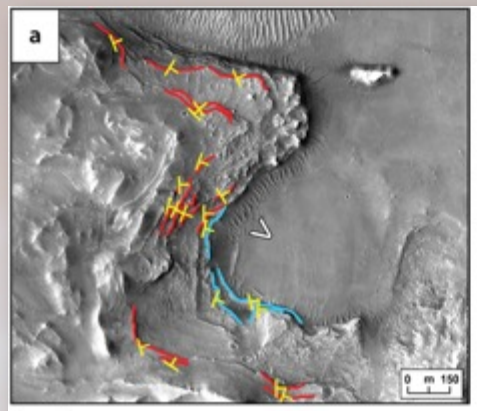
Nili Fossae delta:
Jezero crater

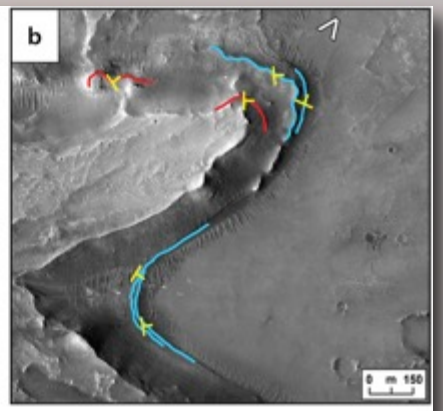


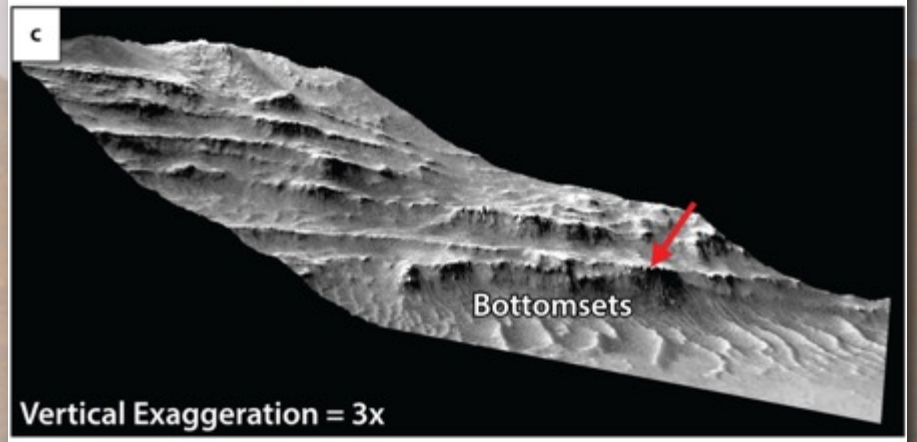
Goudge et al., 2017

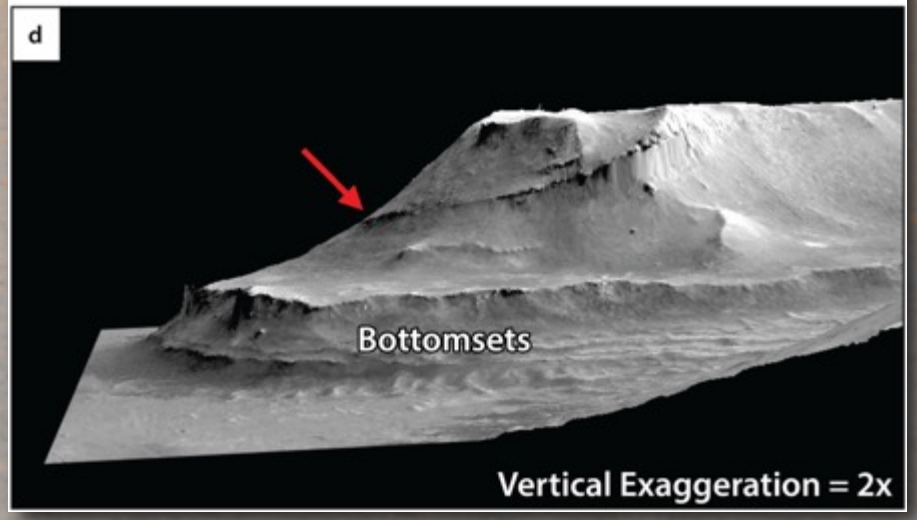






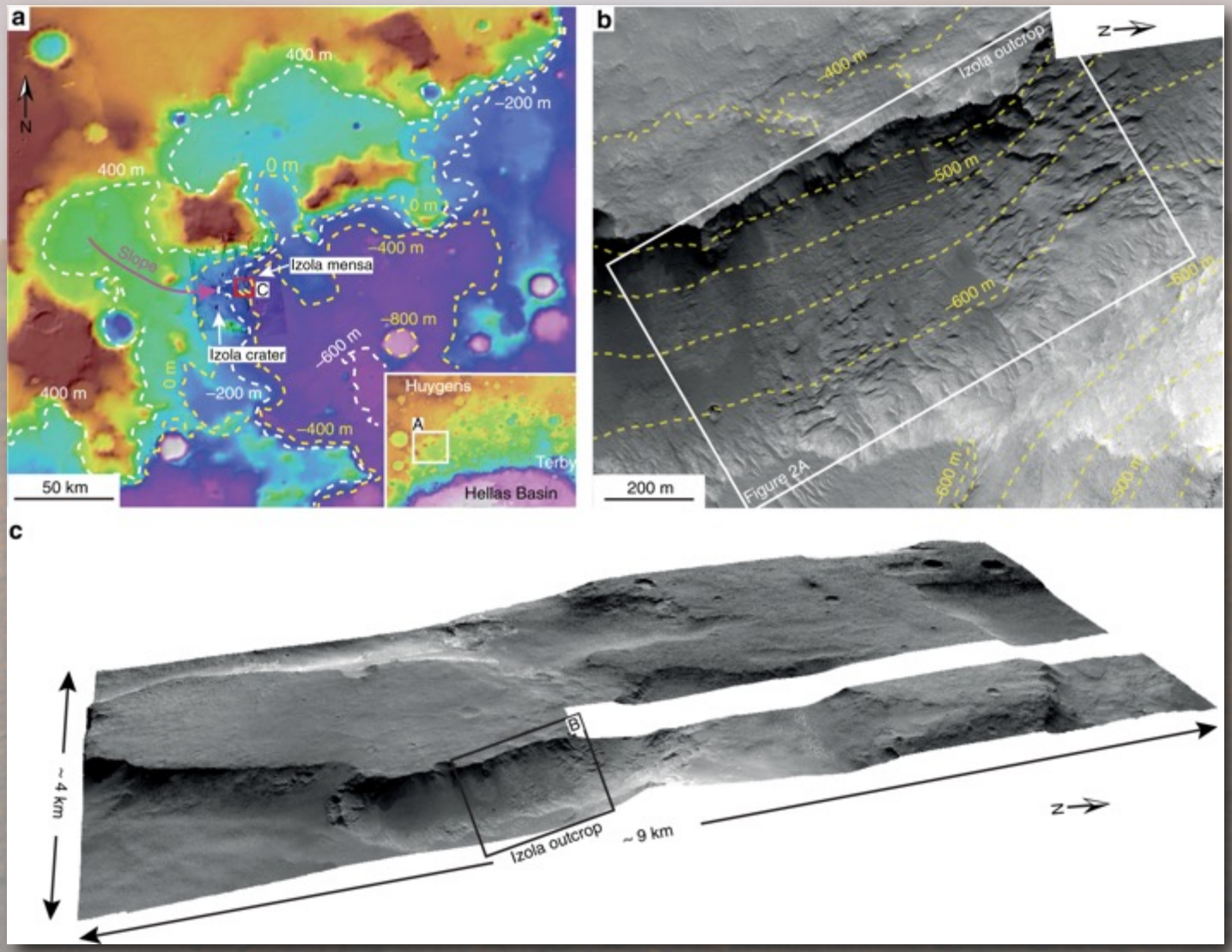






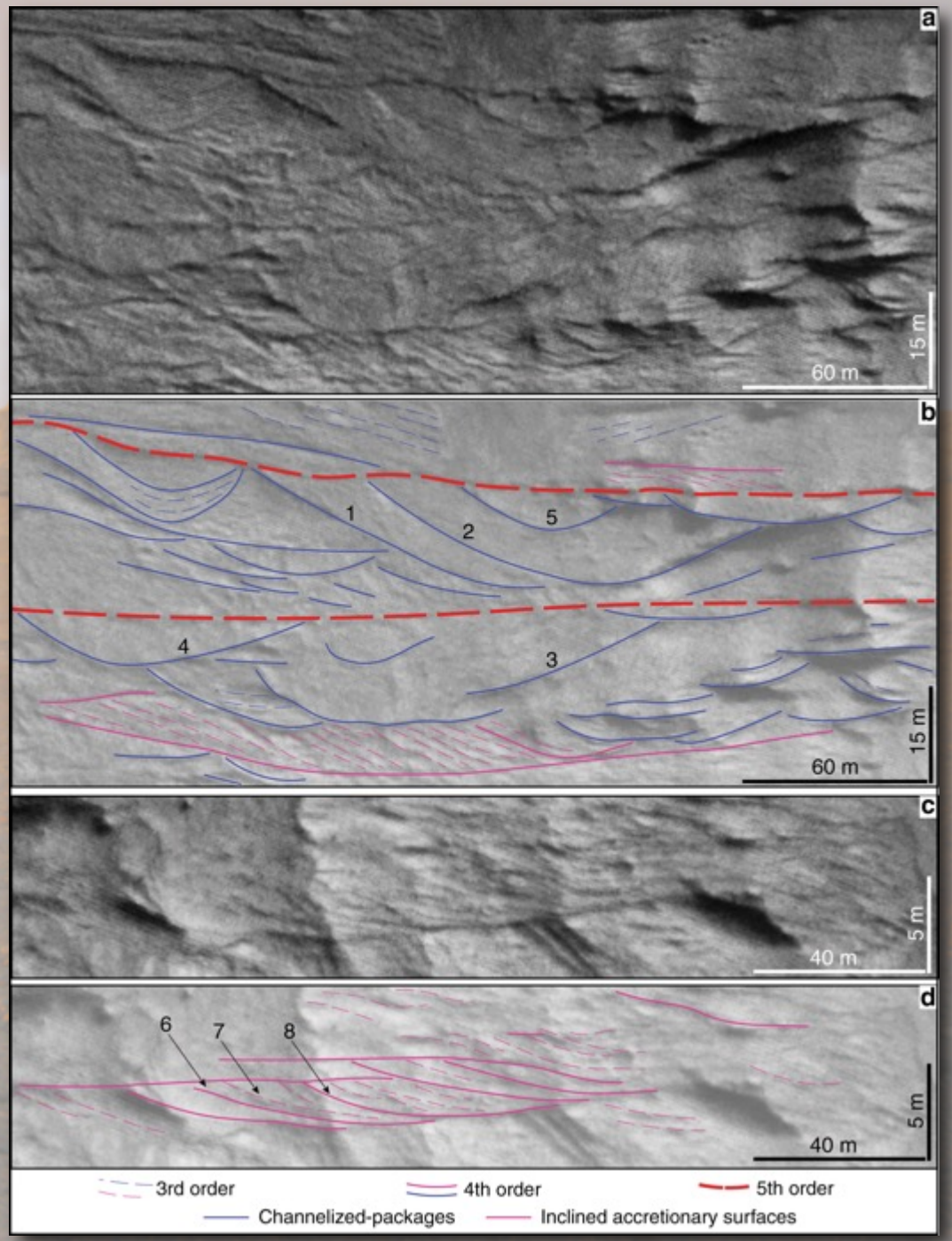
Goudge et al., 2017

Fluvial deposition in Mars' Noachian stratigraphic record



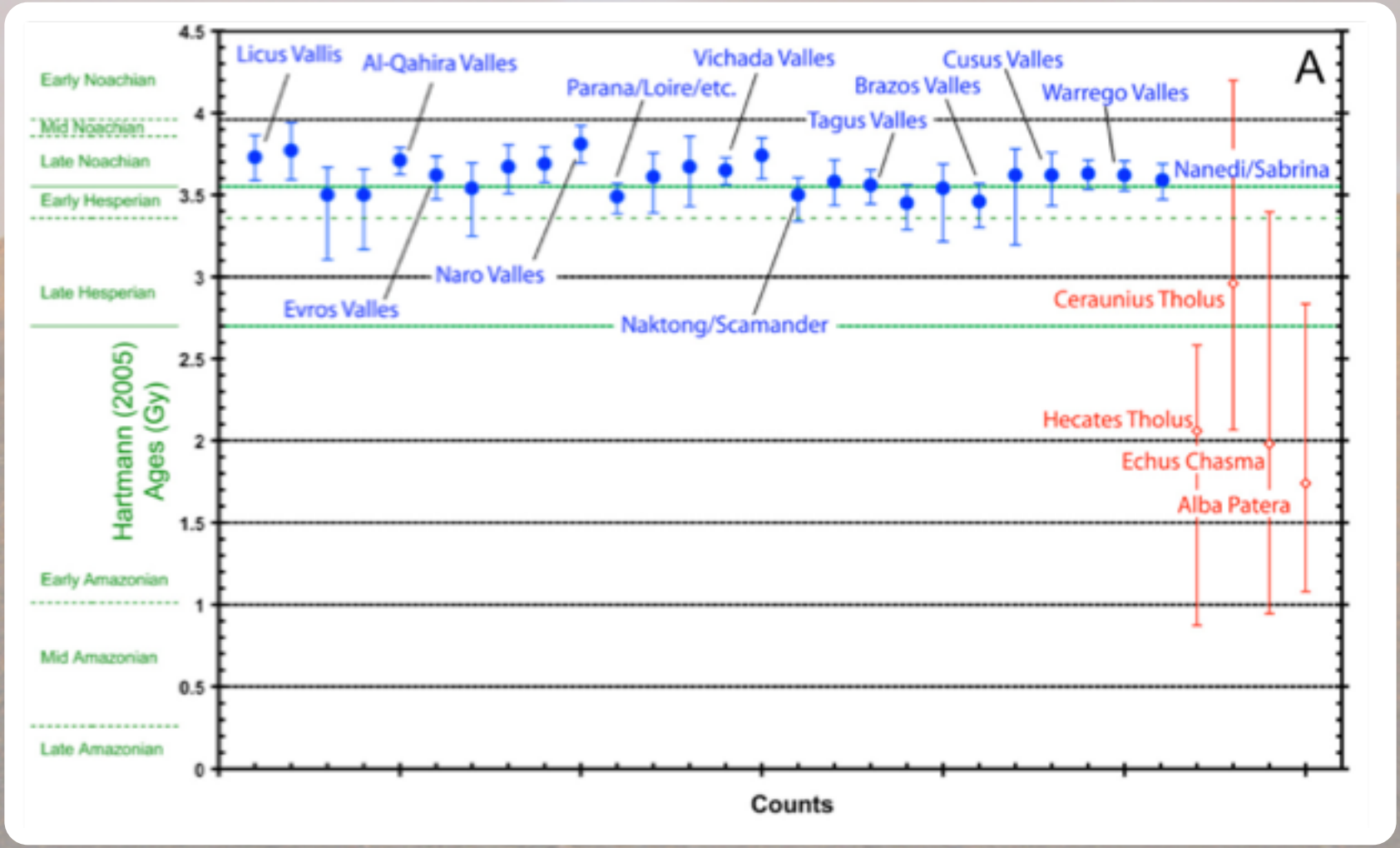
Salese et al., 2020

Sustained fluvial deposition recorded in Mars' Noachian stratigraphic record



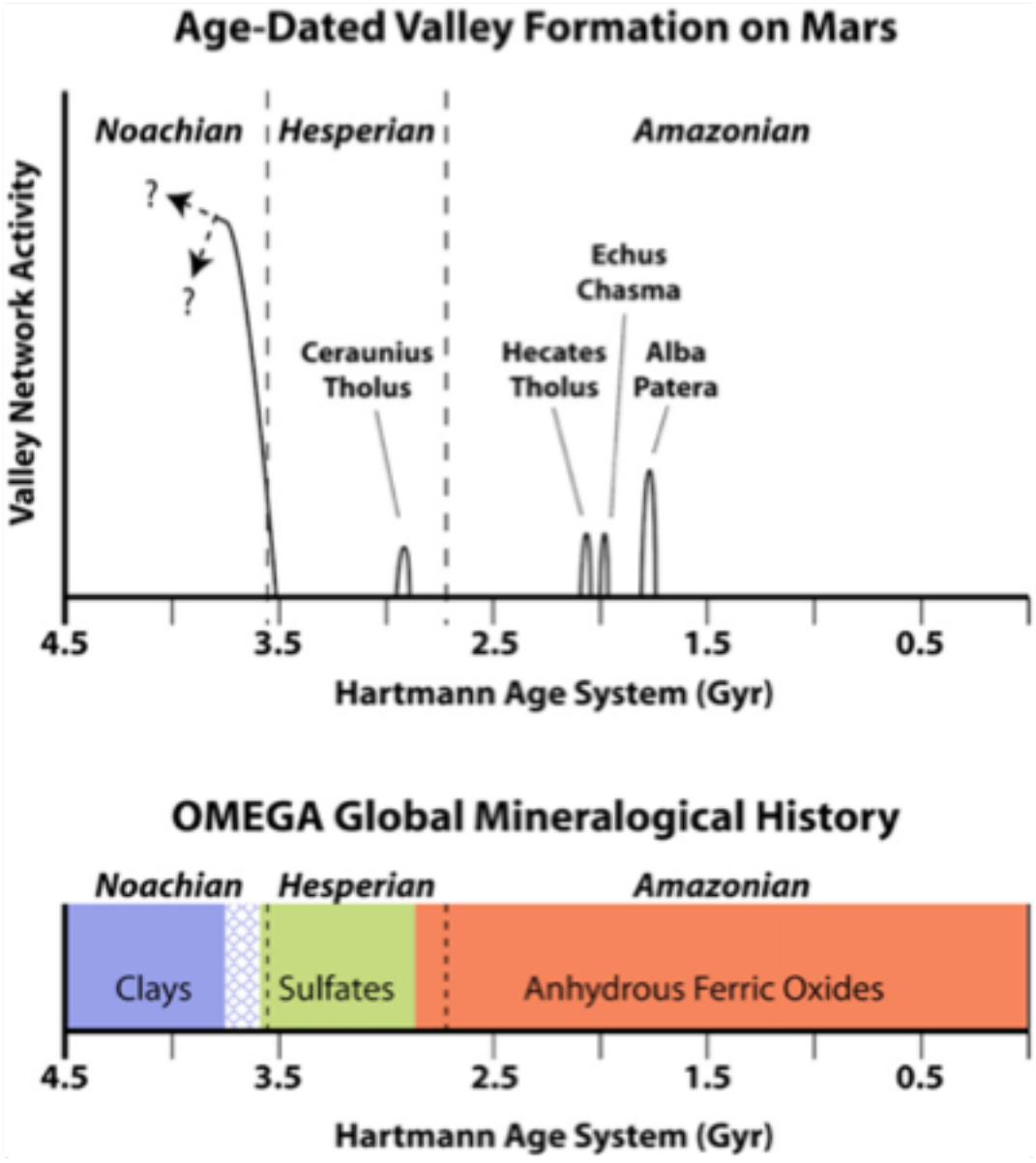
Salese et al., 2020

Valley network ages



Source: Fasset and Head (2008) Icarus

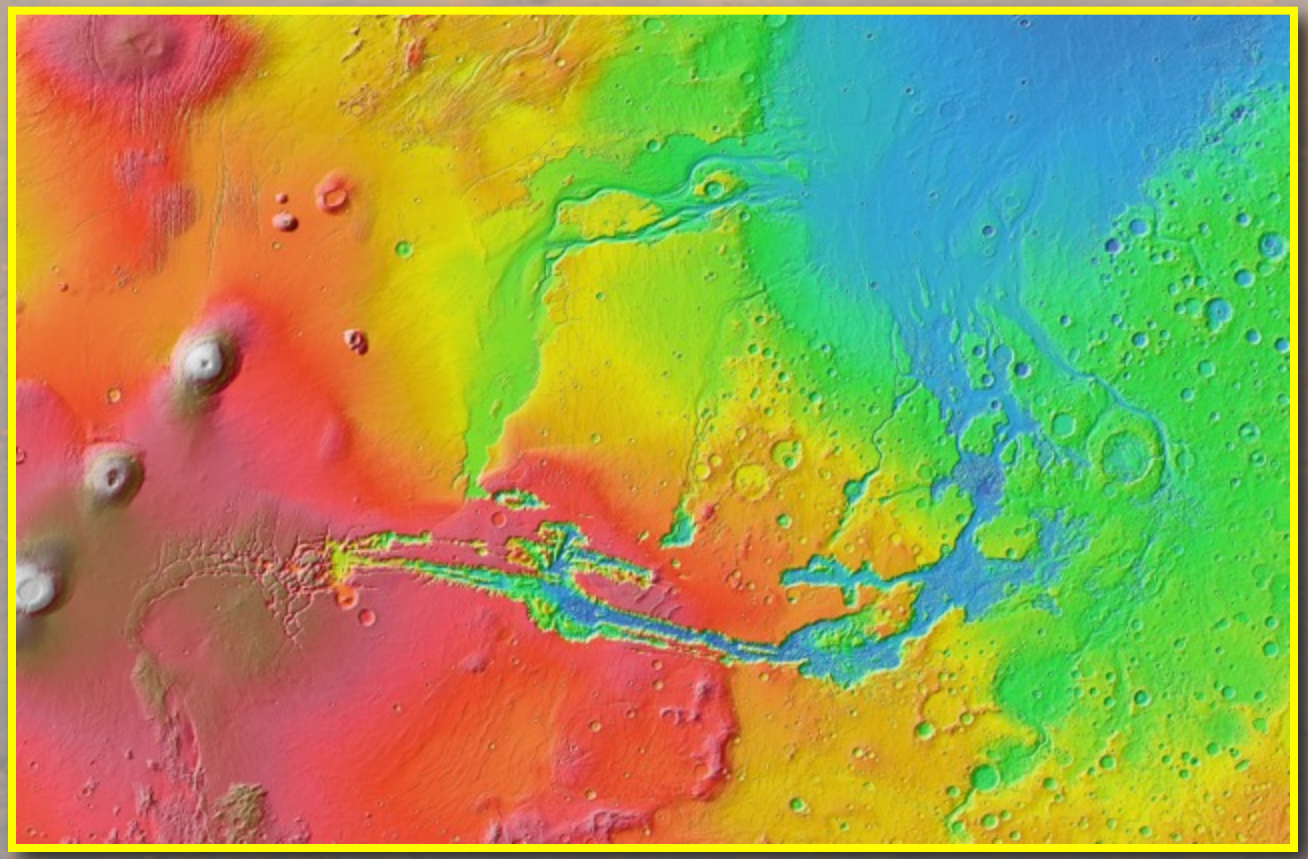
Valley network ages



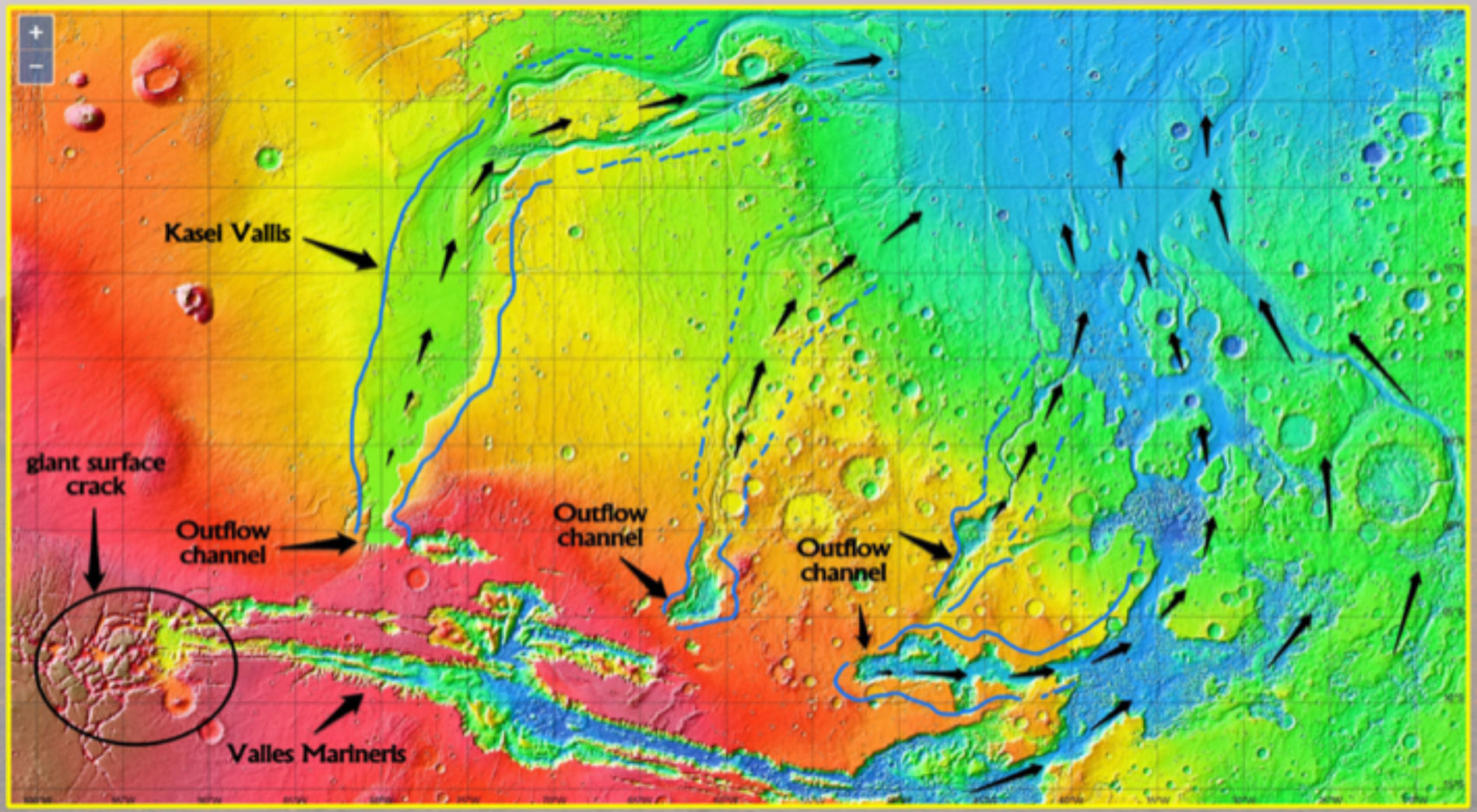
Source: Fasset and Head (2008) Icarus

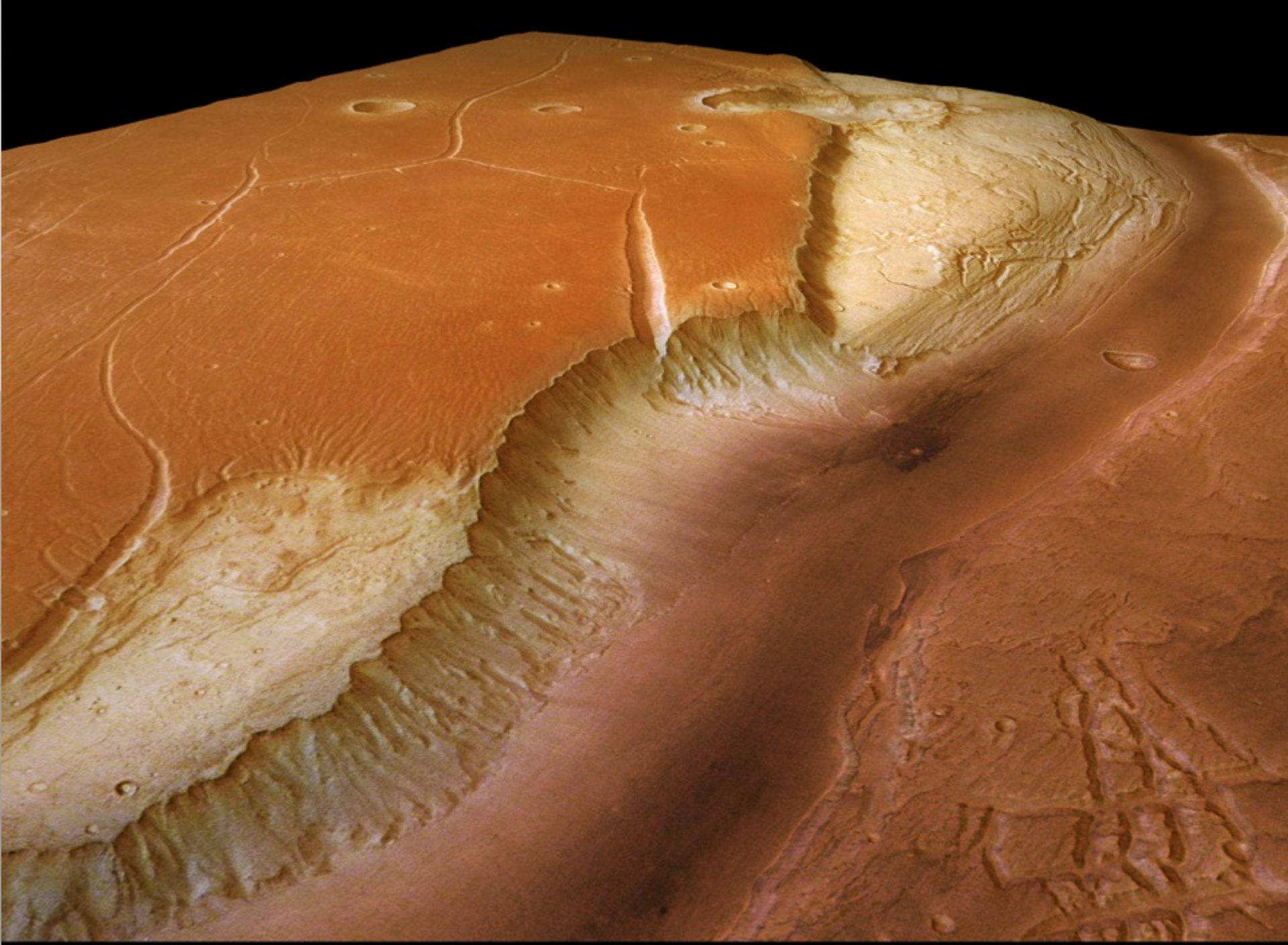
Outflow Channels

- Most channels are found at ‘exit’ of Valles Marineris, in Chryse Planitia.
- Abrupt beginning
- Lack of tributaries
- Formed by catastrophic outpourings of water?

