Inverted, exhumed channel system in Oxia Palus

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

ExoMars 2018 First Landing Site Selection Workshop (LSS WS#1)
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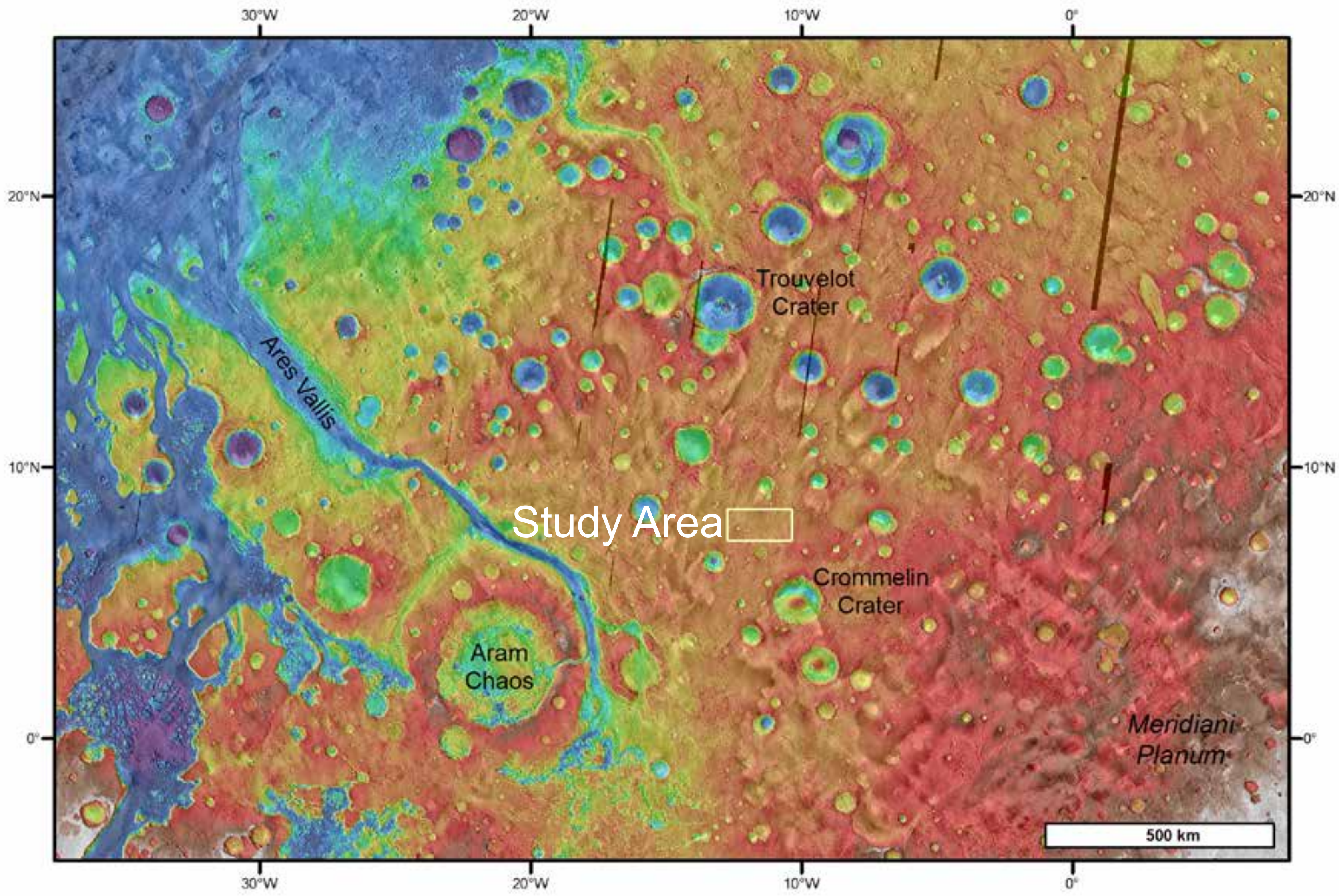
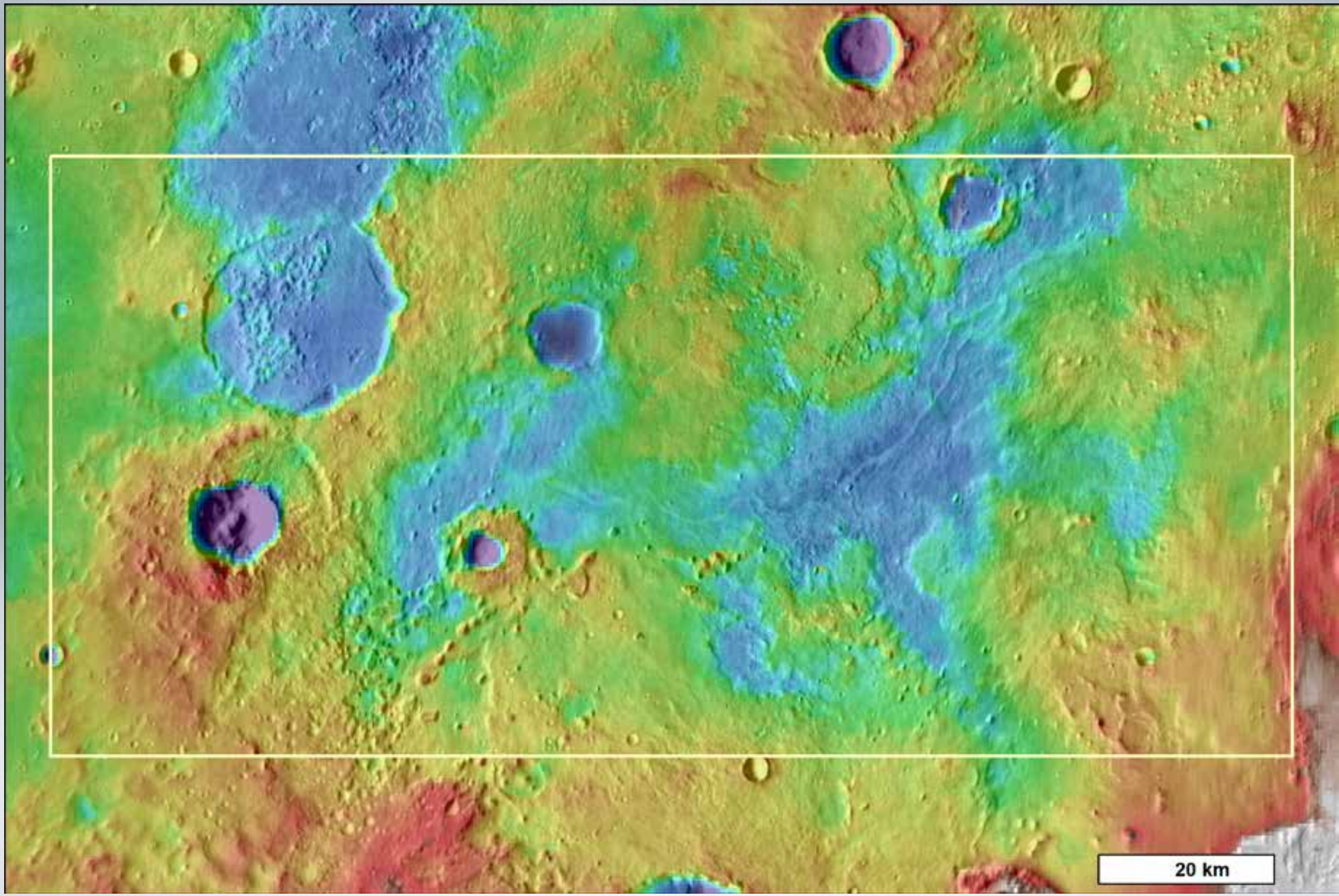
General Site Presentation

