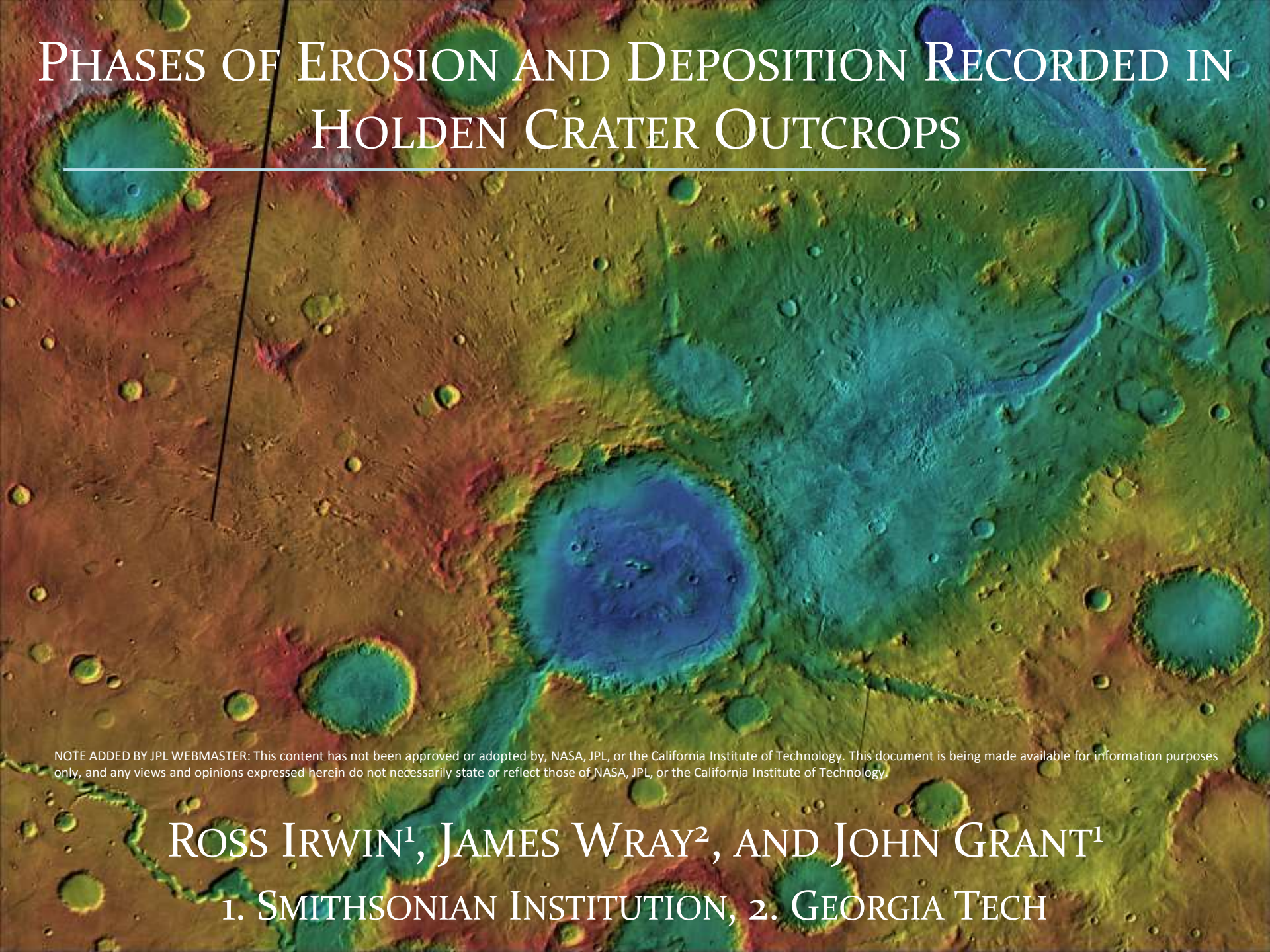
Phases of Erosion and Deposition Recorded in Holden Crater Outcrops



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Ross Irwin[1], James Wray[2], and John Grant[1]

1. Smithsonian Institution, 2. Georgia Tech

Mars Geologic Epochs

Early Amazonian:
3.00-3.46 Ga

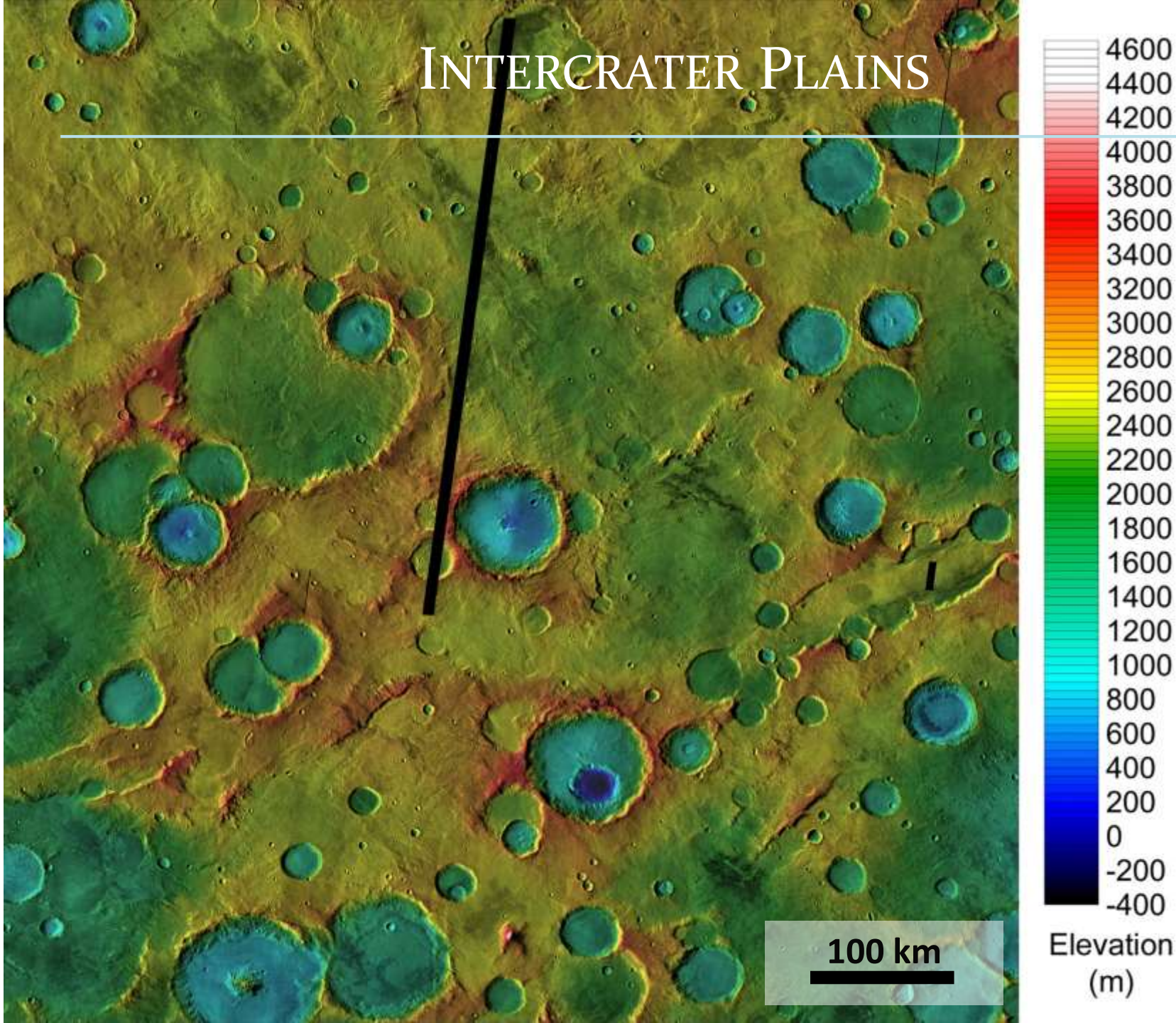
Late Hesperian: Some late fluvial activity
3.40-3.65 Ga
Early Hesperian: Valley networks, oldest 1-4 km craters
3.57-3.74 Ga

Late Noachian: Cratering declines, basin infilling, small landforms eradicated
3.85-3.86 Ga
Middle Noachian: Heavy bombardment, widespread highland resurfacing, Argyre
3.97-3.96 Ga: Isidis
Early Noachian: Heavy bombardment, Hellas
?

Pre-Noachian:

Ages from Werner and Tanaka (2011)

Intercrater Plains



Intercrater Plains

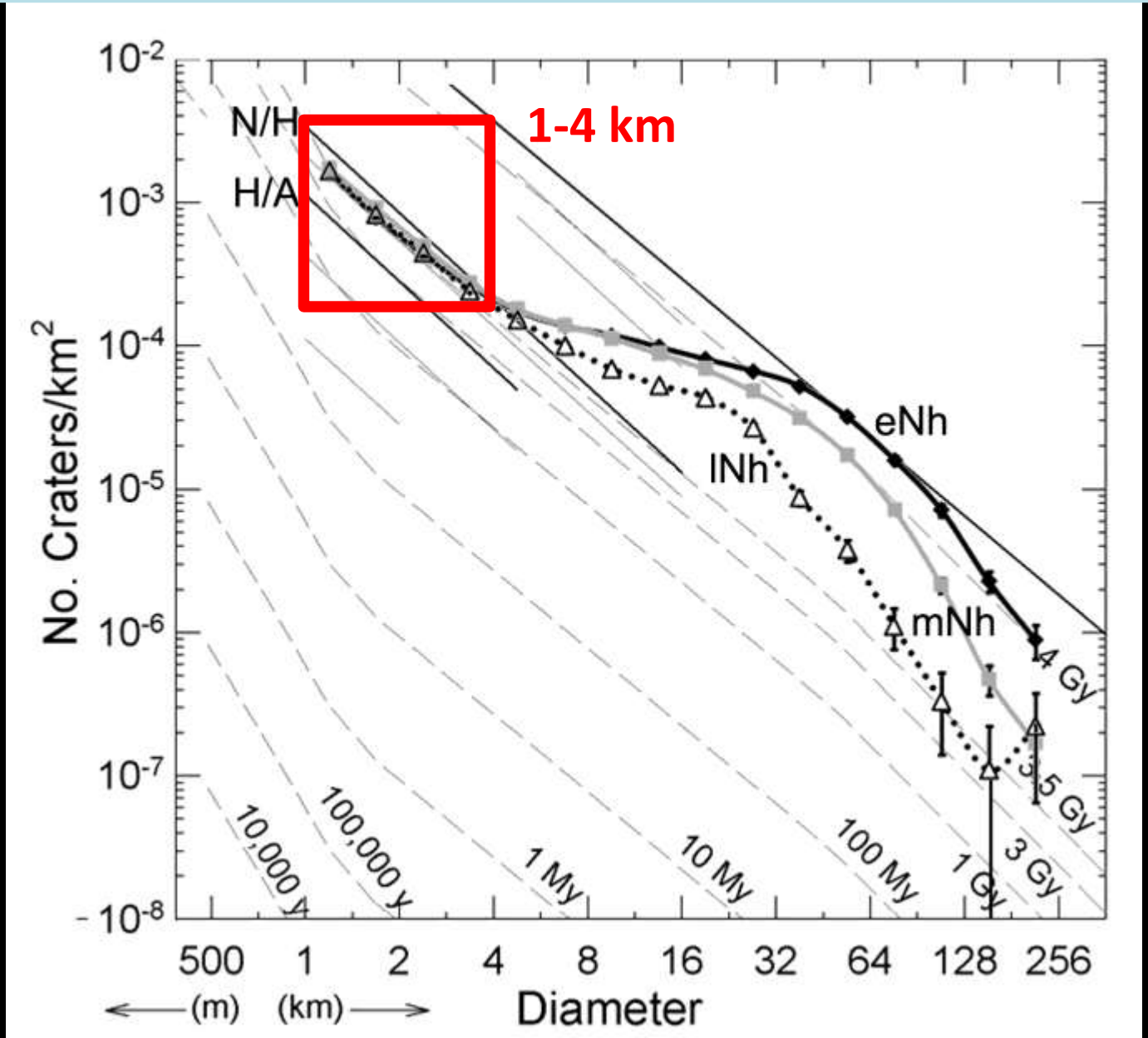
Legend

Unit

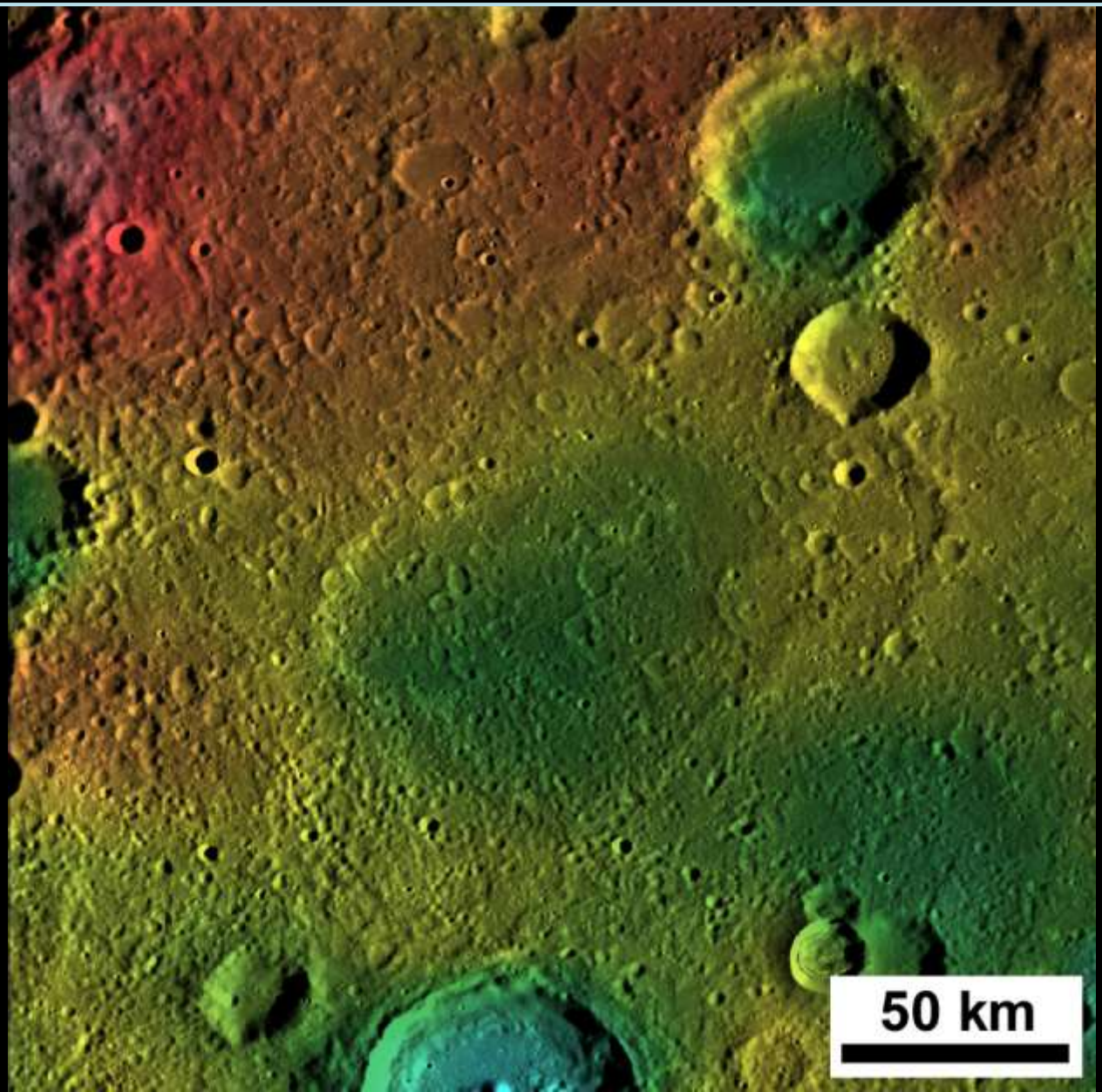
- Crater 1
- Crater 2
- Flow
- Mountain
- Intercrater 1
- Intercrater 2
- Intercrater 3

