Hale Crater - Ancient Water Science, Contemporary Water Resource

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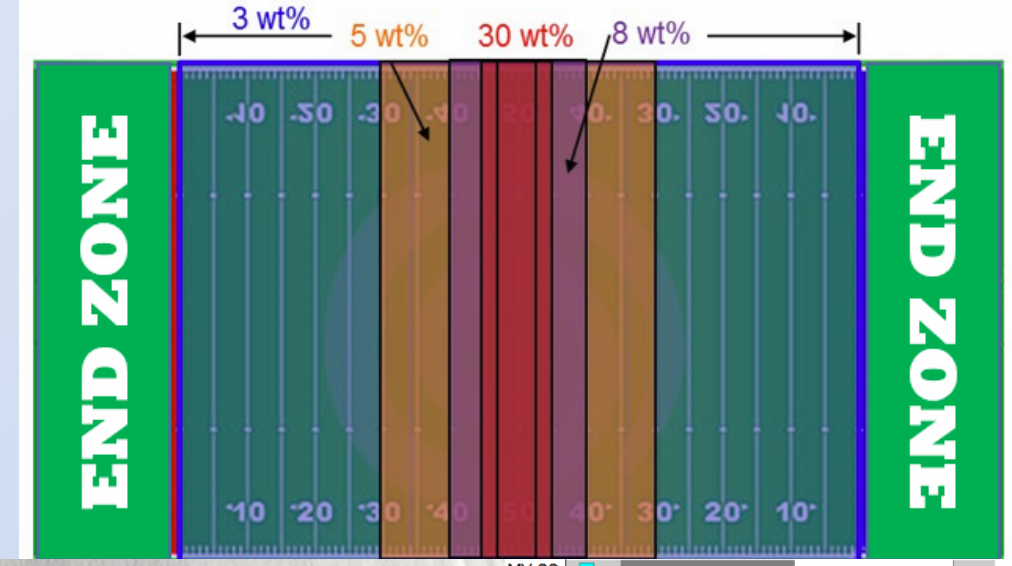
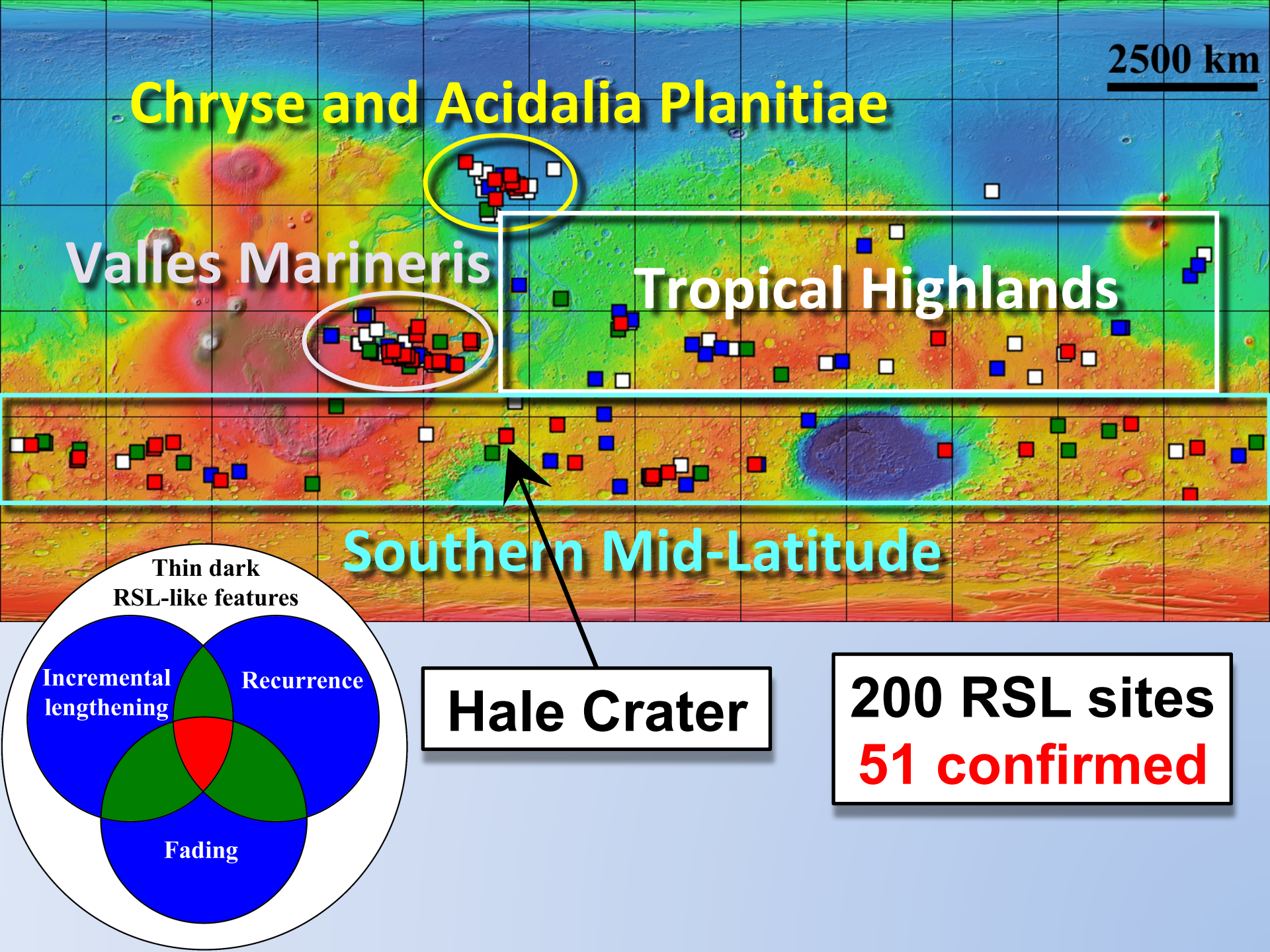
Motivation

- Mining a football field worth of hydrated material

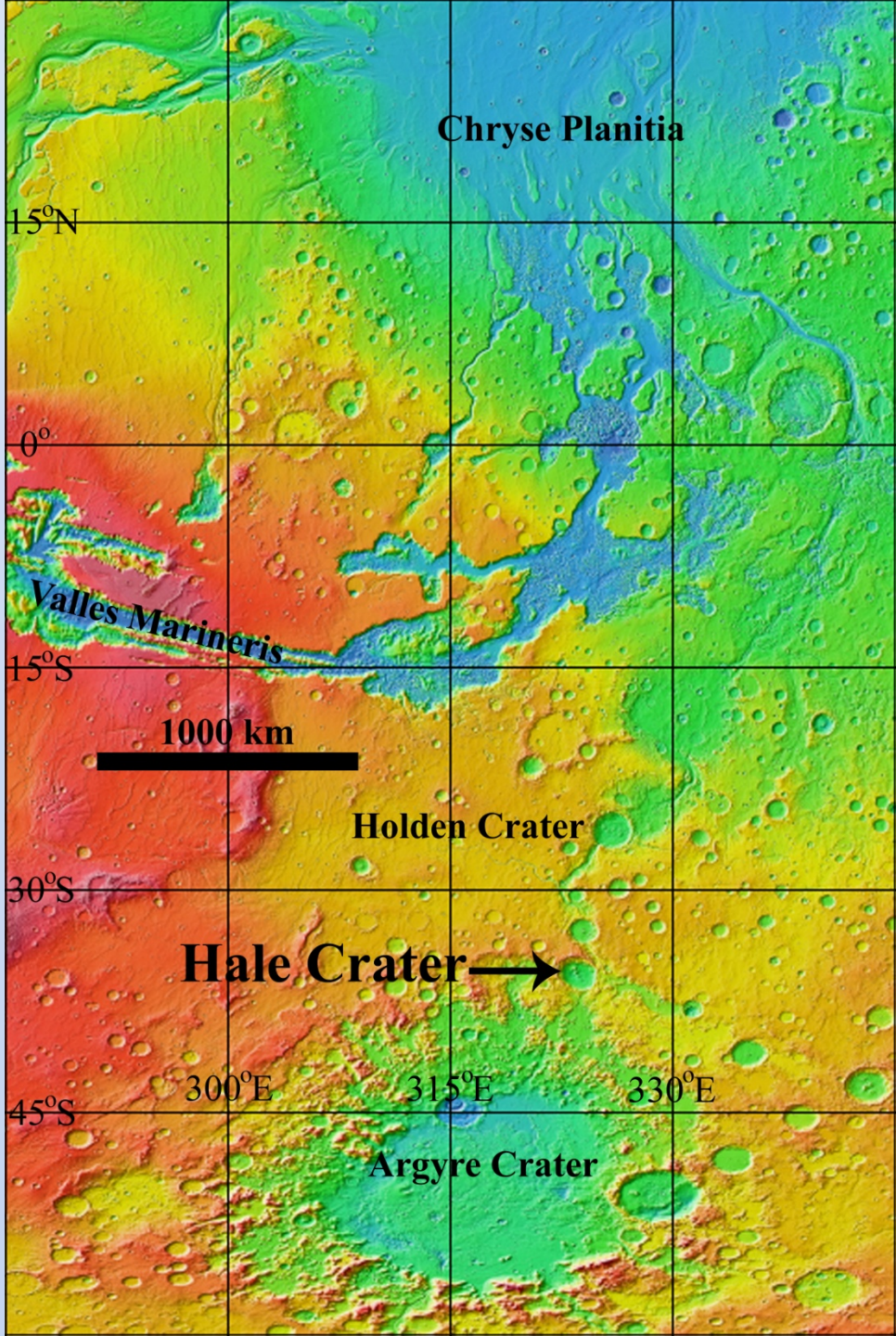
- Go to a natural martian spring (RSL)




2500 km
Chryse and Acidalia Planitiae
Valles Marineris
Tropical Highlands
Southern Mid-Latitude
Hale Crater
200 RSL sites
51 confirmed
Thin dark
RSL-like features
Incremental
lengthening
Recurrence
Fading

