Exhumed Hypanis Fluvial Deltaic system in Xanthe Terra

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J. Michalski, J. Carter, J-P. Muller, P. Sidiropoulos

ExoMars 2018 First Landing Site Selection Workshop (LSS WS#1)
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Table of Contents

Why an ancient delta?

Martian context → early Mars environment	*Support biotic OM formation*	*Support for abiotic OM formation*	*Support OM concentration*	*Support preservation*
Eolian sediments (sand)	low	low	low	low
Altered eolinites (dust)	very low	low	low	low
Fluvial channel	low	low	low	low
Fluvial floodplain	low-mod	low	mod	mod
Alluvial fan	low	low	low	low
Deltaic	high	low	high	high
Lacustrine (perennial)	high	low	high	high
Lacustrine (evaporitic)(Cl)	low	low	high	high-very high
Lacustrine (evaporitic)(SO_4)	mod	low	high	high-very high
Regional groundwater pore system	low	low	low	low
Glacial deposits	low	low	low	low
Permafrost	low	low	low	mod
Soil (surface fines chemically altered by atmosphere)	low	low	low	low
Regolith/Fractured bedrock (not soil)	low	low	low	low

Ancient deltas and lakes are excellent exploration targets for ExoMars

- **Low energy fine-grained sediments**
- **Higher sedimentation rates – due to abrupt gradient in sediment transport rates**
- **High rates of nutrient supply**

Summons et al., 2011

Delta toe deposits interfingering with basinal mudstones

Hypanis – Geological context

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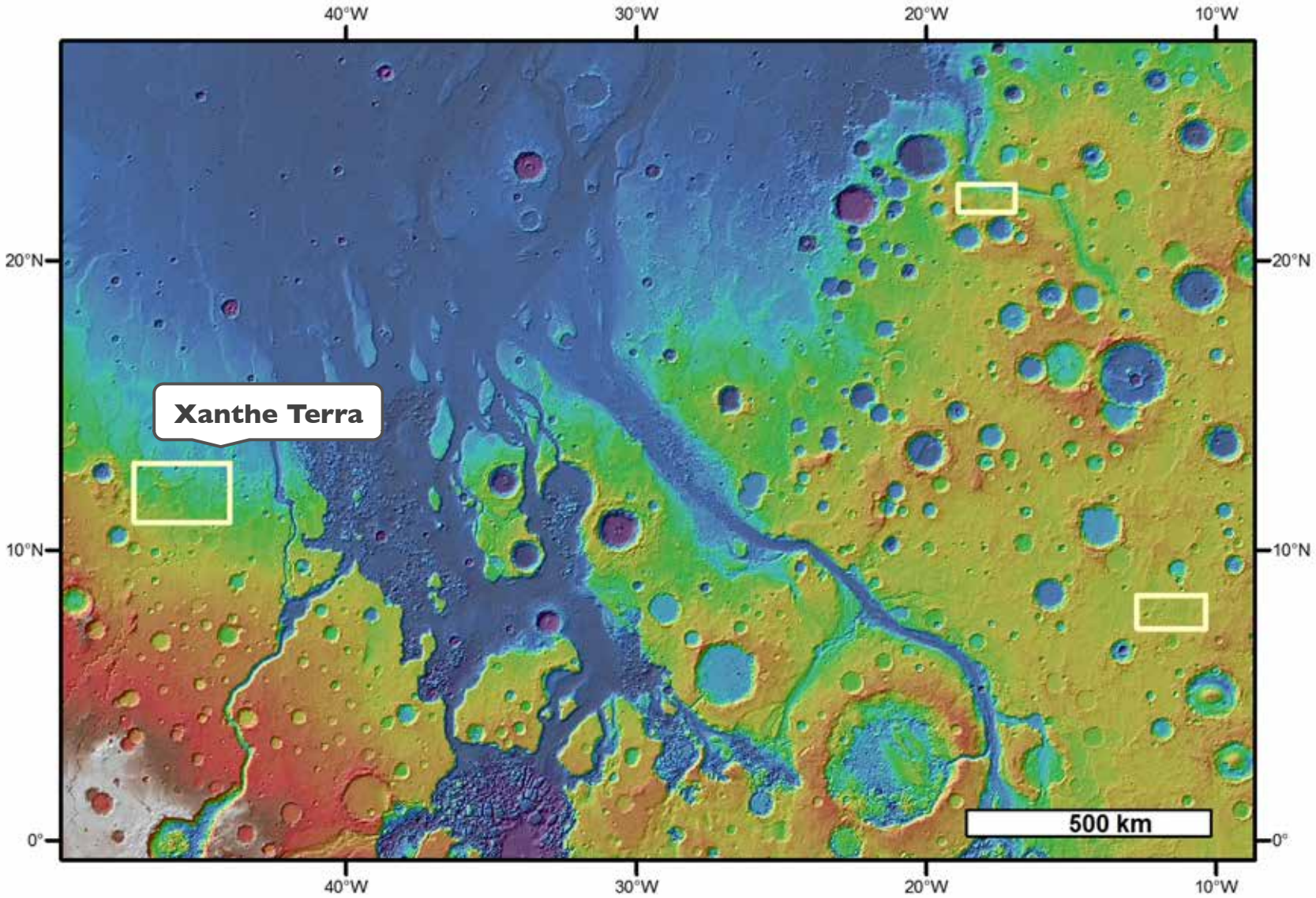
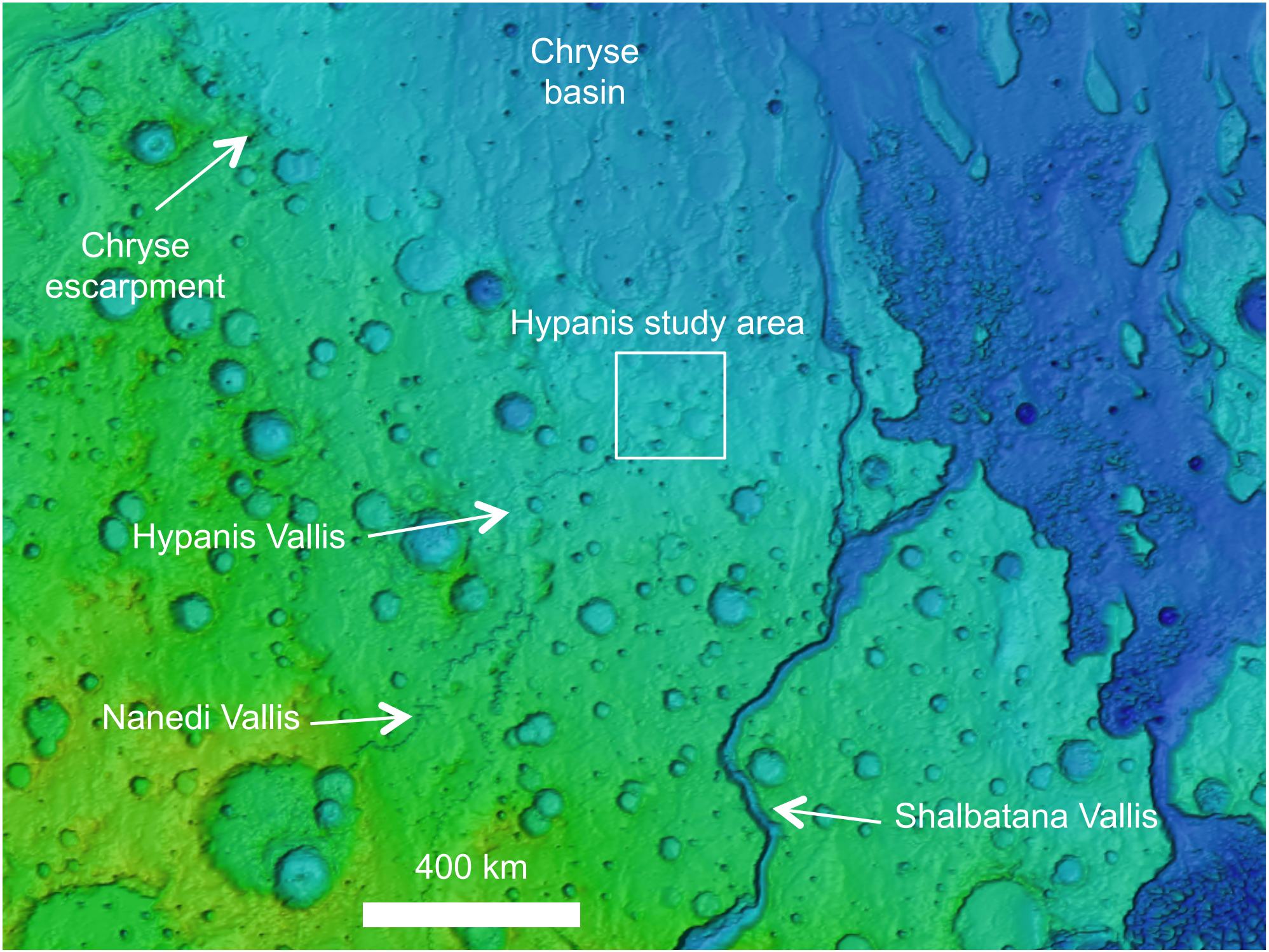
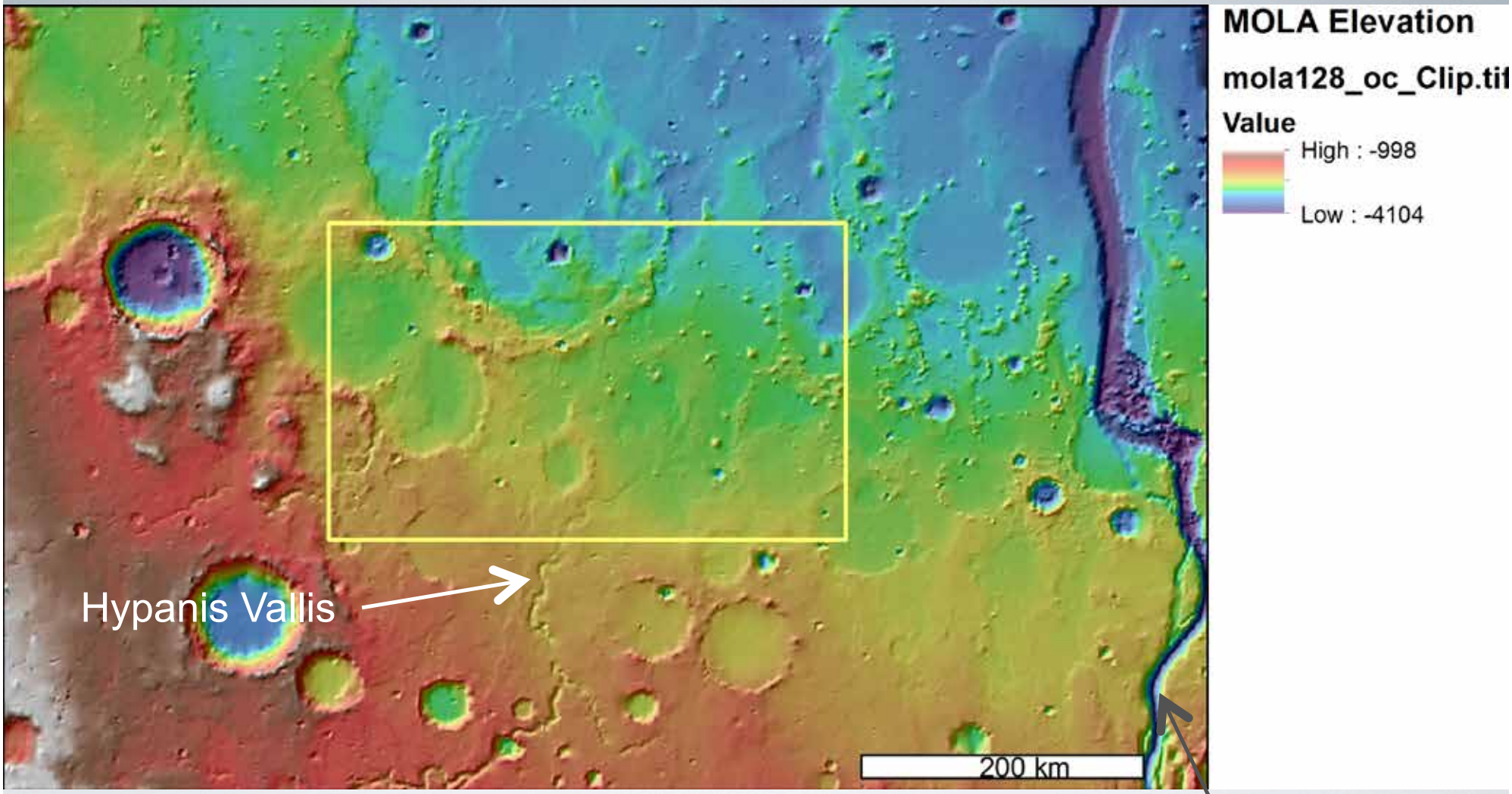
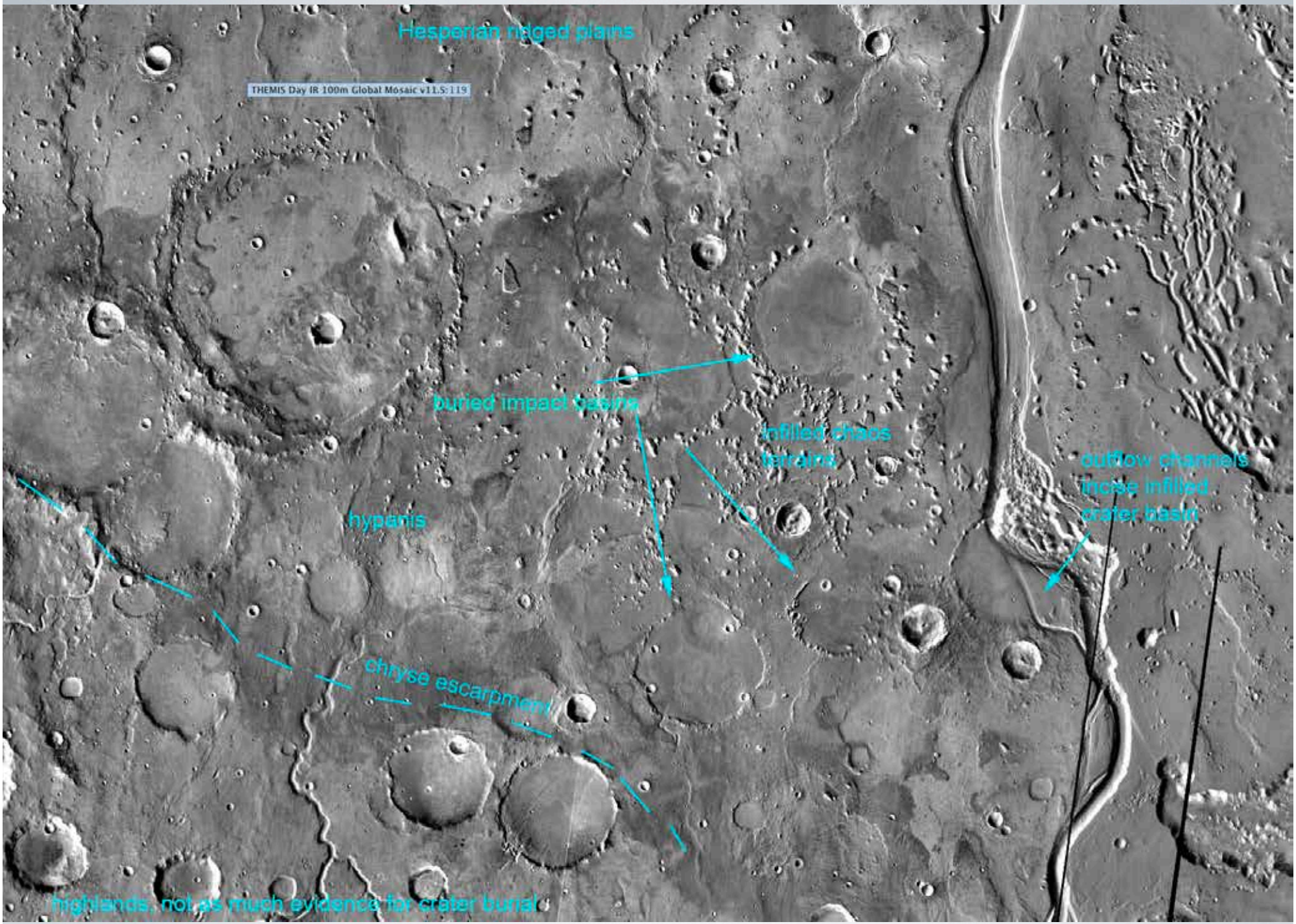
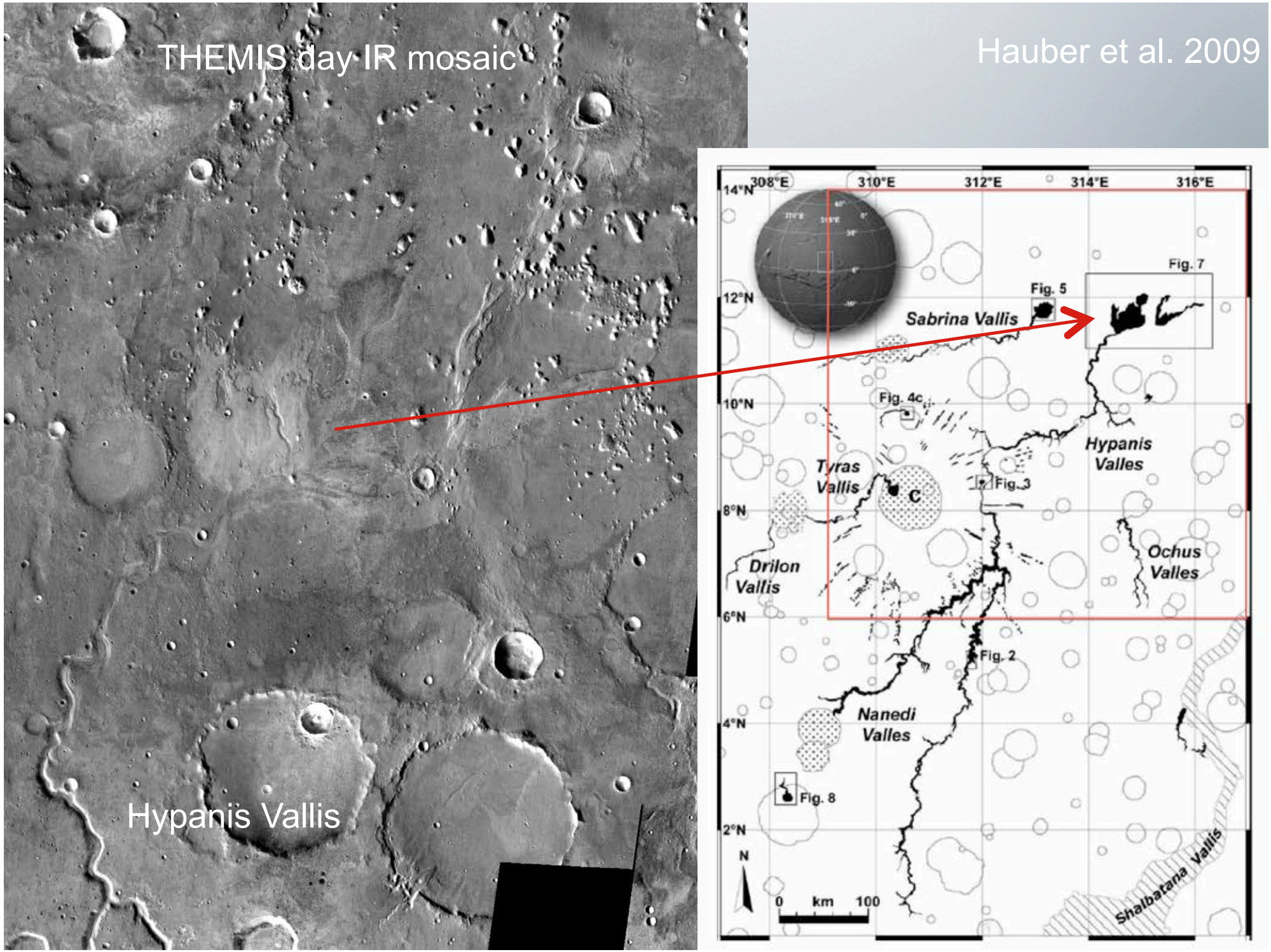
General Site Presentation




Chryse
basin
Chryse
escarpment
Hypanis study area
Hypanis Vallis
Nanedi Vallis
Shalbatana Vallis
400 km


MOLA Elevation
mola128_oc_Clip.tif
Value
High : -998
Low : -4104
Hypanis Vallis
200 km
Shalbatana Vallis


Hesperian ridged plains
THEMIS Day IR 100m Global Mosaic v11.5:119
buried impact basins
infilled chaos terrains
outflow channels incise infilled crater basin
hypanis
chryse escarpment
highlands, not as much evidence for crater burial


THEMIS day IR mosaic
Hauber et al. 2009
Hypanis Vallis
308°E
310°E
312°E
314°E
316°E
14°N
12°N
10°N
8°N
6°N
4°N
2°N
Fig. 7
Fig. 5
Sabrina Vallis
Fig. 4c
Hypanis Valles
Tyras Vallis
C
Fig. 3
Ochus Valles
Drilon Vallis
Fig. 2
Nanedi Valles
Fig. 8
N
0
km
100
Shalbatana Vallis

Source of Hypanis system

- Hypanis fan system is fed by a very extensive bedrock valley – Hypanis Vallis – several hundred kilometres long (?), ~75 m deep
  - Perhaps connects to Nanedi Vallis
- Large volume of rock has been removed by fluvial erosion
- Valley network is very different to drainages sourced from crater rims cf. Gale crater fan and other crater-rim fed fans
- Hypanis is a much bigger system
- Hypanis and Sabrina deltas are located at margin of Chryse escarpment – abrupt transition from erosional to depositional realm
- Timescale of fluvial erosion
  - Difficult to estimate precisely
  - Valley form is different to outflow channels
  - Narrow width, sinuous valley form
  - Suggests long-lived erosion – not instantaneous or short-lived erosion

