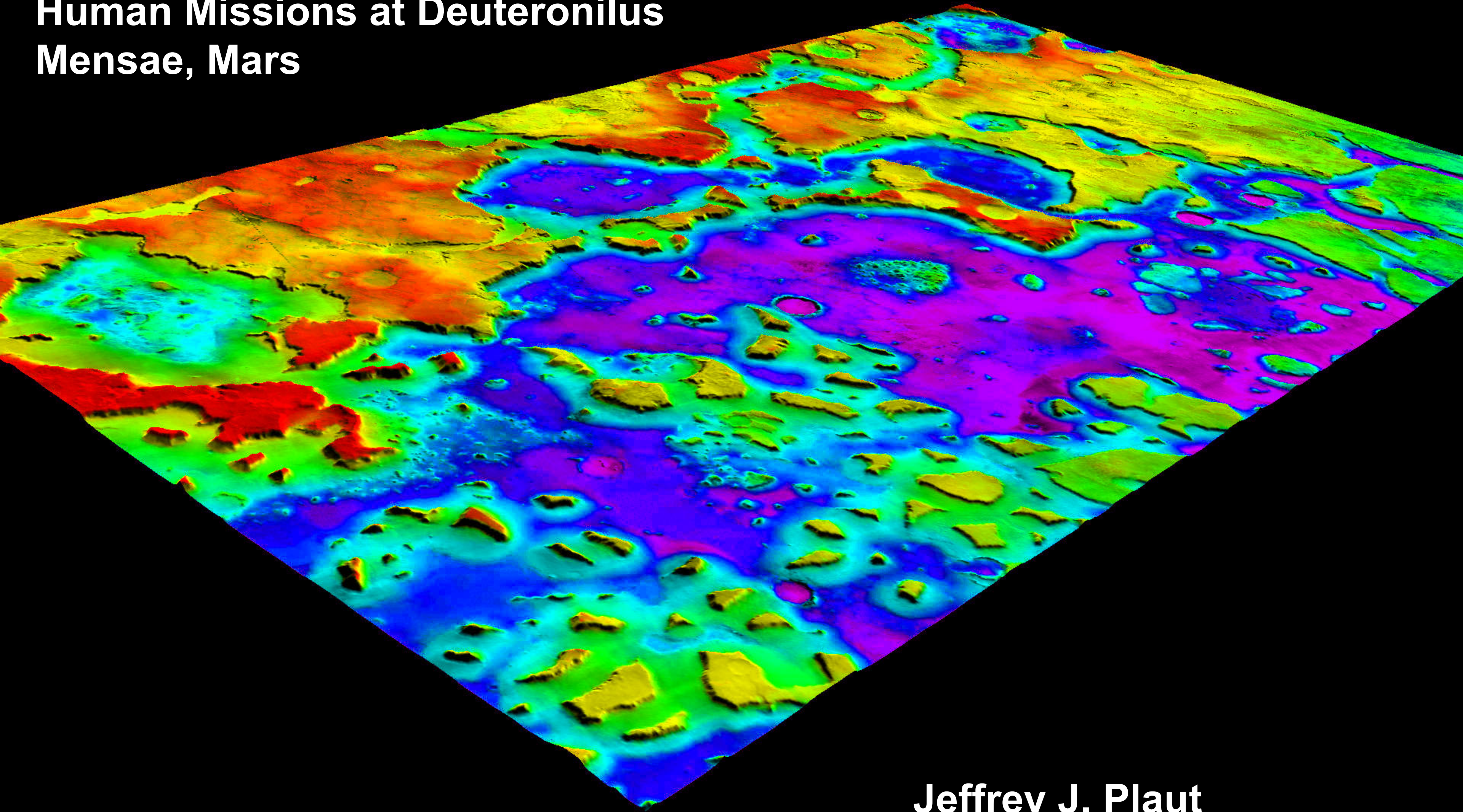
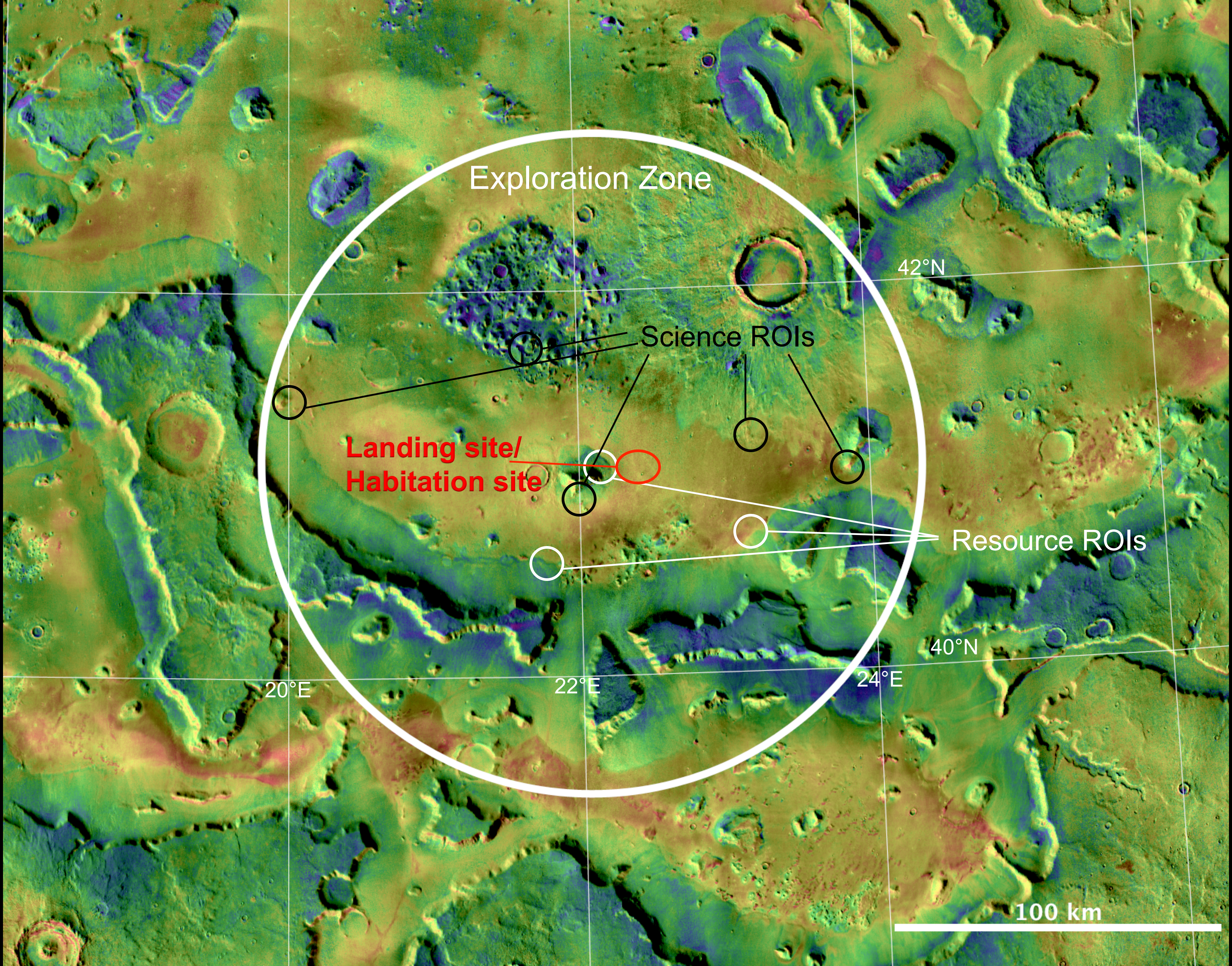
A Resource-rich, Scientifically Compelling Exploration Zone for Human Missions at Deuteronilus Mensae, Mars



Jeffrey J. Plaut
Jet Propulsion Laboratory / California Institute of Technology



Exploration Zone
Science ROIs
Landing site/
Habitation site
Resource ROIs
42°N
40°N
20°E
22°E
24°E
100 km

Science 21 November 2008:

Radar Sounding Evidence for Buried Glaciers in the Southern Mid-Latitudes of Mars

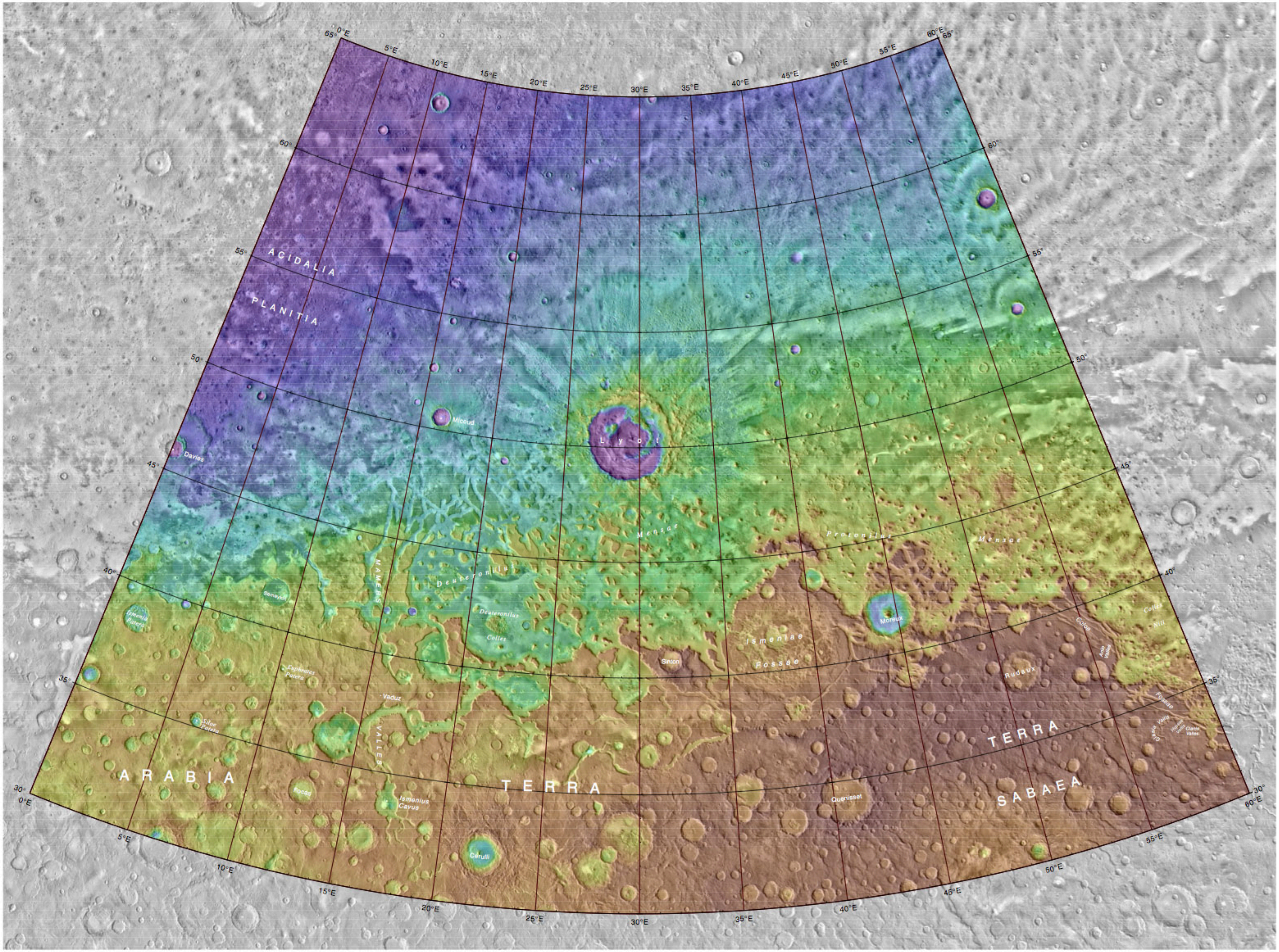
John W. Holt,[1]* Ali Safaeinili,[2] Jeffrey J. Plaut,[2] James W. Head,[3] Roger J. Phillips,[4] Roberto Seu,[5] Scott D. Kempf,[1] Prateek Choudhary,[1] Duncan A. Young,[1] Nathaniel E. Putzig,[4] Daniela Biccari,[5] Yonggyu Gim[2]

GEOPHYSICAL RESEARCH LETTERS, VOL. 36, L02203, doi:10.1029/2008GL036379, 2009

Radar evidence for ice in lobate debris aprons in the mid-northern latitudes of Mars

Jeffrey J. Plaut,[1] Ali Safaeinili,[1] John W. Holt,[2] Roger J. Phillips,[3] James W. Head III,[4] Roberto Seu,[5] Nathaniel E. Putzig,[3] and Alessandro Frigeri[6]

“Present-day thick ice deposits at the mid-latitudes of Mars should be considered as targets for future landed missions. If accessible, the ice could be analyzed for climatological indicators or biomarkers, and potentially be utilized as a resource.”



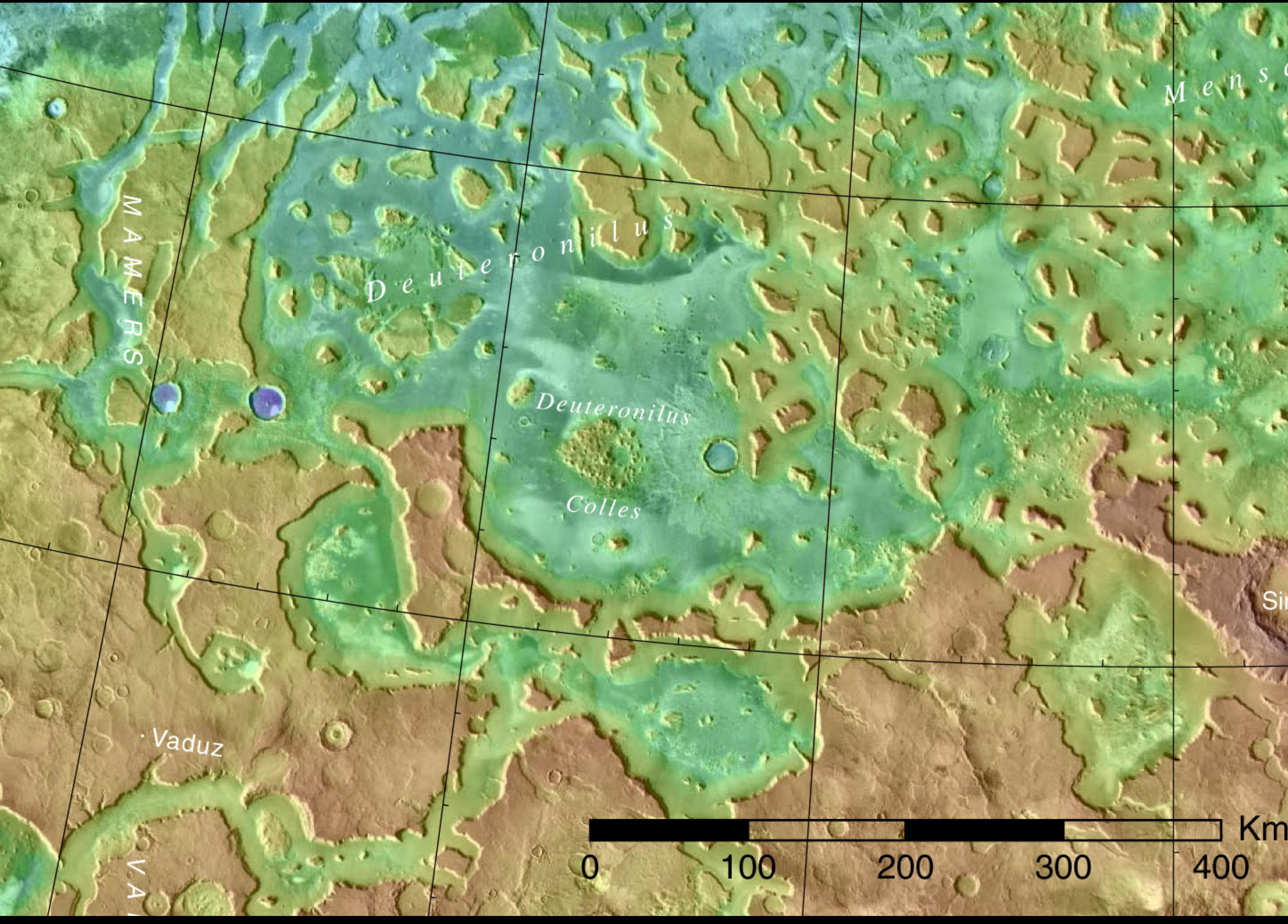
Projection: Lambert Conformal Conic
Datum: Mars 2000 Sphere
Central Meridian: 30.0
Standard Parallel 1: 36.2
Standard Parallel 2: 59.5
Scale Factor: 1.0
Latitude of Origin: 0.0