100 km

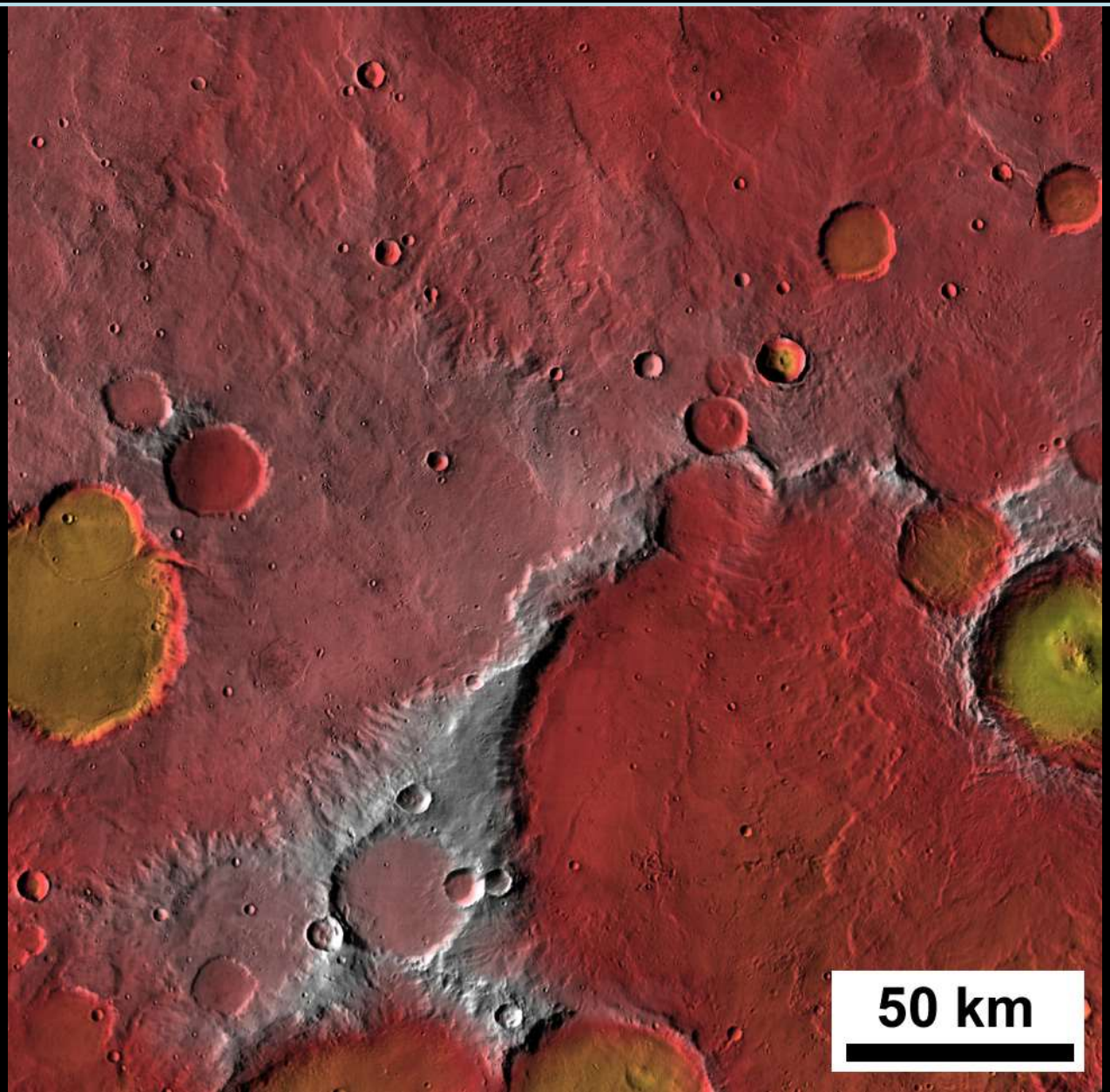
Global Highland Unit Crater Populations



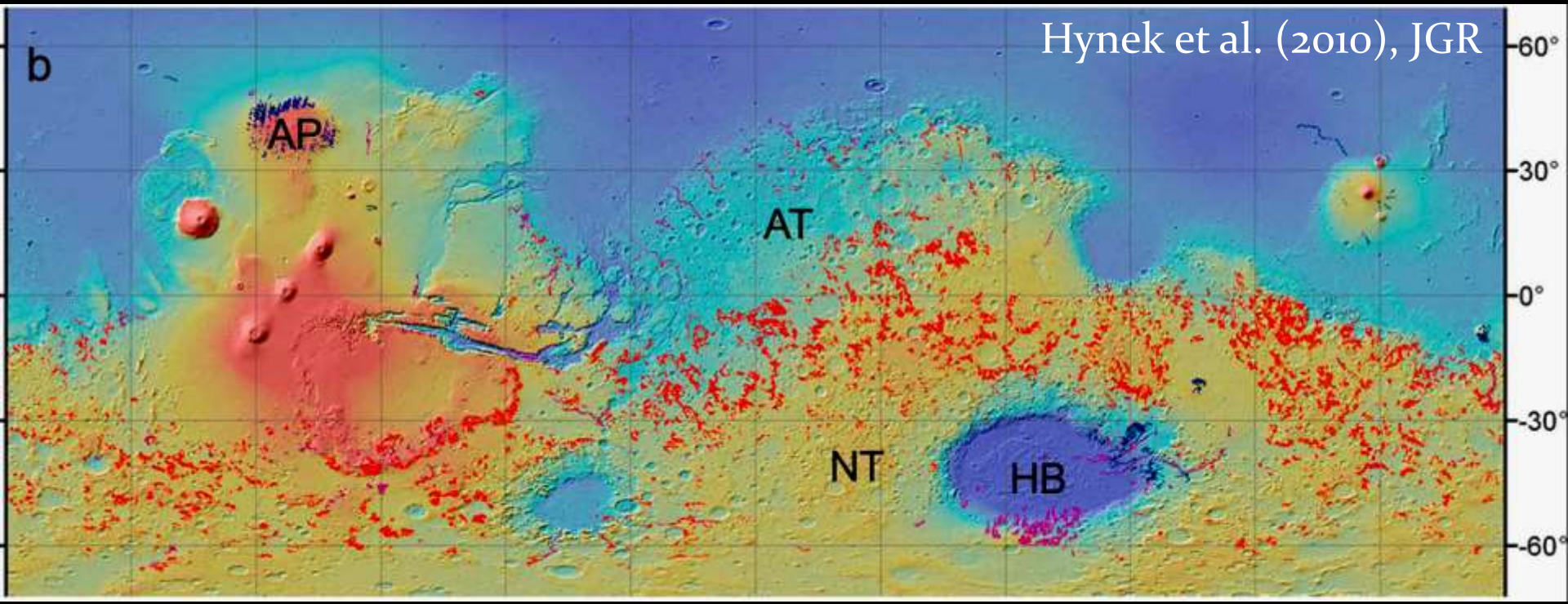
Intercrater Plains on Mercury



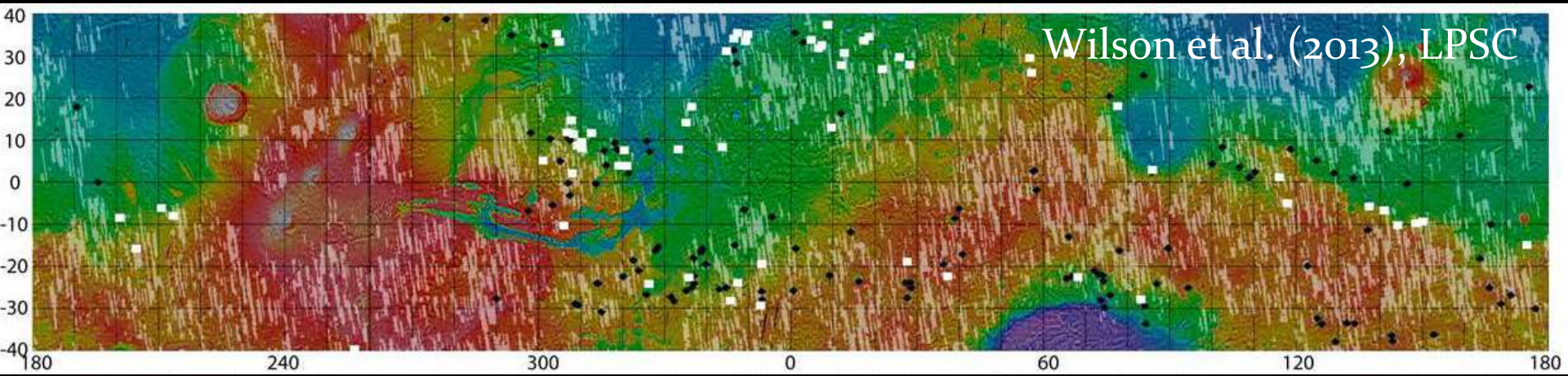
Intercrater Plains on Mars



Valley Networks and Prominent Deposits

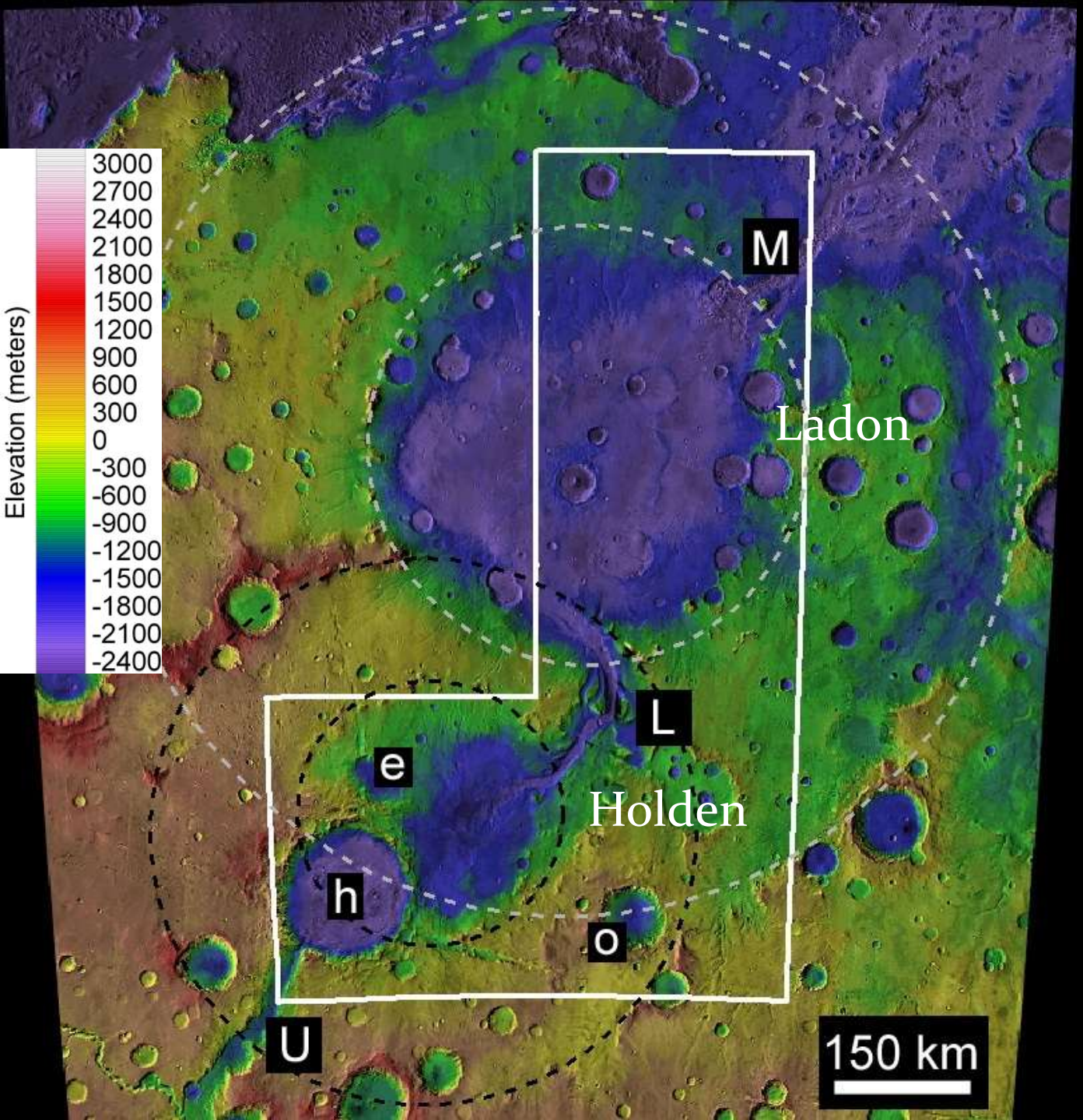


Hynek et al. (2010), JGR



Wilson et al. (2013), LPSC

Regional Context



U: Uzboi Vallis

L: Ladon Valles

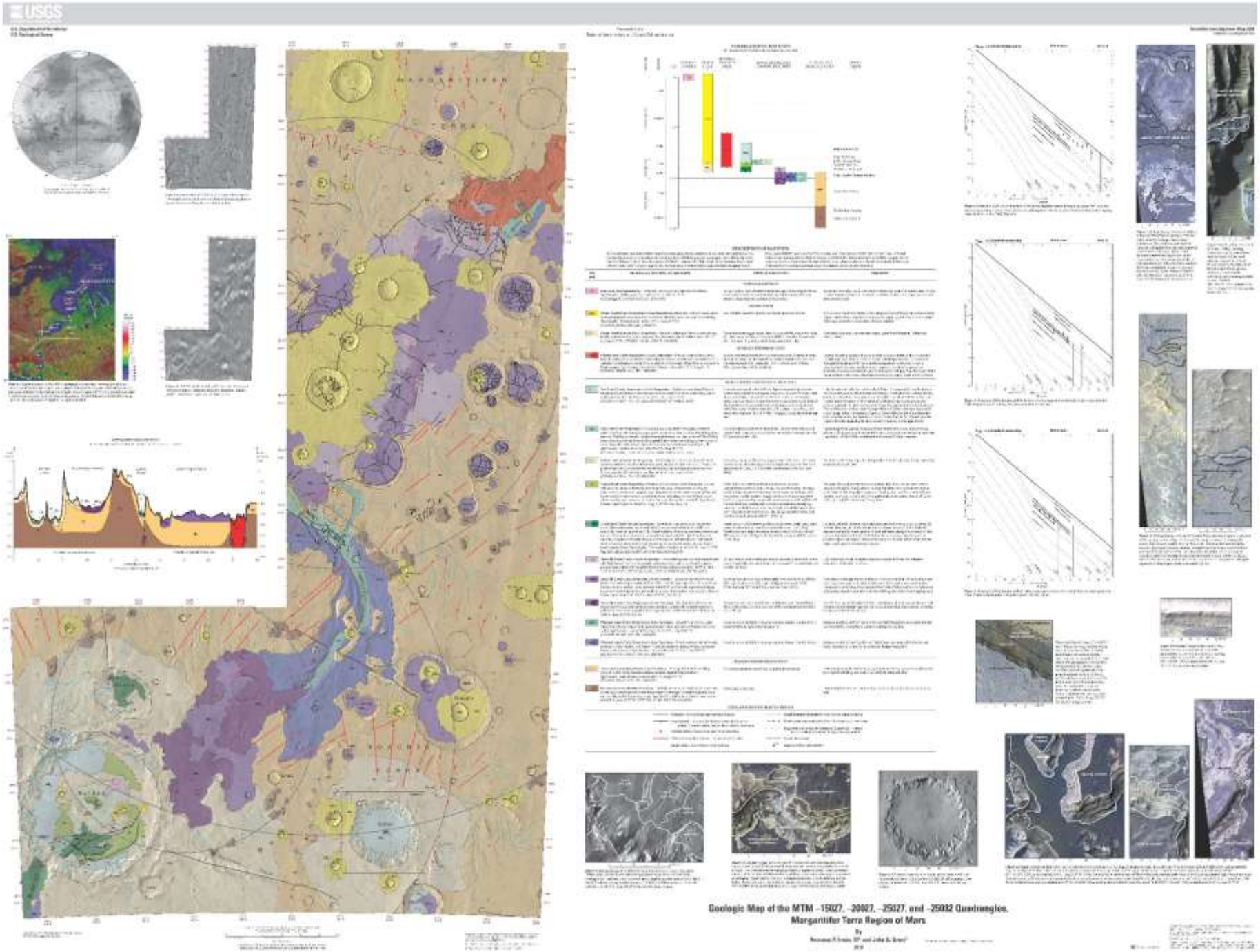
M: Morava Valles

h: Holden crater

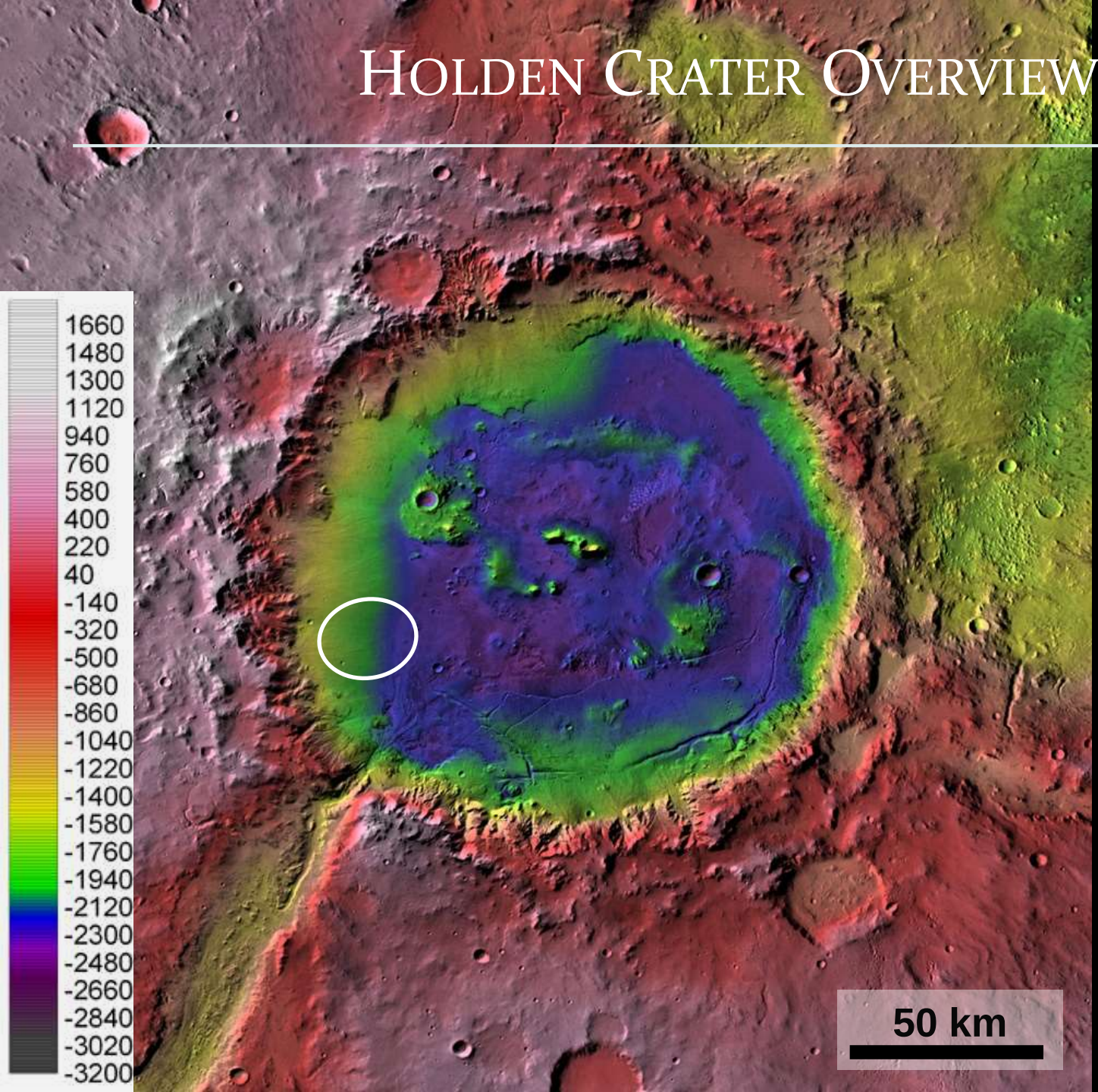