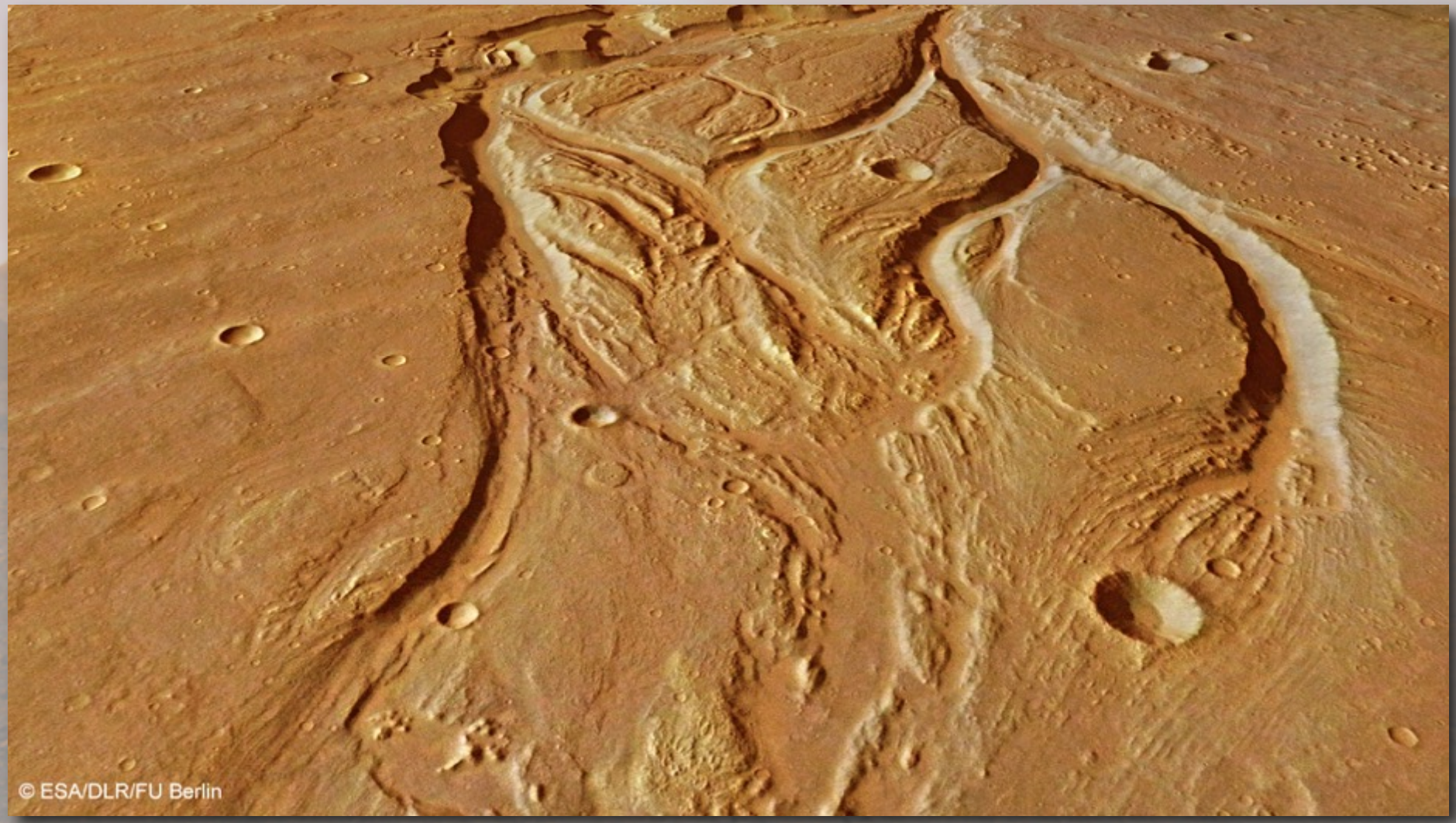


Outflow channels



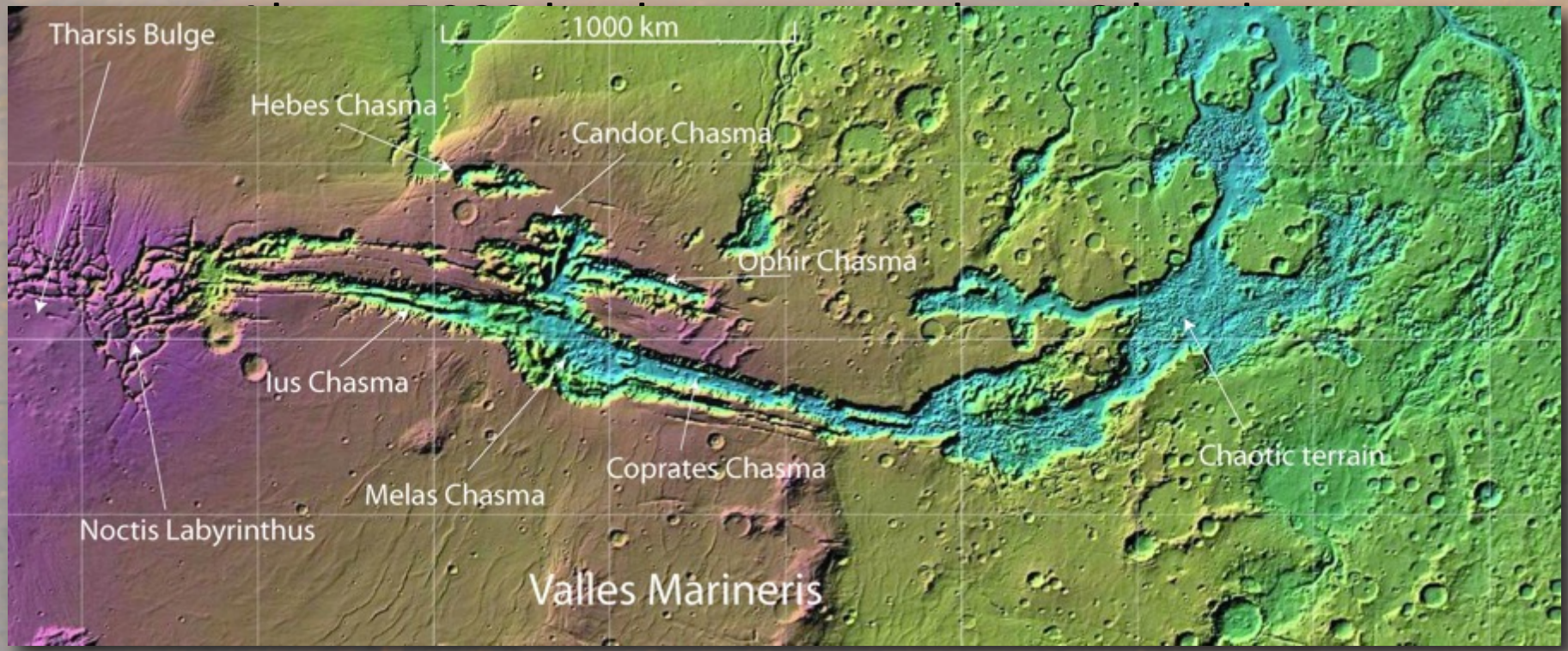


Outflow Channels



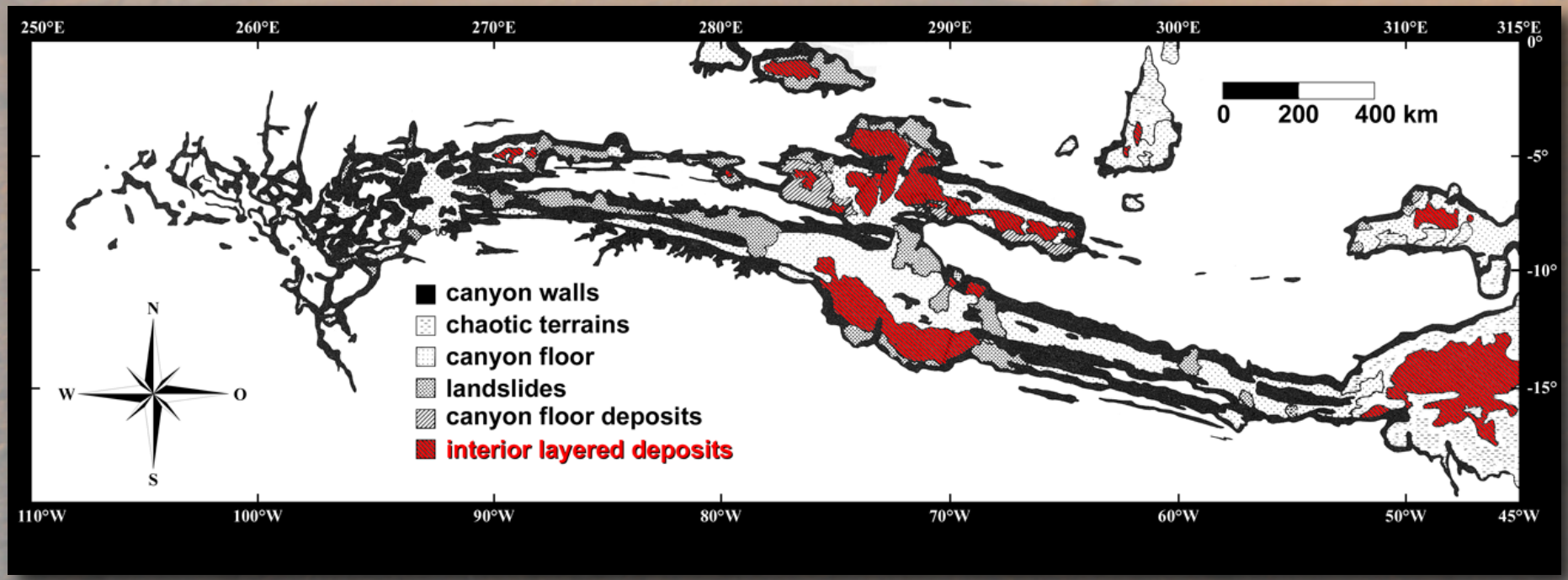
Valles Marineris

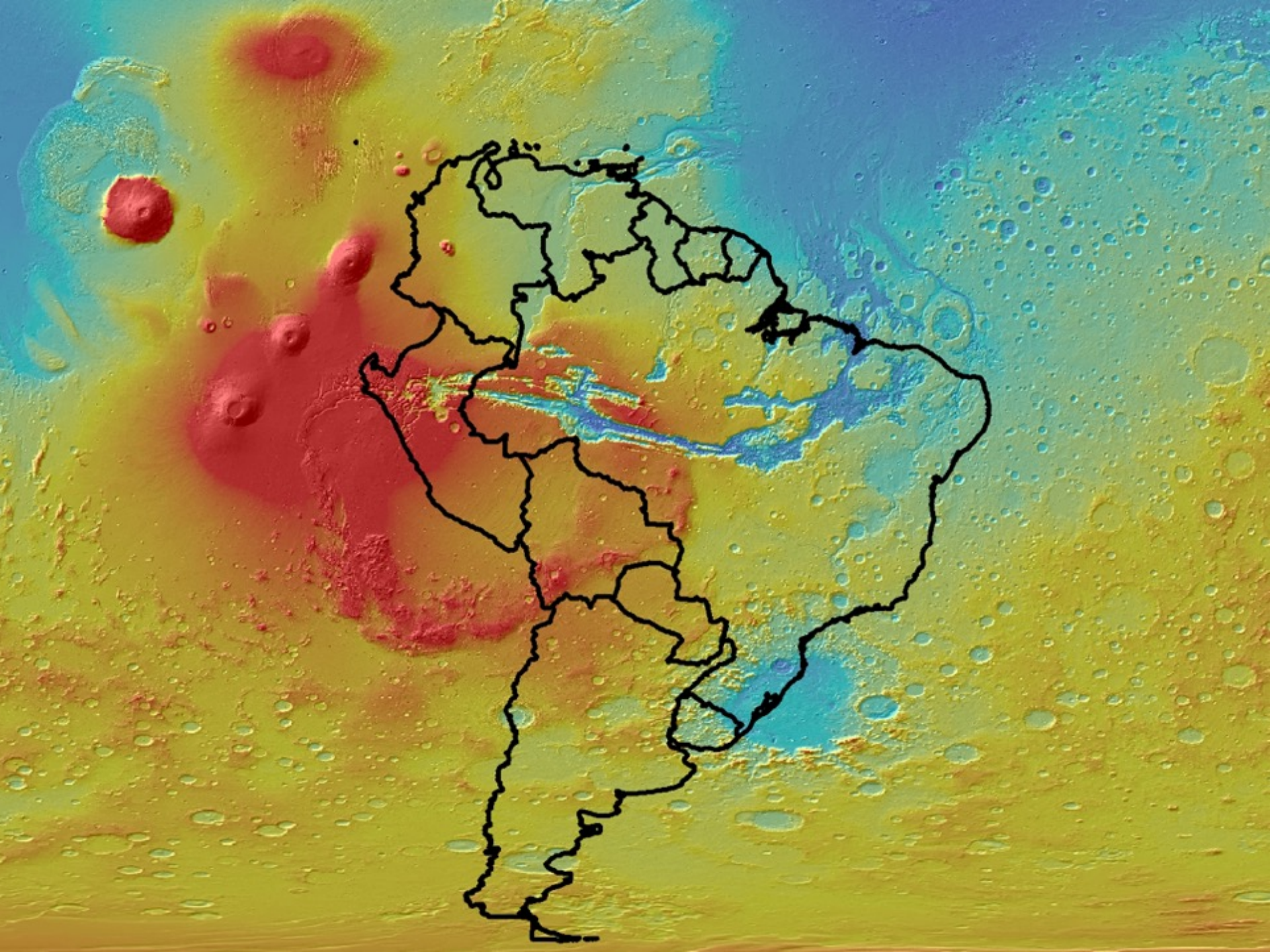
- The largest canyon on Mars and in the solar System
- Closely Linked to Tharsis Bulge and to Chaotic Terrains



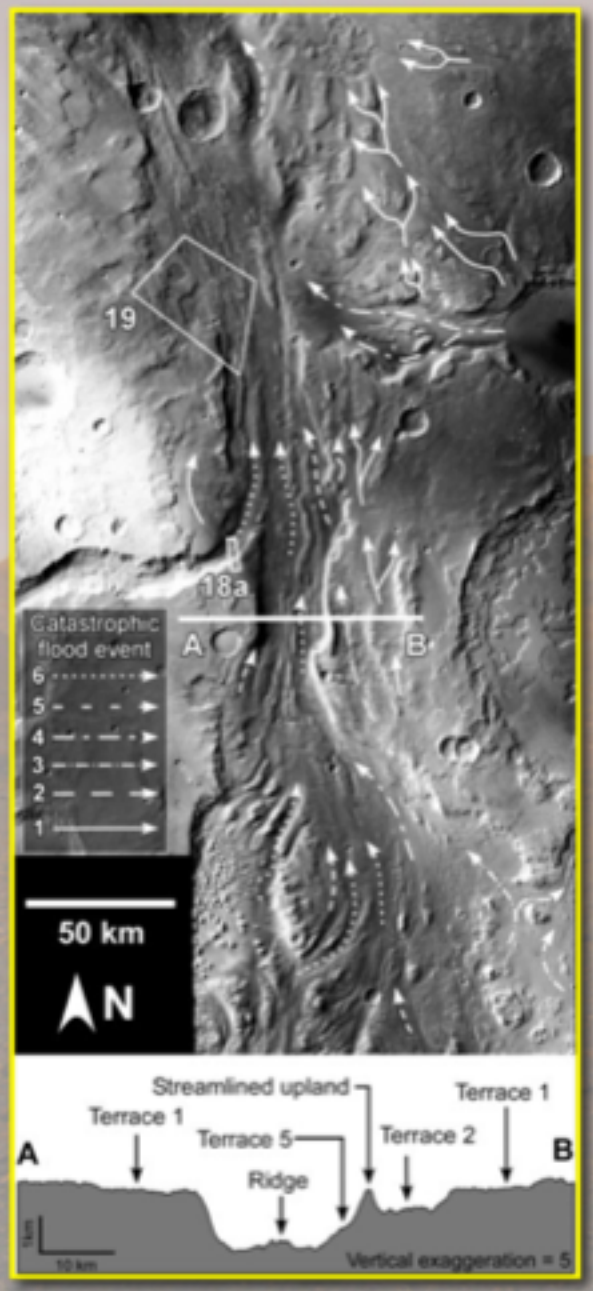
Valles Marineris

- Interior Layered Deposits are located in various parts of Valles Marineris canyon system
- Hydrated minerals have been widely detected (e.g. Gendrin 2005)

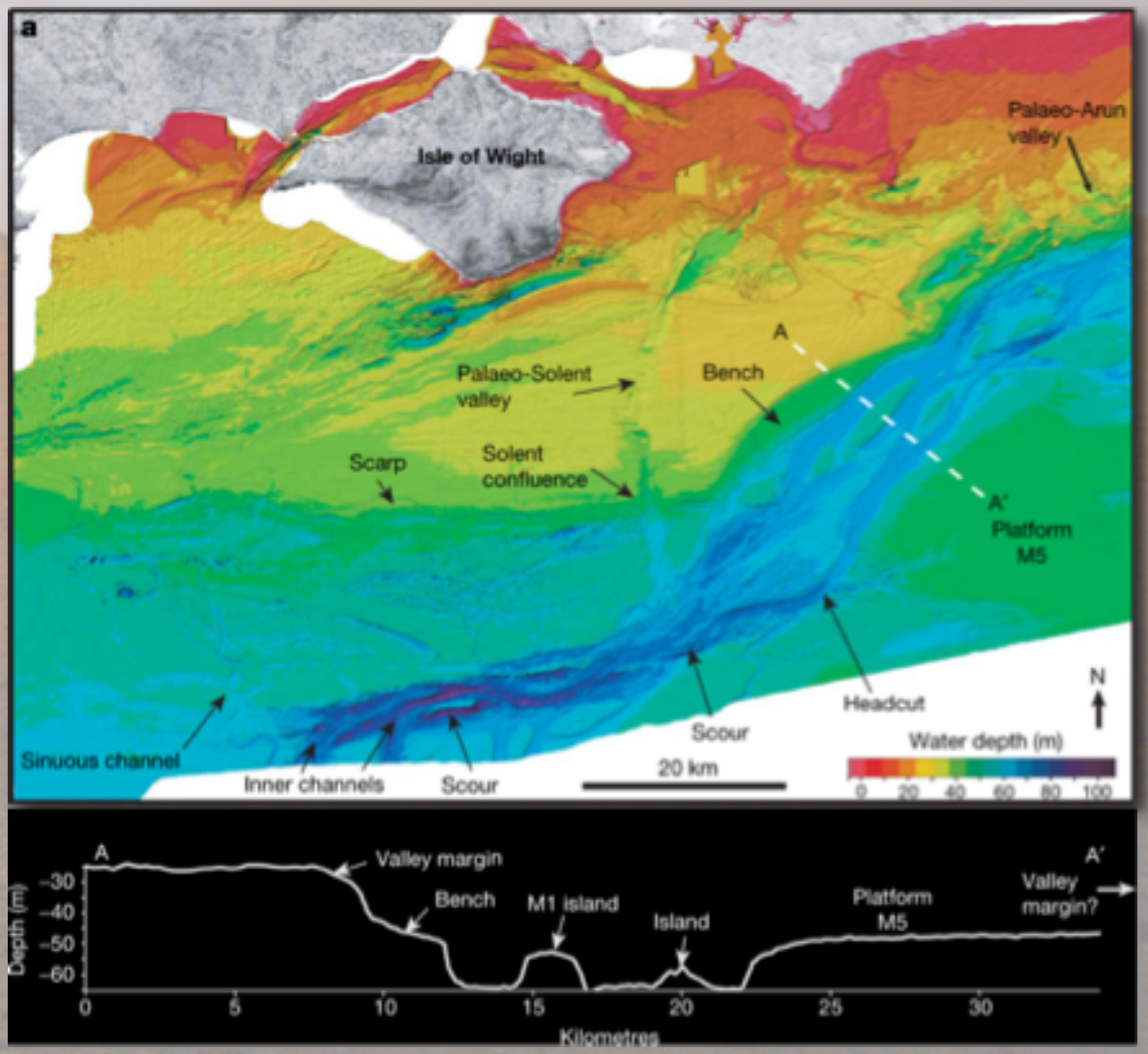




Outflow channels/ Chaos systems



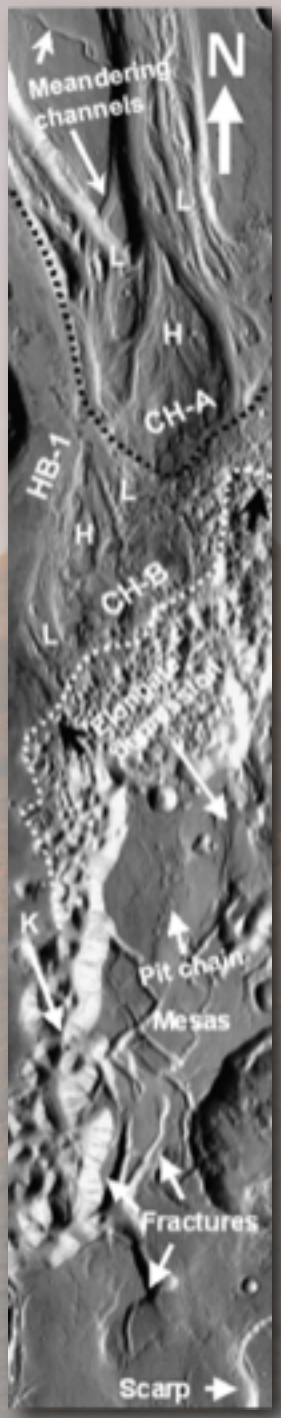
Pacifici et al., 2009

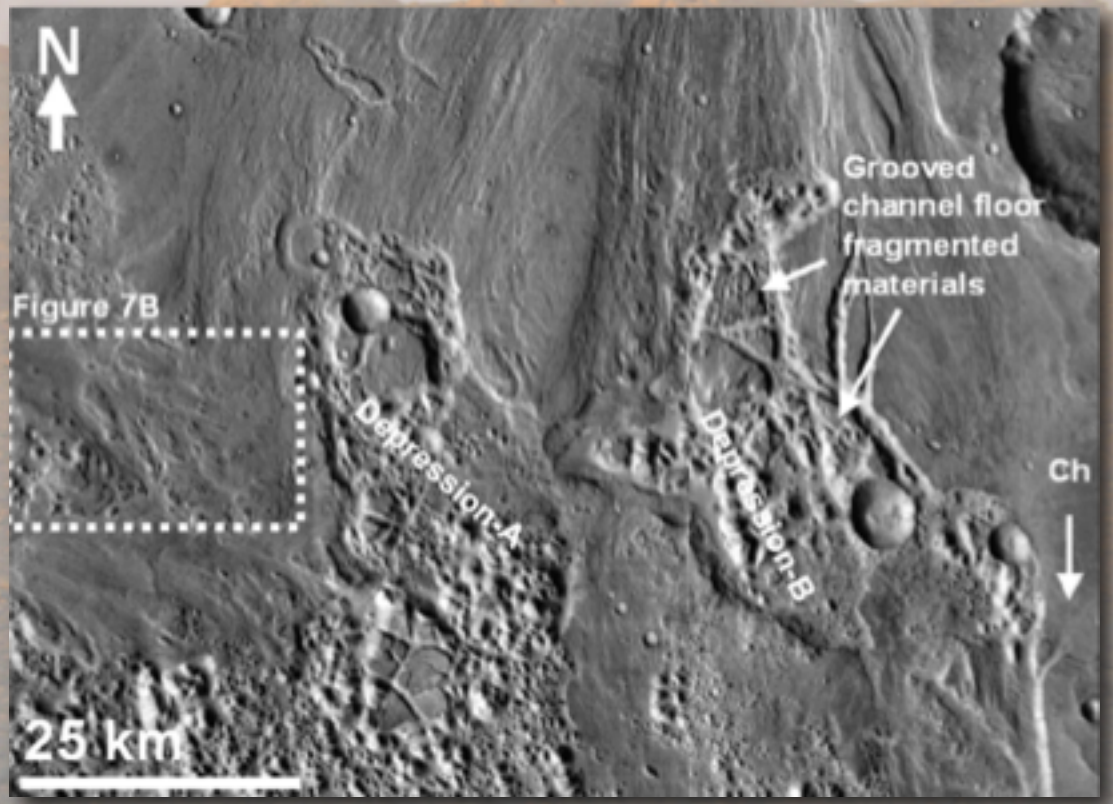


Gupta et al., 2007

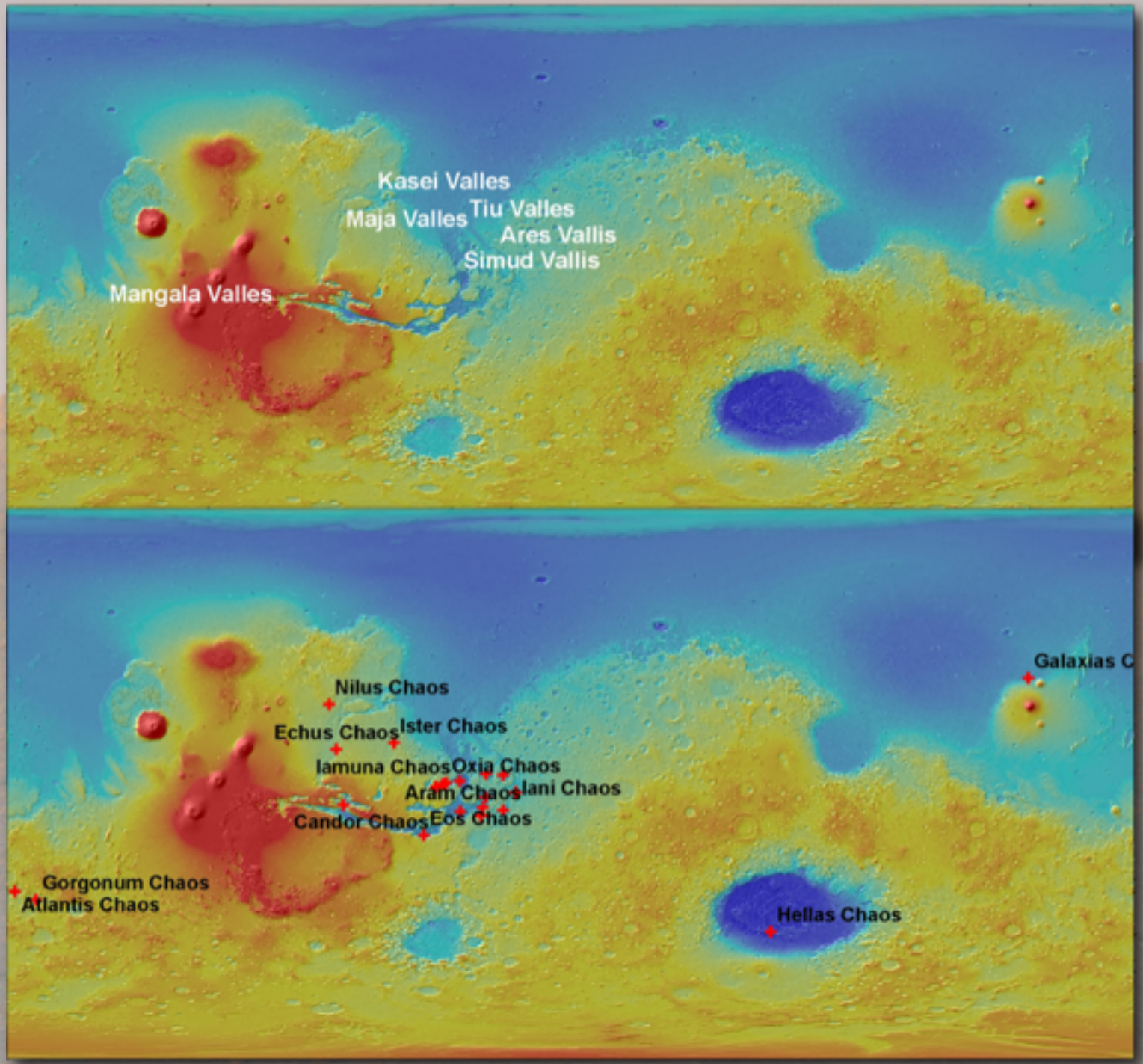
Outflow channels & chaos

Several outflow channels (but NOT all of them) clearly originate from chaotic terrains



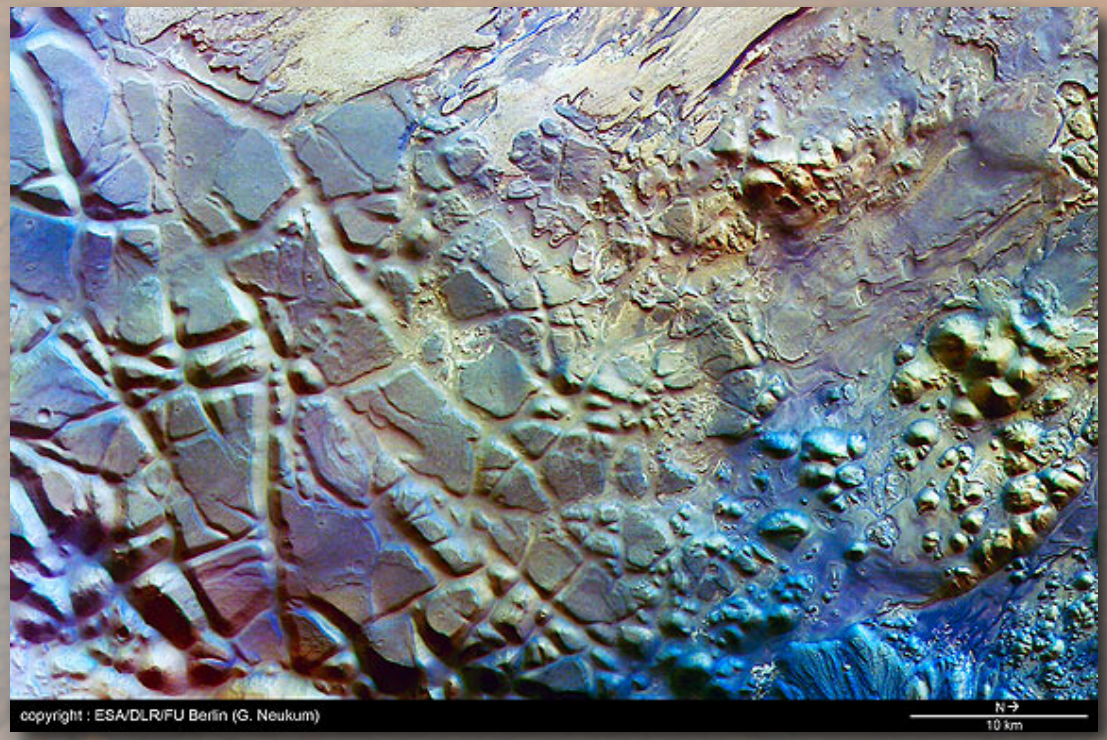


Source: Rodriguez et al. (2004) Icarus


Kasei Valles
Maja Valles
Tiu Valles
Ares Vallis
Simud Vallis
Mangala Valles
Nilus Chaos
Echus Chaos
Ister Chaos
Iamuna Chaos
Oxia Chaos
Aram Chaos
Iani Chaos
Candor Chaos
Eos Chaos
Gorgonum Chaos
Atlantis Chaos
Hellas Chaos
Galaxias C