Argyre

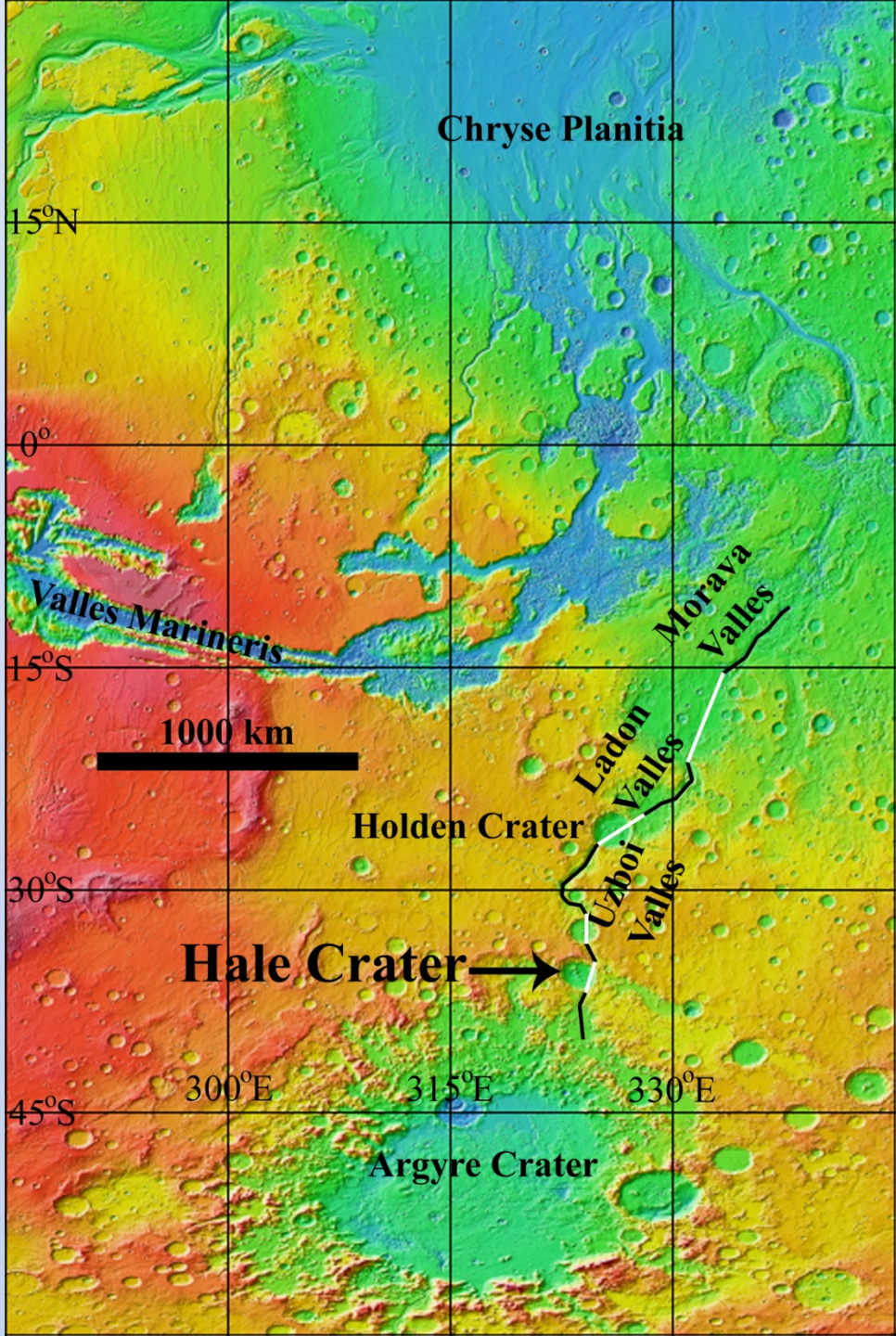
- A *significant* stratigraphic event
- Middle Noachian 3.93 Ga (Robbins et al., *Icarus*, 2013)
- Surrounding features mapped relative to Arygre



Uzboi-Ladon-Morava (ULM) Valles outflow system

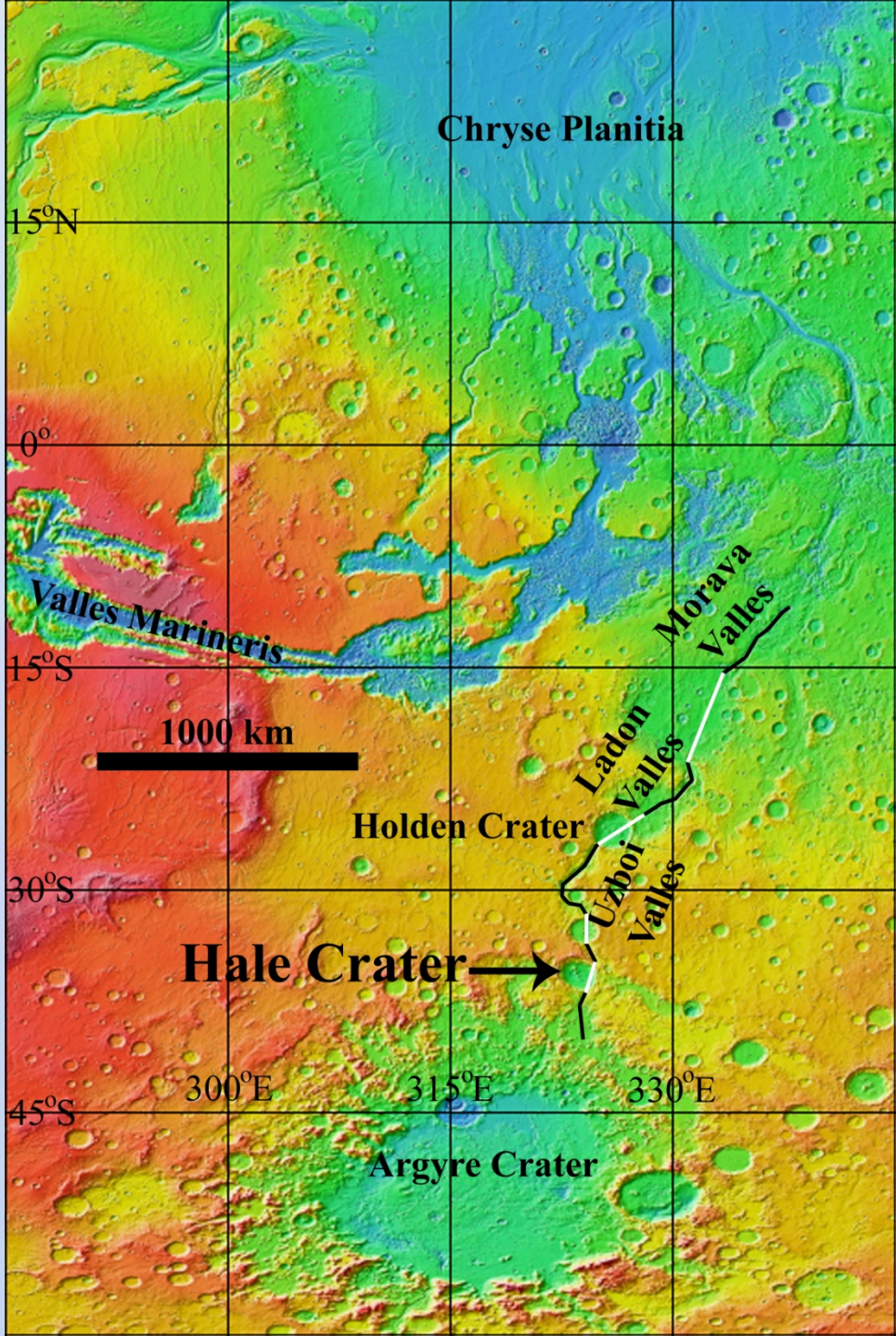
- ULM – transported large volumes of water (150,000–450,000 m^3/s) during late Noachian to early Hesperian (Grant and Parker, *JGR*, 2002)

- ULM source is unknown



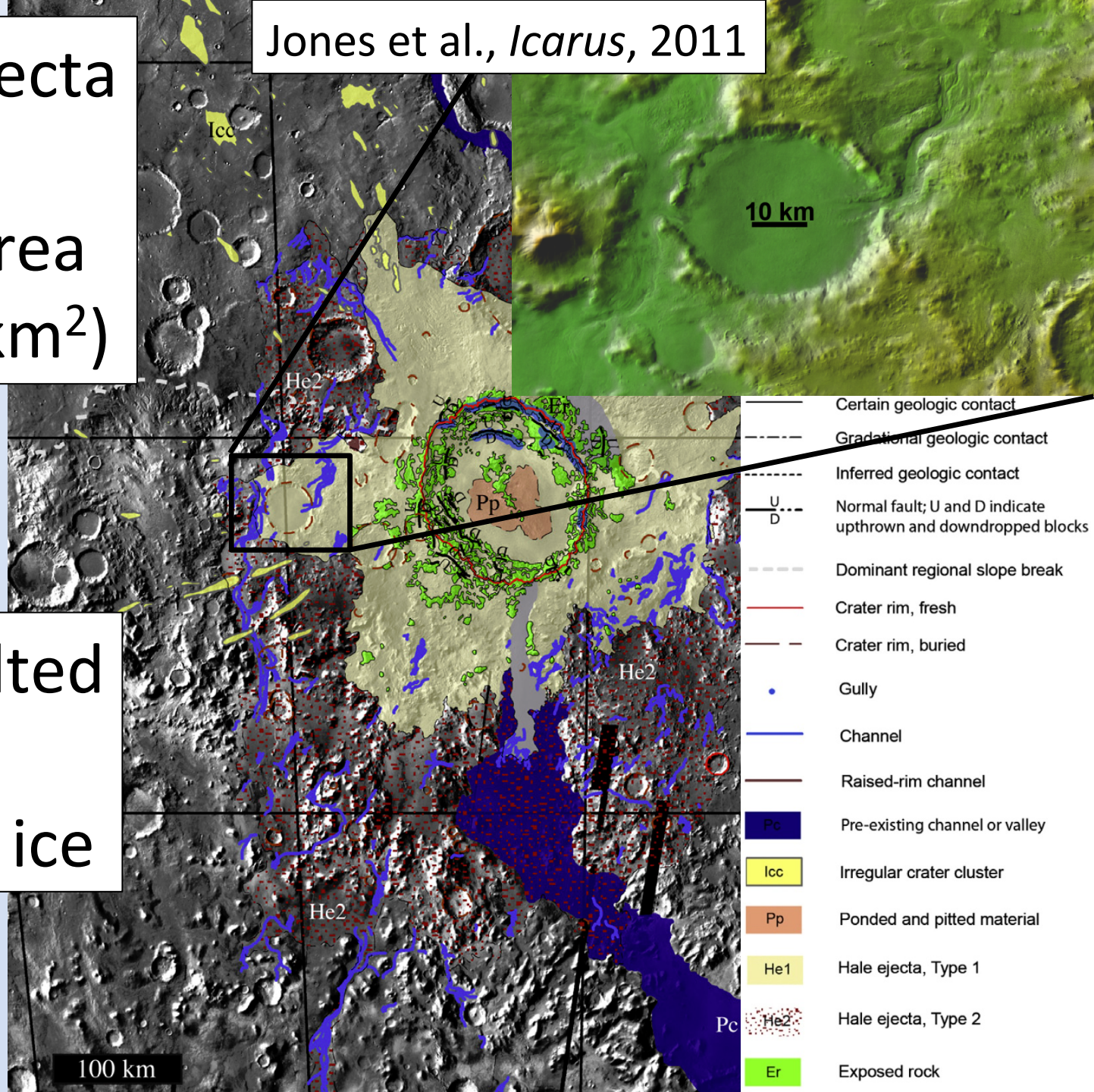
Formation of Hale Crater

- Amazonian crater (>1 Ga) postdates ULM



Fluidized ejecta over an extensive area (>200,000 km^2)