MOLA Elevation (m)
High : 1205
Low : -7013

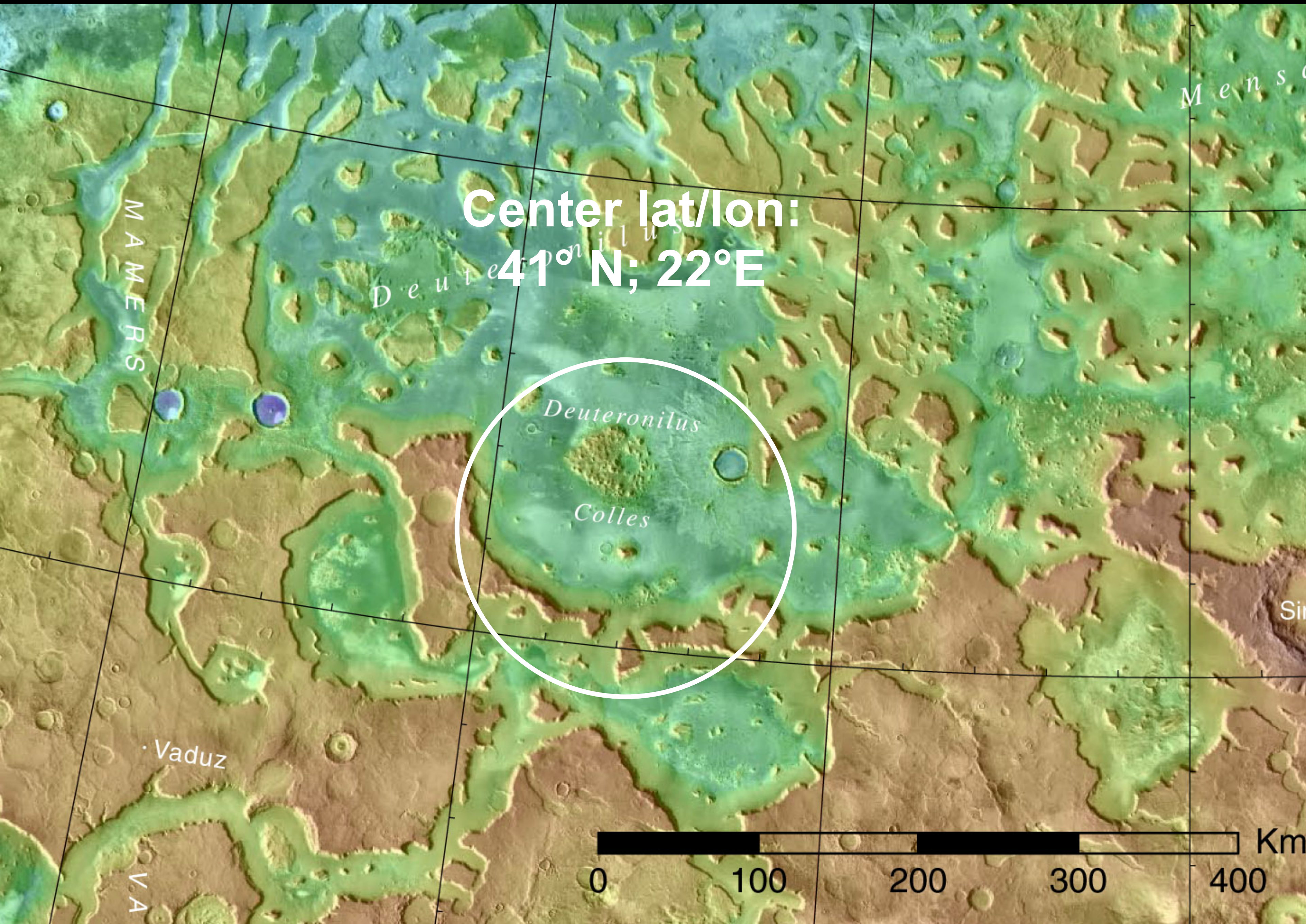
0 100 200 300 400 Km
Scale 1:5,000,000 at standard parallel

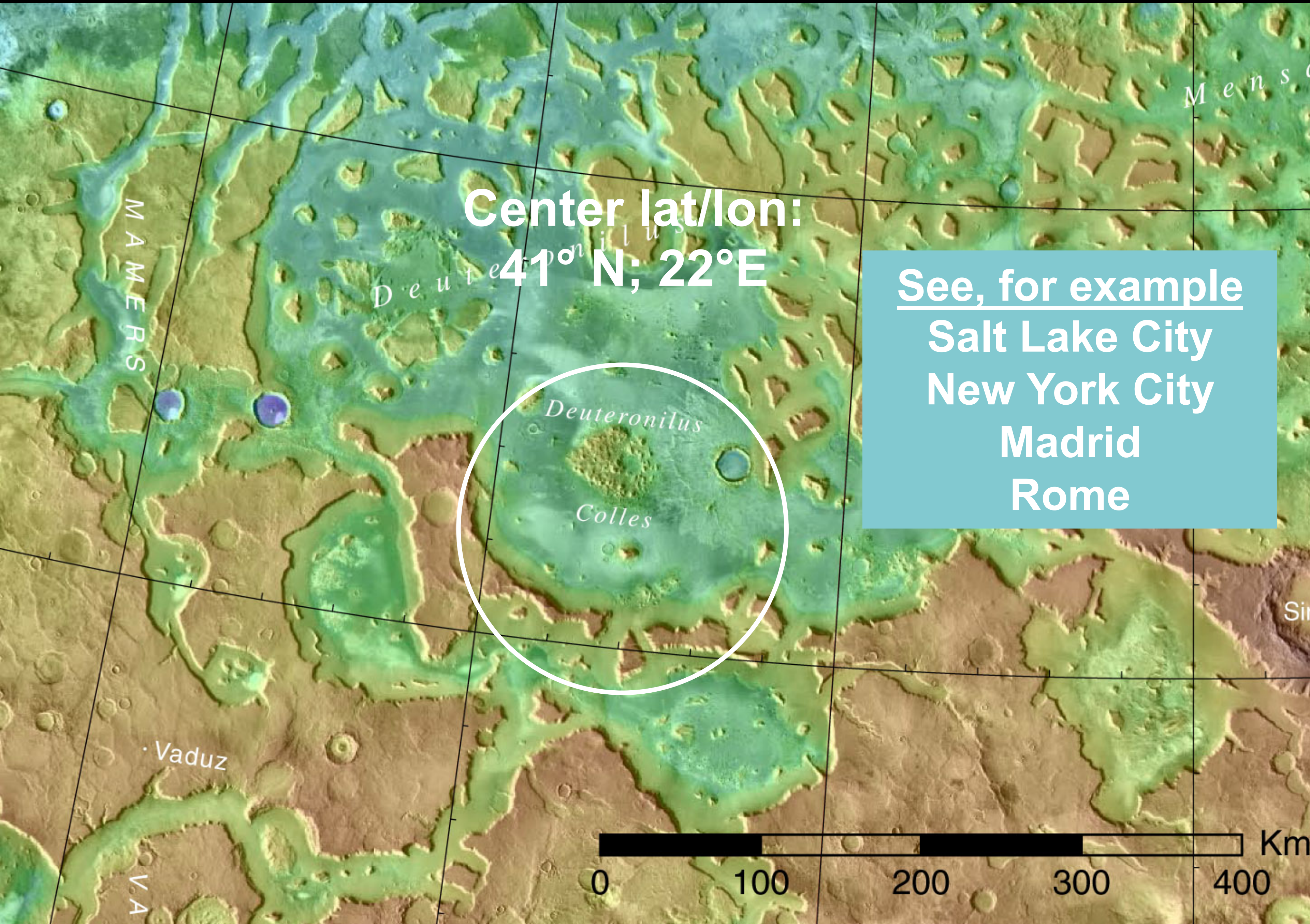
Ismenius Lacus, MC-5

Base image: THEMIS IR Day mosaic by ASU
Margin image: THEMIS IR Global Mosac v11.6, ASU
Colorized Topography: MOLA Elevation Model, GSFC

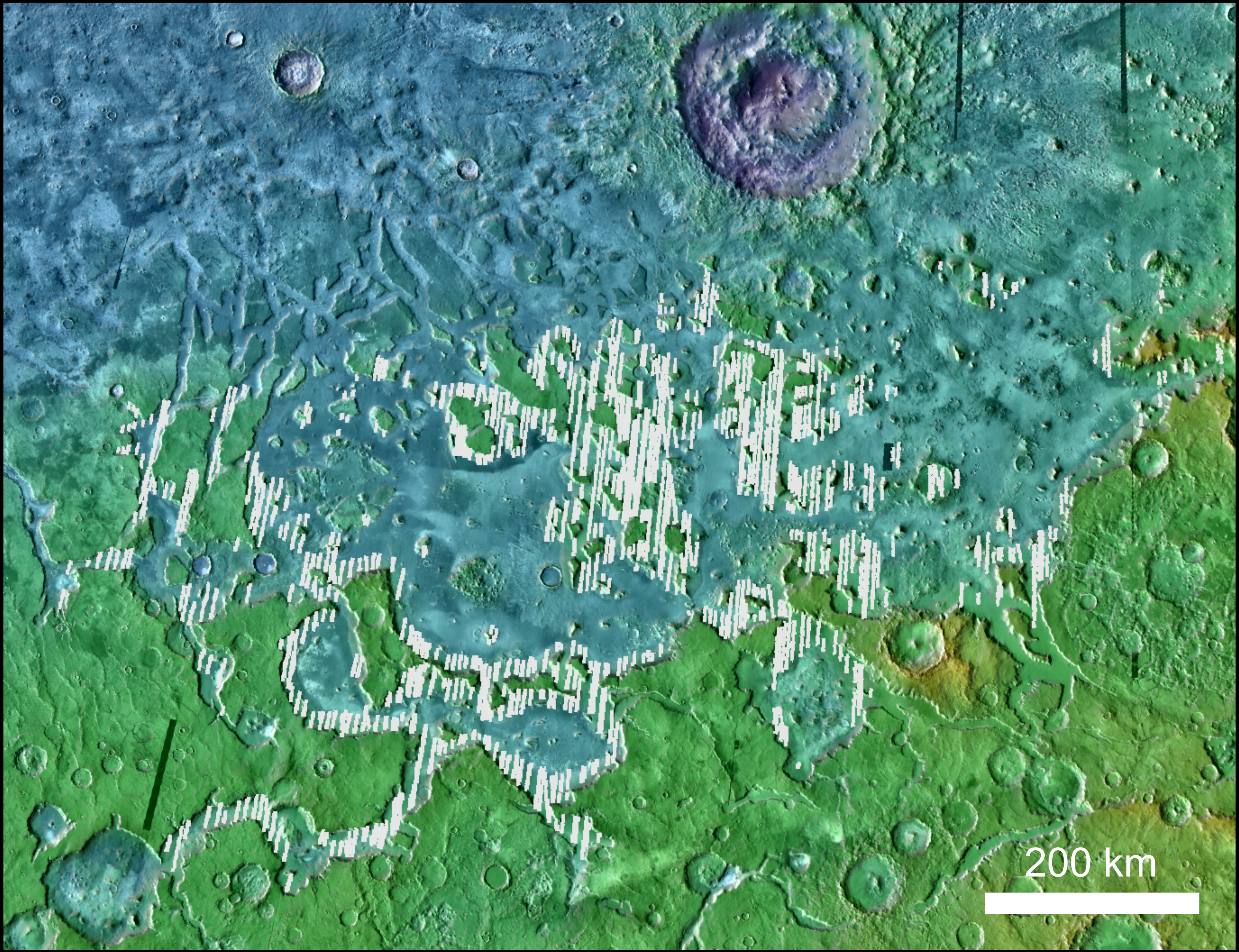


Mens
MAMERS
Deuteronilus
Deuteronilus
Colles
Vaduz
Km
0
100
200
300
400

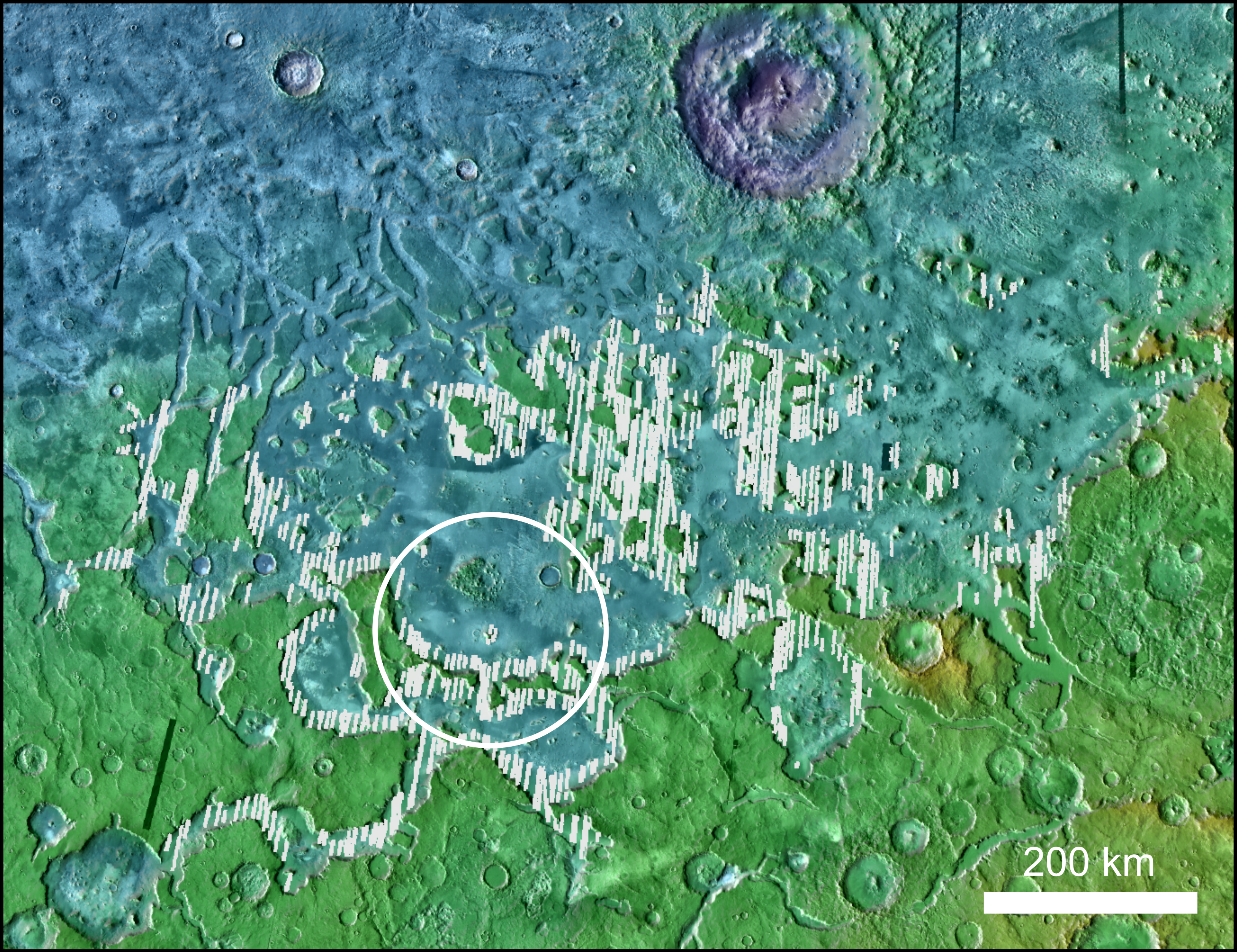

Center lat/lon:
41° N; 22°E
MAMERS
Deuteronilus
Colles
Vaduz
0
100
200
300
400
Km