e: Eberswalde crater

o: Ostrov crater

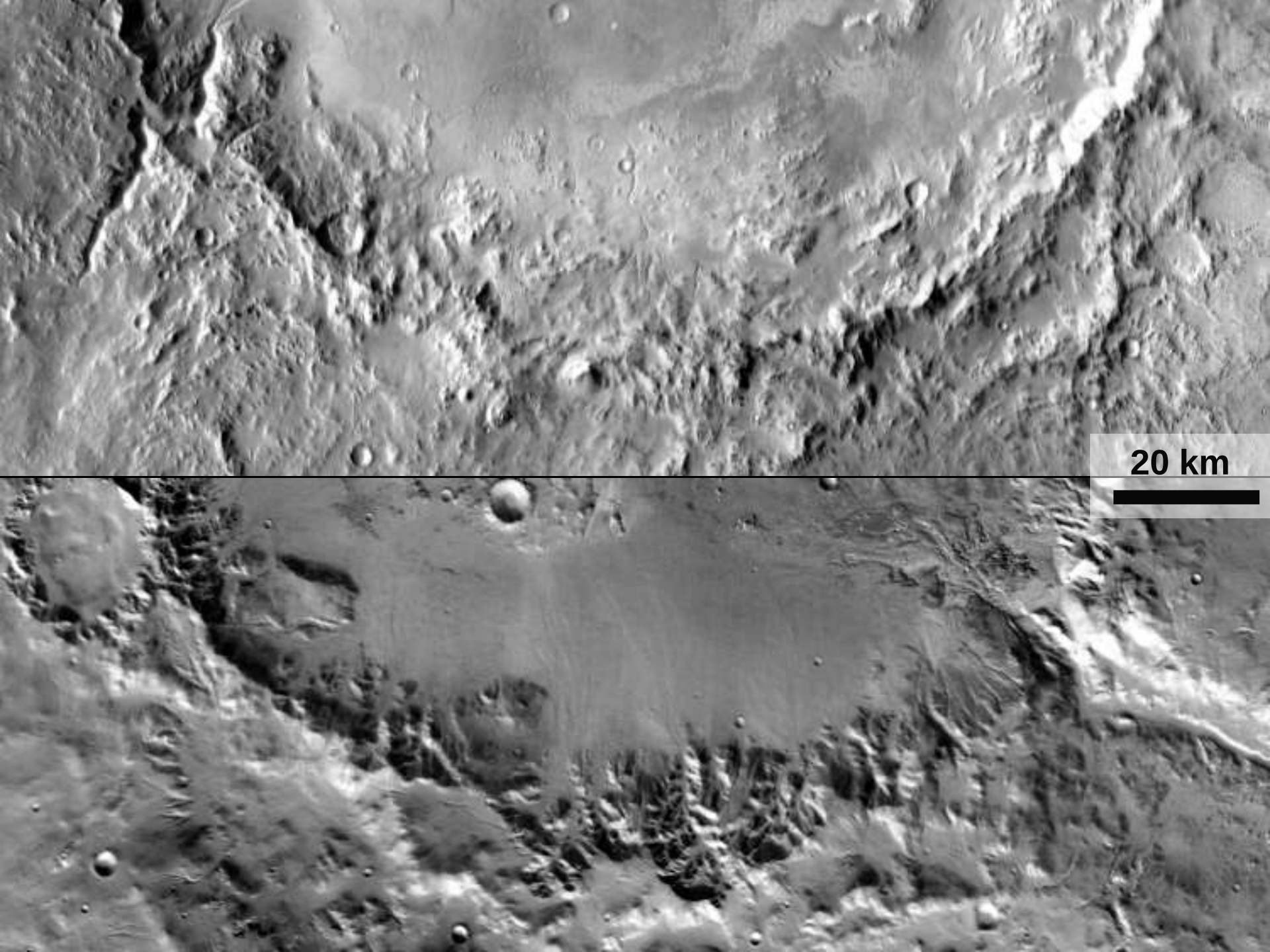
Ladon and Holden impact basin rings are dashed


USGS
Geologic Map of the MTM –15027, –20027, –25027, and –25032 Quadrangles,
Margaritifer Terra Region of Mars

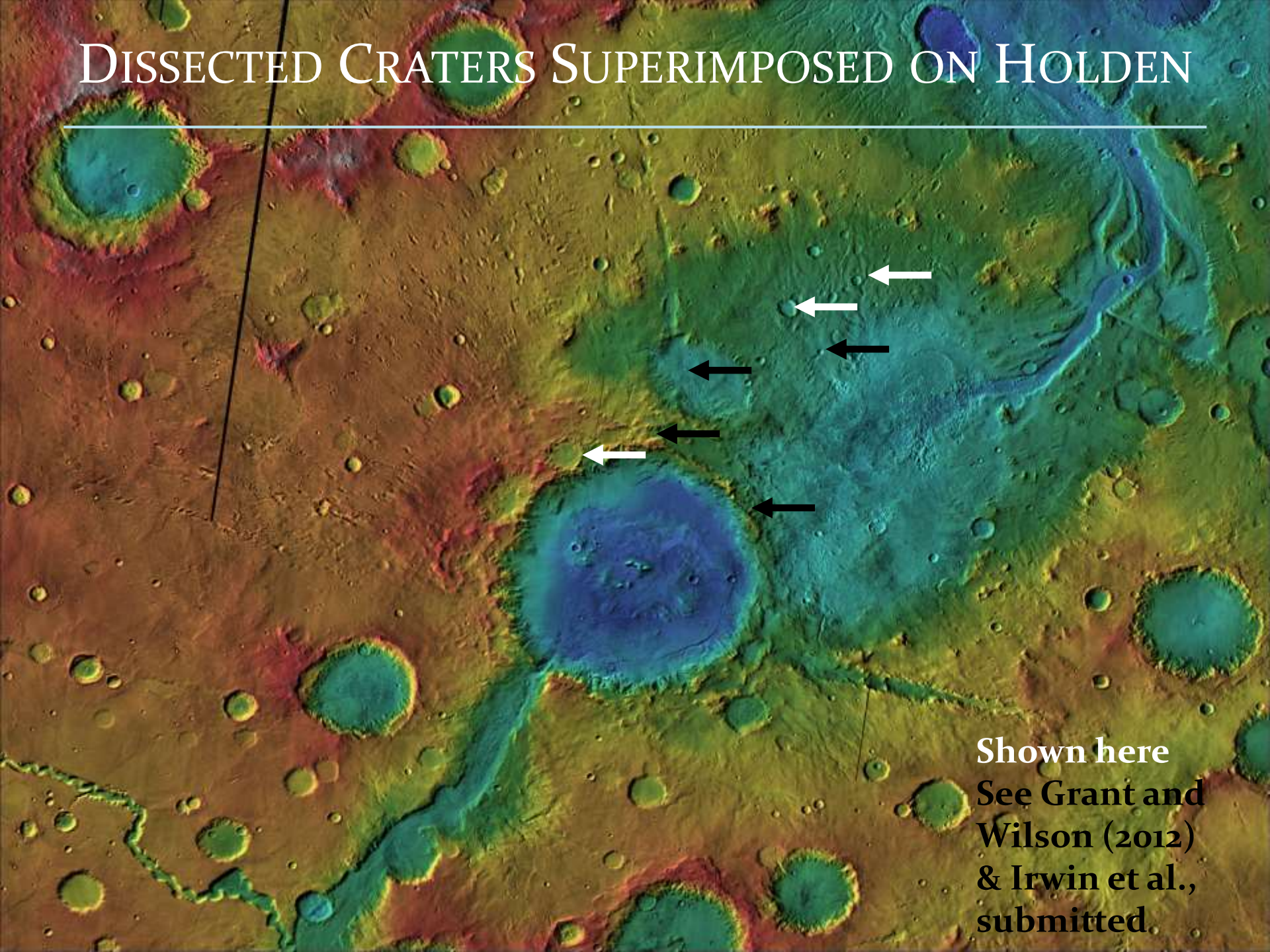
Holden Crater Overview

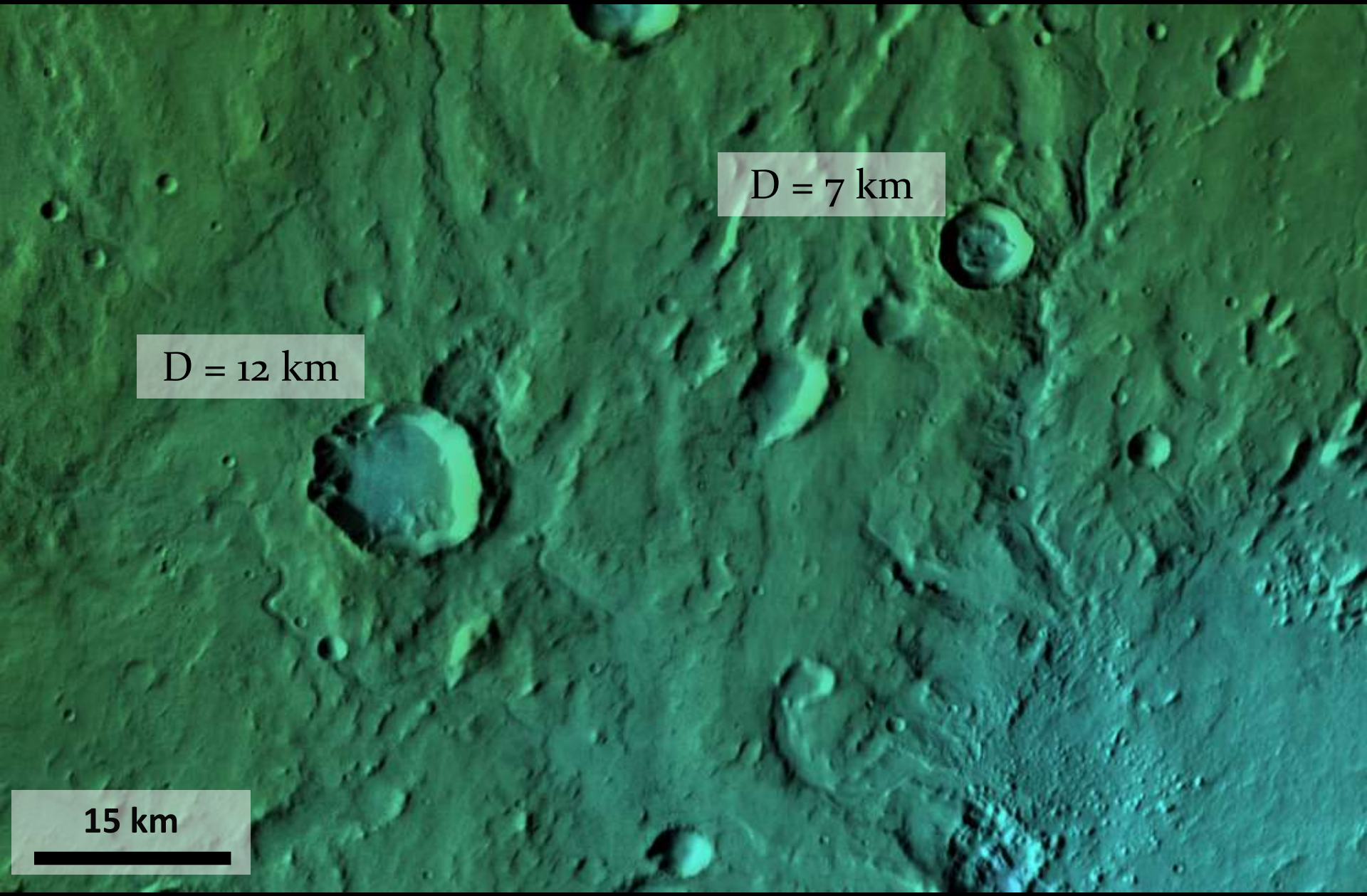


- 26°S, 34°W
- 155 km diam.
- –2 km floor
- Phyllosilicate-rich LTL rocks
- Alluvial fans and bajada from deeply dissected wall alcoves
- Coarse flood deposit from Uzboi Vallis rim breach
- Underlying bedrock outcrops