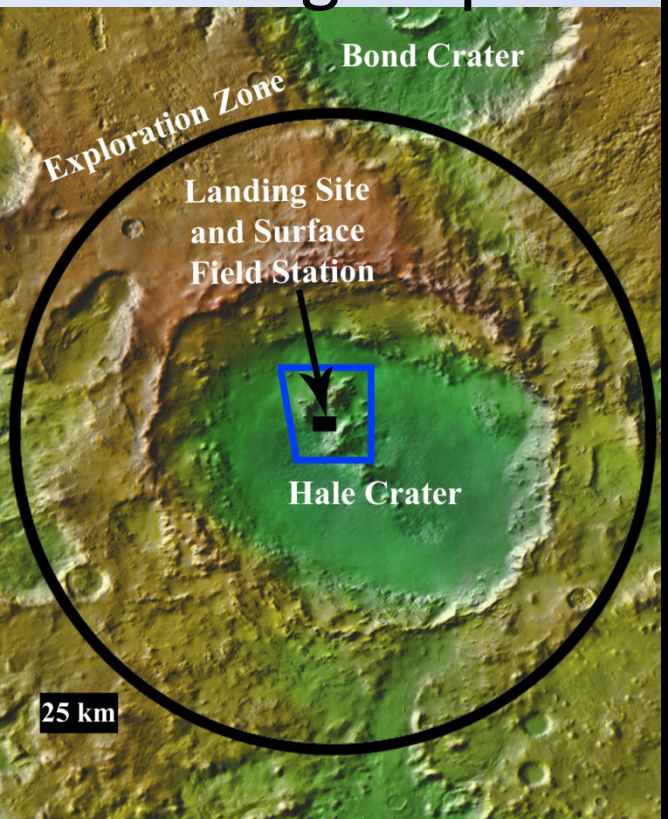
Jones et al., *Icarus*, 2011

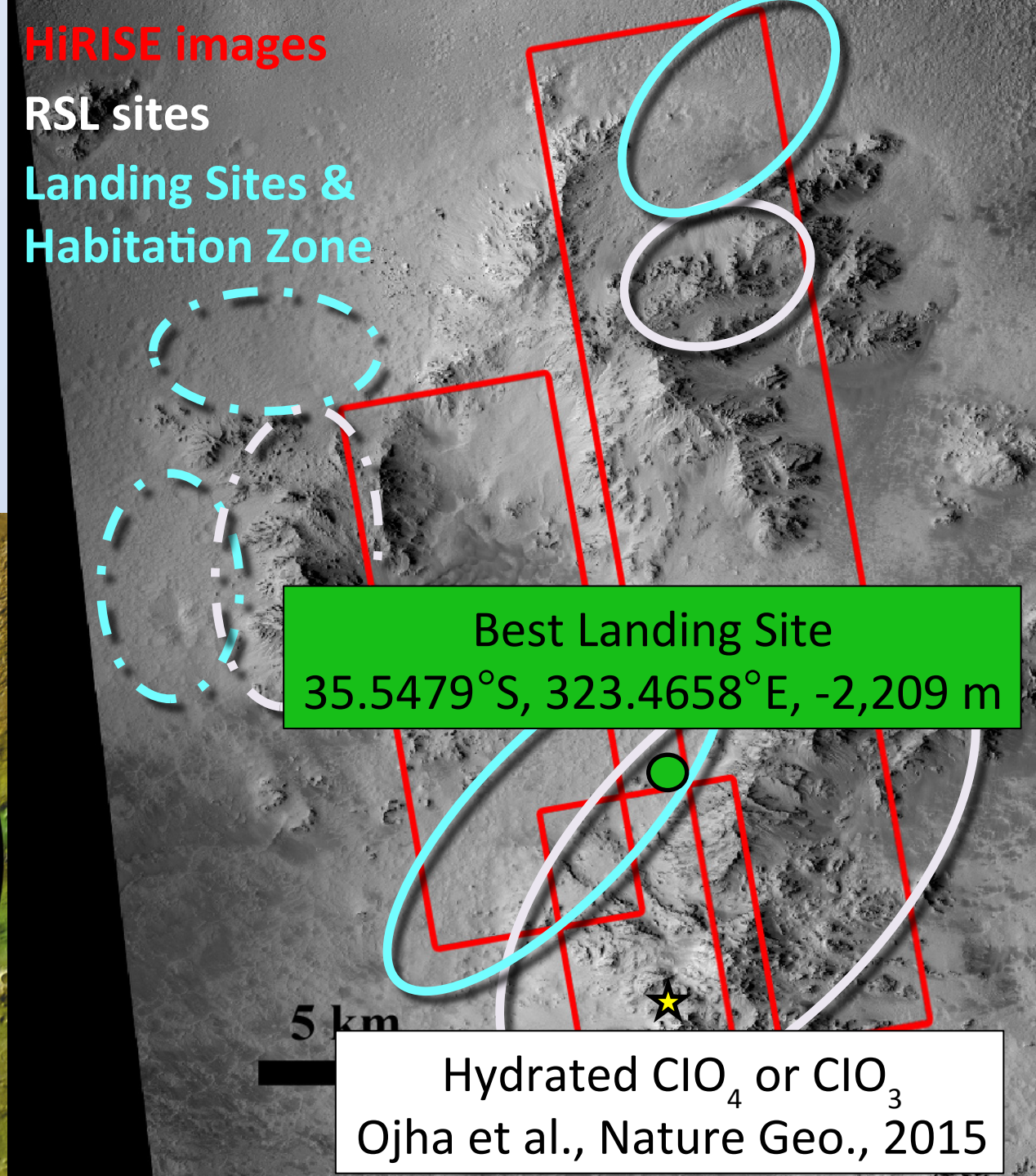


Impact melted 10 km^3 of subsurface ice

Hale LZ/HZ

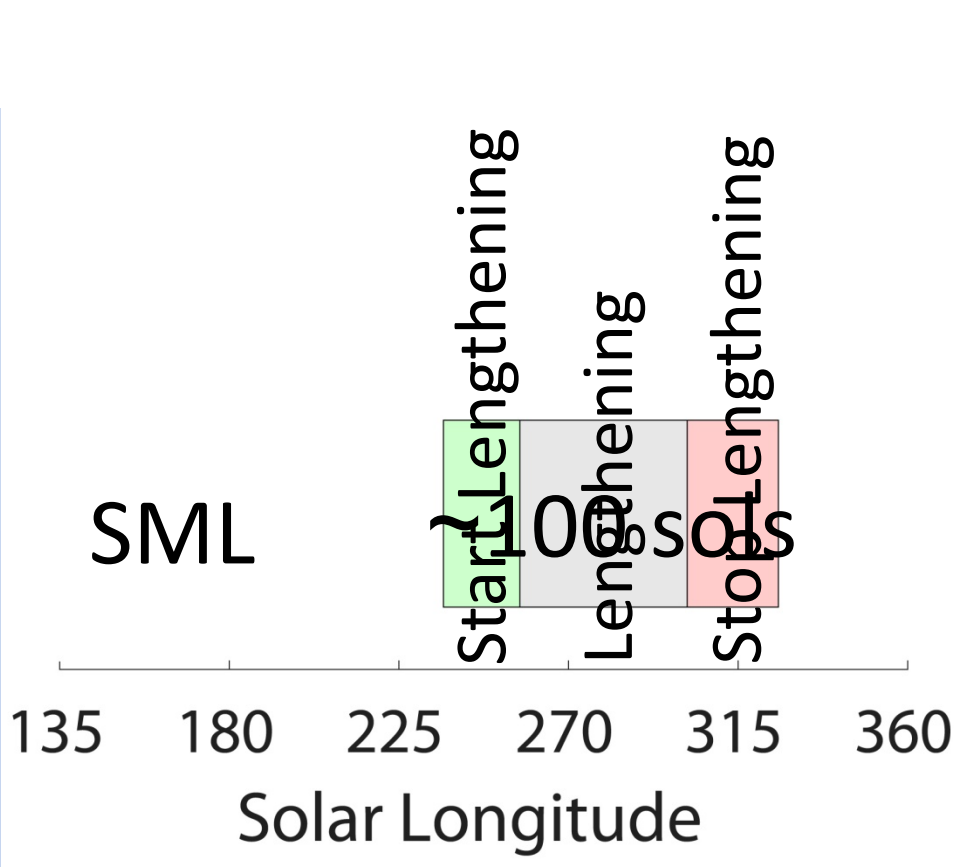
- RSL prefer NW- and W-facing slopes





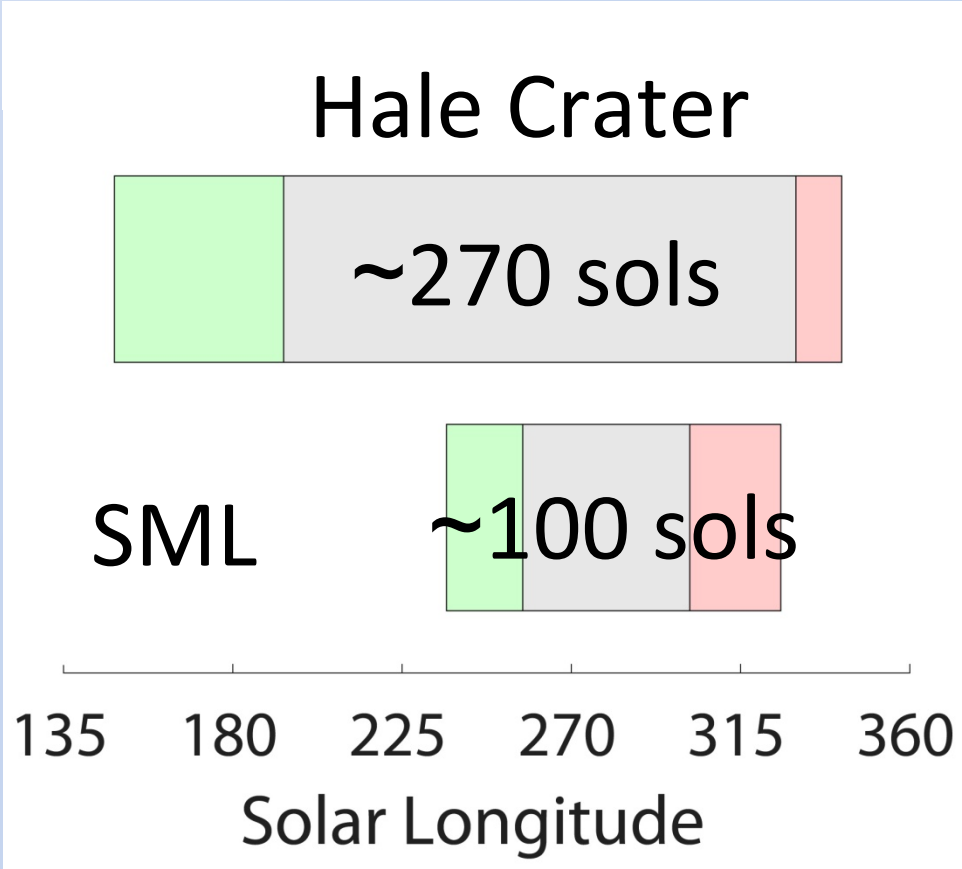
RSL Properties

- Hale crater RSL are anomalous compared to SML RSL



RSL Properties

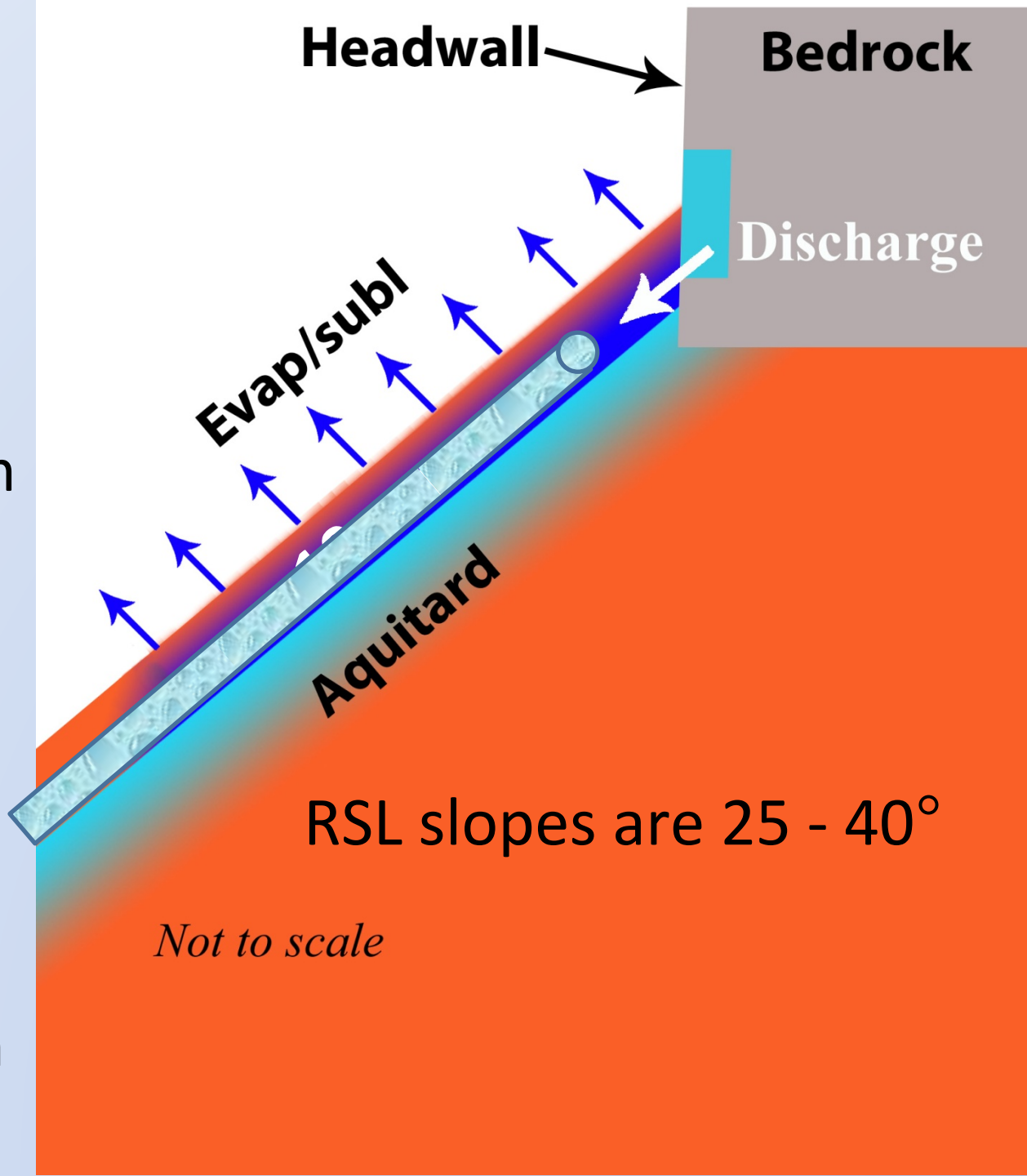
- Hale crater RSL are anomalous
- Duration is 2.7x longer
- Higher concentration of brine
- Thermophysical modeling indicates habitability (i.e., freezing temp of 269-247 K)

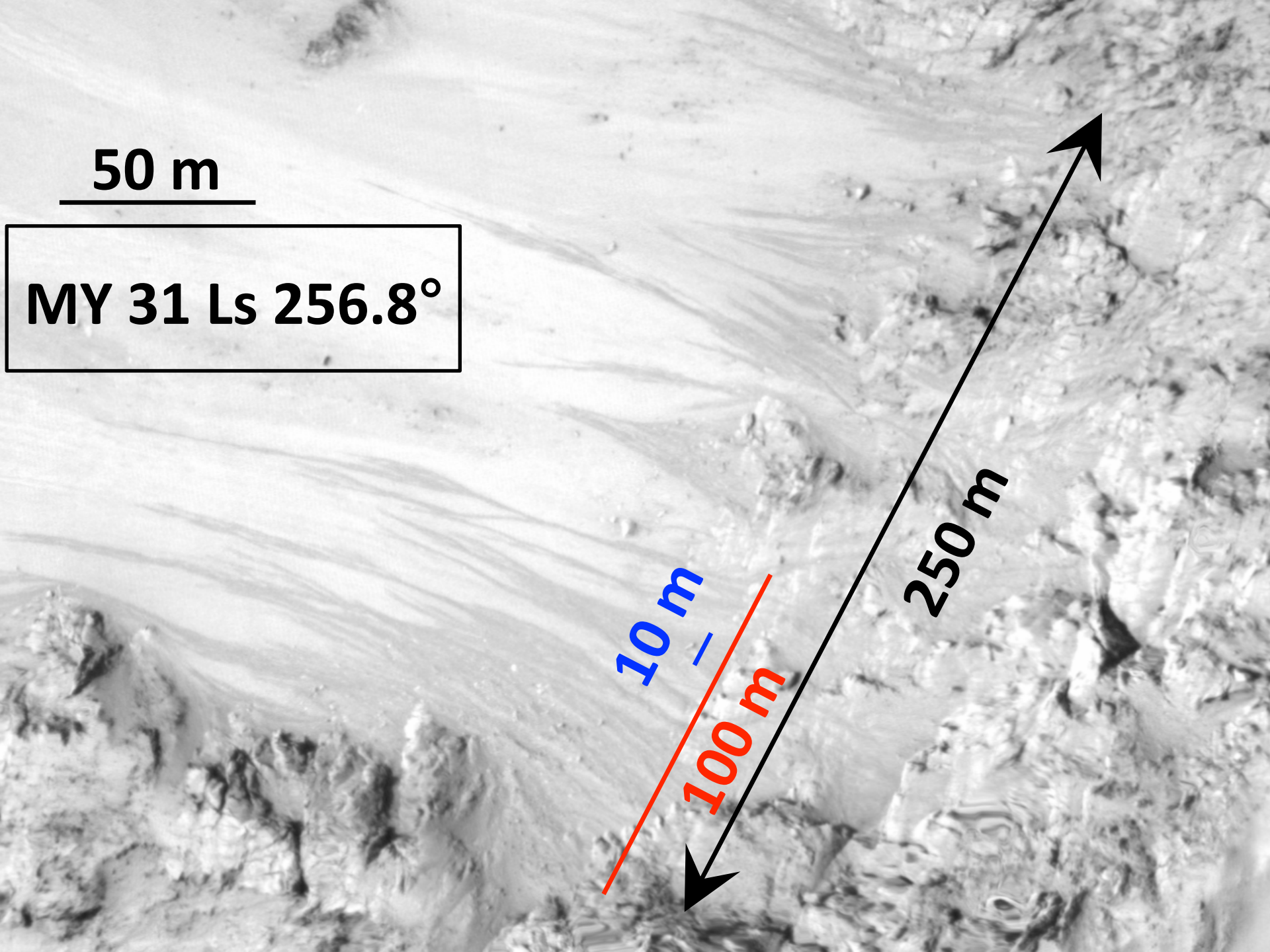


Tap RSL

- Water budget estimate is >1-10 m^3 per m of headwall per yr (Grimm et al., *Icarus*, 2014)