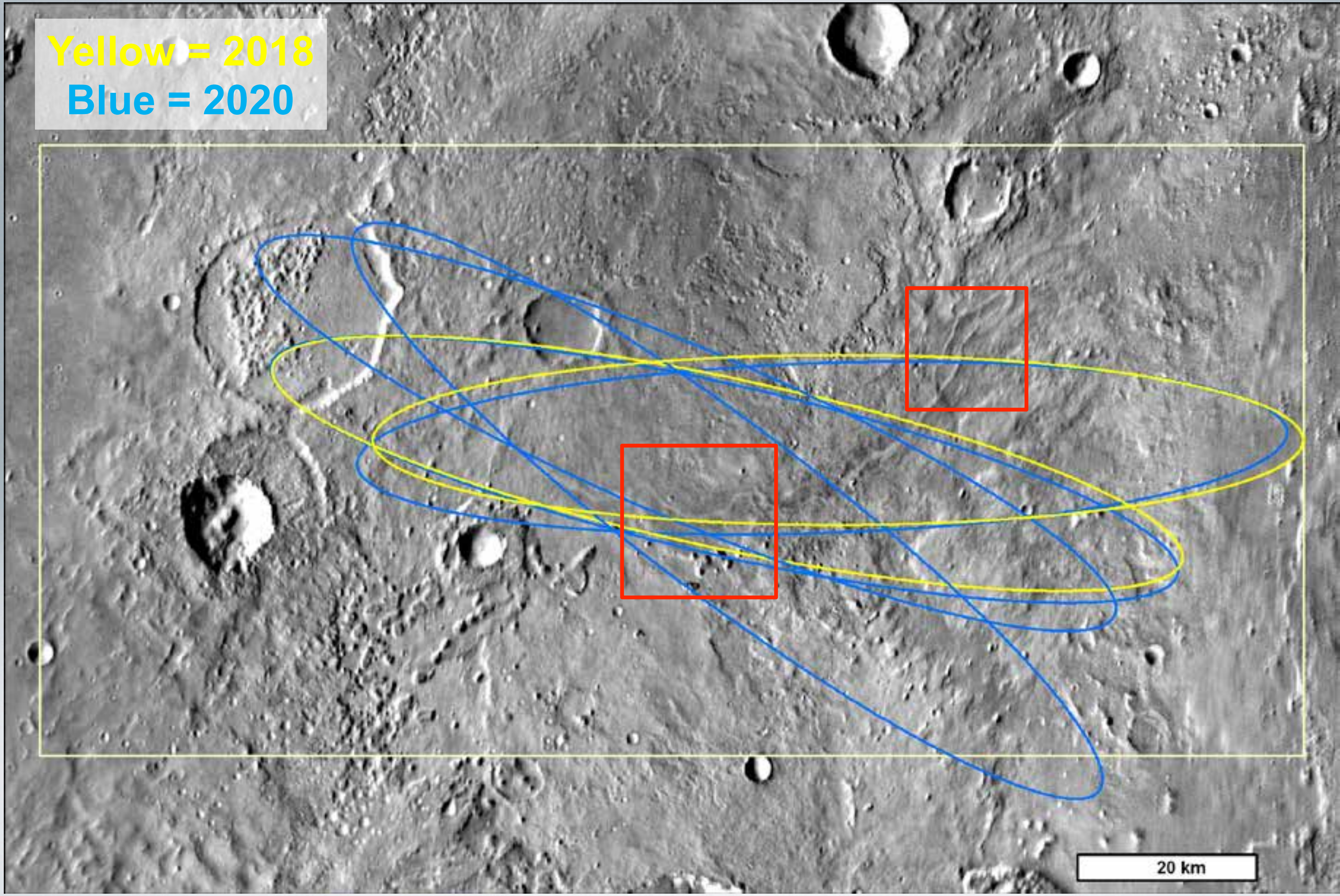


General Site Presentation

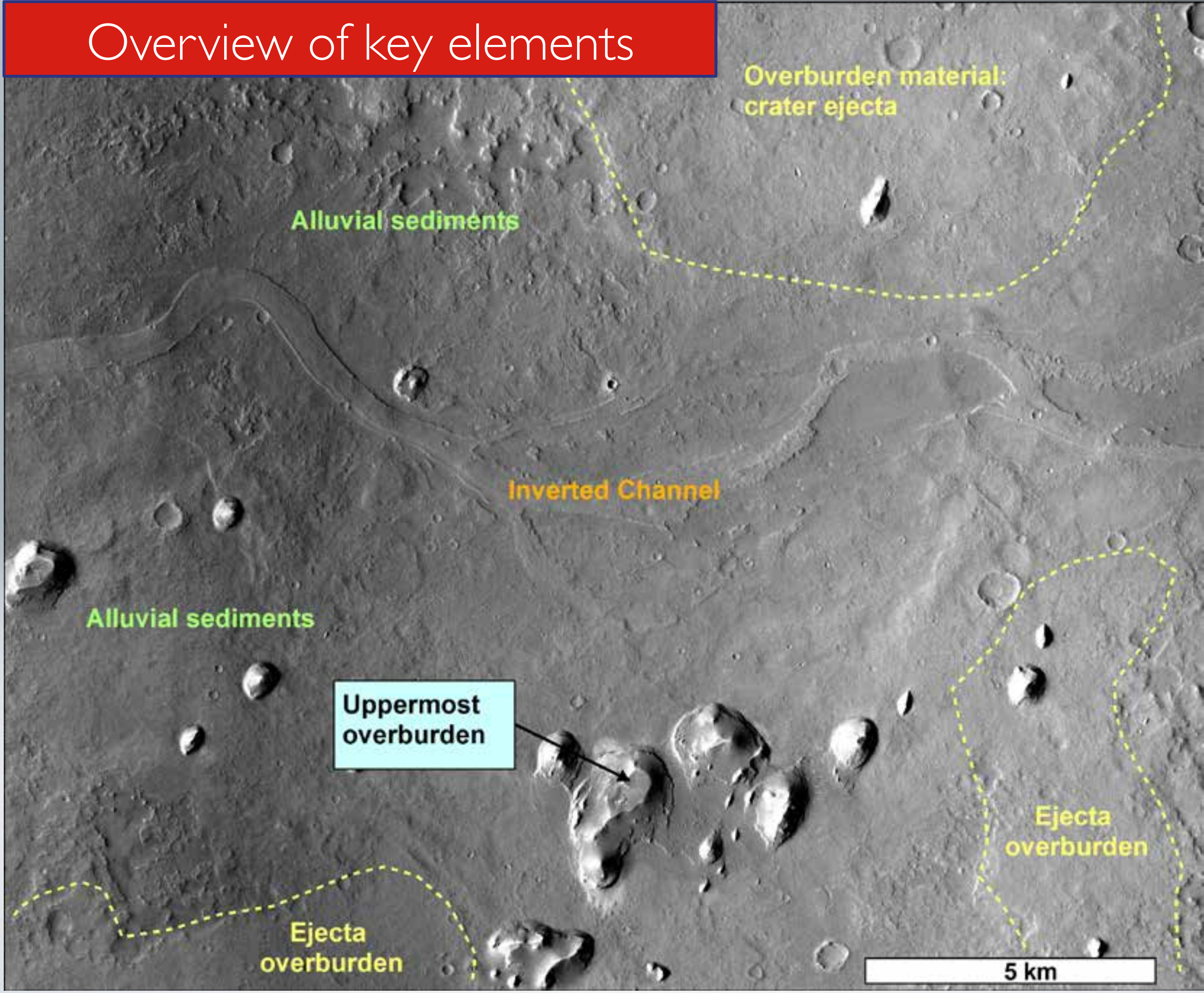


General Site Presentation

EXOMARS

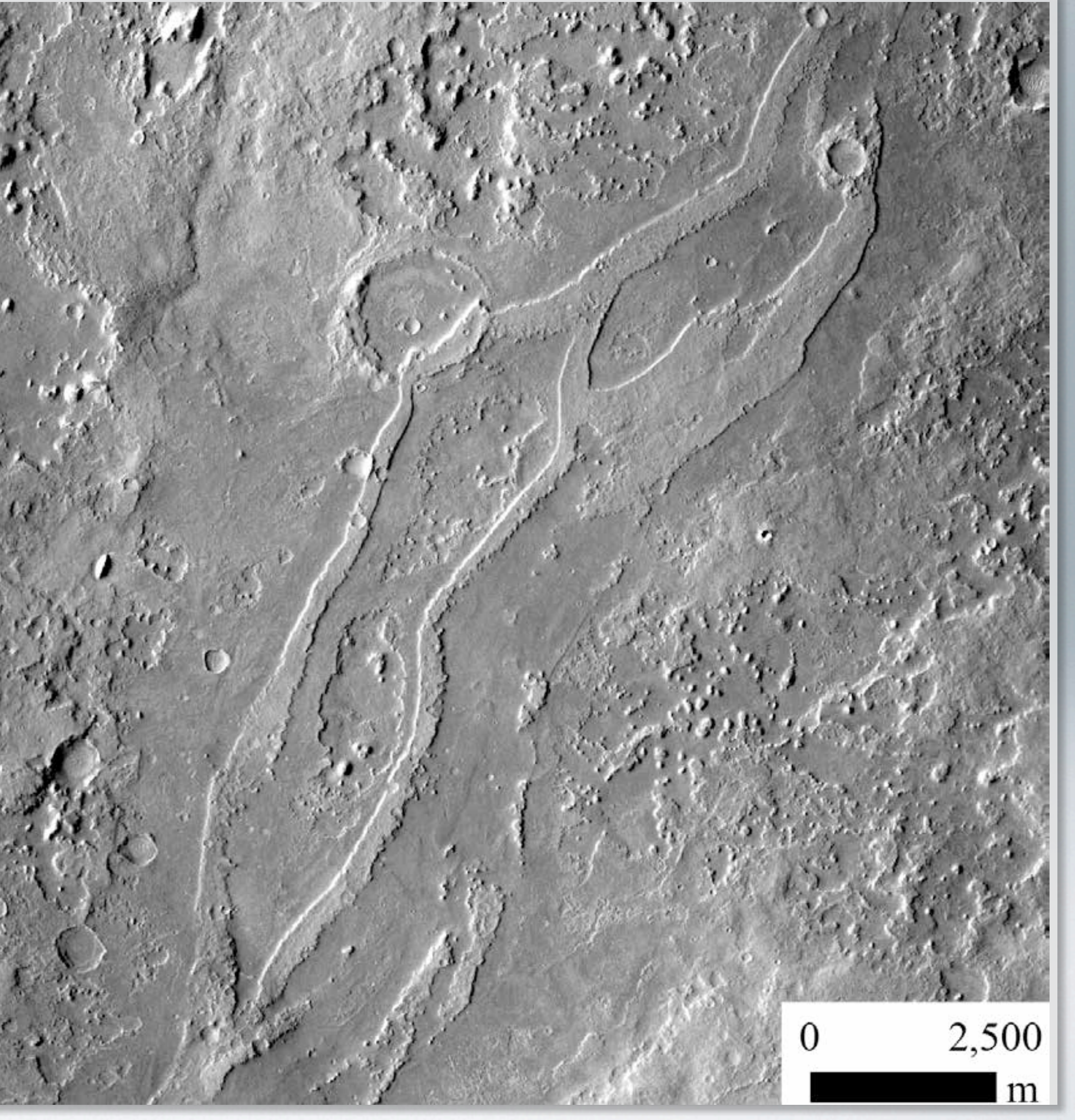


Overview of key elements



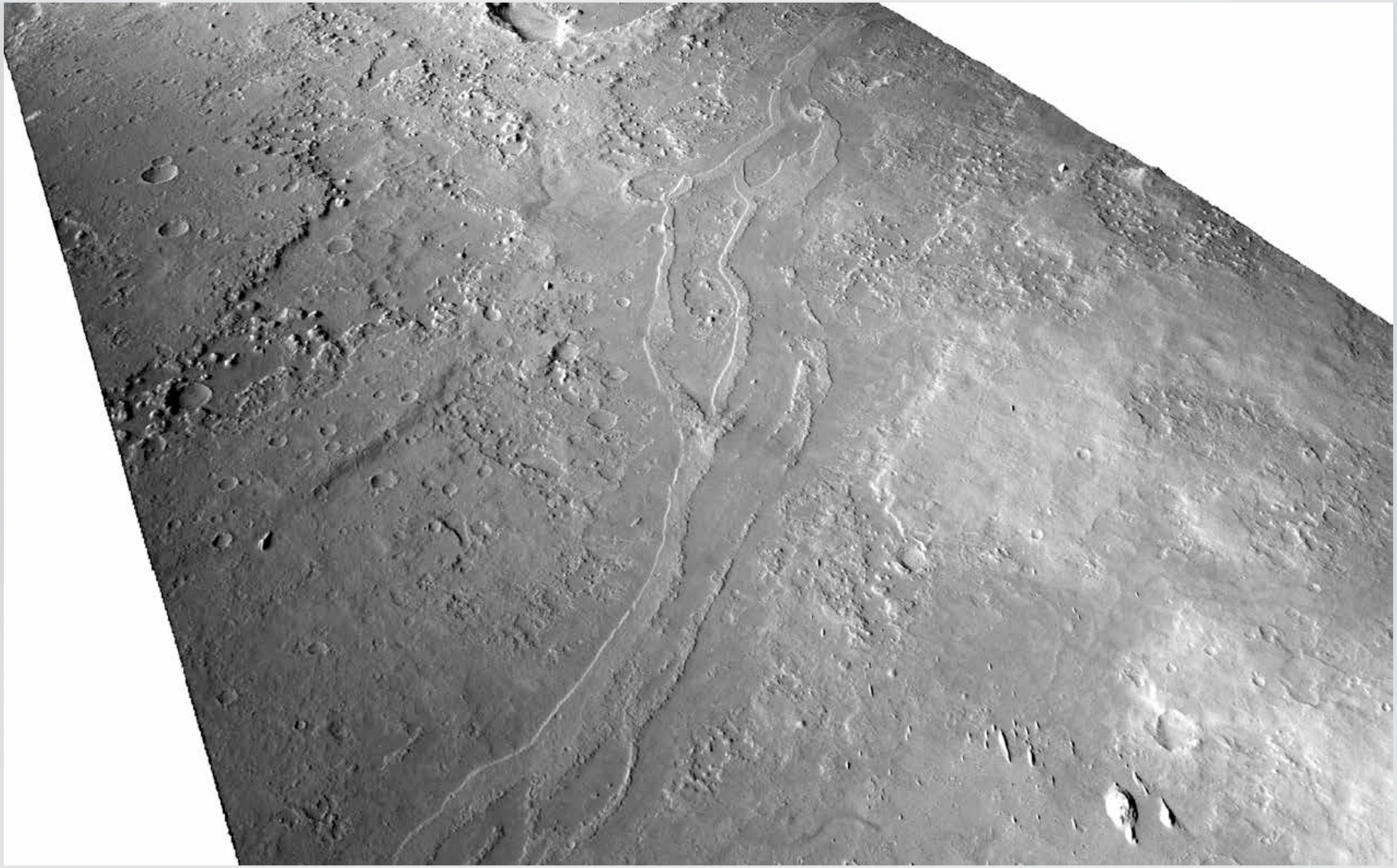
General Site Presentation

- Inverted channel system
- Lateral and vertical channel migration
- Sedimentary terrains surround the channel system
- System ~5 - 10s km wide, ~100 km long (exposure)

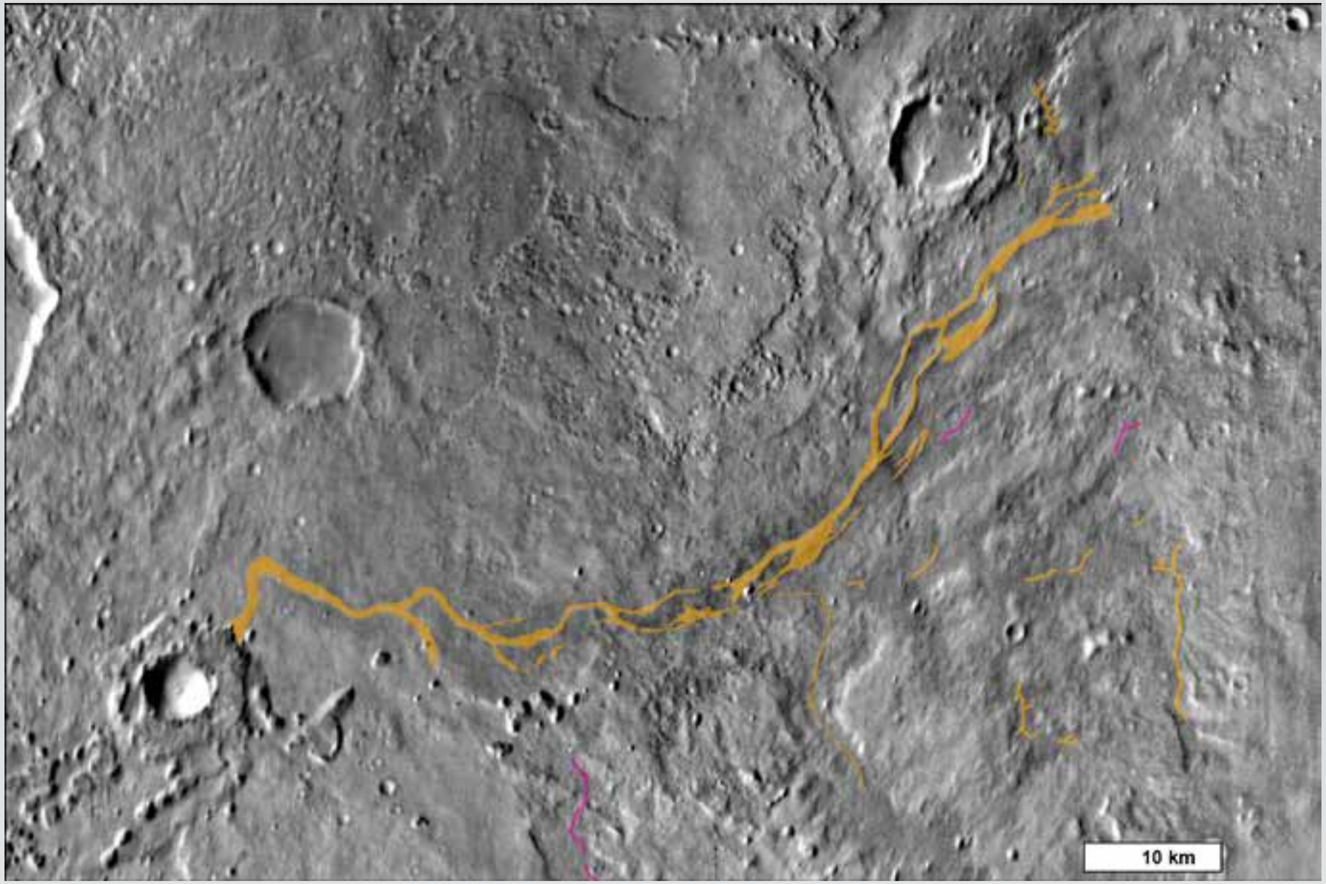


General Site Presentation

EXOMARS

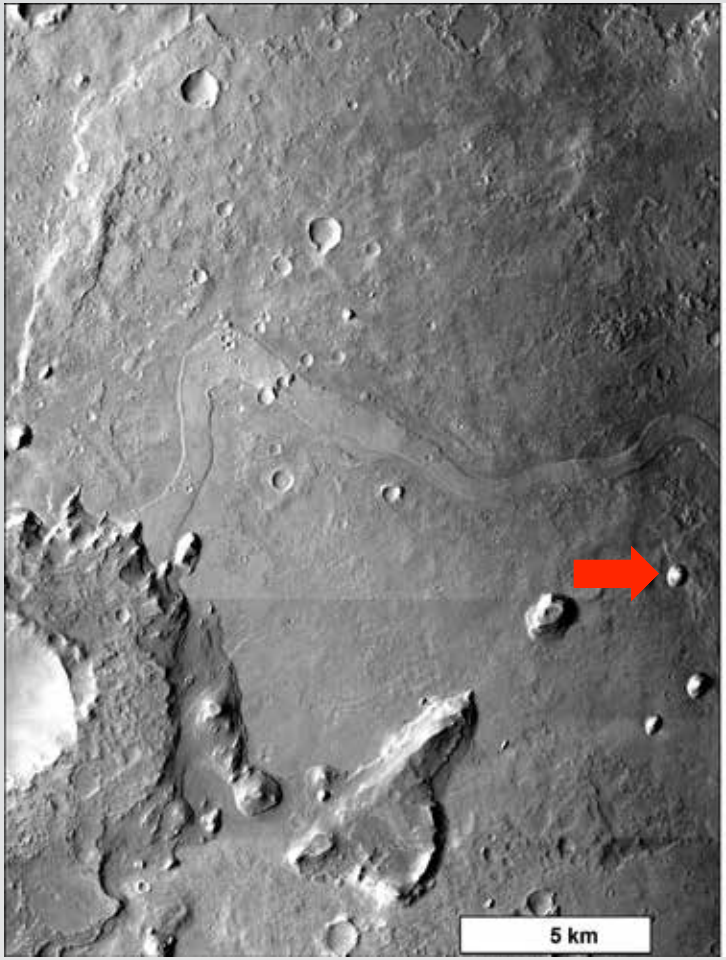


Similar view, from CTX DTM/Ortho (FOV ~30km)



Inverted channels extensive: trunk ~100 km length;
Also, small non-inverted channels (purple)

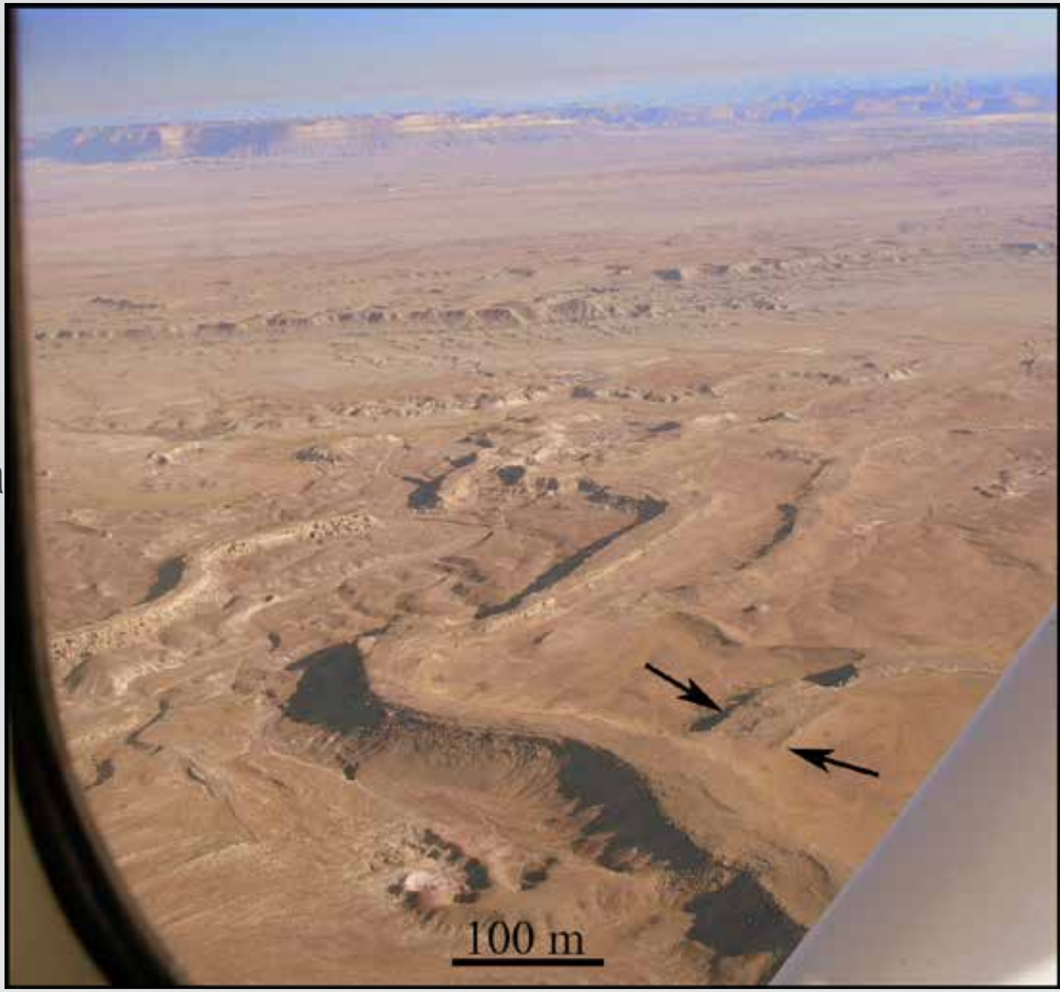
General Site Presentation



Channel system overlain by later ejecta at both ends, and by outliers of layered material in mesas across the whole region