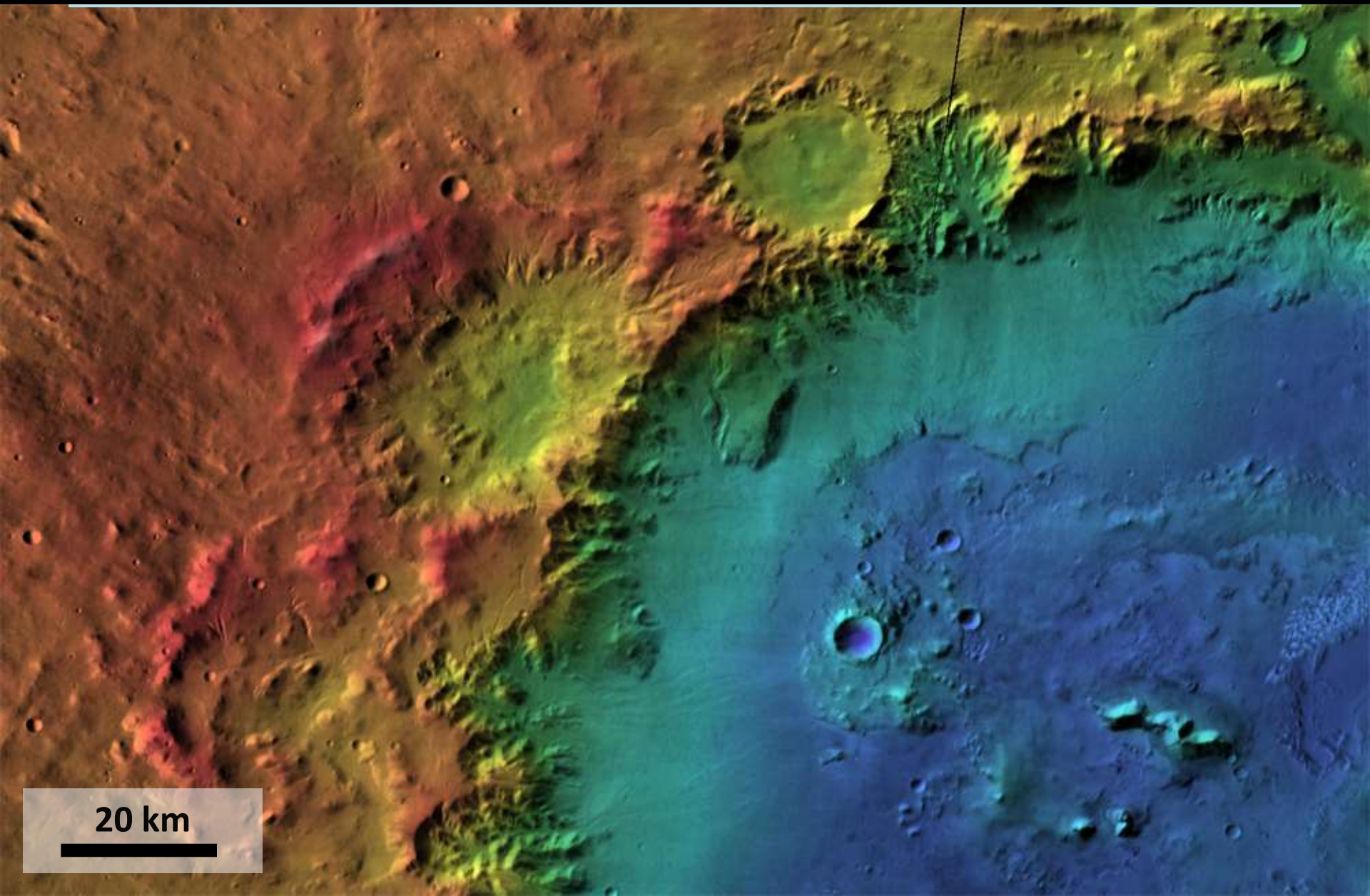

20 km

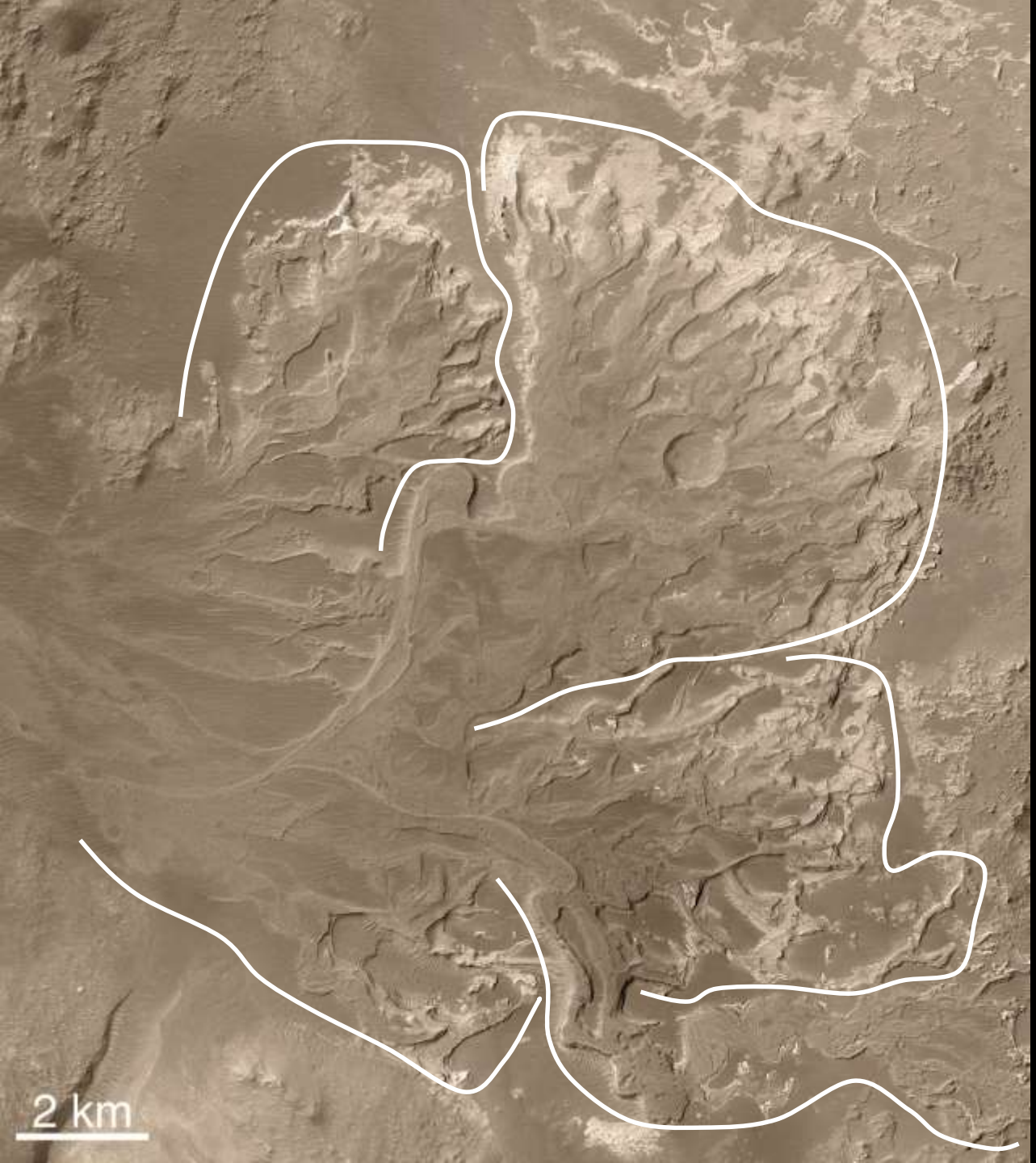
Dissected Craters Superimposed on Holden




D = 7 km
D = 12 km
15 km

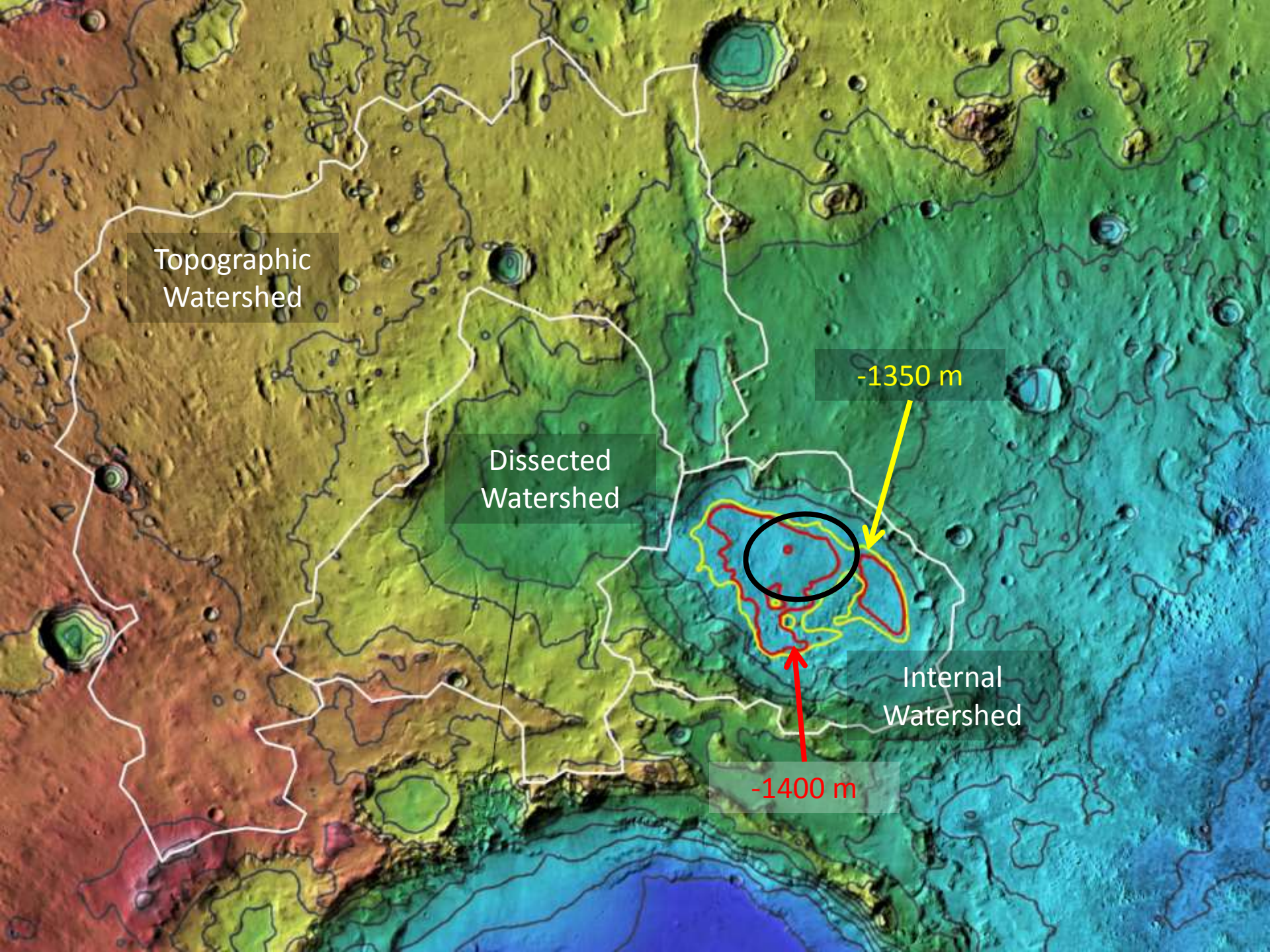
Fans in Northwest Holden Crater





Eberswalde Lobes

Mosaic:
Malin Space
Science Systems


Topographic Watershed
Dissected Watershed
-1350 m
Internal Watershed
-1400 m

Eberswalde Crater Paleohydrology

Width-wavelength relationships in two inverted paleochannels

Consistent with meandering rivers on Earth

Inverted channels are well-preserved here

Bank-full flow for inverted paleochannels

From width: 450 m^3/s (north), 140 m^3/s (south)

From wavelength: 400 m^3/s (north), 180 m^3/s (south)

Annual runoff (lake levels of –1350 and –1400 m, 5,000 km^2 watershed)