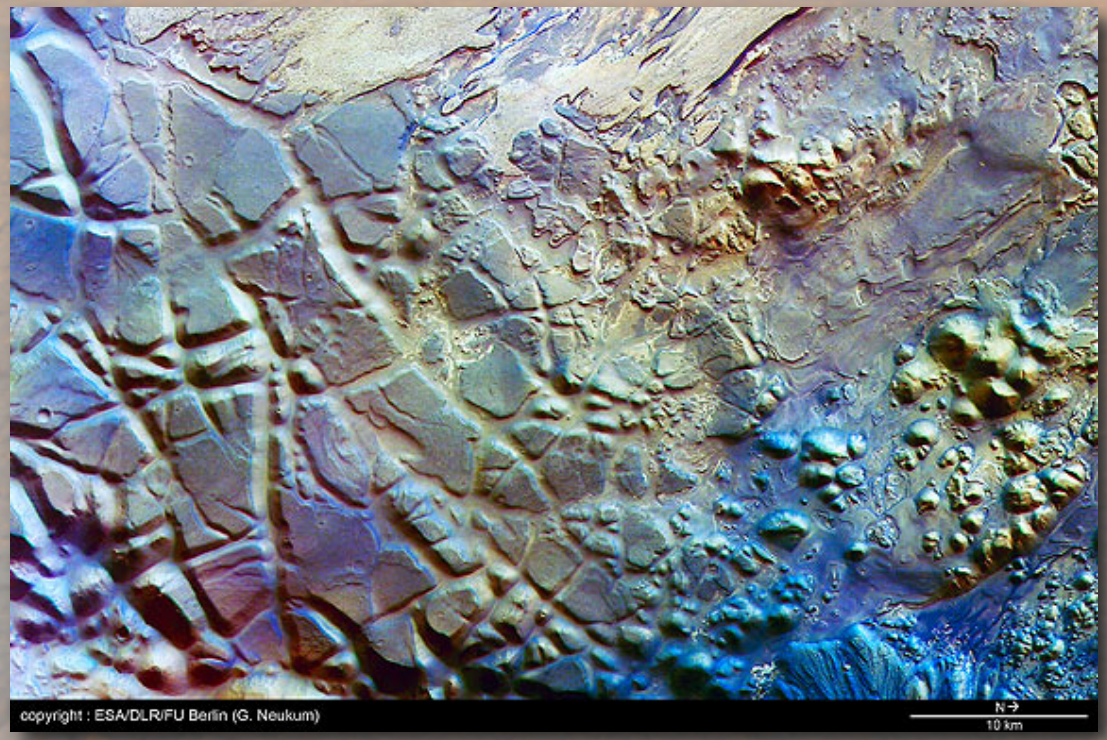
Chaotic Terrains

- Located at the transition between the Valles Marineris canyon system and the Outflow Channels
- Disrupted terrains, with erosion/loss of large volumes of bedrock
- Extremely large amount of subsurface water (aquifers? cryosphere?) released in single or multiple episodes



Chaotic Terrains

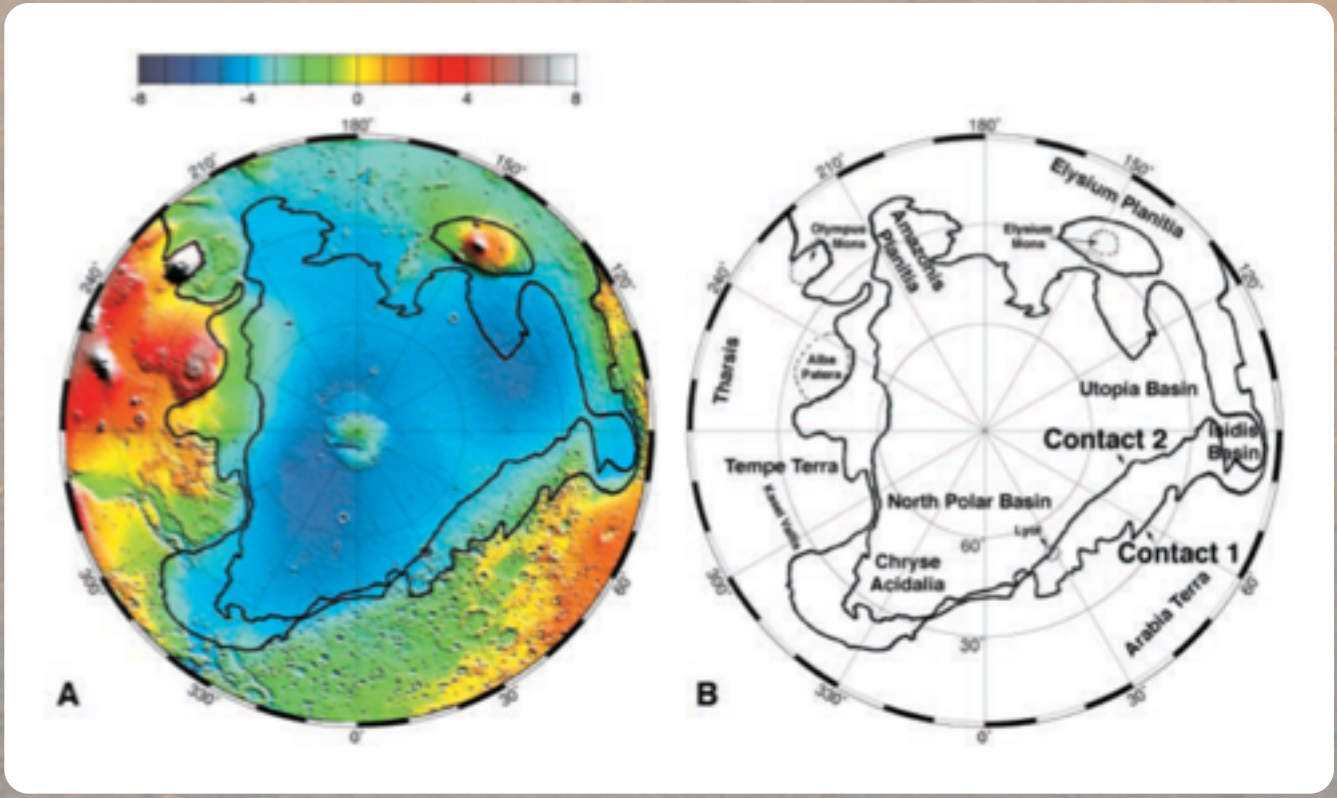
- Up to several km of disrupted upper crust
- Remnants in form of mesas, knobs
- In some cases, evidences of multiple floods and/or water ponding
- Lack of a comparable (both in scale and processes) terrestrial analogue

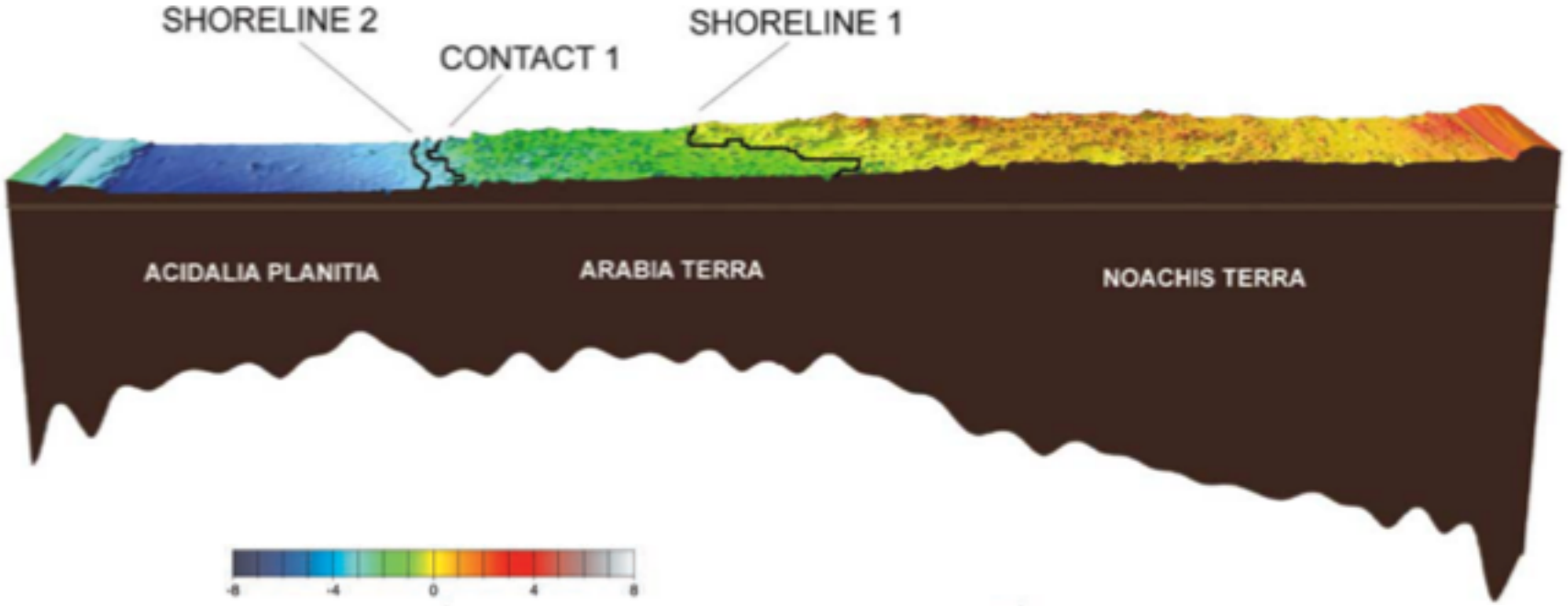


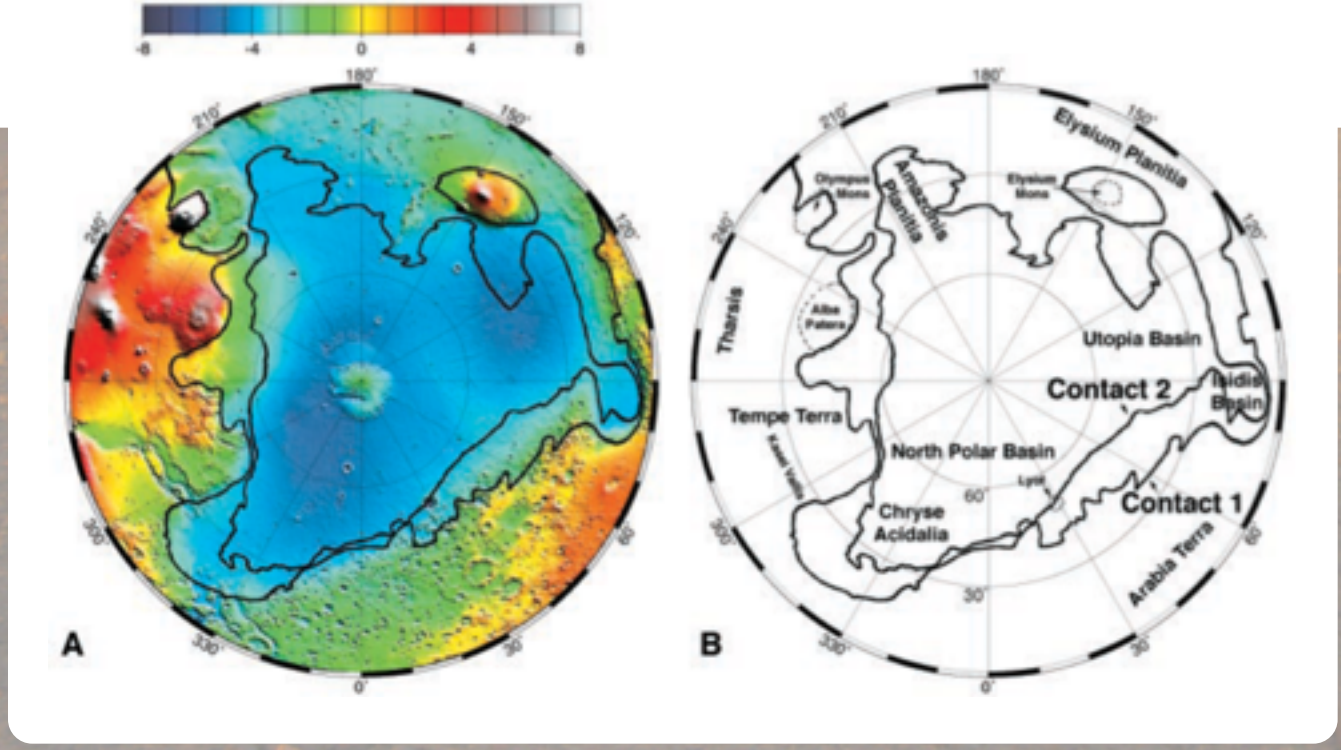
Chaotic Terrains

Ancient Ocean?

- A possible ancient (Noachian) ocean in the Northern Plains has been proposed by different authors
- The purported ocean is characterized by 2 possible coastlines (contact I & II)
- Topography supports the idea, although the geomorphology in high resolution leave some doubts
- Such and ocean in the Northern Plains could have been fed by the activity of outflow channels

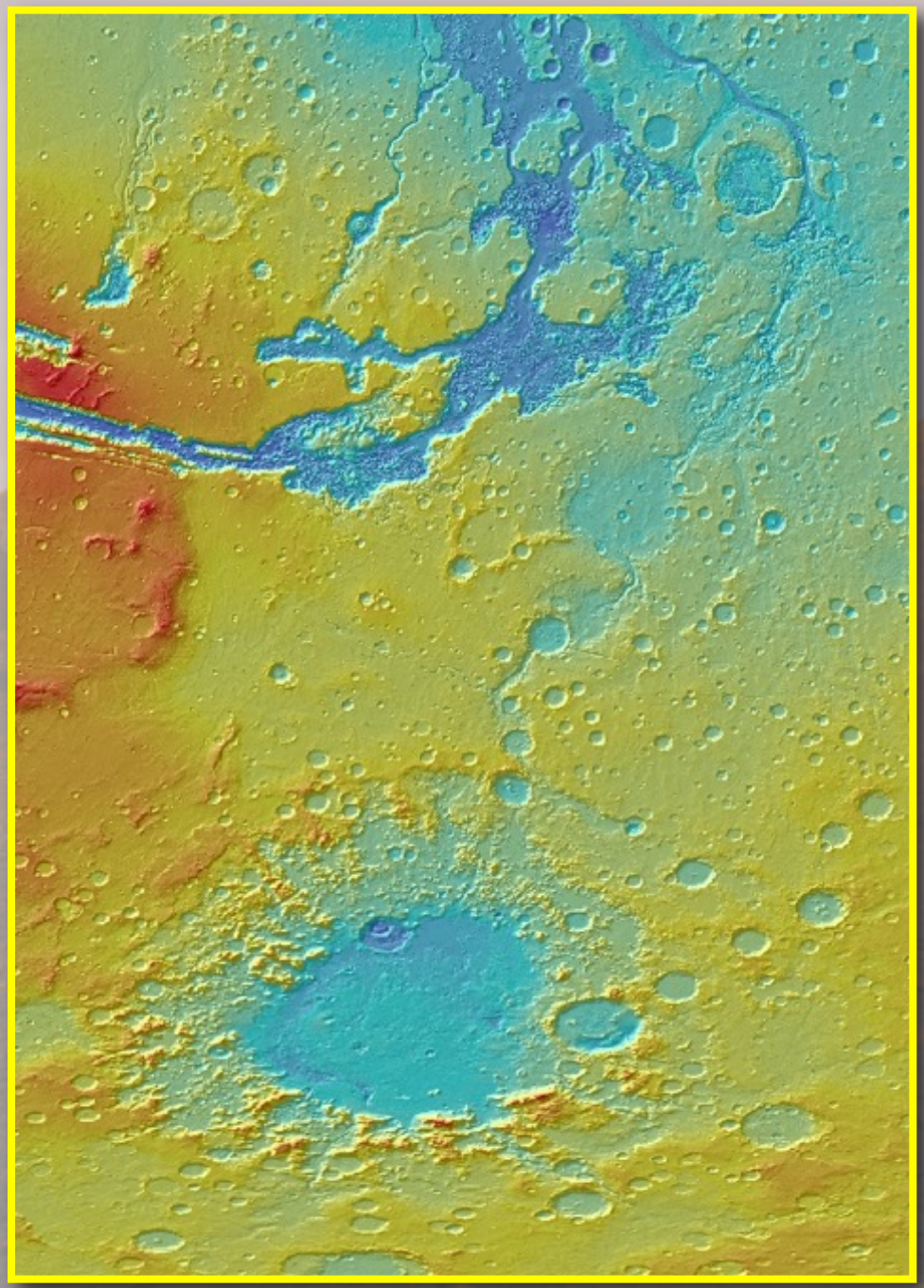



SHORELINE 2
CONTACT 1
SHORELINE 1
ACIDALIA PLANITIA
ARABIA TERRA
NOACHIS TERRA


-8
-4
0
4
8
A
B
Elysium Planitia
Olympus Mons
Amazonis Planitia
Elysium Mons
Tharsis
Alba Patera
Utopia Basin
Contact 2
Isidis Basin
Tempe Terra
North Polar Basin
Lyra
Contact 1
Chryse Acidalia
Arabia Terra

Hellas Basin

- Largest impact basin on mars (excluding the possible impact-formed Norther Plains)
- Surrounded by large volcanic centres (e.g. Hadriaca Patera) and relatively small outflow channels
- Possible evidence of ancient ice sheets

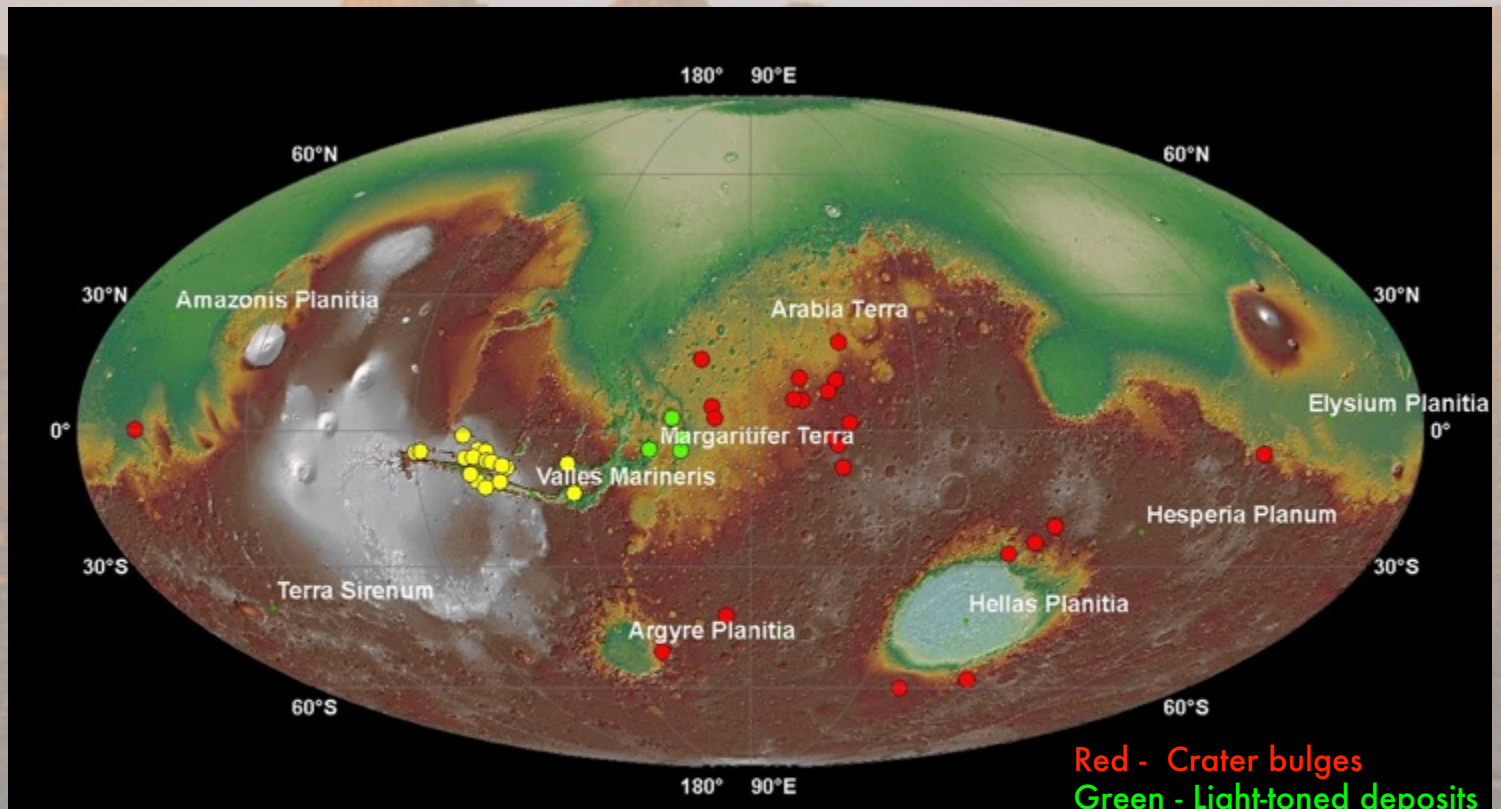


Argyre Basin

- Second larges impact basin on Mars' souther highlands
- Ancient channel system linking Argyre the basins and channels to the North
- Ancient glacial features
- Multi-ringed basin

