Early Martian Lacustrine Evaporite Deposits:
An Archetypal Example in E. Margaritifer Terra

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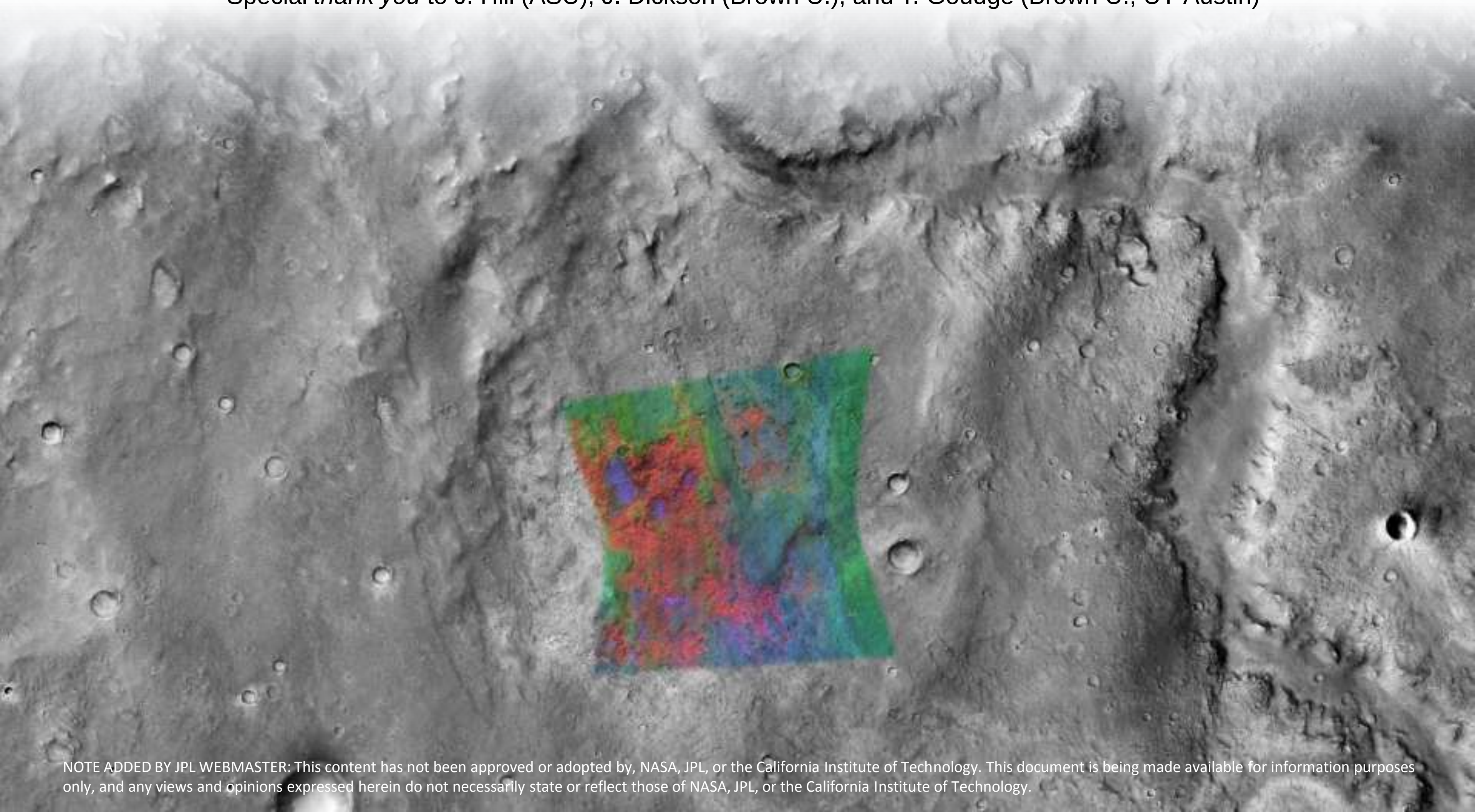
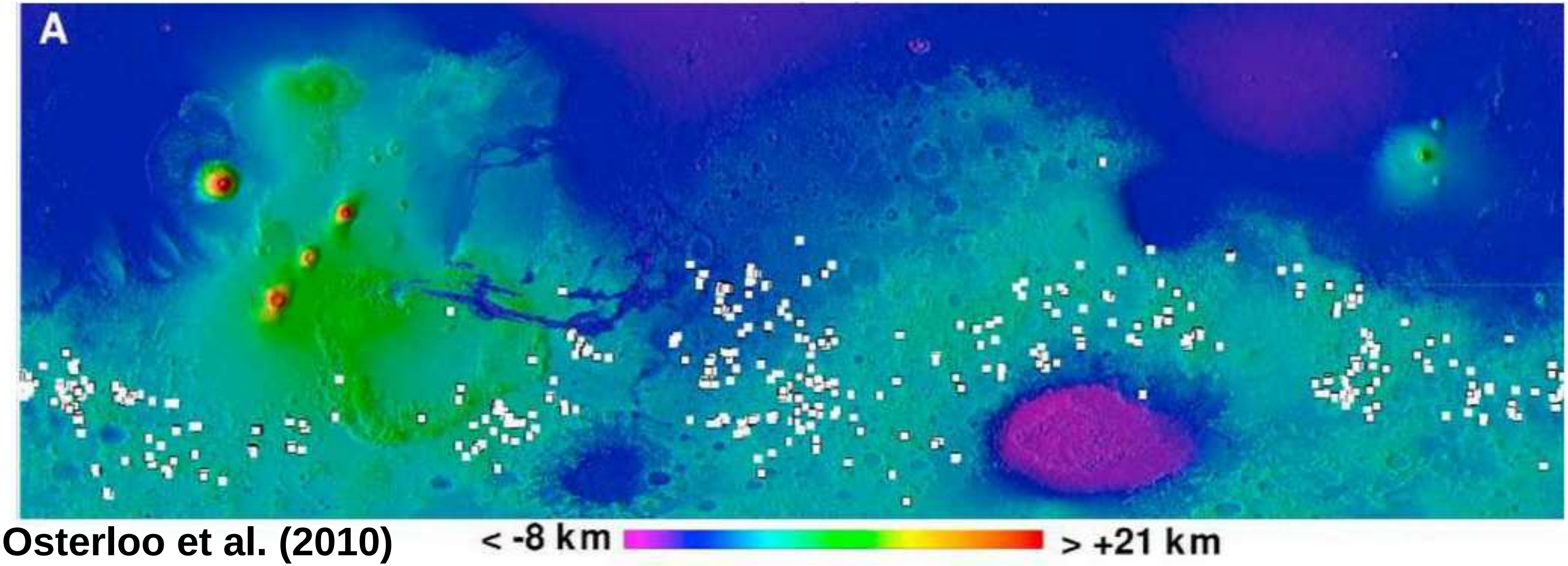
*Special *thank you* to J. Hill (ASU), J. Dickson (Brown U.), and T. Goudge (Brown U., UT-Austin)

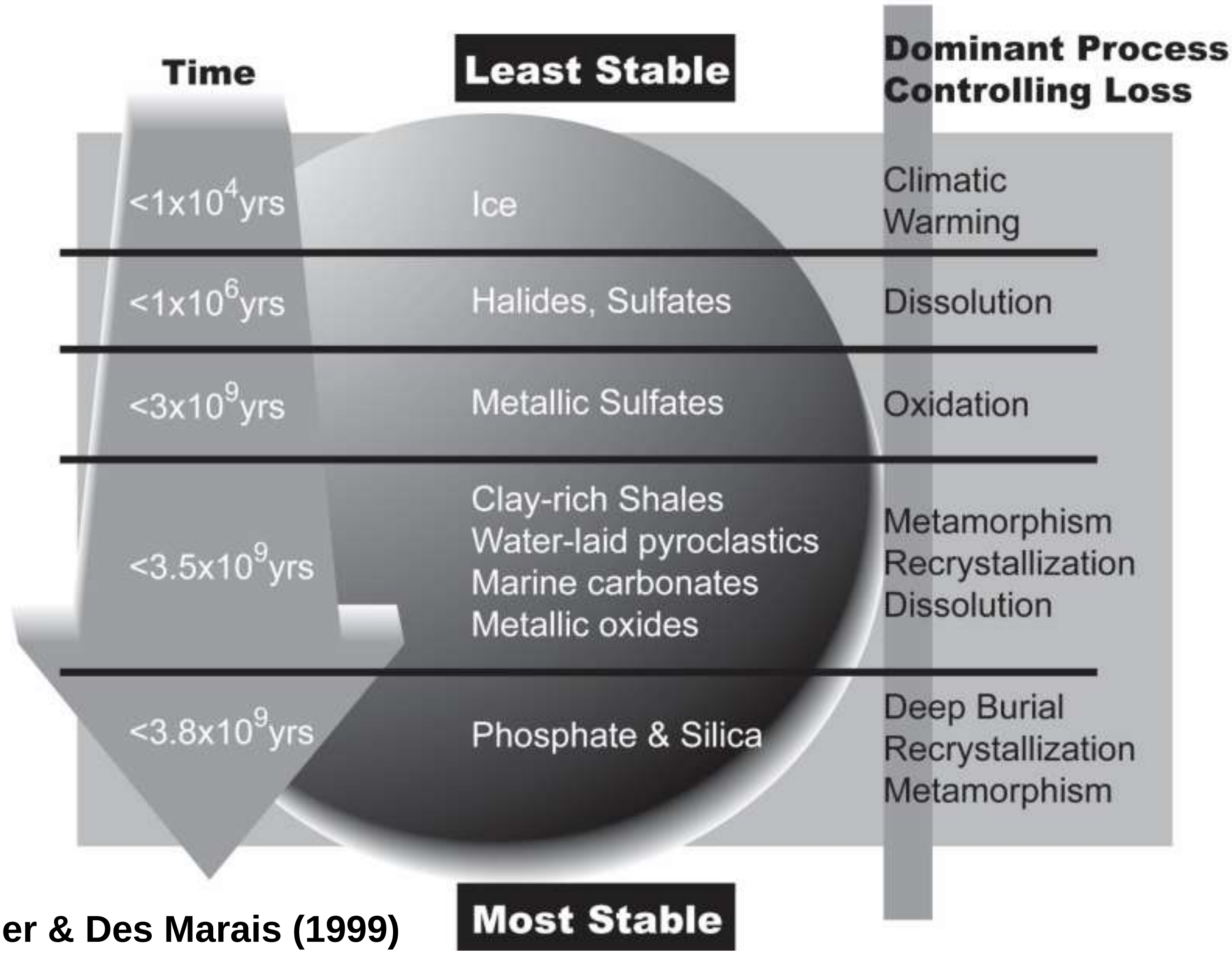




Osterloo et al. (2010)

- **Chloride-bearing deposits are widespread throughout Noachian landscapes, present at a range of elevations (-3 – +4 km MOLA)**
- **Stratigraphy has been widely discussed – young or old?**
- **Several locations provide clear stratigraphic relationships**
  - **E.g., E. Margaritifer Terra**

Residence Times of Minerals in the Earth's Crust



Farmer & Des Marais (1999)

Landing Site Factor	Mars 2020 Mission and Decadal Priority Science Factors																							
	Environmental Setting for Biosignature Preservation and Taphonomy of Organics								Type 1A & 1B Samples: Aqueous Geochemical Environments indicated by Mineral Assemblages									Type 2 Samples: Igneous		Context: Martian History Sampled, Timing Constraints				
	Deltaic or Lacustrine (perennial)	Lacustrine (evaporitic)	Hydrothermal (<100°C) surface	Hydrothermal (<100°C) subsurface	Pedogenic	Fluvial/Alluvial	No diagenetic overprinting	Recent exposure	Crustal phyllosilicates	Sedimentary clays	Al clays in stratigraphy	Carbonate units	Chloride sediments	Sulfate sediments	Acid sulfate units	Silica deposits	Ferric Ox./Ferrous clays	Igneous unit (e.g, lava flow, pyroclastic, intrusive)	2nd Igneous unit	Pre- or Early-Noachian Rocks	Oldest stratigraphic constraint	Youngest stratigraphic constraint	Stratigraphy of units well-defined	Dateable surface, volcanic (unmodified crater SFD)
E Margaritifer Chloride	~	●				○	●			●			●					●	~		MN	?	●	●

Dendritic fluvial channel to north and east of ROIs. Channel dated to Late Noachian (Fassett & Head, 2008)

Spectrally confirmed in VNIR, TIR. High abundances required (> 25% by weight)

Evaporation of solute-rich solution. On Earth, entomb brine inclusions and biosignatures.

Stratified smectite deposits present throughout region.