- 100 MT you need 10-100 m of headwall

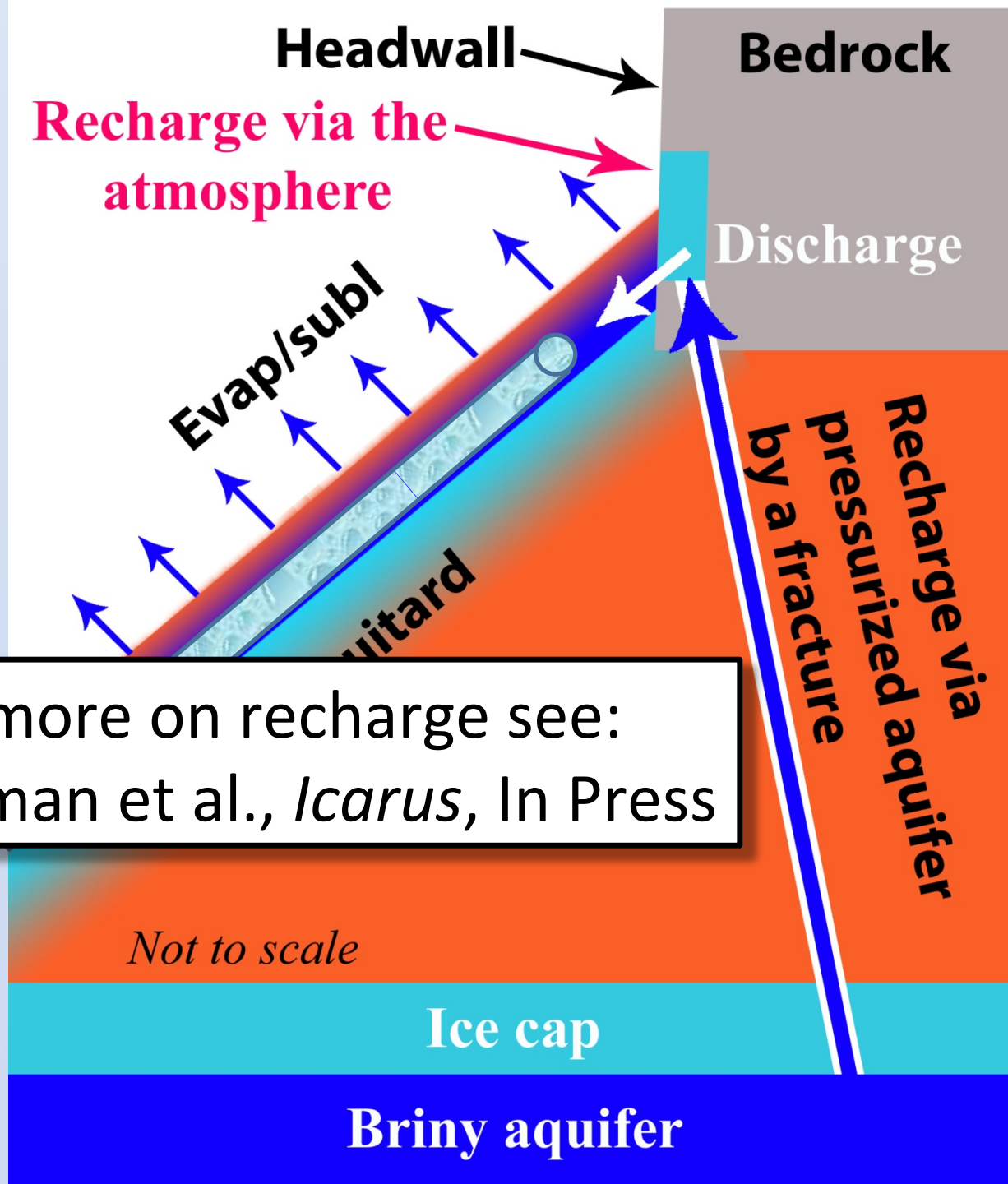



50 m
MY 31 Ls 256.8°
10 m
100 m
250 m

Tap RSL

- Water budget estimate is >1-10 m^3 per m of headwall per yr (Grimm et al., *Icaru* 2014)