Light-Toned Deposits (LTDs)

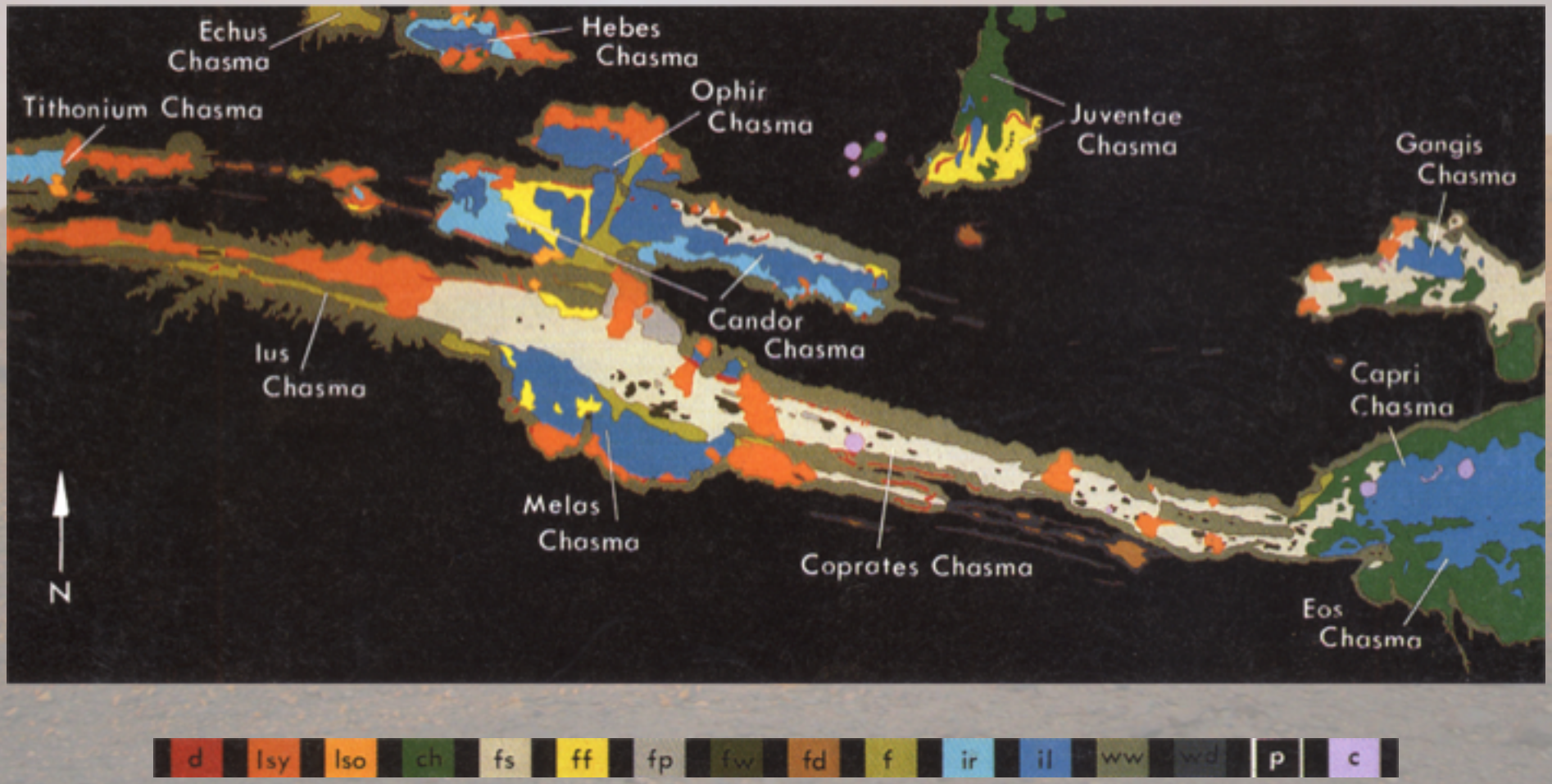
- Thick, layered material (up to 7 km!)
- Light-toned
- Recently detected presence of hydrated minerals
- Complex stratigraphy



Bulges, Interior Layered Deposits
and light-toned deposits in chaotic terrains
are all located in relative low topography areas

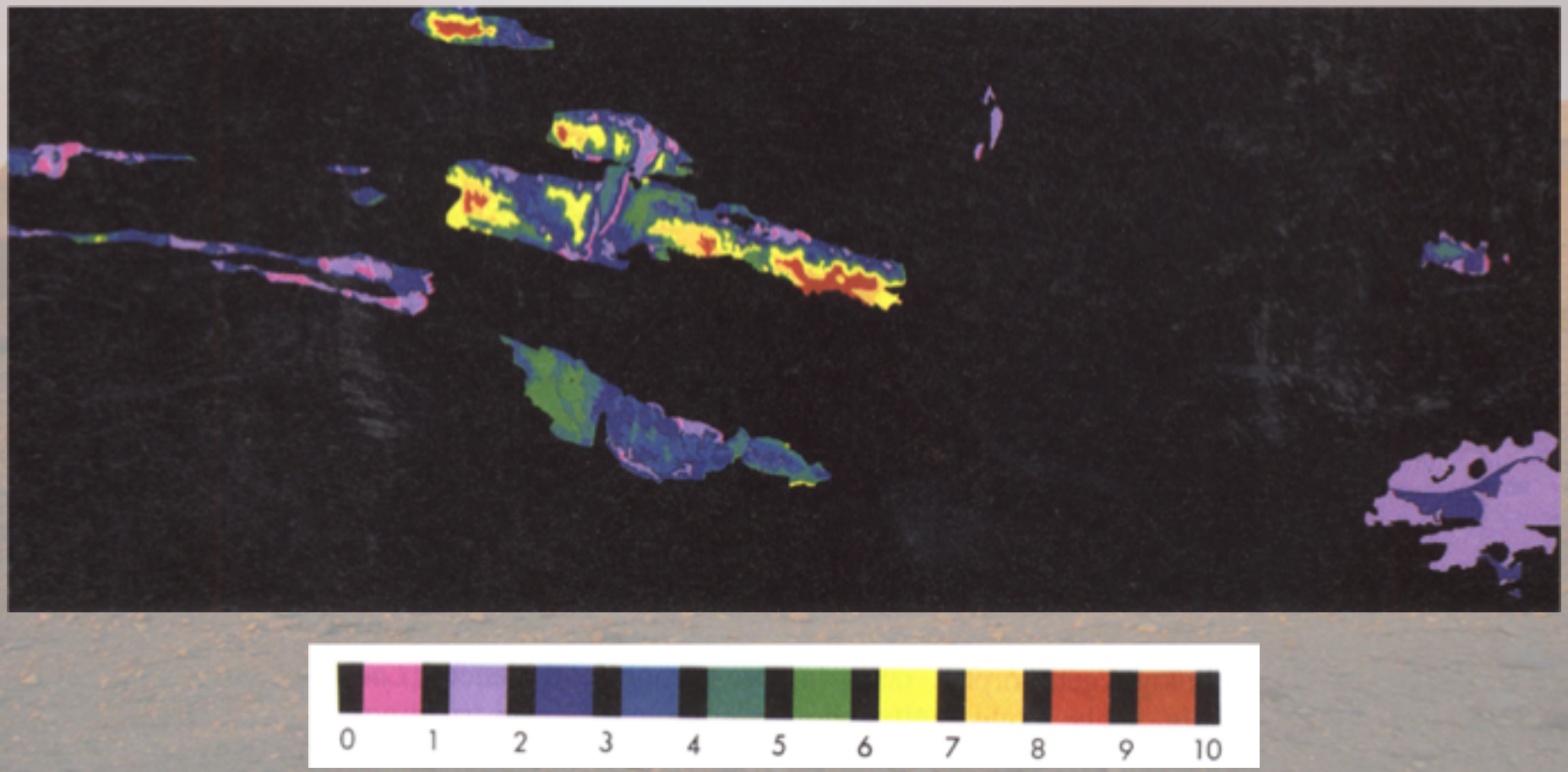
Red - Crater bulges
Green - Light-toned deposits in Chaos
Yellow - Interior layered deposits

Valles Marineris LTDs

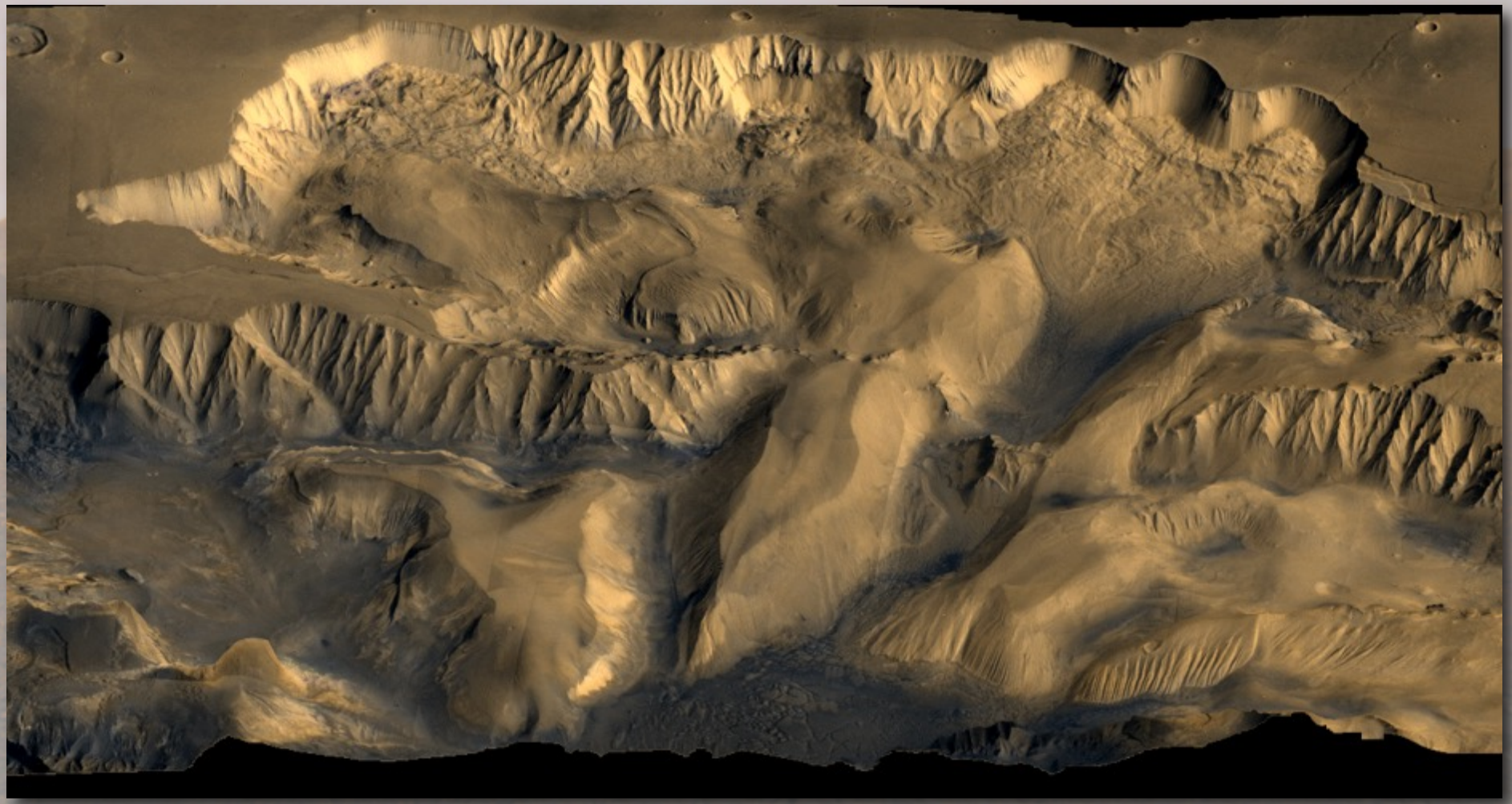


Source: Lucchitta et al. (1994) JGR-Planets

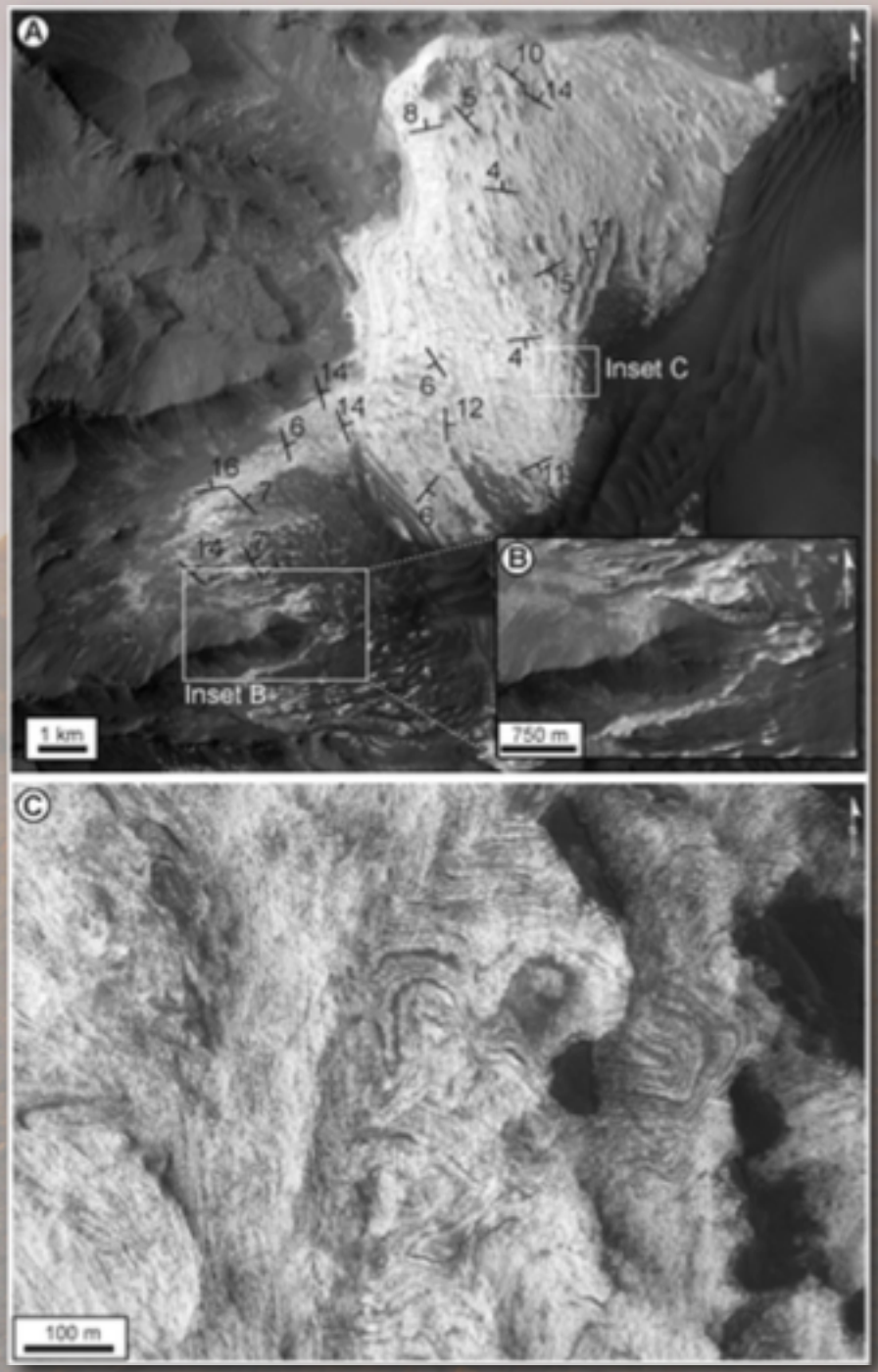
Valles Marineris LTDs: thickness



Valles Marineris LTDs: thickness

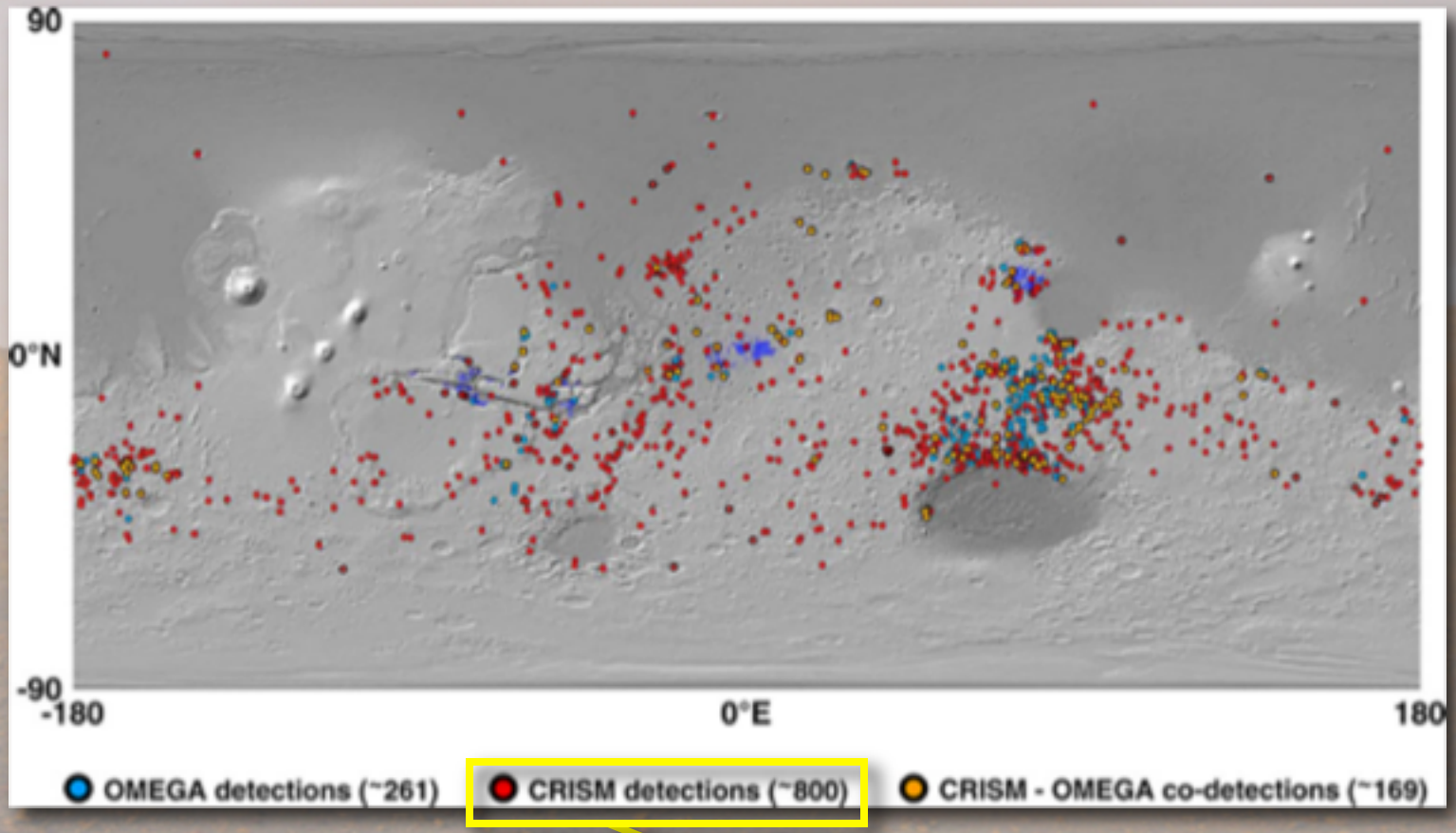


Valles Marineris



Journal of Geophysical Research: Planets, Volume: 122, Issue: 11, Pages: 2223-2249, First published: 10 October 2017, DOI: (10.1002/2017JE005334)