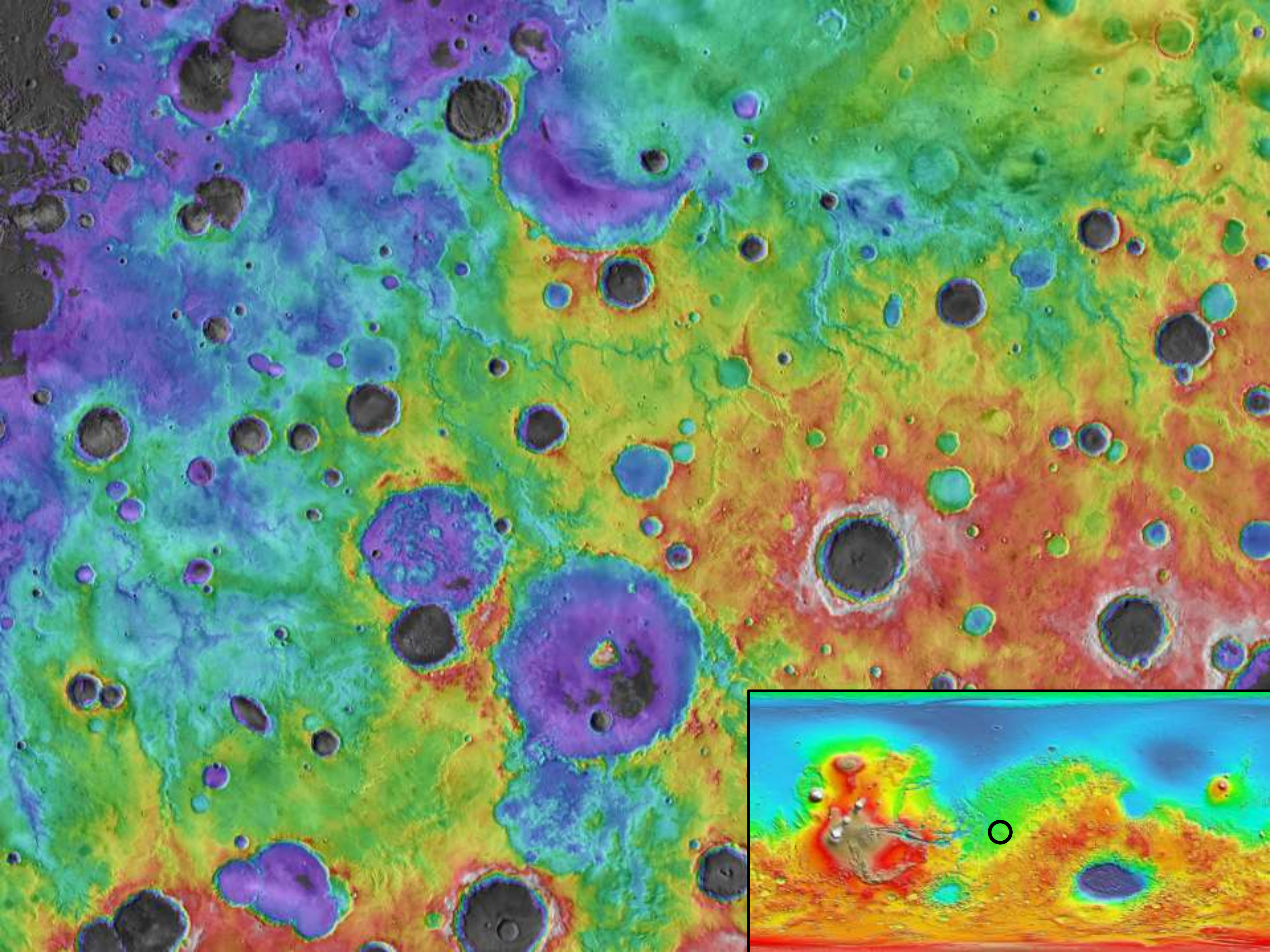
Unobscured contacts, clear cross-cutting rel.

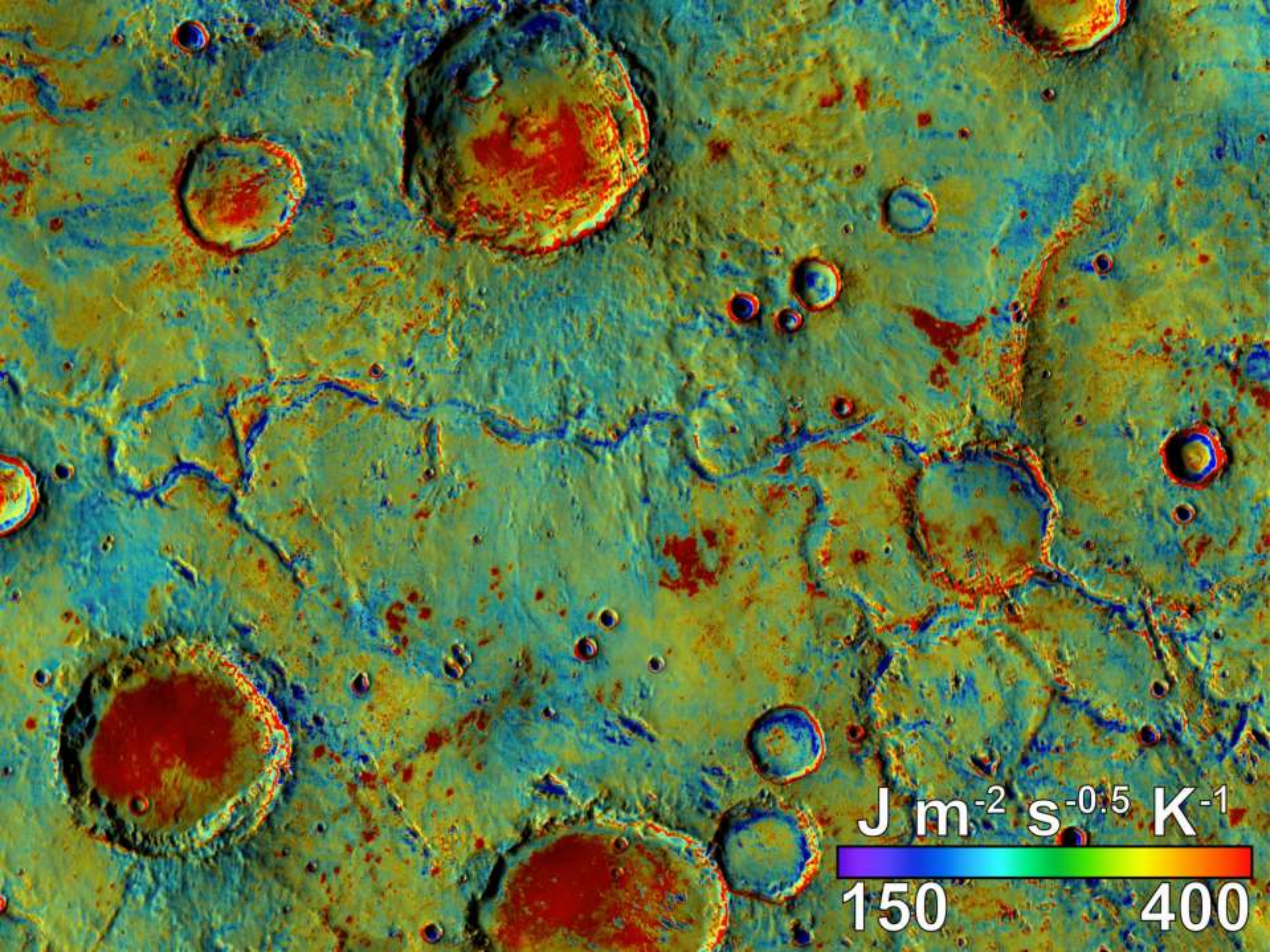
Ejecta deposits, Noachian plains material.

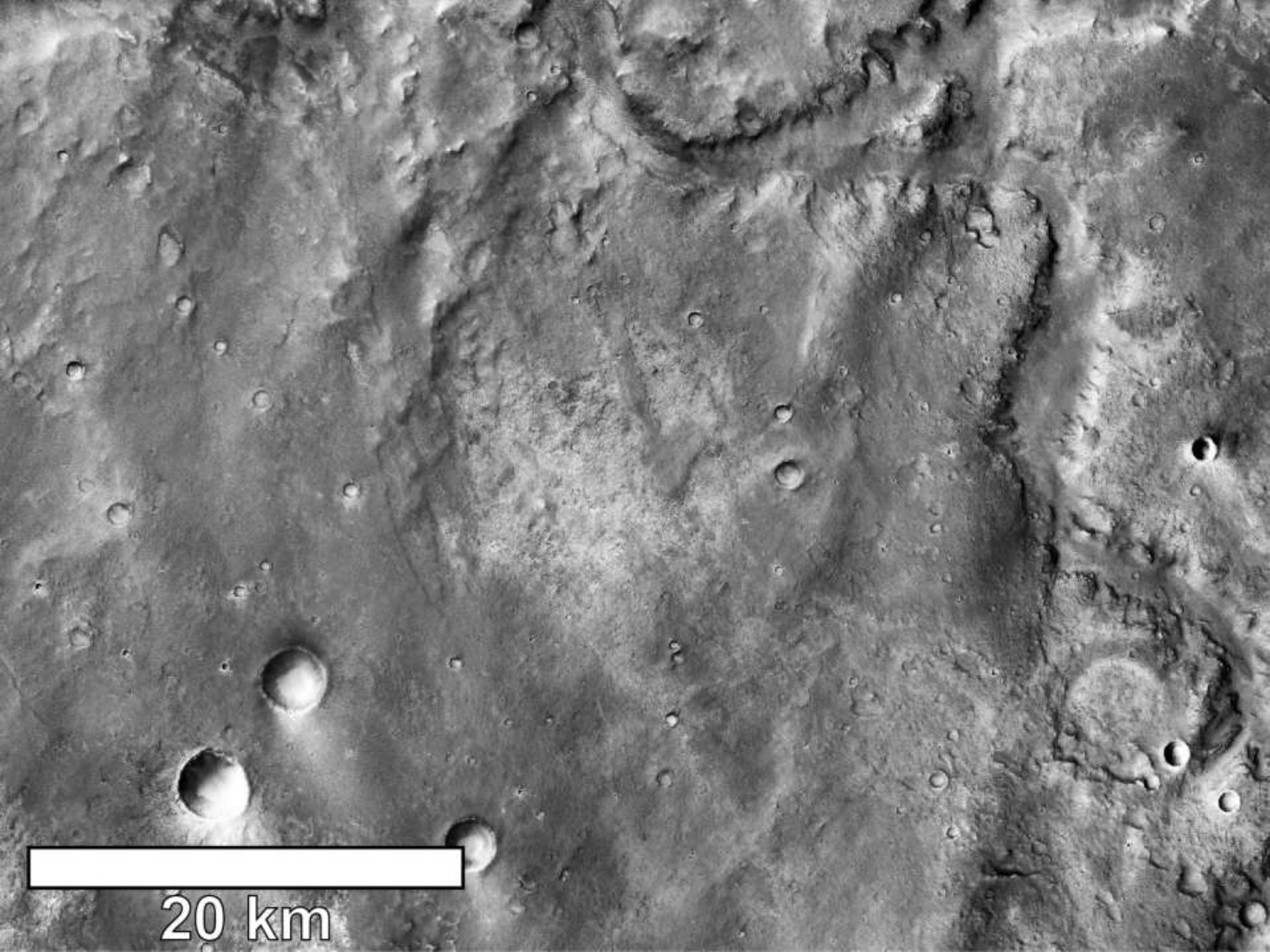
Potential lacustrine origin for stratified smectite clays?

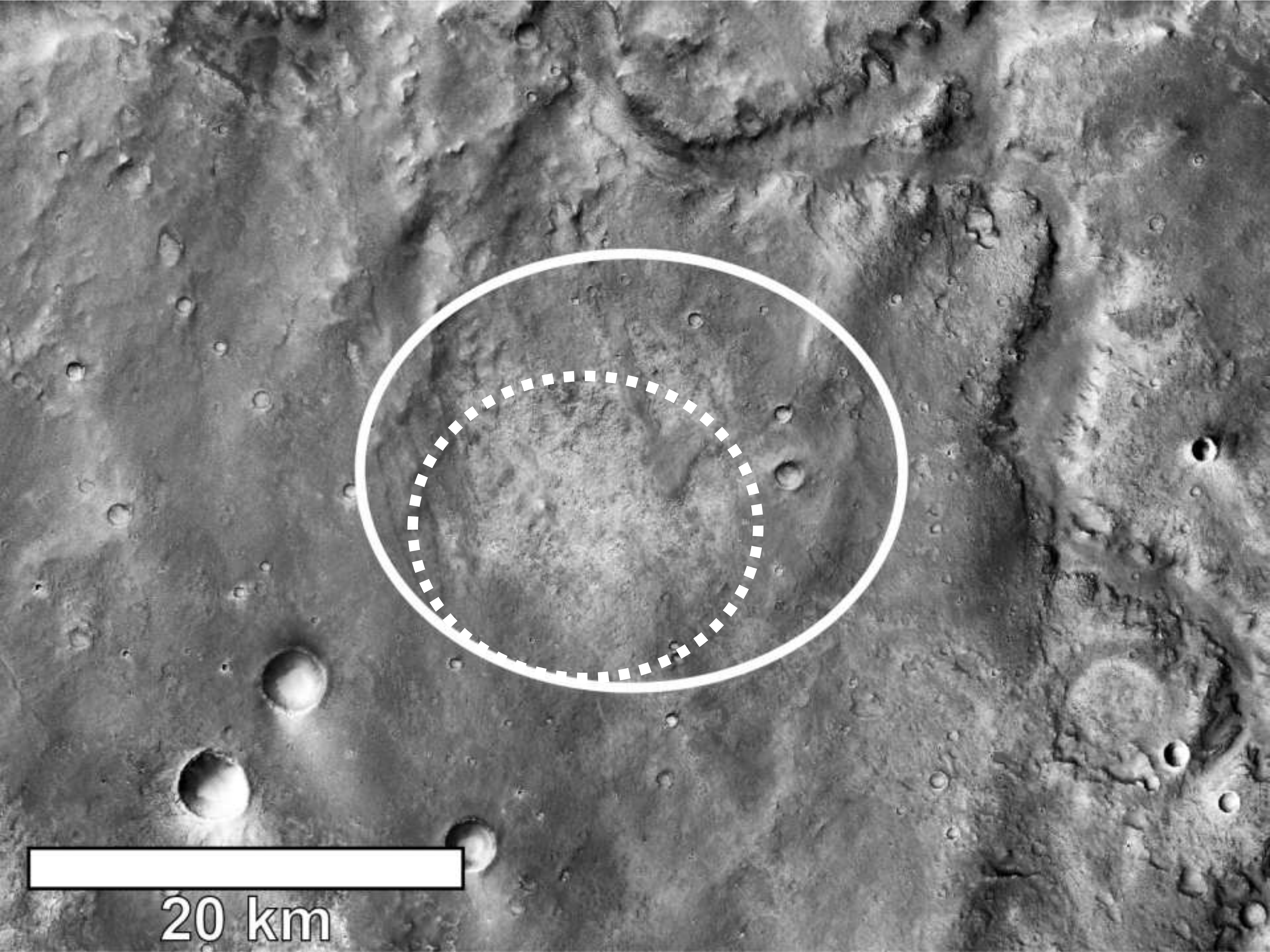
Unique property beneficial to enhanced biopreservation.