Hypanis – Depositional geomorphology

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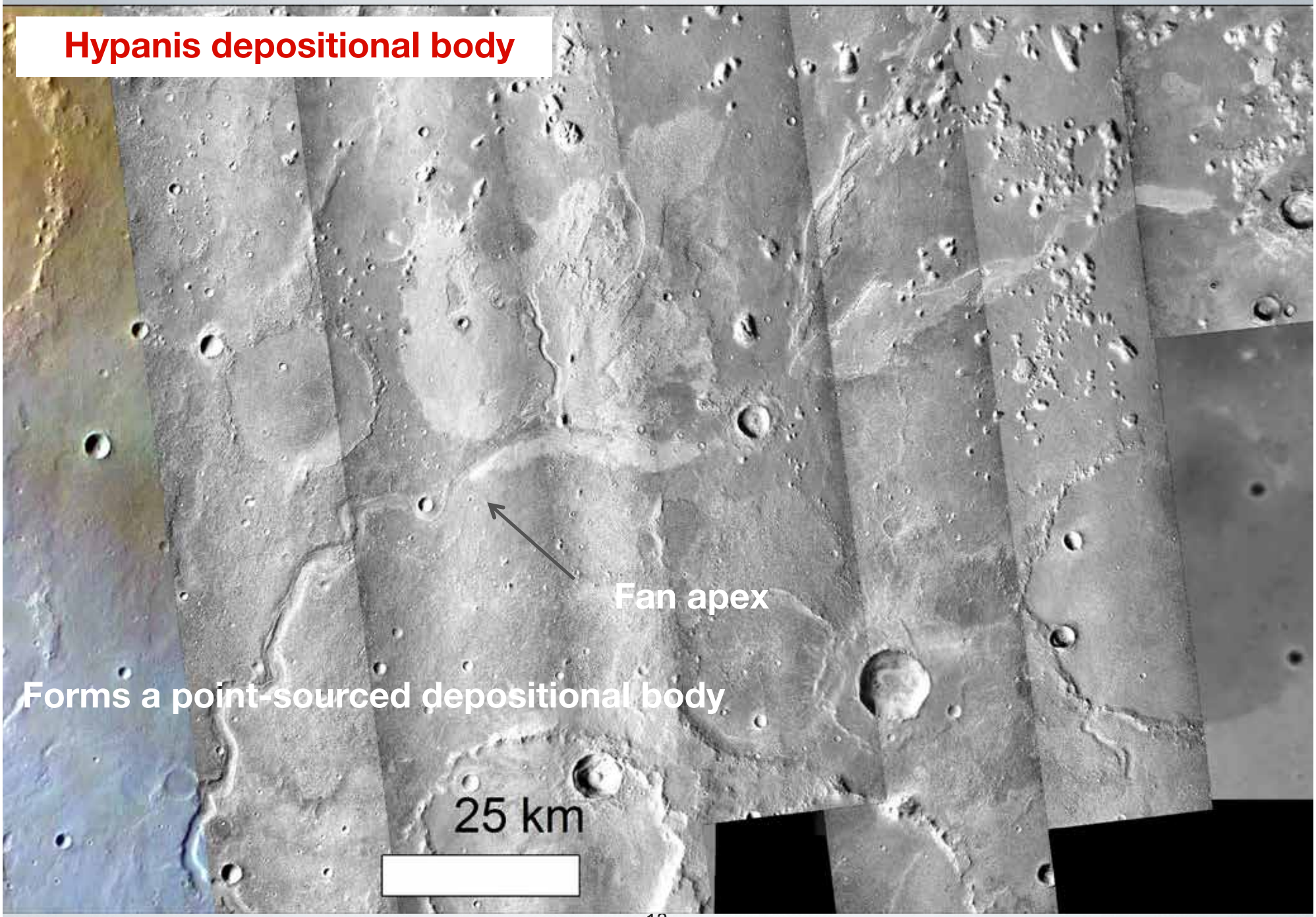
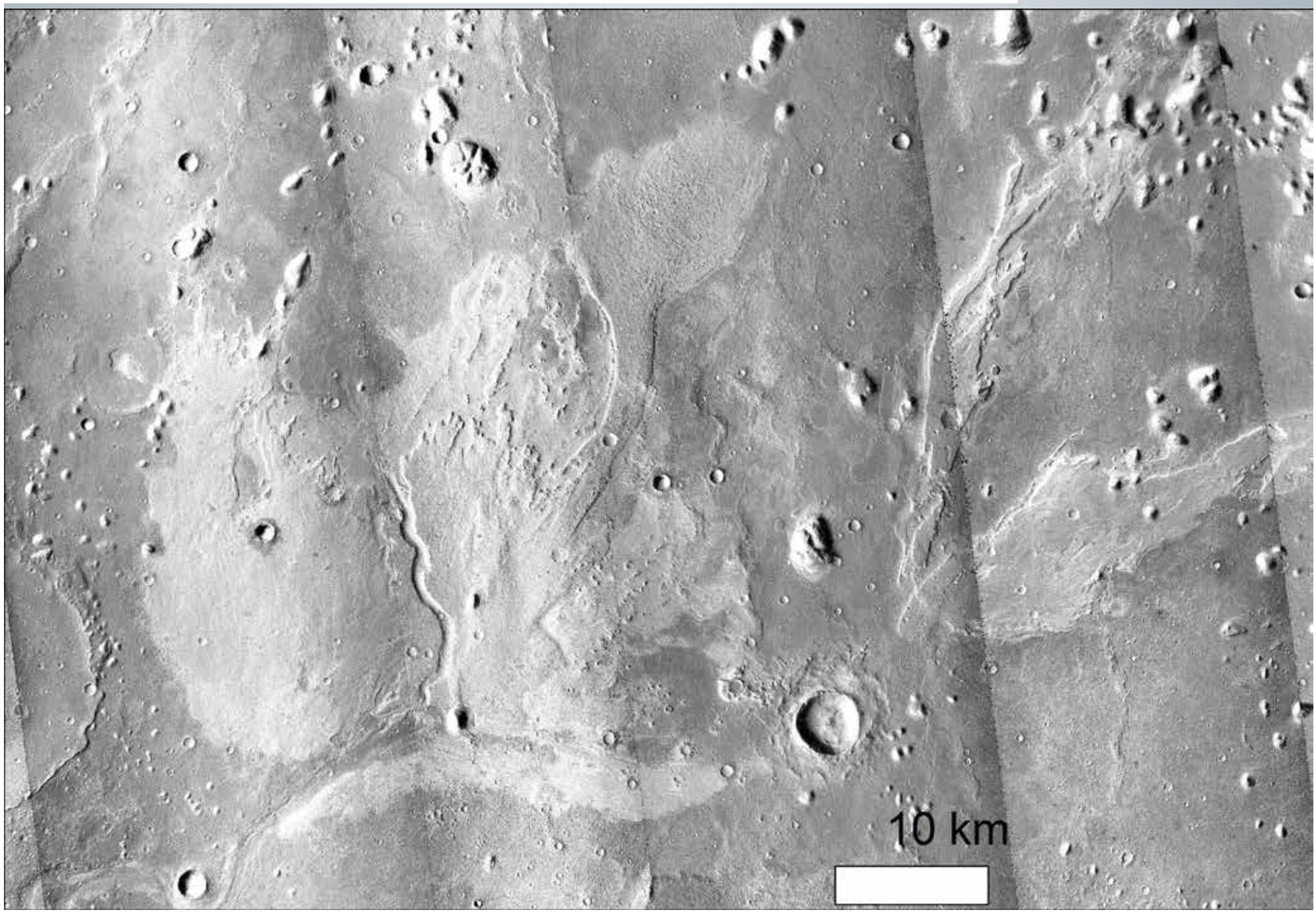
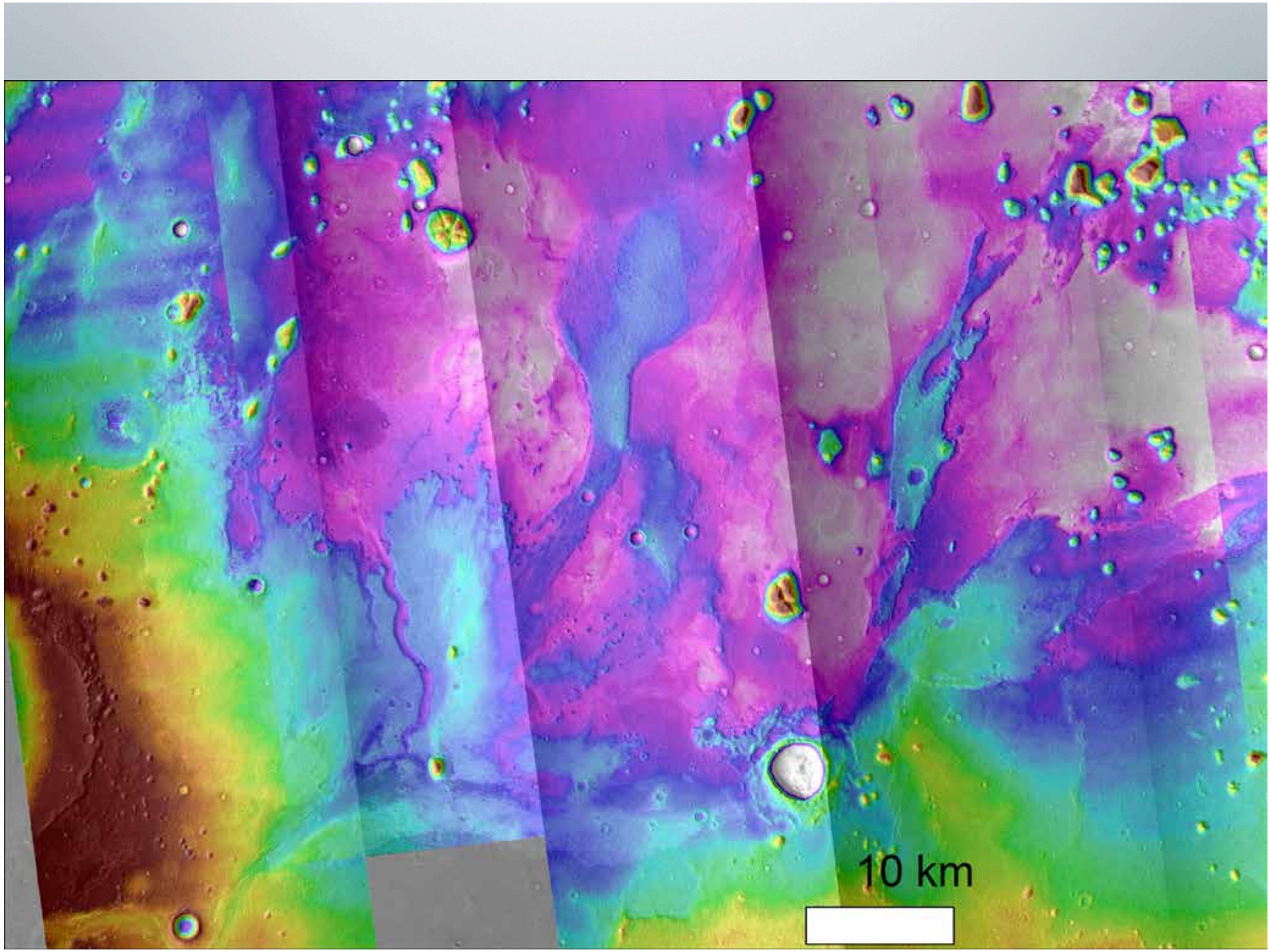
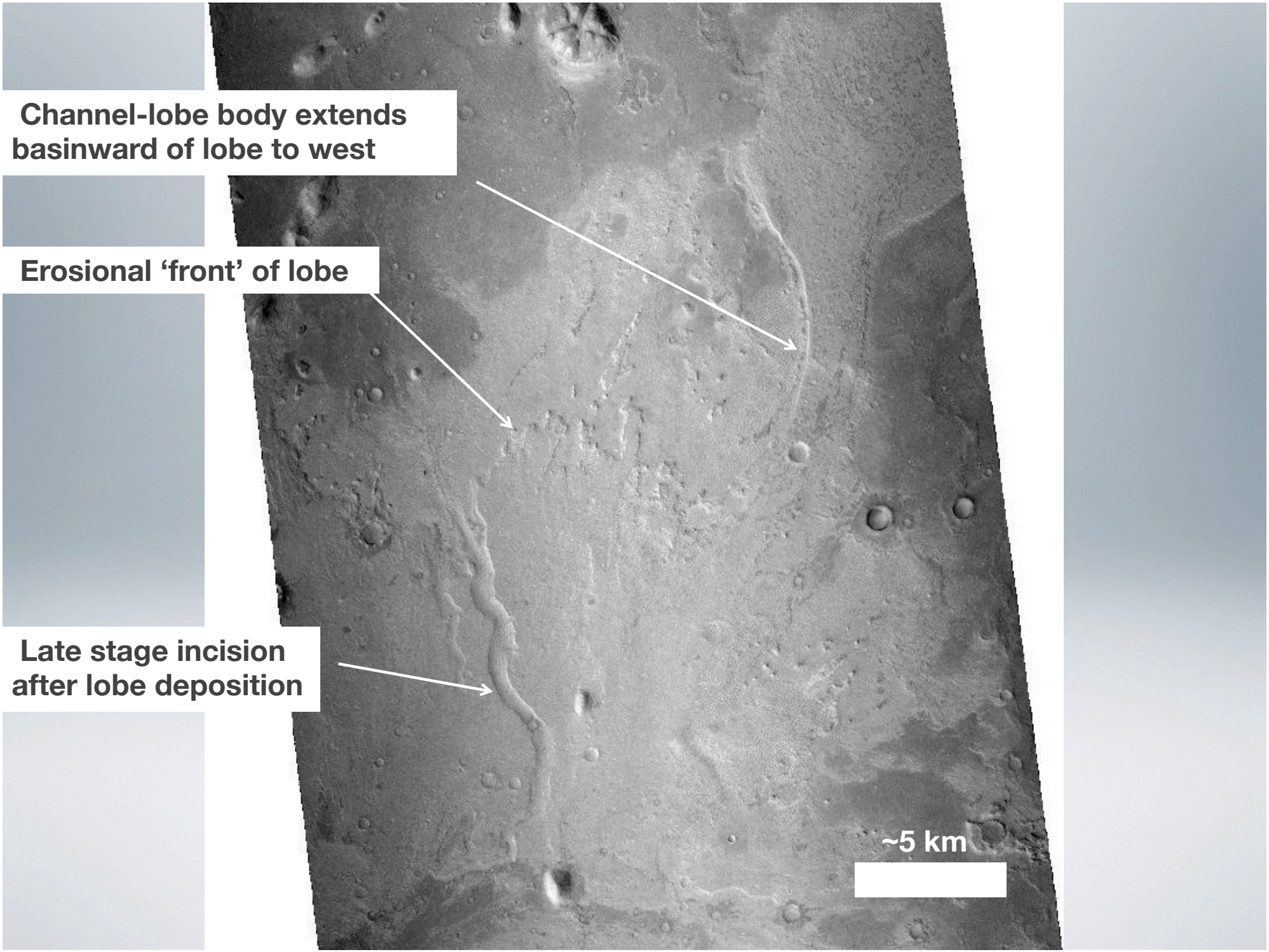
Hypanis depositional body

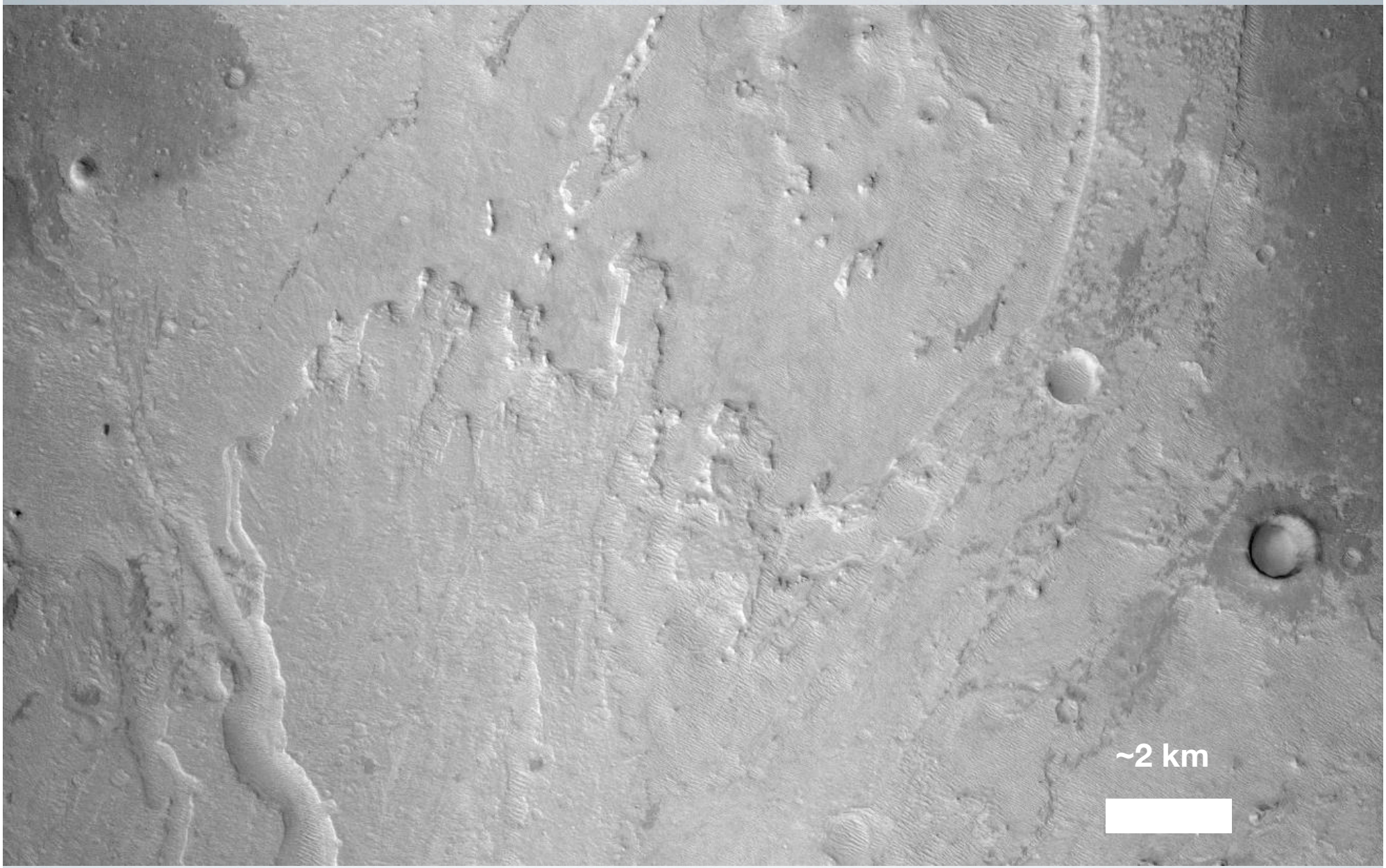


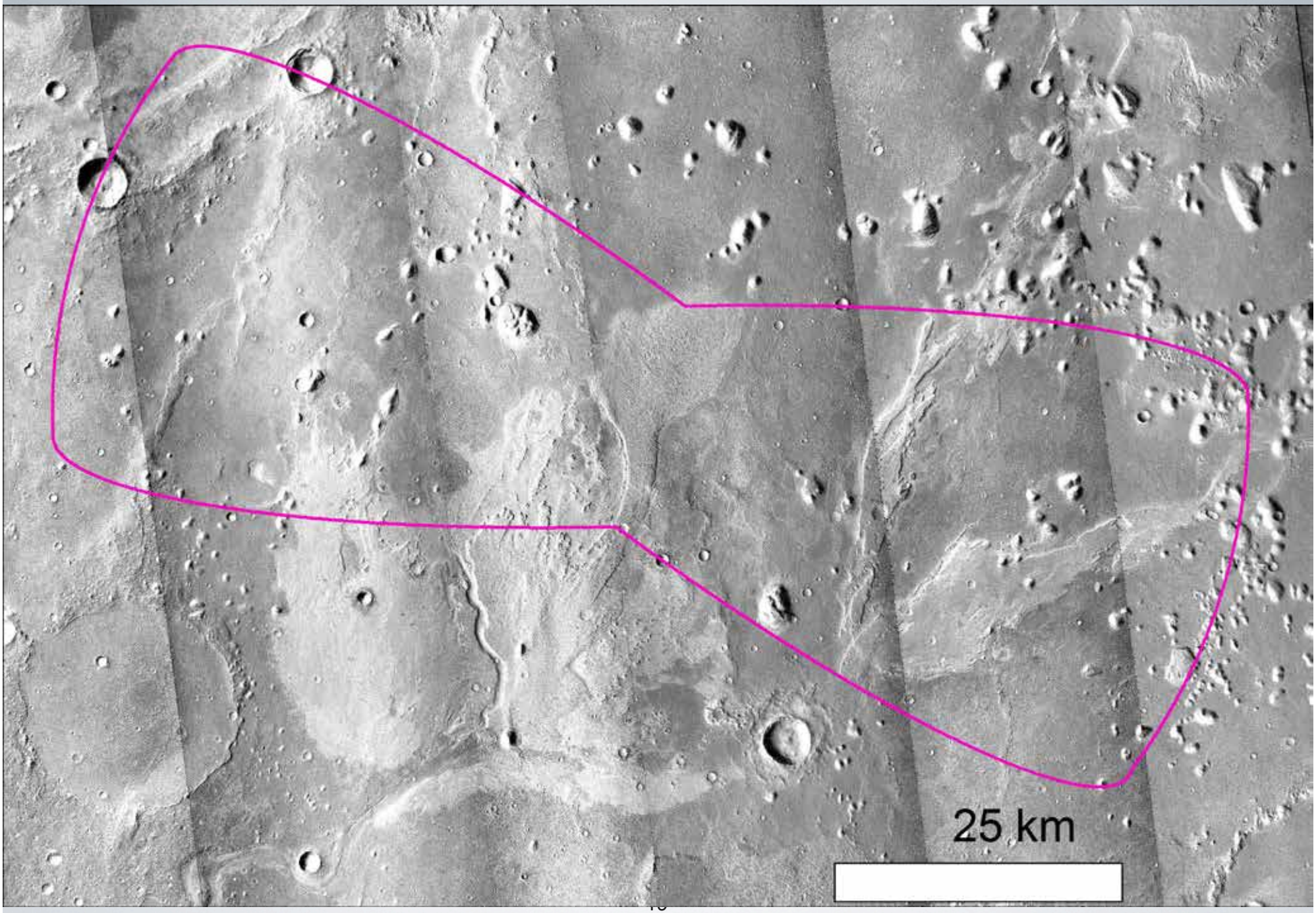
Hypanis – multiple depositional lobes

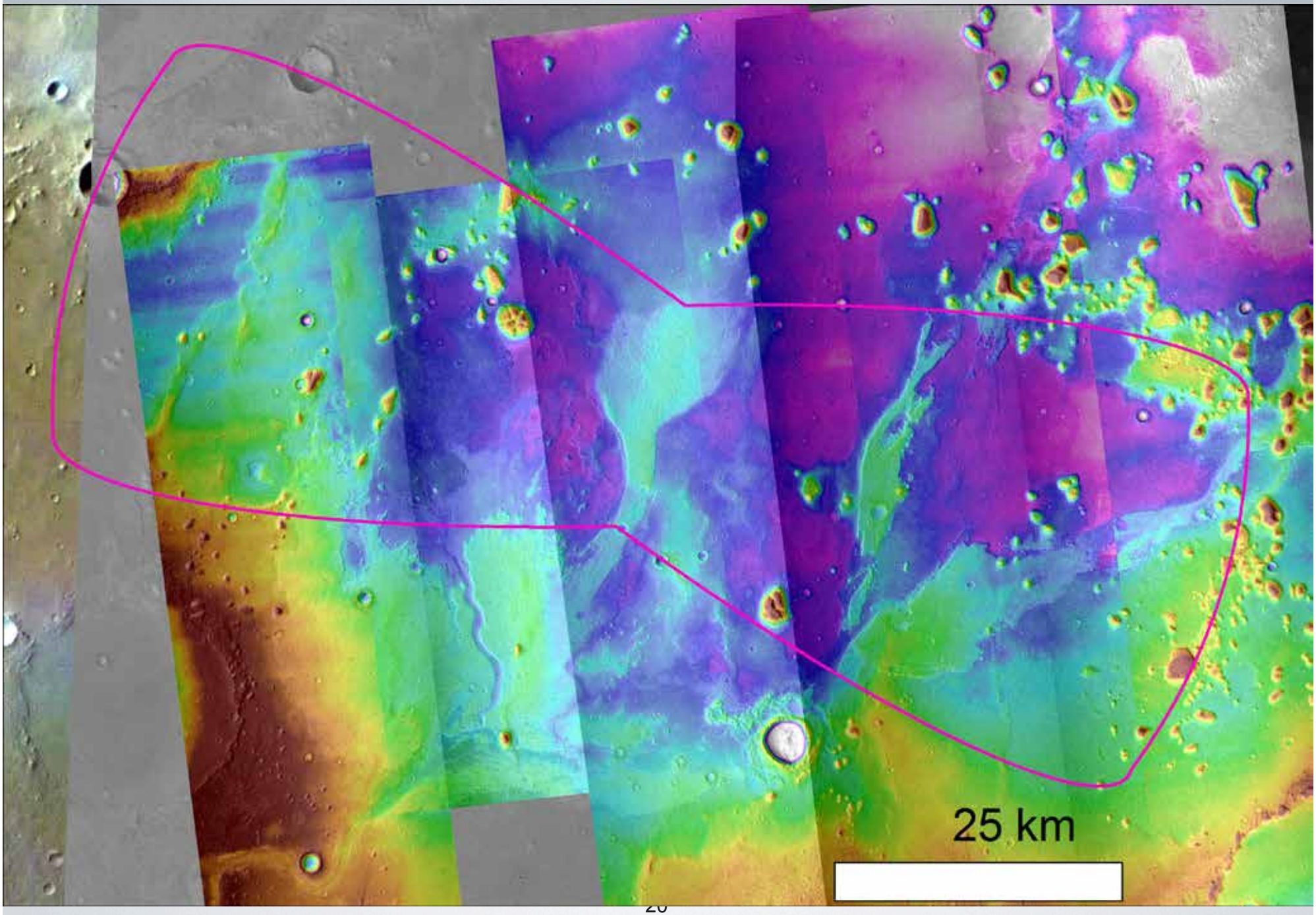



10 km


Channel-lobe body extends basinward of lobe to west
Erosional ‘front’ of lobe
Late stage incision after lobe deposition
~5 km