Center lat/lon:
41° N; 22°E
See, for example
Salt Lake City
New York City
Madrid
Rome
MAMERS
Deuteronilus
Colles
Vaduz
0
100
200
300
400
Km

Detections of Thick Ice in Deuteronilus



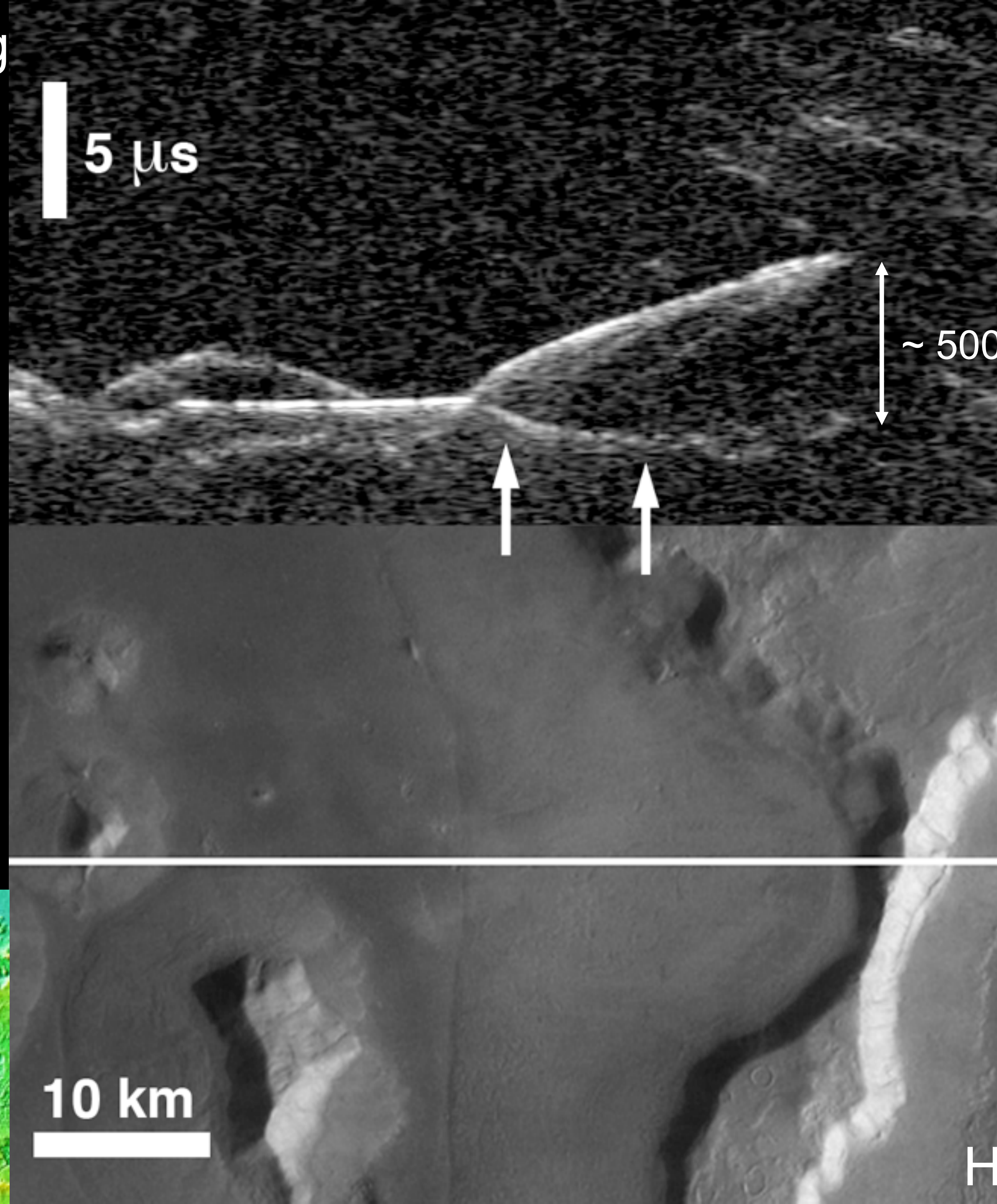
Detections of Thick Ice in Deuteronilus

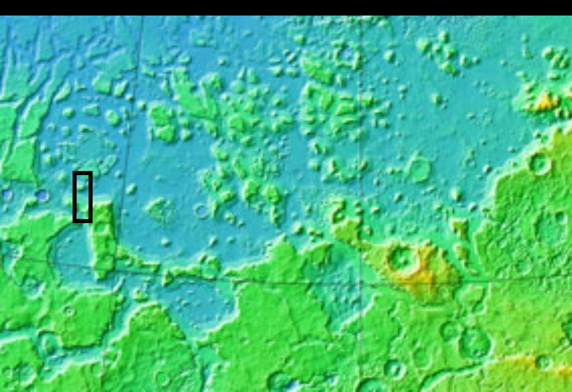


Resource ROI 1 – Margin of Apron

Resource ROI 1 – Margin of Apron

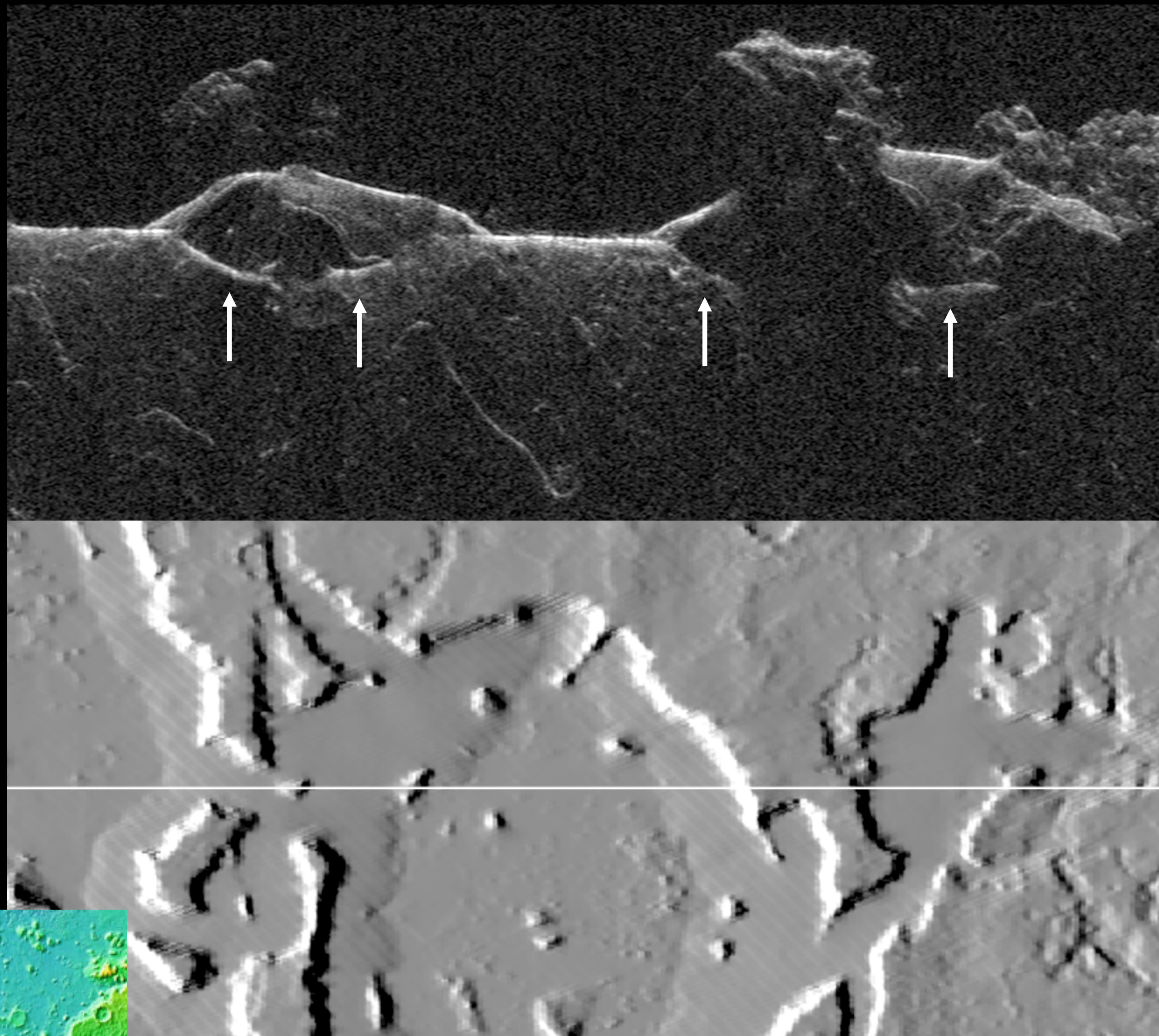
SHARAD Sounding of Lobate Debris Aprons

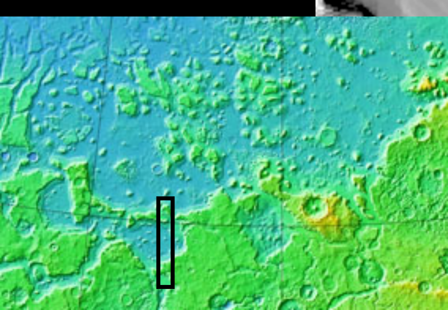




Converting Time to Depth

Time

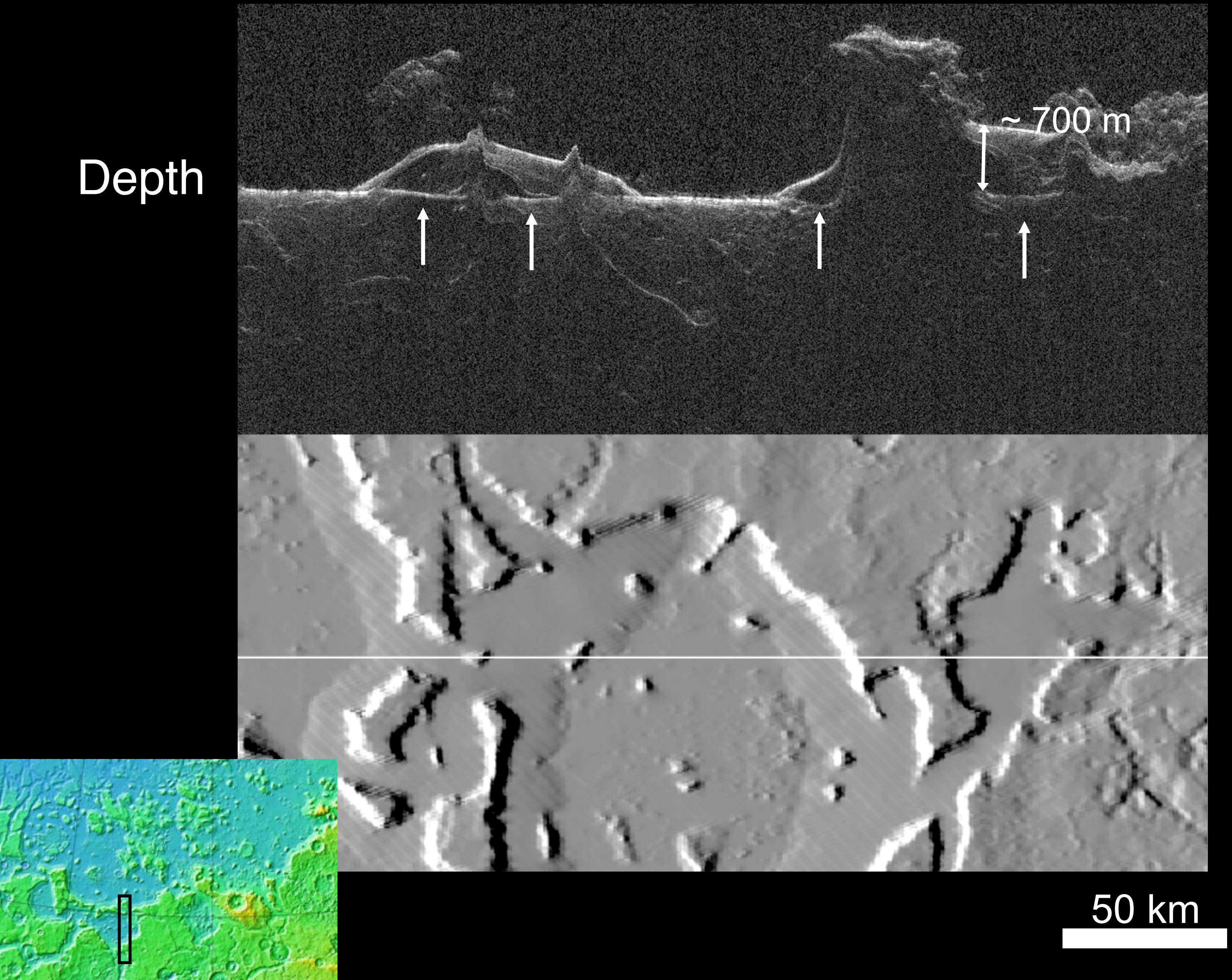




50 km

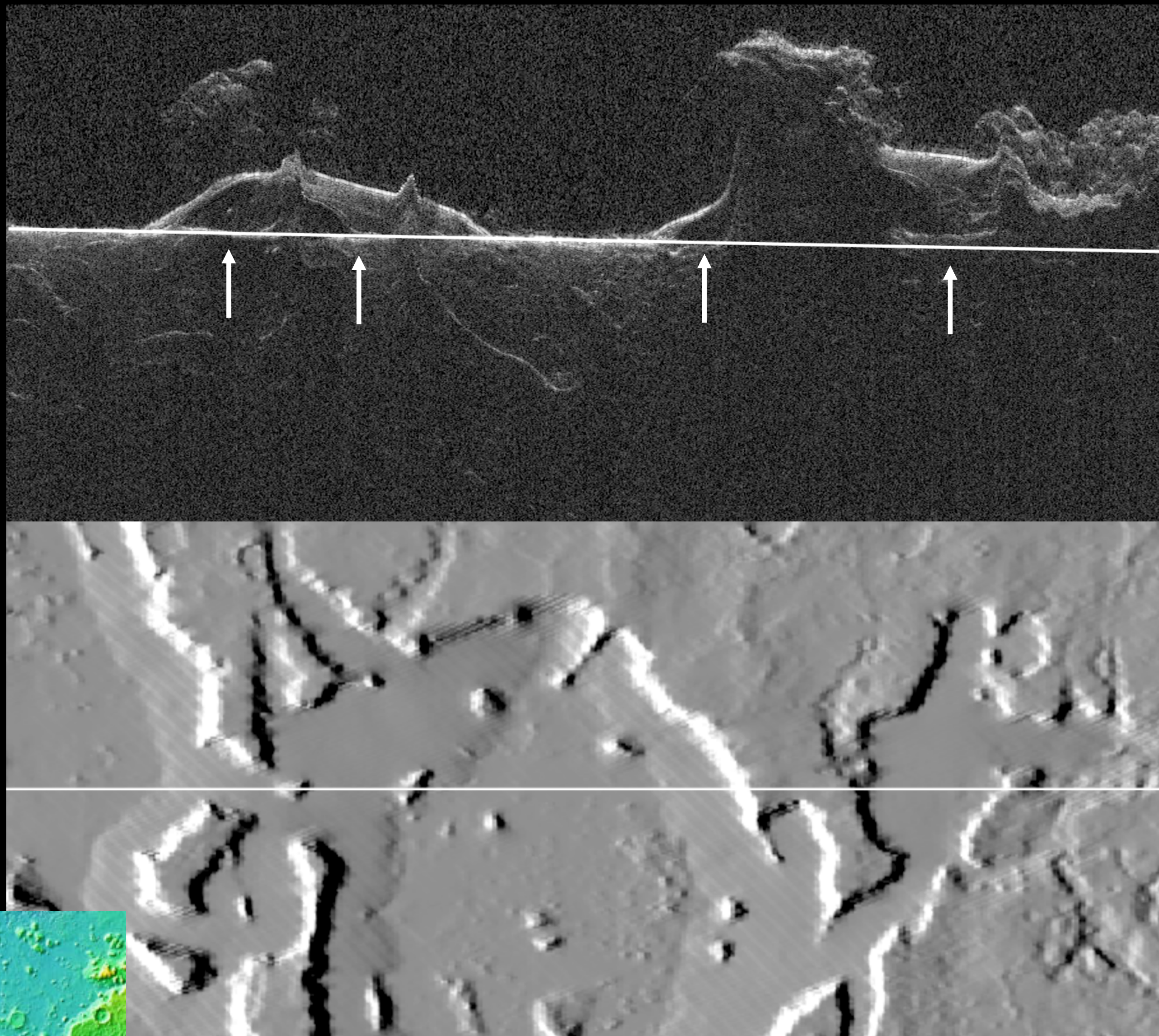
Converting Time to Depth

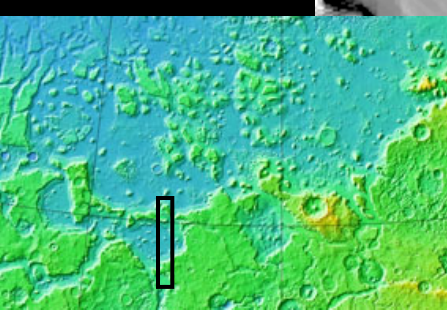
Depth



Converting Time to Depth

Depth





50 km