- 100 MT you need 10-100 m of headwall

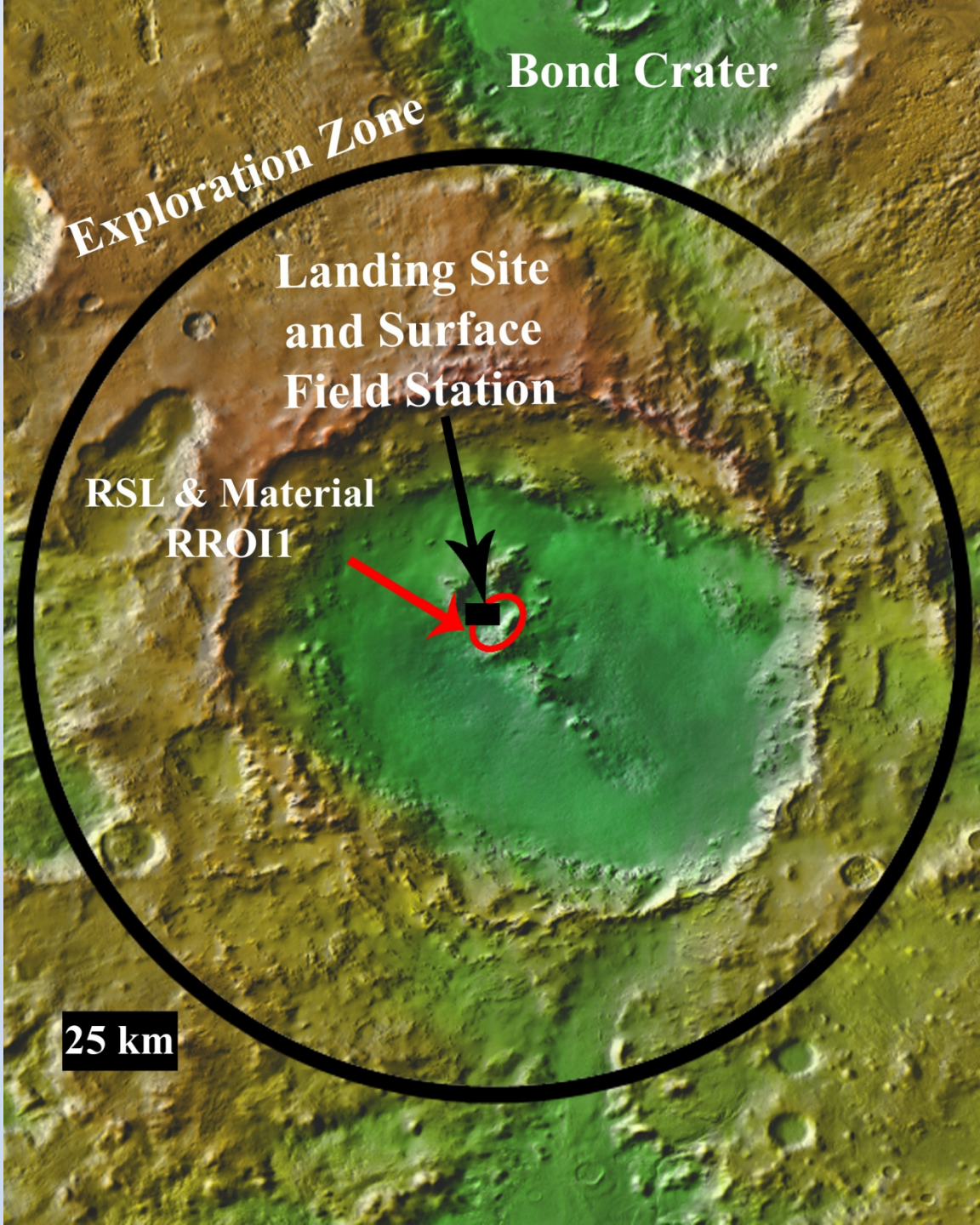


For more on recharge see: Stillman et al., *Icarus*, In Press

RSL & Material Resource ROI1

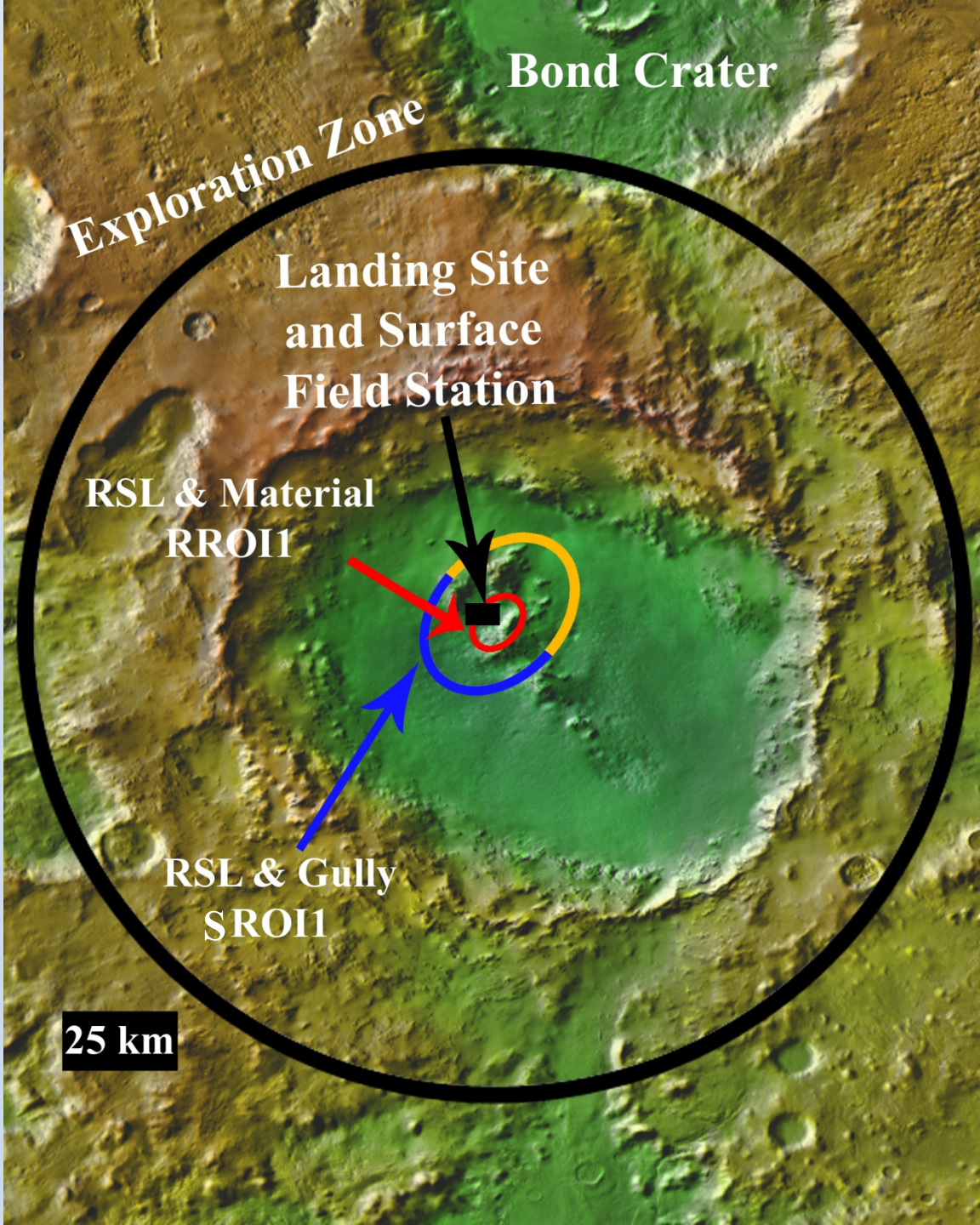
- RSL Resource ROI - NW- and W-facing slopes