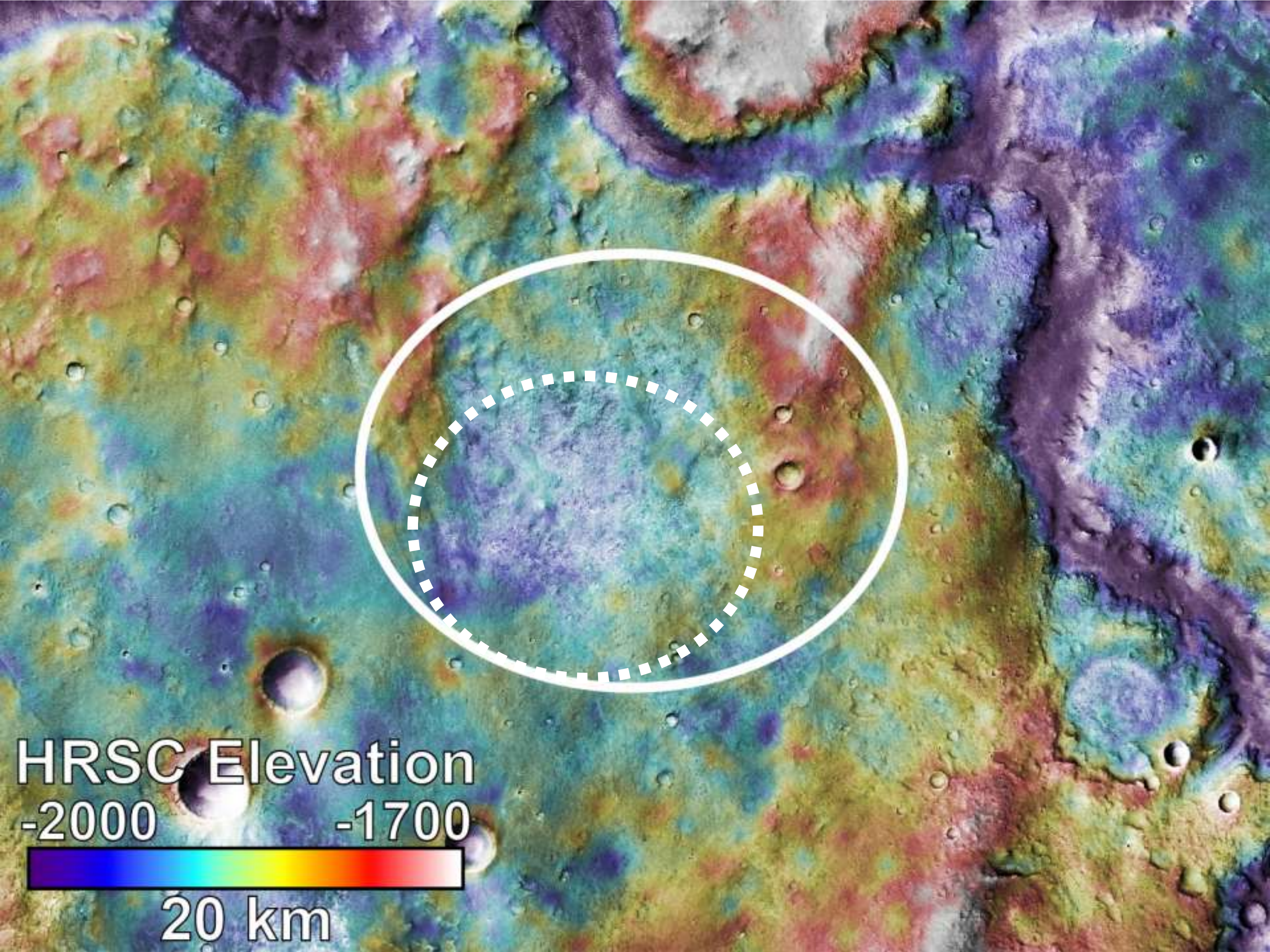
Regional plains unit, Tanaka et al. (2014)