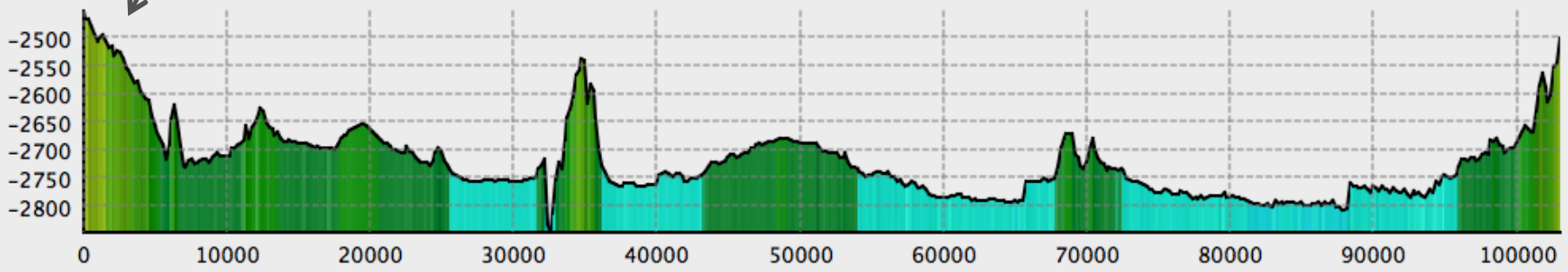

~2 km


25 km


25 km

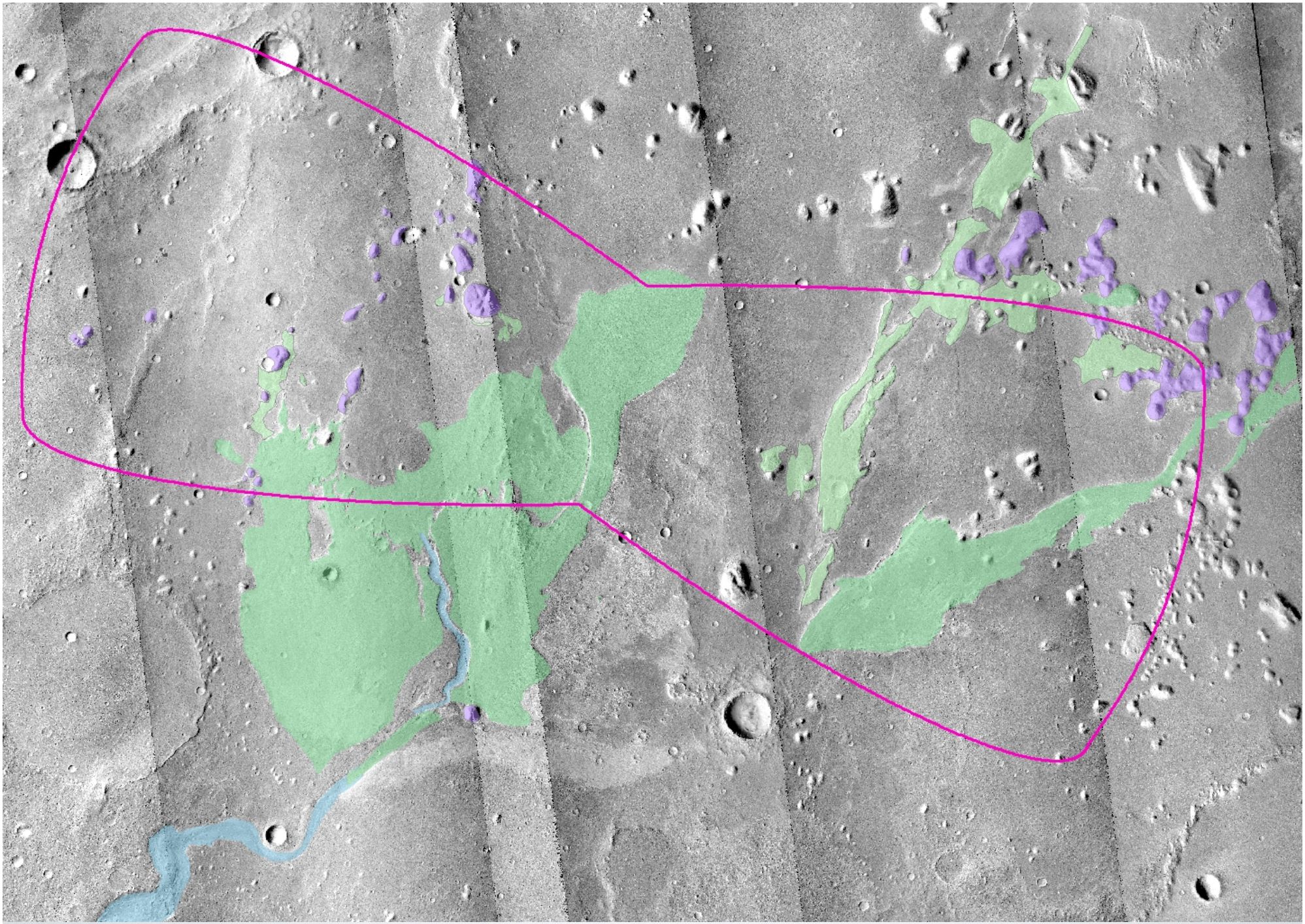
Topographic profile across long axis of ellipse

Crater ejecta



Inverted channel

Inverted channel



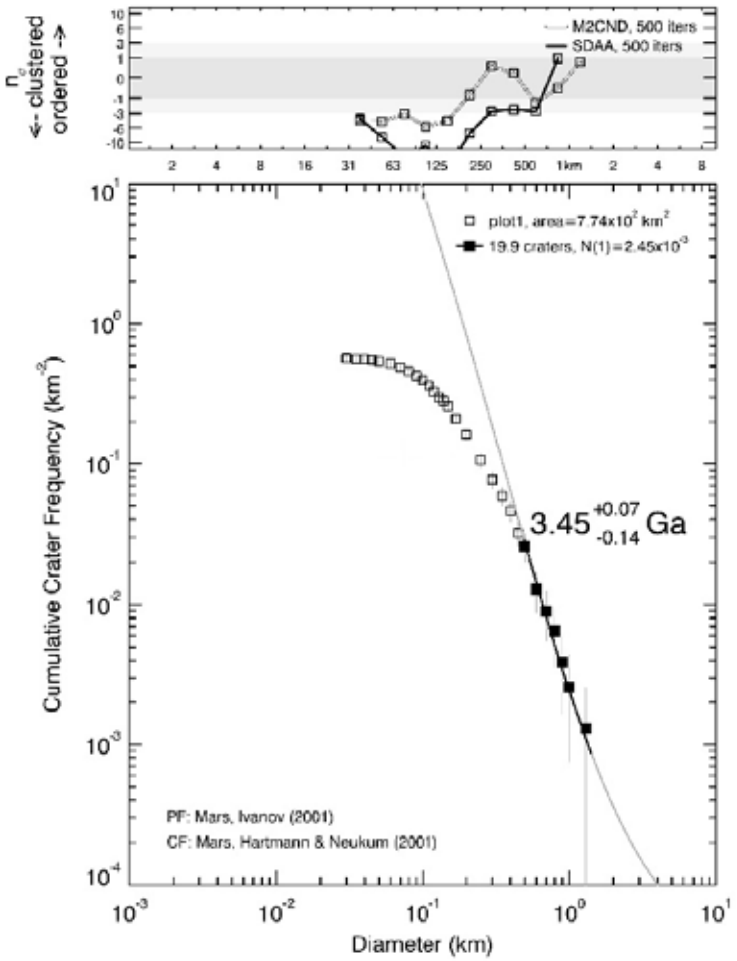
Large-scale geometry of Hypanis system

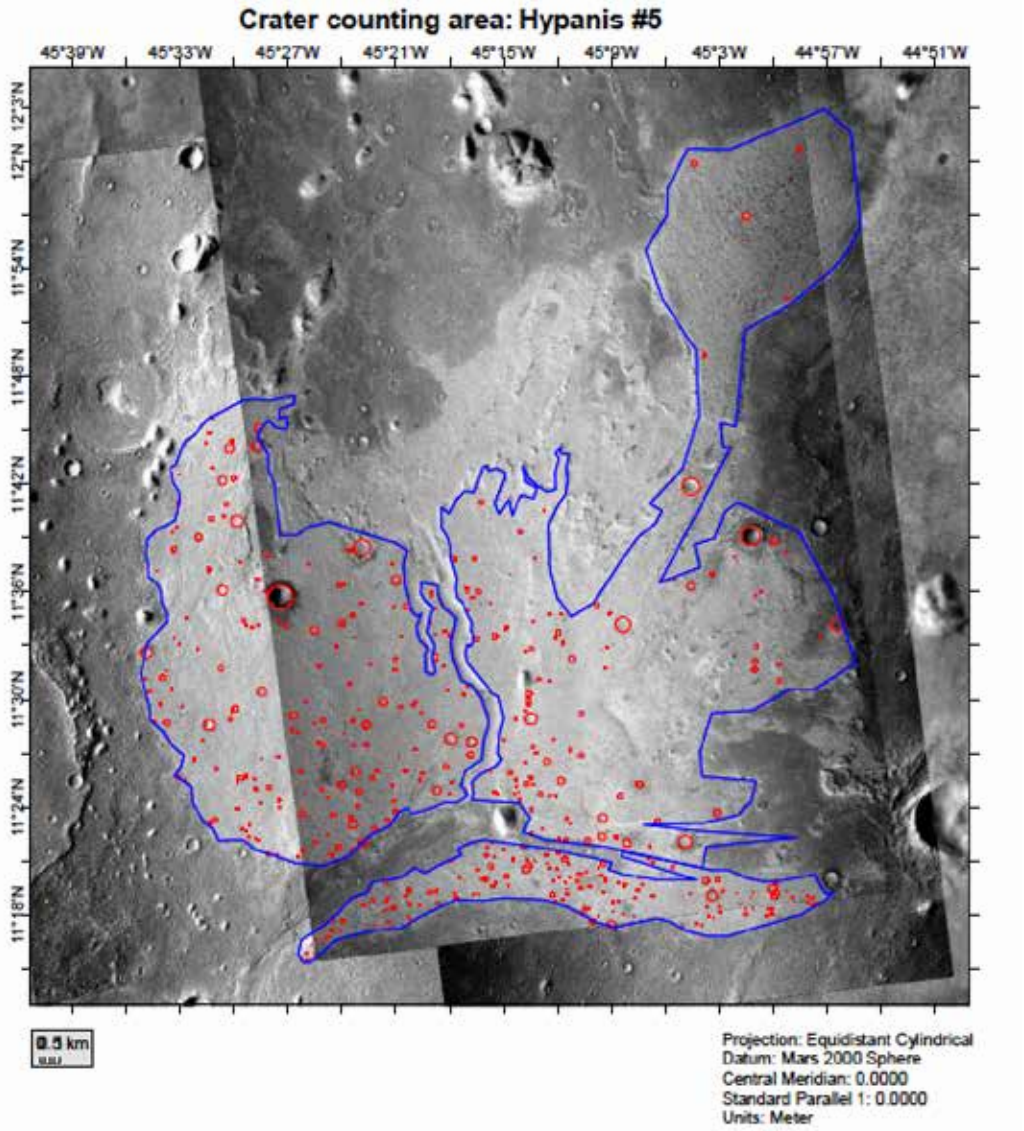
- Hypanis system comprises multiple depositional lobes
- Individual lobes appear to cross-cut each other
- => we observe temporal variation in deposition – lobes are shifting sideways through time – this is classical behaviour – called compensation cycles
- Channel-lobe features appear to shift basinward
  - System progrades basinwards…
- In eastern part of ellipse, we observe long, inverted channel system extending beyond termination of central lobe
  - Does this indicate further basinward progradation of fluvial systems?
  - Maybe an overall progradational system.. Would prograde over finer-grained basinal lower energy deposits

What is the bath-tub that ponded water?

Was the Chryse basin the sink?

Formation and exhumation ages





Hauber et al 2013

Hypanis – Sedimentology/ Stratigraphy

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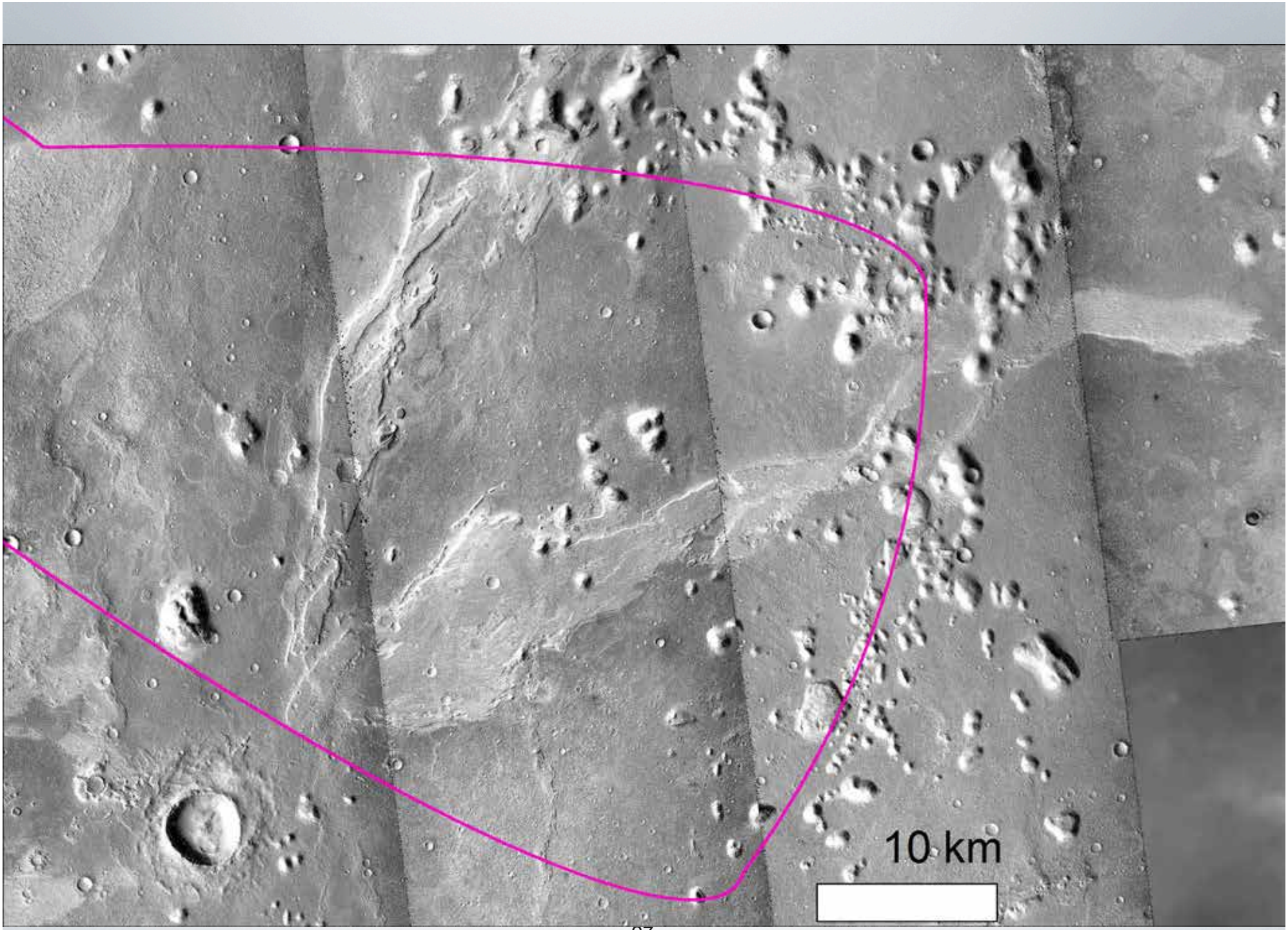
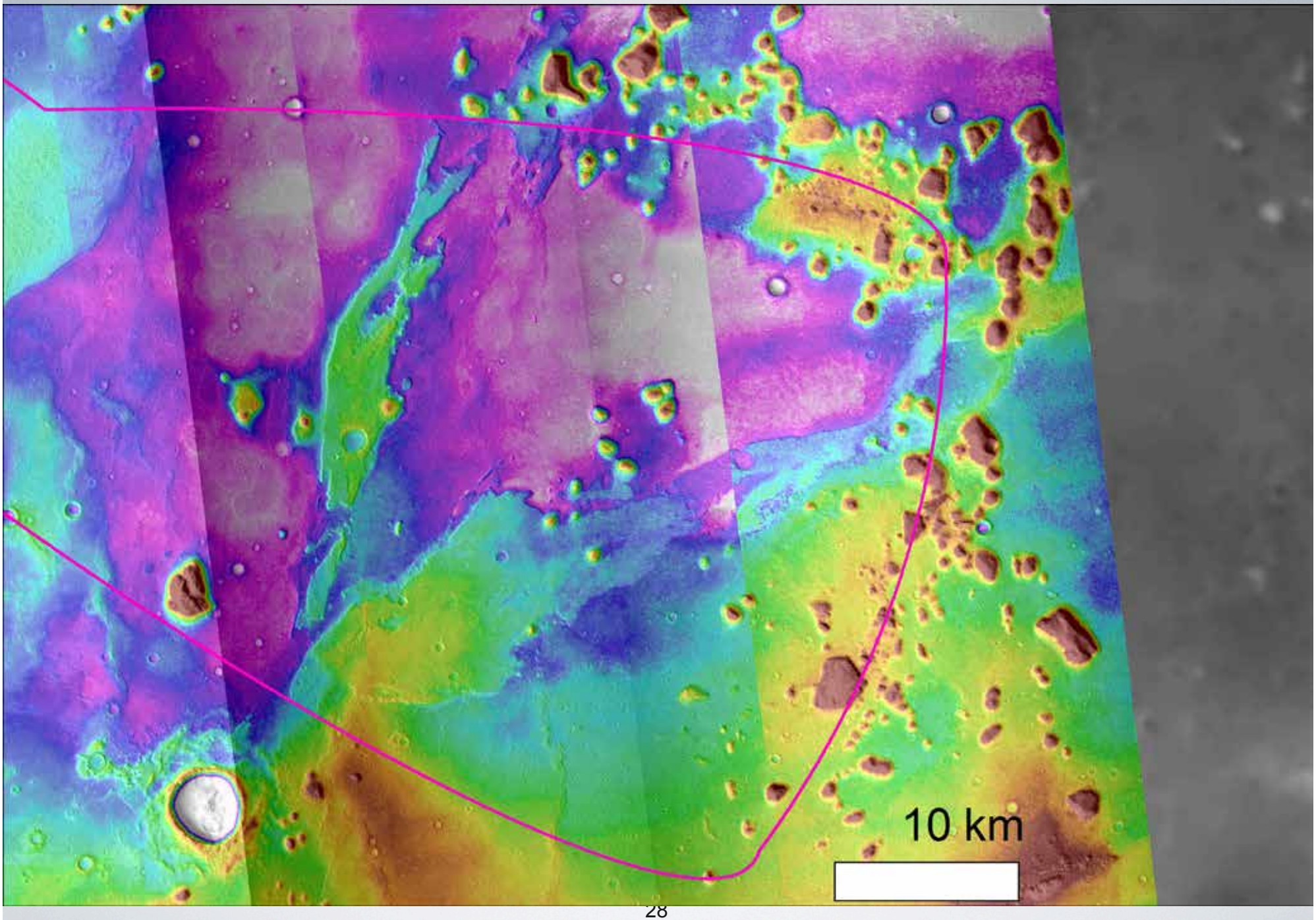
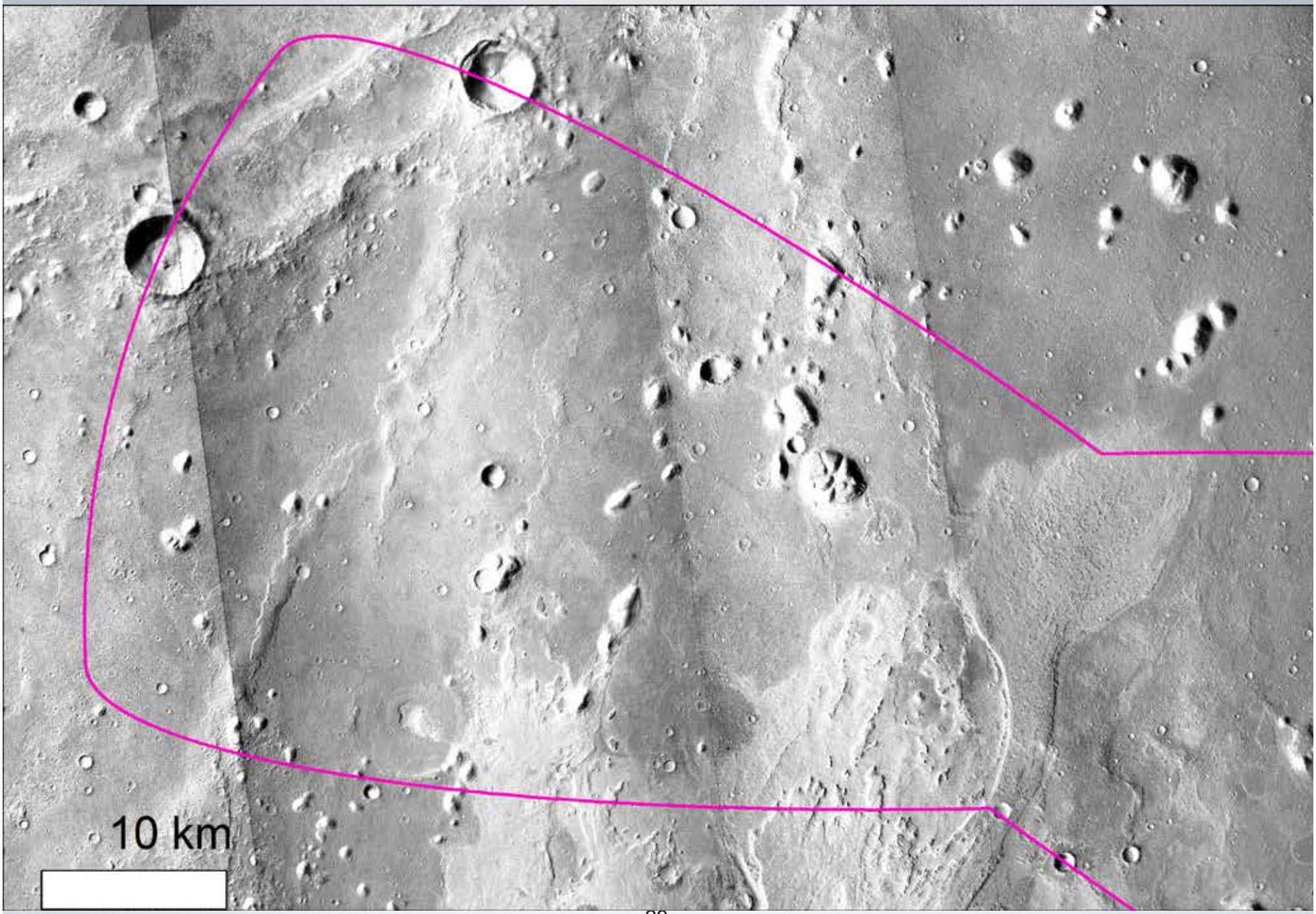
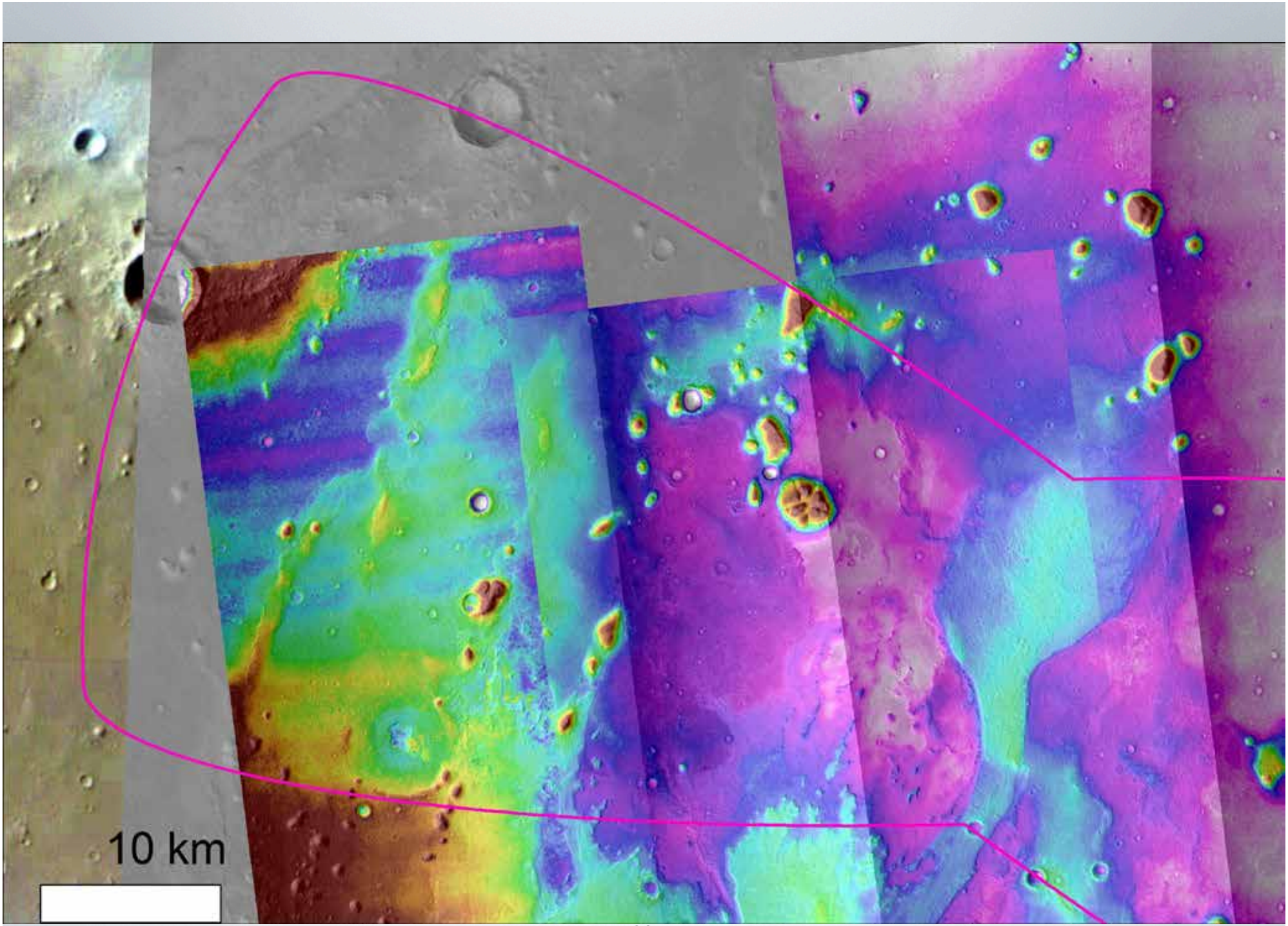
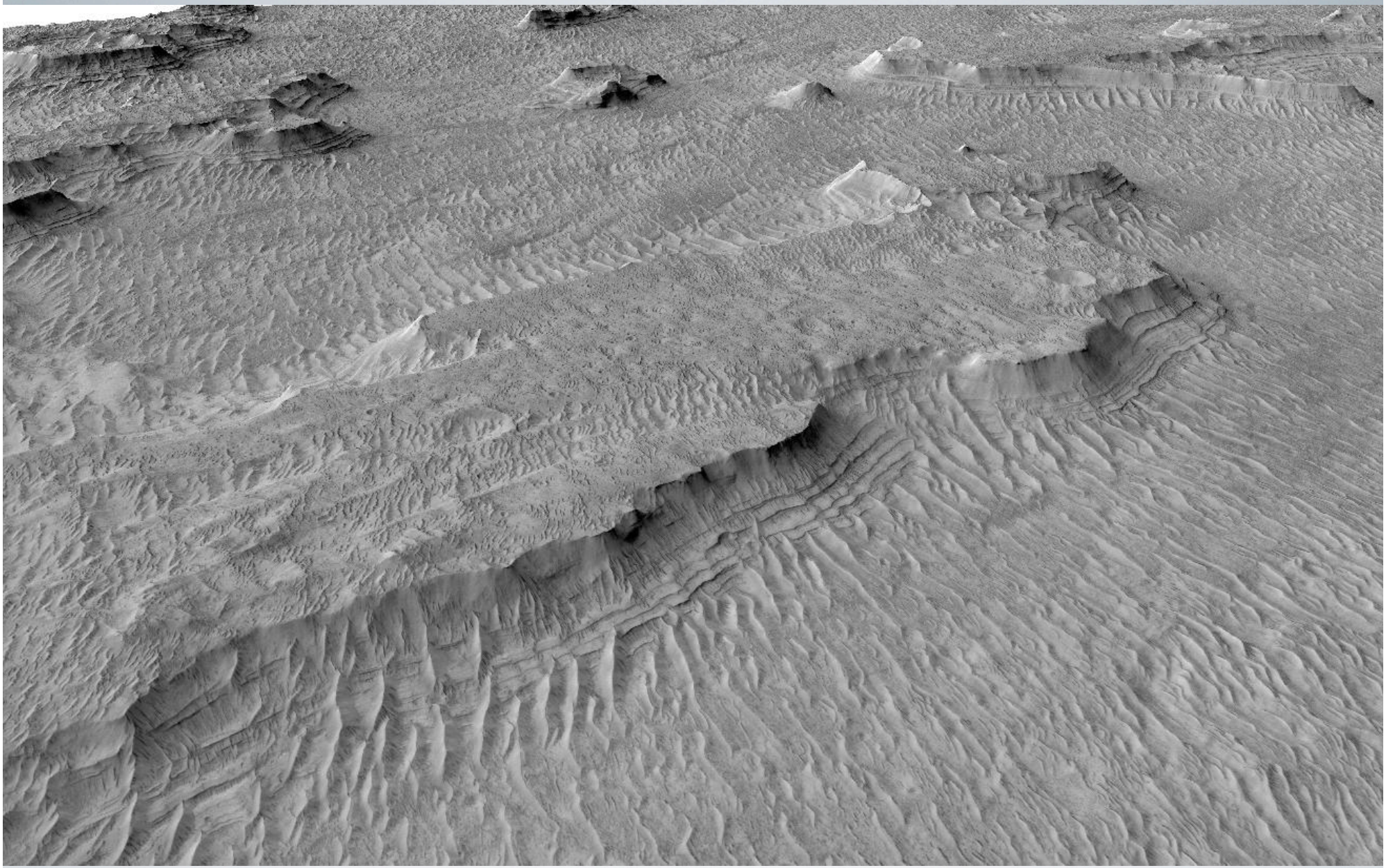