- Material Resource ROI - Scree slopes



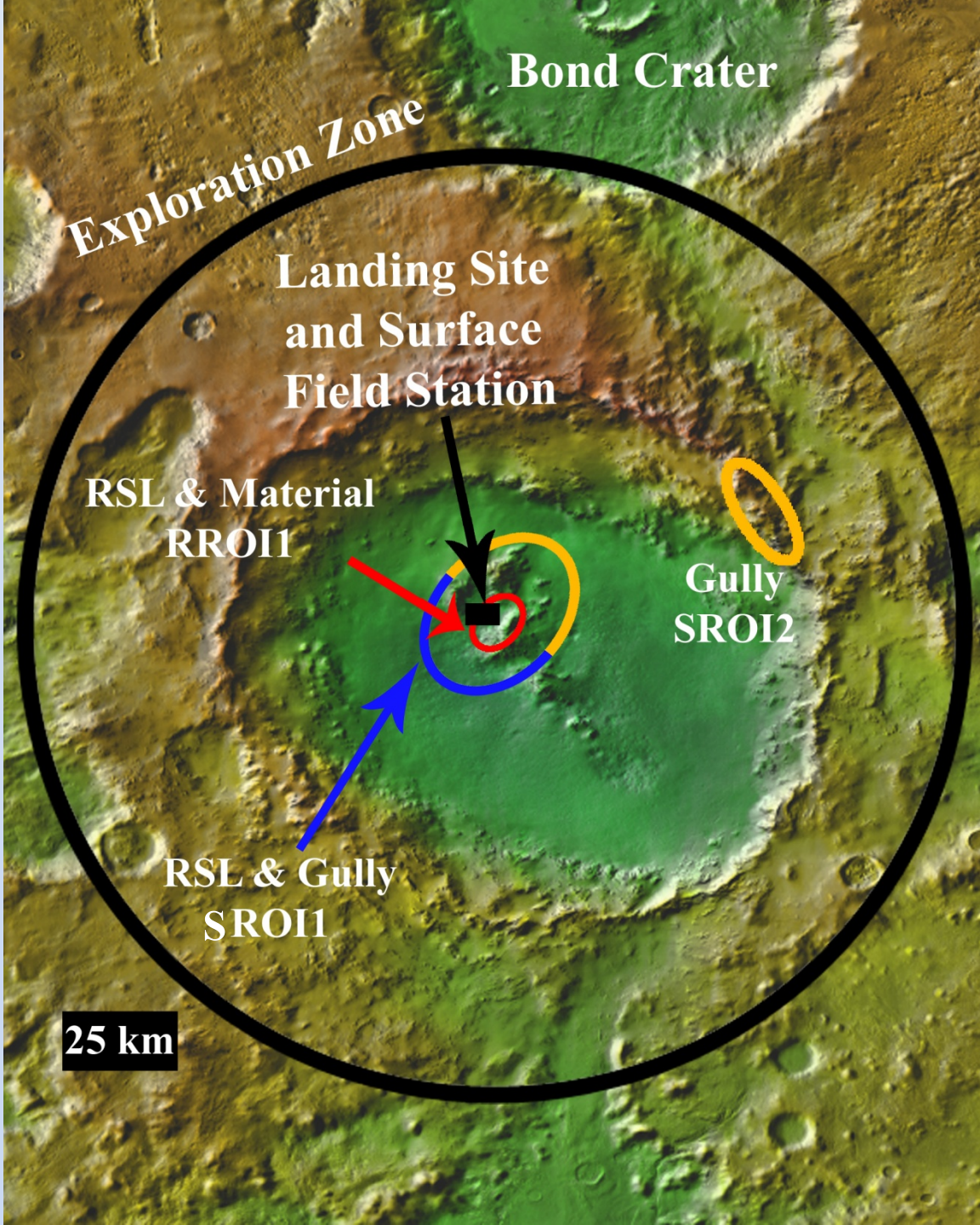
RSL & Gully SROI1

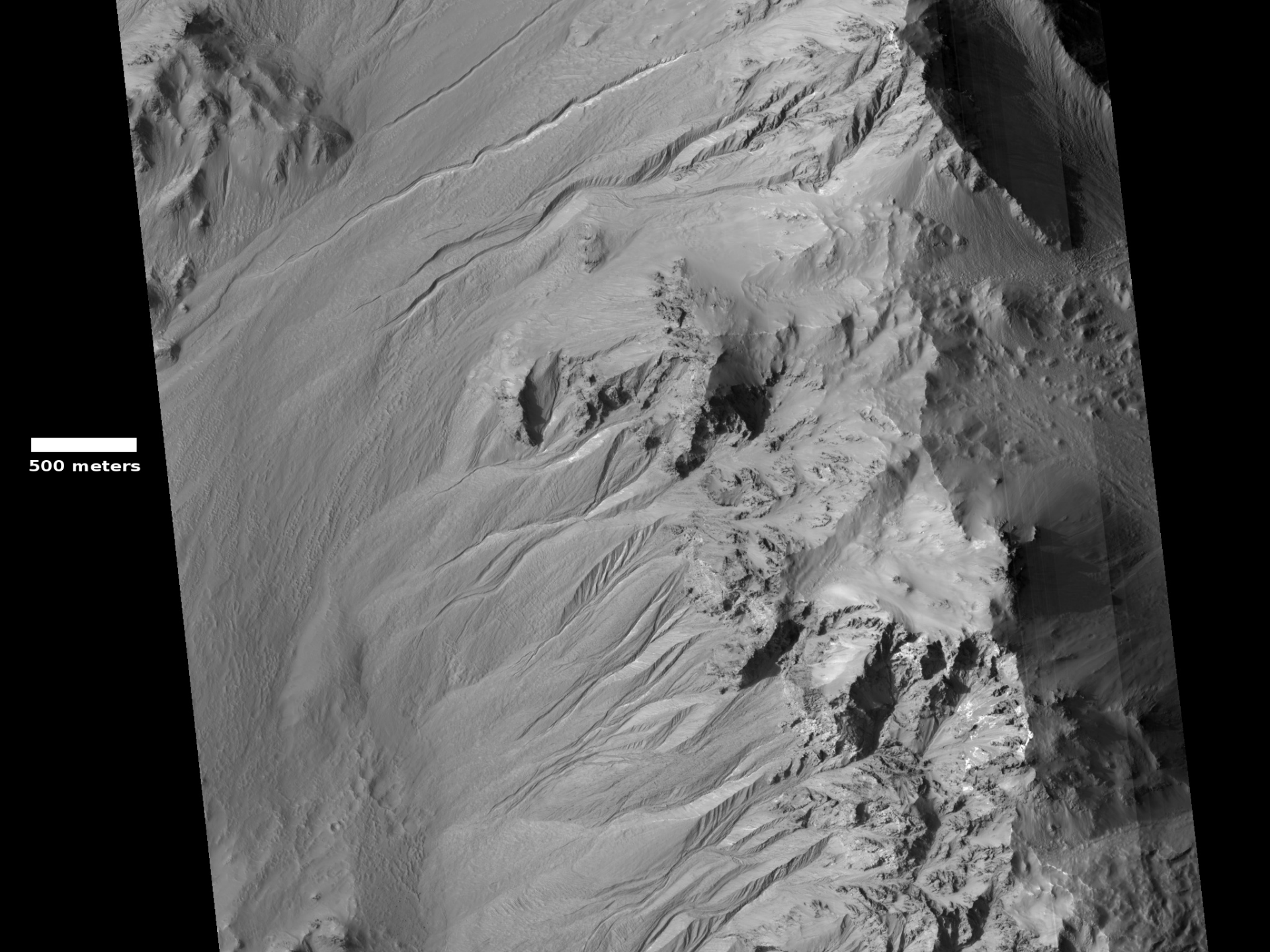
- Science of pristine RSL



Gully SROI2

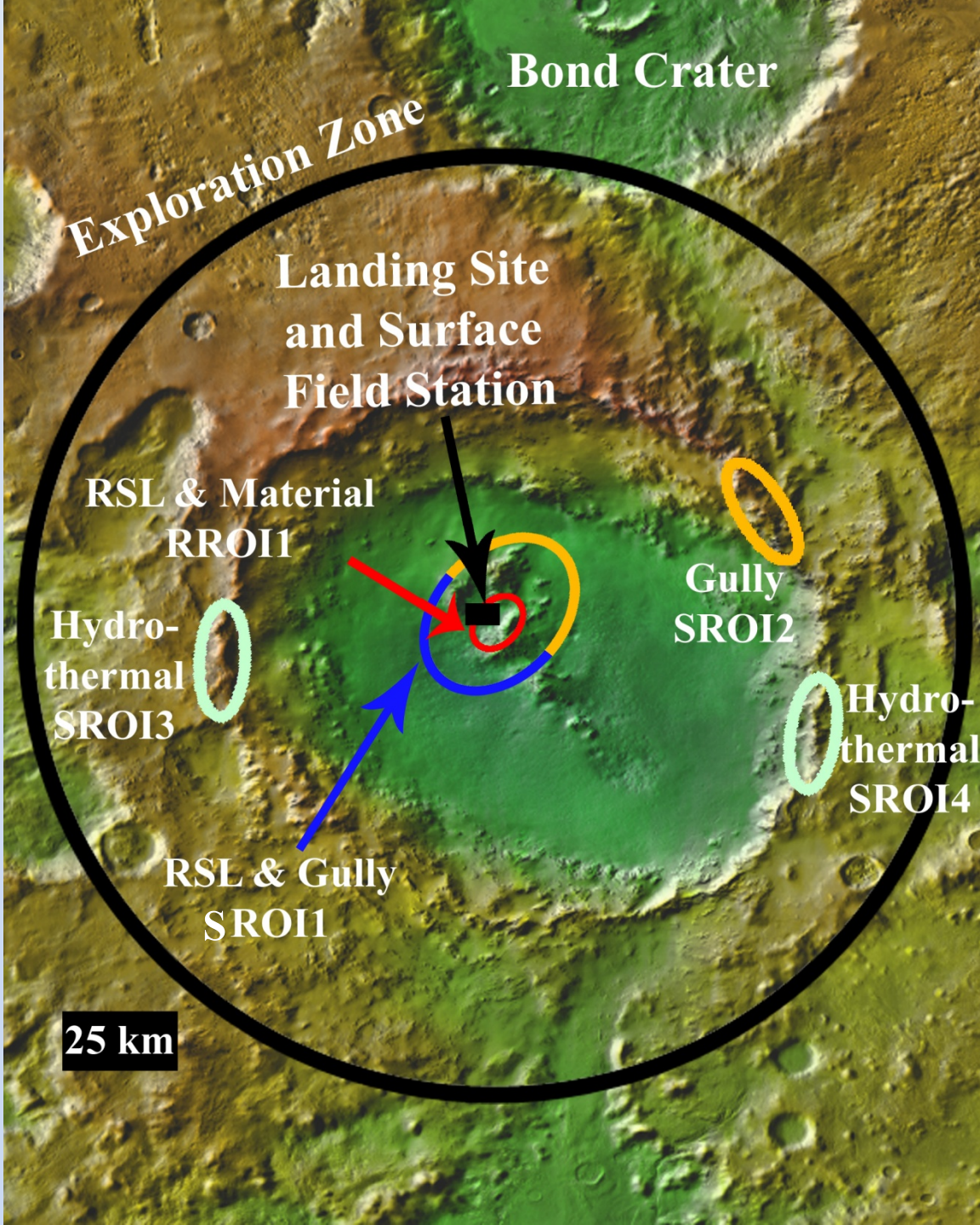
- When and how (water or CO_2) were these originally carved?




500 meters

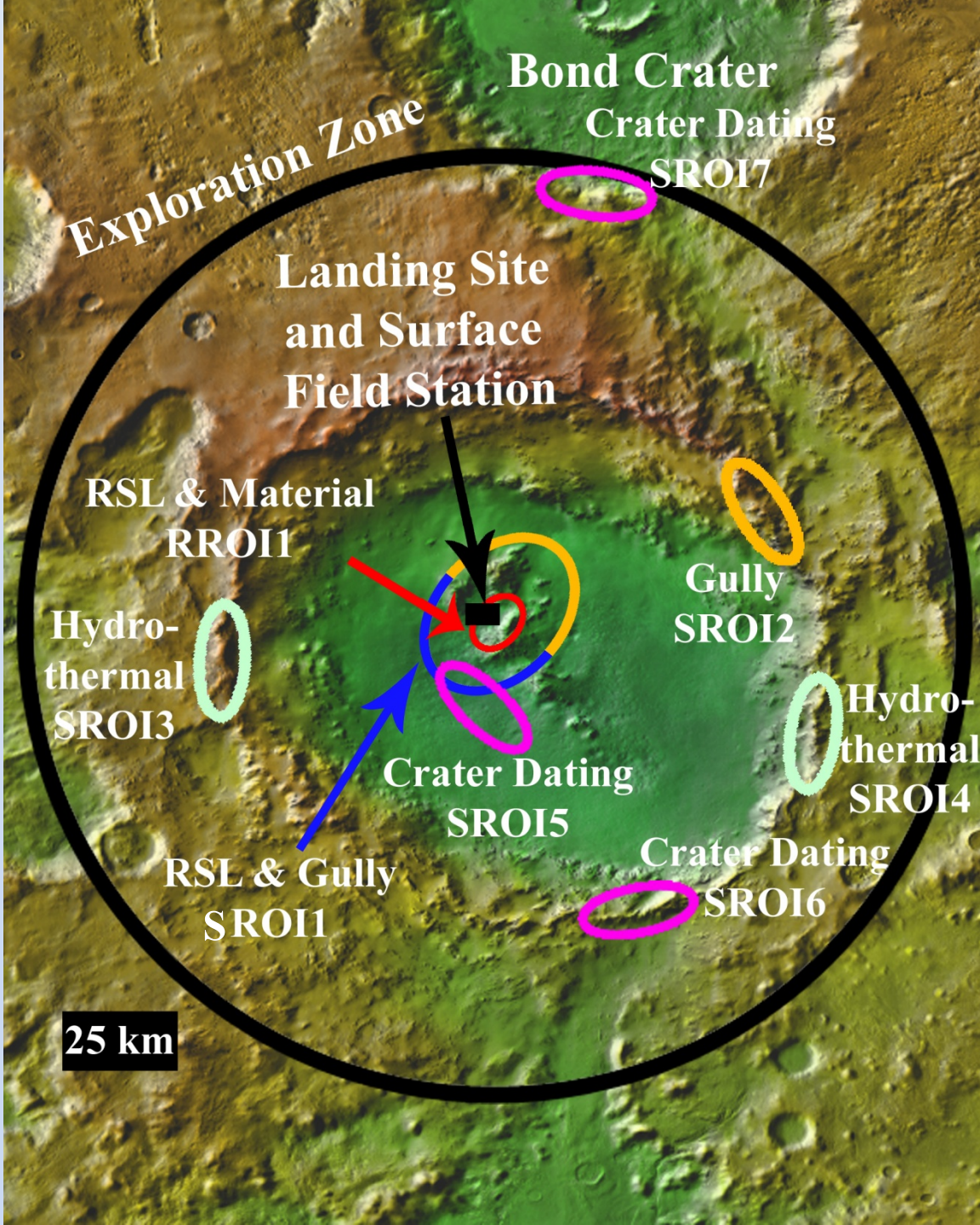
Hydrothermal SROI3, 4