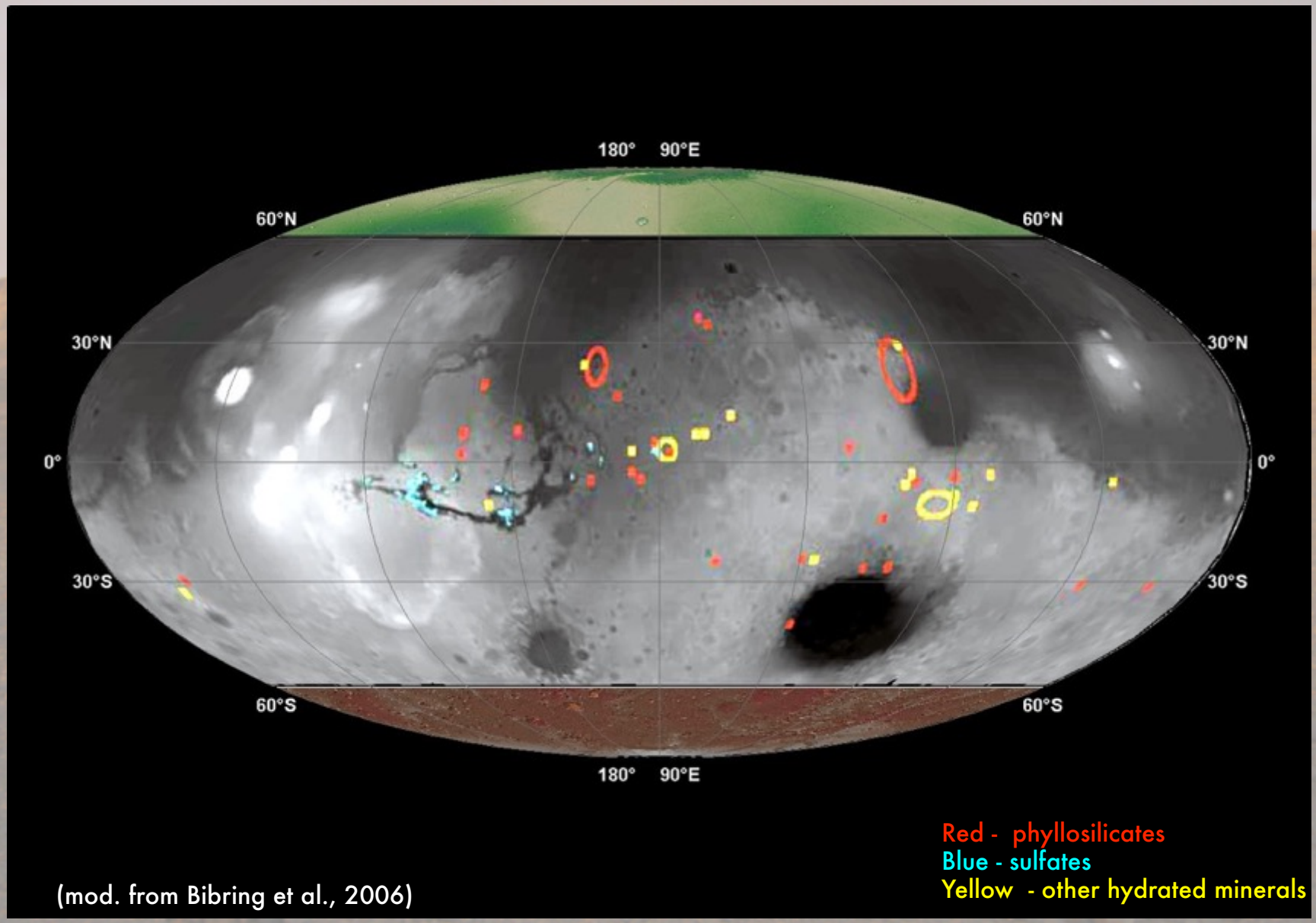
Hydrated minerals



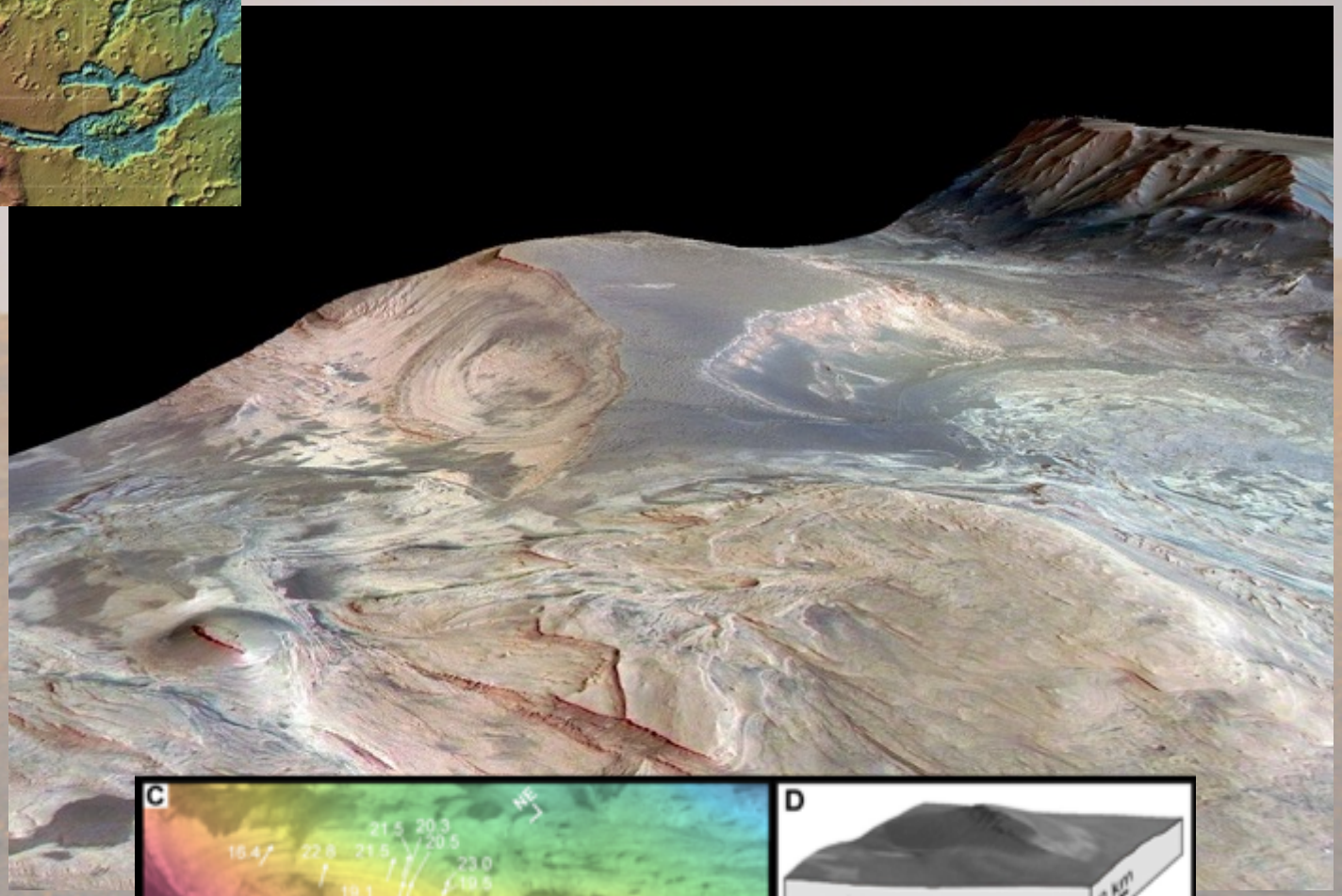
Compact Reconnaissance Imaging Spectrometer for Mars, on board of Mars Reconnaissance Orbiter