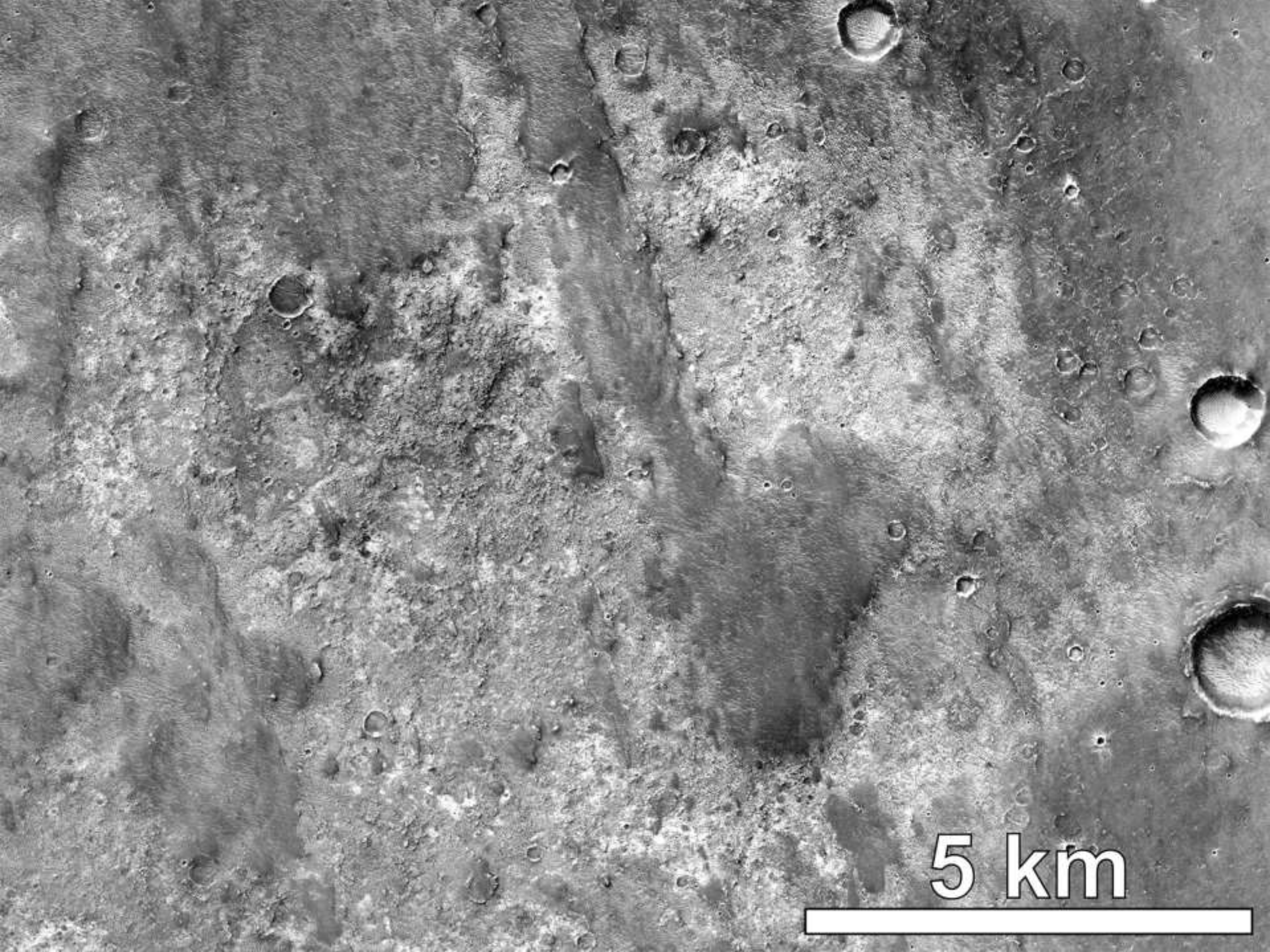


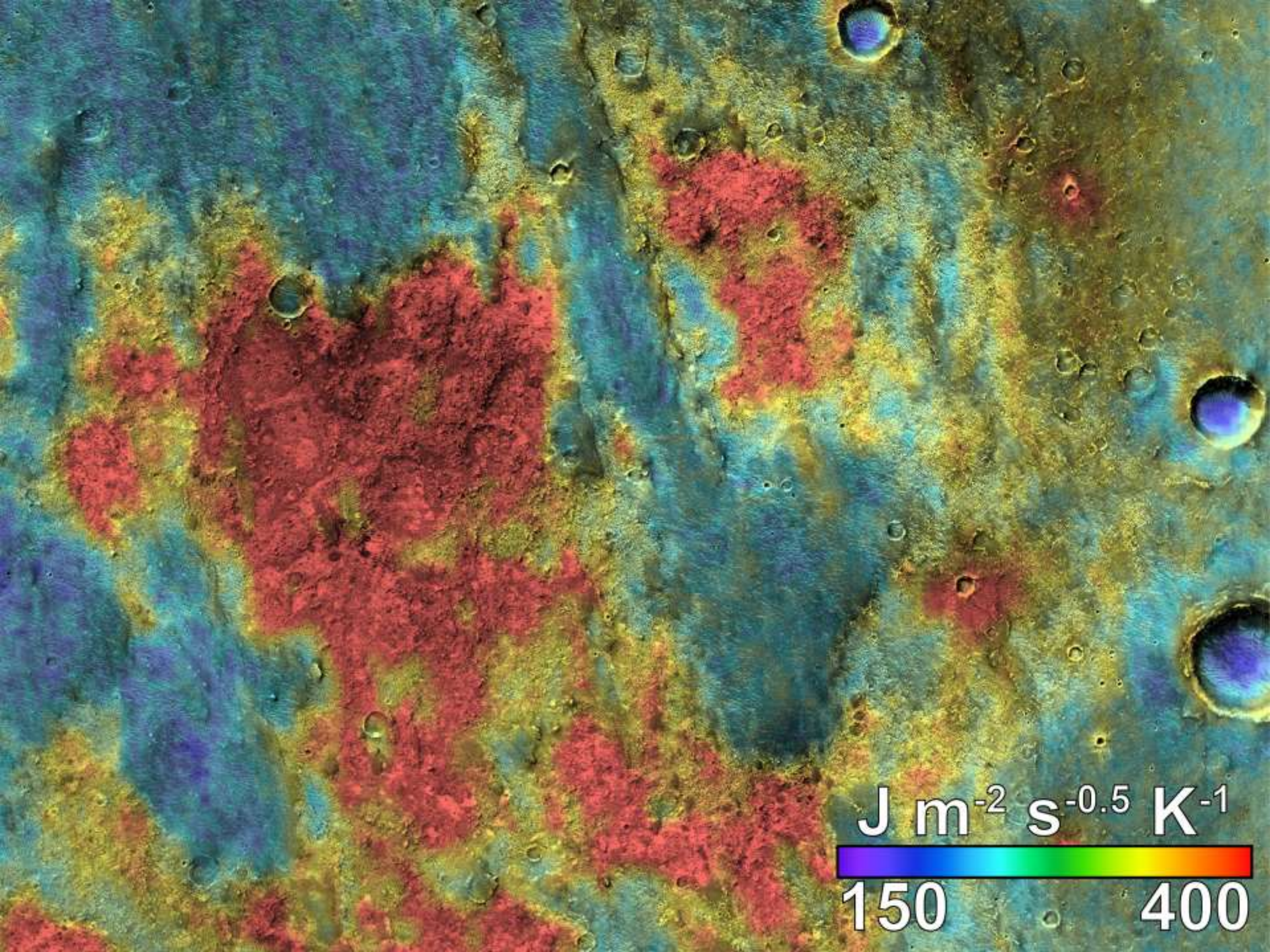

J m-2 s-0.5 K-1
150
400


20 km

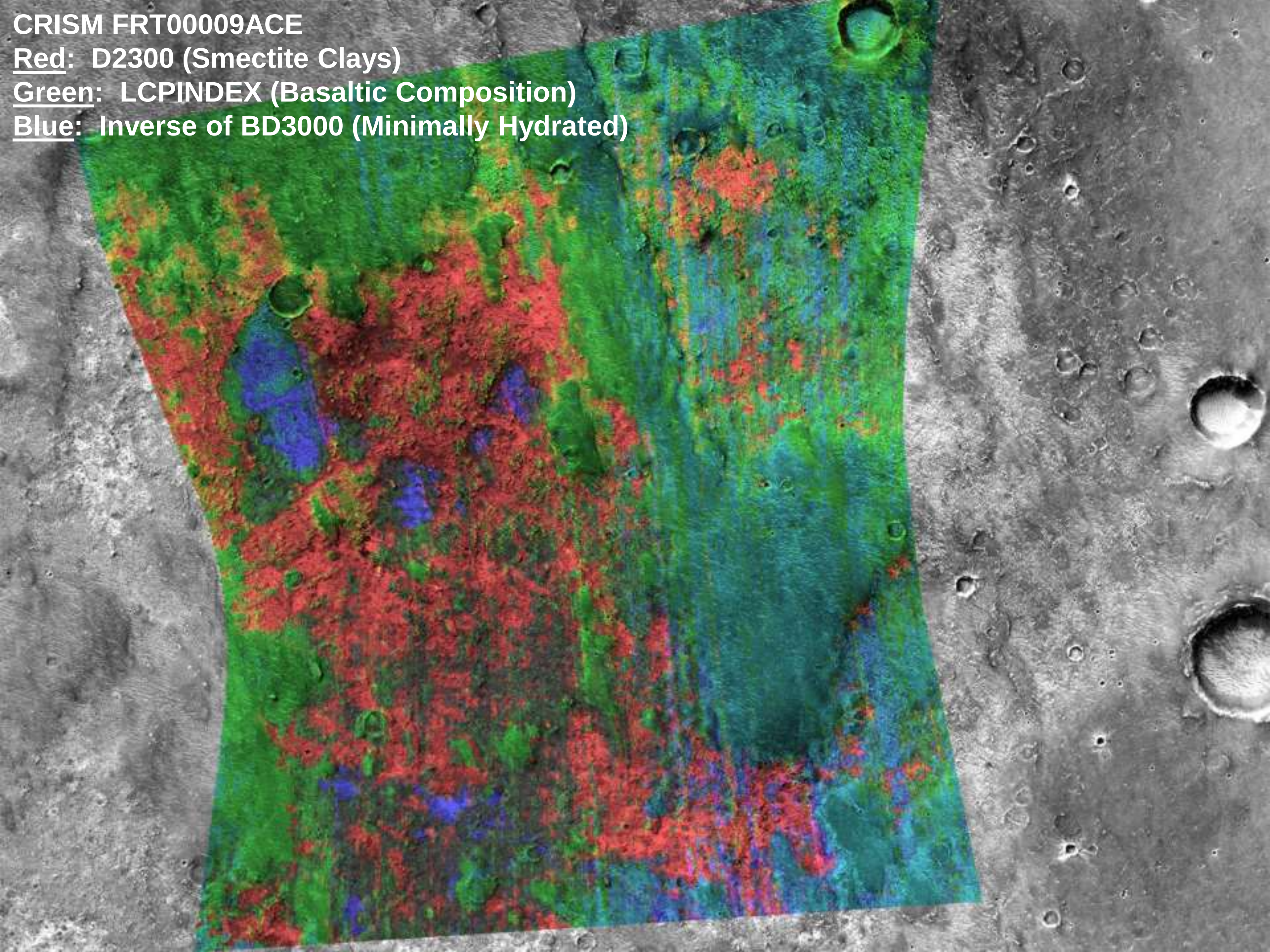

20 km

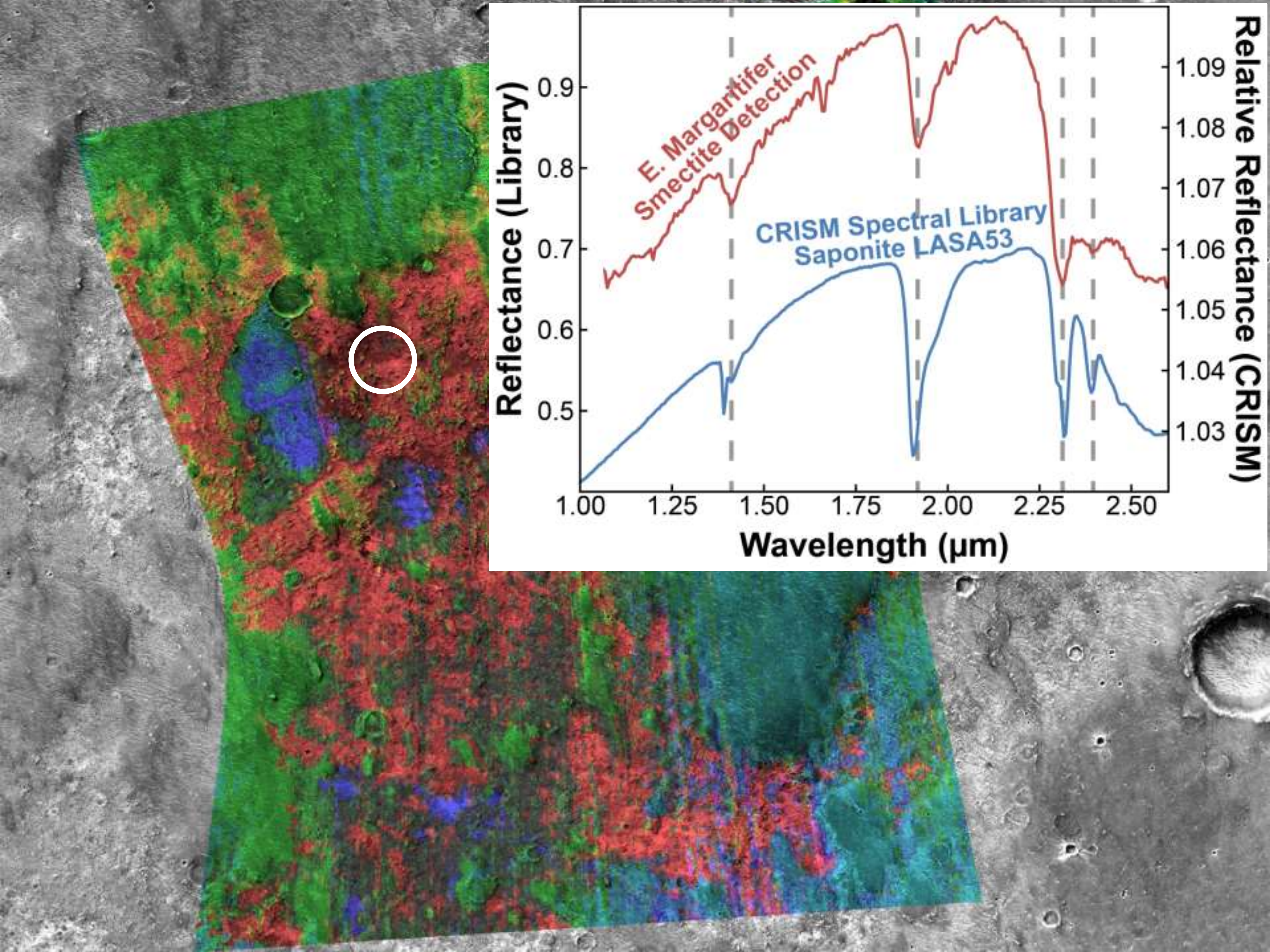

HRSC Elevation
-2000
-1700
20 km


5 km

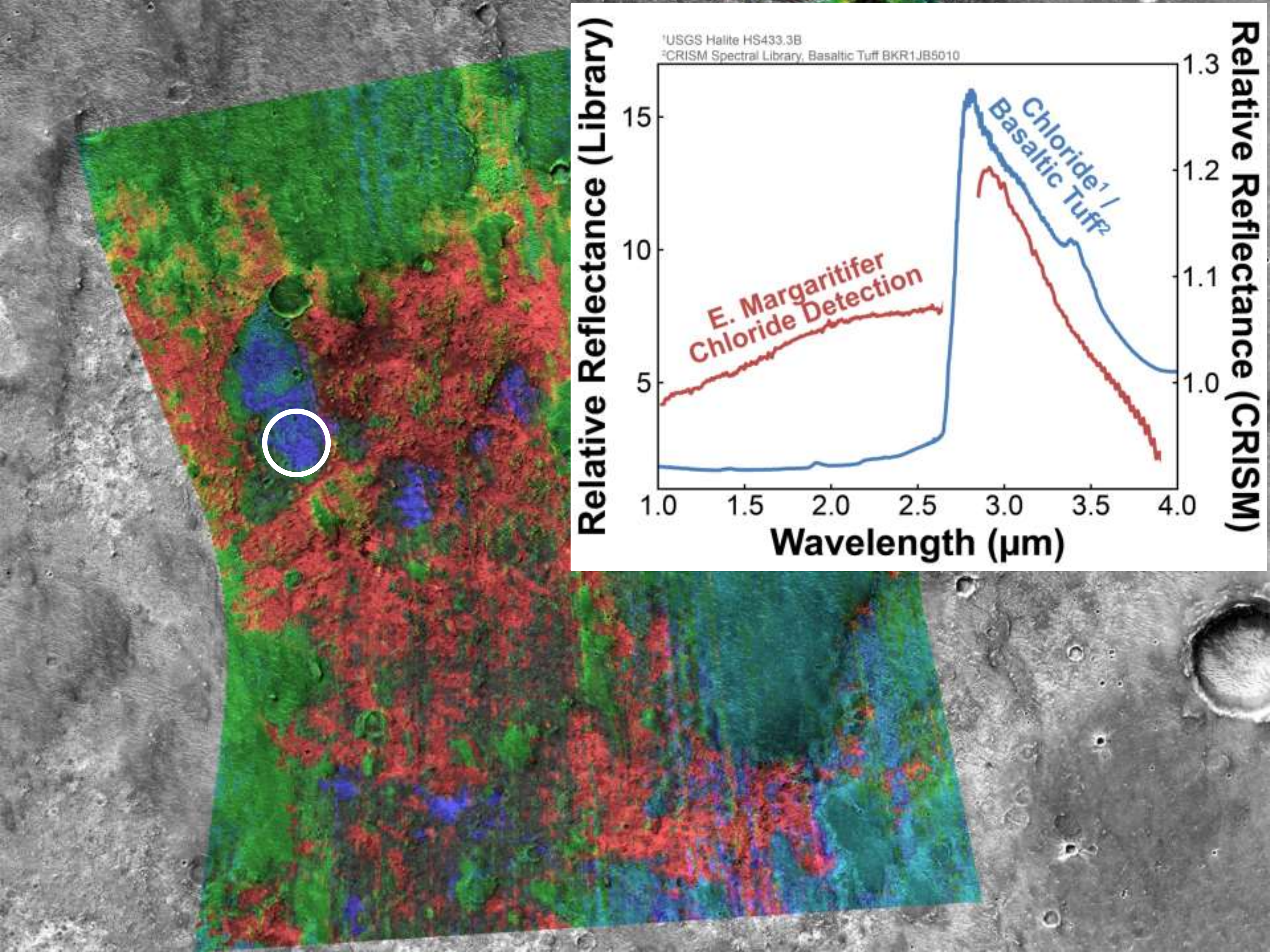

J m^{-2} s$^{-0.5}$ K^{-1}
150
400


THEMIS Decorrelation Stretch
Bands 8-7-5 (RGB, respectively)
I09462029

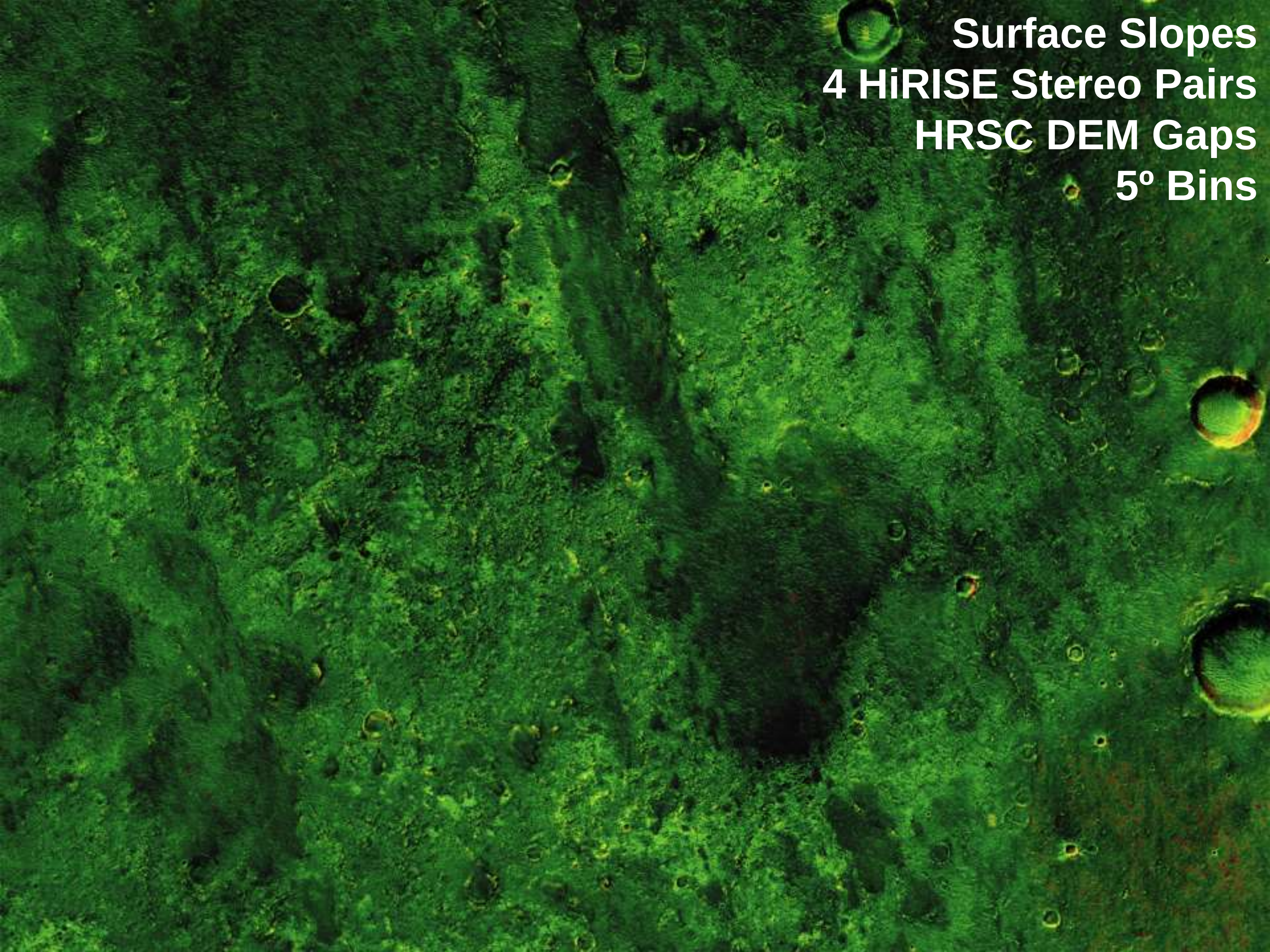

CRISM FRT00009ACE
Red: D2300 (Smectite Clays)
Green: LCPINDEX (Basaltic Composition)
Blue: Inverse of BD3000 (Minimally Hydrated)