- Spectral evidence of hydothermal alteration (Dohm et al., *Icarus*, 2015)
- May have created zones of habitability

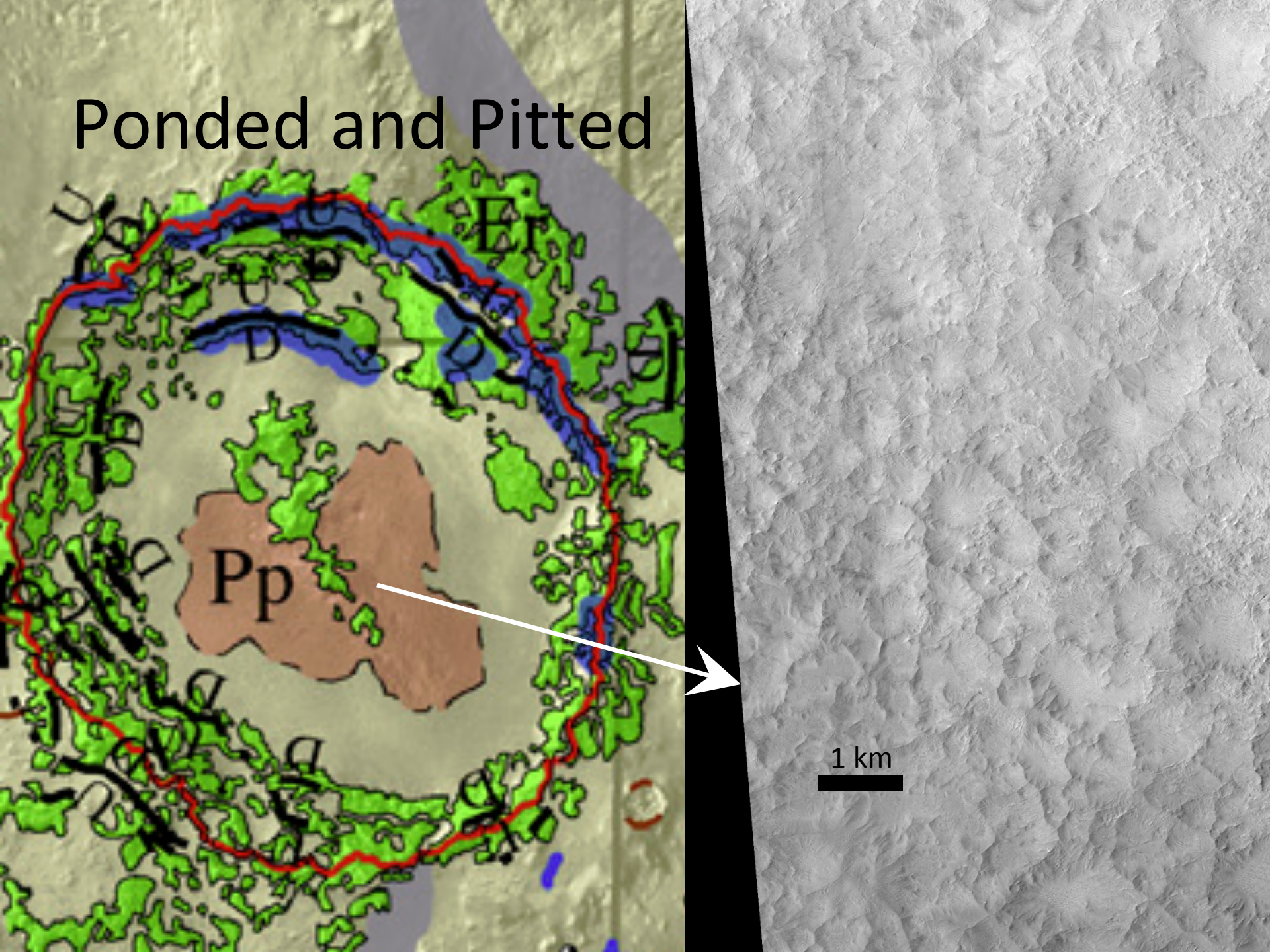


Crater Dating SROI5, 6, 7

- Calibrate crater counts to martian chronology
- Shocked date of Hale, Bond, and Argyre craters
- Best to date melt pond via drilling (possibly melted and pitted material)