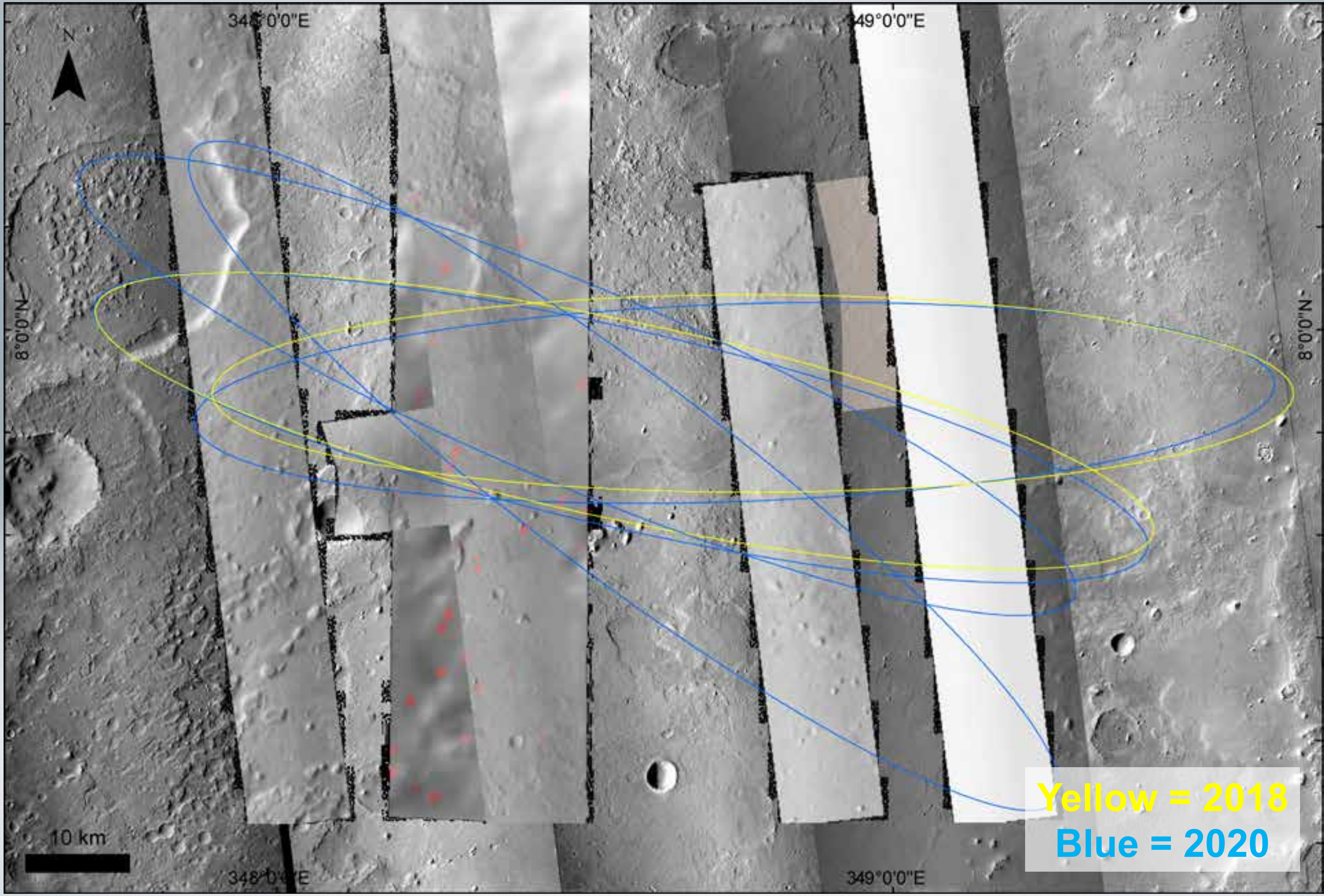
Possible Earth analogue: Exhumed Paleo-channels near Green River, Utah, USA.

Both are sinuous, multi-level inverted channel systems (black arrow is a stratigraphically lower channel, not a branch), and both have been exhumed from >100s of metres of burial.



See: Williams *et al*., GSA Spec. Pub. 483, 2011

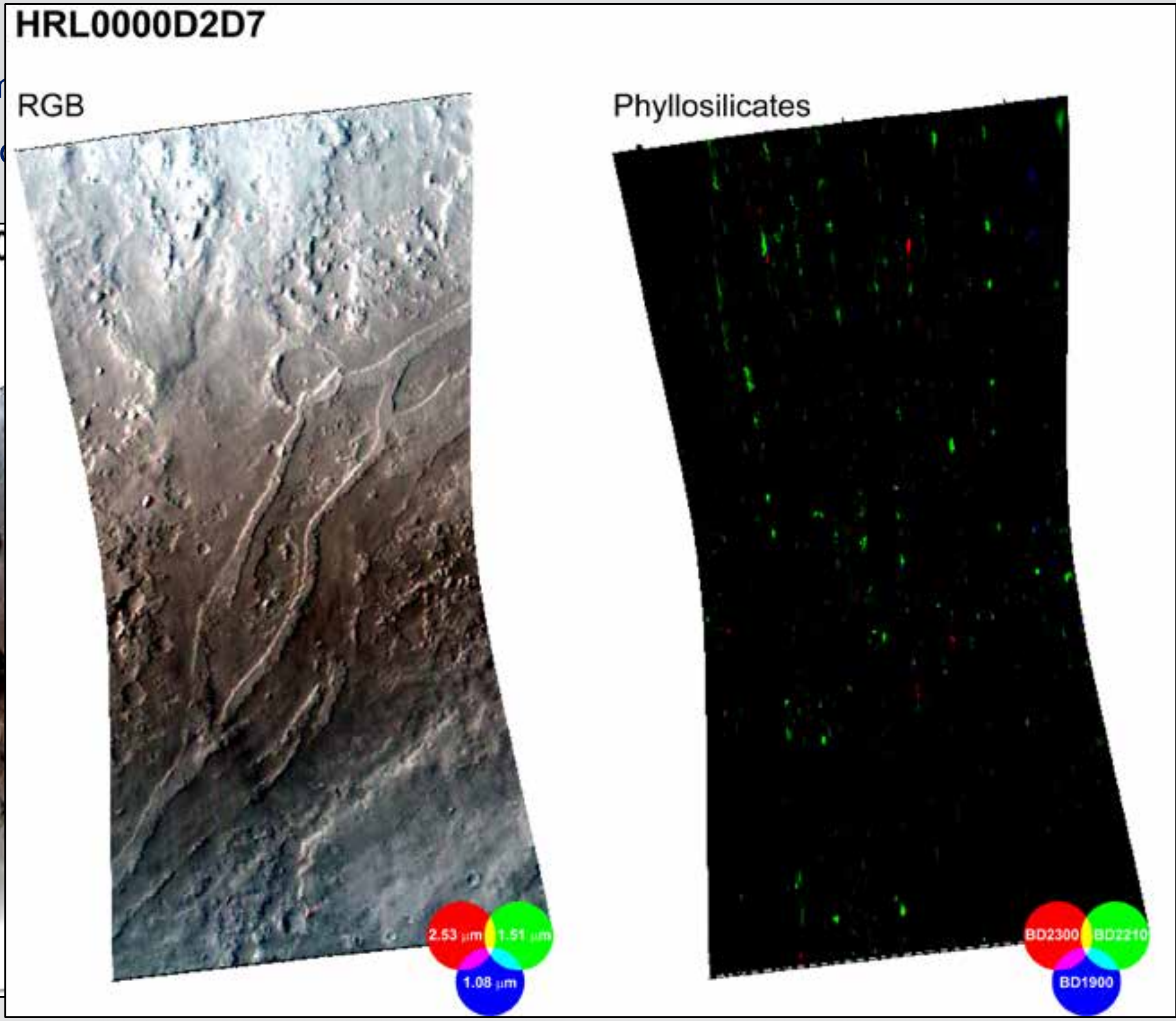
Mineralogical Description



Mineralogical Description

CRISM

- Extrem
- Limite … tes.

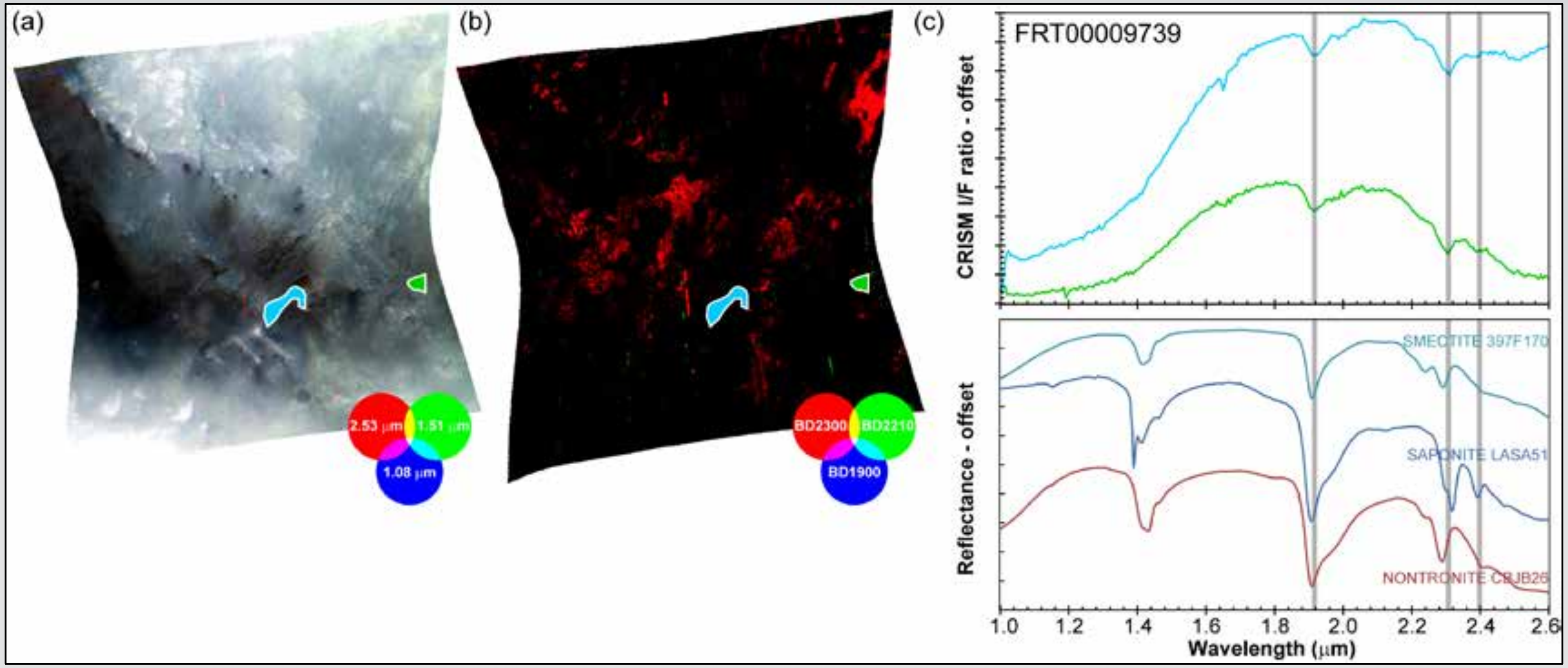


Mineralogical Description

E X O M A R S

CRISM Mineralogy – outside ellipse(s)

- More CRISM data available outside ellipse.
- Most images & best exposure in large impact crater 100 km SW of ellipse(s).
- Strong Fe/Mg phyllosilicate signatures (nontronite?) in central peak.
- Ejecta from this (and other) impacts have been emplaced and eroded within ellipse(s).



Mineralogical Description

EXOMARS

- More CRISM images have been requested, covering ellipse region.

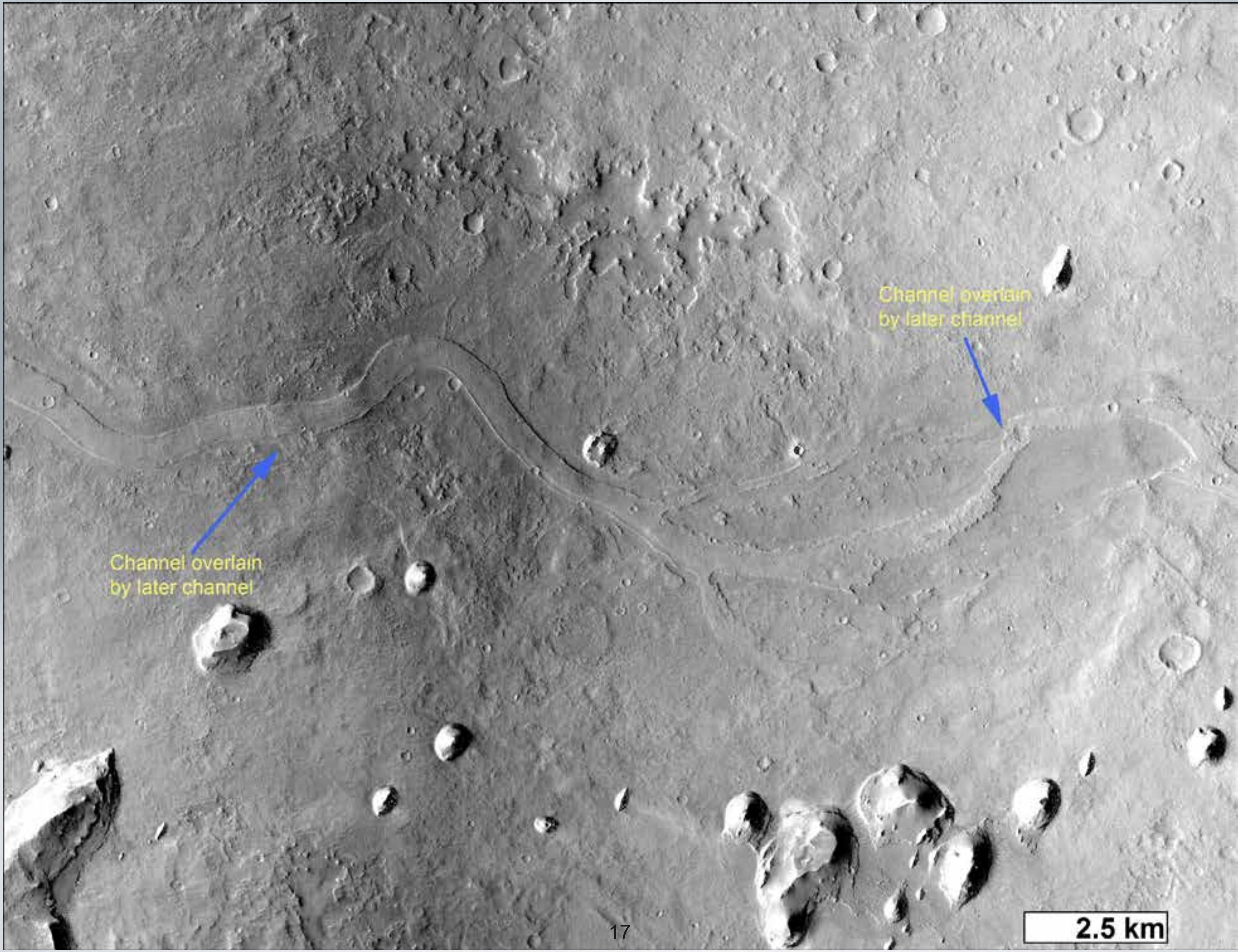
- New CRISM data could show evidence of aqueous alteration, as:
    1. Allochthonous deposits – channel eroding and depositing Noachian material.
    2. Autochthonous deposits – in situ alteration possible in low-energy environment.
    3. Deep alteration products – brought up and distributed by impacts.
    4. Hydrothermal alteration products – result of impact process.