10 km


10 km

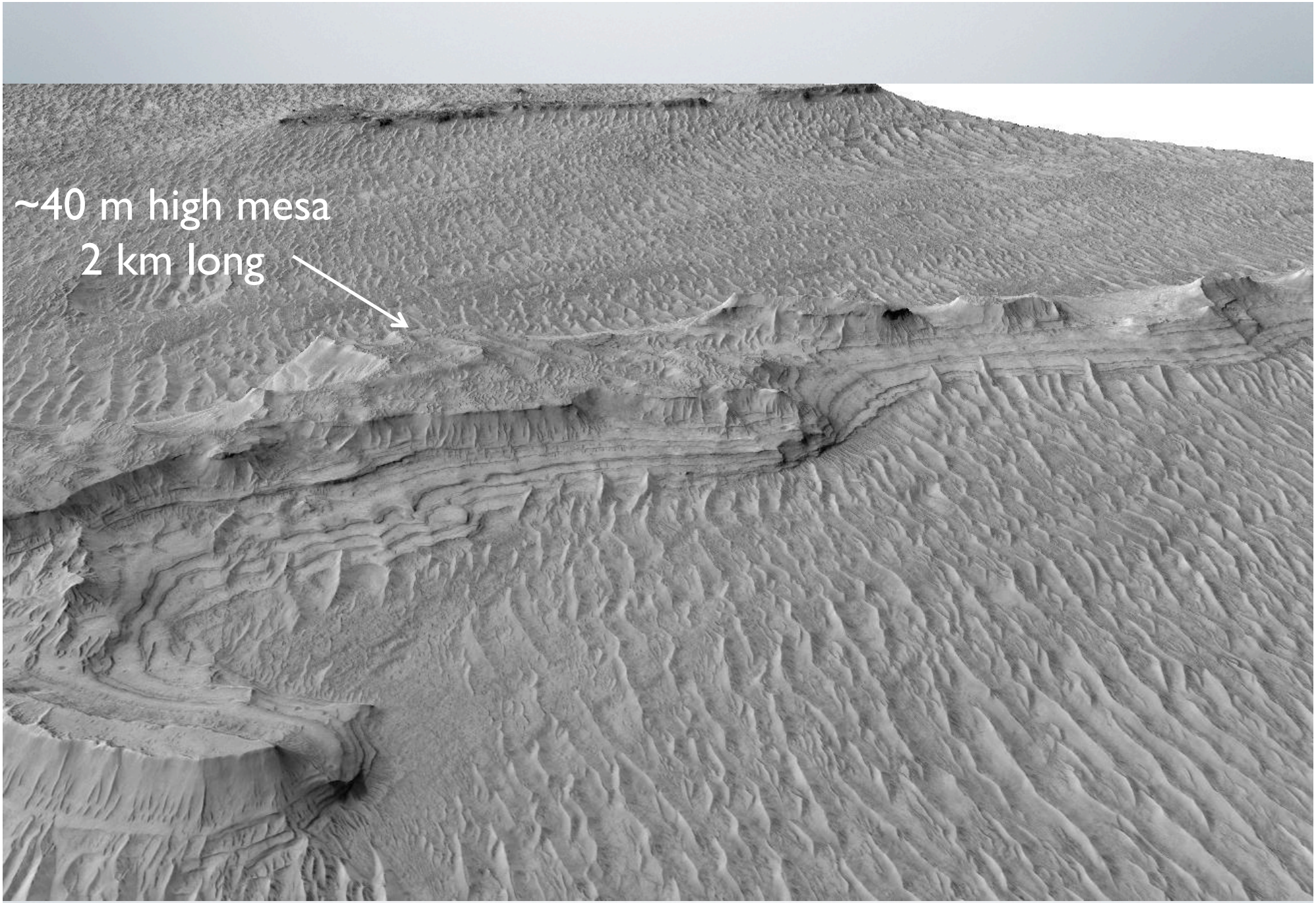

10 km


10 km

CTX image and dtm

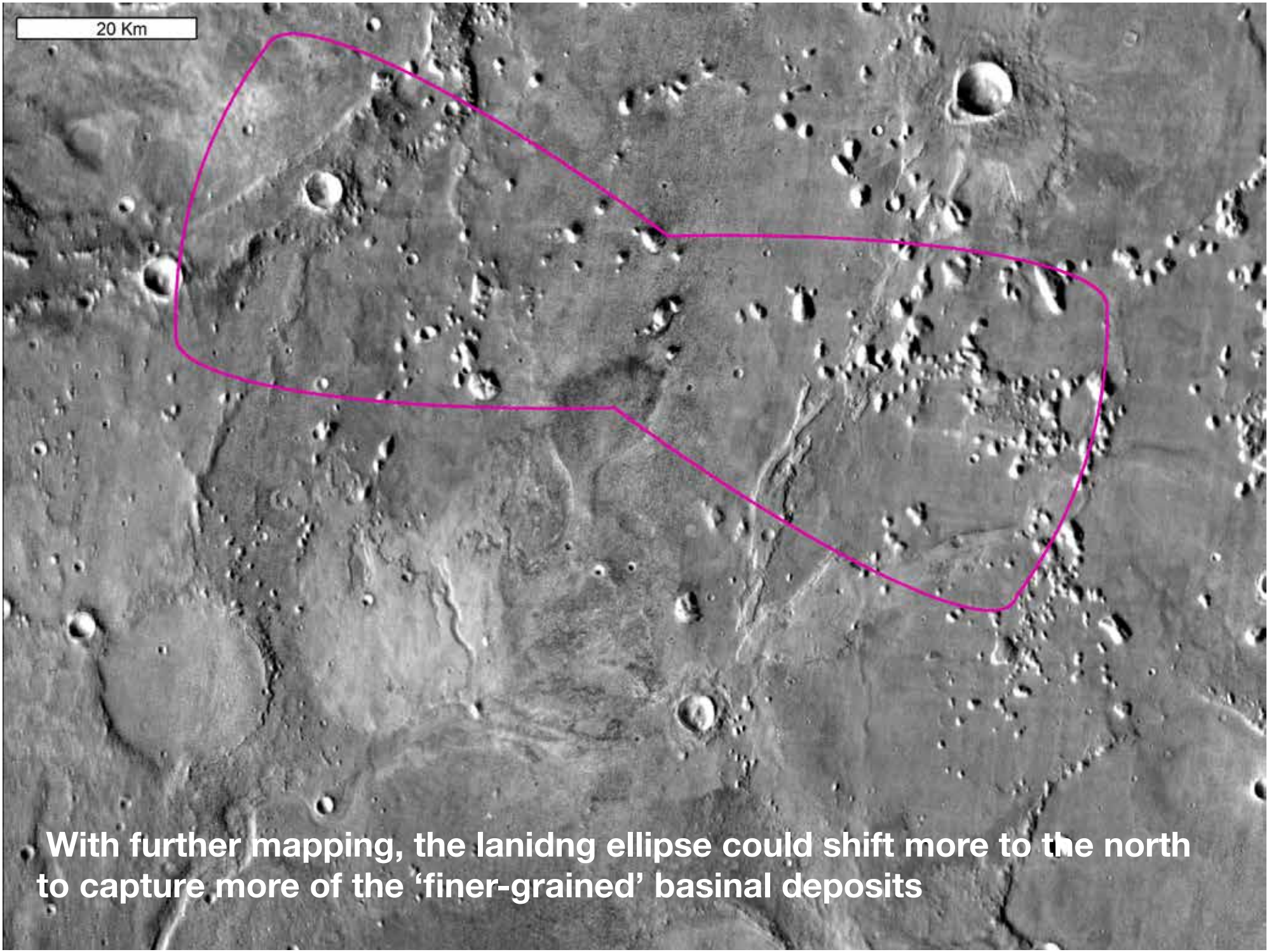


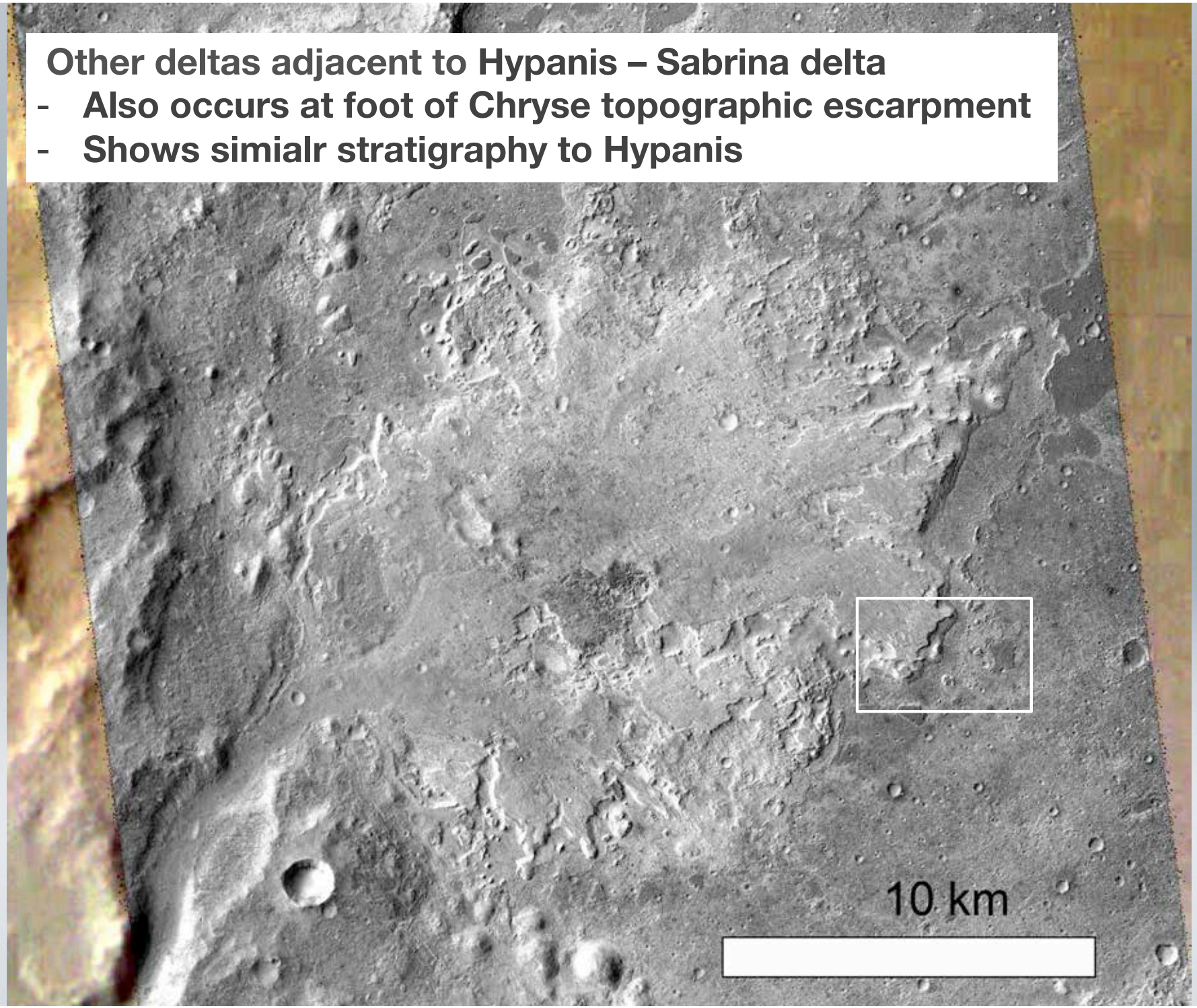
Hirise image and dtm

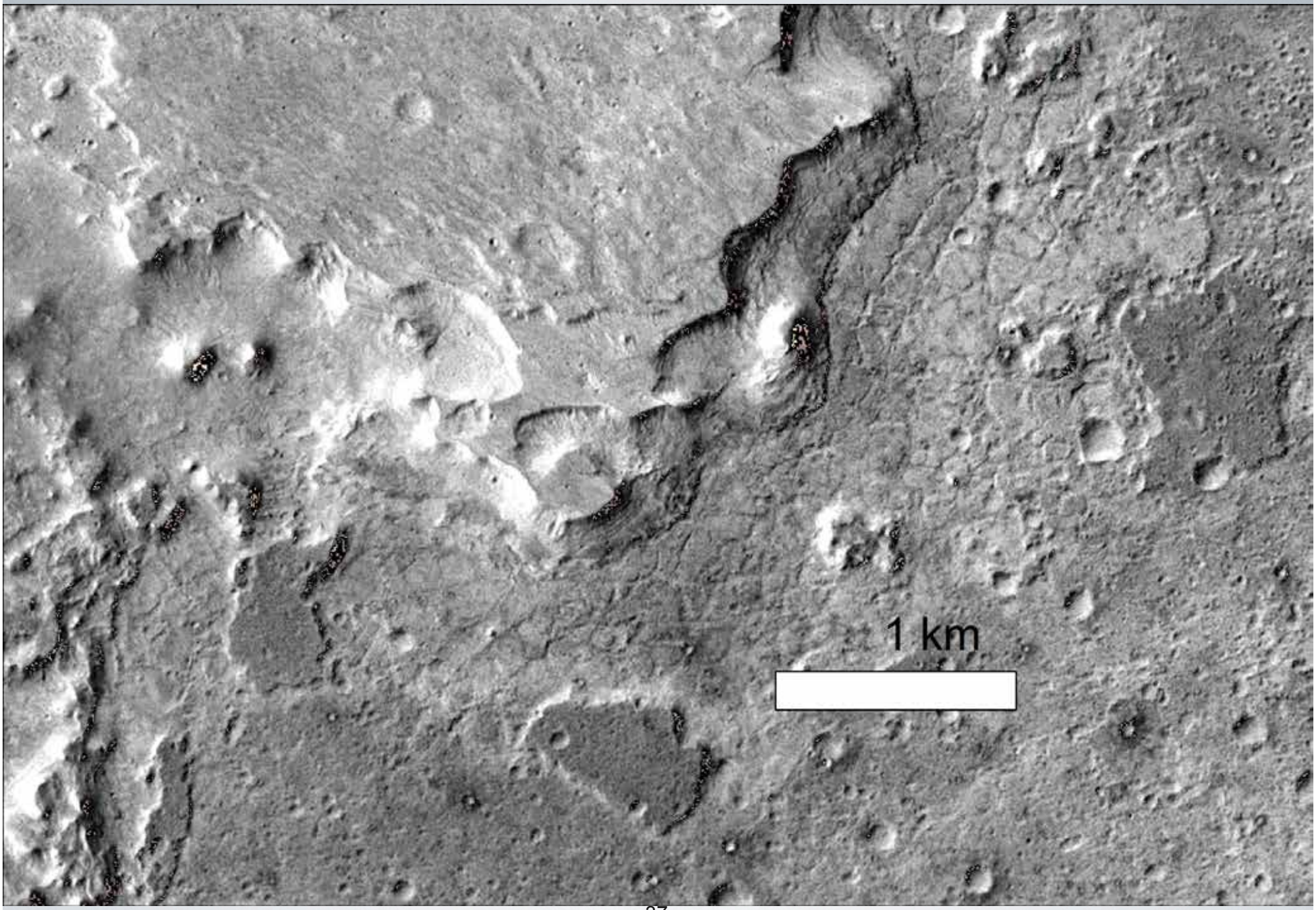


Hirise image and dtm

CTX image and dtm


20 Km
With further mapping, the lanidng ellipse could shift more to the north to capture more of the ‘finer-grained’ basinal deposits


Other deltas adjacent to Hypanis – Sabrina delta
- Also occurs at foot of Chryse topographic escarpment
- Shows simialr stratigraphy to Hypanis
10 km


1 km

Hypanis – Earth analogues

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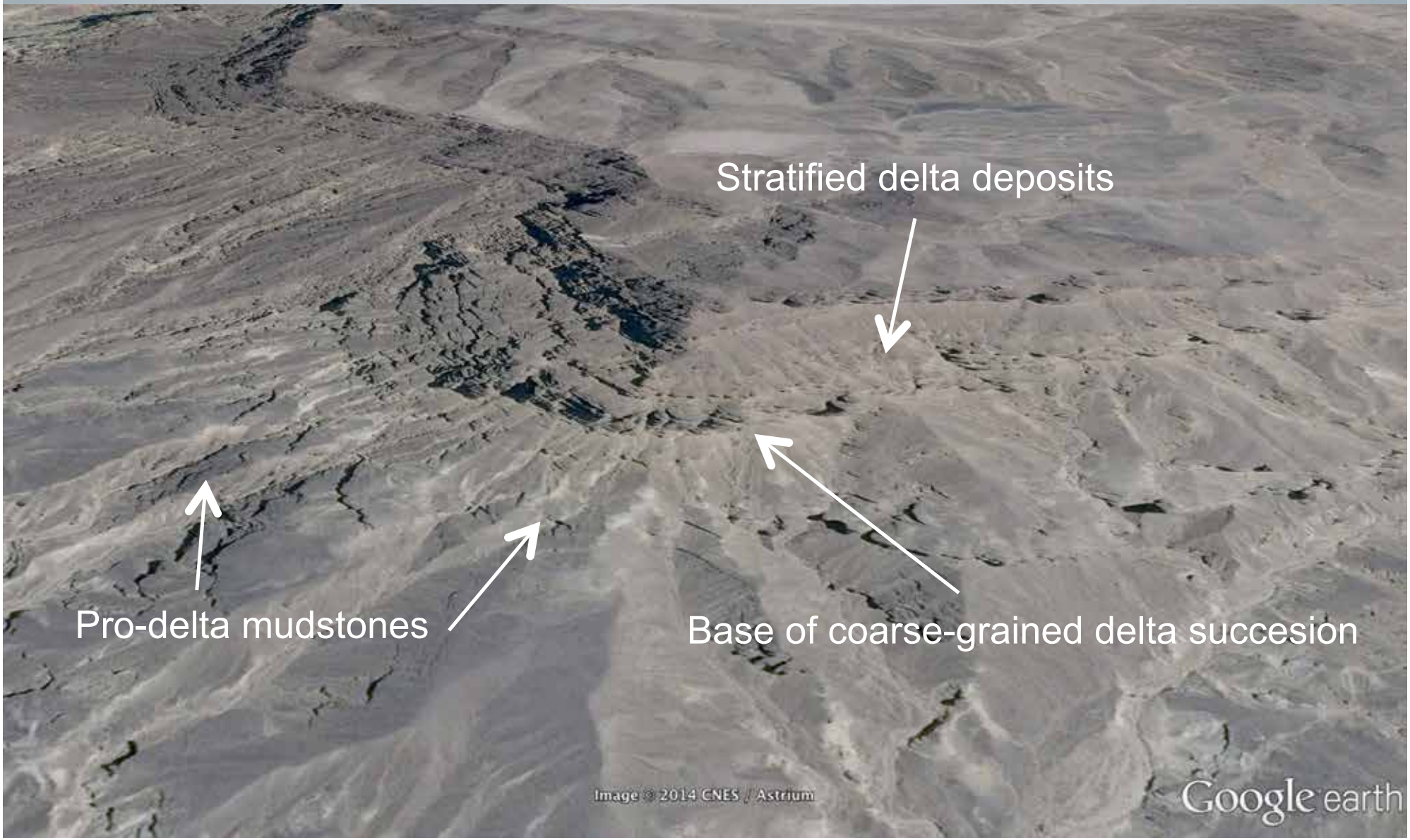
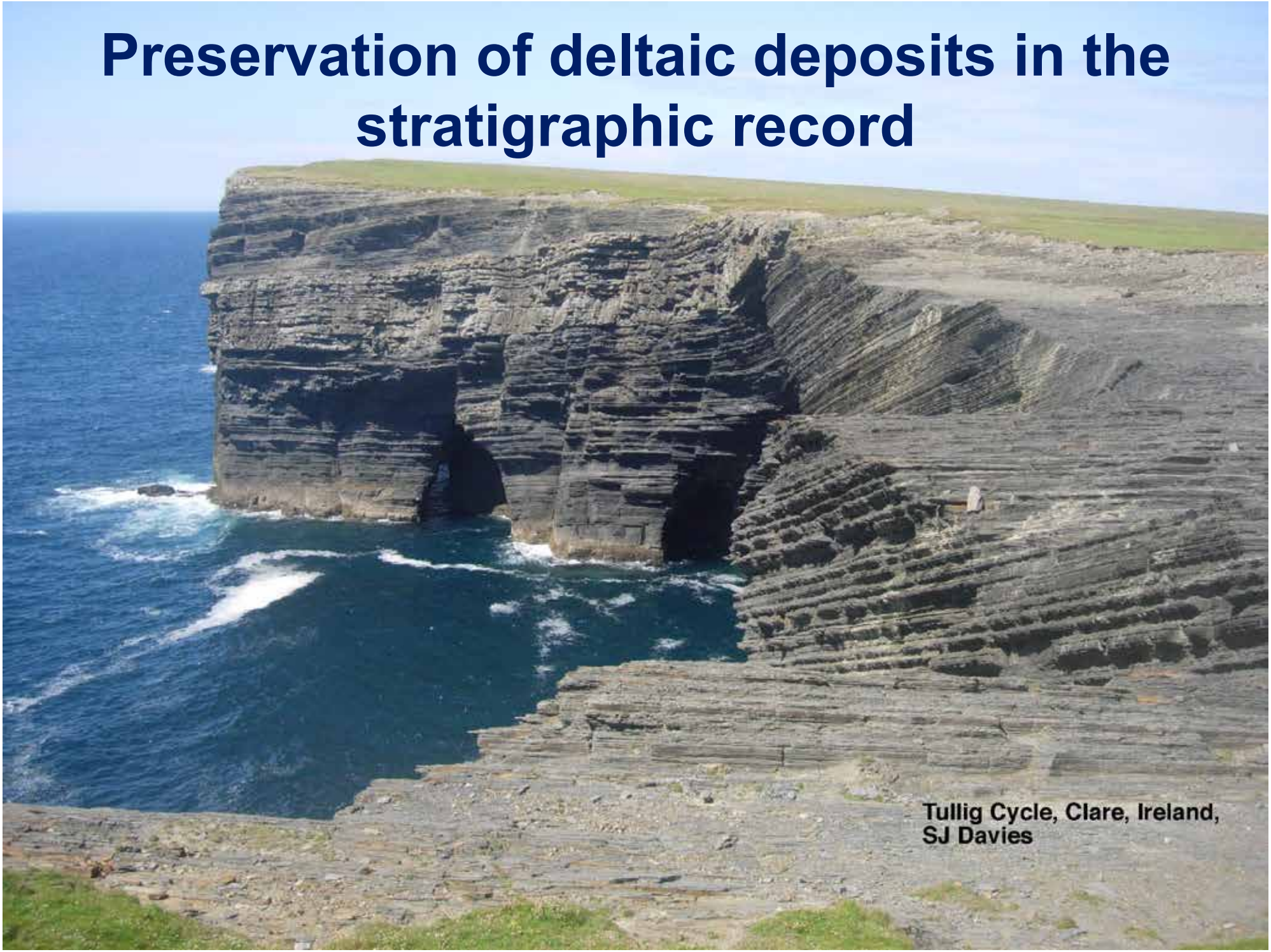
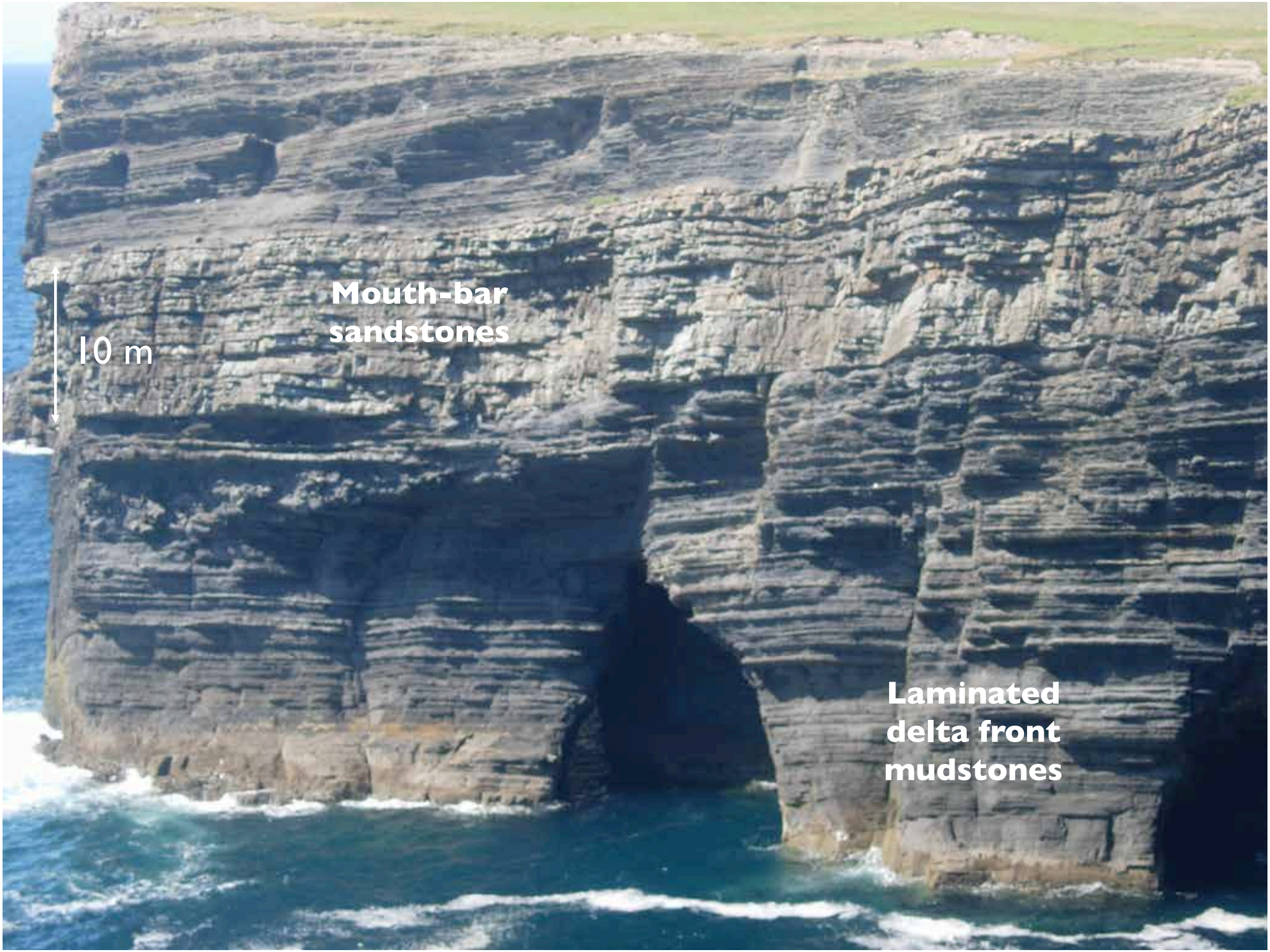
Google Earth image of ancient deltas in Sinai Peninsula