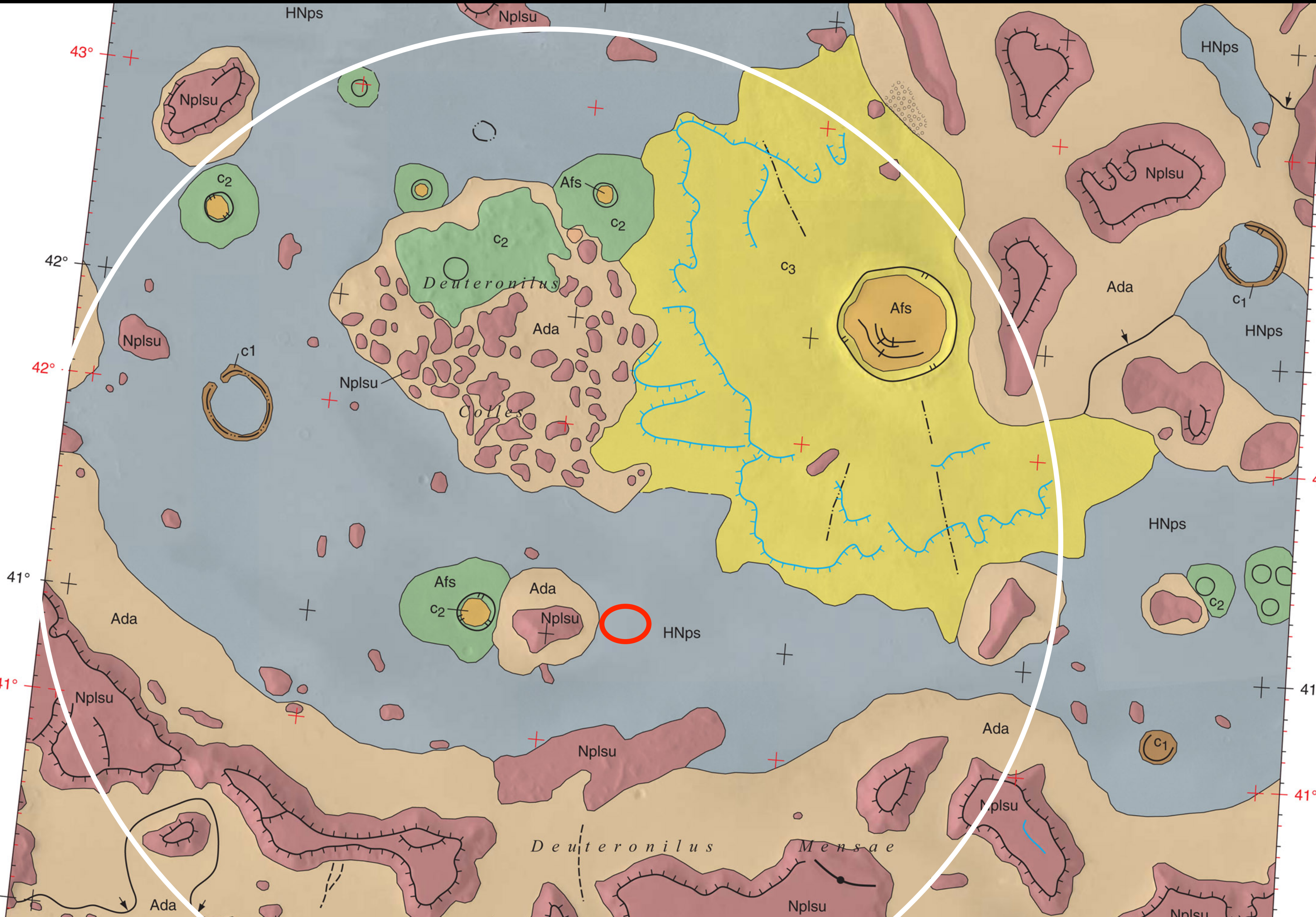
Constraining the thickness of overburden (How deep is the top of the ice?)

- No enhancement in H content is seen in Odyssey GRS or Neutron data.
  - Implies that the upper 0.5-1.0 m is “dry”.

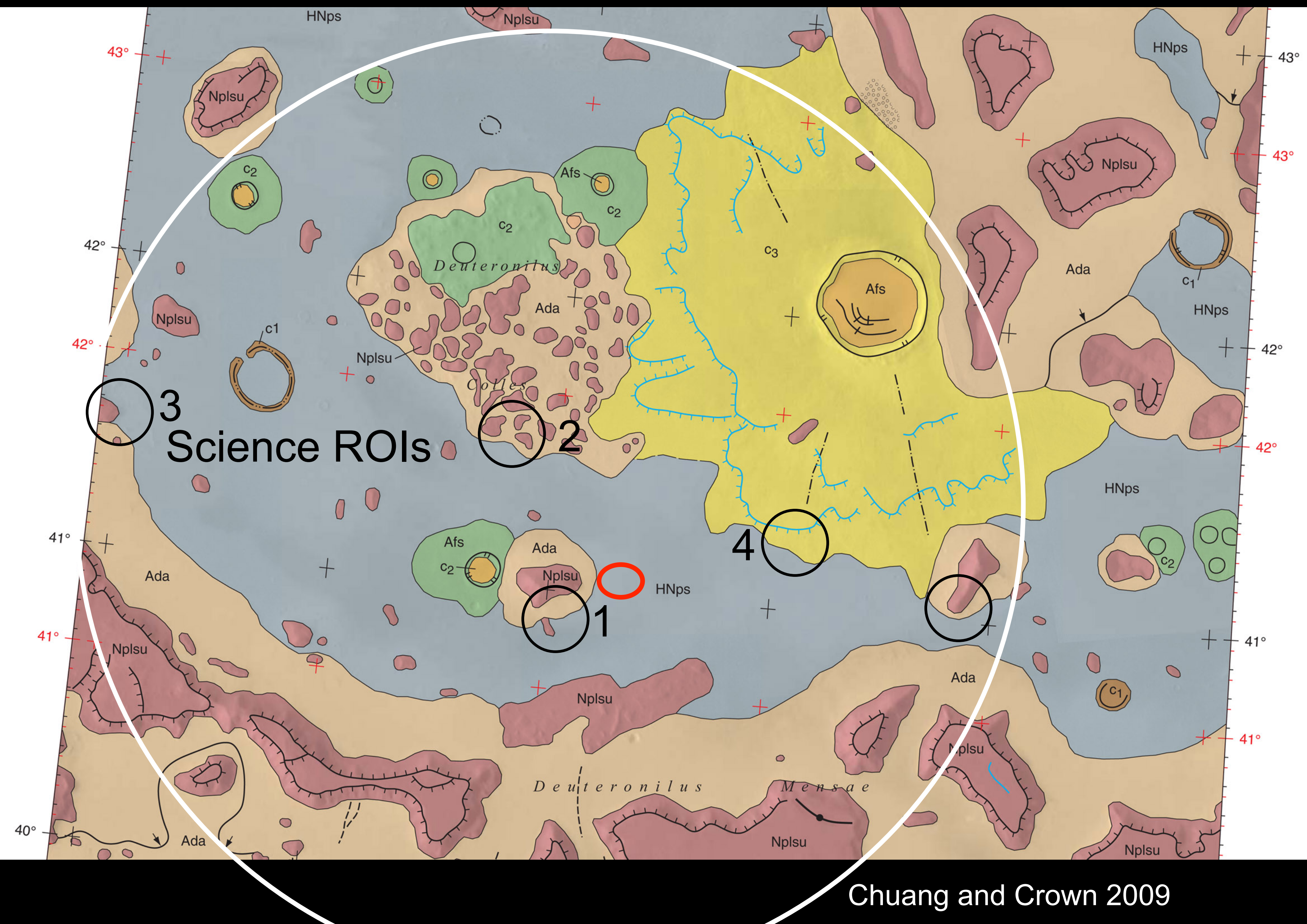
- No shallow boundary between dry overburden and massive ice is seen in SHARAD data. Implies either:
  - a) boundary is in the near-surface blind zone (~10m), or
  - b) boundary does not provide sufficient dielectric contrast to produce an echo.

- Preferred interpretation is a) above, because a thick debris layer is unlikely to be low enough in density (source is mass wasted bedrock; compaction of thick layer will increase density).

- Best current estimate of overburden thickness is 1-10 m.