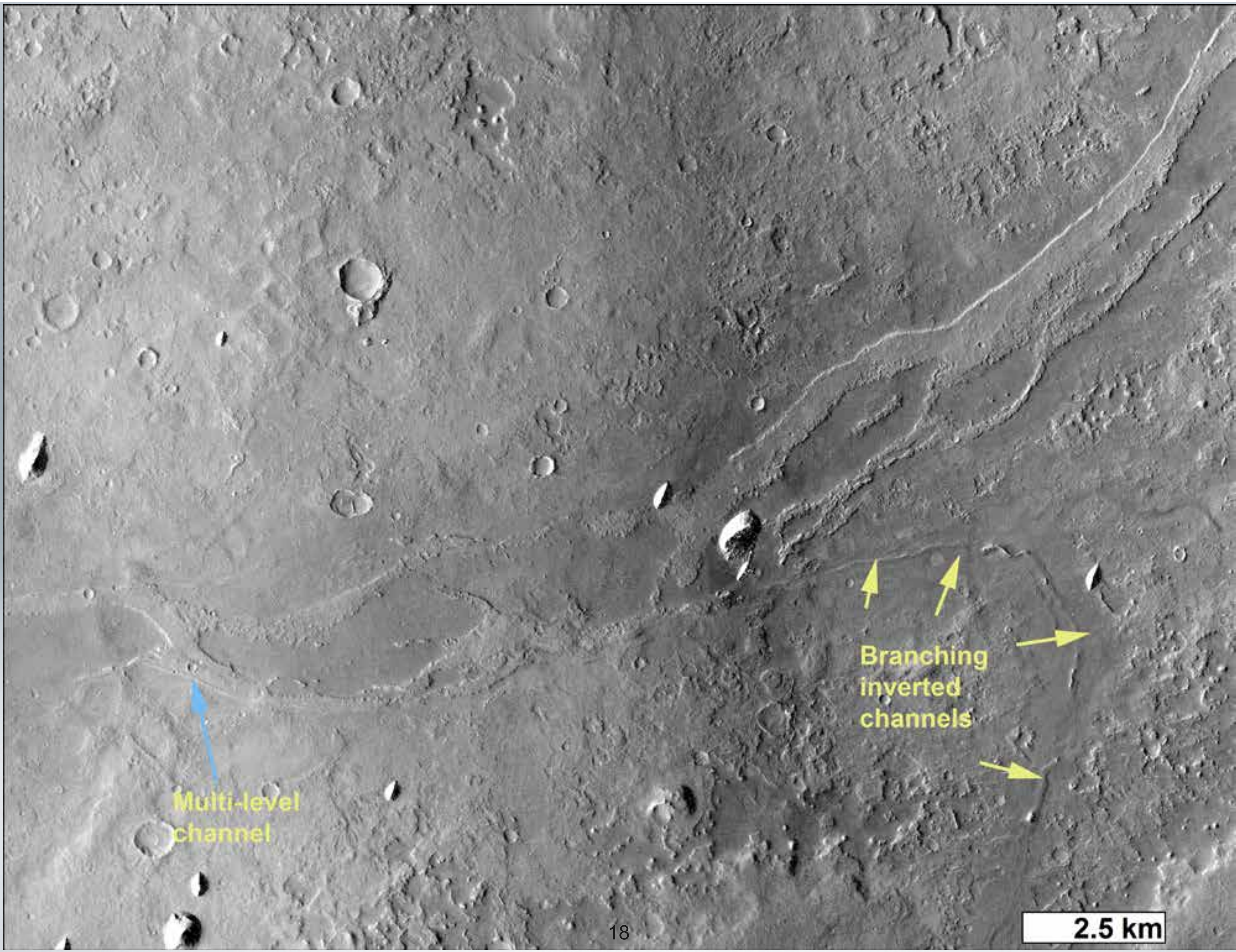
- Although would be able to determine depositional setting for any aqueous alteration mineralogy, is impact-delivered ejecta a good preservation medium?
- Possible Fe/Mg phyllosilicates in association with impact craters indicative of closed system & low-water-to-rock ratio?
- Al phyllosilicates in association with channel more indicative of open-system & increased exchange with atmosphere? [e.g. *Ehlmann et al., 2011*]
- Phyllosilicates in fluvial depositional setting good candidates for concentration and preservation of organic material [e.g. *Ehlmann et al., 2008*]

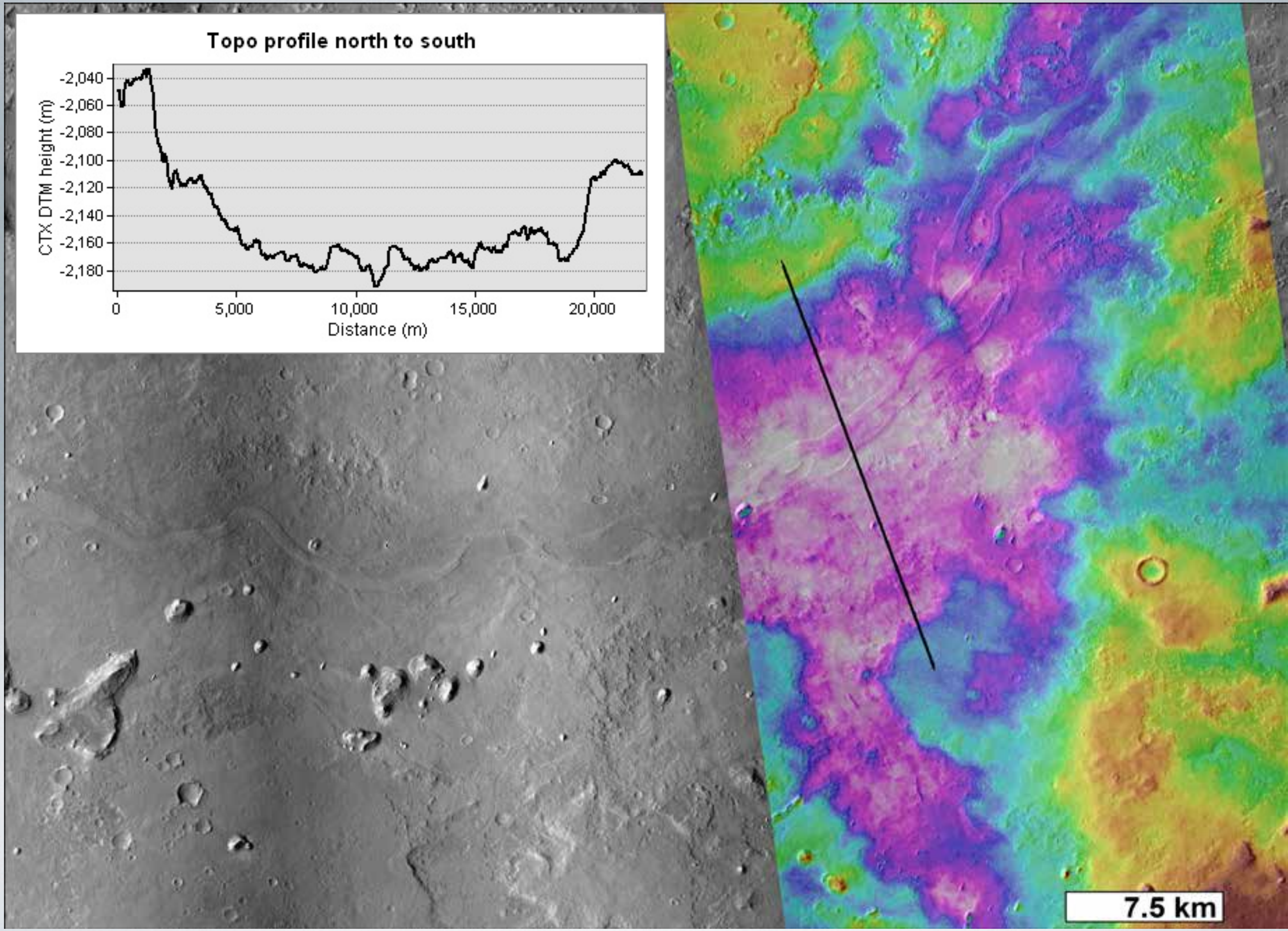
GIS "Fieldtrip" - (Questions welcome!)

Four key questions to answer during this field trip:

1) ***Did this site have long-lived/frequent aqueous activity and therefore habitable environments?***
2) ***Does the site include fine-grained water-lain sediments to allow biomarker preservation?***
3) ***Are the sediments ancient, and has there been recent exhumation?***
4) ***How are 'prime targets' distributed within the ellipse?***


Channel overlain
by later channel
Channel overlain
by later channel
2.5 km


Branching inverted channels
Multi-level channel
2.5 km


Topo profile north to south
CTX DTM height (m)
-2,040
-2,060
-2,080
-2,100
-2,120
-2,140
-2,160
-2,180
0
5,000
10,000
15,000
20,000
Distance (m)
7.5 km

Key points:

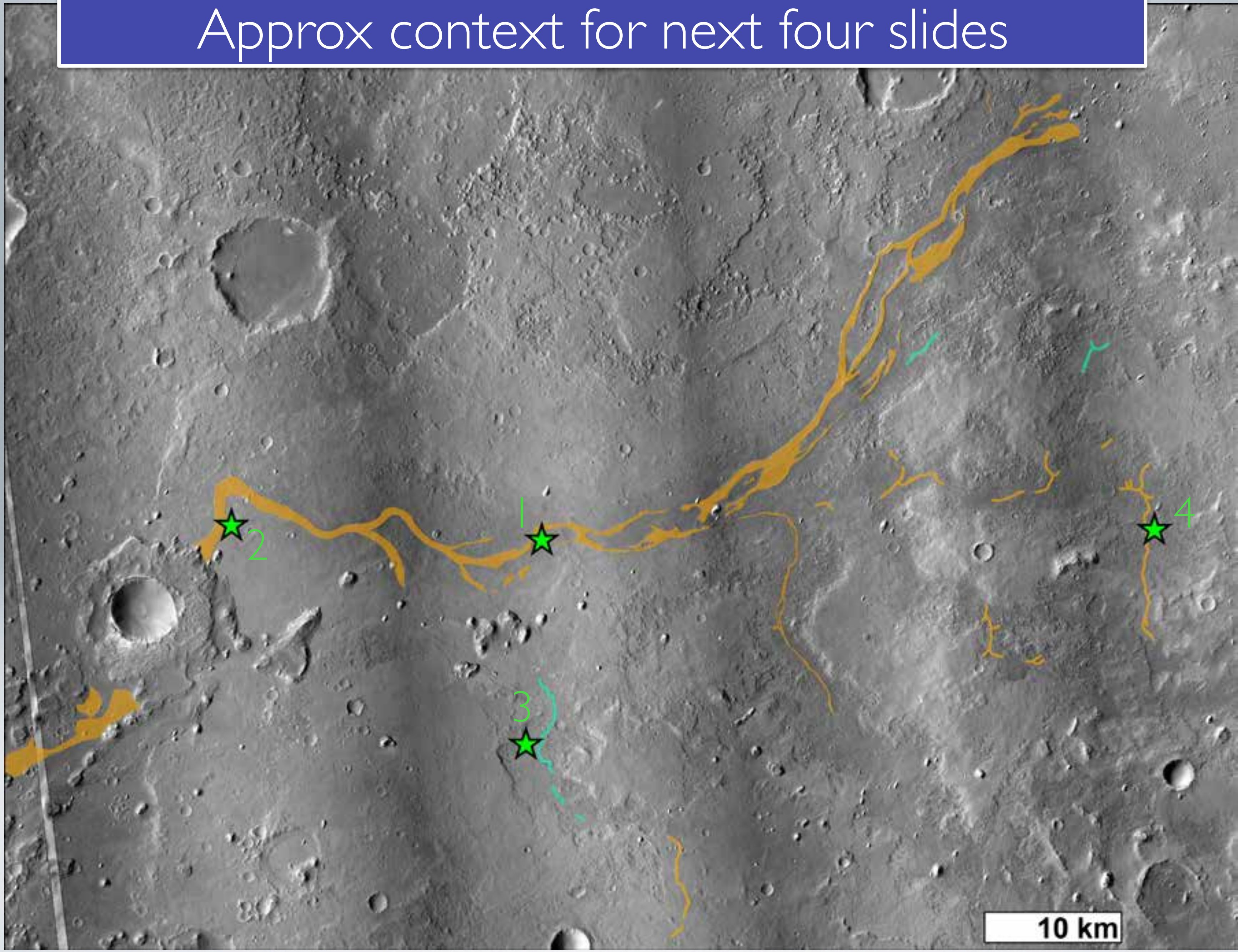
- Channel system long (~100km). No evidence for fluvial megafloods (no streamlined islands, no grooves, no catatracts). Suggest this is more like a quiescent river than a bedrock channel.

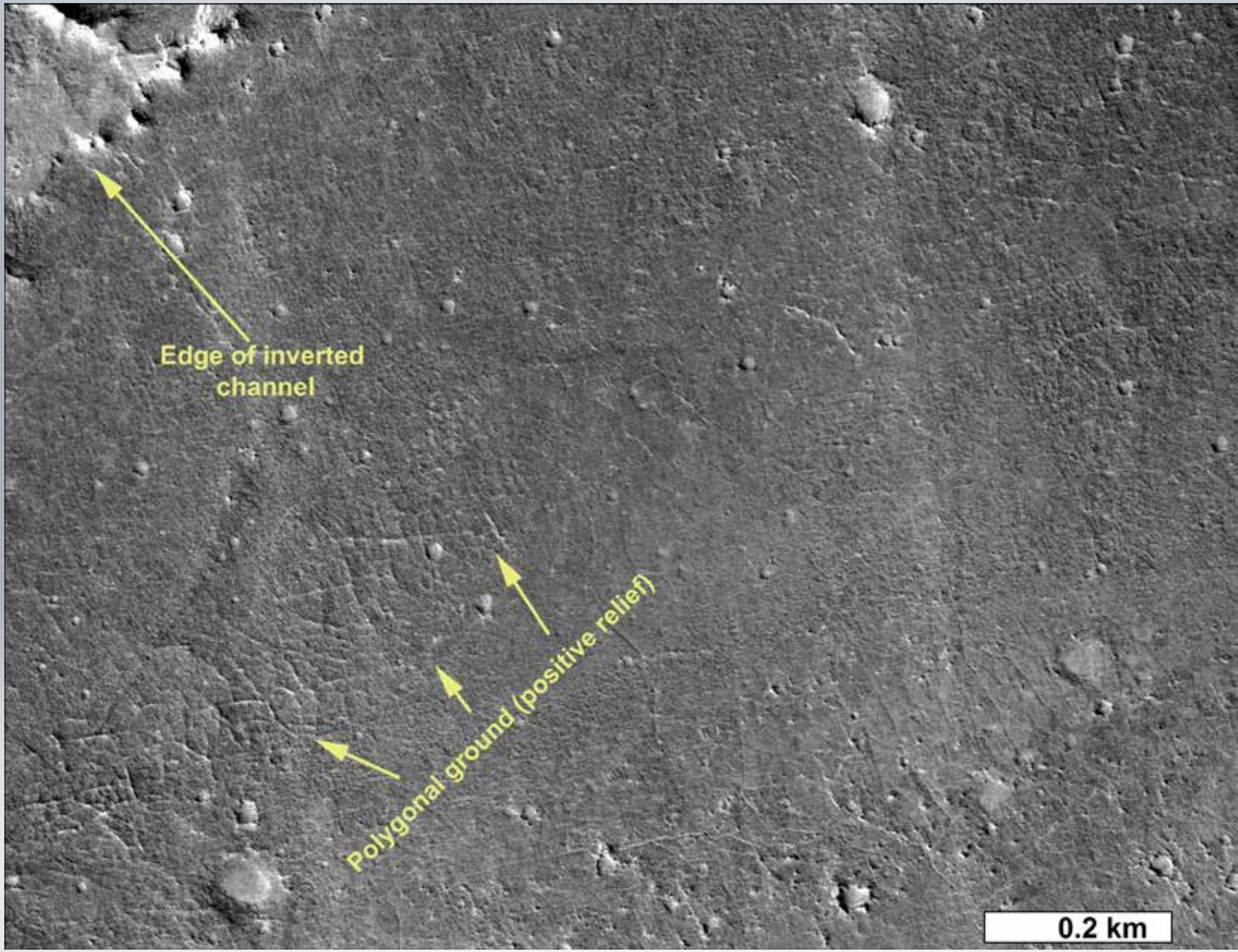
- Topo profile from CTX DTM supports this – infilling of topography with alluvial sediments to form an alluvial plain. Long profile is shallow too: < 0.05°.