For evaporation of 1 m/y: 8–16 cm/y

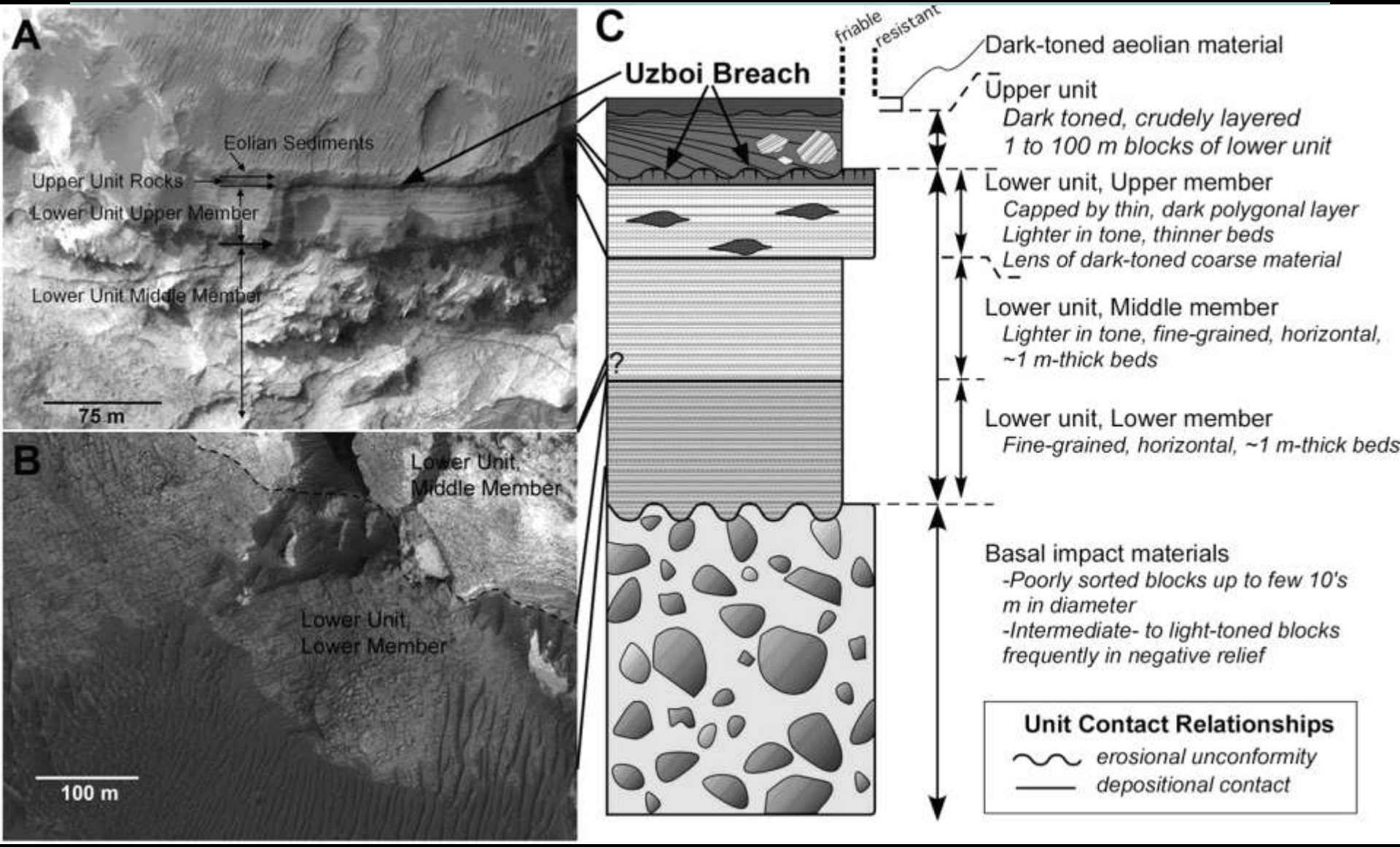
For evaporation of 0.1 m/y: 0.8–1.6 cm/y

Deposition timescale (deposit volume of 6 km^3)

For water/sediment volume ratio of 1,000: tens to hundreds of thousands of years

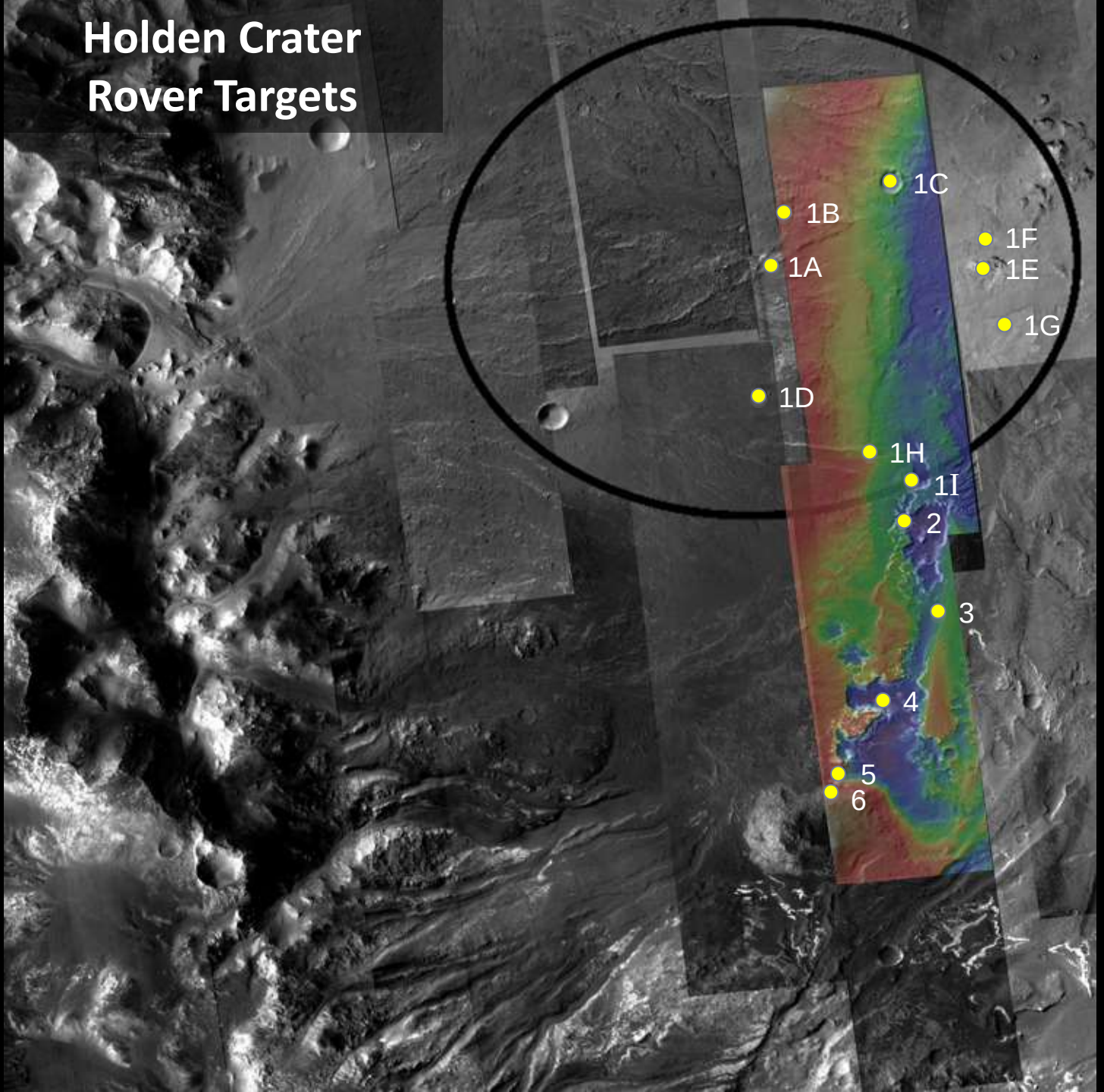
For water/sediment volume ratio of 10,000: hundreds of thousands to millions of yrs

Holden Crater Stratigraphy



Grant et al., 2008

Holden Crater Rover Targets



Inside ellipse

1A: inverted channels at ellipse center

1B-D: craters with layered outcrops on fan surface

1E: knob of underlying material (megabreccia)

1F: upper LTL outcrops

1G: coarse material (distal Uzboi, poss. megabreccia)

1H: fan toe (exposed contact between alluvium and underlying material)

1I: LTL outcrop

[*Other outcrops of each material type are available*]

Outside ellipse

2: many LTL outcrops

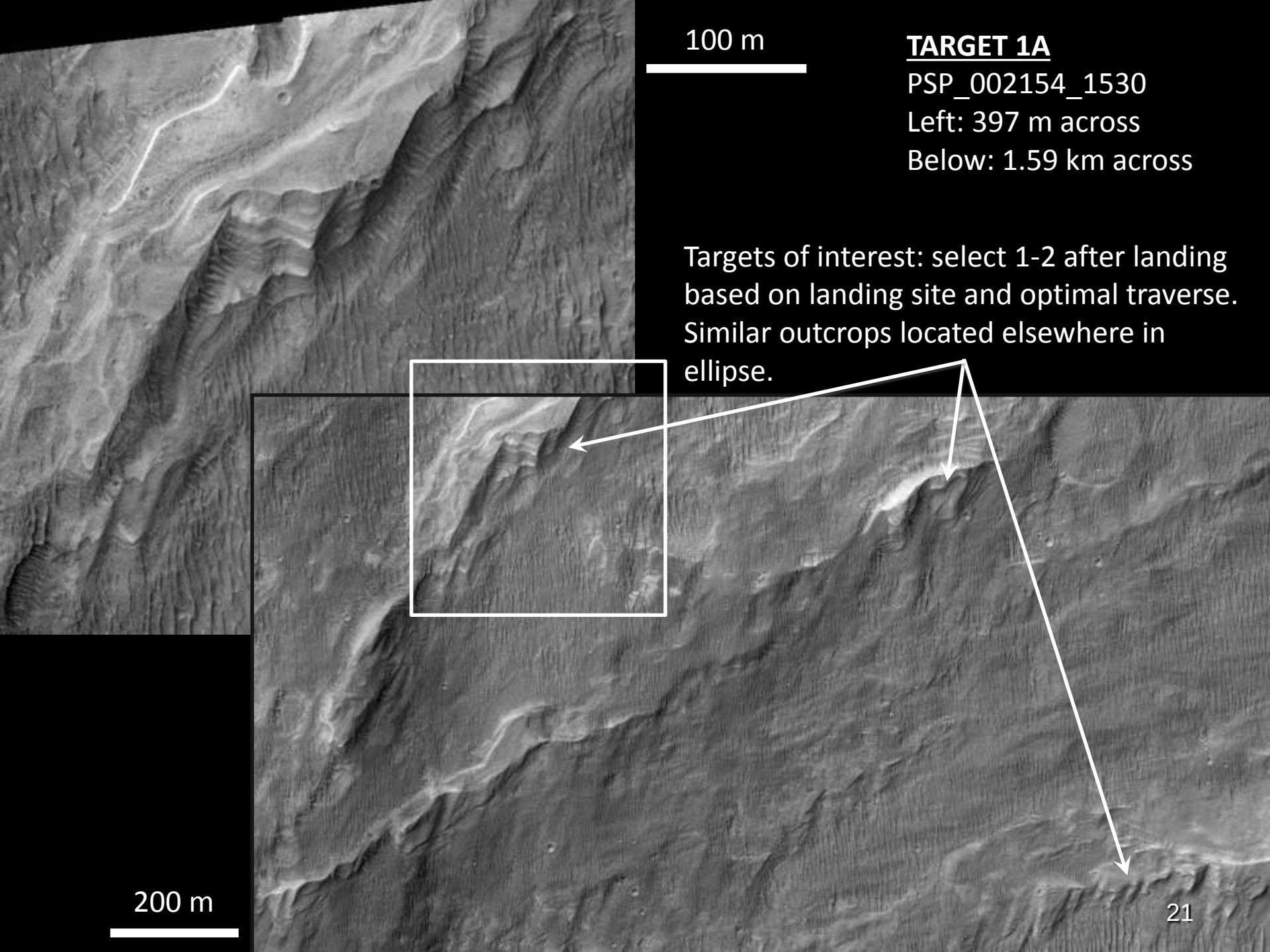
3: bedded coarse deposits (proximal Uzboi)

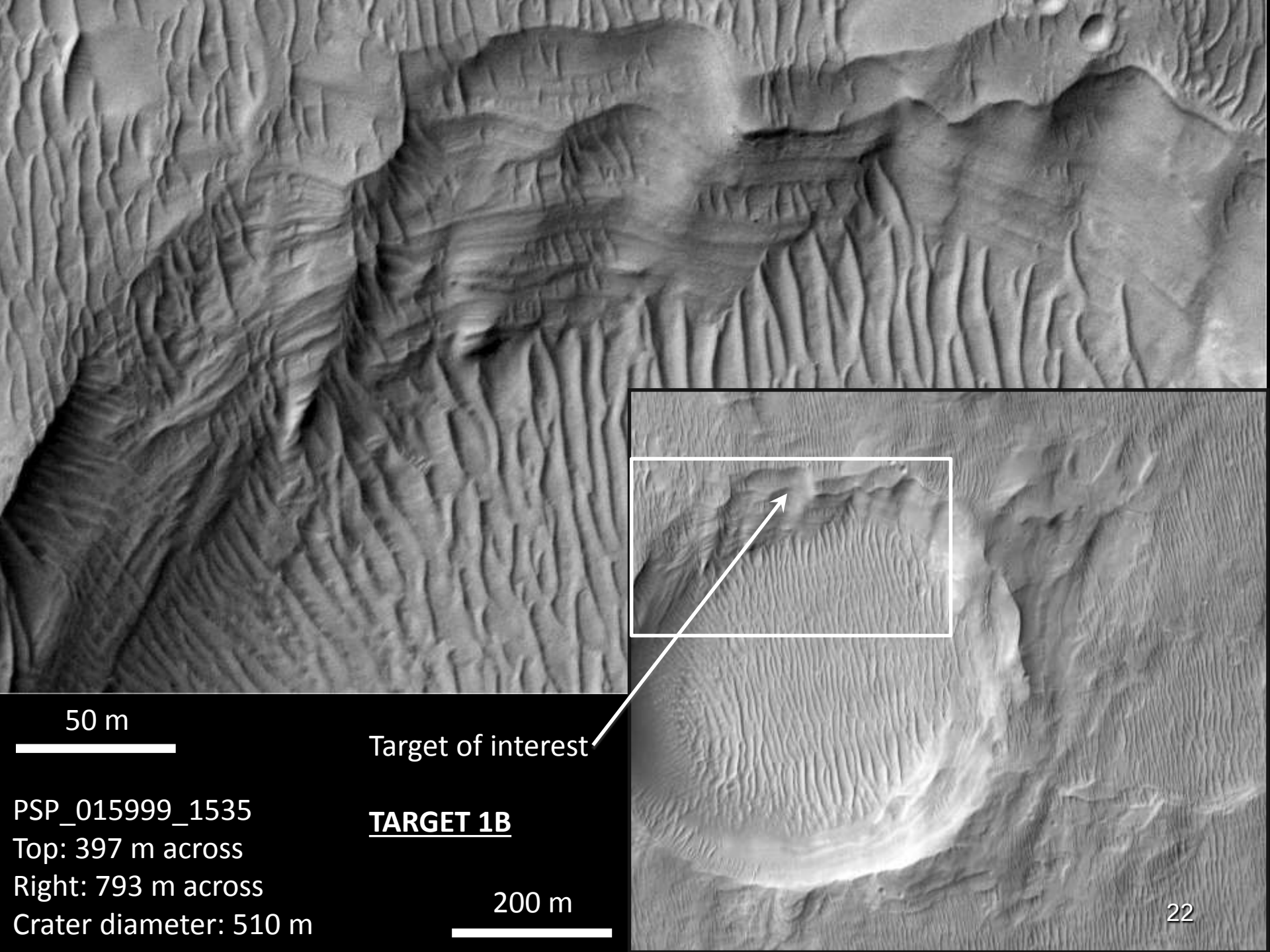
4: LTL outcrops, higher phyllosilicate abundance

Extended mission

5: topographically higher LTL section

6: knob of underlying material (megabreccia)


100 m
TARGET 1A
PSP_002154_1530
Left: 397 m across
Below: 1.59 km across
Targets of interest: select 1-2 after landing based on landing site and optimal traverse. Similar outcrops located elsewhere in ellipse.
200 m


50 m
Target of interest
PSP_015999_1535
Top: 397 m across
Right: 793 m across
Crater diameter: 510 m
TARGET 1B
200 m