Preservation of deltaic deposits in the stratigraphic record




10 m
Mouth-bar
sandstones
Laminated
delta front
mudstones

Hypanis – Mineralogy

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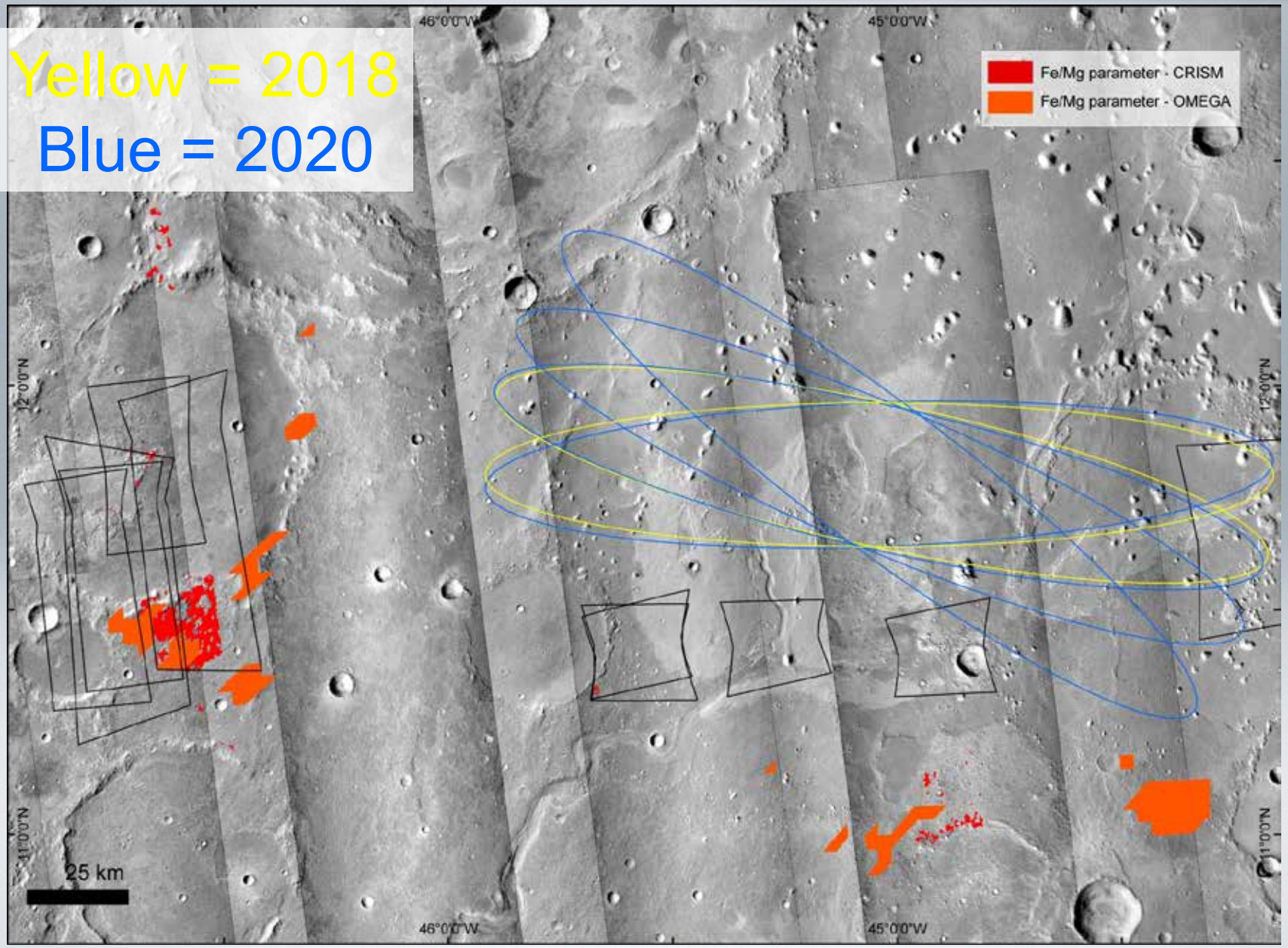
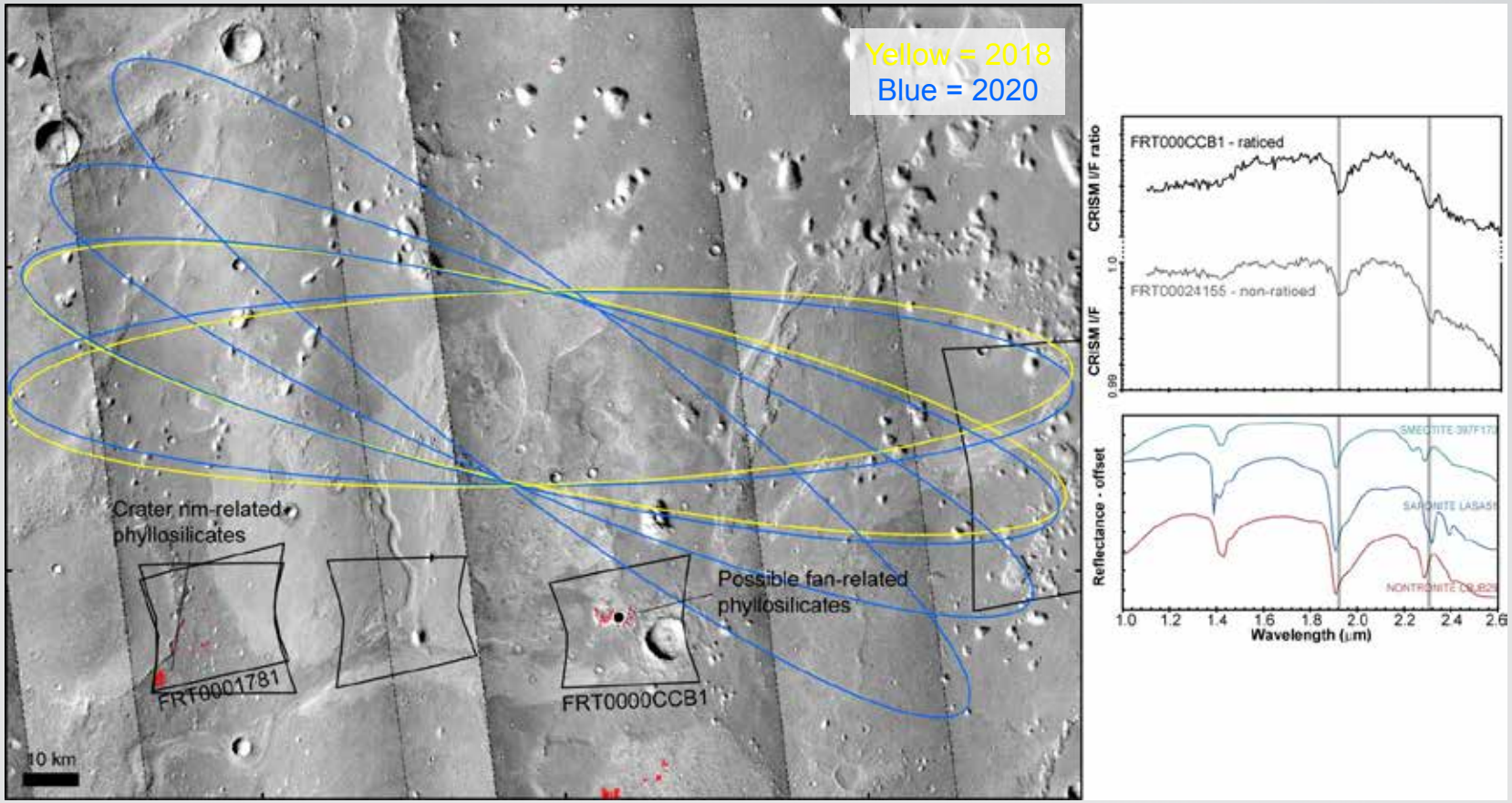
Mineralogical Description



Mineralogical Description

CRISM Mineralogy – within ellipse (just!)

- Limited by available data – only two CRISM images intersect edge of ellipse(s).
- Limited (ambiguous) mineralogy within ellipse(s), although possible phyllosilicates.

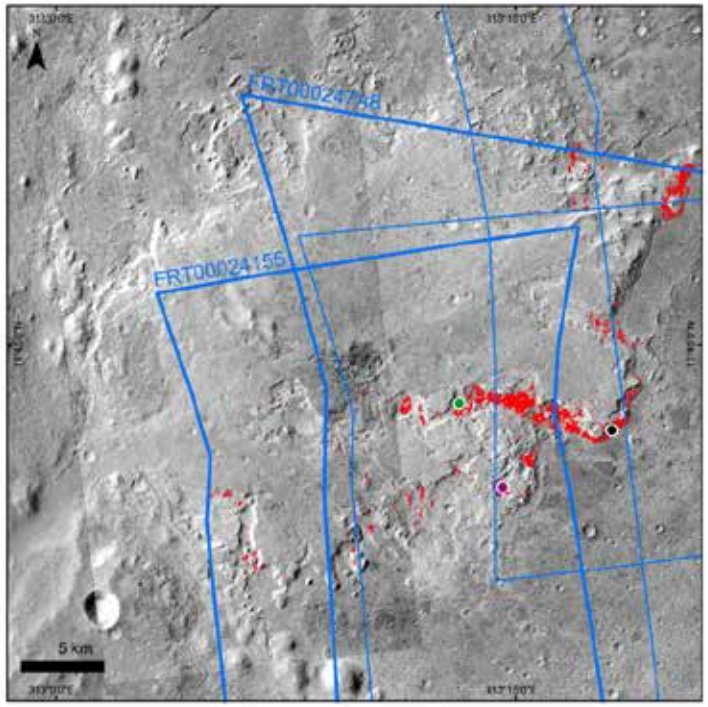


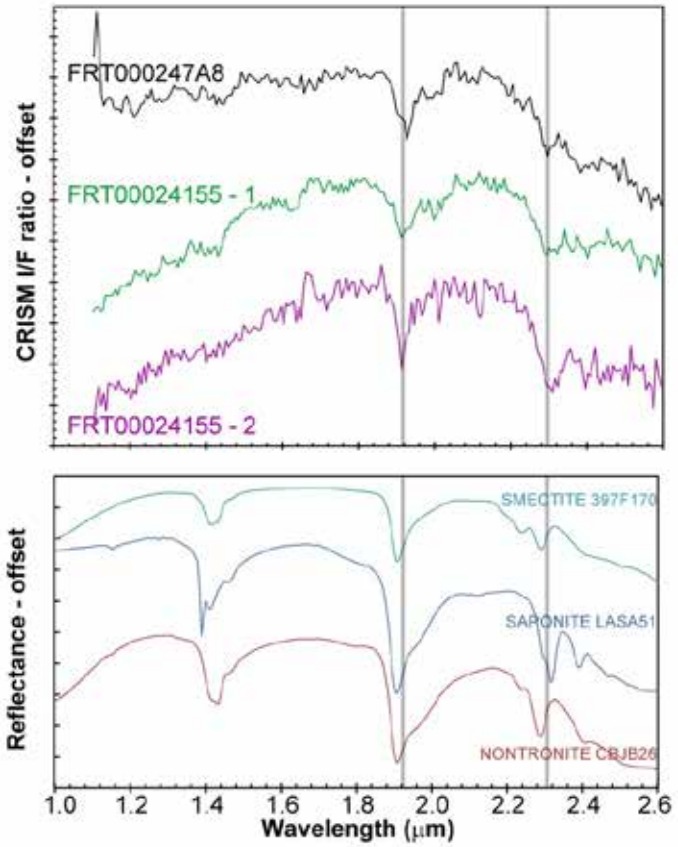
Mineralogical Description

CRISM Mineralogy – outside ellipse

- Analogous fan mineralogy, ~75 km west of ellipse(s).
- Fe/Mg phyllosilicates (nontronite?) at low stratigraphic level in fan deposits.

Fan at end of Sabrina Vallis



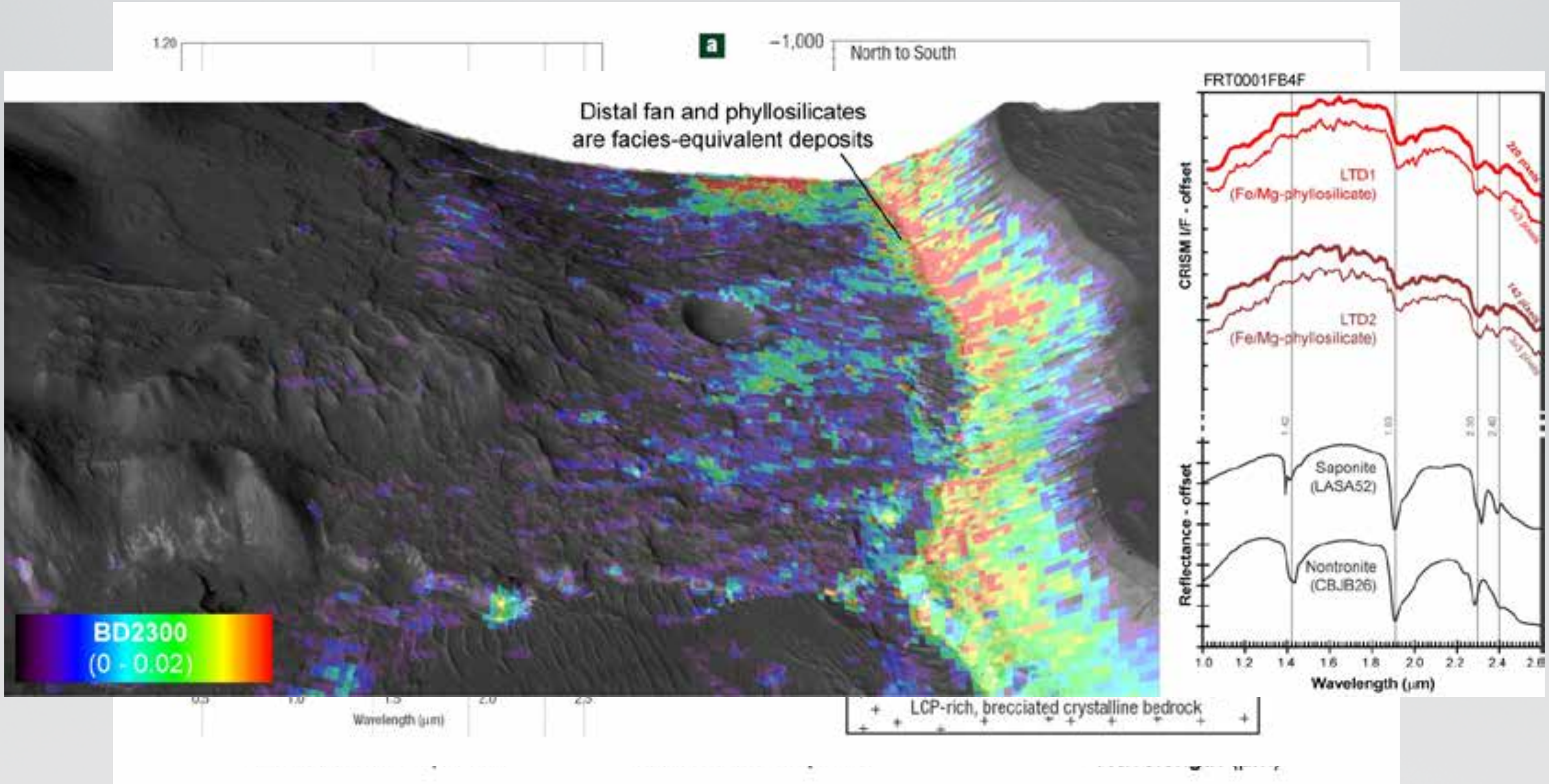


Mineralogical Description

E X O M A R S

CRISM Mineralogy – outside ellipse

- Aqueous alteration deposits at low stratigraphic levels in many fan deposits on Mars.



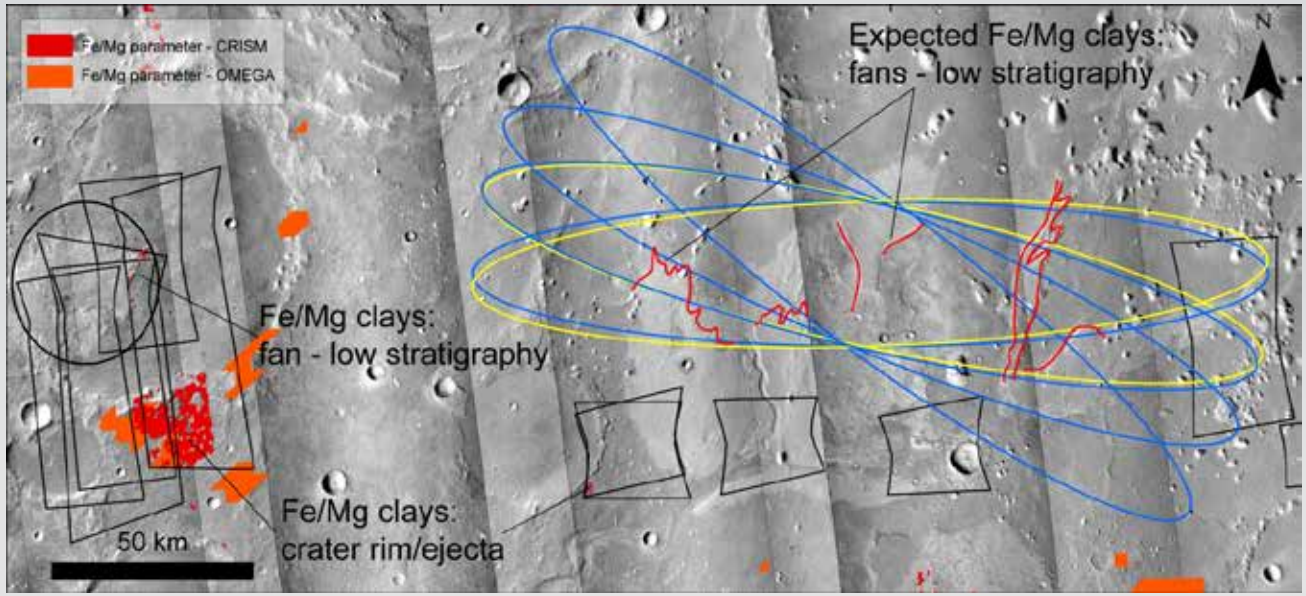
HGaubdertnealan(2ti1ap)re2p0)08aFacsSieicquisivfanslefnt Xdaepohsteitersa anzdeAro Cirattienrse

Mineralogical Description

CRISM Mineralogy – predicted

- More CRISM images have been requested, covering distal (low stratigraphy) fan region.
- New CRISM data could show evidence of aqueous alteration, as:

1. Allochthonous deposits – channel eroding and depositing Noachian material.
2. Autochthonous deposits – in situ alteration possible in low-energy environment.
3. Deep alteration products – brought up and distributed by impacts.