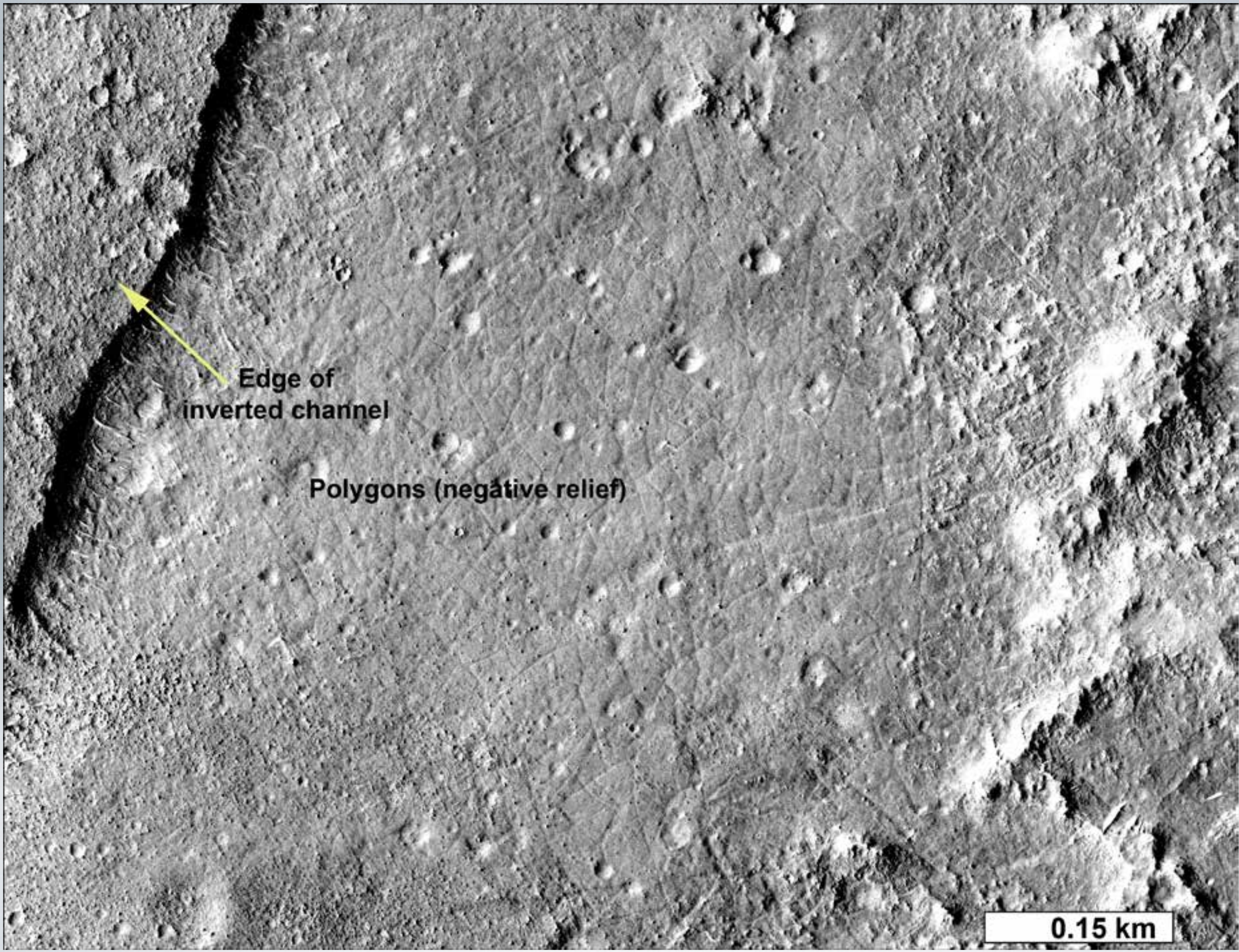
- Evidence for vertical and transverse motion of channels implies long-lived system, migrating channels, and multiple levels of channels forming in agrading/degrading flucial plains.

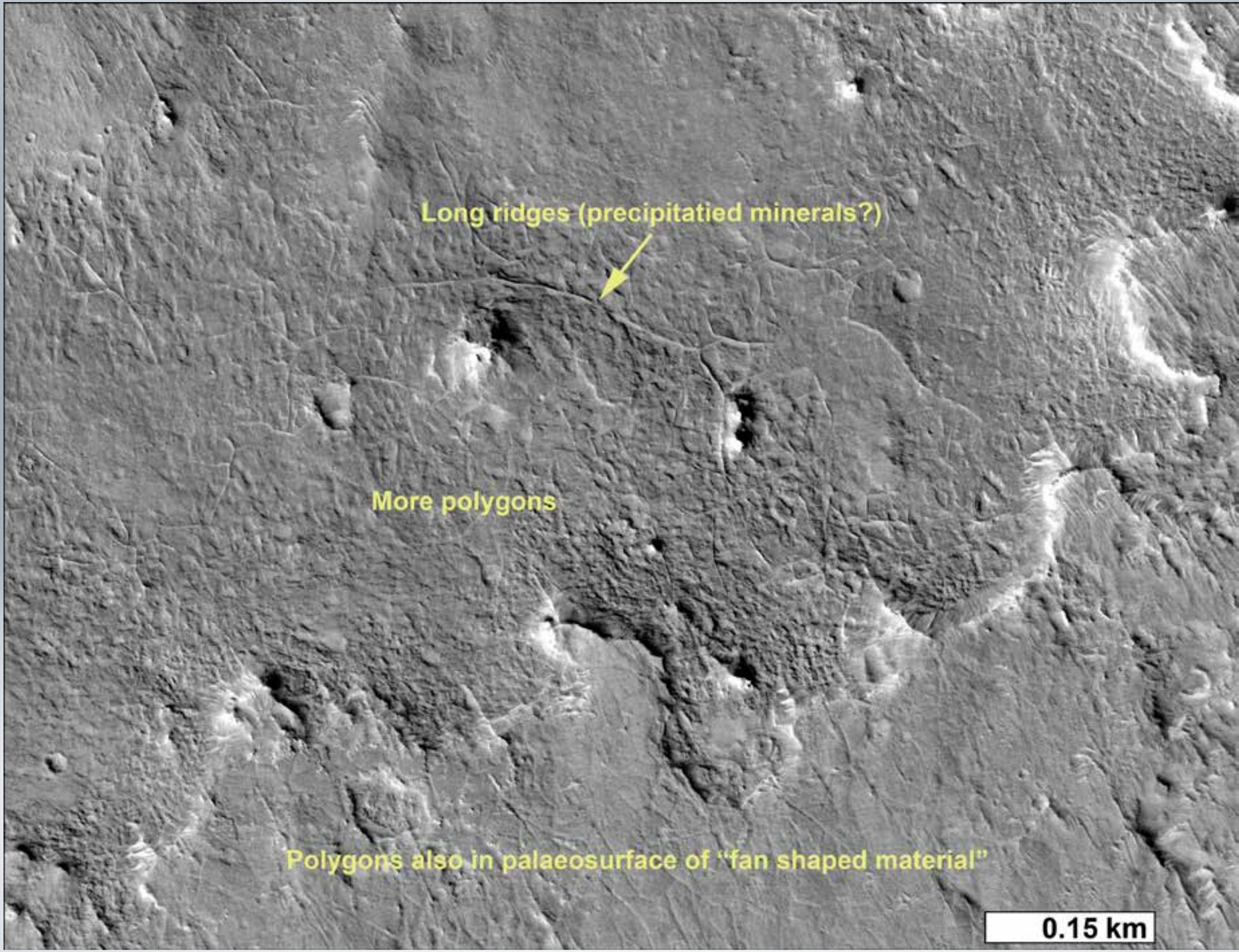
- Channel has meanders: Implies banks stability, and hence banks made up of ice-rich reglolith, cementation or simply fine-grained sediments.
- This is an alluvial systems with channel marginal unit composed of fine-grained material.