Carter et al., 2013 - Journal of Geophysical Research, 118

Hydrated minerals

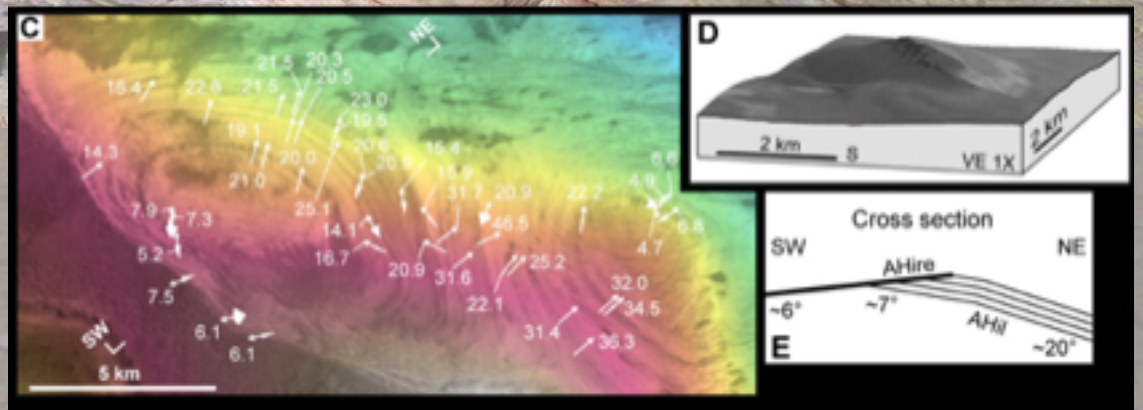


Internal Layered Deposits (ILDs): Candor

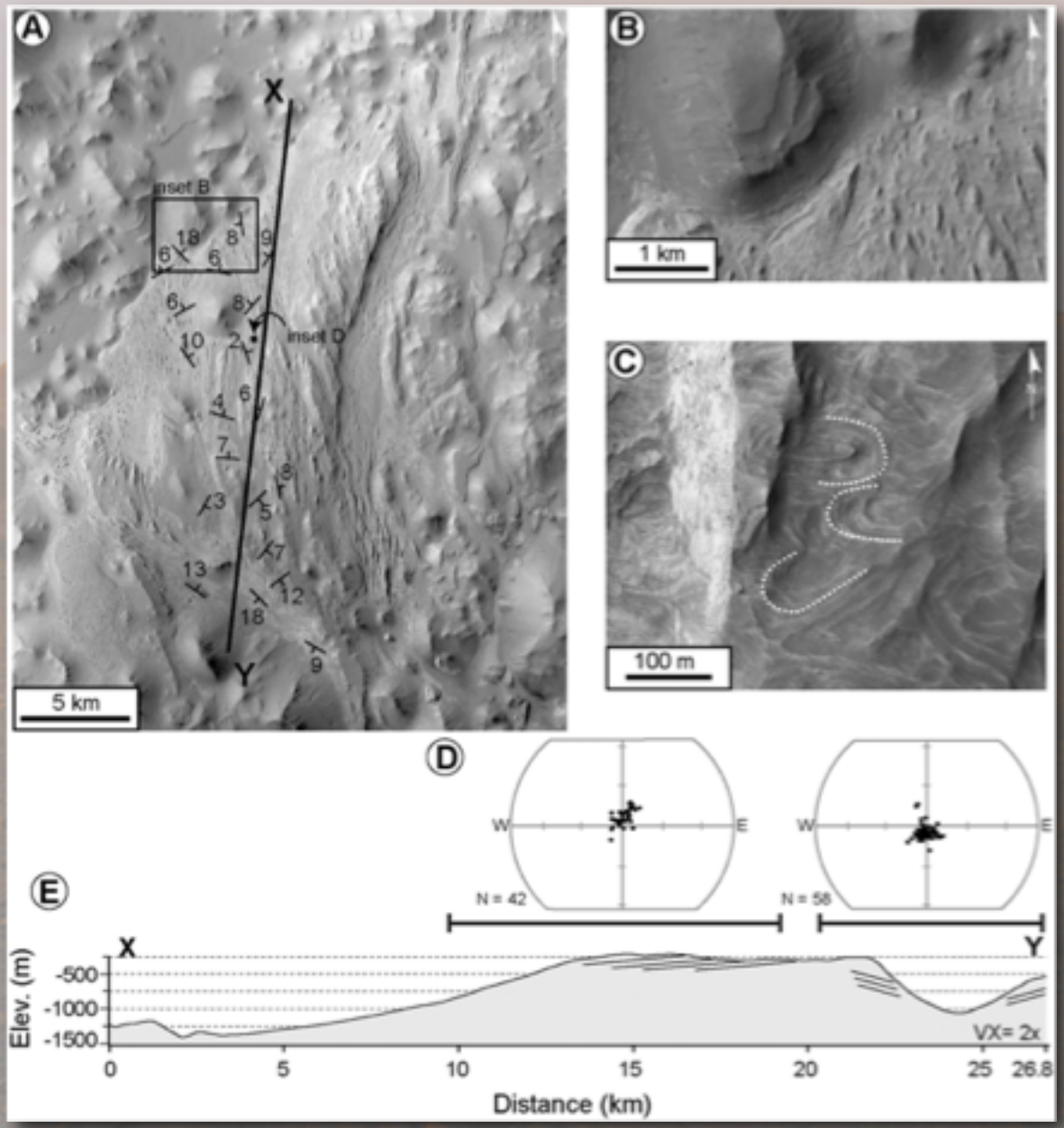


Layered deposits show locally draping, HRSC color composite from orbit 2116

Layers appear to dip outwards, consistently with a mound-like morphology

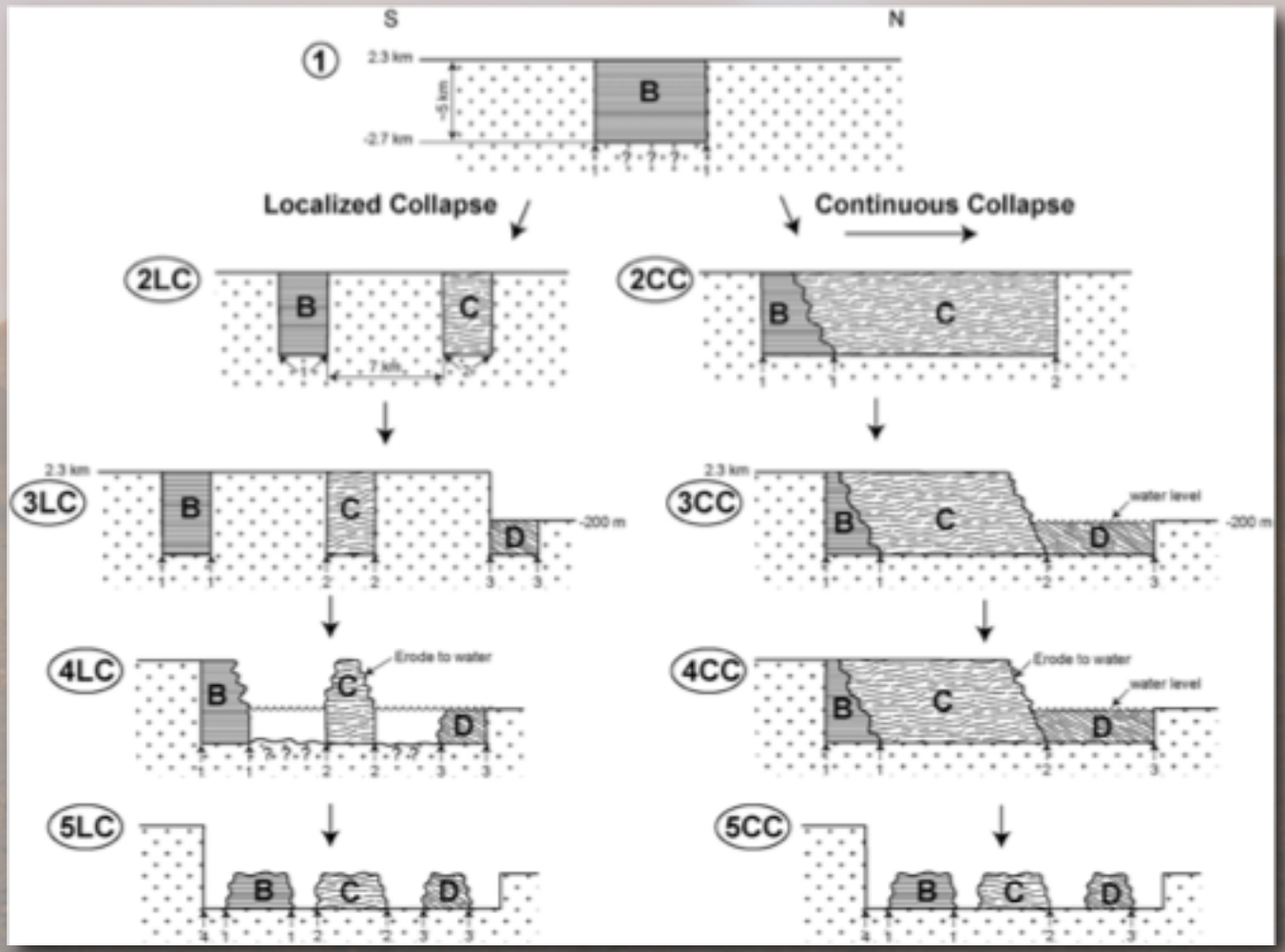


Layered Deposits in Juventae Chasma

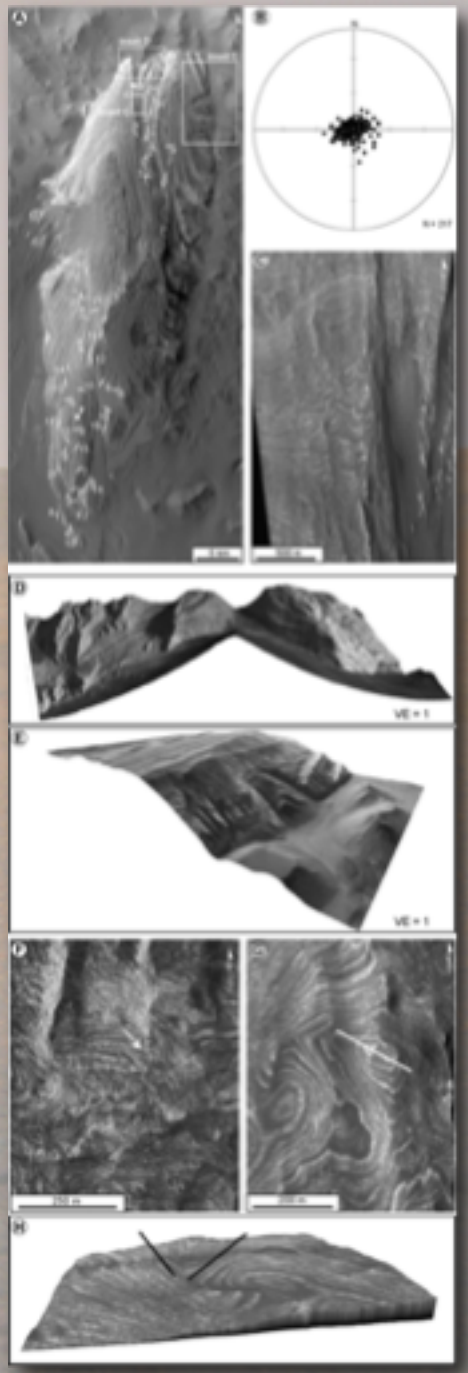


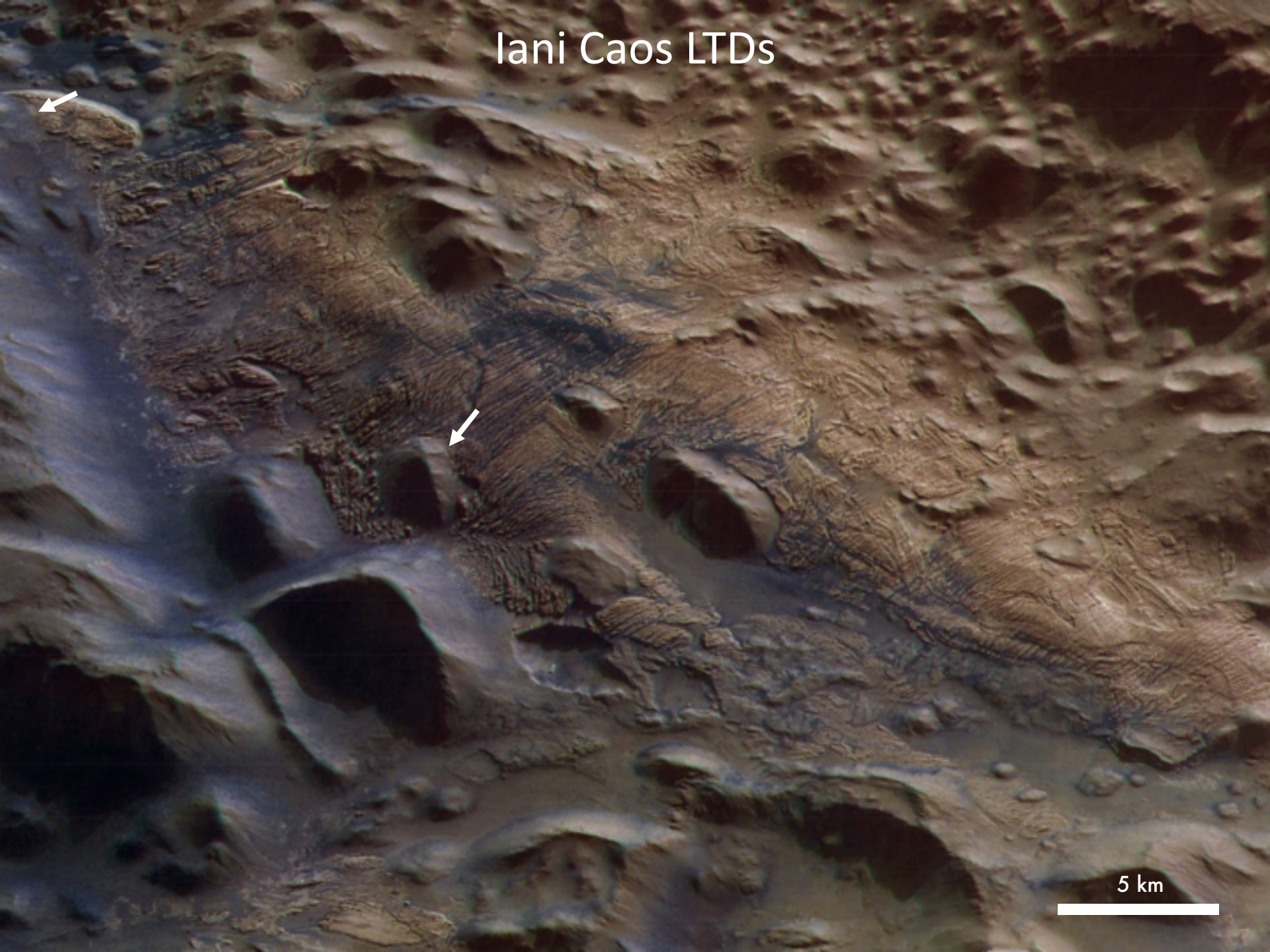
Fueten et al. (2014)
JGR Planets

Layered Deposits in Juventae Chasma

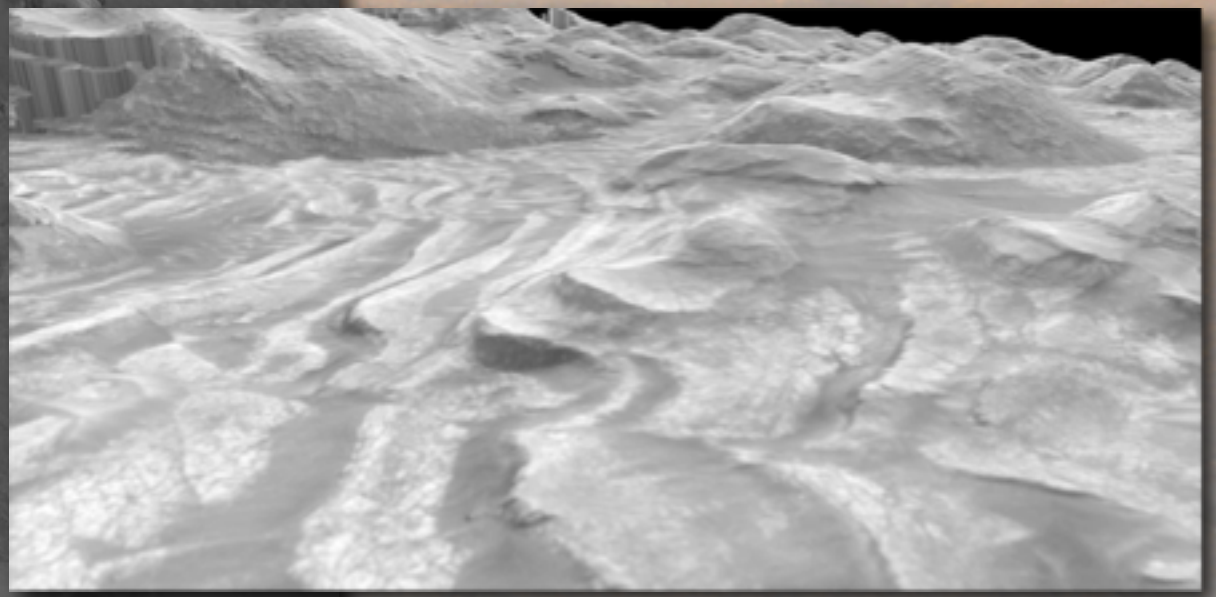


Fueten et al. (2014) JGR Planets




Iani Caos LTDs
5 km

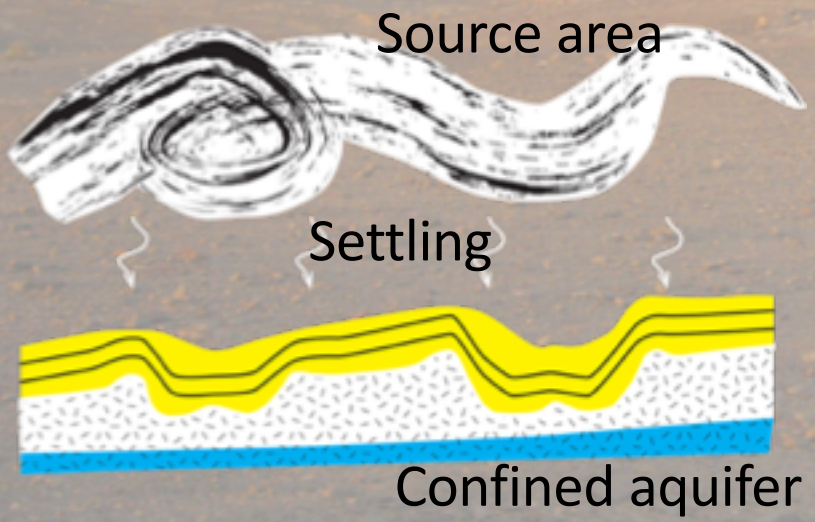
Crater bulges

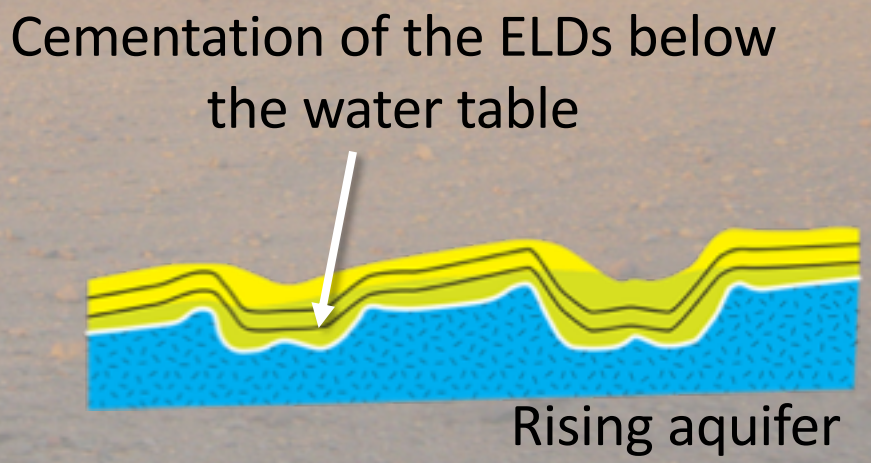


ELDs formation -→ Proposed scenarios

E.g., Andrews-Hanna et al., 2007, 2011; Michalski and Niles, 2012; Zabrusky et al., 2012; Michalski et al., 2013; Hynek and Di Achille, 2017.

- Airfall and/or pyroclastic flows.
- Lower portions cemented by groundwater-related processes.