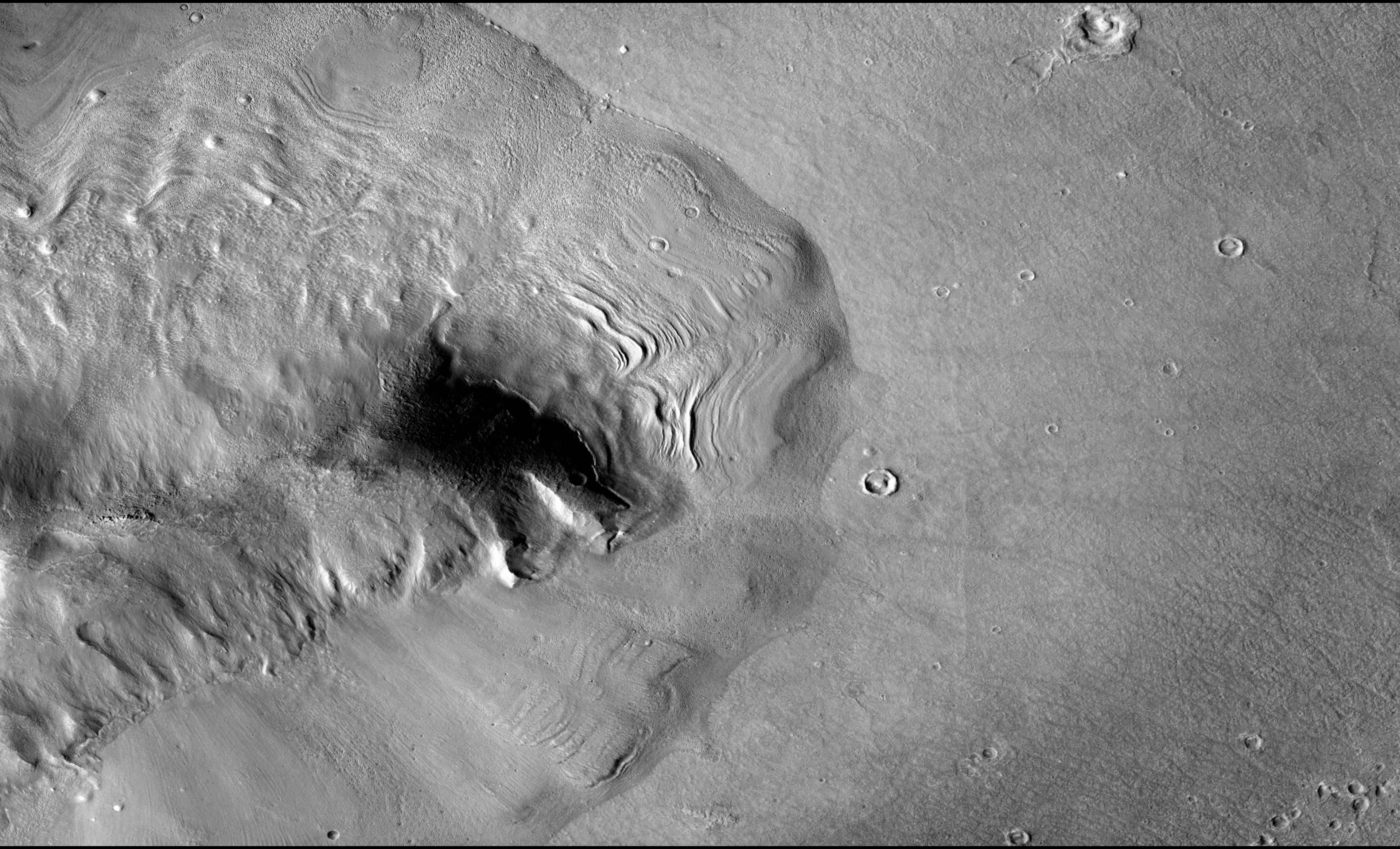


Chuang and Crown 2009

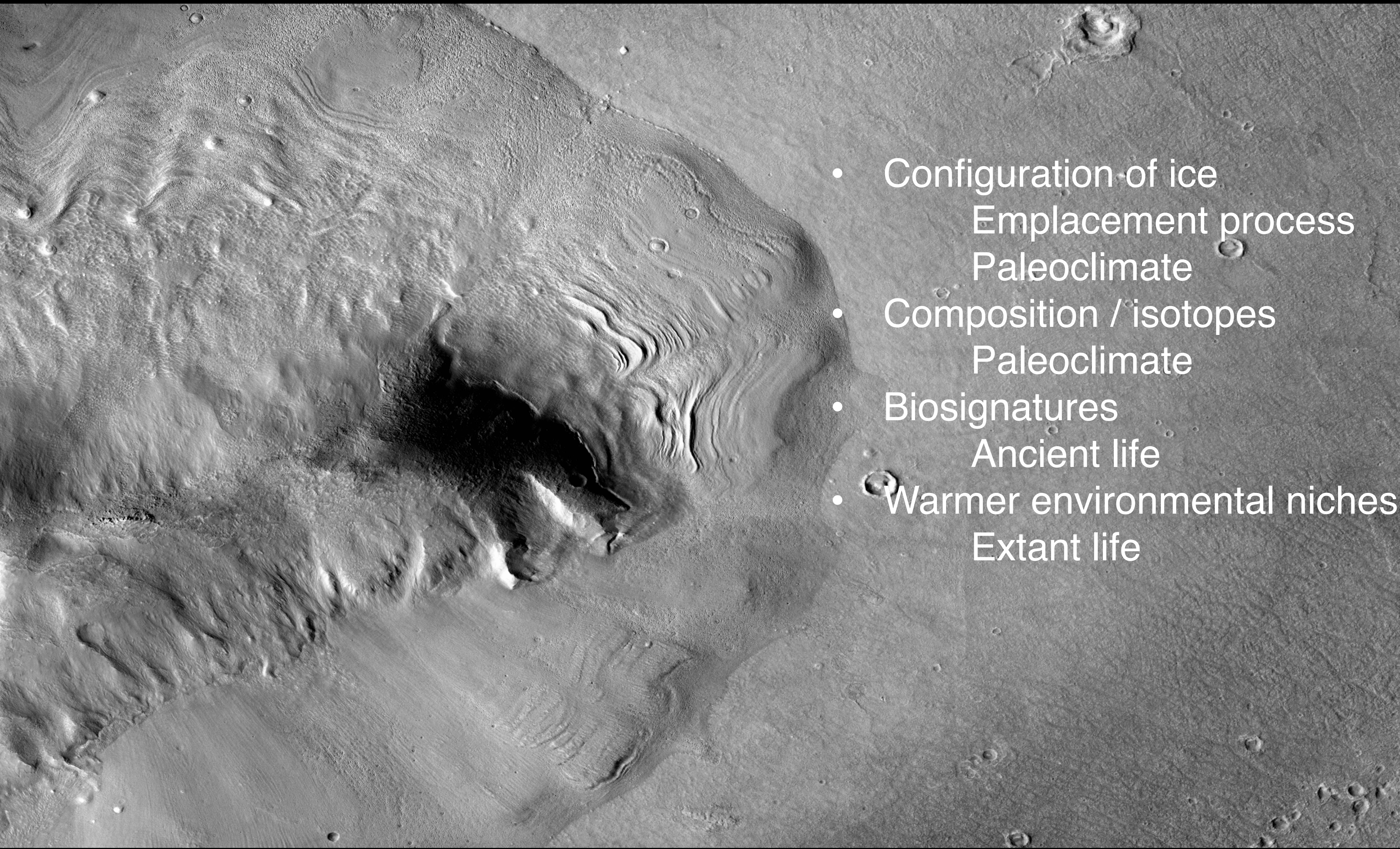


Chuang and Crown 2009

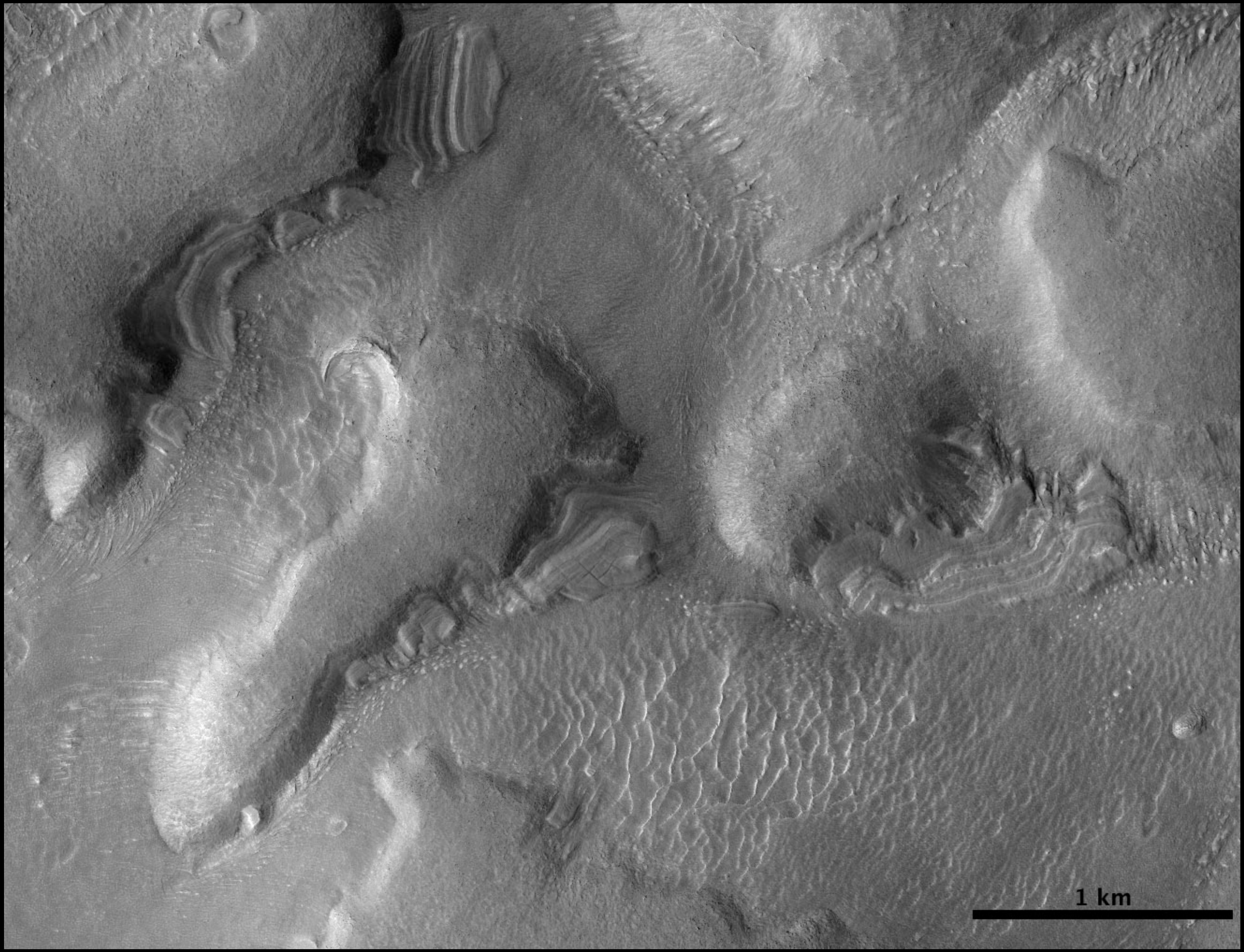
Science ROI 1 – Margin of Apron



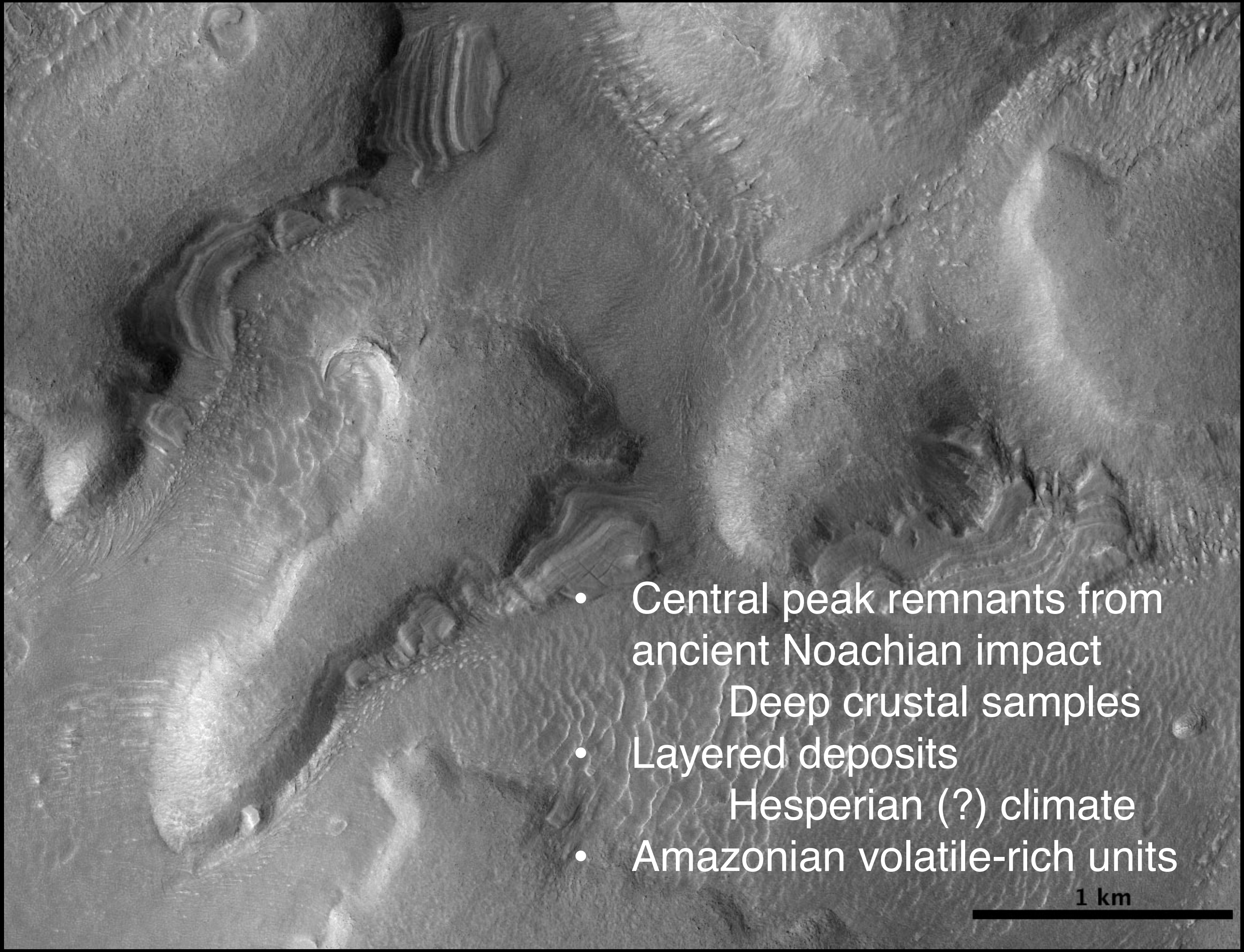
Science ROI 1 – Margin of Apron



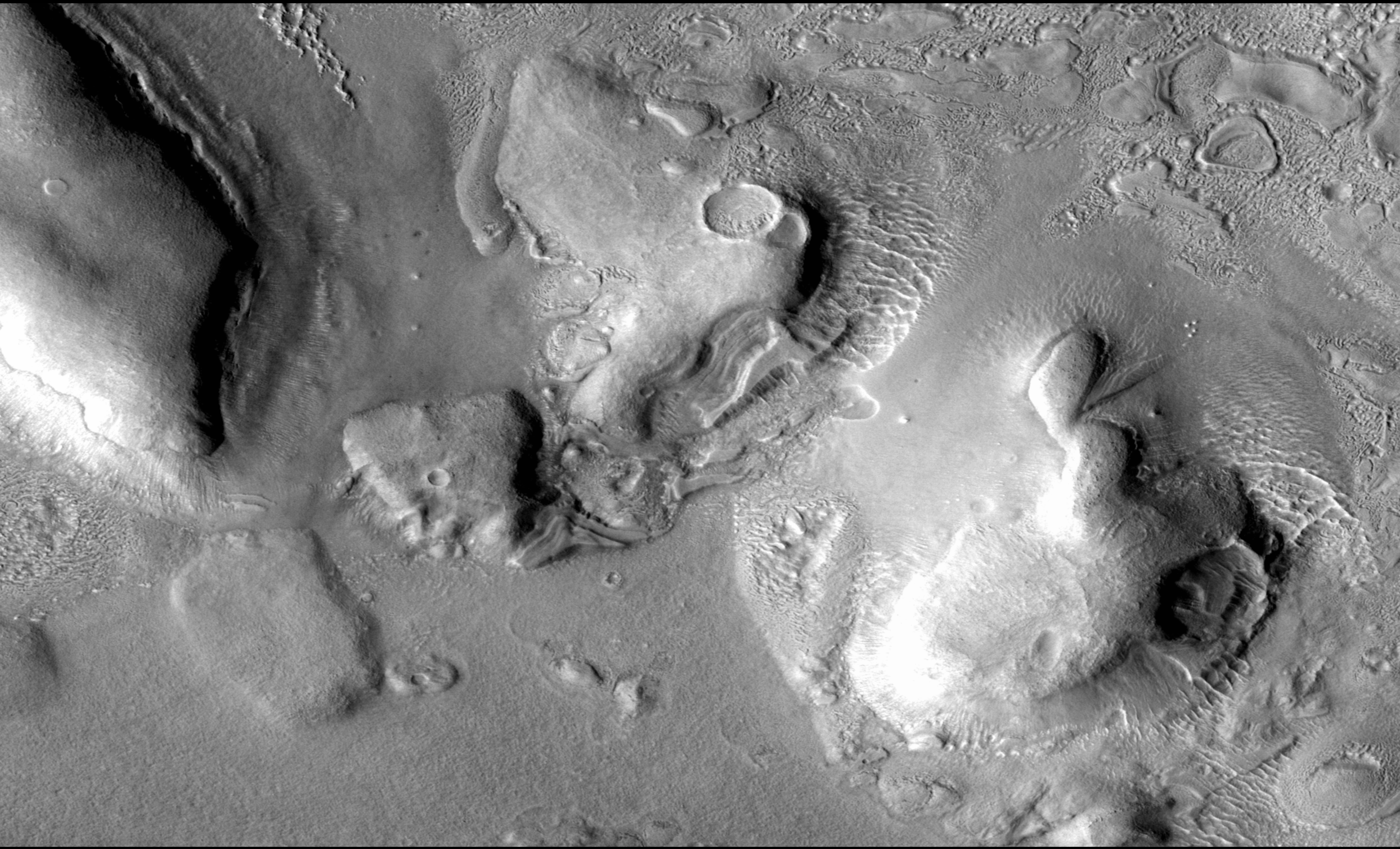
Science ROI 2 – Colles Knobs and Layered Deposits



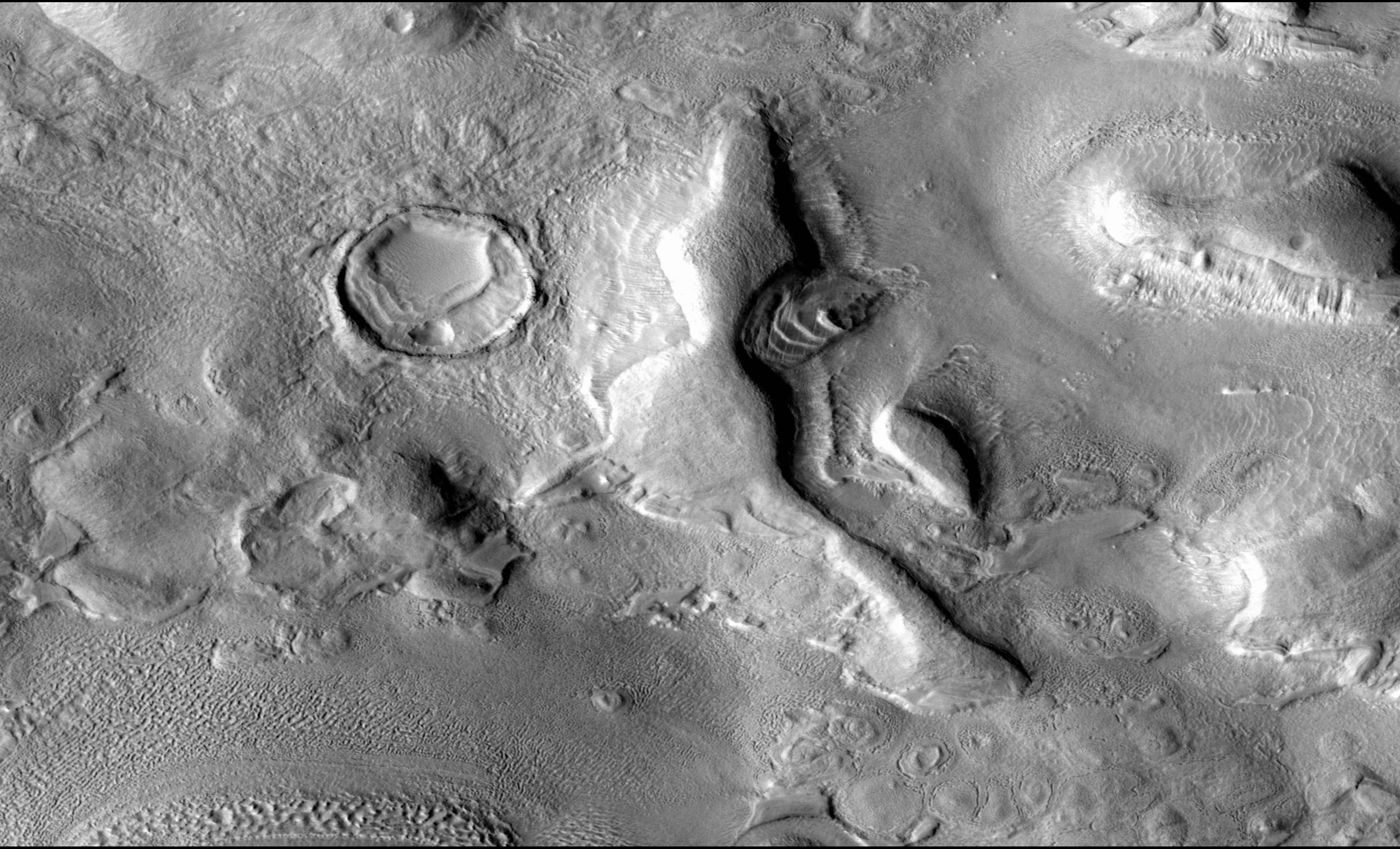
Science ROI 2 – Colles Knobs and Layered Deposits