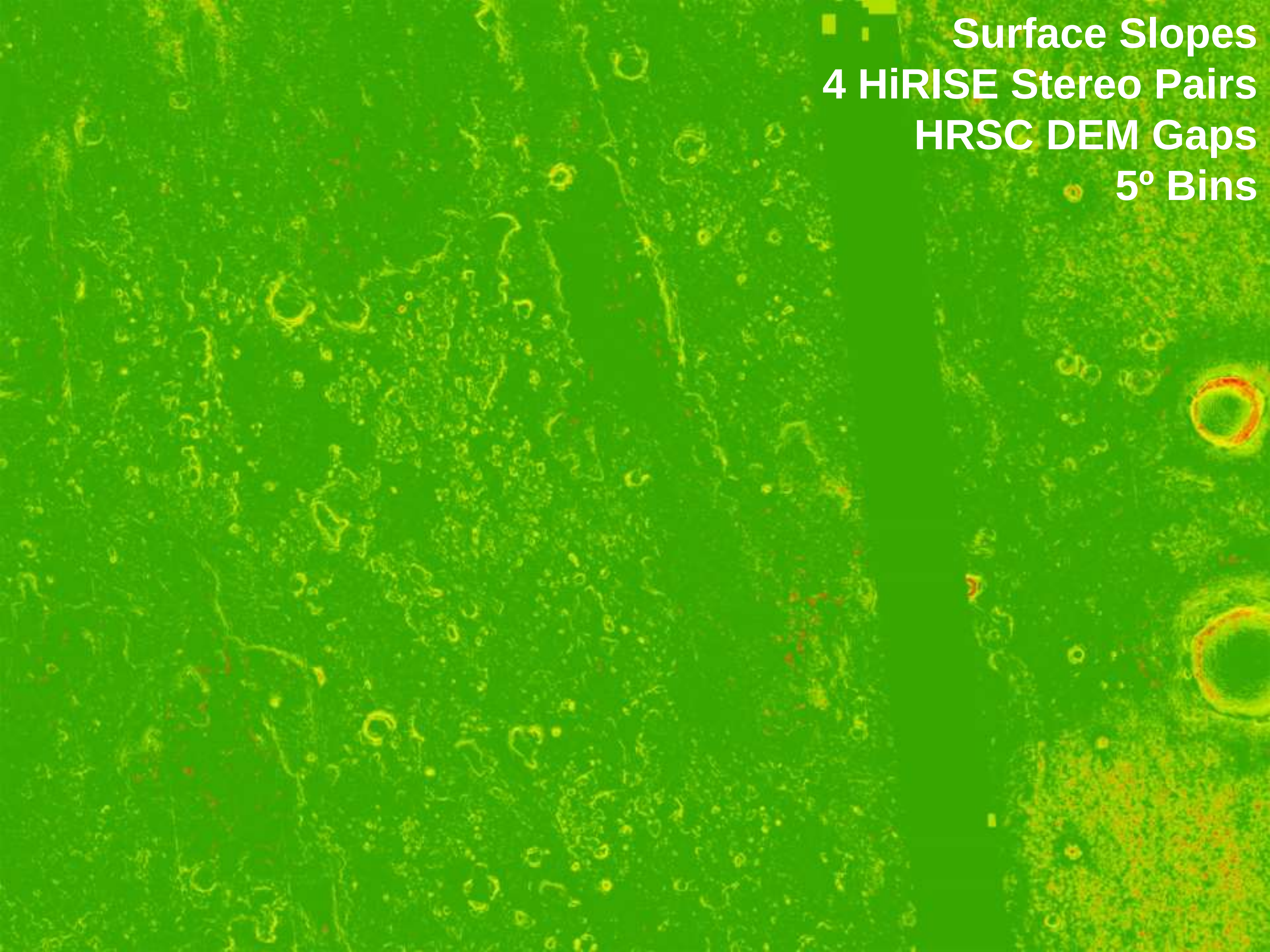


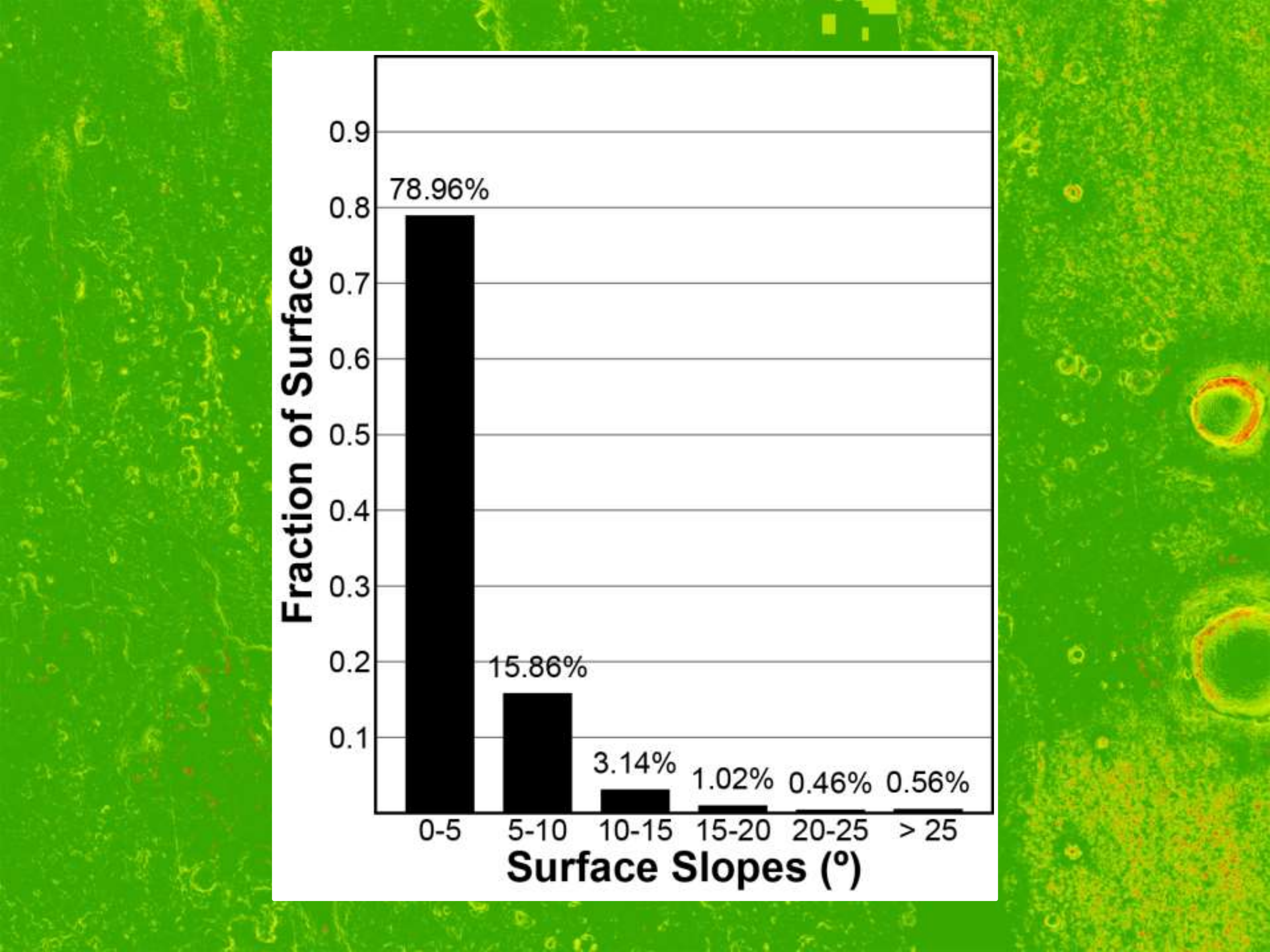
E. Margaritifer
Smectite Detection
CRISM Spectral Library
Saponite LASA53
Reflectance (Library)
Relative Reflectance (CRISM)
Wavelength (μm)
0.5
0.6
0.7
0.8
0.9
1.03
1.04
1.05
1.06
1.07
1.08
1.09
1.00
1.25
1.50
1.75
2.00
2.25
2.50



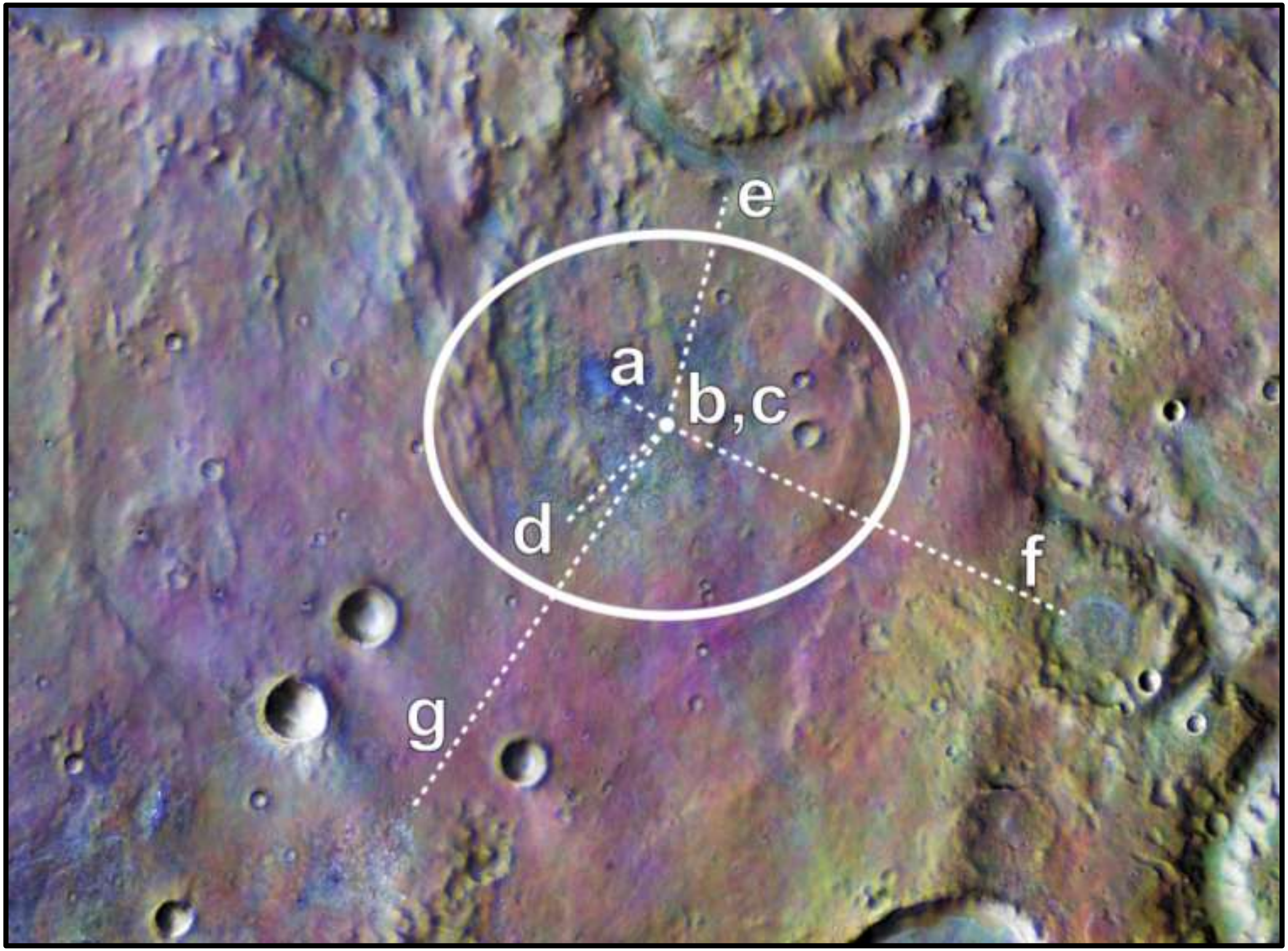
¹USGS Halite HS433.3B
²CRISM Spectral Library, Basaltic Tuff BKR1JB5010
Relative Reflectance (Library)
Relative Reflectance (CRISM)
Wavelength (μm)
E. Margaritifer Chloride Detection
Chloride¹ / Basaltic Tuff²