- Differential aeolian erosion.





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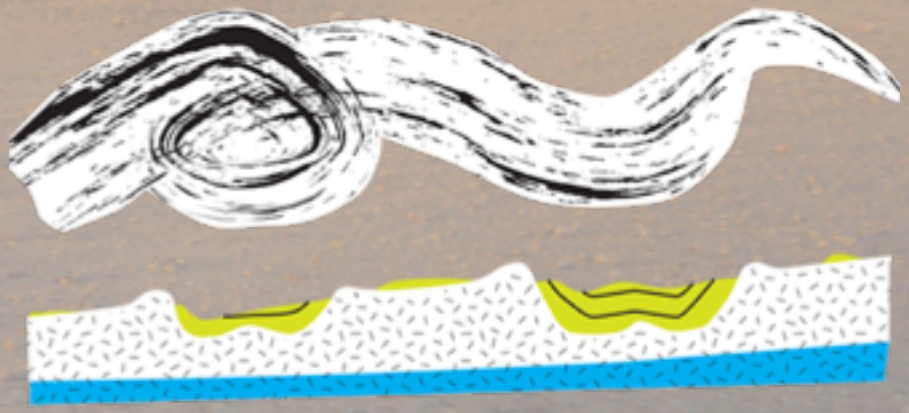
Quick erosion of the dry sediments

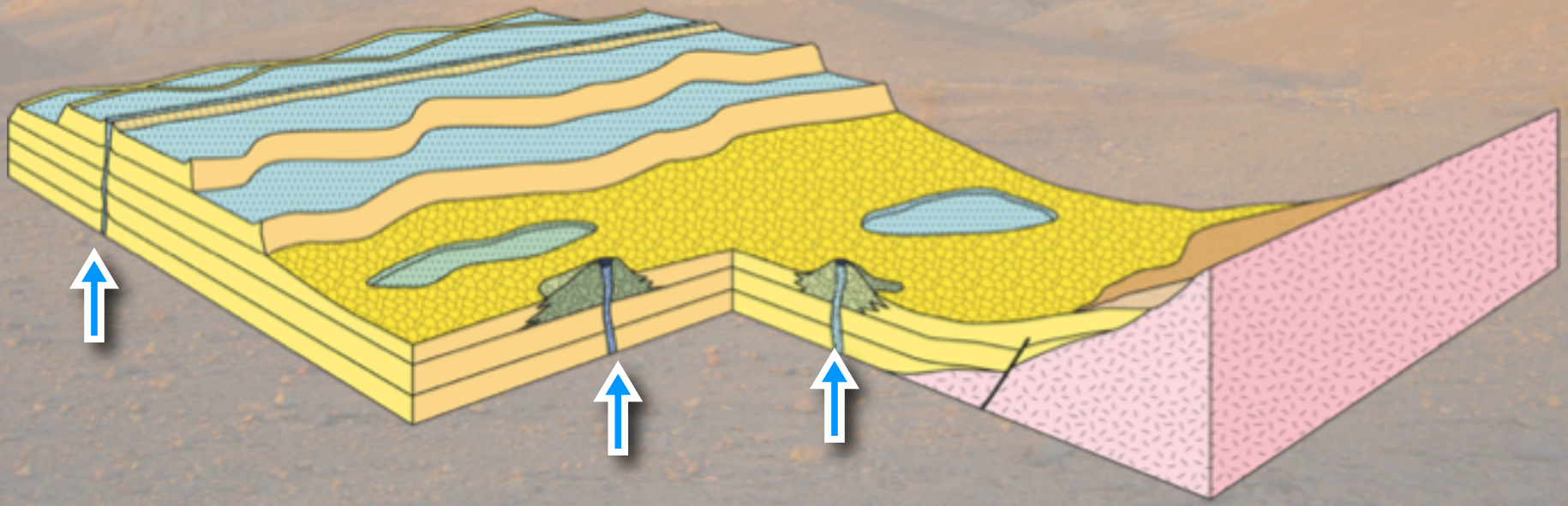


Aeolian erosion of some wet deposits

ELDs formation -→ Proposed scenarios

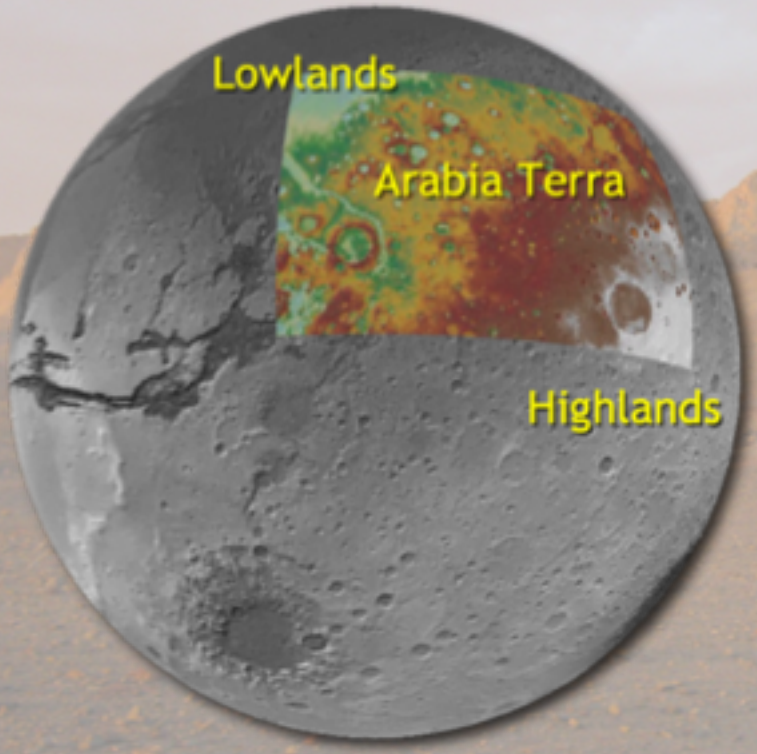
E.g., Rossi et al., 2008; Allen and Oehler, 2008; Pondrelli et al., 2011, 2015, Franchi et al., 2014; Pozzobon et al., 2019.

- ✓ Water upwelling from a confined aquifer.
- ✓ Spring and playa deposits with aeolian erosion and reworking.



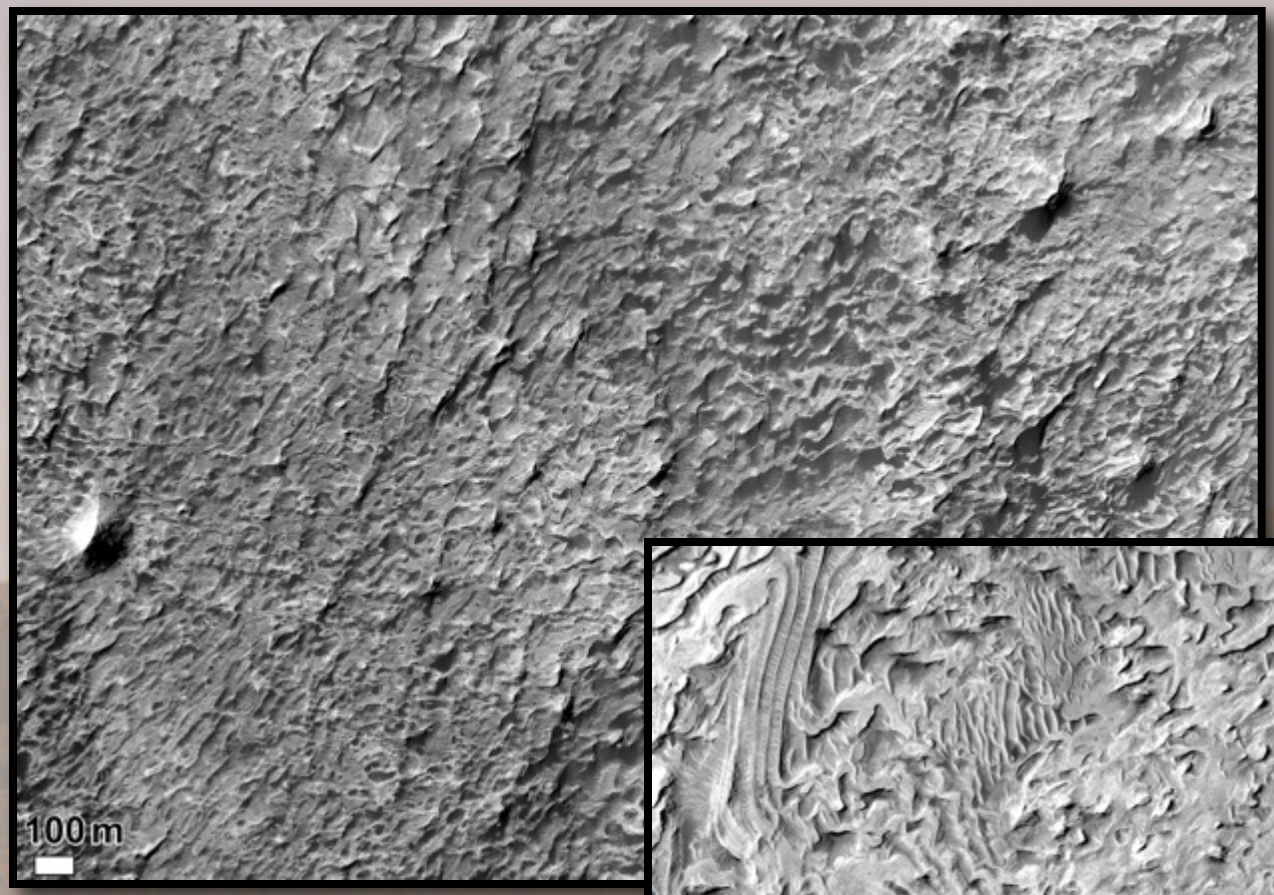
Source area

Equatorial Light-toned Layered Deposits in Arabia Terra (ELDs)



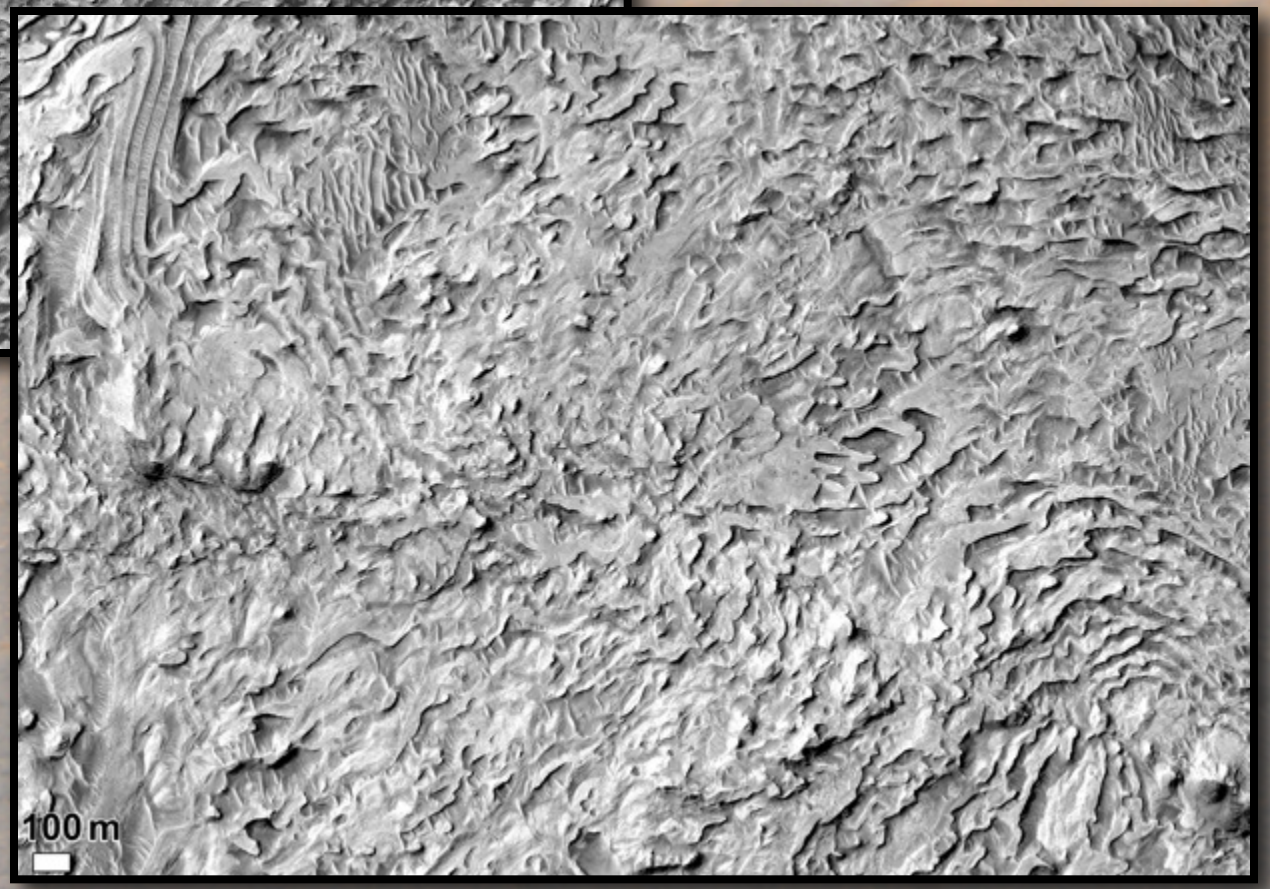
- **Gradual topographic transition between Martian Highlands and Lowlands;**
- **layered deposits in the craters and in the plateau;**
- **extensive documentation of sulphates.**

Good habitability potential of many sulfate-bearing depositional environments coupled with good preservation potential.