Approx context for next four slides

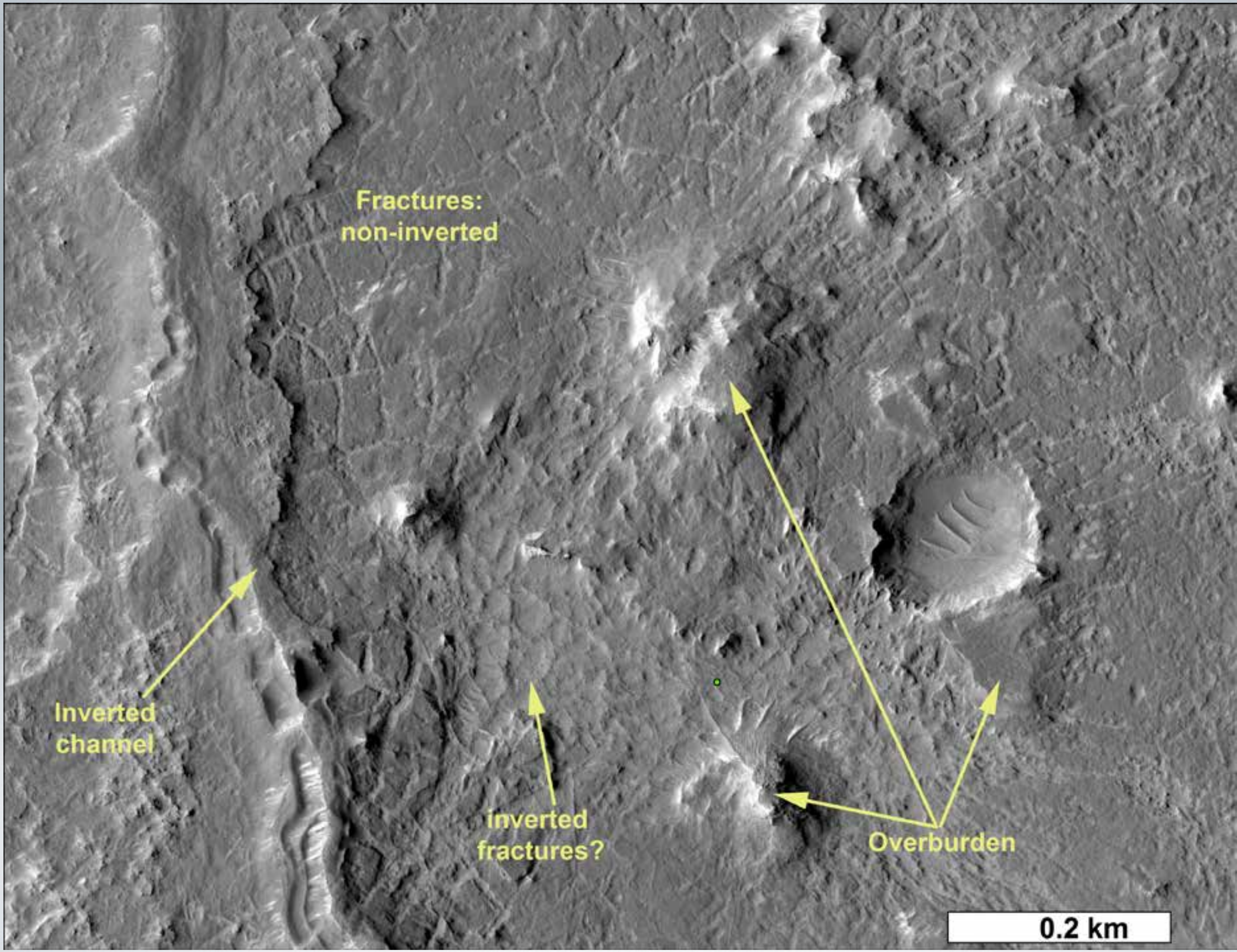



Edge of inverted channel
Polygonal ground (positive relief)
0.2 km

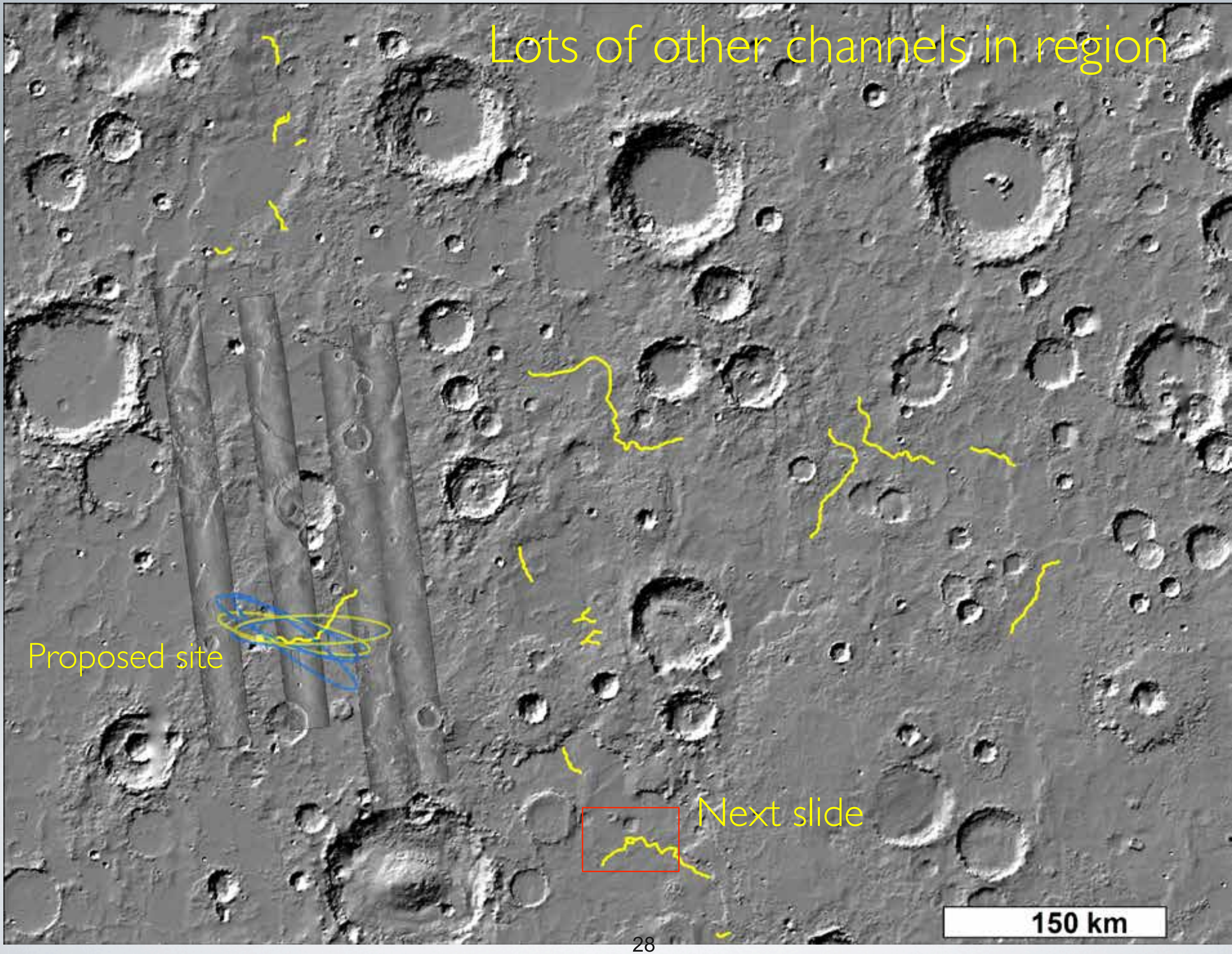

Edge of
inverted channel
Polygons (negative relief)
0.15 km

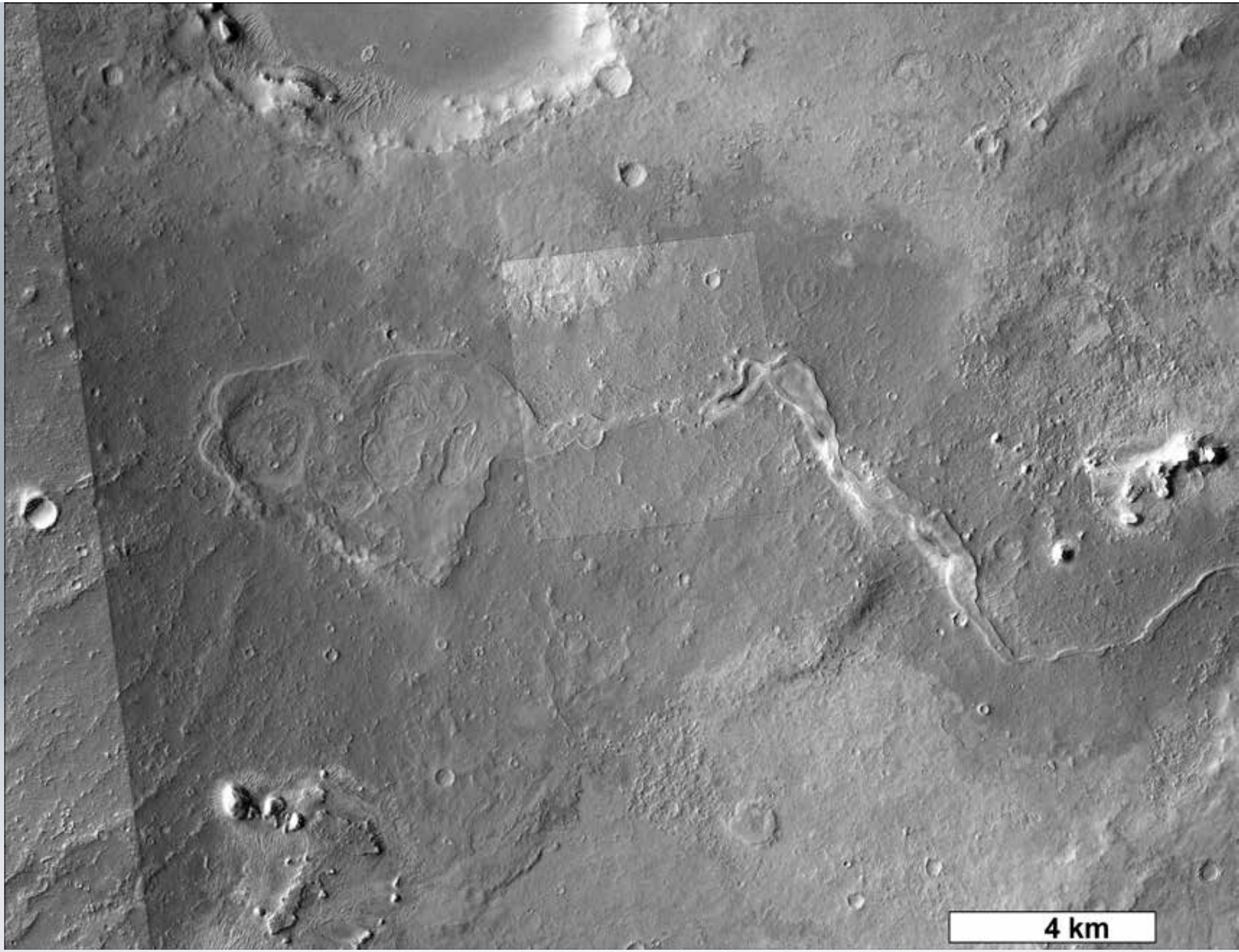


Long ridges (precipitatied minerals?)
More polygons
Polygons also in palaeosurface of "fan shaped material"
0.15 km

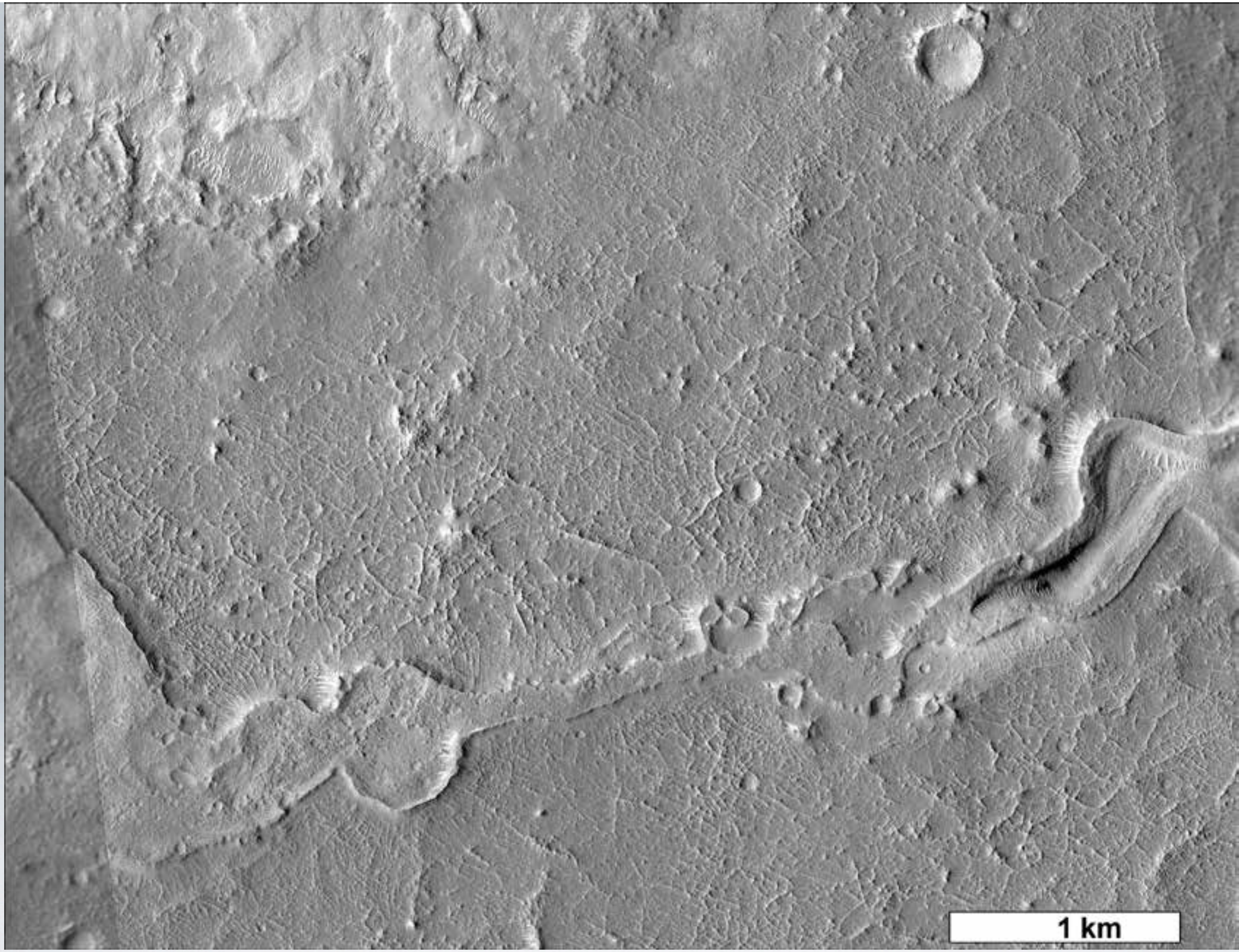

Fractures:
non-inverted
Inverted
channel
inverted
fractures?
Overburden
0.2 km

- The polygonal fractured, darker regions are diagnostic of the channel marginal material
- Occur by the channel, and in erosional windows throughout the ellipse
- Next slide shows other channels across the region

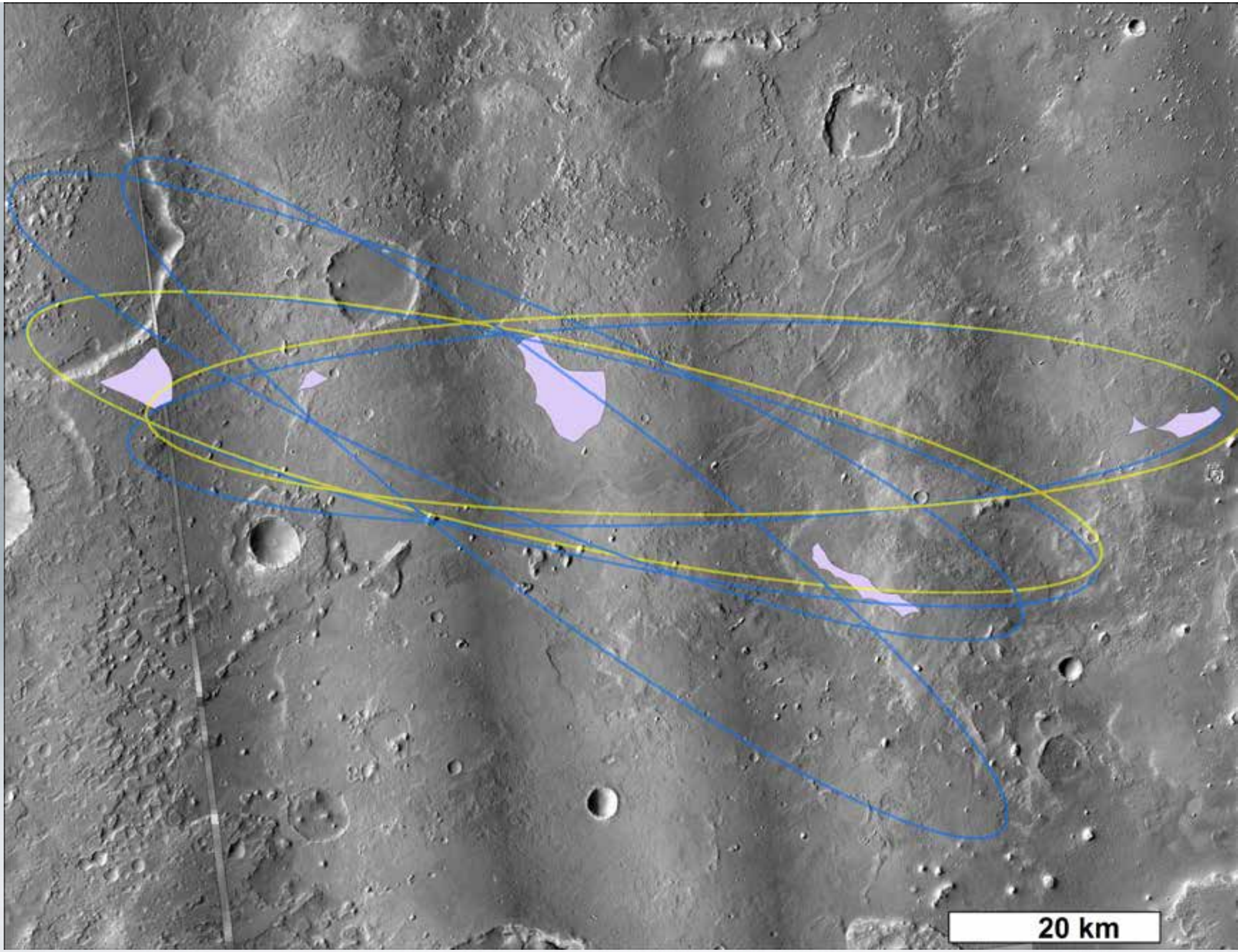

Lots of other channels in region
Proposed site
Next slide
150 km



Inverted channel and lake with dark surrounds
Overlain by lighter material

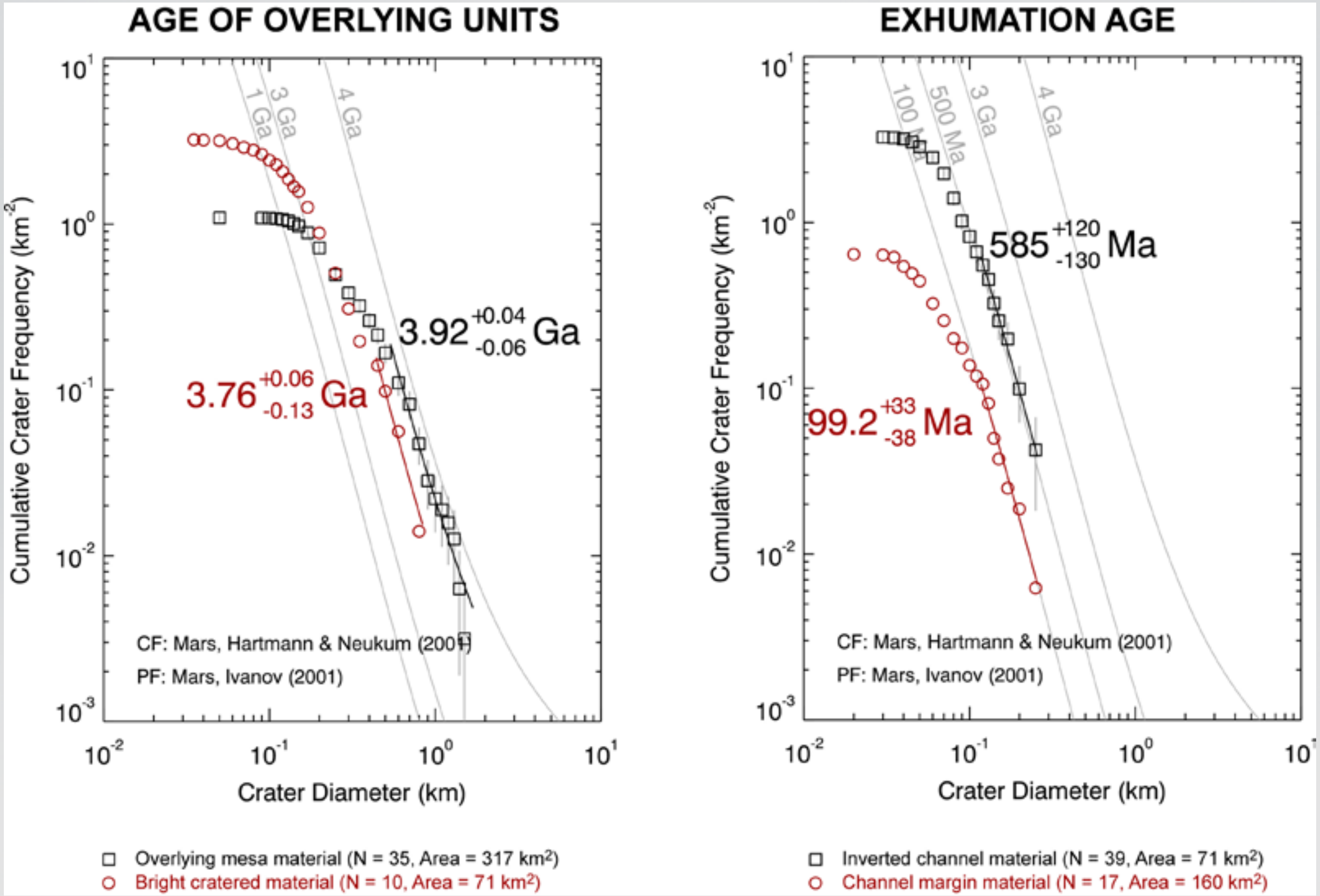


HiRISE shows amazing polygonisation



Large areas are direct prime targets: areas > 2km from 'interesting areas' are very small (above)

Formation and exhumation ages



Target Accessibility and Dust

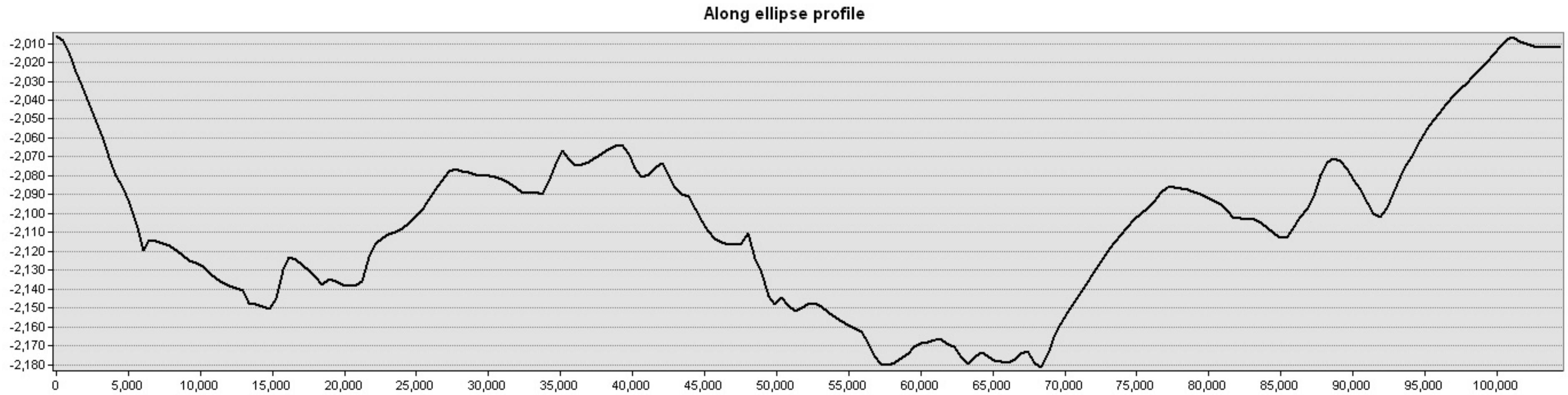
E X O M A R S

Please provide an estimate of the accessibility—distance (in km) to primary target outcrops:

- **Preliminary mapping shows (i) prime targets throughout the central parts of the ellipse (ii) erosional windows revealing interesting targets throughout the ellipses**

Please describe the type and distribution of dust-and sand-related features from TI data and imagery :

- **Very few dark (basaltic) dunes are present.**
- **Ripple/TARs (Transverse Aeolian Ridge) coverage is also low, except in localised areas**
- **Dust cover index (Ruff & Christensen, JGR 2002) is moderate**


Along ellipse profile
-2,010
-2,020
-2,030
-2,040
-2,050
-2,060
-2,070
-2,080
-2,090
-2,100
-2,110
-2,120
-2,130
-2,140
-2,150
-2,160
-2,170
-2,180
0
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000
50,000
55,000
60,000
65,000
70,000
75,000
80,000
85,000
90,000
95,000
100,000

General Site Presentation - summary

What are the attractive points of this location?