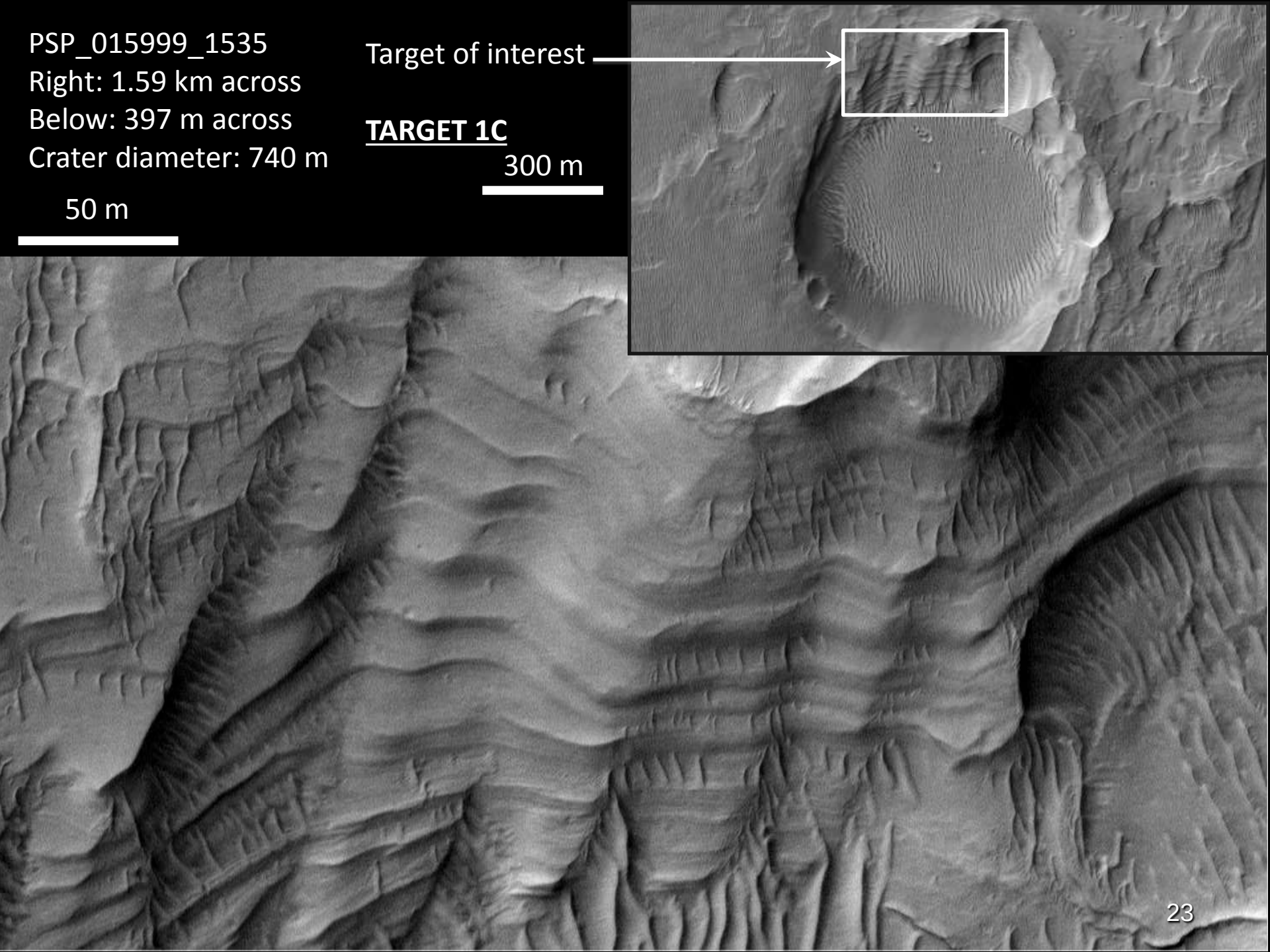
PSP_015999_1535
Right: 1.59 km across
Below: 397 m across
Crater diameter: 740 m

50 m

Target of interest

TARGET 1C

300 m



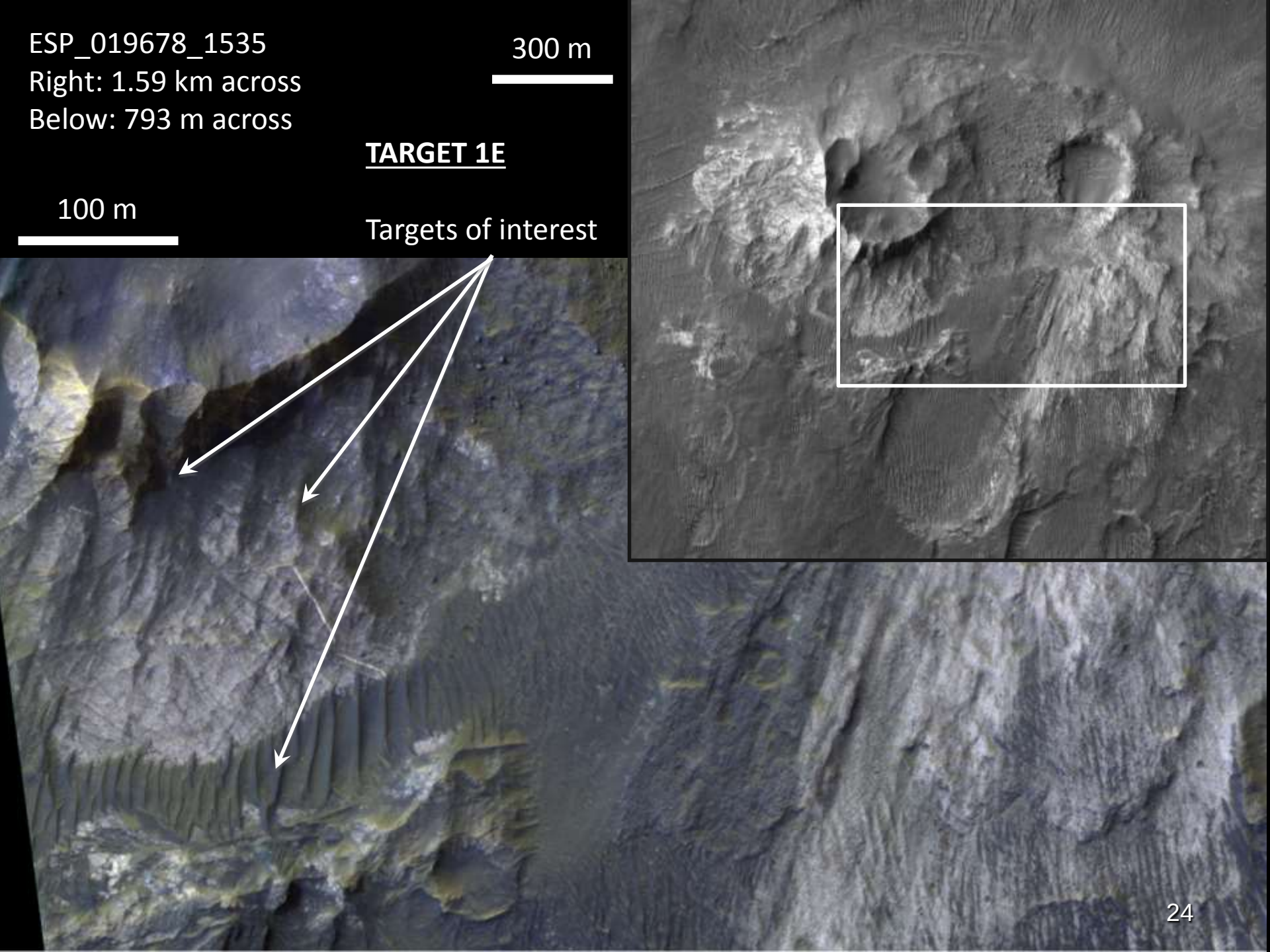
ESP_019678_1535
Right: 1.59 km across
Below: 793 m across

300 m

TARGET 1E

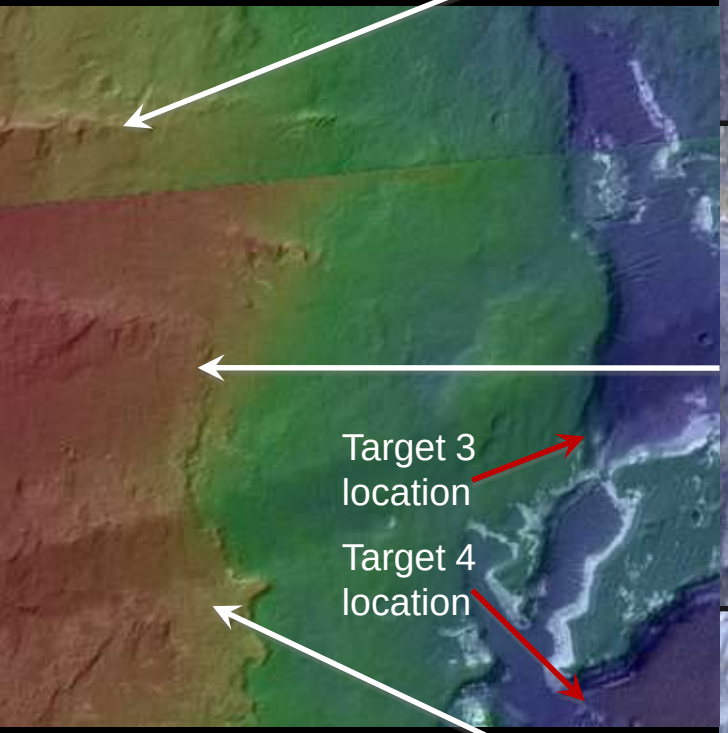
100 m

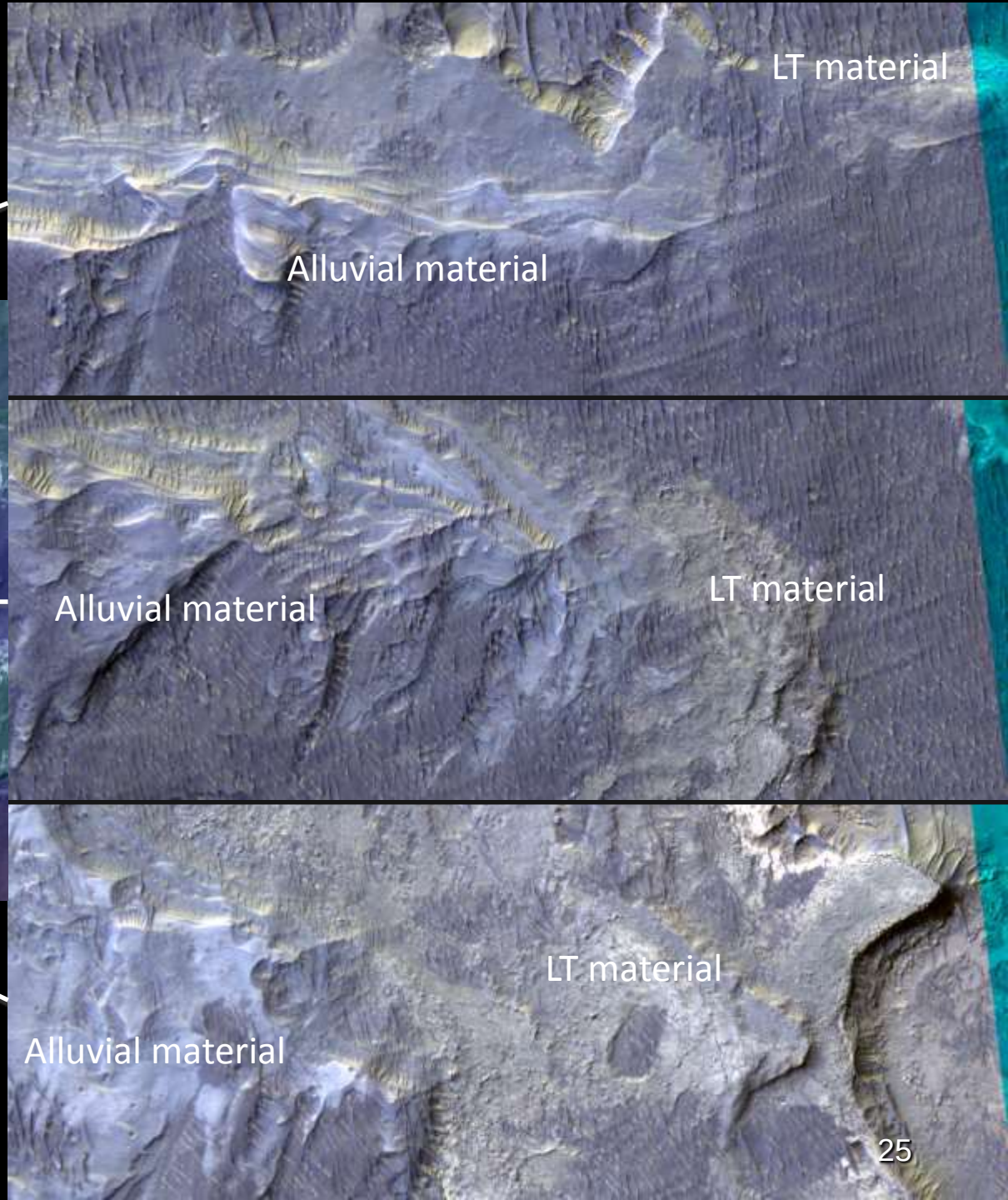
Targets of interest



TARGET 1H

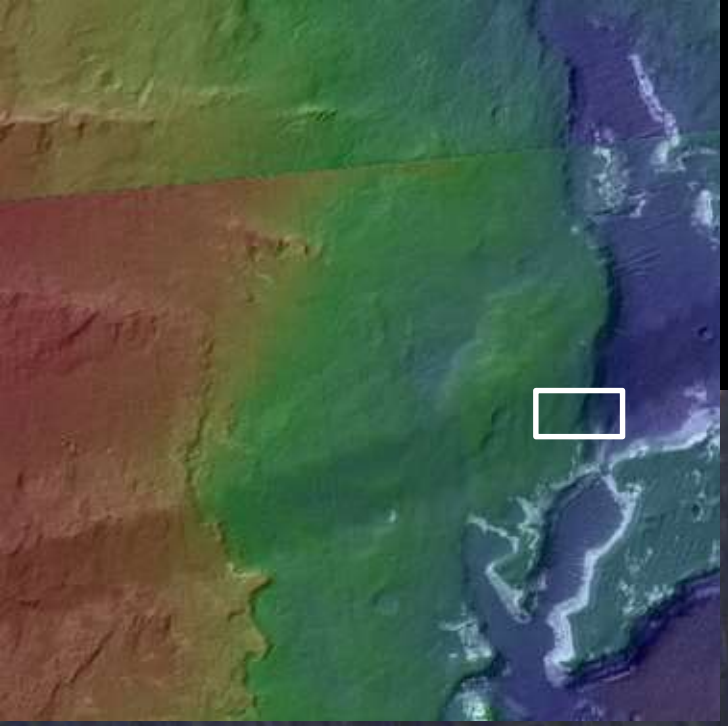
Layered alluvial deposits overlie fractured, lighter-toned material at the fan toe.