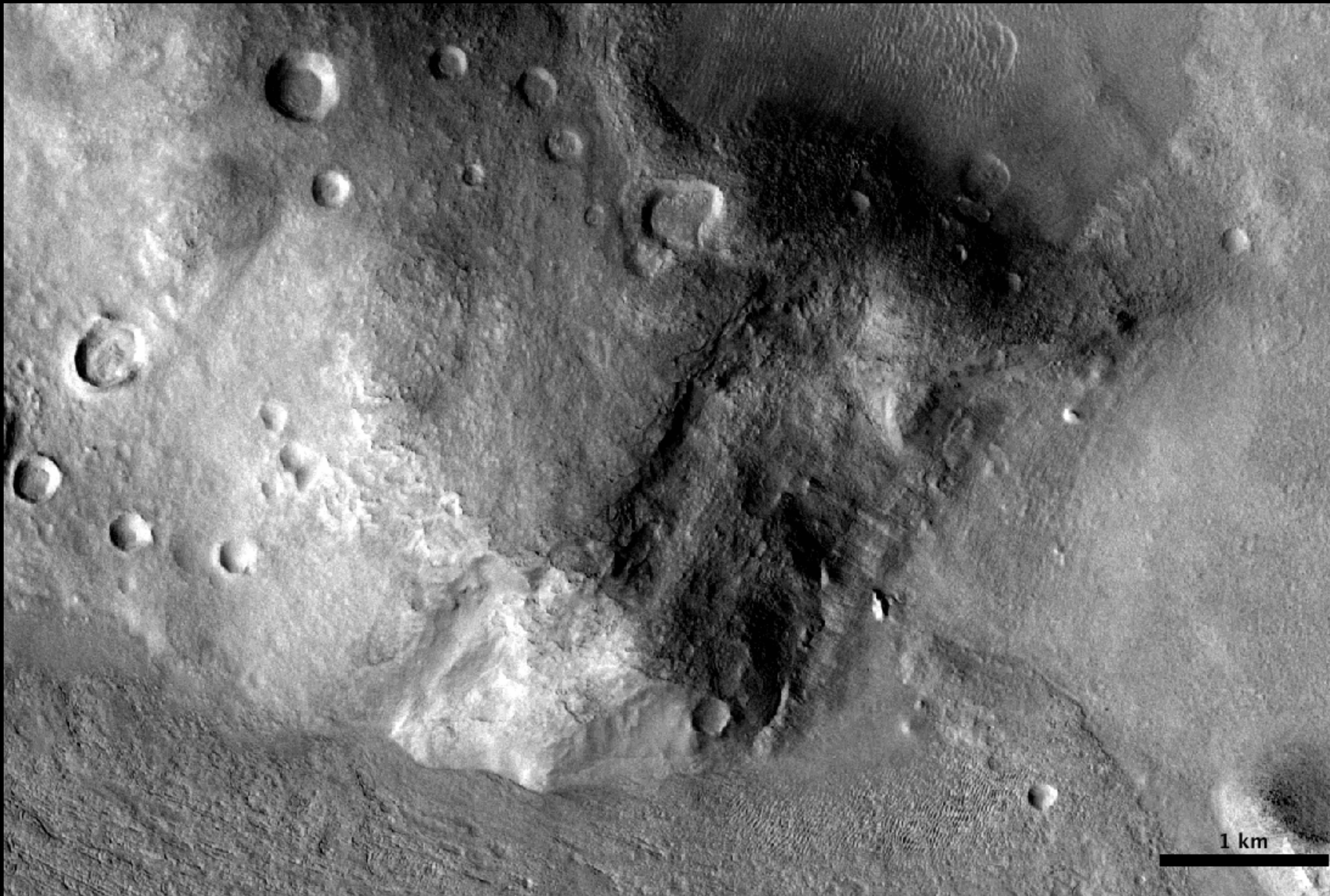
Science ROI 2 – Colles Knobs and Layered Deposits



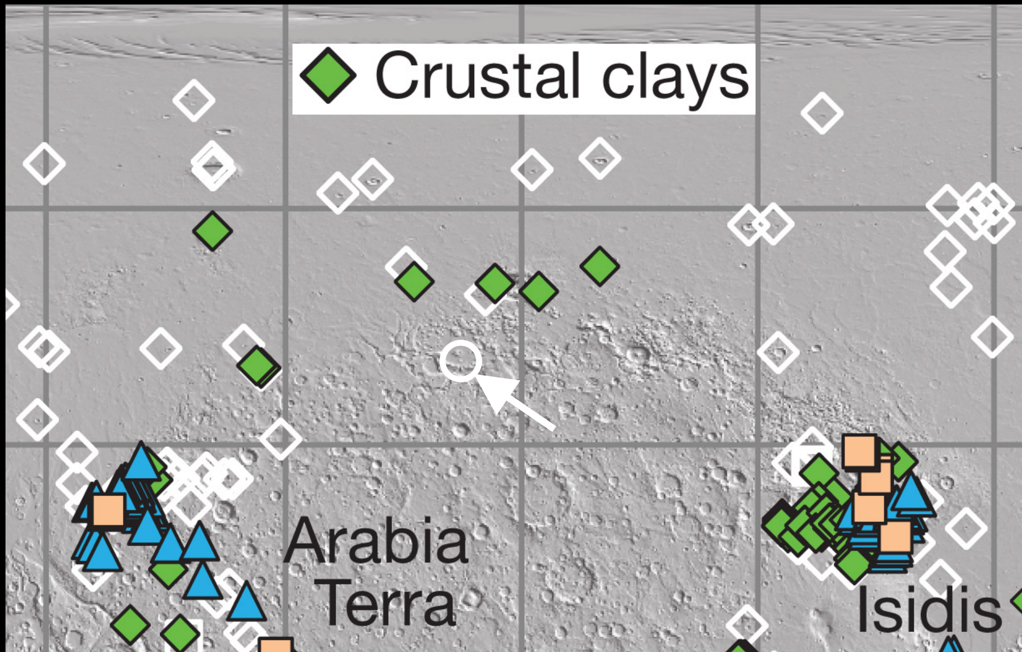
Science ROI 2 – Colles Knobs and Layered Deposits



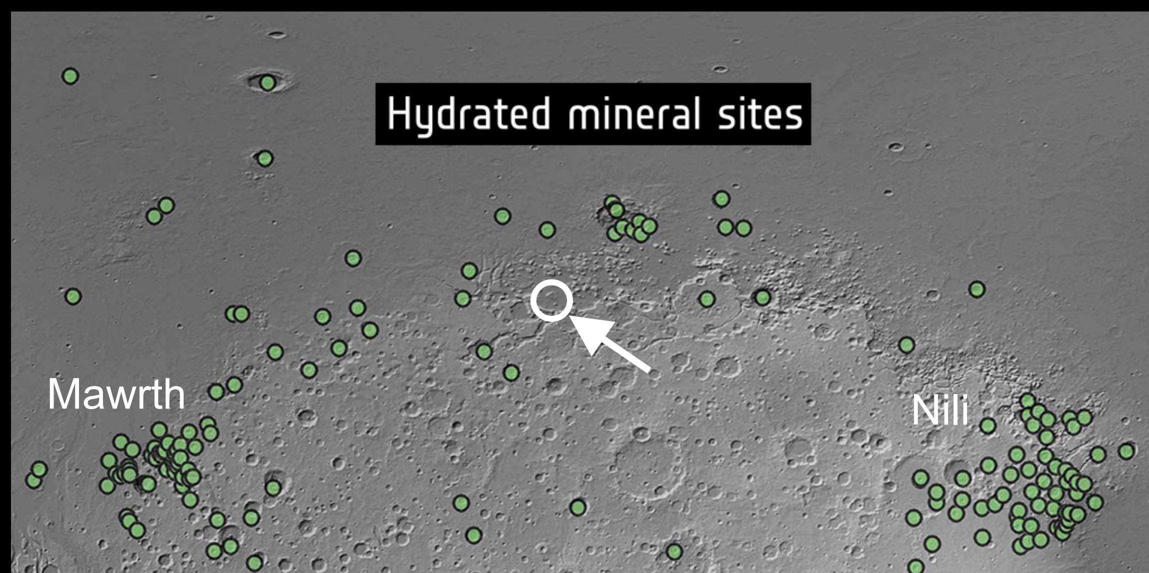
Science ROI 3 – Noachian Terrains at Dichotomy Boundary



Clays and other hydrated minerals detected in Noachian terrains at the Dichotomy Boundary

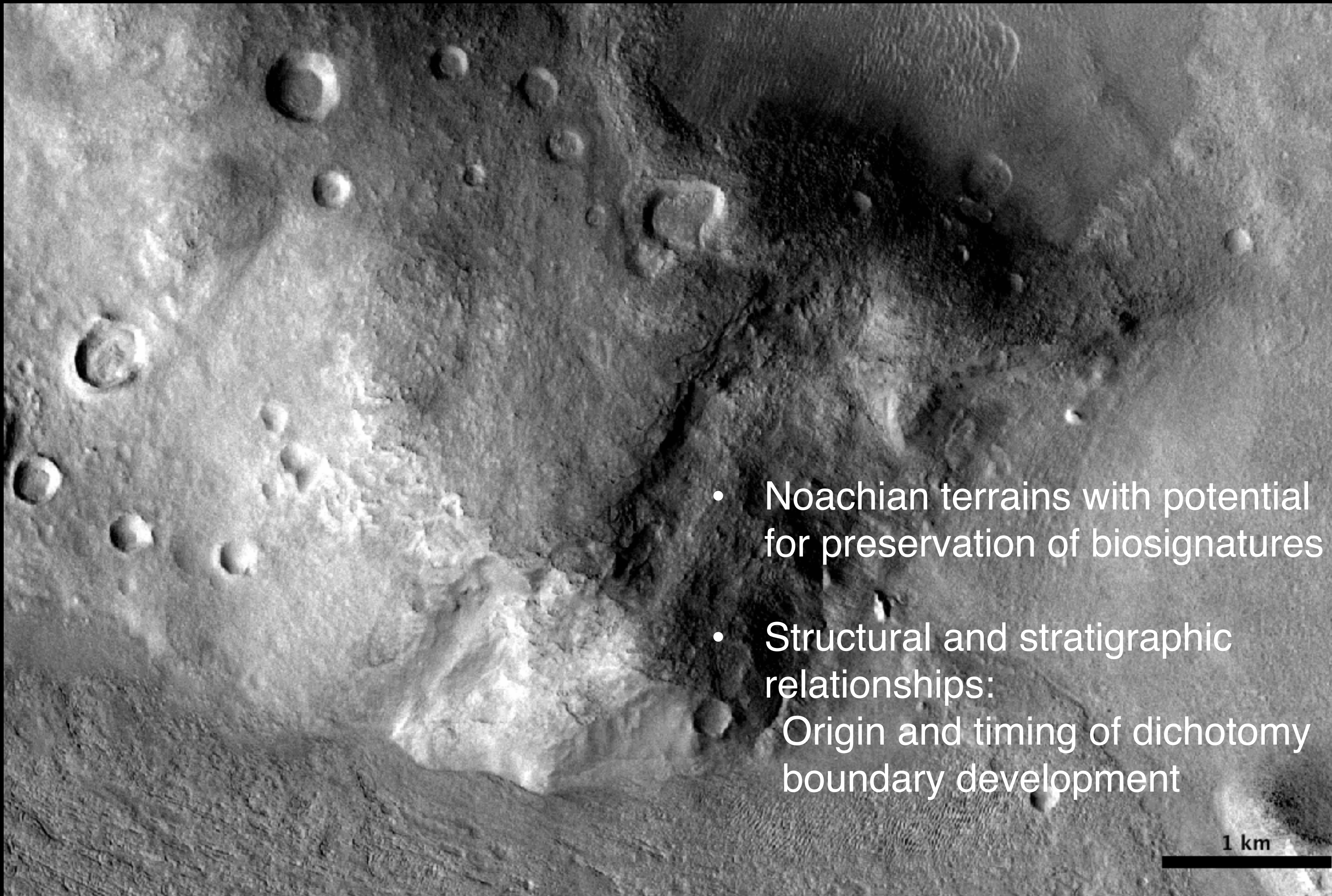


Ehlman et al., 2011

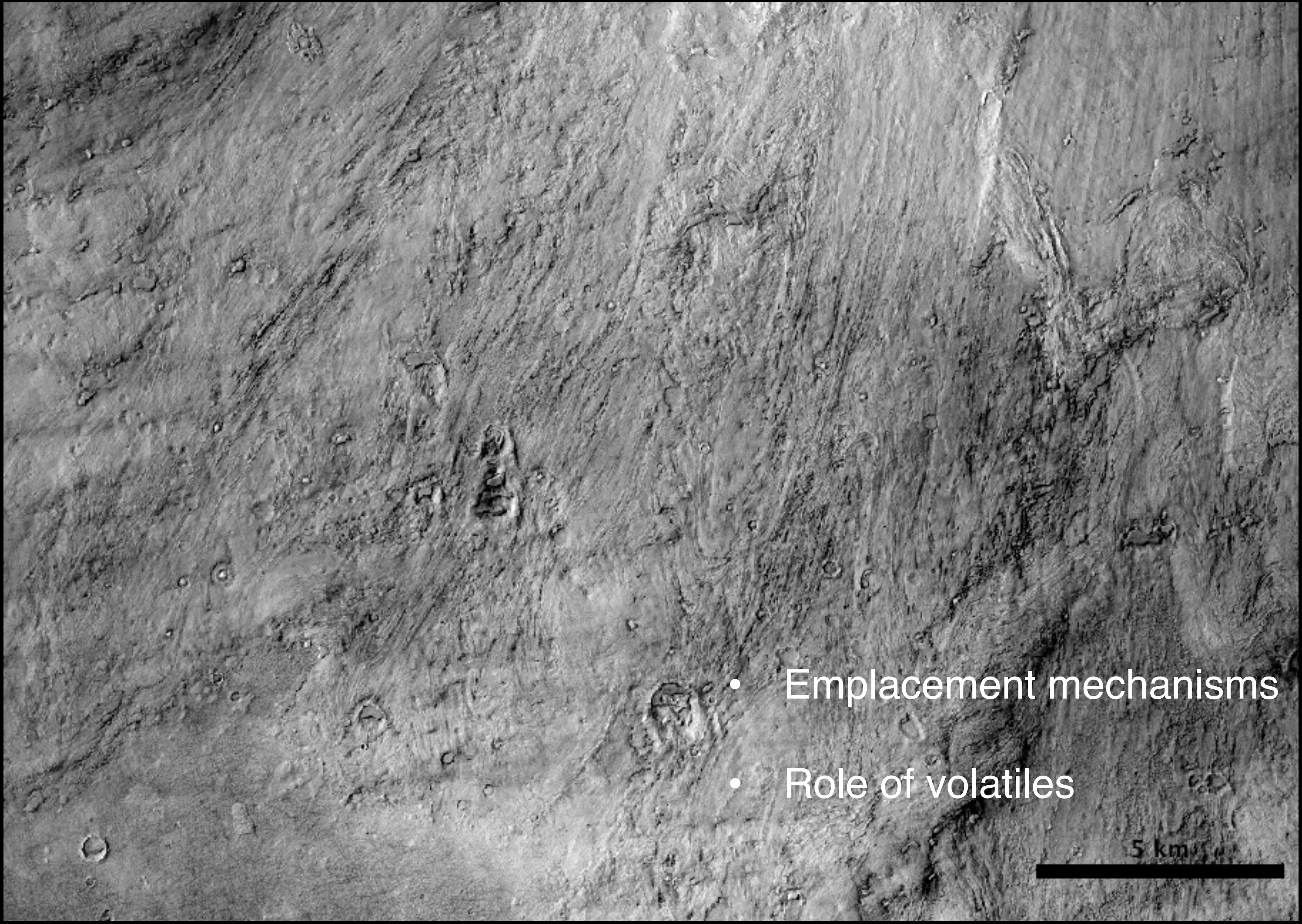


ESA image release
(Carter et al., 2013)