Surface Slopes
4 HiRISE Stereo Pairs
HRSC DEM Gaps
5º Bins

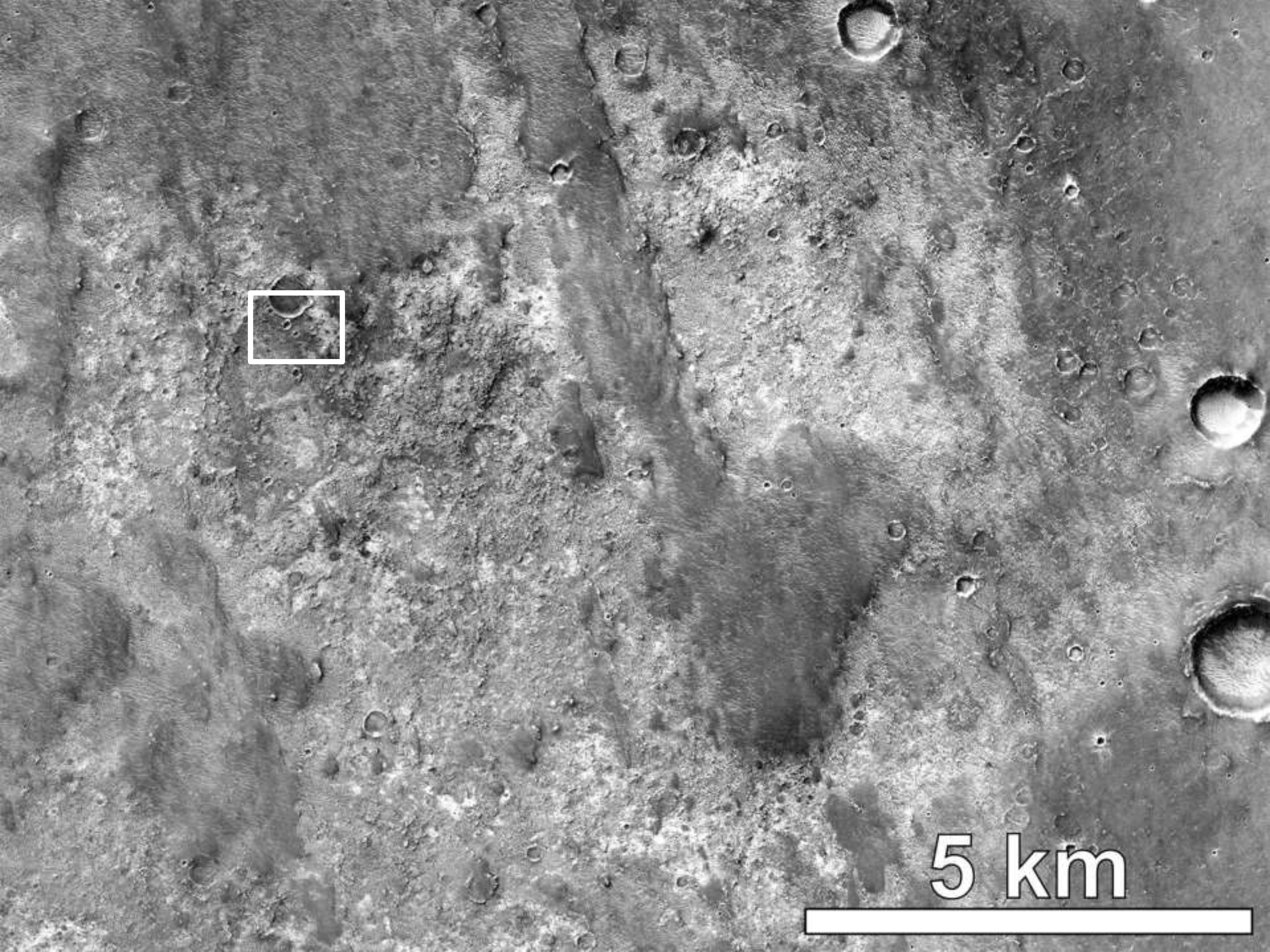

Surface Slopes
4 HiRISE Stereo Pairs
HRSC DEM Gaps
5º Bins

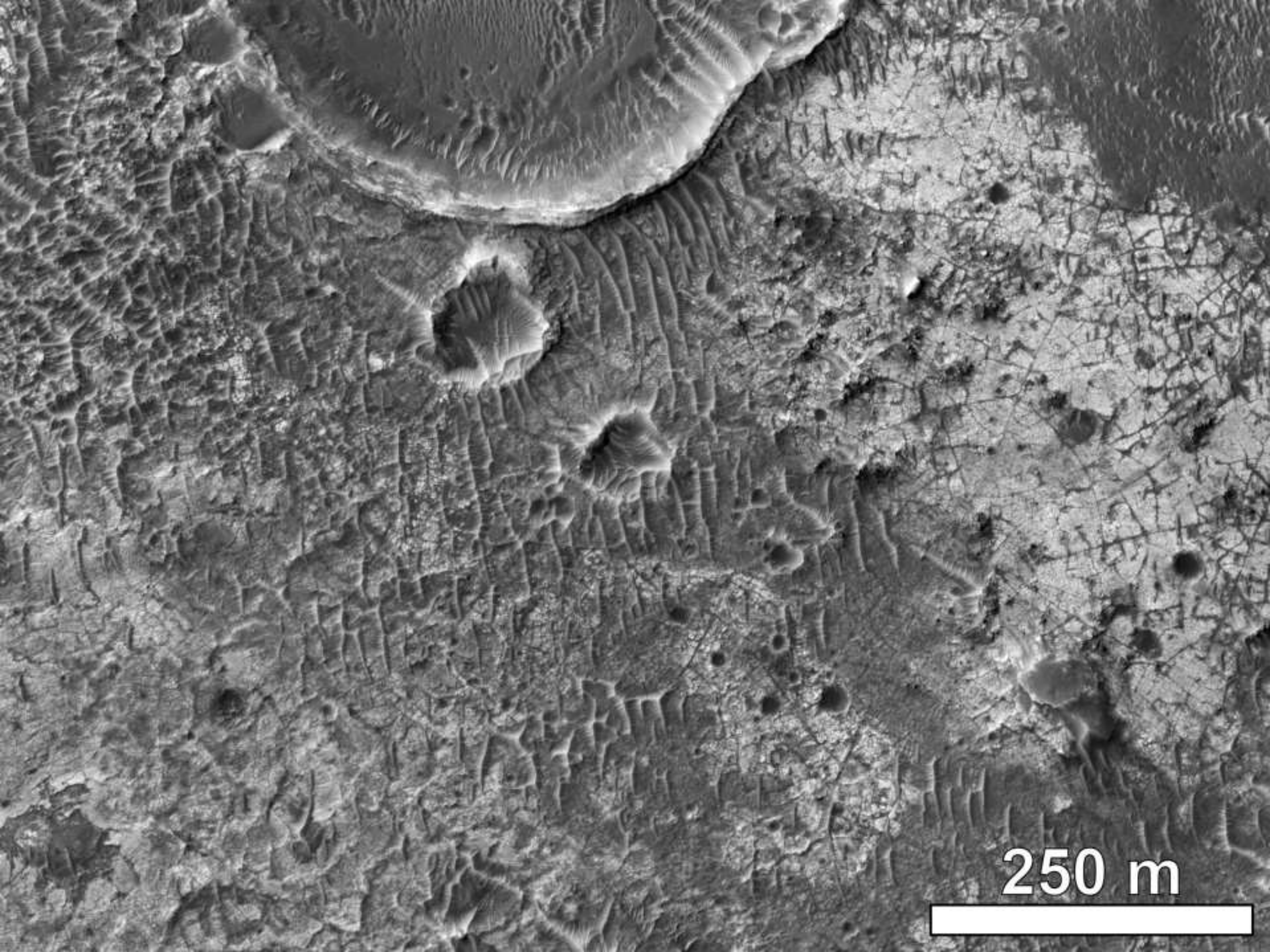

0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Fraction of Surface
78.96%
15.86%
3.14%
1.02%
0.46%
0.56%
0-5
5-10
10-15
15-20
20-25
> 25
Surface Slopes (º)

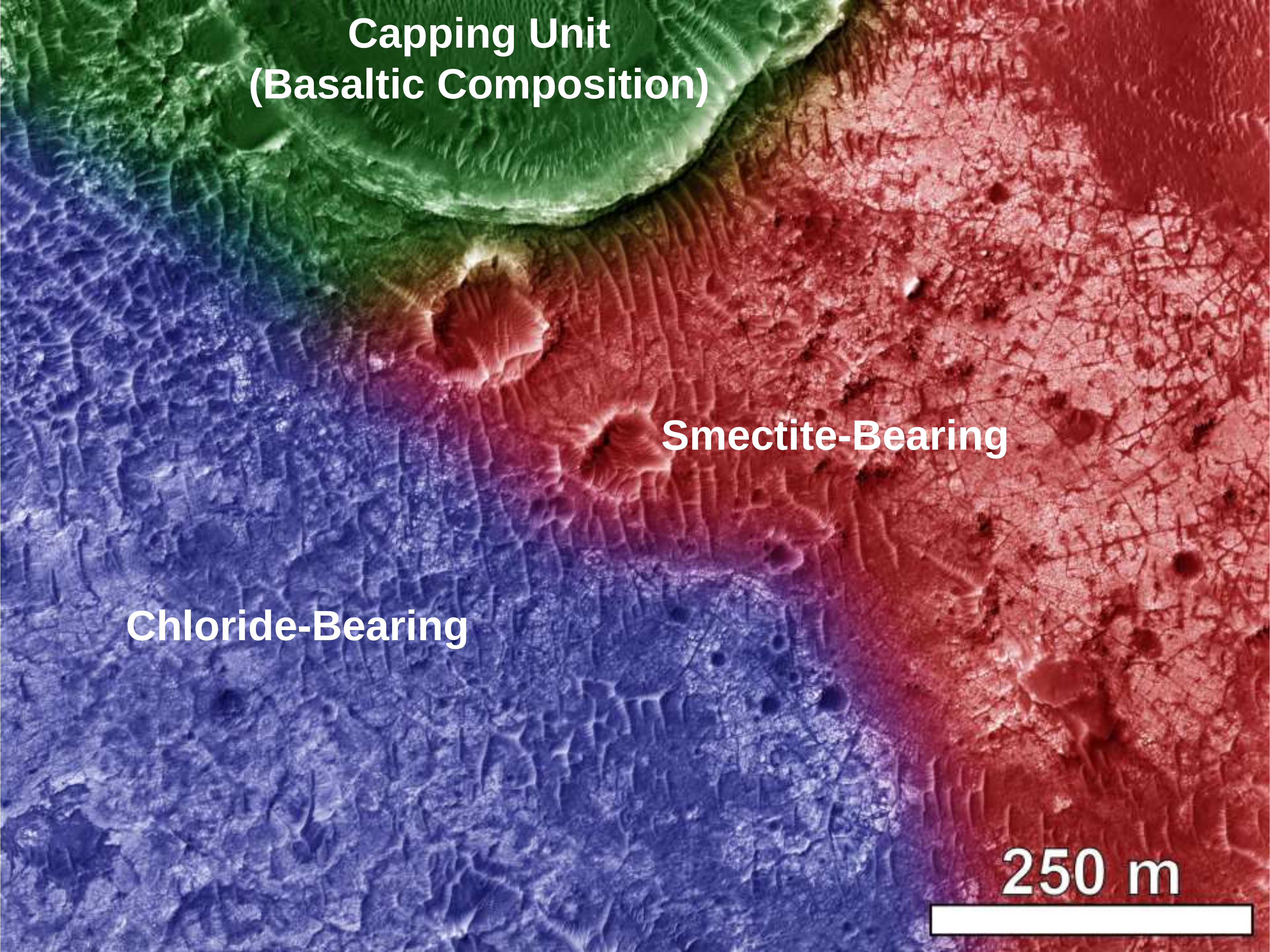
THEMIS Decorrelation Stretch Bands 8-7-5 (RGB, respectively)