PSP_001468_1535
Each 793 m across

100 m



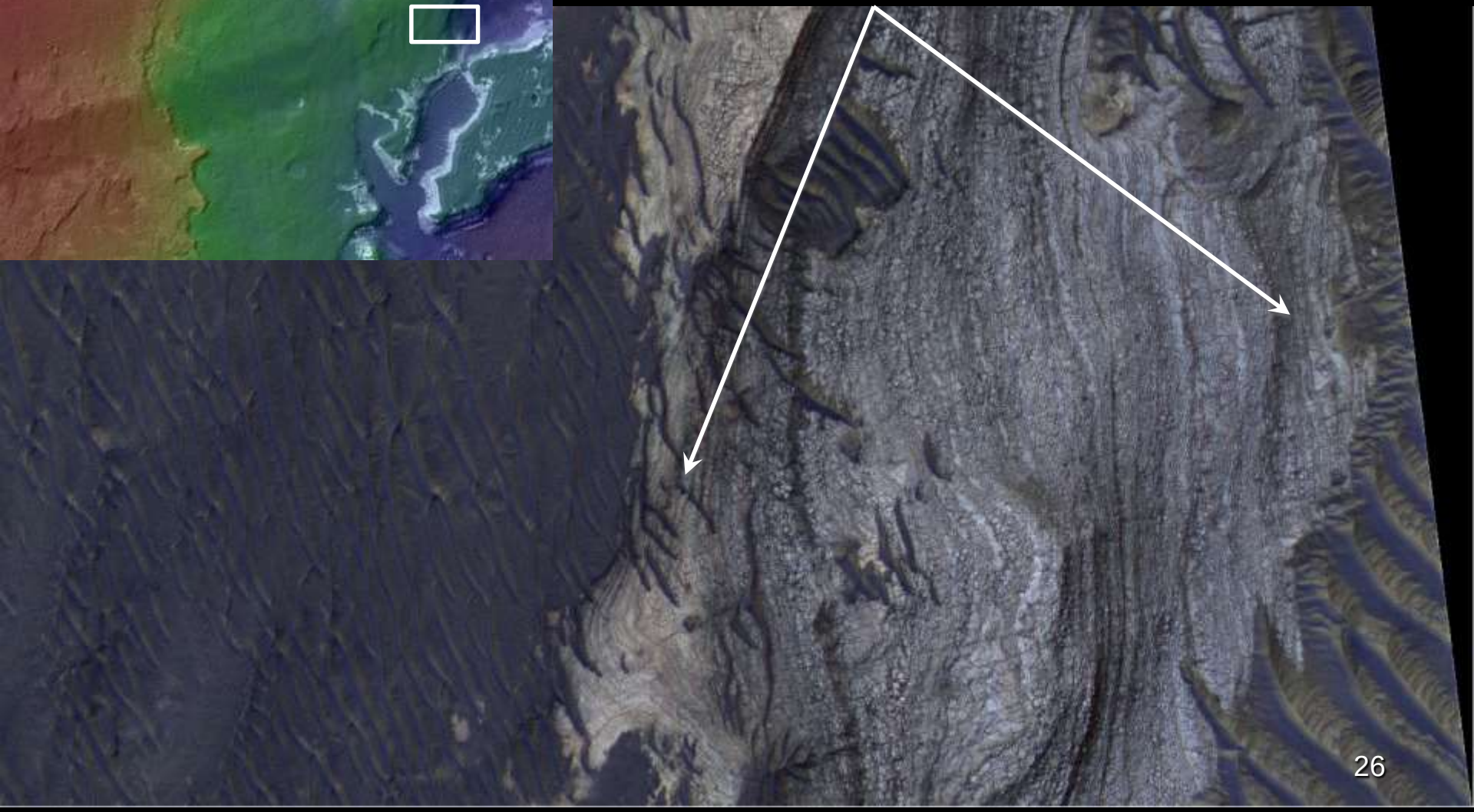
33 m section
8°slope
>40 light/dark pairs

TARGET 1I

ESP_016276_1535
397 m across

50 m

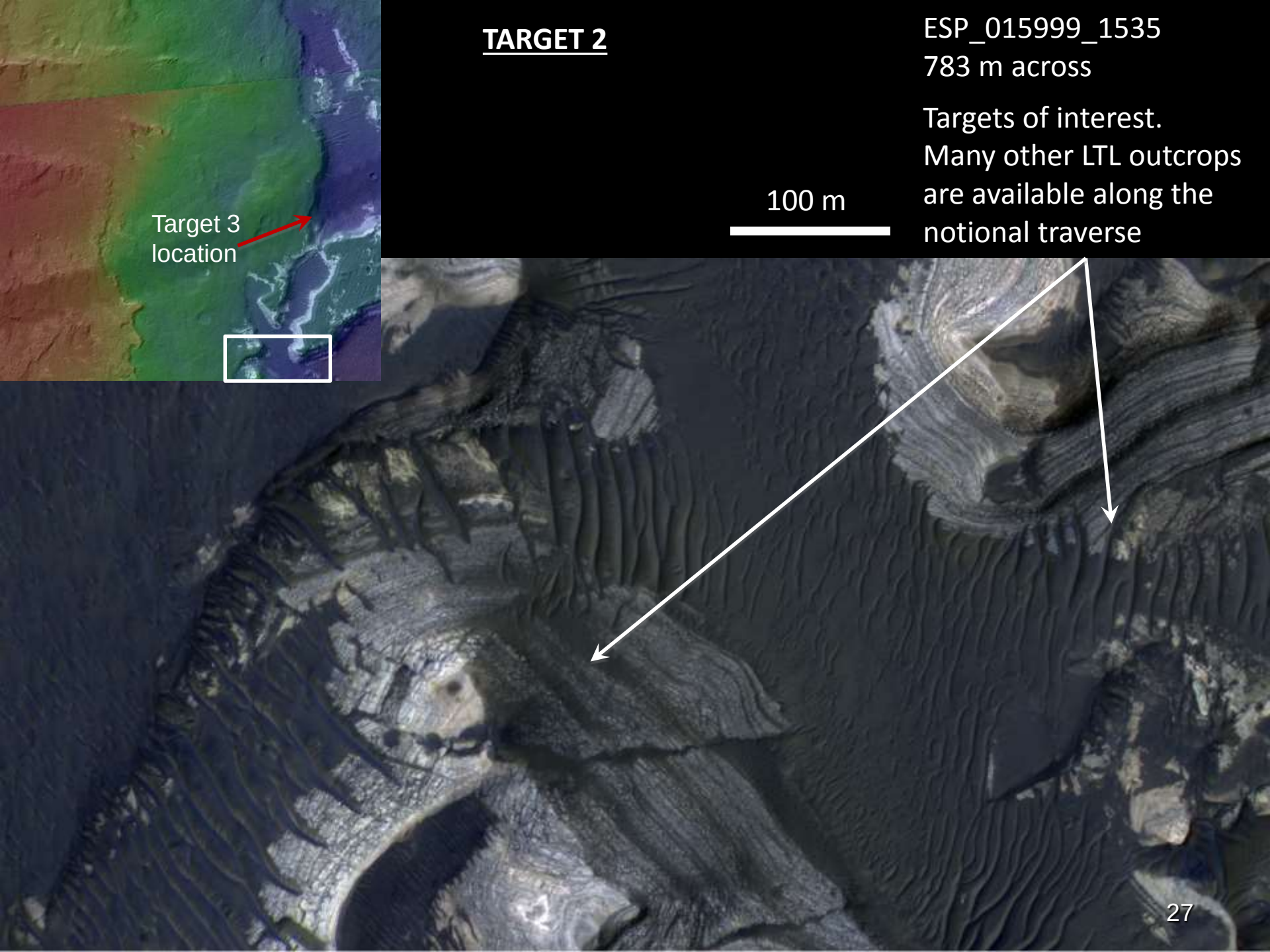
Target of interest



TARGET 2

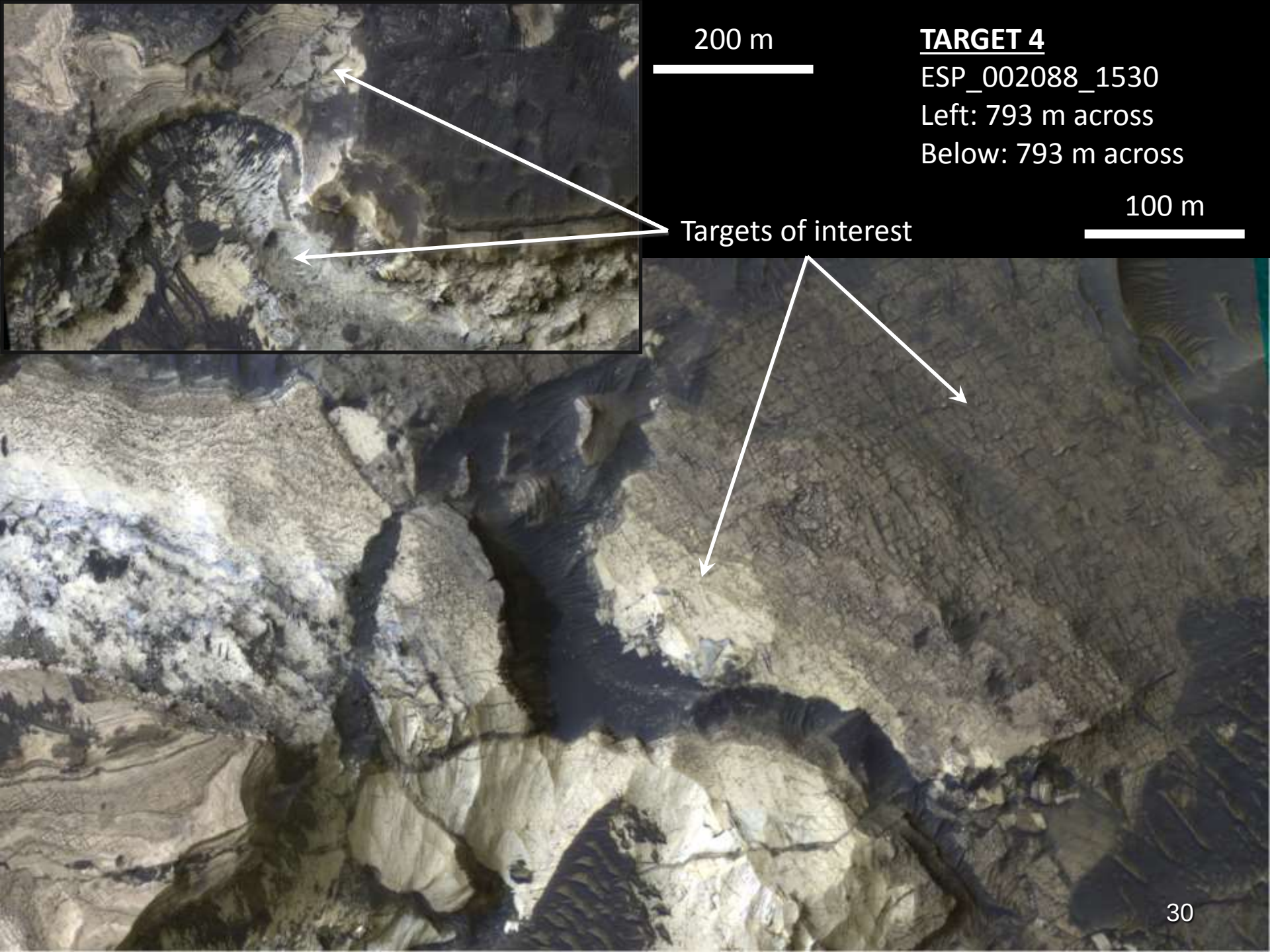
ESP_015999_1535
783 m across

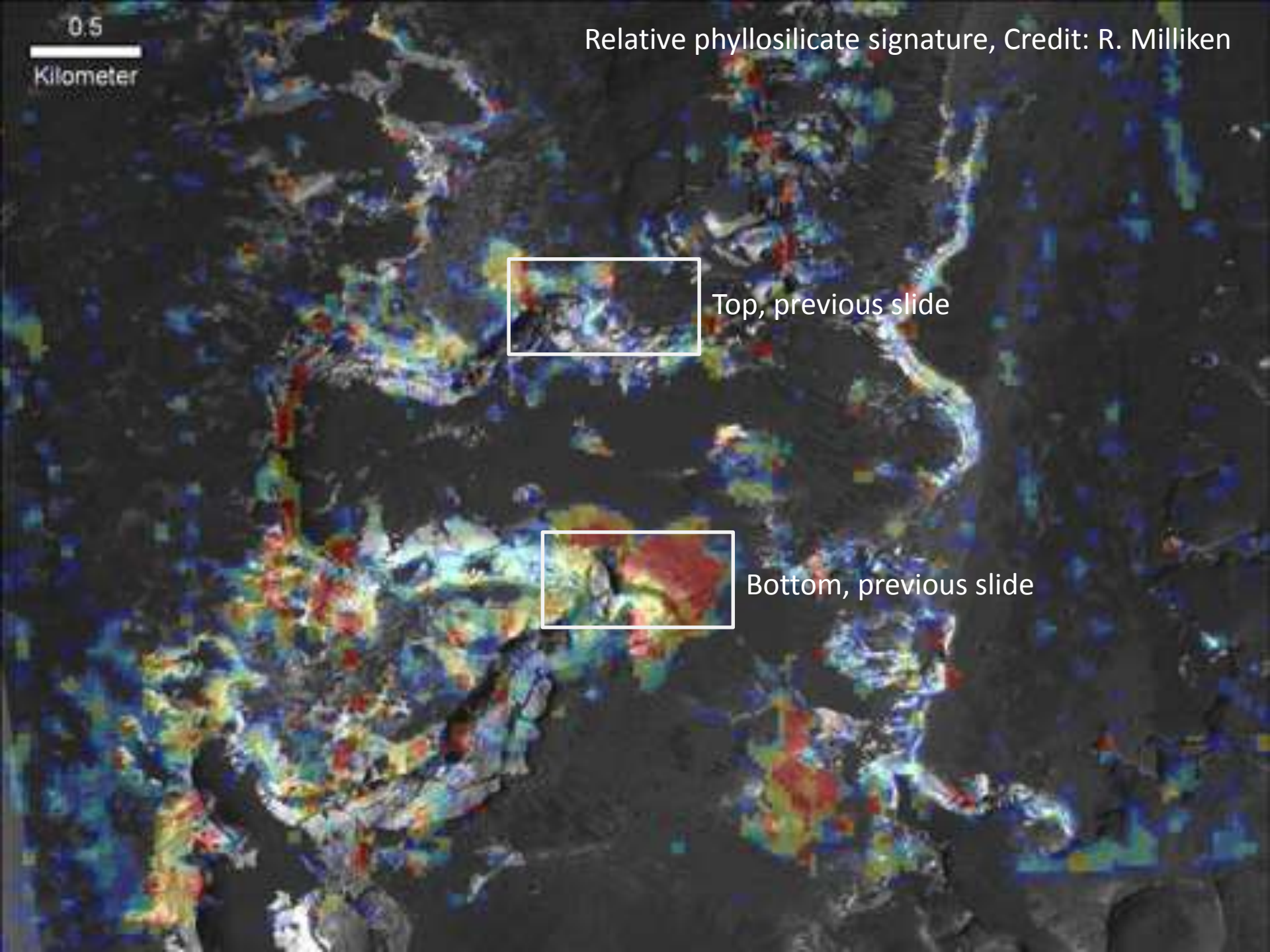
Targets of interest.
Many other LTL outcrops are available along the notional traverse