- Phyllosilicates in depositional fluvial setting good candidates for concentration and preservation of organic material and biomarkers [e.g. Ehlmann et al., 2008]

Hypanis – Preservation

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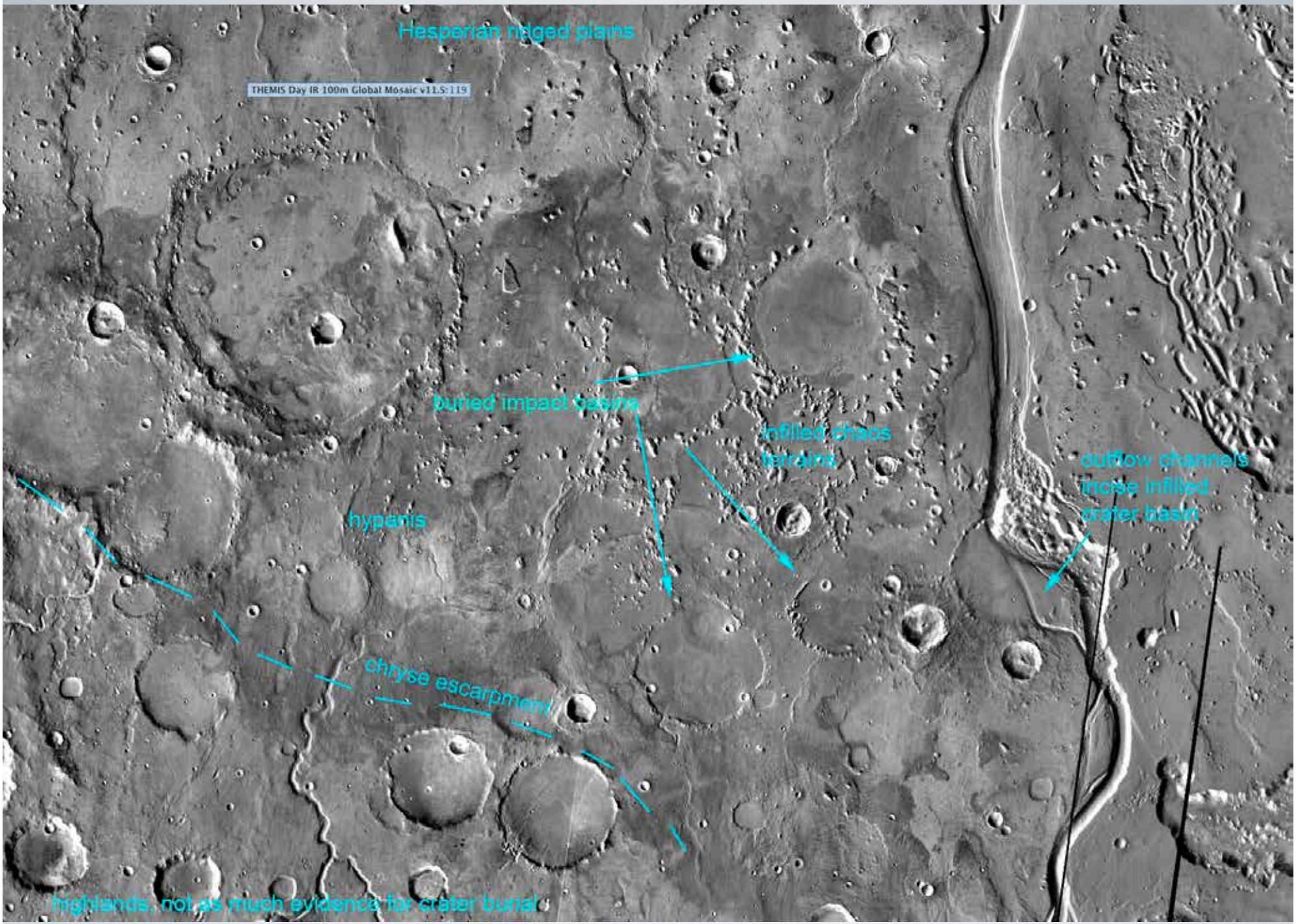
Hesperian ridged plains
THEMIS Day IR 100m Global Mosaic v11.5:119
buried impact basins
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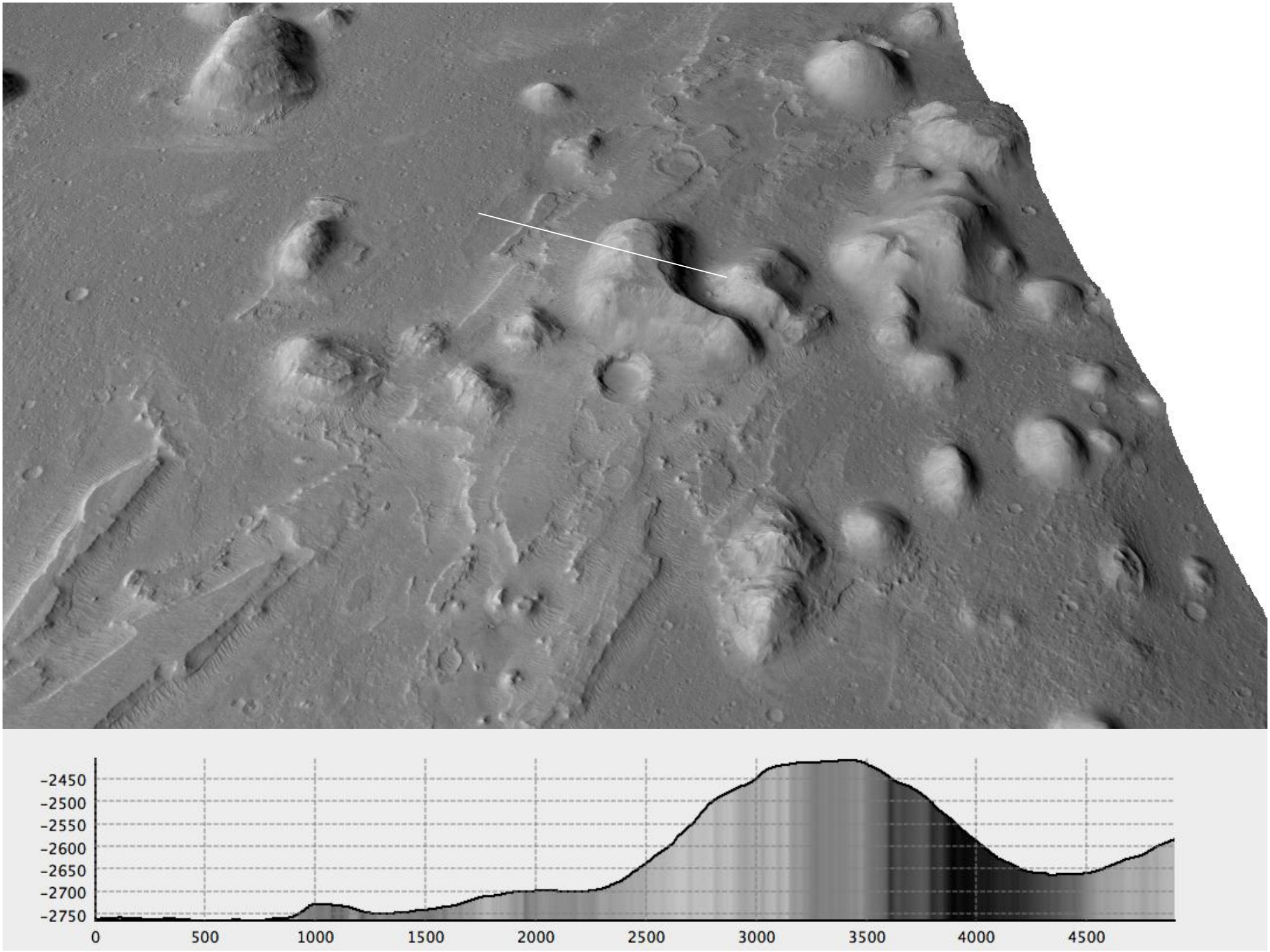
-2450
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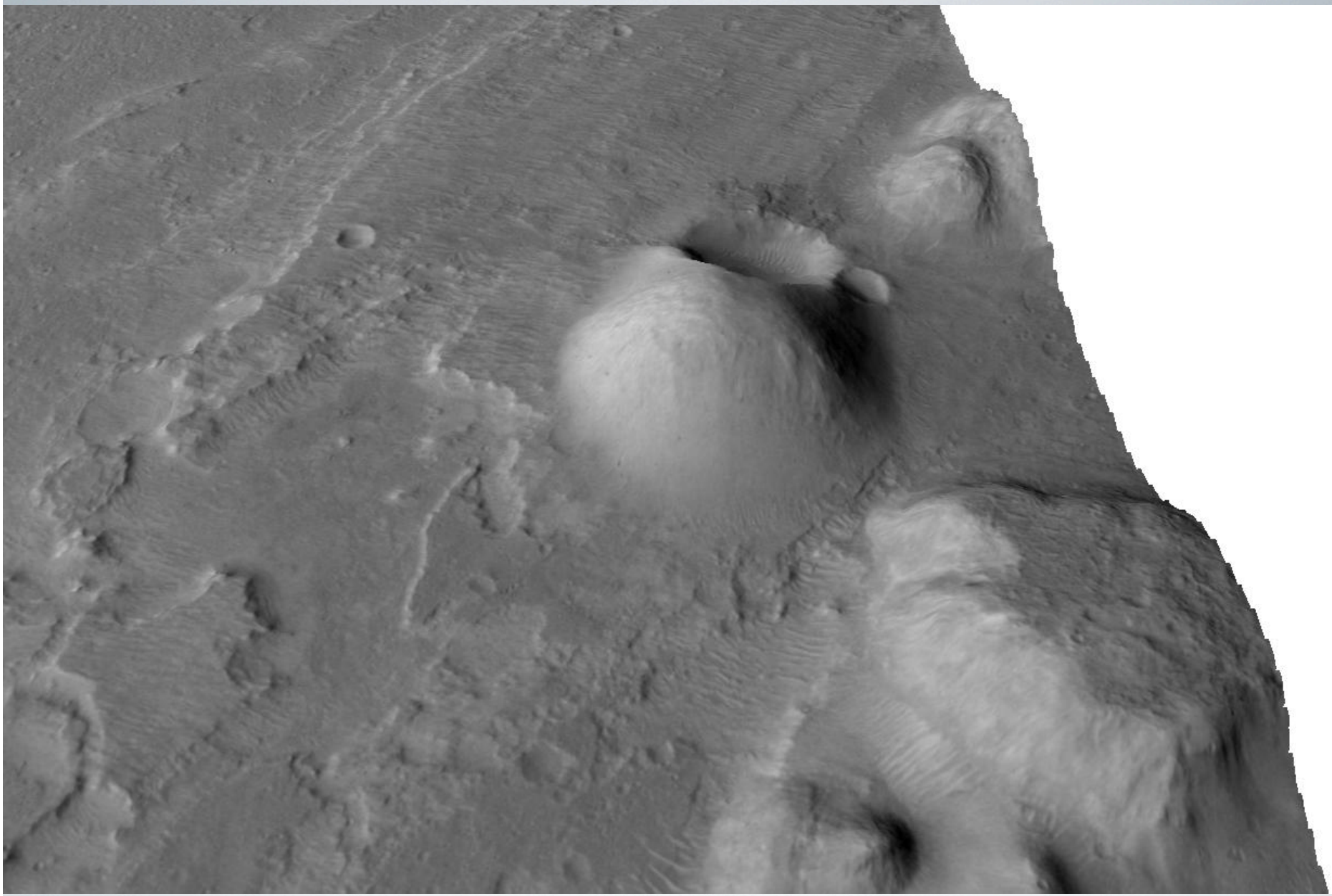

Hypanis – Target accessibility and dust cover

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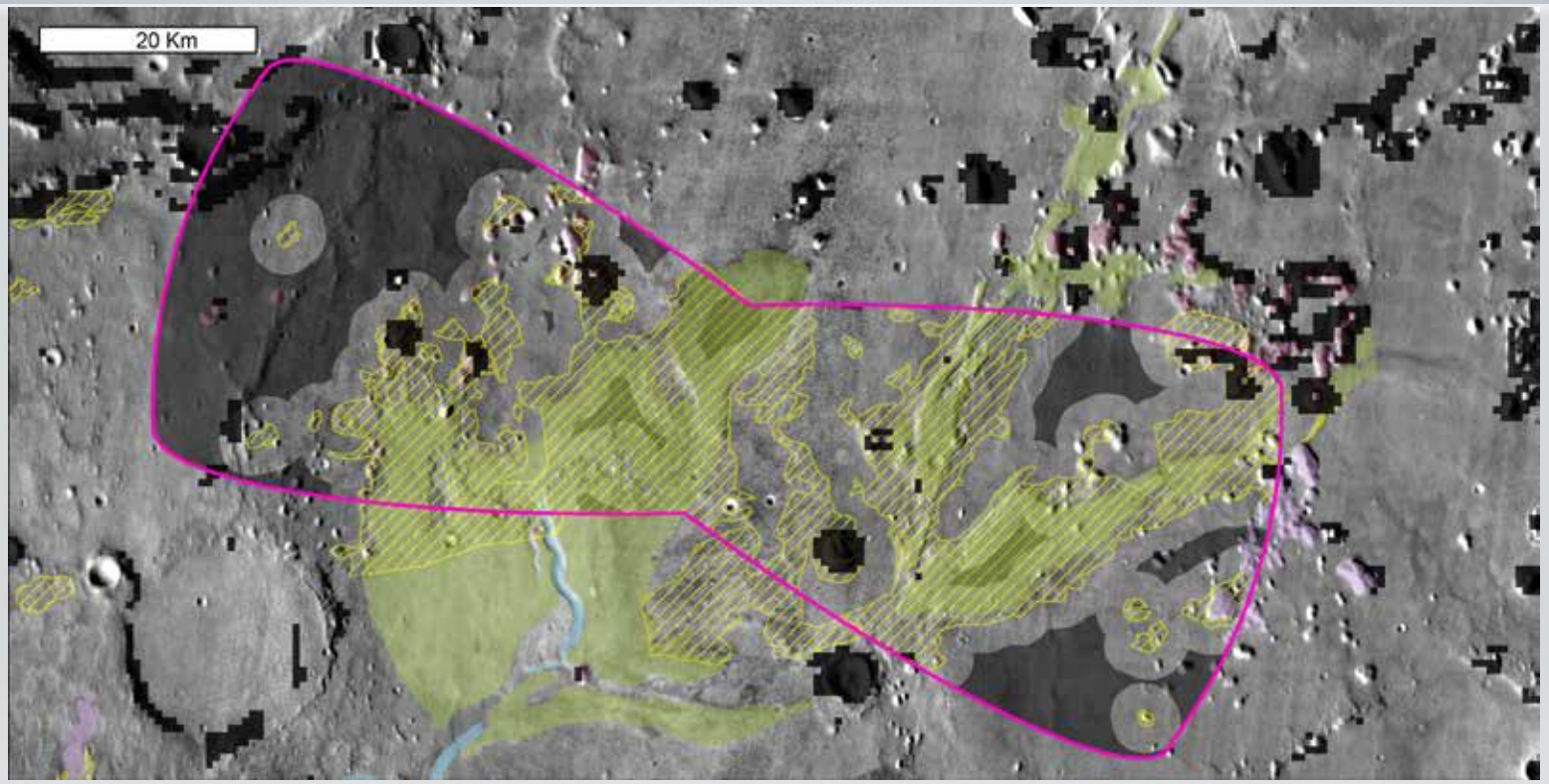
Target Accessibility

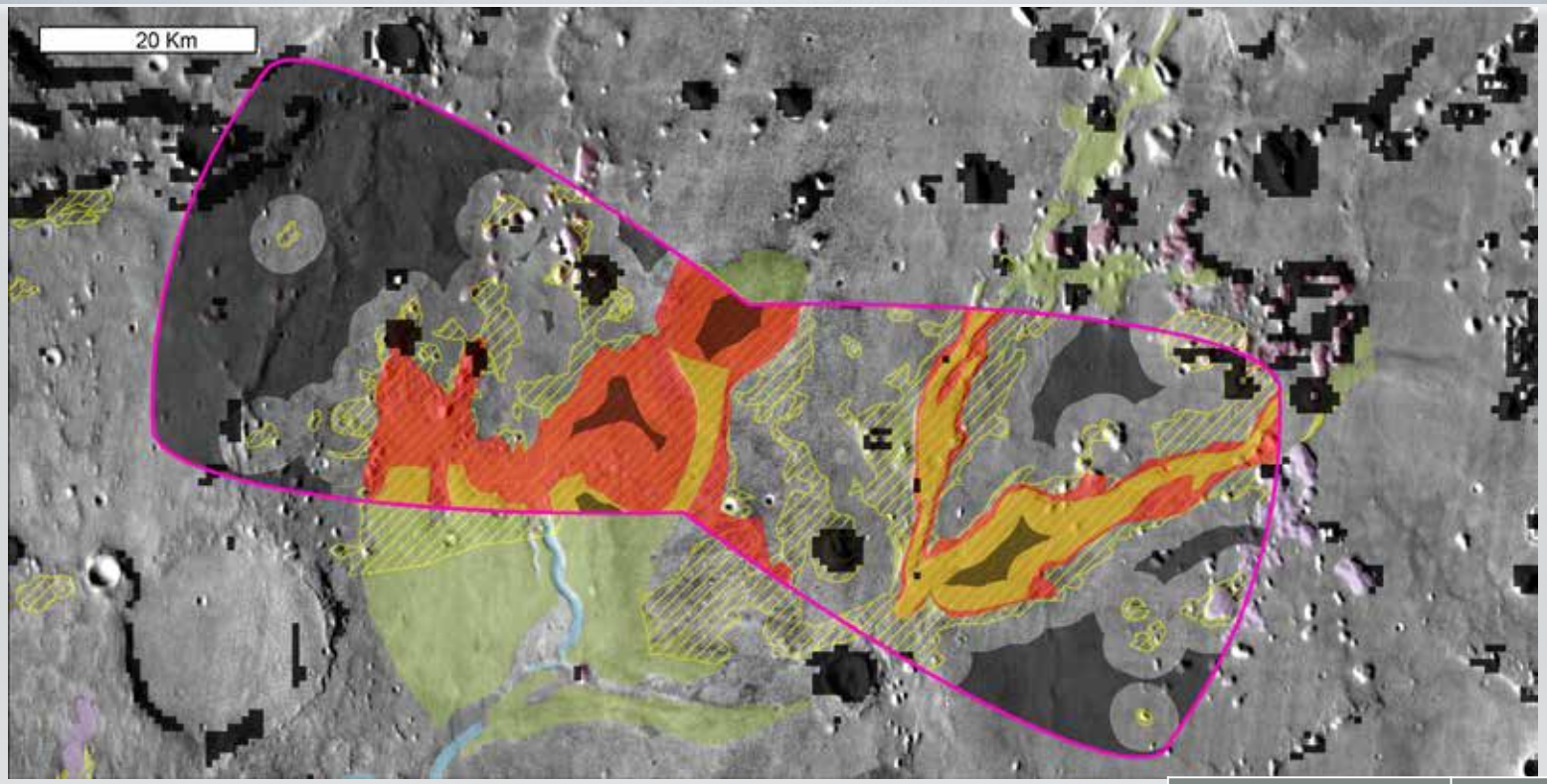


	Distance
From Ellipse centre	0
Between areas	5 km from CTX reconnaissance. Detailed investigation reveals wider target distribution

Widespread outcrops

(view shows very conservative estimate)

Dust and TARs



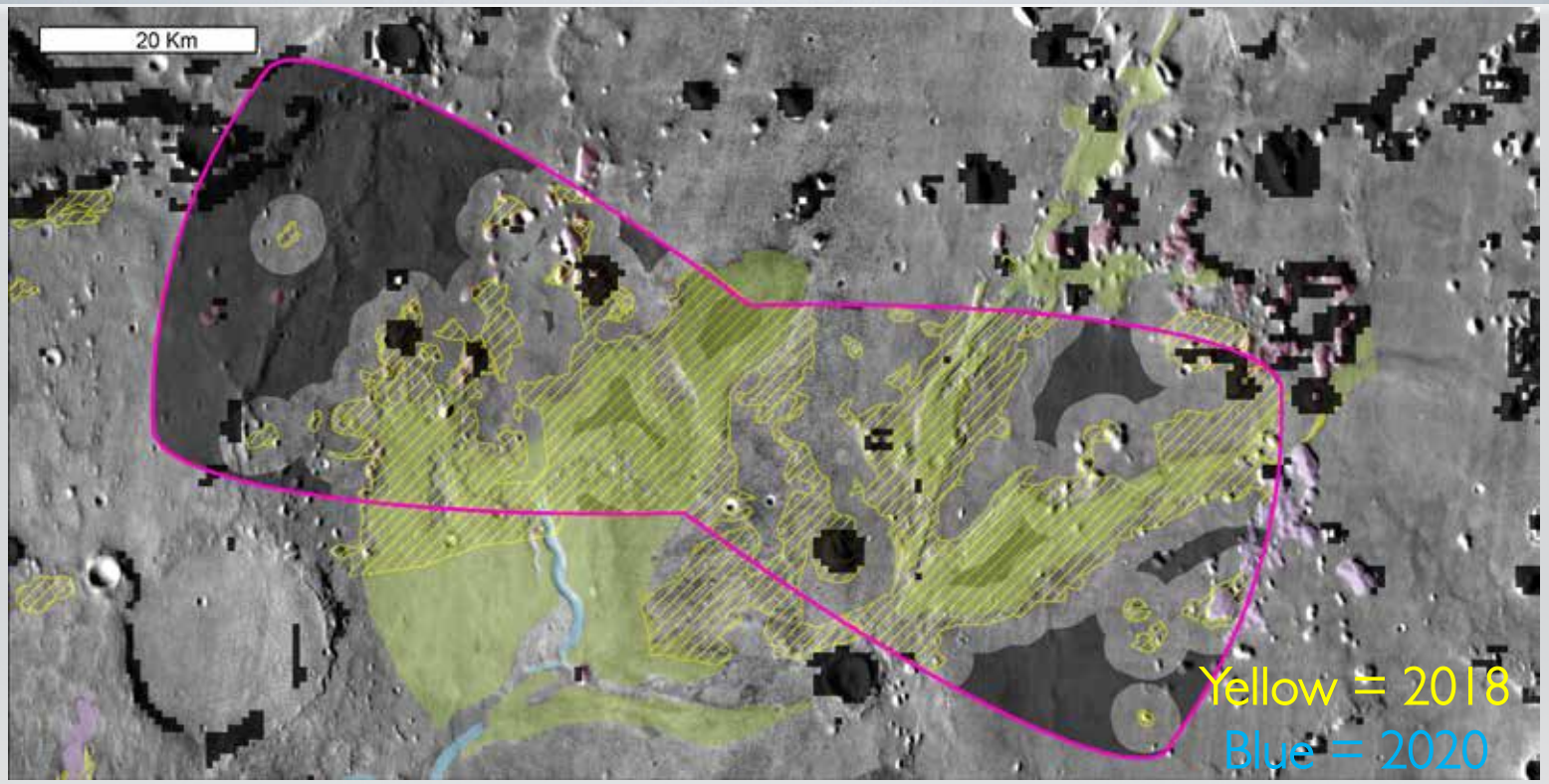
Red/Orange = TAR.

TARs are distributed on deflating deltas not on fine grained material.

There is very little dust coverage

Dust coverage	
min	**0.927**
max	**0.967**
mean	**0.952**
stdve	**0.006**

Sample traverse



	Distance
From Ellipse centre	0
Between areas	5 km from CTX reconnaissance. Detailed investigation reveals wider target distribution

Widespread outcrops

(view shows very conservative estimate)

General Site Presentation - summary

What are the attractive points of this location?

- **Late Hesperian aged, sedimentary rocks throughout the ellipse**
  - ➢ **Therefore, lots of science targets**
- **Clear fluvio-deltaic context – excellent aqueous geological setting**
- **Likely downstream association with low energy fine-grained pro-delta and lacustrine deposits**
  - ➢ **High rates of sedimentation**
  - ➢ **Good biomarker preservation potential**

General Site Presentation - summary

Are there any unique advantages to this site?