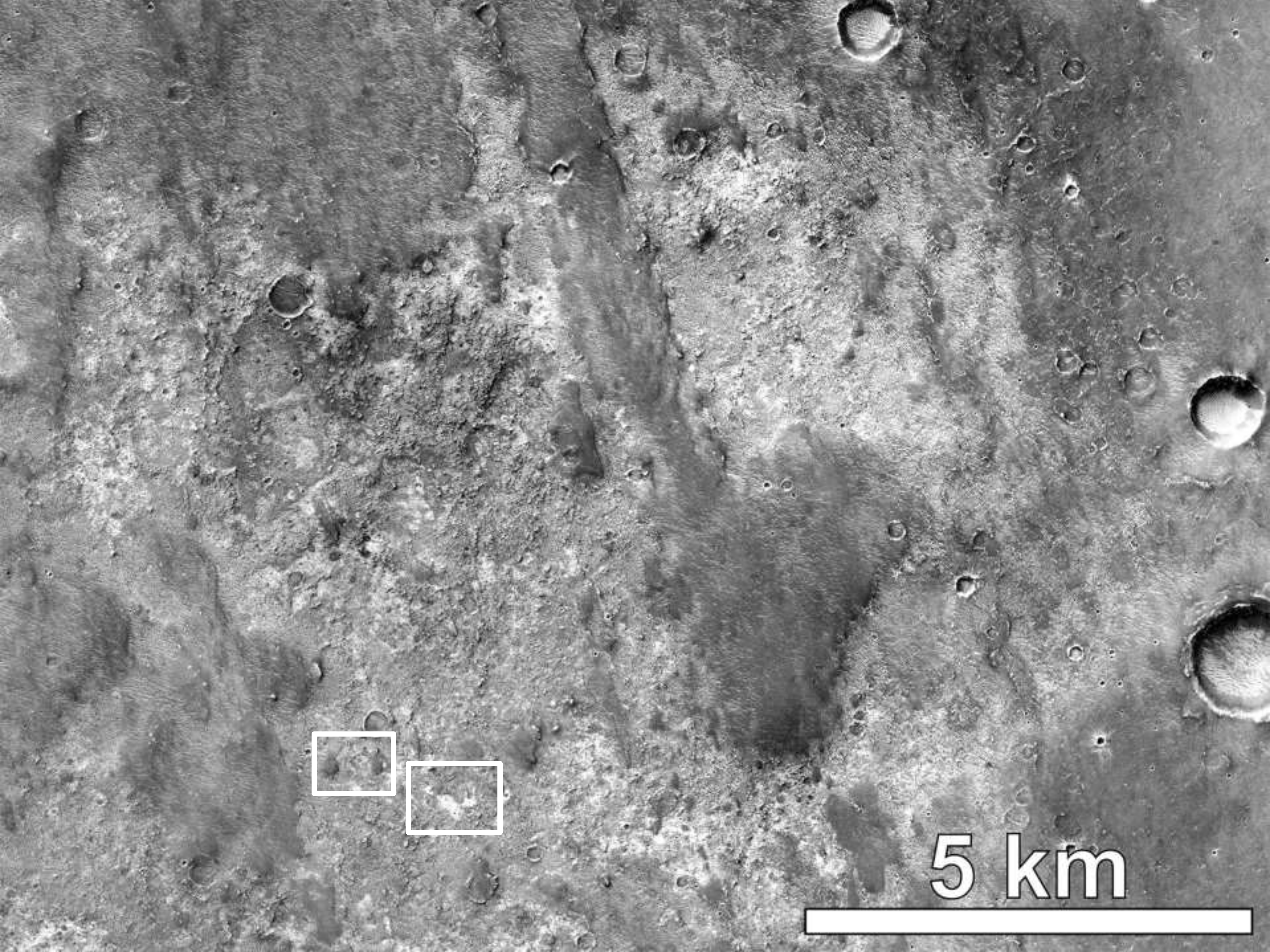


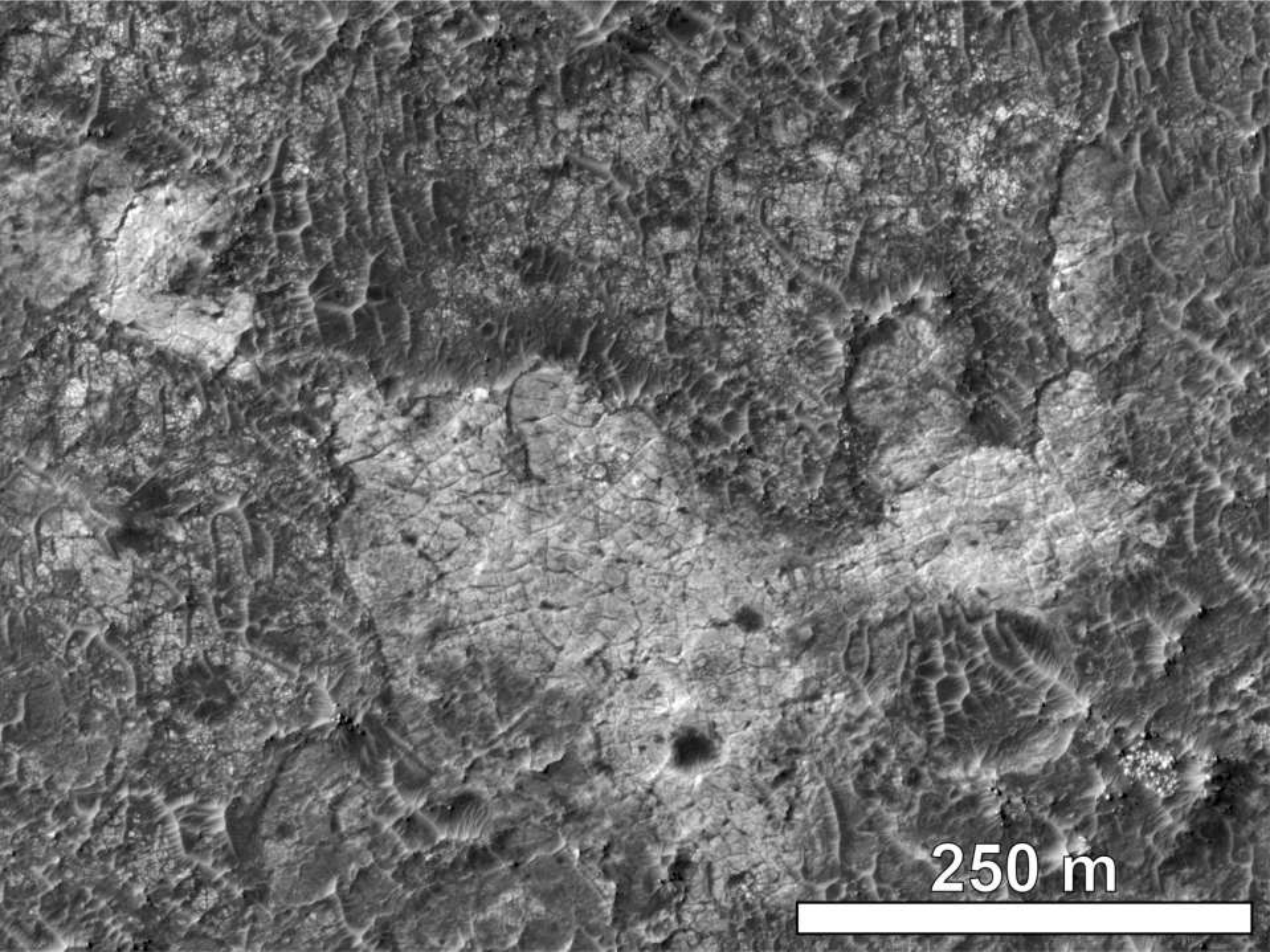
a: Main chloride deposit (***2.6 km***)
b: Fractured smectite-enriched unit (***0.0 km***)
c: Ejecta from 41km crater to north (***0.7 km***)
d: Basaltic capping unit (***7.5 km***)
e: Entry to fluvial channel (***13.2 km***)
f: Crater with chloride floor (***23.0 km***)
g: Distant lacustrine deposits (***24.2 km***)