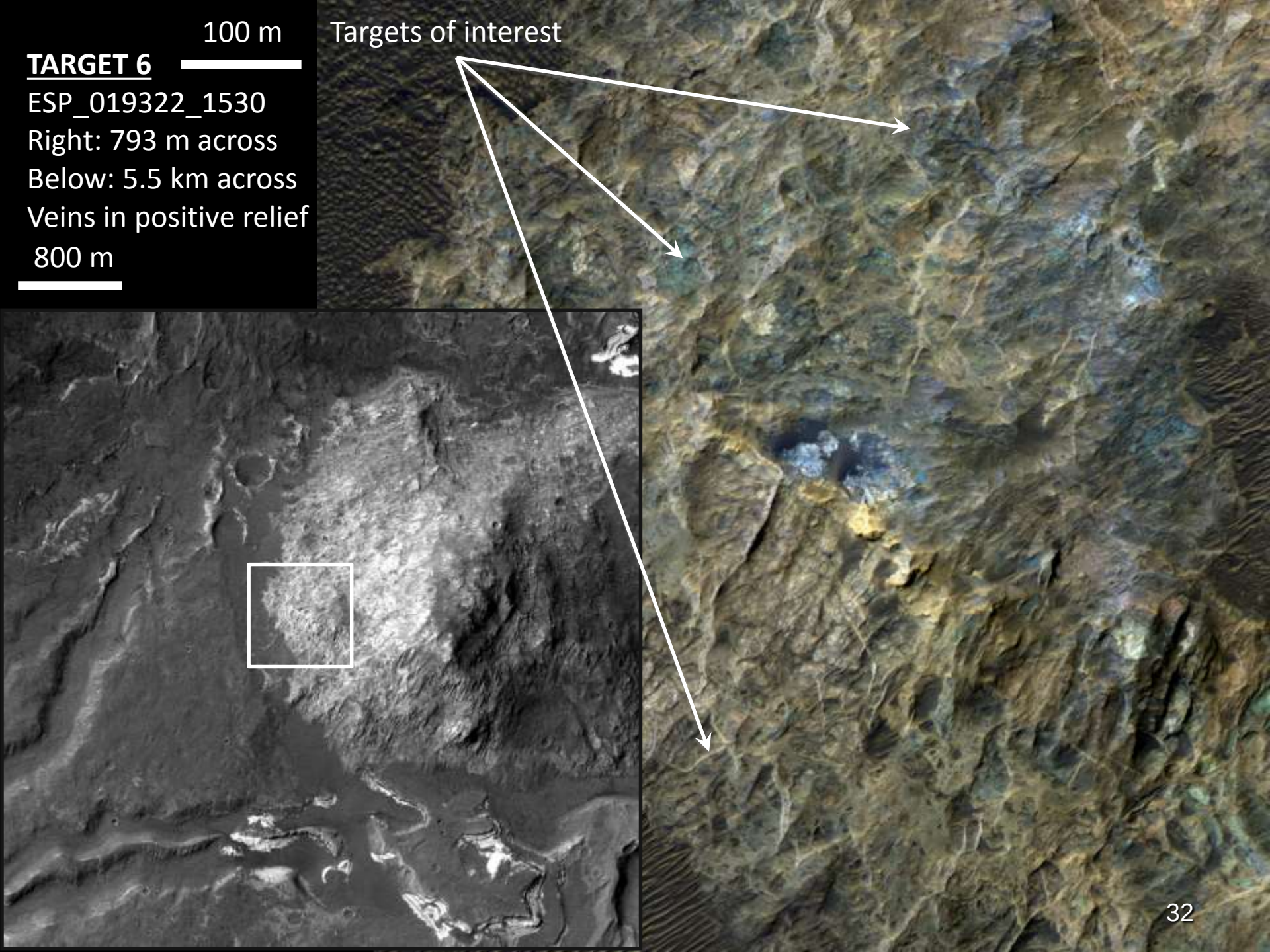


100 m

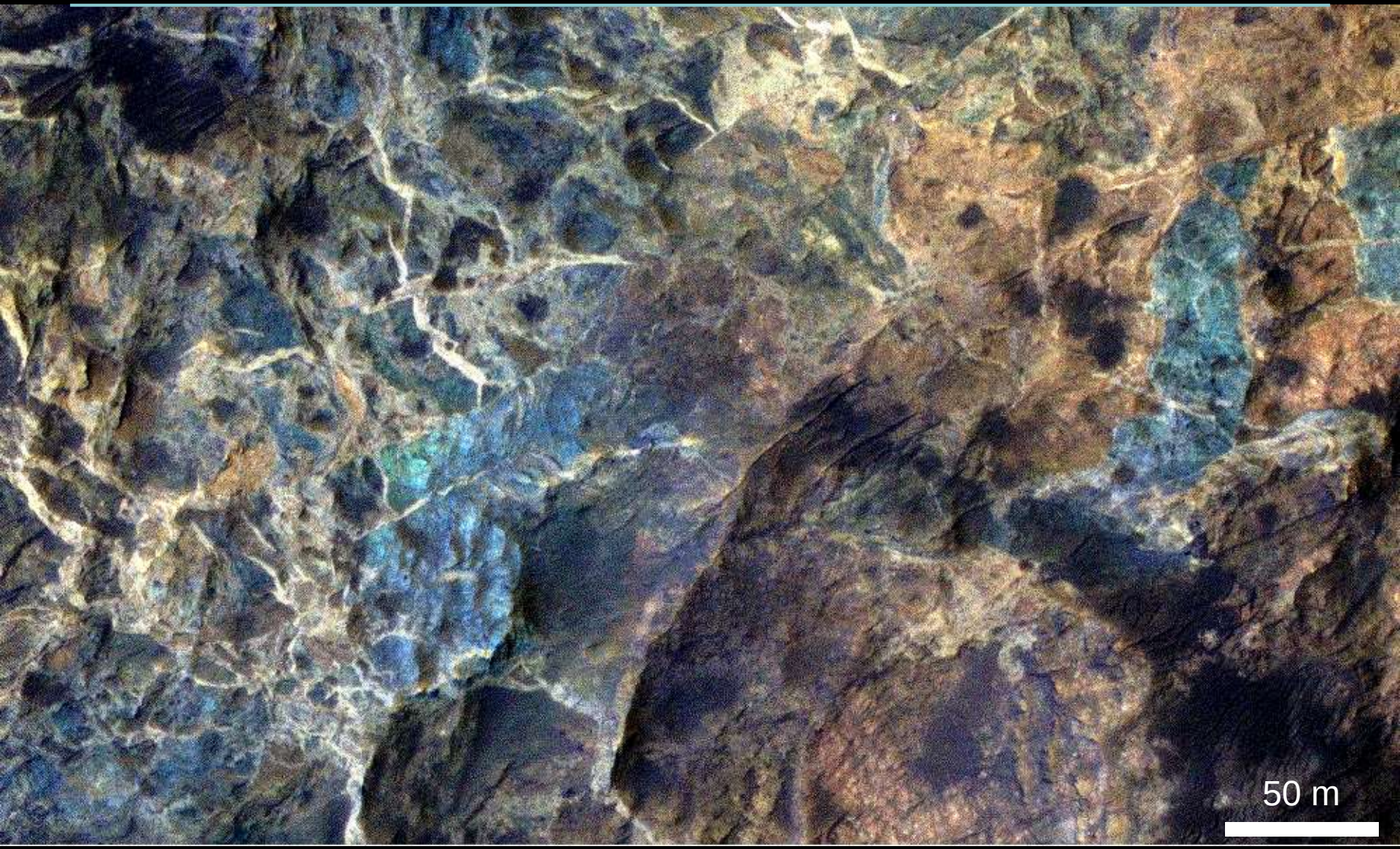
100 m
Targets of interest
ESP_002088_1530
Above: 793 m across
Right: 199 m across
TARGET 3
50 m


200 m
TARGET 4
ESP_002088_1530
Left: 793 m across
Below: 793 m across
100 m
Targets of interest


0.5
Kilometer
Relative phyllosilicate signature, Credit: R. Milliken
Top, previous slide
Bottom, previous slide

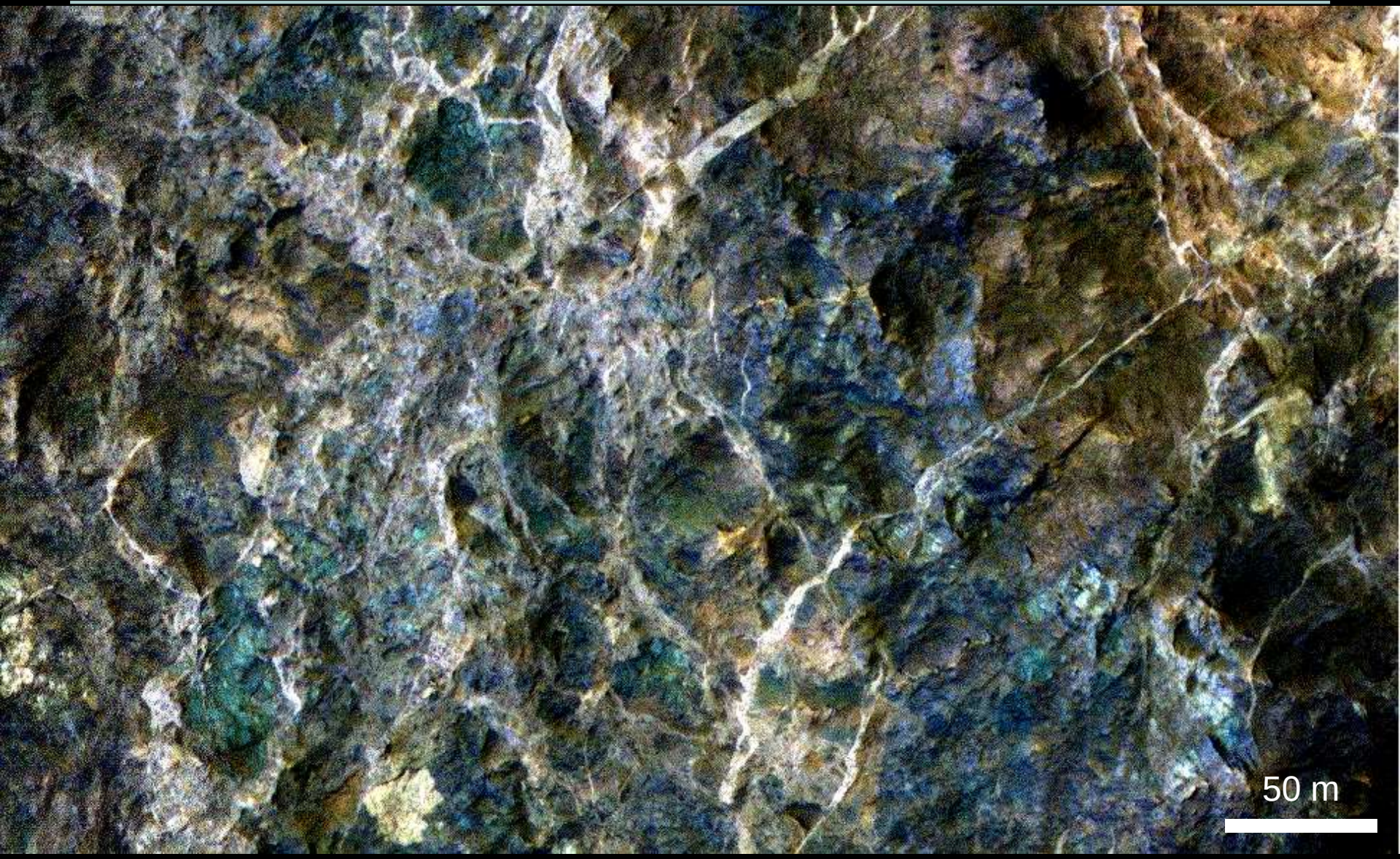

100 m
TARGET 6
ESP_019322_1530
Right: 793 m across
Below: 5.5 km across
Veins in positive relief
800 m
Targets of interest

Megabreccia Knob



HiRISE ESP_012386_1530

Megabreccia Knob



HiRISE ESP_012320_1530

Spectroscopy Summary

- **Holden's mineralogy is diverse**

Fan source area:	Ellipse:	Layered deposits:	Megabreccia:
Low-Ca pyroxene	*Hydrate: silica?*	***Strong*** *Fe/Mg-clays*	*Fe/Mg-clay*
High-Ca pyroxene	*Fe/Mg-clay*	*Hydrated phase*	*Much more!*
Mg-rich olivine		*2.5 µm phase?*	
Fe-rich olivine?			
Fe/Mg-clay			
Hydrated salt/zeolite			

- Diverse minerals and strong clay signatures ***with geologic context***

- Alluvial/lacustrine deposits enable comparisons to MSL findings in Gale crater, while mineralogic/astrobiologic characterization of diverse Noachian rocks (altered and unaltered) has a high priority for MSR

Credit: Marli Bryant Miller

Diversified Habitability Investigation

Alluvial fans

- Paleoclimate and atmospheric evolution: Paleohydrology and runoff requirements for observed sediment load from a well-defined watershed
- Mineralogy, weathering, and diagenetic alteration: Alluvial gravel/cobbles sample top 1-2 km of highland crust, up to 800 Myr of the Noachian Period

Light-toned, layered materials with Fe,Mg phyllosilicates

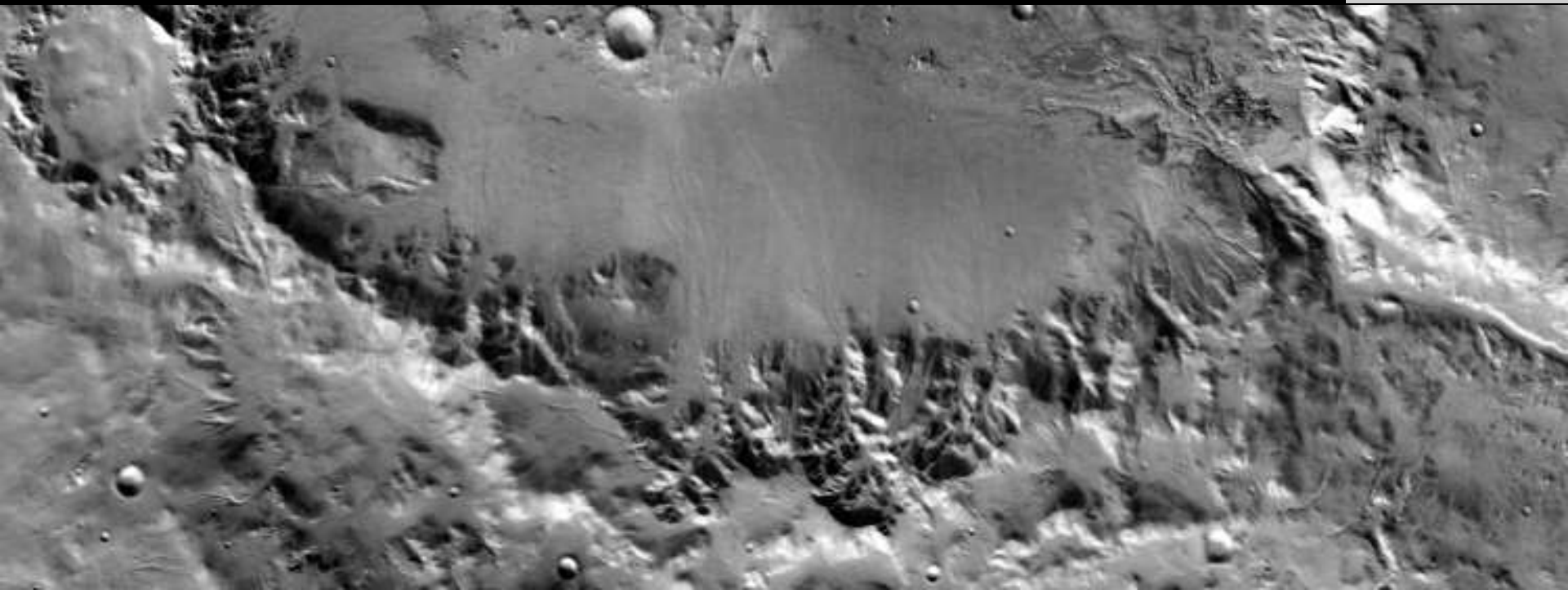
- Stratigraphy, sedimentology, and geochemistry of 100-m-thick medium to fine-grained section reflects depositional environment and change over time
- Ideal site to search for organics and effects of biological processes

Flood deposits

- Paleoflood hydrology, rocks from rim breach & Uzboi, late-stage weathering

Bedrock outcrops

- Ancient bedrock uplifted during impact, possible hydrothermal system

Conclusions

- Good outcrops of all four target materials are available within the MSL ellipse
- More outcrops and lower strata of all four are accessible to the south
- One of the most deeply eroded crater rims on Mars: abundant water
- Diversified habitability investigation minimizes risk
- Sampling and chronology opportunities
- Safe landing site, low elevation, accessible science