Science ROI 3 – Noachian Terrains at Dichotomy Boundary



Science ROI 4 – Impact with Multiple Layer Ejecta



- Emplacement mechanisms
- Role of volatiles

Resource ROIs Rubric

1st EZ Workshop for Human Missions to Mars

Criteria	Category	Level	AND/OR	Site Factors	RROI1
ISRU and Civil Engineering Criteria	Engineering			Meets First Order Criteria (Latitude, Elevation, Thermal Inertia)	●
	Water Resource	Threshold	AND/ OR	**Potential for ice or ice/regolith mix**	●
				Potential for hydrated minerals	○
				Quantity for substantial production	●
				Potential to be minable by highly automated systems	●
				Located less than 3 km from processing equipment site	●
				Located no more than 3 meters below the surface	○
				Accessible by automated systems	●
		Qualifying		Potential for multiple sources of ice, ice/regolith mix **and** hydrated minerals	●
				Distance to resource location can be >5 km	N/A
				Route to resource location must be (plausibly) traversable	●
	Civil Engineering	Threshold		**~50 sq km region of flat and stable terrain with sparse rock distribution**	●
				1–10 km length scale: <10°	●
				Located within 5 km of landing site location	●
		Qualifying		Located in the northern hemisphere	●
				Evidence of abundant cobble sized or smaller rocks and bulk, loose regolith	○
				Utilitarian terrain features	?
	Food Production	Qualifying		Low latitude	
				No local terrain feature(s) that could shadow light collection facilities	●
				Access to water	●
				Access to dark, minimally altered basaltic sands	○
	Metal/Silicon Resource	Threshold		**Potential for metal/silicon**	?
				Potential to be minable by highly automated systems	?
				Located less than 3 km from processing equipment site	?
				Located no more than 3 meters below the surface	?
				Accessible by automated systems	?
		Qualifying		Potential for multiple sources of metals/silicon	?
				Distance to resource location can be >5 km	?
				Route to resource location must be (plausibly) traversable	?

Key	
●	**Yes**
○	**Partial Support or Debated**
	No
?	**Indeterminate**

Criteria	Category	Type	Criterion	Assessment
ISRU and Civil Engineering Criteria	Engineering		Meets First Order Criteria (Latitude, Elevation, Thermal Inertia)	●
	Water Resource	Threshold	AND/OR: **Potential for ice or ice/regolith mix**	●
			AND/OR: **Potential for hydrated minerals**	○
			Quantity for substantial production	●
			Potential to be minable by highly automated systems	●
			Located less than 3 km from processing equipment site	●
			Located no more than 3 meters below the surface	○
			Accessible by automated systems	●
		Qualifying	Potential for multiple sources of ice, ice/regolith mix **and** hydrated minerals	●
			Distance to resource location can be >5 km	N/A
			Route to resource location must be (plausibly) traversable	●
	Civil Engineering	Threshold	**~50 sq km region of flat and stable terrain with sparse rock distribution**	●
			1–10 km length scale: <10°	●
			Located within 5 km of landing site location	●
		Qualifying	Located in the northern hemisphere	●
			Evidence of abundant cobble sized or smaller rocks and bulk, loose regolith	○
			Utilitarian terrain features	?
	Food Production	Qualifying	Low latitude	
			No local terrain feature(s) that could shadow light collection facilities	●
			Access to water	●
			Access to dark, minimally altered basaltic sands	○
	Silicon Resource	Threshold	**Potential for metal/silicon**	?
			Potential to be minable by highly automated systems	?
			Located less than 3 km from processing equipment site	?
			Located no more than 3 meters below the surface	?
			Accessible by automated systems	?
			[illegible]	

Science ROIs Rubric

Science Site Criteria			Site Factors	SROI1	SROI2	SROI3	SROI4
Astrobio	Threshold	AND/OR	**Potential for past habitability**	●	●		
			Potential for present habitability/refugia	●	●		
	Qualifying		Potential for organic matter, w/ surface exposure				
Atmospheric Science	Threshold		**Noachian/Hesperian rocks w/ trapped atmospheric gases**		●	●	●
	Qualifying		Meteorological diversity in space and time	●	●		
			High likelihood of surface-atmosphere exchange	●	●		●
			Amazonian subsurface or high-latitude ice or sediment	●			
			High likelihood of active trace gas sources				
Geoscience	Threshold		**Range of martian geologic time; datable surfaces**		●	●	●
			Evidence of aqueous processes	●	●	●	●
			Potential for interpreting relative ages	●	●	●	
	Qualifying		Igneous Rocks tied to 1+ provinces or different times				
			Near-surface ice, glacial or permafrost	●	●		
			Noachian or pre-Noachian bedrock units		●	●	
			Outcrops with remnant magnetization				
			Primary, secondary, and basin-forming impact deposits				●
			Structural features with regional or global context		●	●	
			Diversity of aeolian sediments and/or landforms				

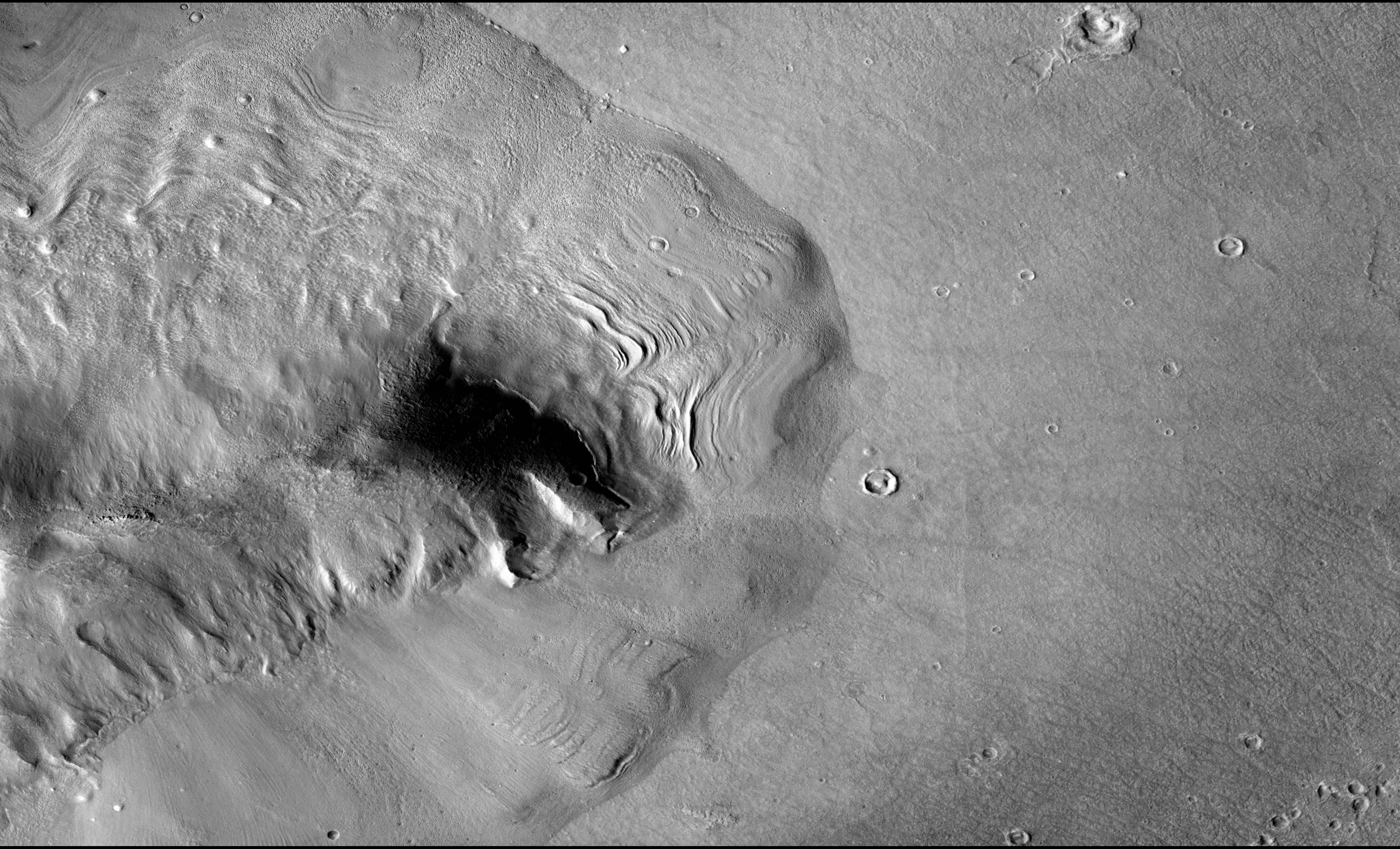
Key	
●	**Yes**
○	**Partial Support or Debated**
	No
?	**Indeterminate**

Highest Priority EZ Data Needs

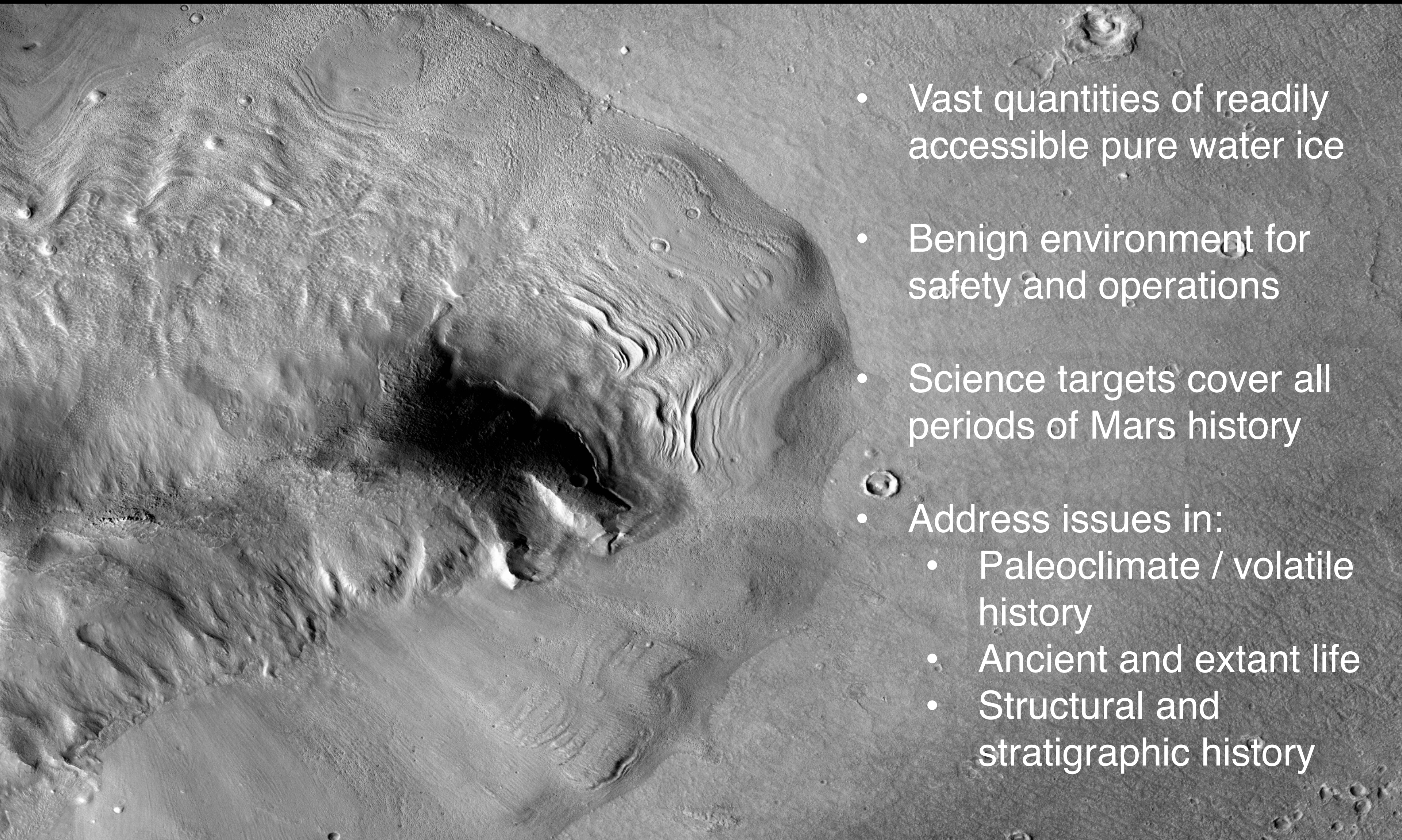
– What is the single most important additional data set needed to assess the science potential of the EZ?
– What is the single most important additional data set needed to assess the resource potential of the EZ?

HiRISE imagery, including stereo, of the LDA margin areas that would be access points for resource and science sampling.