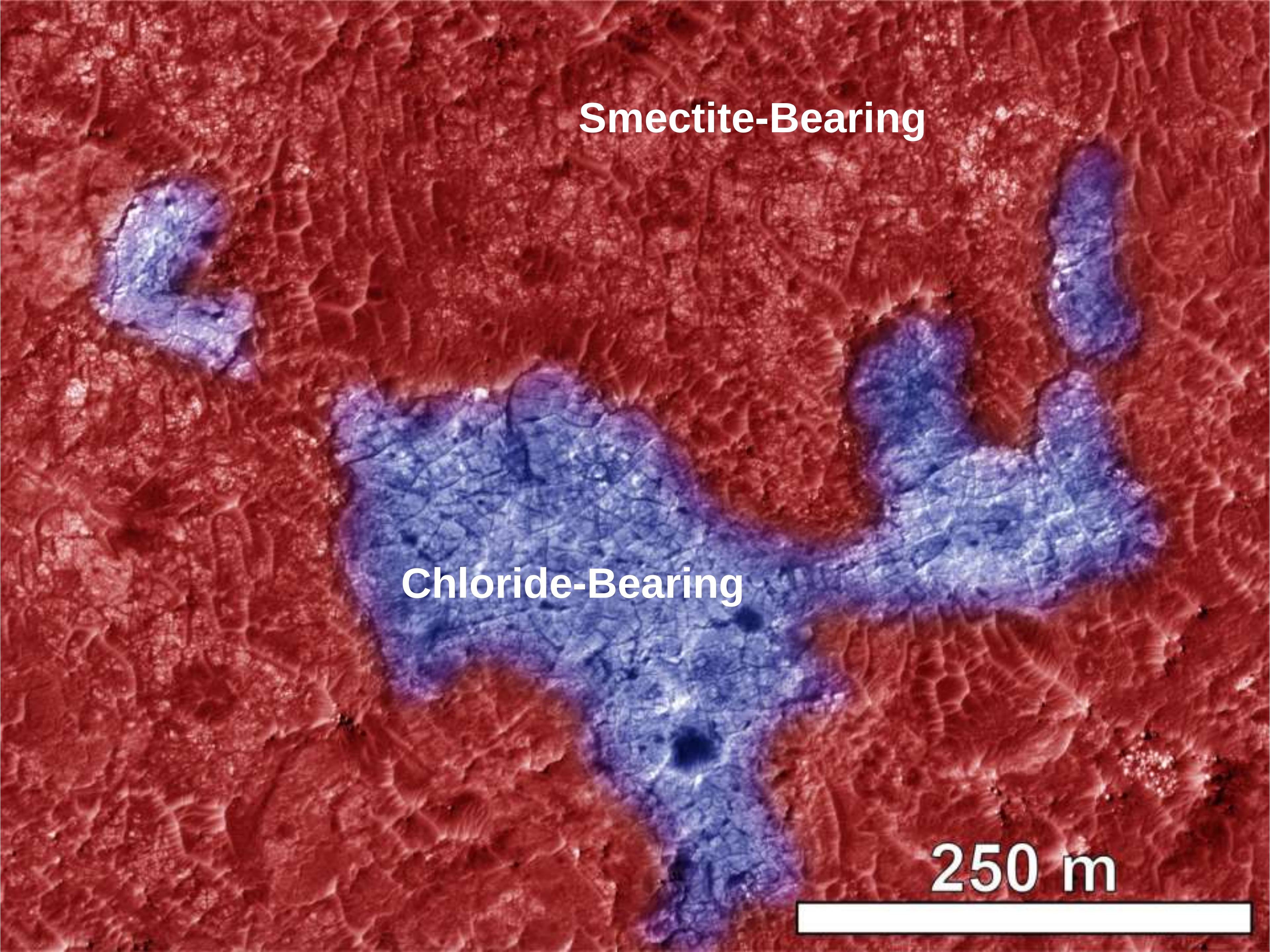

5 km

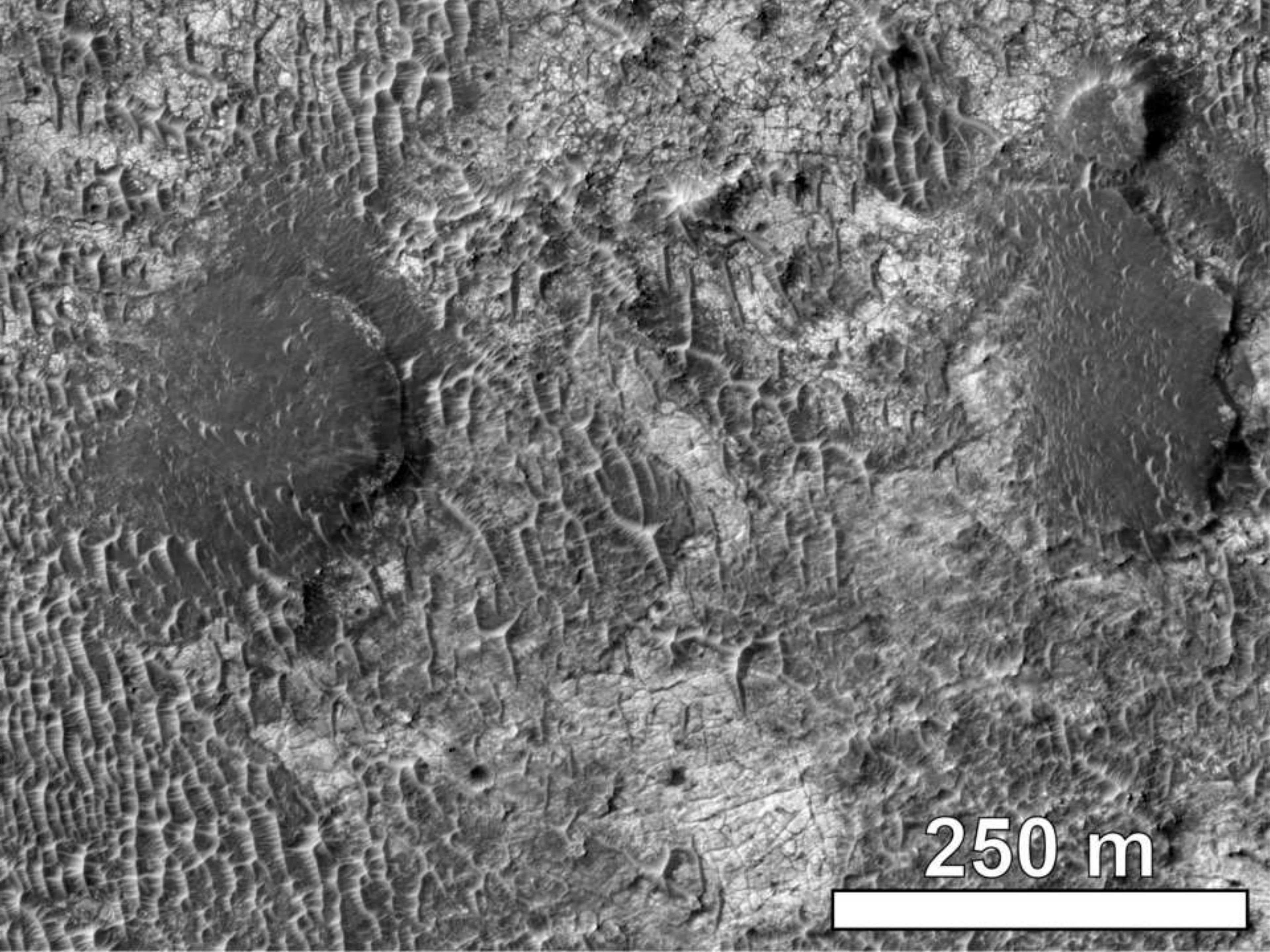

250 m

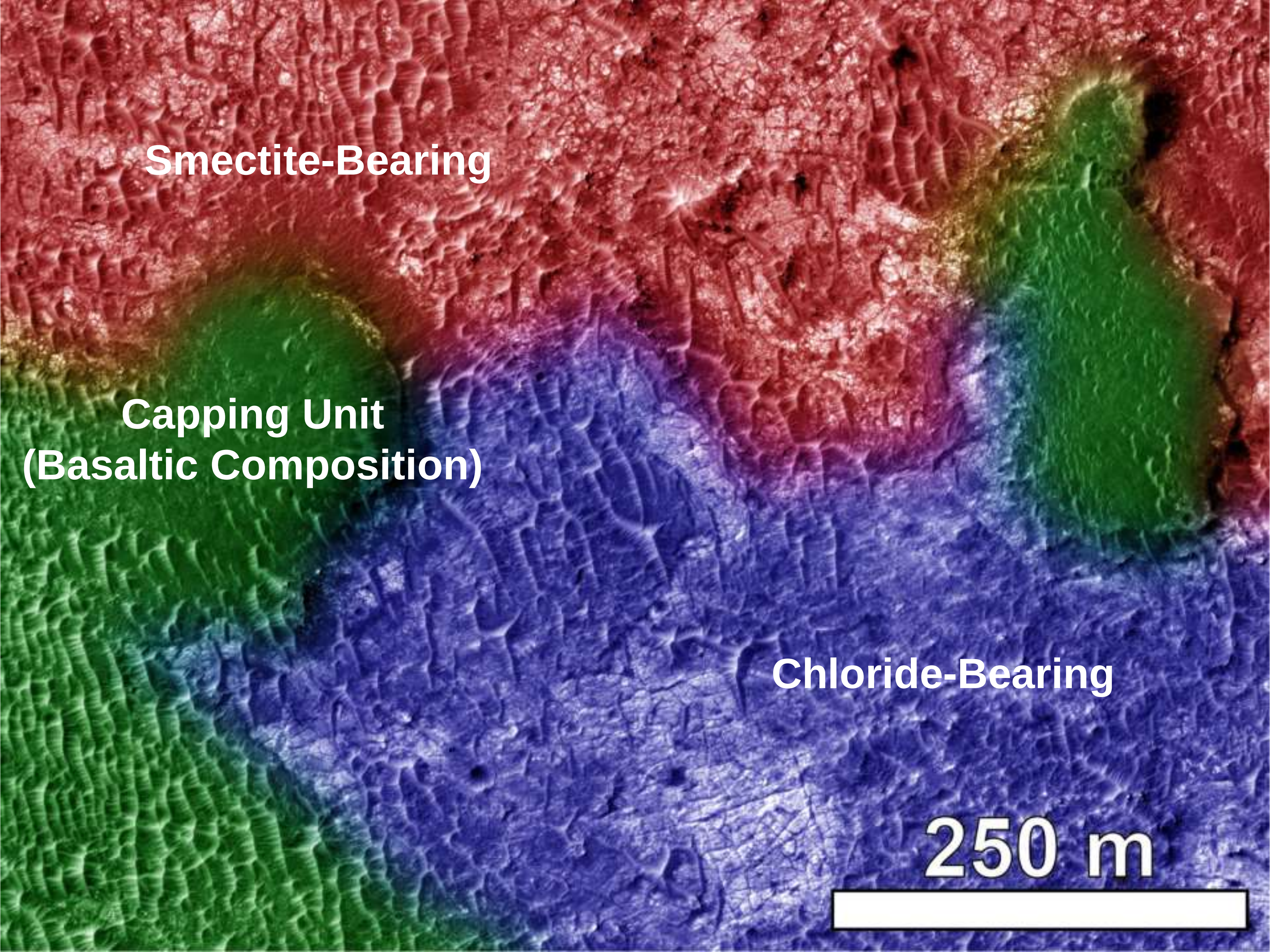

Capping Unit
(Basaltic Composition)
Smectite-Bearing
Chloride-Bearing
250 m


5 km


250 m


Smectite-Bearing
Chloride-Bearing
250 m


250 m


Smectite-Bearing
Capping Unit
(Basaltic Composition)
Chloride-Bearing
250 m

Shorthand	Criteria	AB	CC	EMT
Age Range, Surface Water	Regional geology spanning a significant range of geologic age (wider range is better), and rocks must be present from the period of abundant surface water (TBC: LN, EH)	●	●	●
Water-Rock Interaction	Rocks that preserve evidence of extensive water-rock interaction. Prioritization: 1. Sedimentary rocks deposited in long-lived standing water (lake, ocean); 2. Sustained near-surface hydrothermal conditions (e.g. sinter); 3. Deep, subsurface high-T hydrothermal	●		●
Igneous Diversity	Potential to acquire diverse igneous samples (some diversification strategies: outcrop, float, alluvial fan, conglomerate, ejecta, breccia)		●	●
Crater Calibration	Datable unit with a defined crater retention age (Priority: Hesperian age)		●	●
Deep Ejecta	Ejecta from deep crustal impacts	●	●	●
Low-T Geochem.	Diversity of low-T (0-200º C) geochemical environments (esp. as indicated by diversity of mineralogic detections such as clays, sulfates, carbonates)	●	●	●
Context	Local and/or regional context for samples can be established (some investigations require outcrop-level context, others only regional-level context).	●	●	●
No Metamorph.	Absence of regional metamorphism	●	●	●

E. Margaritifer Terra provides the opportunity to research many topics of interest to the astrobiological and cosmochemical communities.

Objective	Criteria	E. Margaritifer Terra
Objective A	The geologic setting and history of the landing site can be characterized and understood through a combination of orbital and in-situ observations.	Clear stratigraphy exists between alteration phases and other geologic units. New observations will confirm stratigraphic relationship between alteration phases.
Objective B	The landing site offers an ancient habitable environment. Rocks with high biosignature preservation potential are available and are accessible to investigation for astrobiological purposes with instruments onboard the rover.	Lacustrine (evaporitic, detrital?) environment(s?) In situ evaporitic and sedimentary deposits are available for in situ analyses and sampling.
Objective C	The landing site offers an adequate abundance, diversity, and quality of samples suitable for addressing key astrobiological questions if and when they are returned to Earth. The landing site offers an adequate abundance, diversity, and quality of samples suitable for addressing key planetary evolution questions if and when they are returned to Earth.	Salt crystals and brine inclusions are ideal for biomarker preservation. Sedimentary deposits ideal for understanding historical changes in hydrology, climatology, and geology

Exposed geologic history in E. Margaritifer Terra is directly relevant to the M2020 scientific objectives.

E. Margaritifer Chloride Site Summary

- **Site characteristics:**
  - **Coordinates & Elevation**: 5.64º S, 353.87º E **|** -1.22 km MOLA
  - **Thermal Inertia**: 240 ± 35 J m^{-2} $s^{-0.5}$ K^{-1}
  - **Albedo & Dust Index**: 0.12 **|** 0.97
  - **Slopes**: 95% < 10º **|** 0.56% > 25º
- **Easily trafficable ellipse with high density of scientific ROIs**
- **Land-on site, exposed detrital and evaporitic sedimentary deposits, dateable surface(s?), ancient landscape dominated by fluvial/ lacustrine processes**
- **Chlorides and stratified smectites, lacustrine deposits?**
- ***Exceptional* preservation potential – will <u>undoubtedly</u> lead to a better understanding of martian habitability, climate, and aqueous history**

Landing Site Factor	Mars 2020 Mission and Decadal Priority Science Factors																							
	Environmental Setting for Biosignature Preservation and Taphonomy of Organics								Type 1A & 1B Samples: Aqueous Geochemical Environments indicated by Mineral Assemblages									Type 2 Samples: Igneous		Context: Martian History Sampled, Timing Constraints				
	Deltaic or Lacustrine (perennial)	Lacustrine (evaporitic)	Hydrothermal (<100°C) surface	Hydrothermal (<100°C) subsurface	Pedogenic	Fluvial/Alluvial	No diagenetic overprinting	Recent exposure	Crustal phyllosilicates	Sedimentary clays	Al clays in stratigraphy	Carbonate units	Chloride sediments	Sulfate sediments	Acid sulfate units	Silica deposits	Ferric Ox./Ferrous clays	Igneous unit (e.g, lava flow, pyroclastic, intrusive)	2nd Igneous unit	Pre- or Early-Noachian Rocks	Oldest stratigraphic constraint	Youngest stratigraphic constraint	Stratigrapy of units well-defined	Dateable surface, volcanic (unmodified crater SFD)
E Margaritifer Chloride	~	●				○	●			●			●					●	~		MN	?	●	●

Dendritic fluvial channel to north and east of ROIs. Channel dated to Late Noachian (Fassett & Head, 2008)

Spectrally confirmed in VNIR, TIR. High abundances required (> 25% by weight)

Evaporation of solute-rich solution. On Earth, entomb brine inclusions and biosignatures.

Stratified smectite deposits present throughout region.

Unobscured contacts, clear cross-cutting rel.

Ejecta deposits, Noachian plains material.

Potential lacustrine origin for stratified smectite clays?

Unique property beneficial to enhanced biopreservation.

Regional plains unit, Tanaka et al. (2014)

		Landing Site Factor	EMT	Comments
Mars 2020 Mission and Decadal Priority Science Factors	Environmental Setting for Biosignature Preservation and Taphonomy of Organics	Deltaic or Lacustrine (perennial)	~	Potential lacustrine origin for underlying smectite clays (Glotch et al. 2010; Davila et al., 2011)?
		Lacustrine (evaporitic)	●	Evaporation of solute-rich solution. On Earth, entomb brine inclusions and biosignatures (e.g. Farmer & Des Marais, 1999).
		Hydrothermal (<100°C) surface		
		Hydrothermal (<100°C) subsurface		
		Pedogenic		
		Fluvial/Alluvial	○	Dendritic fluvial channel to north and east of ROIs. Channel dated to Late Noachian (Fassett & Head, 2008)
		No diagenetic overprinting	●	Unique property beneficial to enhanced biopreservation (Huval & Vreeland, 1991; Knauth, 1993; Fredrickson et al., 1997).
		Recent exposure		
	Type 1A & 1B Samples: Aqueous Geochemical Environments indicated by Mineral Assemblages	Crustal phyllosilicates		
		Sedimentary clays	●	Layered smectite deposits present throughout region.
		Al clays in stratigraphy		
		Carbonate units		
		Chloride sediments	●	Spectrally confirmed in VNIR, TIR (e.g., Osterloo et al., 2008, 2010; Glotch et al., 2010). High abundances required (> 25% by weight) (Murchie et al., 2009).
		Sulfate sediments		
		Acid sulfate units		
		Silica deposits		
		Ferric Ox./Ferrous clays		
	Type 2 Samples: Igneous	Igneous unit	●	Ejecta deposits, Noachian plains material with indurated capping unit of unaltered basaltic composition (Tanaka et al., 2014).
		2nd Igneous unit	~	
	Context: Martian History Sampled, Timing Constraints	Pre- or Early-Noachian Rocks		
		Oldest stratigraphic constraint	MN	Regional plains unit (Tanaka et al., 2014), fluvial channel (Fassett & Head, 2008)
		Youngest stratigraphic constraint	?	
		Stratigrapy of units well-defined	●	Unobscured contacts, stratigraphic relationships observable at the rover-scale.
		Dateable surface(s)	●	Ejecta, indurated mantling surface, confirming channel formation age (Fassett & Head, 2008)