- **Noachian aged, sedimentary rocks throughout the ellipse**
  - ➢ **Therefore, lots of science targets**
- **Clear fluvial and associated alluvial context**
- **Possible associated sedimentary environments such as lacustrine and ancient groundwater systems.**
  - ➢ **Good biomarker preservation potential**
- **Few topographic obstacles or steep slopes**

General Site Presentation - summary

EXOMARS

Are there any unique advantages to this site?

- Clear exhumation history; much of the site has been buried (protected) for most of Mars' geological history
- Clear alluvial geomorphic context
- One of several such systems in the region – this could be a representative example of a widespread, ancient alluvial landscape that could be sampled at other locations in the future
- These outcrops sit near the bottom of a regional pile of sediments, the top of which has been explored by MER Opportunity in Meridiani

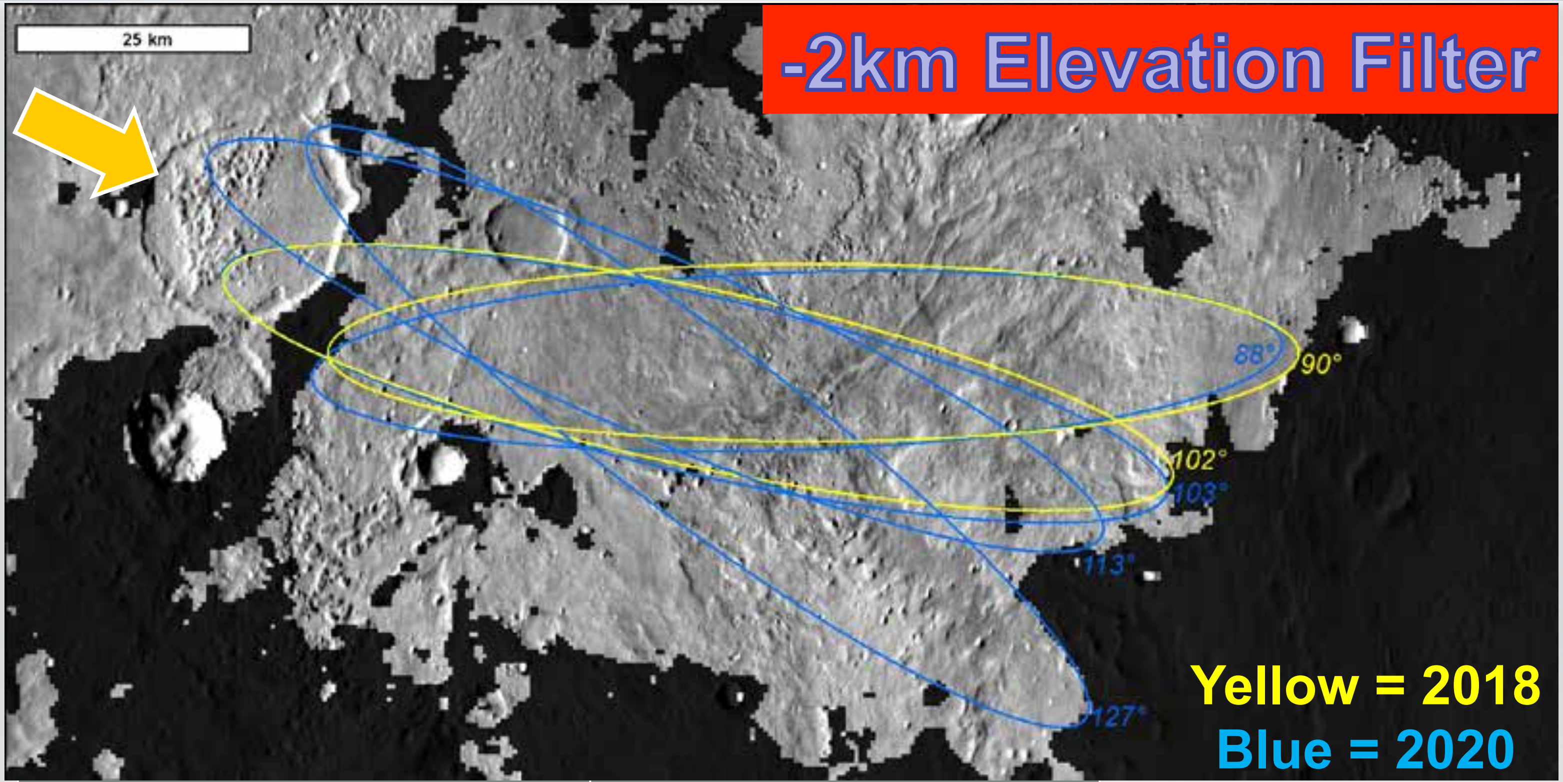
Planetary Protection

EXOMARS

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**
- **<u>No new slope streaks found</u>**
- **Also, <u>no landforms that could be reliably identified as slope streaks or RSLs</u> 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*]**

Landing Ellipse Properties - ELEVATION



Ellipse Year/Azim.)	% above -2000m
2018 - 90°	0.4
2018 - 102°	3.4
2020 – 88°	0.4
2020 – 103°	3.5
2020 – 113°	4.7
2020 – 127°	4.7

Almost all 'bad' areas are up-range

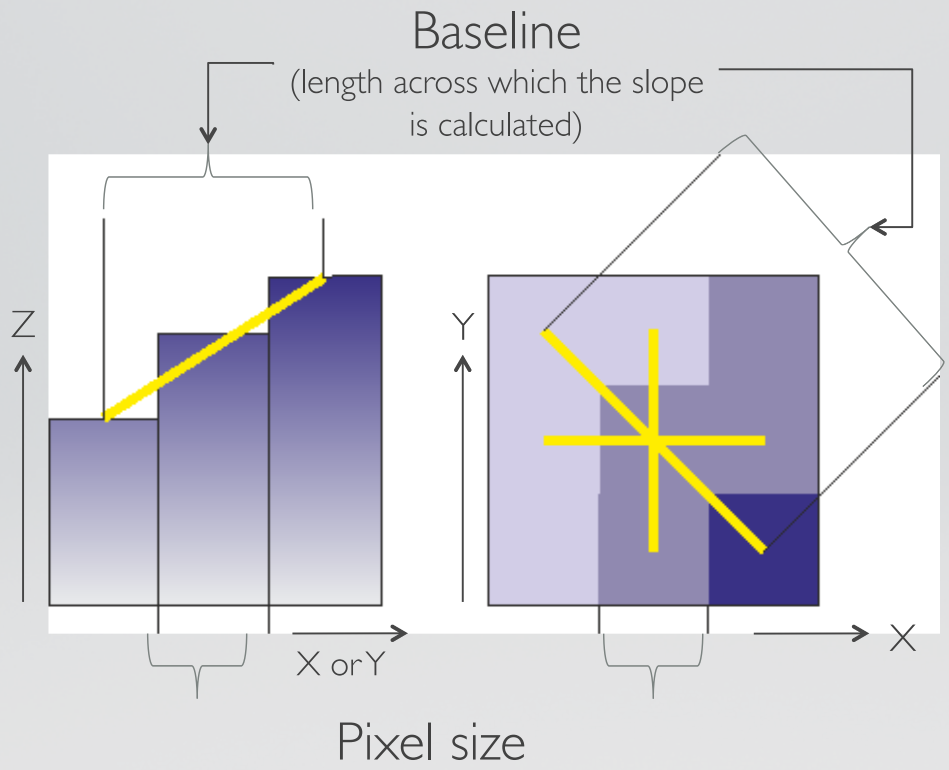
Landing Ellipse Properties - SLOPE

EXOMARS

Slope map creation method

- Raw data: MOLA point data, or CTX/HiRISE stereo DTMs 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 DTM
  - MOLA DTM interpolated from raw Global point data
  - CTX/HiRISE DTMs 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

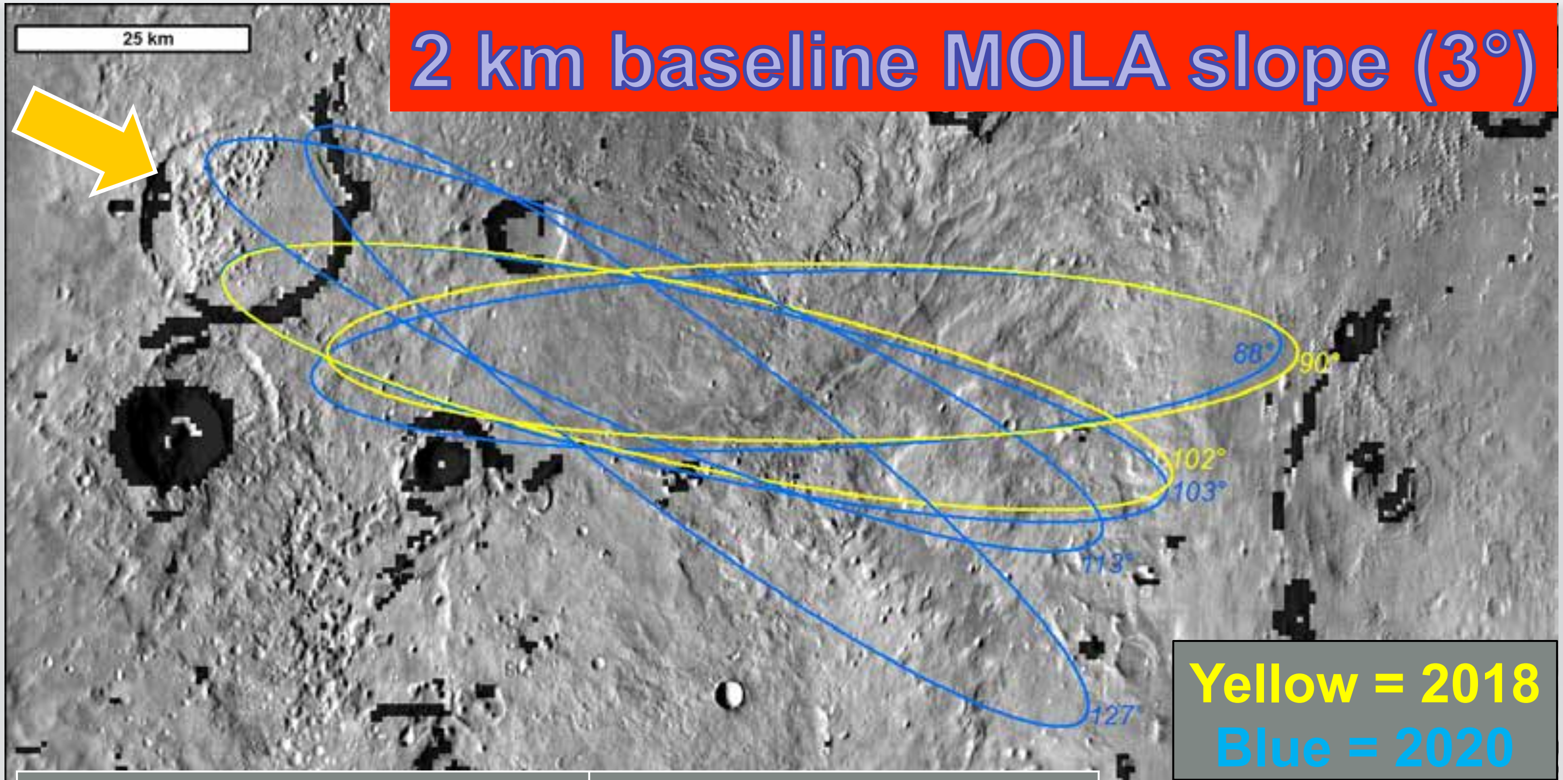


Maximum baseline ≈ 3 x pixel size

=> Pixel size ≈ 1/3 x baseline

Landing Ellipse Properties - SLOPE

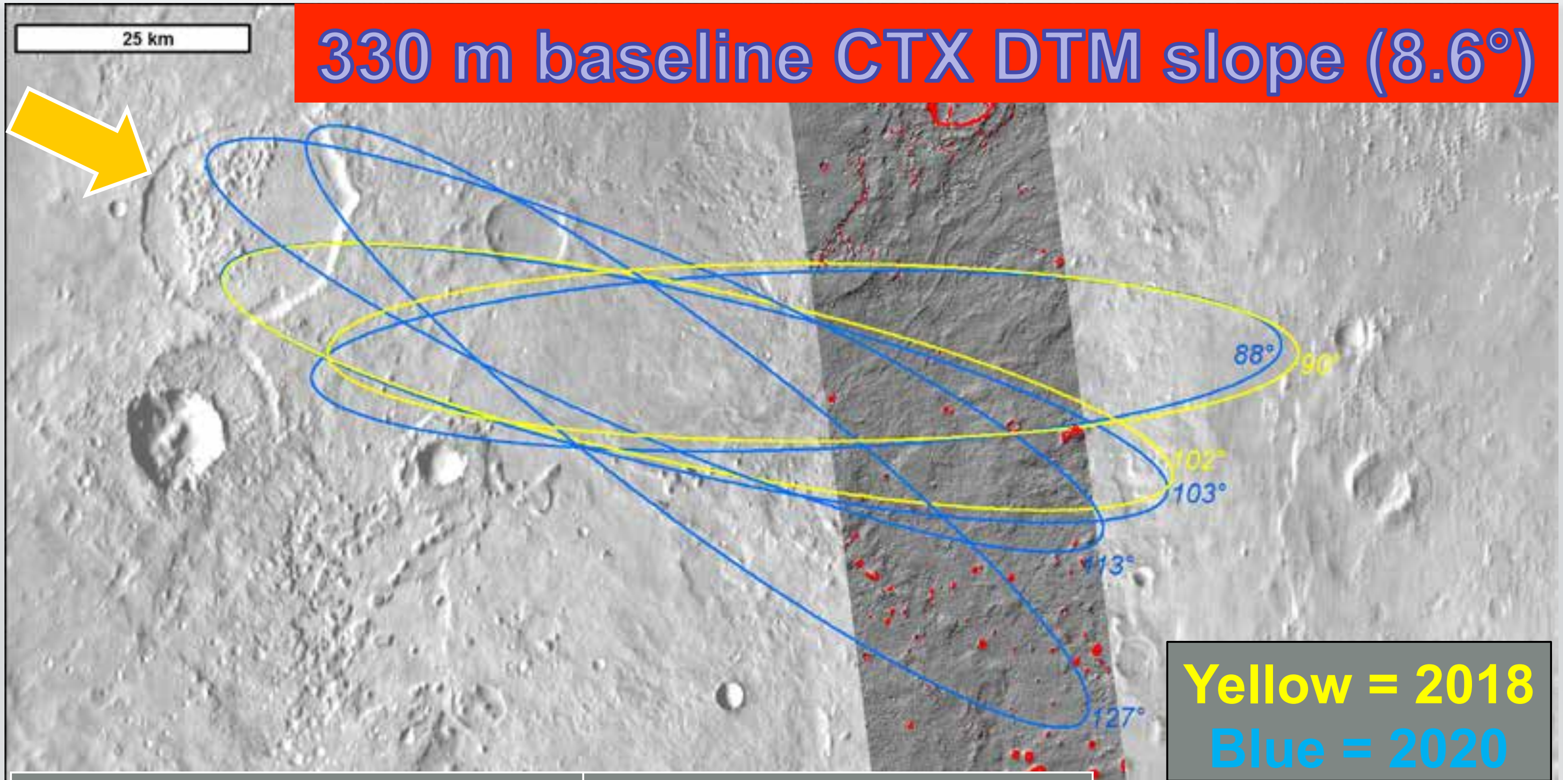
E X O M A R S



Ellipse (Year/Azim.)	% above 3°
2018 - 90°	0
2018 - 102°	2.4
2020 – 88°	0.9
2020 – 103°	2.3
2020 – 113°	3.9
2020 – 127°	3.6