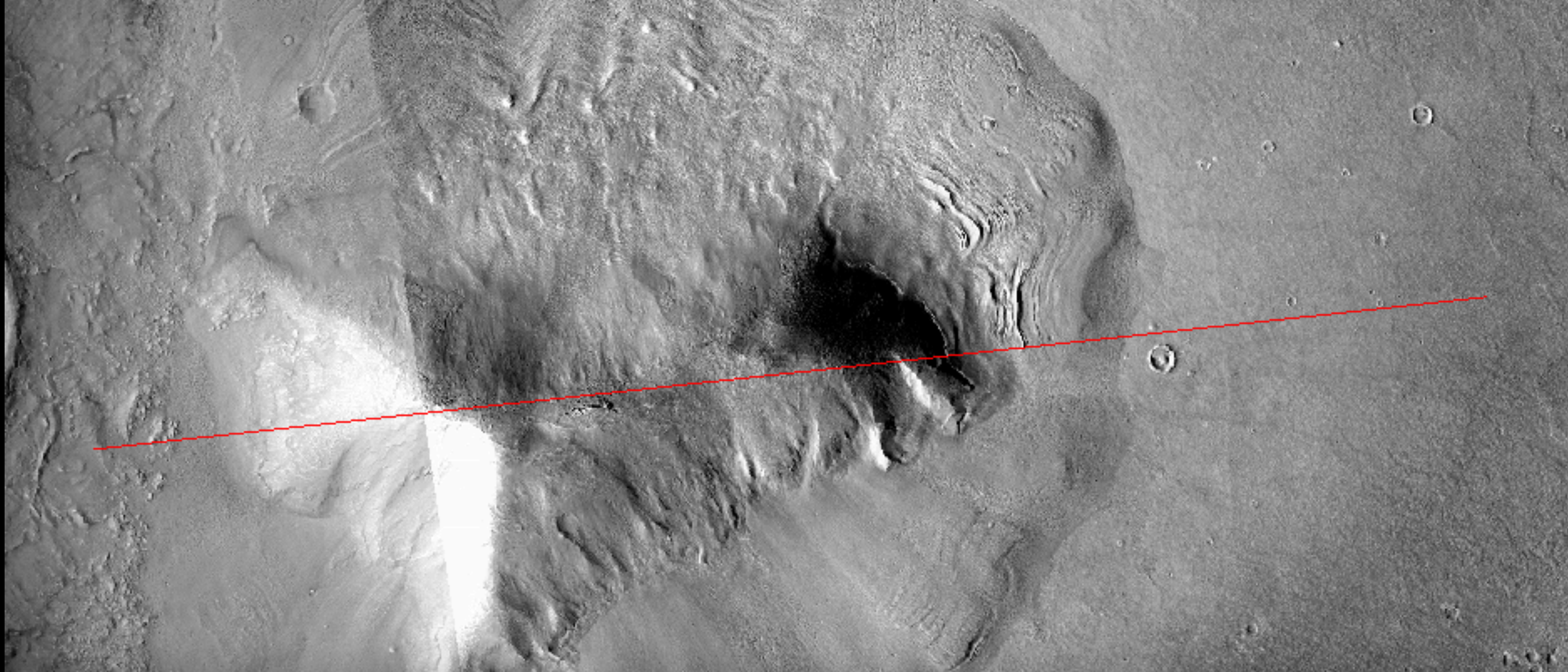
Summary

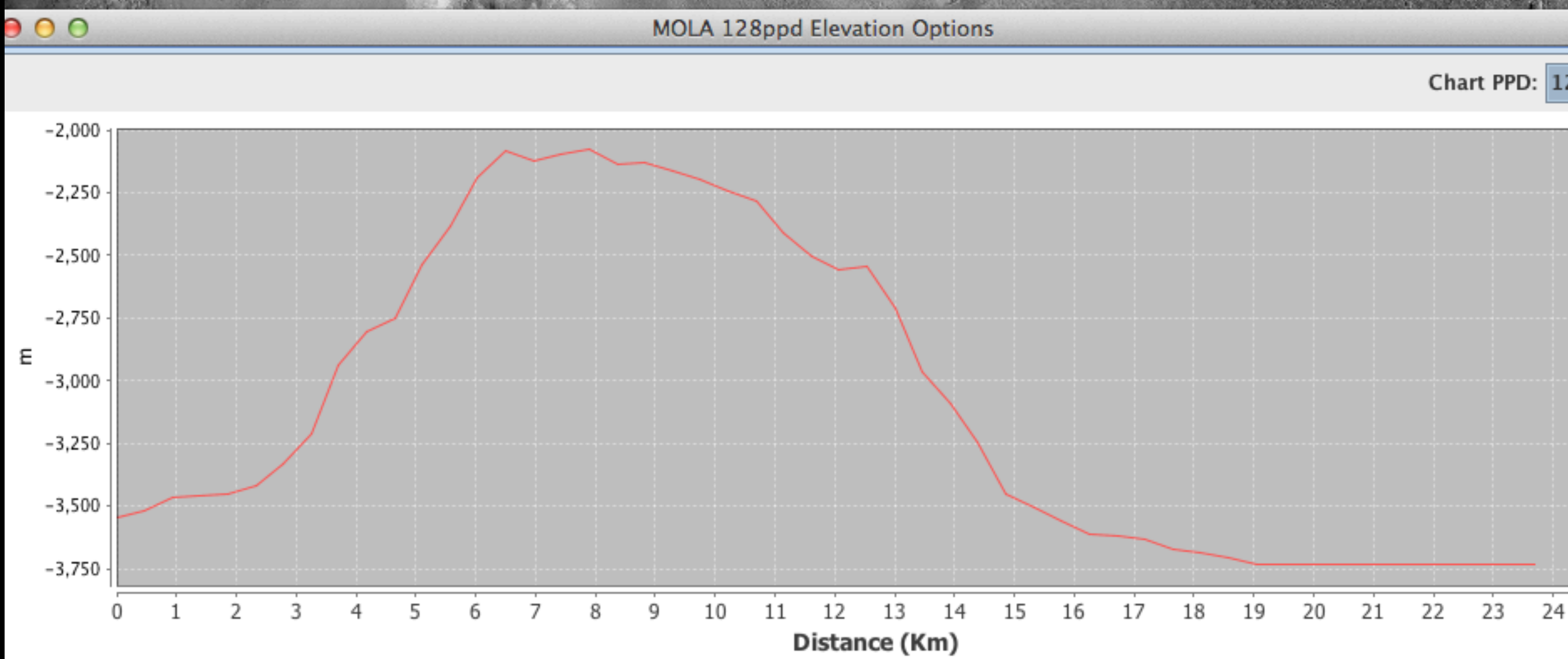


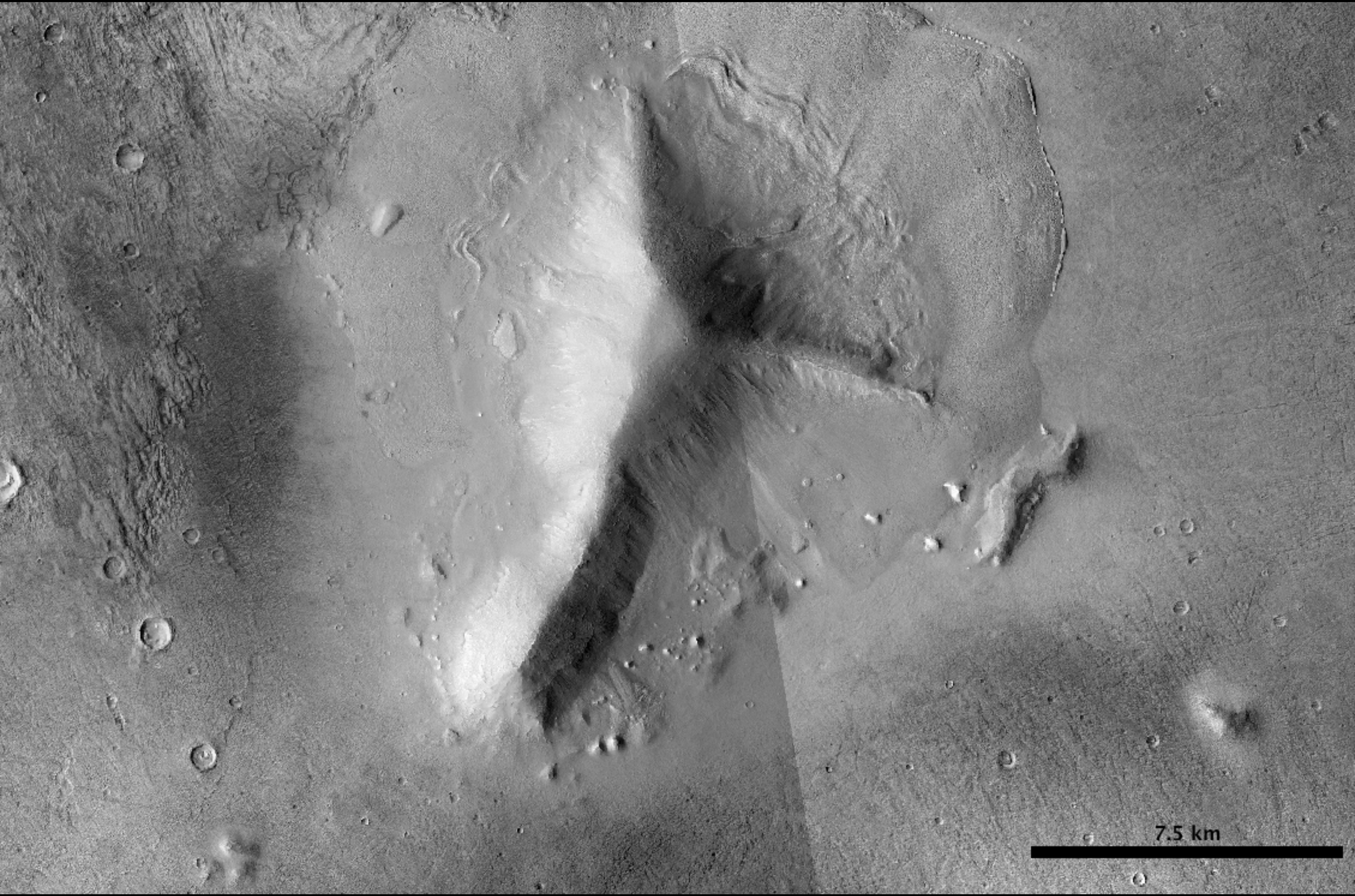
Summary



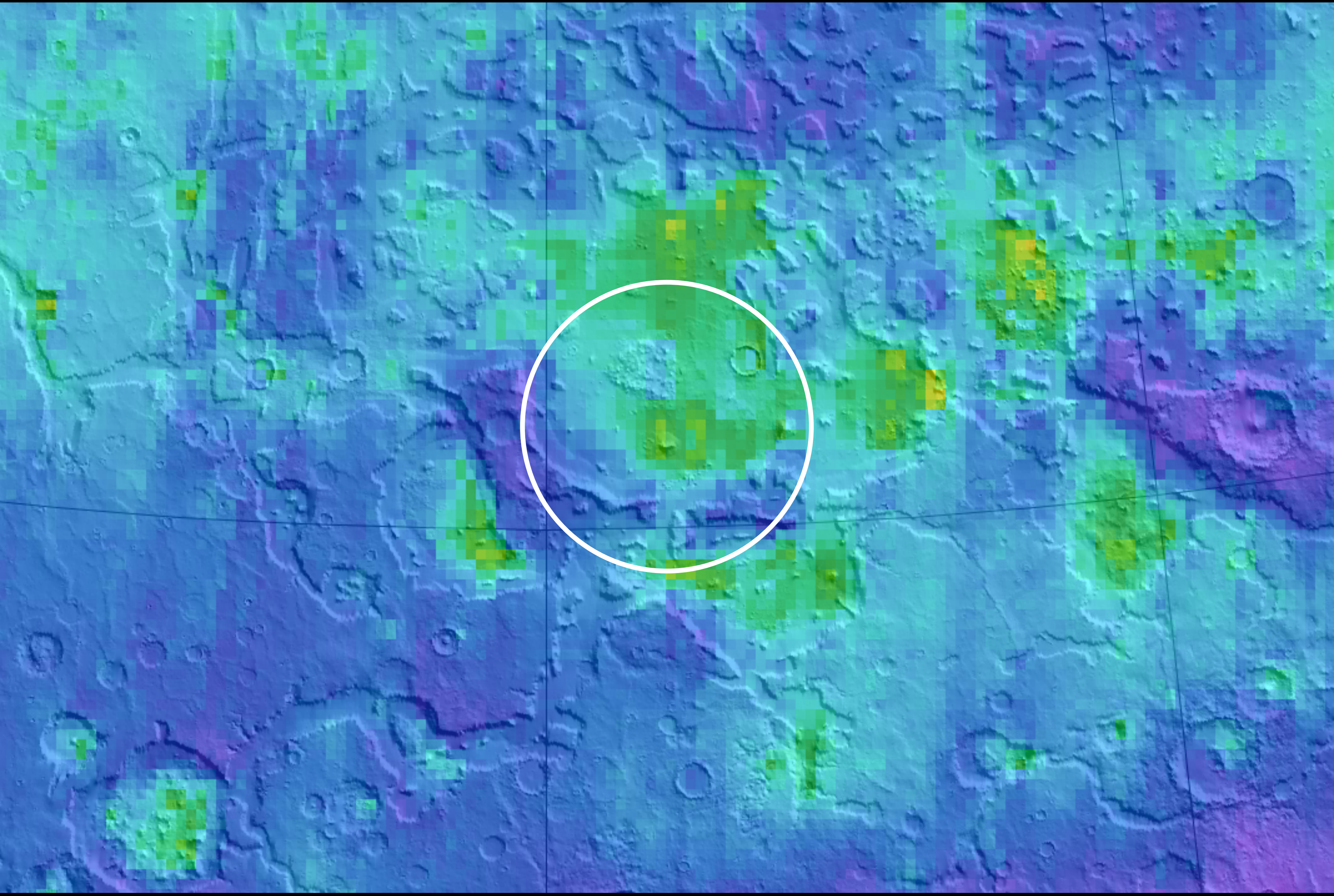
- Vast quantities of readily accessible pure water ice
- Benign environment for safety and operations
- Science targets cover all periods of Mars history
- Address issues in:
  - Paleoclimate / volatile history
  - Ancient and extant life
  - Structural and stratigraphic history

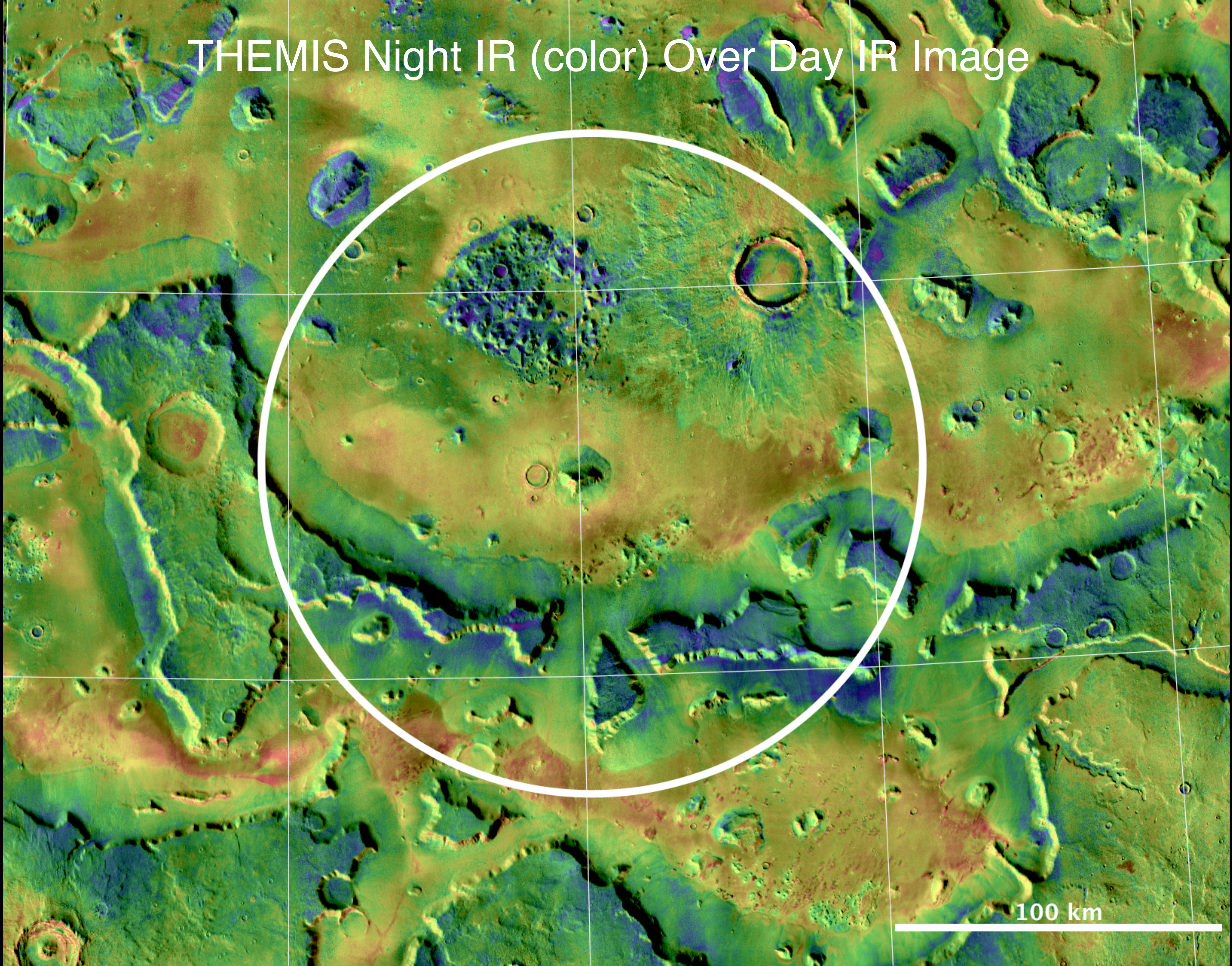



MOLA 128ppd Elevation Options
Chart PPD: 128
-2,000
-2,250
-2,500
-2,750
-3,000
-3,250
-3,500
-3,750
m
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Distance (Km)


7.5 km

TES Thermal Inertia – Range 100-300 TI Units




THEMIS Night IR (color) Over Day IR Image
100 km