- **Clear fluvio-deltaic geomorphic context**
- **Extensive layered sedimentary rocks associated with geomorphic features**
- **One of several deltaic systems in the region – this could be a representative example of widespread, ancient deltaic systems at Chryse basin margin (but see Hauber et al 2013)**
- **Low altitude site**
- **At a more southerly location => keep smaller landing ellipse**

Planetary Protection

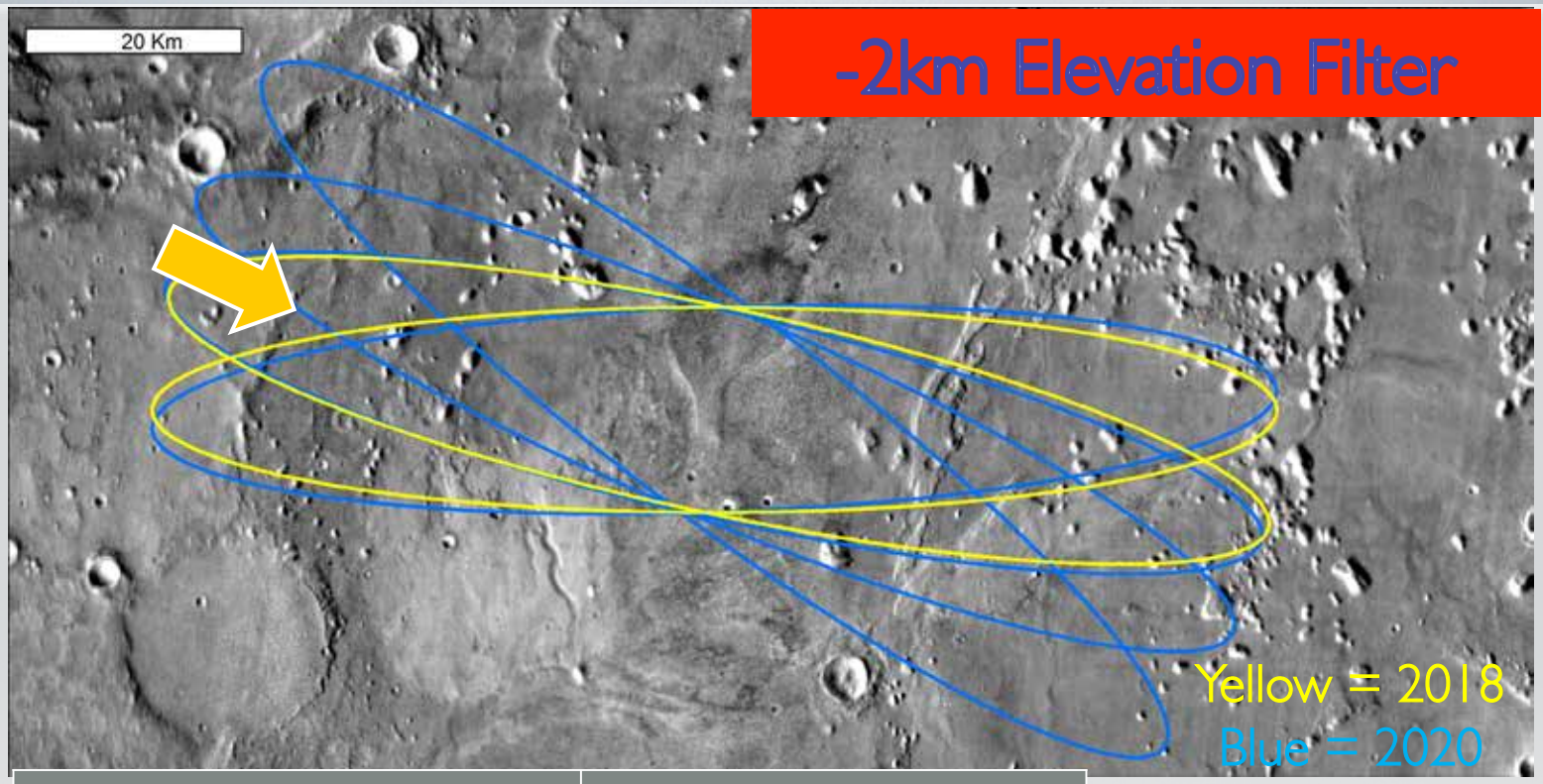
Please describe how you have verified that there are no dark streaks/recurring slope lineae (RSL) in the proposed landing site

- **We used repeat coverage image data to search for morphological changes that might indicate slope streaks and RSLs (thanks, Jan-Peter Muller and Panos Sidiropoulos)**
- **Data used: all HiRISE, MOC-NA, CTX, THEMIS–Vis, HRSC**
- **Covers 6 Mars years at < 18m/pixel resolution**
- **No new slope streaks found**
- **Also, no landforms that could be reliably identified as slope streaks or RSLs were found within the ellipse**
- **A robust search for RSLs requires new HiRISE images**
- **BUT! This areas is well outside the latitudinal band (30-50°S) where RSLs are most common [*Ojha et al., Icarus 2014*]**

Hypanis – Engineering constraints

S. Gupta, P. Fawdon, P. Grindrod, M. Balme,
J. Michalski, J. Carter, J-P. Muller, P. Sidiropoulos

Landing Ellipse Properties - ELEVATION



Ellipse Year/Azim.)	% above -2000m
2018 / 2020	0

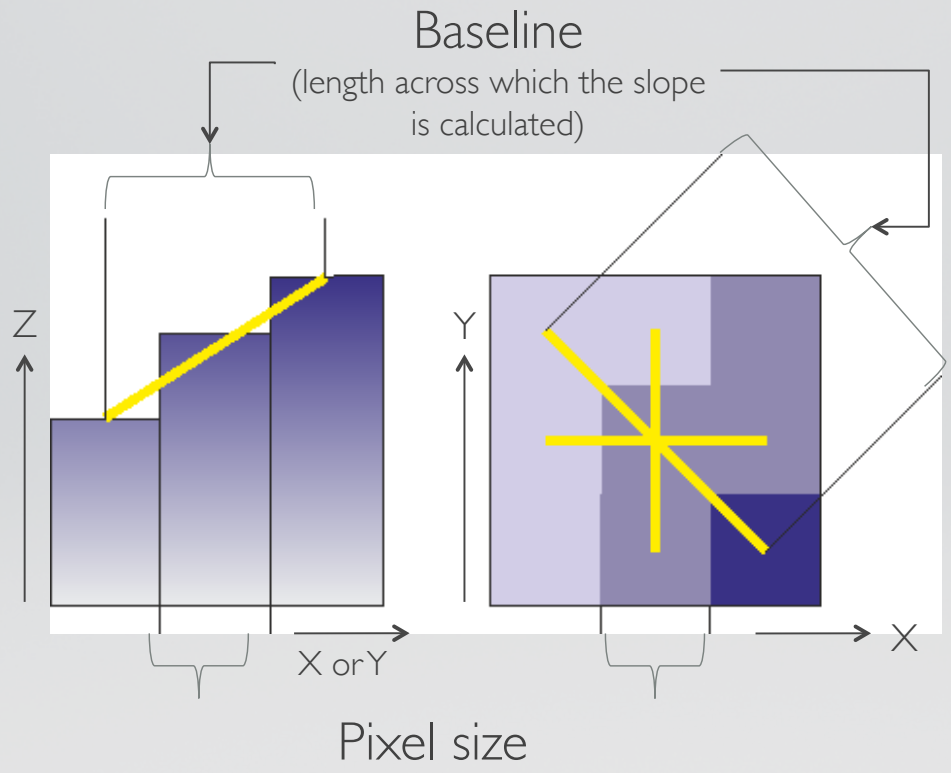
No violation

Landing Ellipse Properties - SLOPE

Slope map creation method

- Raw data: MOLA point data, or CTX/HiRISE stereo DEMs created in BAE SocetSet software
- Data sampled at 1/3 of baseline length (e.g. 666m/pixel for a 2km baseline) to produce a gridded, interpolated DEM
  - MOLA DEM interpolated from raw Global point data
  - CTX/HiRISE DEMs created at 20m/1m gridding originally, then down-sampled to 110m for CTX (for 330m baseline) or to 2.33m for HiRISE (for 7m baseline)
- Slope maps then created in ArcGIS using 3D analyst tools
- Compliance maps then created by applying a 'greater than' mask to the slope maps

Slope Methodology

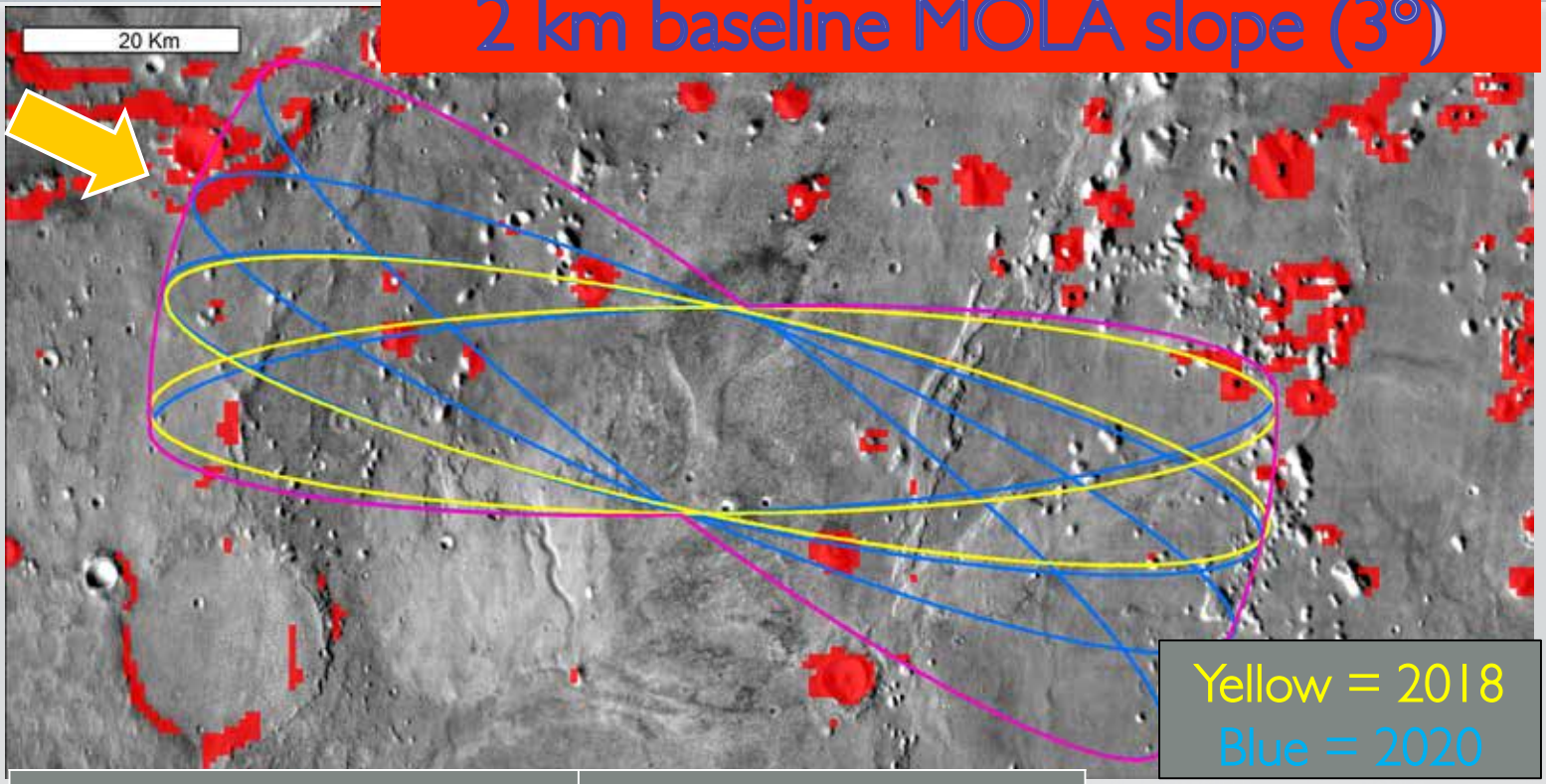


Maximum baseline ≈ 3 x pixel size

=> Pixel size ≈ 1/3 x baseline

Landing Ellipse Properties - SLOPE

2 km baseline MOLA slope (3°)

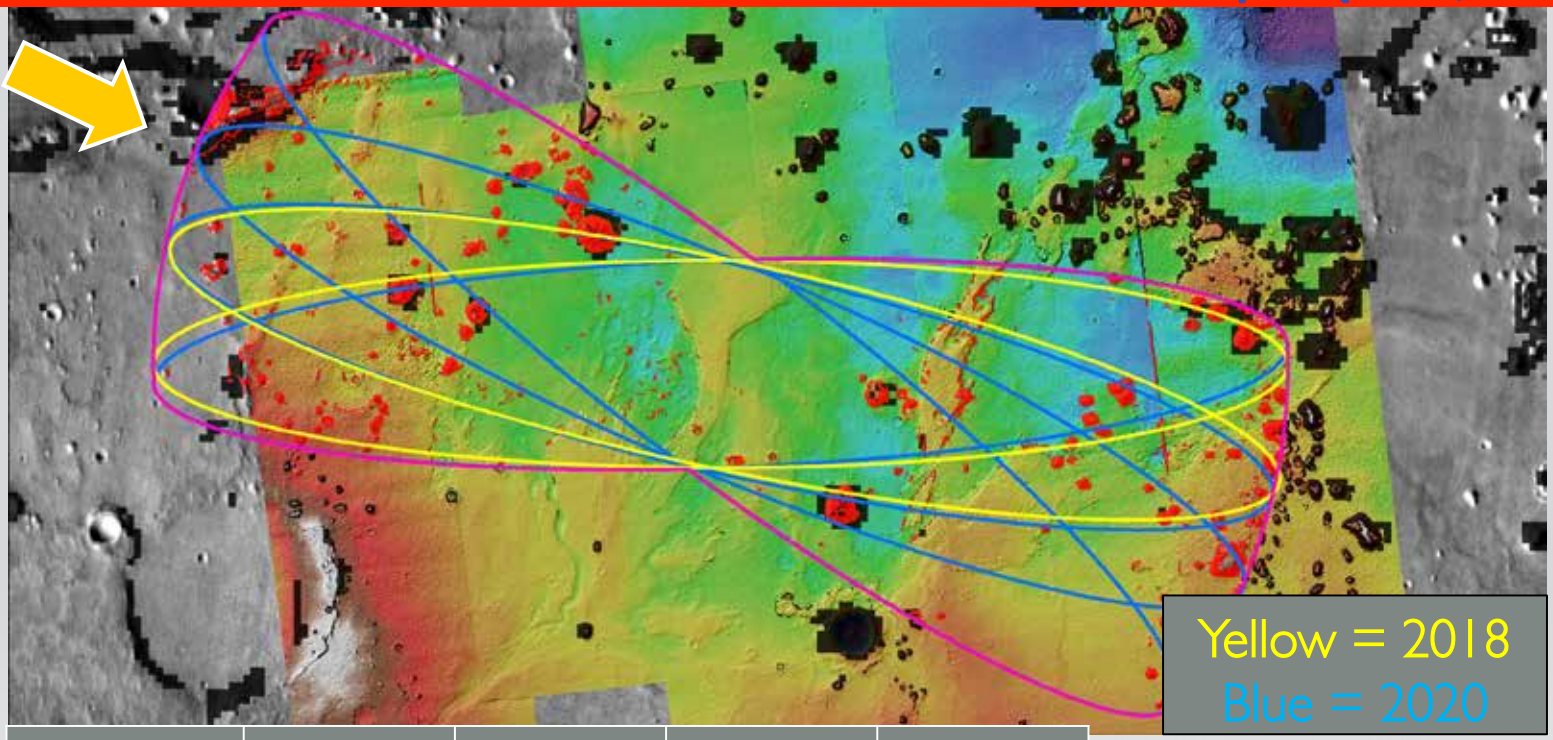


Ellipse (Year/Azim.)	% above 3°
2018 / 2020	3.5

Slopes on rounded knobs

Landing Ellipse Properties - SLOPE

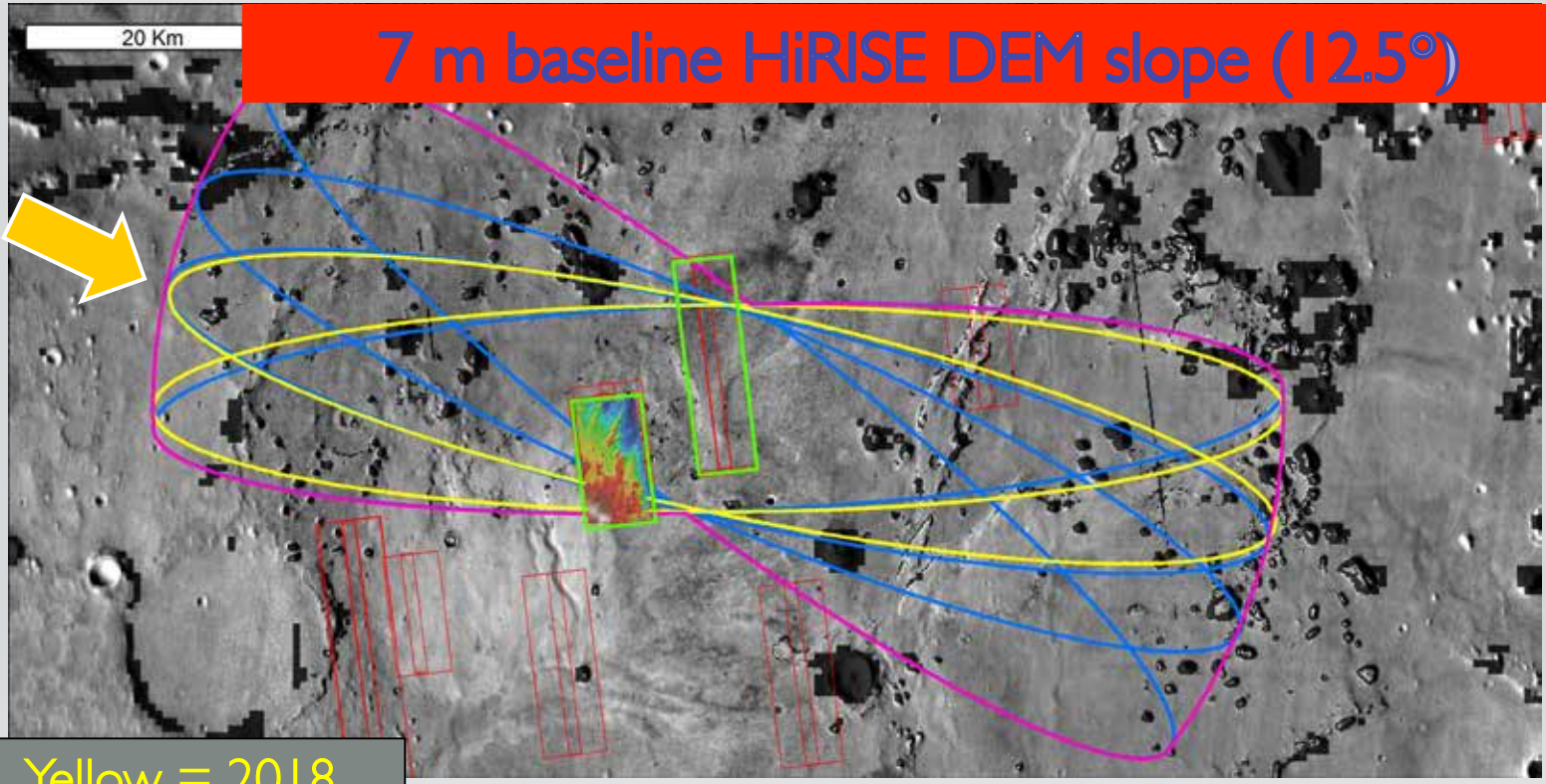
330 m baseline HRSC and CTX DEM slope (8.6°)



Ellipse (Year/ Azim.)	% above 8.6°	Starting Pixel size	Slope map pixel size	Baseline
2018/2020 (CTX area)	4.5	20	110 m	330 m
2018/2020 (HRSC area)	4.48	50	110 m	330 m

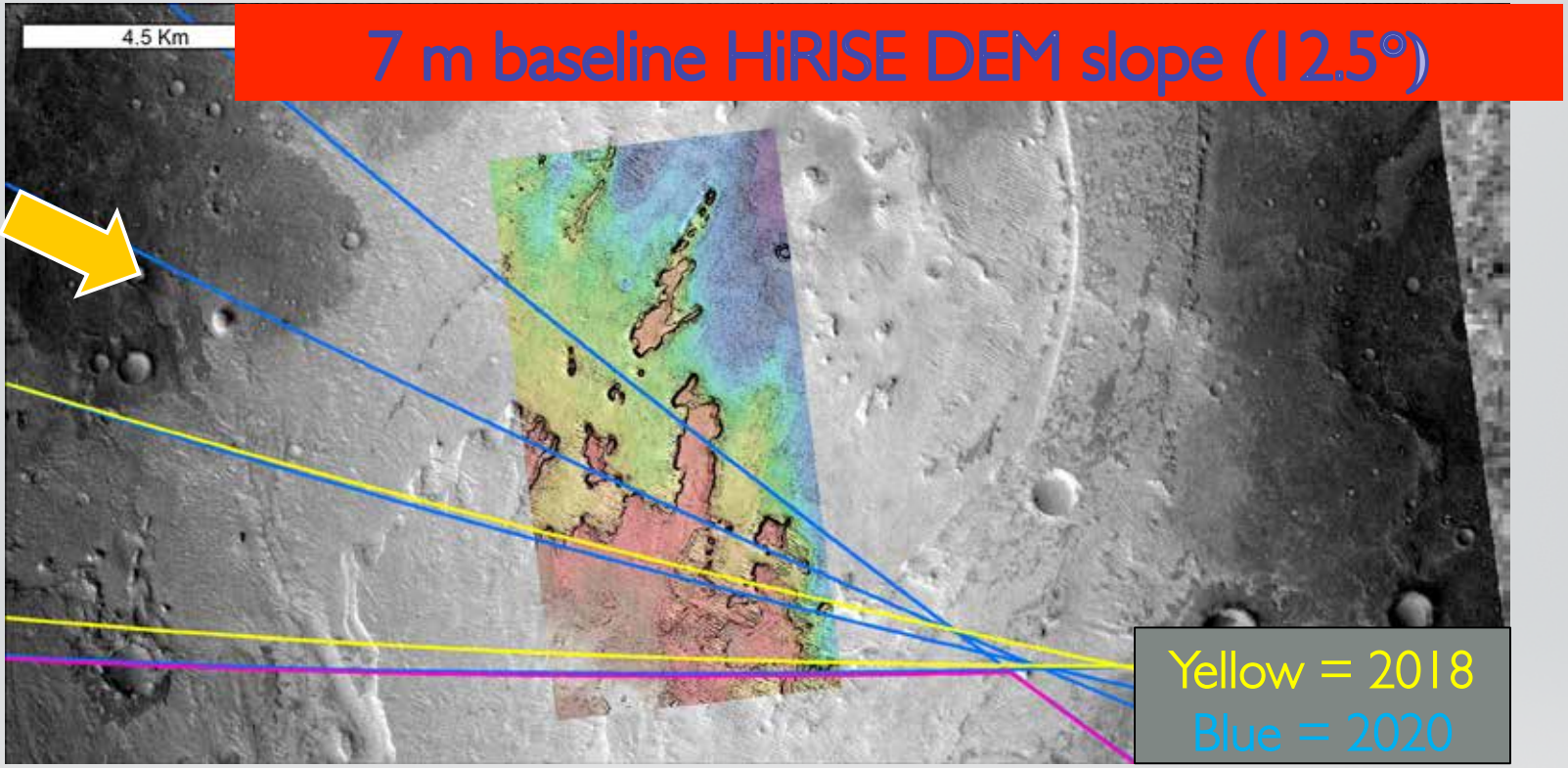
Slopes are on rounded knobs and the edges of inverted landforms

Landing Ellipse Properties - SLOPE



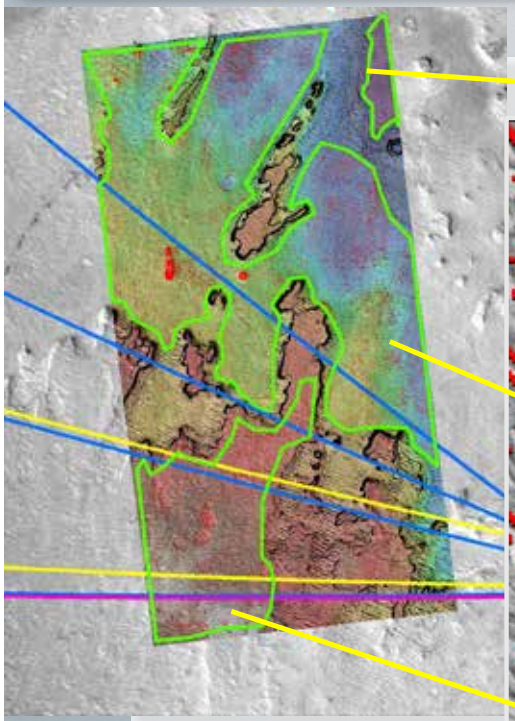
Only 2 stereo pairs. One DEM produced

Landing Ellipse Properties - SLOPE



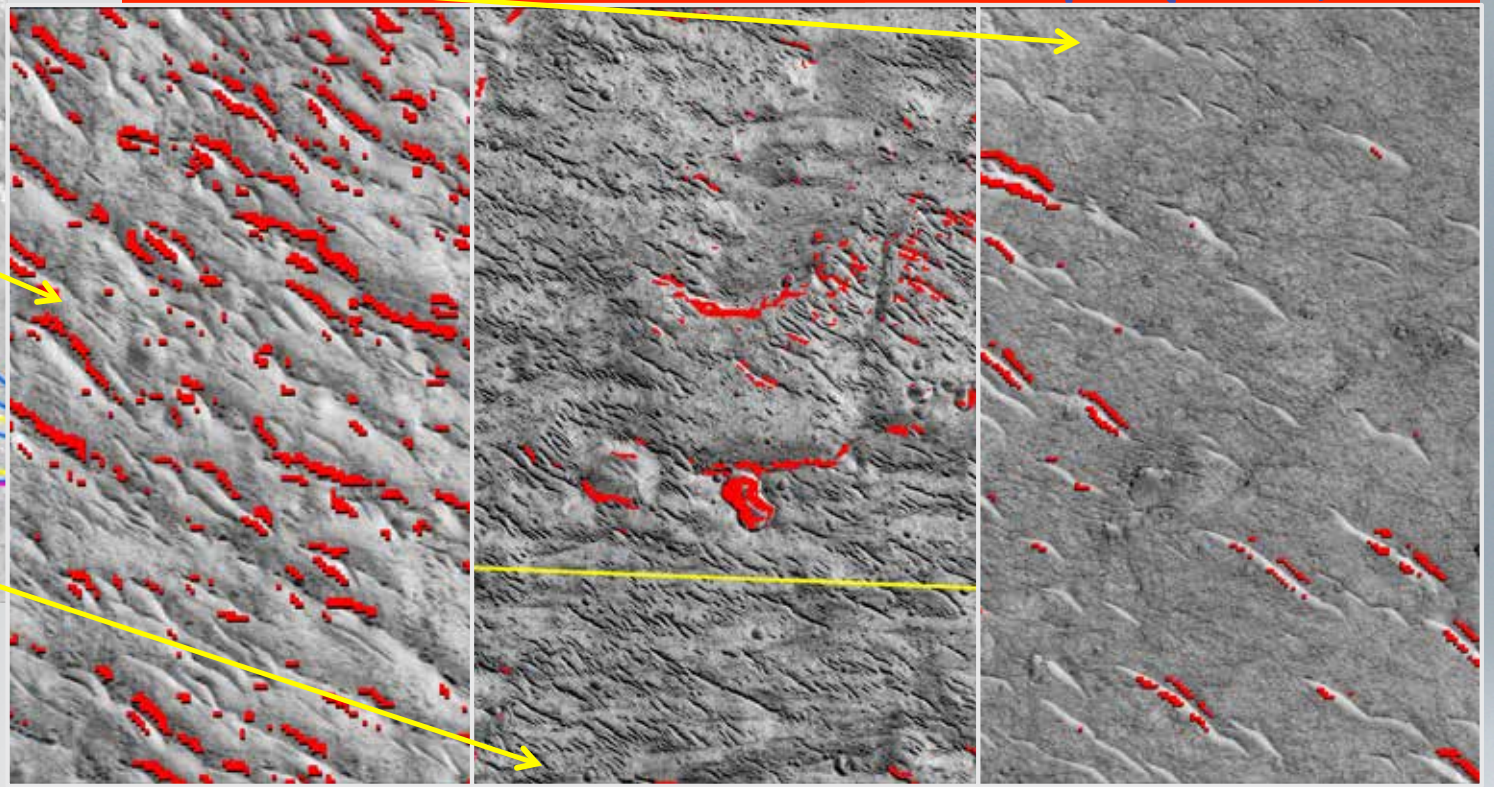
~10.4 % of DEM within the ellipse patterns > 12.5° slope.