HiRISE ESP_035329_1825_RED
Res. 0.25 m/pix

Firsoff Crater



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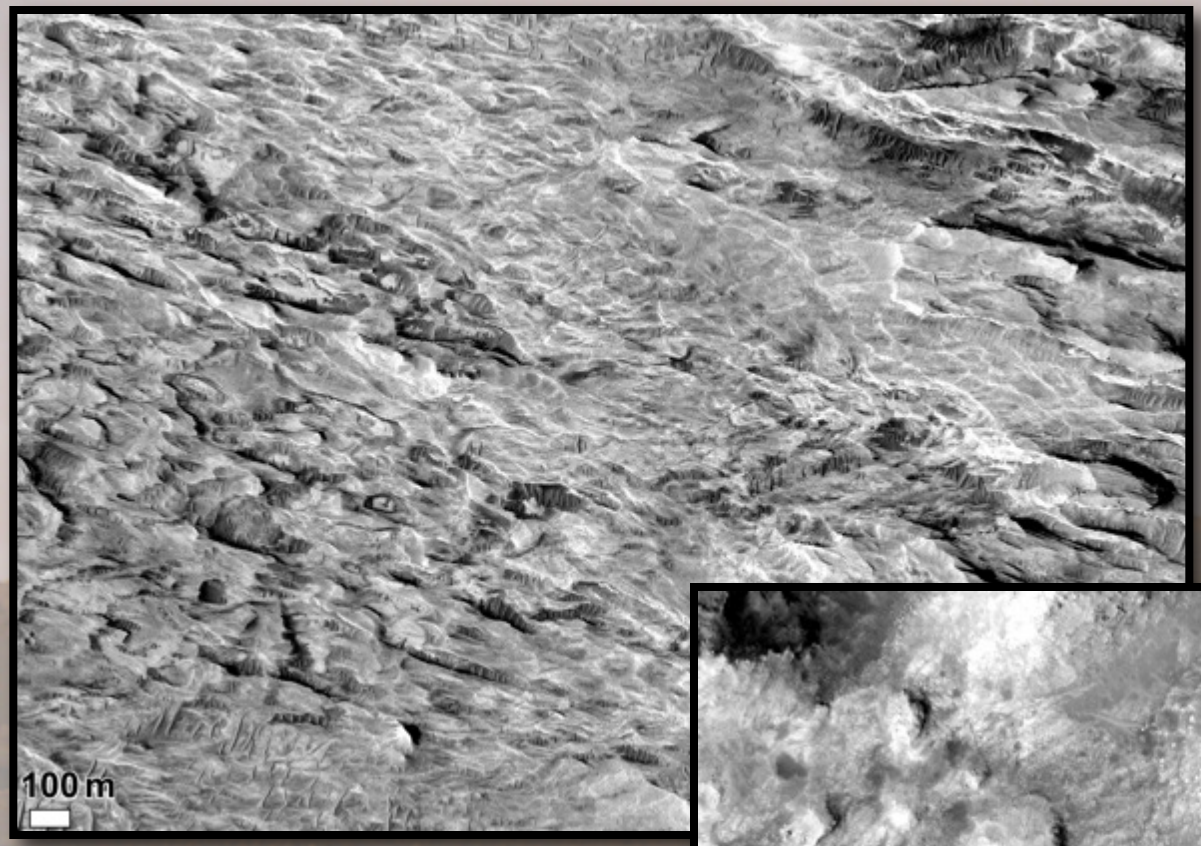
~35 km large crater south of Firsoff Crater



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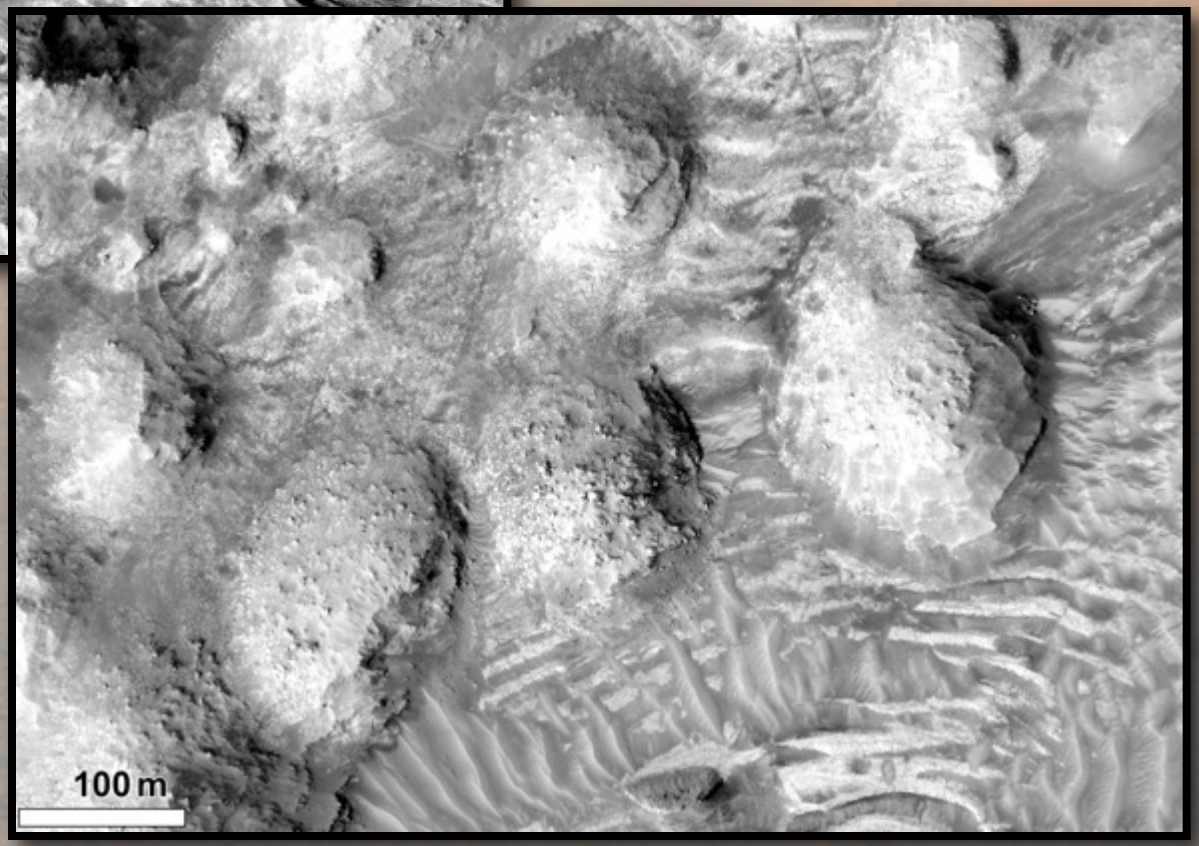
Plateau



HiRISE PSP_003788_1820_RED
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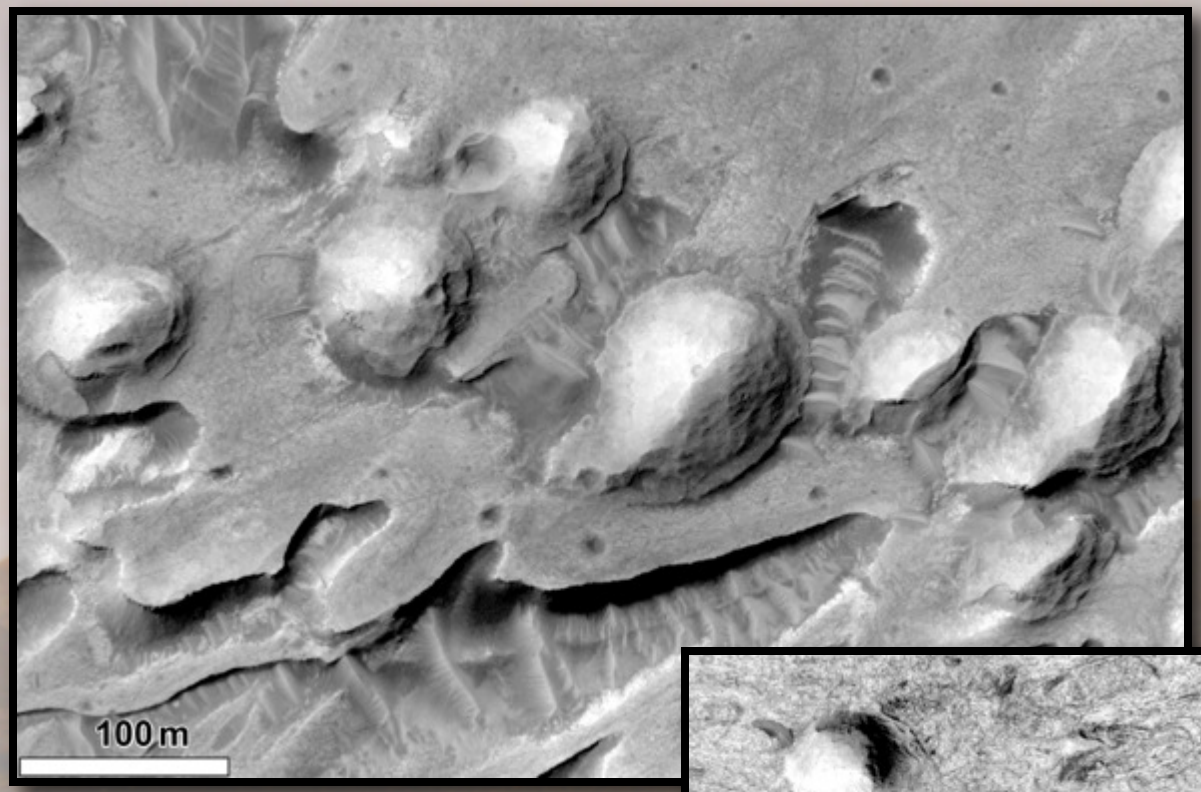
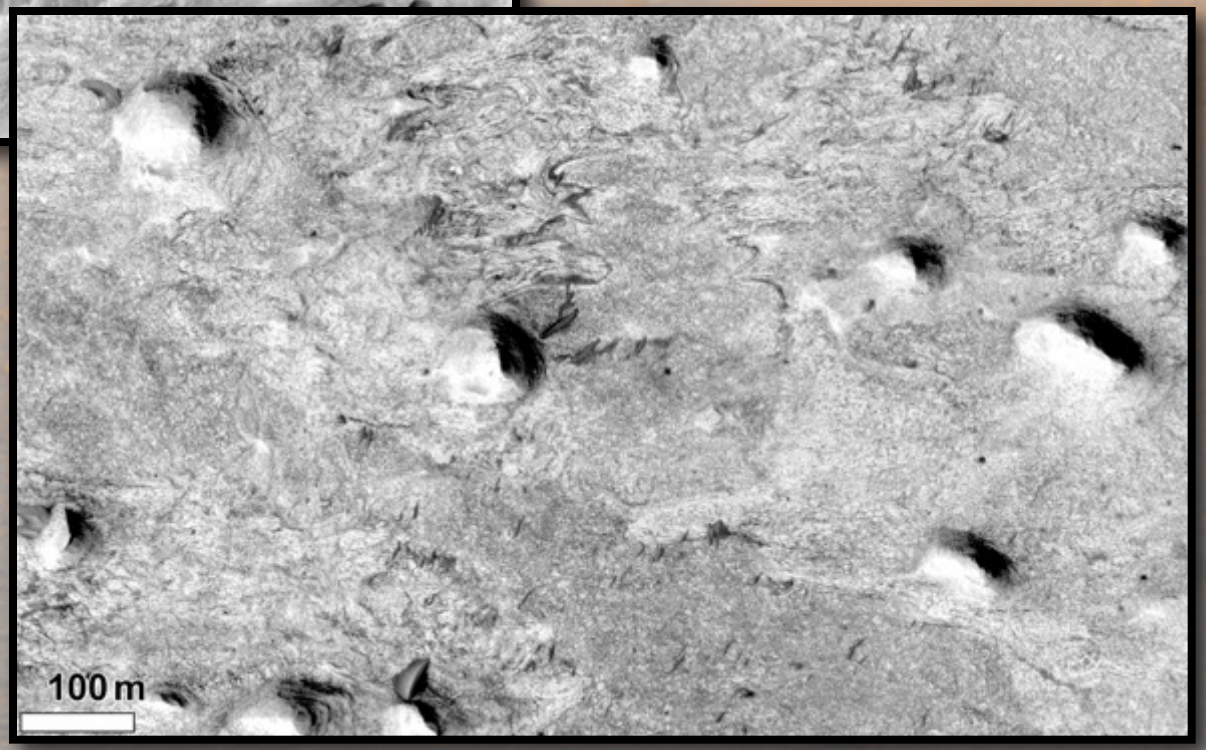
Firsoff crater



HiRISE ESP_016776_1810_RED
Res. 0.50 m/pix

~35 km large crater south of Firsoff Crater



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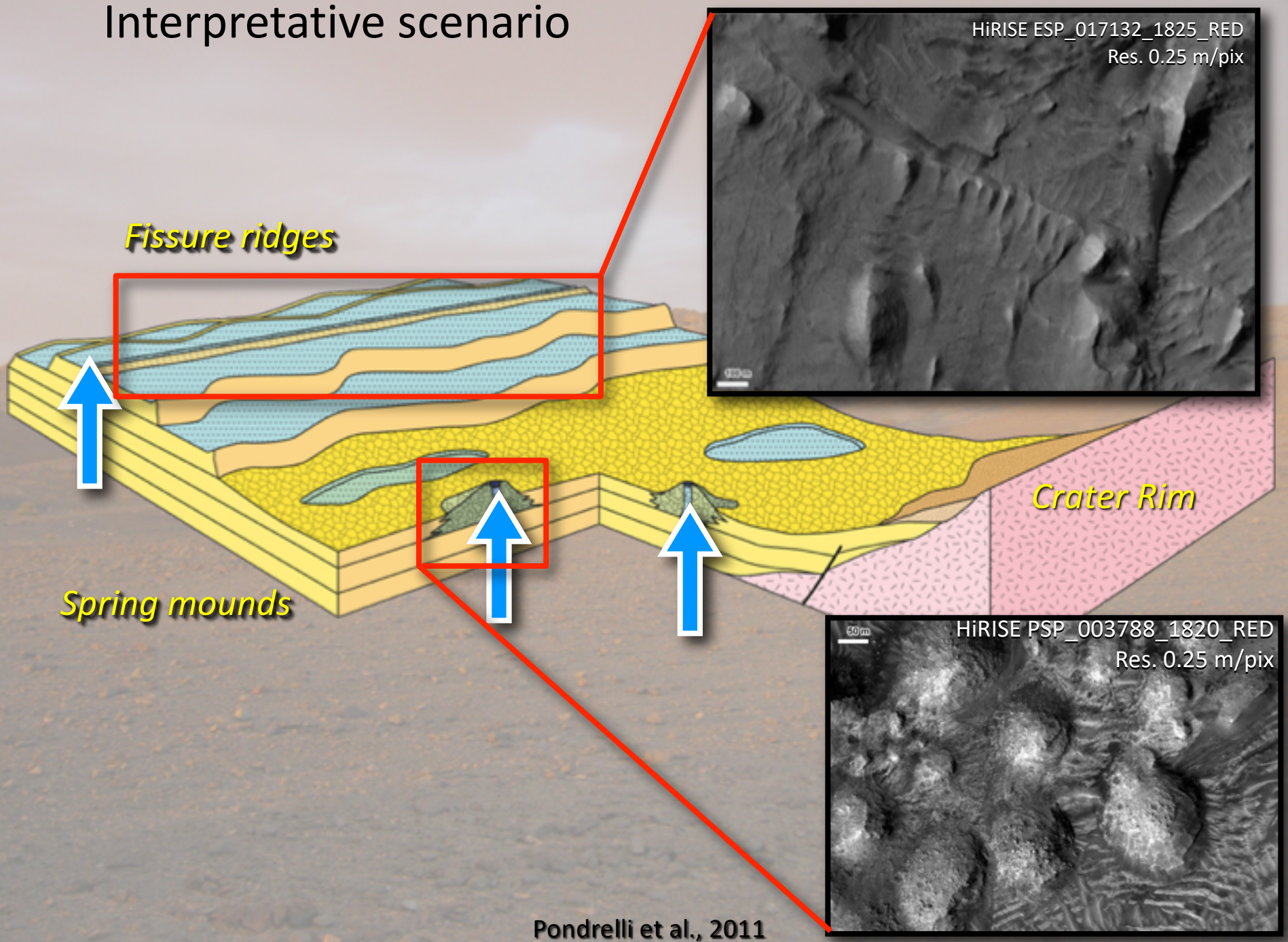
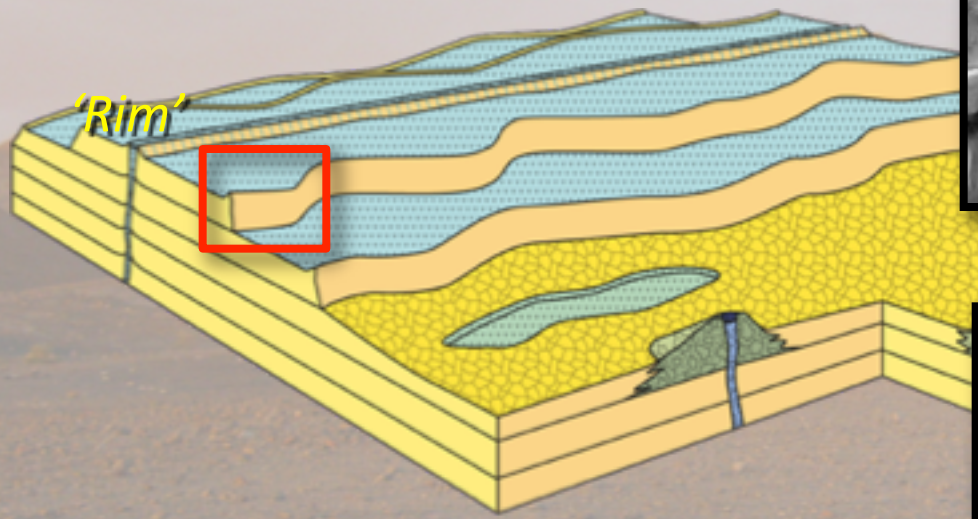
Res. 0.25 m/pix

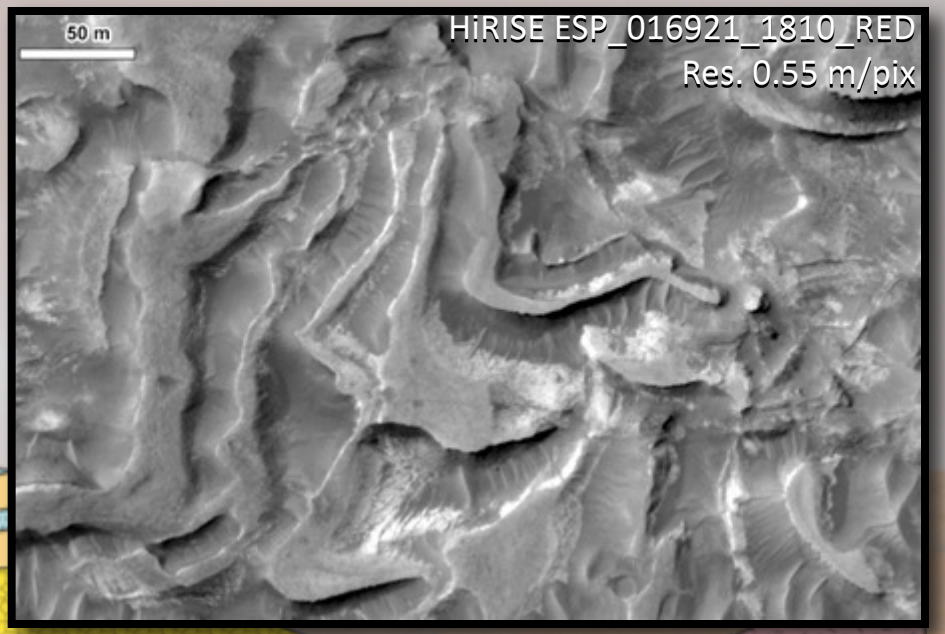
Plateau

Interpretative scenario



Interpretative scenario






THANK YOU