Almost all 'bad' areas are up-range again

Landing Ellipse Properties - SLOPE

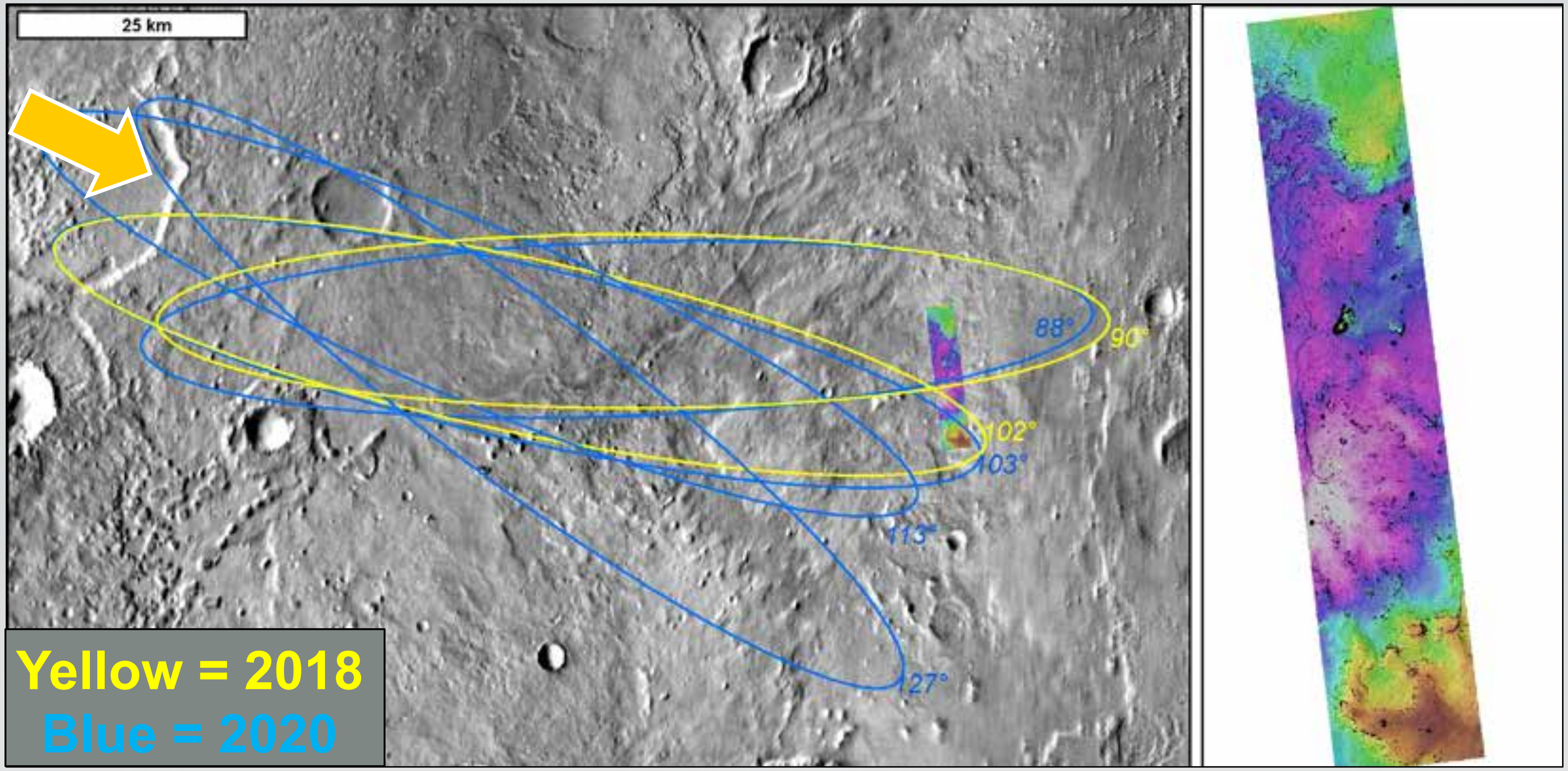


Ellipse (Year/Azim.)	% above 8.6°
2018 - 90°	0.5
2018 - 102°	0.8
2020 – 88°	0.5
2020 – 103°	0.8
2020 – 113°	0.5
2020 – 127°	1.4

Not continuous coverage!

Landing Ellipse Properties - SLOPE

7 m baseline HiRISE DTM slope (12.5°)

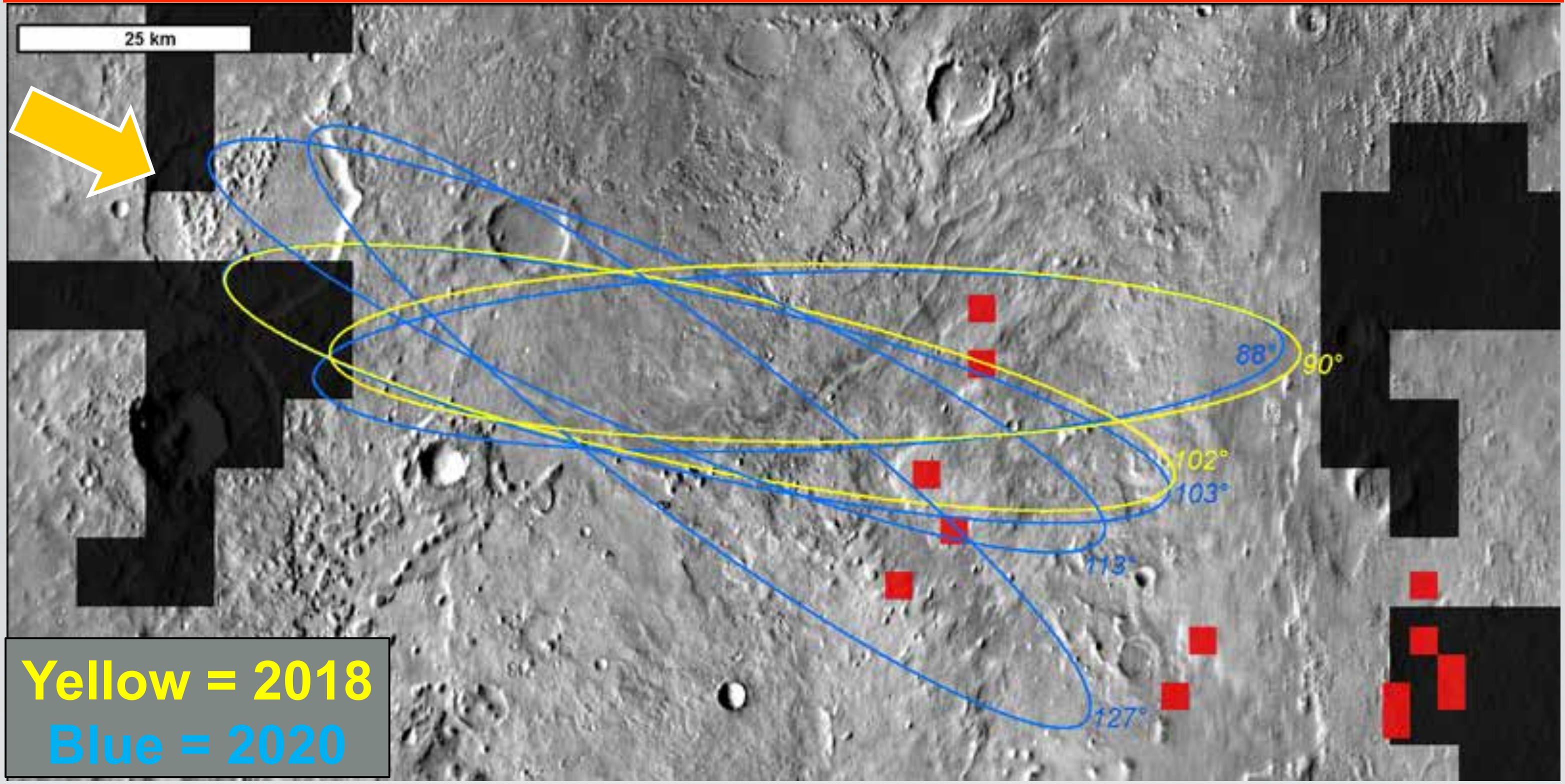


~ 4% of DTM > 12.5° slope. But… Far west of ellipse, so not really representative. Plus, quite a rough area compared to most. *NEED MORE HIRISE DTMs.*

Landing Ellipse Properties - OTHER

E X O M A R S

TES Rock abundance, thermal inertia, albedo



Black = TES rock abundance > 7% (Nowicki et al. JGR 2007)
Red = TES Thermal inertia ≥ 150 J m^{-2} $s^{-0.5}$ K^{-1} (Putzig & Mellon, Icarus, 2007)
Whole region meets the albedo criterion: 0.1 ≤ albedo ≤ 0.26

Rocks, TI, Albedo, Radar, Winds

E X O M A R S

Please present compliance rock abundance, thermal inertia, albedo, and radar reflectivity:

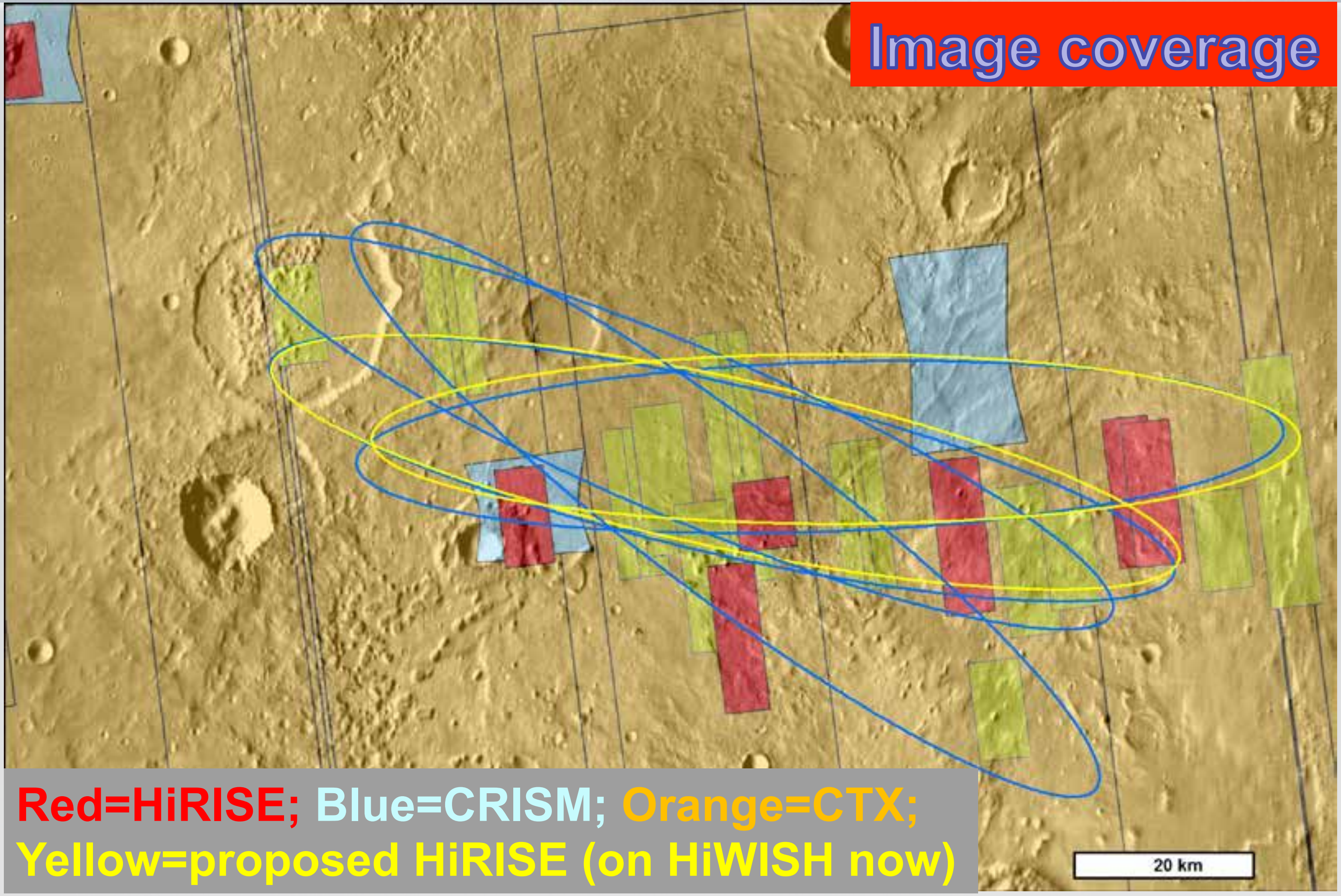
- **We have used published, peer-reviewed global data products from the TES instrument (Mars Global Surveyor) for Rock Abundance, Thermal Inertia and Albedo**
- **No RADAR reflectivity data have been analysed yet**

Comment on ellipse size increase:

- **This site can probably cope with ~20% increase in ellipse size without changing the elevation percentage numbers too much (at least for the ellipses that are already at around 3-4% above ceiling). The better ellipses will suffer most from an increase in ellipse size**

HiRISE, CTX, CRISM, OMEGA, HRSC

E X O M A R S



- Centre of ellipses and 'risky' areas targeted
- New CRISM in centre of ellipse would be good too.

Summary 1

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

- **Part of a regional alluvial system, all of which is being exhumed from beneath Noachian-aged material**
- **Young overall exhumation age and many erosional outliers: large areas will have been protected from the martian environment until recently**
- **Very likely to be large areas of fine-grained (so likely to preserve biomarkers) sedimentary rocks within the ellipse.**
- **Sediments of alluvial origin, including probable representatives of lacustrine, fluvial-channel and flood-plain environments**
- **Geomorphic context clear, but more detailed mapping is required because this is not a site that has an extensive background literature**

Summary 2 – ExoMars Science Goals

EXOMARS

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

1. *"Age (period in martian history) of the deposits)"*
   ☑ Noachian
2. *"Fine-grained sedimentary outcrops with a water-rich/hydrothermal history that we associate with life favourable conditions (e.g. evidence of ponded water)"*
   ☑ Low-energy deposition of fine-grained alluvial sediments
3. *"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)"*
   ☑ Recent exhumation – exhumation ongoing
4. *"Distribution of prime targets within the landing ellipse (will we land on top or be able to reach them?)"*
   ☑ Much of ellipse consists of prime targets

Summary 3

E X O M A R S

Summary of percentage compliance with engineering requirements. (Ranges given cover best to worst of specific landing ellipses from both 2018 and 2020)

Criterion	Specification	Data Used	This Landing Site
Latitude	5 S to 25 N	MOLA	7.85˚ N, 11.50˚ W (348.5E)
Elevation	Below –2 km	MOLA	**0.5 to 4.7% is** non-compliant
Slopes (2–10 km)	≤ 3.0˚	MOLA	N/A – indistinguishable from 2km baseline
Slopes (2–10 km)	≤ 3.0˚	MOLA	**0 to 3.9%** is non-compliant
Slopes (330 m)	≤ 8.6˚	HRSC	No HRSC DTM coverage
Slopes (330 m)	≤ 8.6˚	CTX	**0.5 to 1.4%** is non-compliant (for sampled regions – MORE CTX DTMs needed!)
Slopes (7 m)	≤ 12.5˚	HiRISE	**3.8%** is non-compliant (for sampled regions – MORE HiRISE DTMs needed!)
Slopes (3 m)	≤ 15.0˚	No Data	**2.8%** is non-compliant
Rock abundance	≤ 7%	IRTM	Nearly 100% compliant (but using low-resolution TES data)
Rock abundance	≤ 7%	HiRISE	Visual inspection shows few rocks
Thermal Inertia	≥ 150 J m^{-2} $s^{-0.5}$ K^{-1}	TES	Nearly 100% compliant (1 or two out of spec. pixels per ellipse)
Albedo	0.1 ≤ albedo ≤ 0.26	TES	100 % of each 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 (or no data in consistent format, at least)
Horizontal Wind (1 m above ground)	≤ 0.30 m/s	GCM	No Data

Backup - winds

EXOMARS

U_{max} - monthly