Landing Ellipse Properties - SLOPE



Yellow = 2018
Blue = 2020

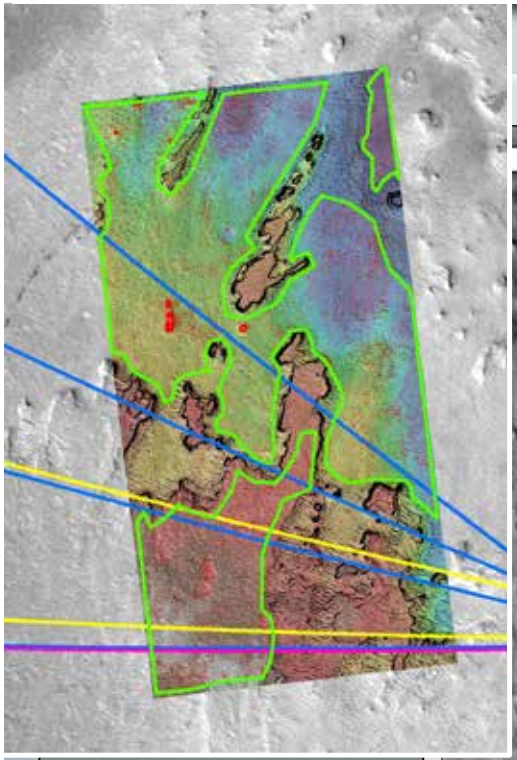
7 m baseline HiRISE DEM slope (12.5°)



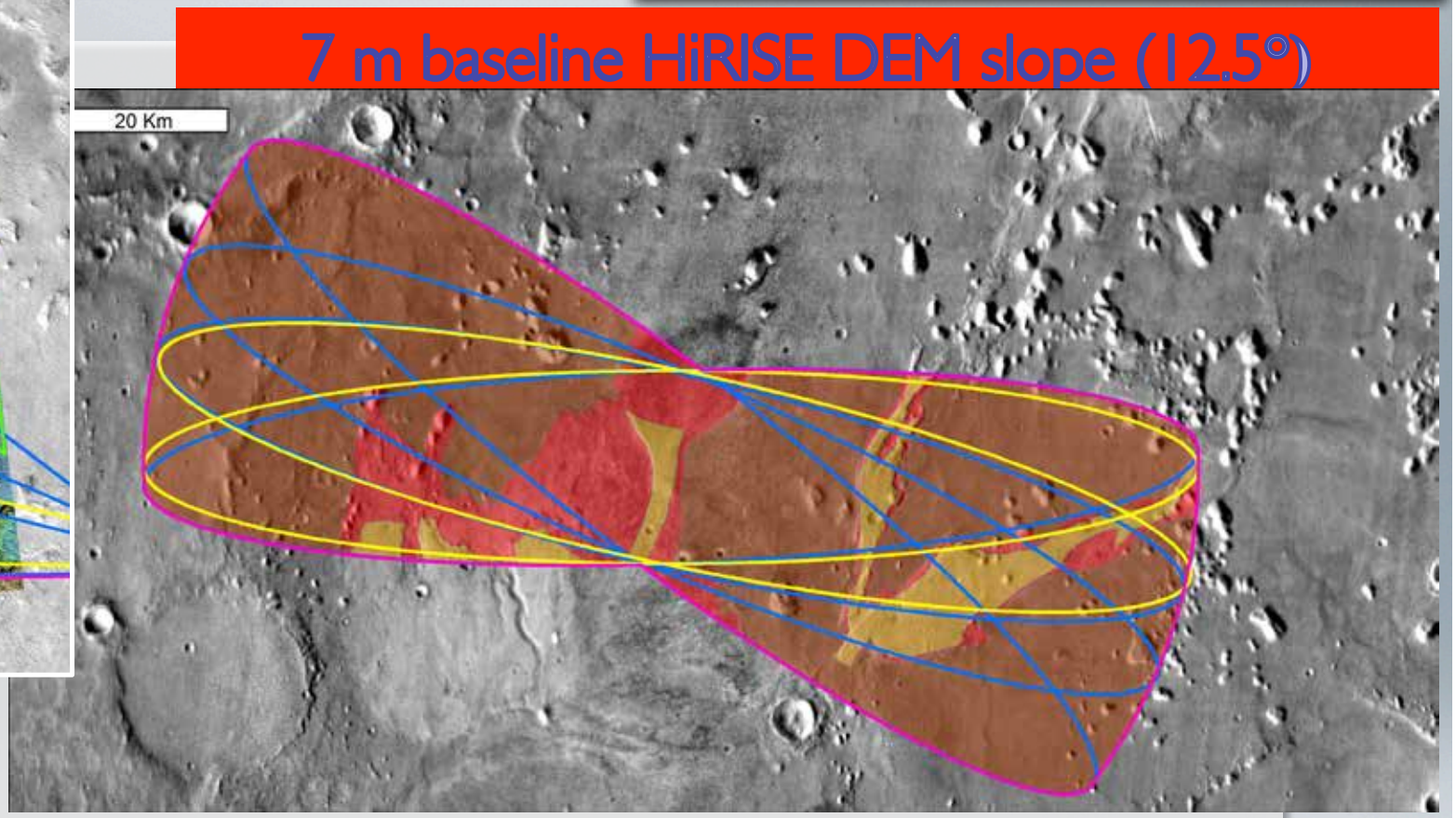
Area	% above 12.5°	Representative of
Dark floor	1.9 %	Large area of dark surface underlying deltas
Deflating delta	38.0 %	Area where the delta forms are being stripped back
Delta top	2.2 %	The top of deltas and inverted chanels

~10.4 % of DEM within the ellipse patterns > 12.5° slope.

Landing Ellipse Properties - SLOPE



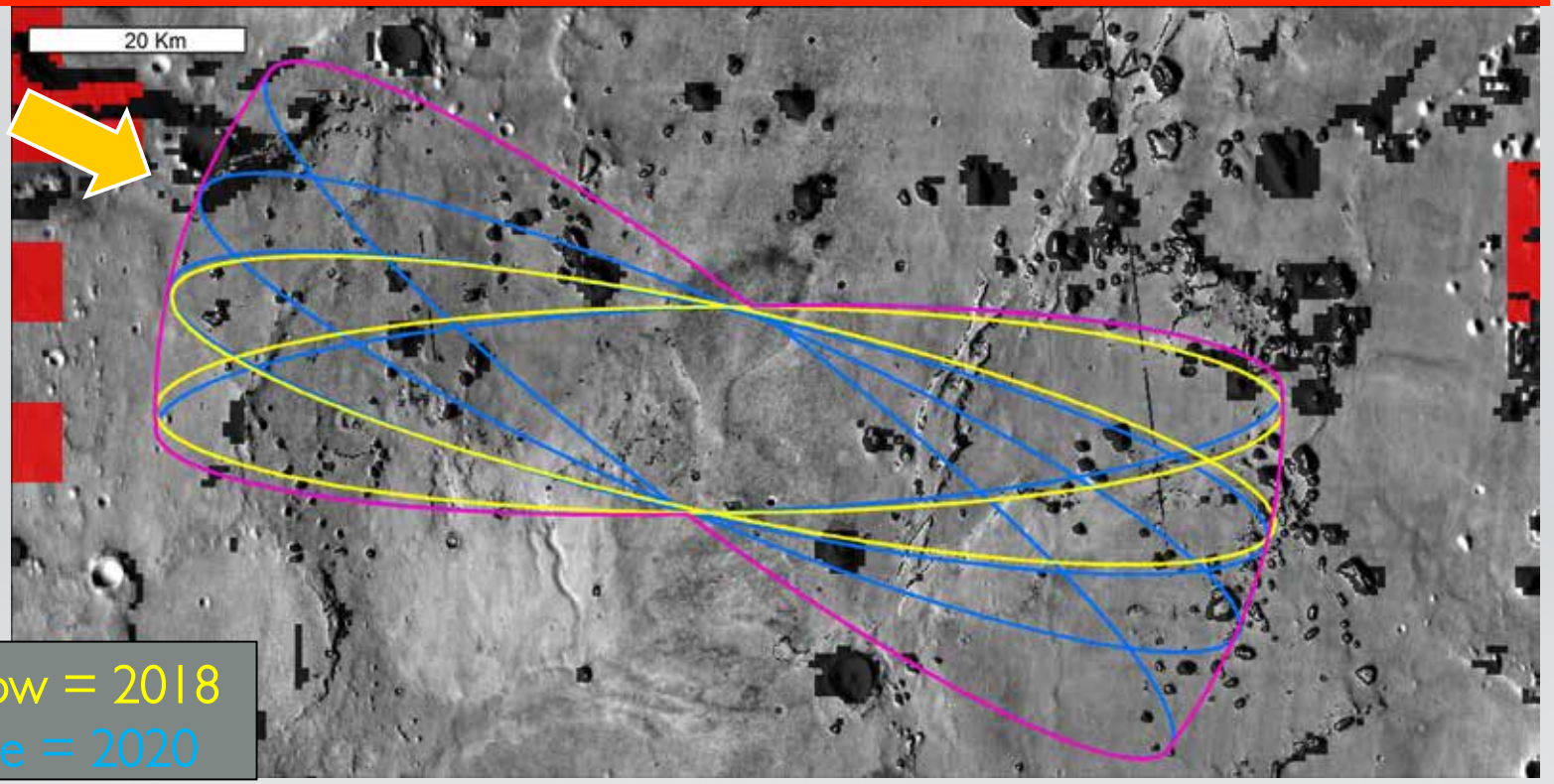
Yellow = 2018
Blue = 2020



Area	% above 12.5°	Representative of	
Dark floor	1.9 %	Large area of dark surface underlying deltas	≈ 75 %
Deflating delta	38.0 %	Area where the delta forms are being stripped back	≈ 16 %
Delta top	2.2 %	The top of deltas and inverted chanels	≈ 9 %

Landing Ellipse Properties - OTHER

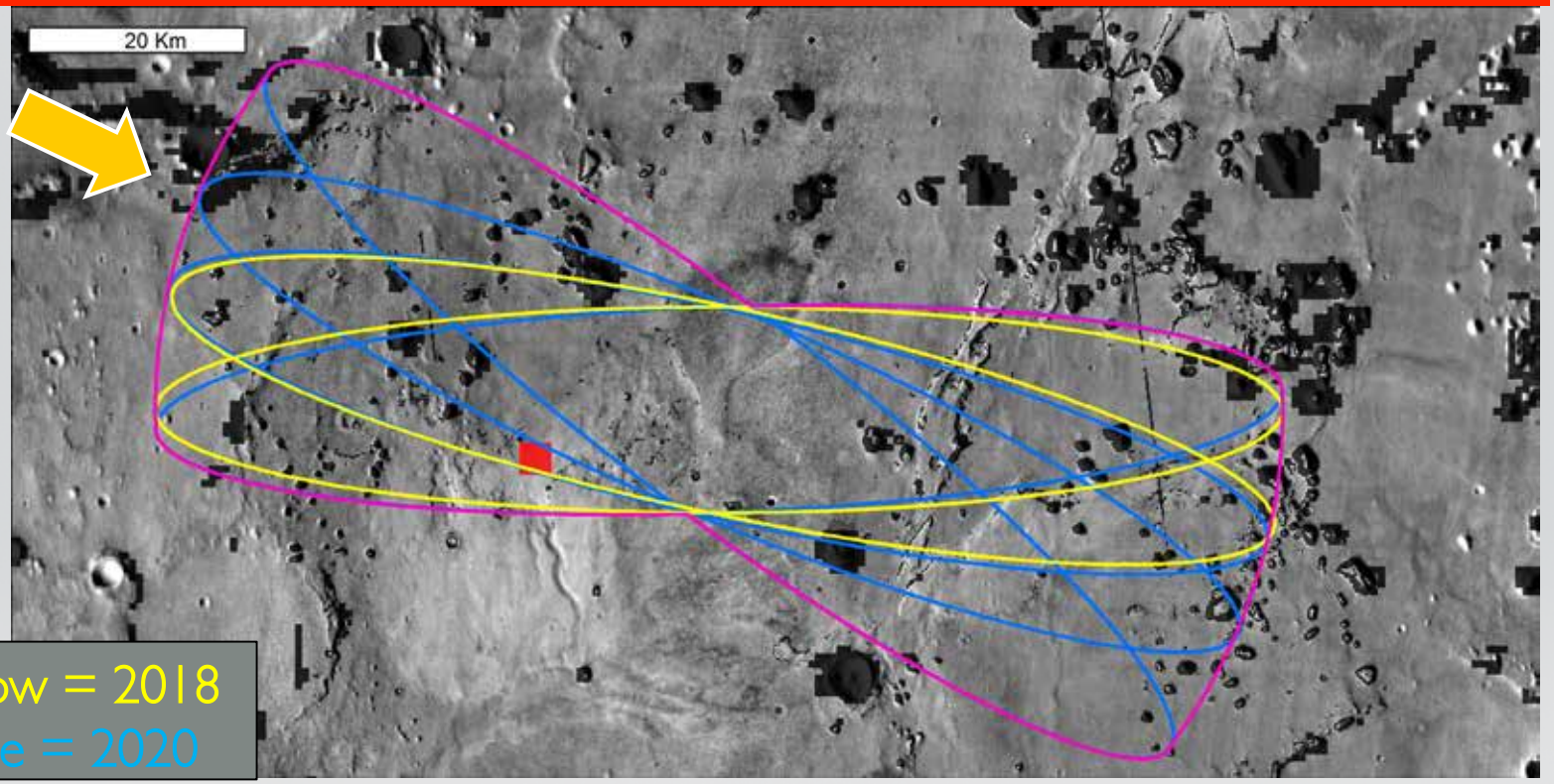
Rock abundance,



Red = TES rock abundance > 0% (Nowicki et al. JGR 2007)

Landing Ellipse Properties - OTHER

Thermal inertia,

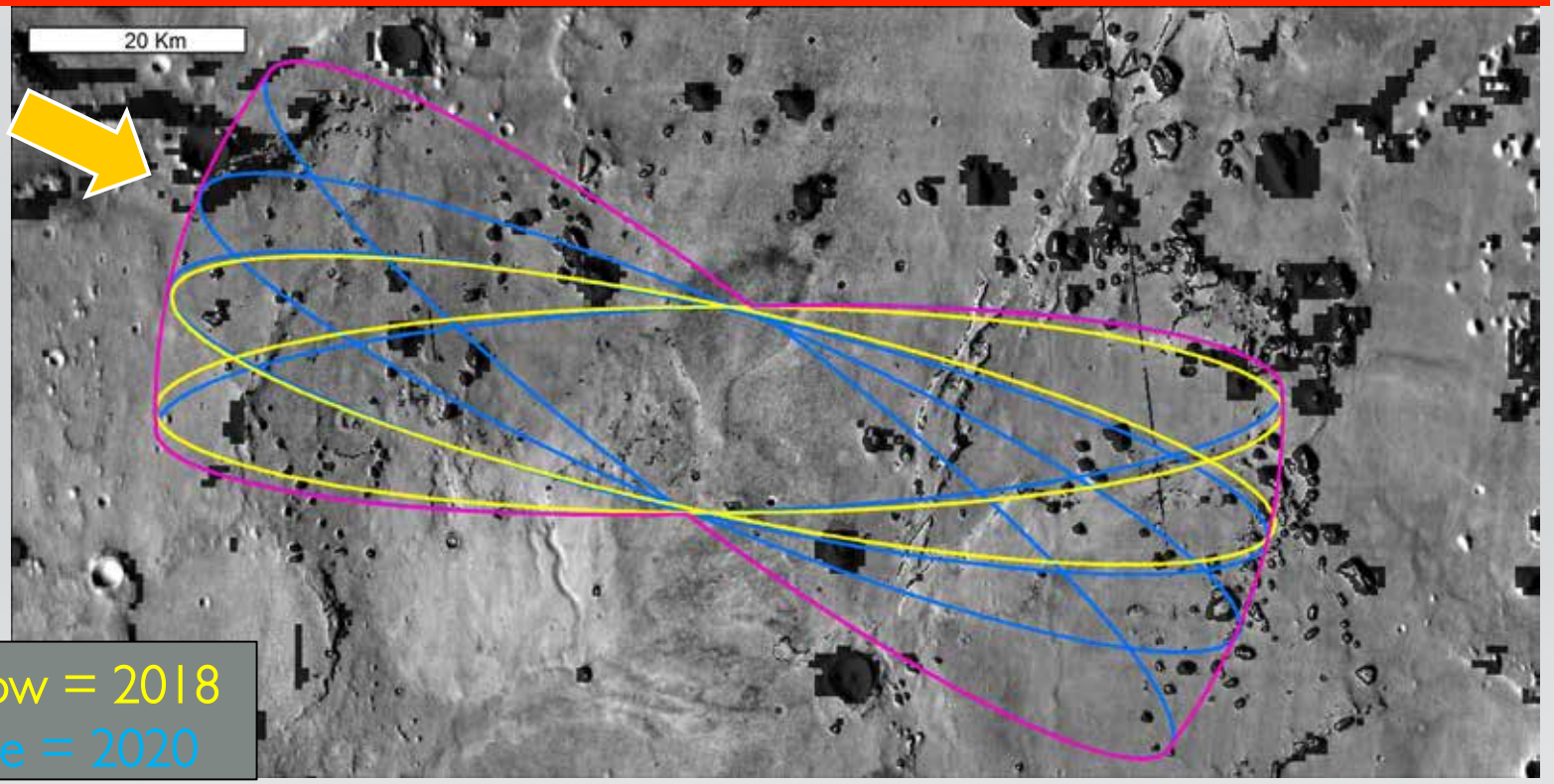


Yellow = 2018
Blue = 2020

Red = TES Thermal inertia **≥ 150 J m^{-2} s$^{-0.5}$ K^{-1}**

Landing Ellipse Properties - OTHER

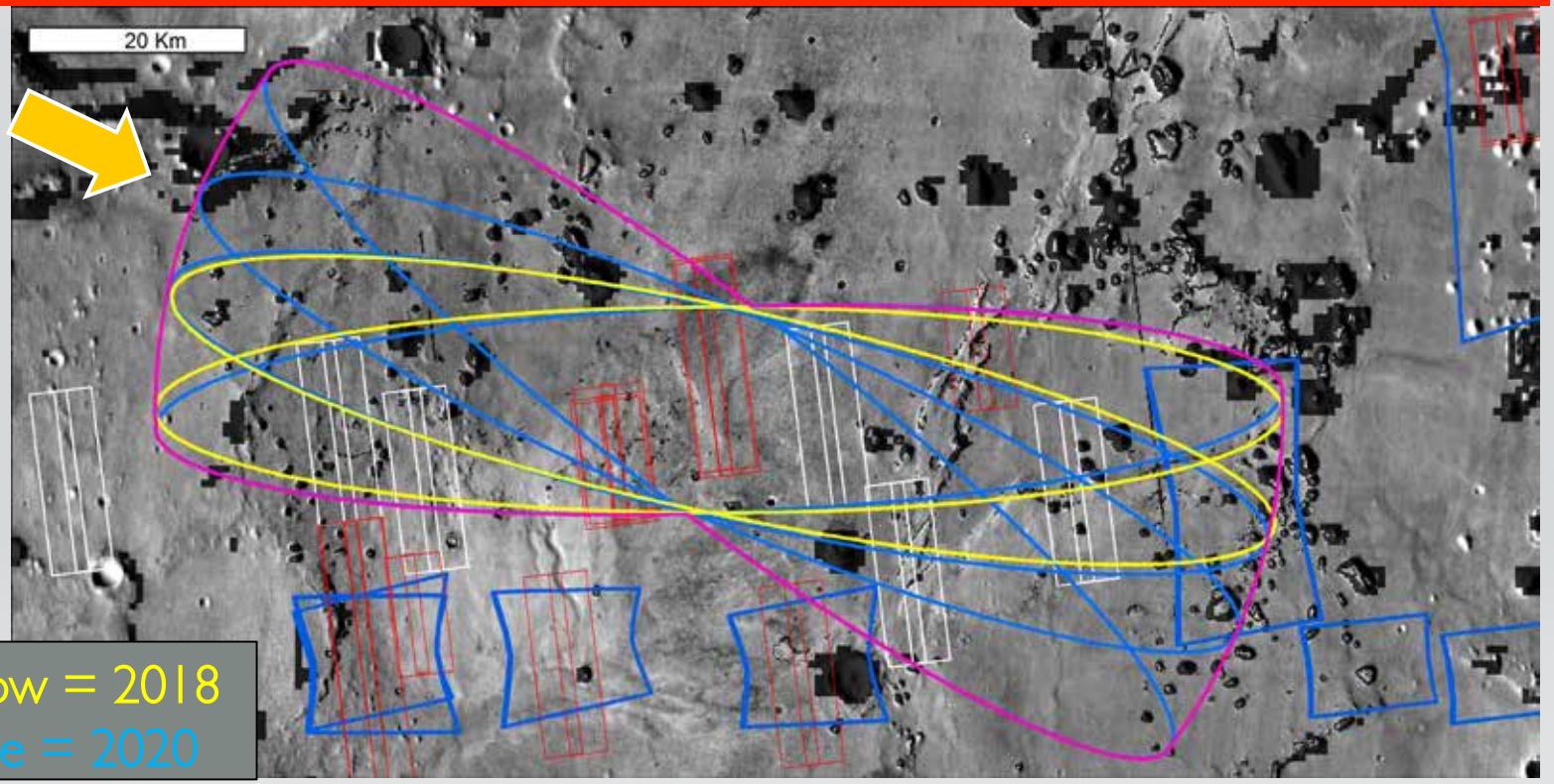
Albedo,



The whole region meets the albedo criterion: 0.1 ≤ albedo ≤ 0.26

Landing Ellipse Properties - OTHER

DATA



Yellow = 2018
Blue = 2020

Red = HiRISE
Blue = CRISM
White = 4 of 6 requested HiRISE

Summary 1

Please summarise your site's main scientific attributes for the ExoMars mission's objectives

- **Has a clearly defined early Hesperian aqueous geomorphic context**
- **Sourced from a very long fluvial system – likely represents long duration of fluvial activity**
- **Shows excellent development of fan system with well defined proximality trends – we have a sedimentary model for where to search for fine-grained sediments**
- **Downstream of fan lobes likely to be large areas of fine-grained (so likely to preserve biomarkers) sedimentary rocks within the ellipse – possibly lacustrine.**
- **Presence of multiple lobes suggest temporally extensive duration of sedimentation**
- **Fans adjacent show presence of clay minerals from orbit in layered sediments at base of fan**

Summary 2 – ExoMars Science Goals

"For the mission's search-for-traces-of-life objectives we are interested in:"

1. *"Age (period in martian history) of the deposits)"*
   ☑ Early Hesperian
2. *"Fine-grained sedimentary outcrops with a water-rich/hydrothermal history that we associate with life favourable conditions (e.g. evidence of ponded water)"*
   ☑ Deltaic and low-energy pro-deltaic lacustrine sediments. *"Preservation of … biosignatures against radiation and oxidant damage (not just old sites, but old sites that have been recently exhumed; they are better for preservation)"*
   ☑ Exhumation ongoing – overburden is being stripped
3. *"Distribution of prime targets within the landing ellipse (will we land on top or be able to reach them?)"*
   ☑ Much of ellipse is at edge of downstream of deltaic sedimentary bodies

Summary 2

Criterion	Specification	Data Used	This Landing Site
Latitude	5 S to 25 N	MOLA	11.08˚ N, -45.04˚ W
Elevation	Below –2 km	MOLA	100 % of ellipse is below, 0 % is above
Slopes (2–10 km)	≤ 3.0˚	MOLA	100 % of ellipse is in spec
Slopes (2–10 km)	≤ 3.0˚	MOLA	At 2 km, 96.6 % of ellipse is below, 3.4 % is above
Slopes (330 m)	≤ 8.6˚	HRSC	95.6 % of ellipse is below, 4.4 % is above
Slopes (330 m)	≤ 8.6˚	CTX	95.5 % of ellipse is below, 4.5 % is above
Slopes (7 m)	≤ 12.5˚	HiRISE	89.6% of ellipse is below, 10.4 % is above **(of unrepresentative sampled area)**
Slopes (2 m)	≤ 15.0˚	No Data	No Data
Rock abundance	≤ 7%	IRTM	100 % of ellipse is in spec
Rock abundance	≤ 7%	HiRISE	No Data
Thermal Inertia	≥ 150 J m^{-2} $s^{-0.5}$ K^{-1}	TES	99.7 % of ellipse is above (night time data)
Albedo	0.1 ≤ albedo ≤ 0.26	TES	100 % of ellipse is in spec
Radar Reflectivity	–15 dB ≤ Ka band backscatter cross section at nadir ≤ 27.5 dB	No Data	No Data
Horizontal Wind (1 m–10 km agl)	≤ 0.25 m/s	GCM	No data
Horizontal Wind (1 m above ground)	≤ 0.30 m/s	GCM	No Data