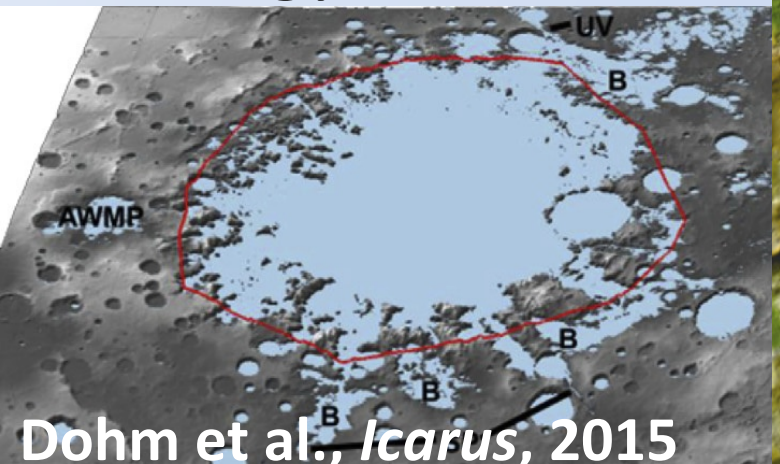


Ponded and Pitted



Ancient Channel SROI8,9

- Fluvial modification via Hale impact
- Did the ULM connect to Argyre?

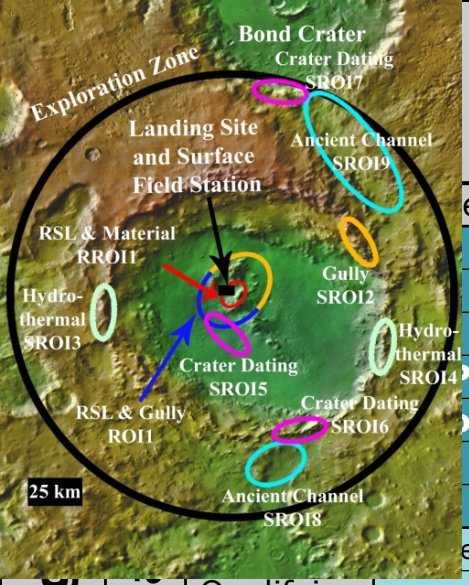


Dohm et al., *Icarus*, 2015

Science ROI Rubric

Site Factors

				SROI1	SROI2	SROI3,4	SROI5,6,7	SROI8,9	RROI1	EZ SUM
Science Site Criteri			**Potential for past habitability**	●	●	●		●	●	7.0
			Potential for present habitability/refugia	○					○	0.2
	Atmo Sc	Qualifying	Potential for organic matter, w/ surface exposure	●	●	●			●	5.0
			Noachian/Hesperian rocks w/ trapped atmospheric gases				○			0.1
			Meteorological diversity in space and time	●	●	●	●	●	●	10.0
			High likelihood of surface-atmosphere exchange	●					●	2.0
			Amazonian subsurface or high-latitude ice or sediment	●	○				●	2.1
			High likelihood of active trace gas sources	?	?	?	?	?	?	0.0
	Geoscience	**Threshold**	**Range of martian geologic time; datable surfaces**				●	○		3.2
			Evidence of aqueous processes	●	●	●		●	●	7.0
			Potential for interpreting relative ages	●	●			●	●	5.0
		Qualifying	Igneous Rocks tied to 1+ provinces or different times							0.0
			Near-surface ice, glacial or permafrost	●	○				●	2.1
			Noachian or pre-Noachian bedrock units	●		●			●	4.0
			Outcrops with remnant magnetization	○	○	○	○	○	○	0.10
			Primary, secondary, and basin-forming impact deposits	●	●	●	●	●	●	10.0
			Structural features with regional or global context	●	●	●		●	●	7.0
			Diversity of aeolian sediments and/or landforms	●					●	2.0



Resource ROI Rubric

Site Factors

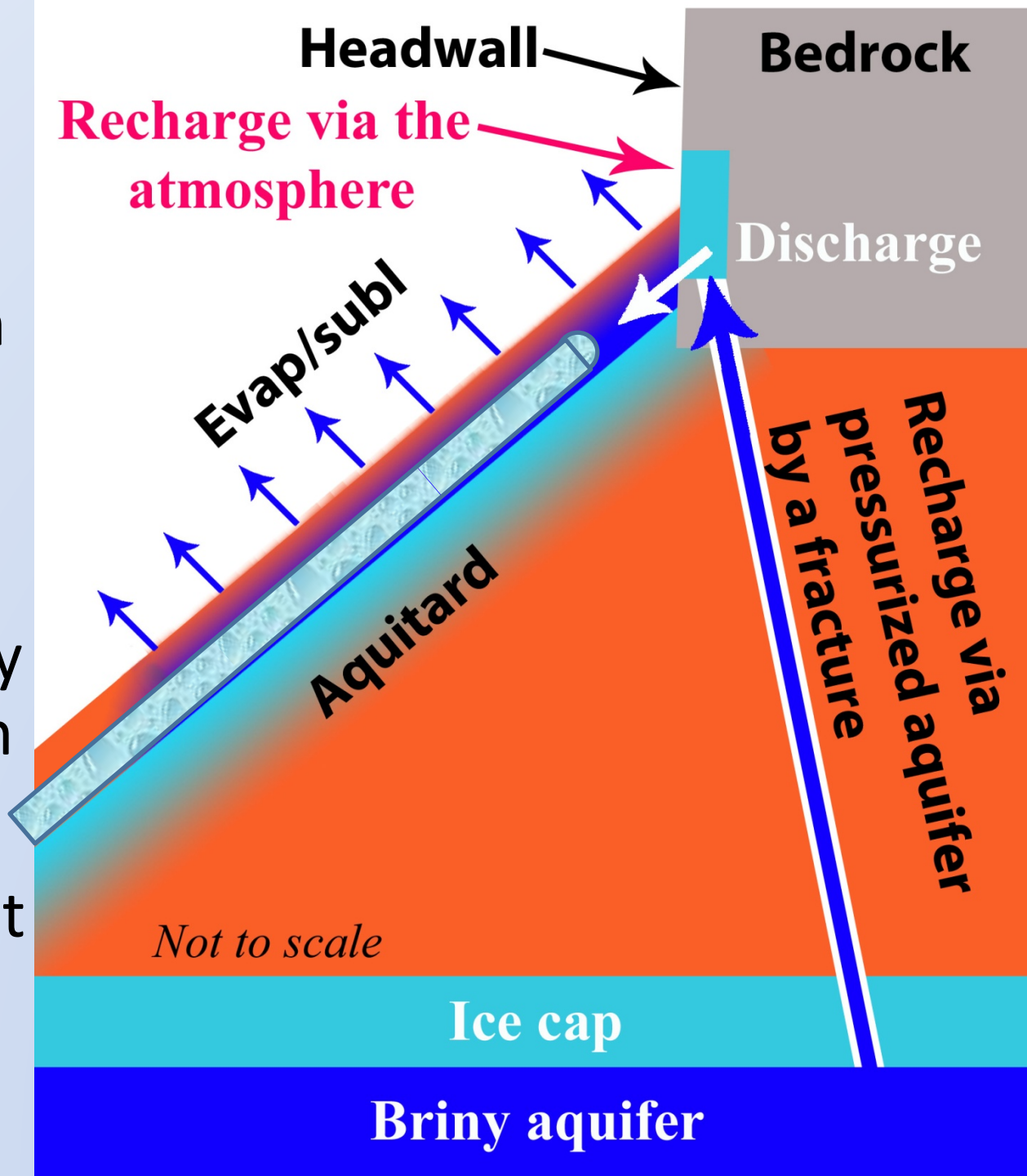
				SROI1	SROI2	SROI3,4	SROI5,6,7	SROI8,9	RROI1	EZ SUM
ISRU and Civil Engineering			ets First Order Criteria (Latitude, Elevation, Thermal Inertia)	●	●	●	●	●	●	10.0
			Potential for ice or ice/regolith mix	●	○	?	?	?	●	2.1
			Potential for hydrated minerals	●		●			●	4.0
			Quantity for substantial production	●					●	2.0
			otential to be minable by highly automated systems	○					○	0.2
			ocated less than 3 km from processing equipment site						●	1.0
			Located no more than 3 meters below the surface	●	○	●	○	○	●	4.3
			Accessible by automated systems	○					○	0.2
			ential for multiple sources of ice, ice/regolith mix **and** hydrated minerals	●	?	●	?	?	●	3.0
	W	Qualifying	Distance to resource location can be >5 km						●	1.0
			Route to resource location must be (plausibly) traversable	●	●	●	●	●	●	10.0
	Civil Engineering	**Threshold**	**~50 sq km region of flat and stable terrain with sparse rock distribution**	●			●	●	●	5.0
			1–10 km length scale: <10°	●			●	●	●	5.0
			Located within 5 km of landing site location						●	1.0
		Qualifying	Located in the northern hemisphere							0.0
			Evidence of abundant cobble sized or smaller rocks and bulk, loose regolith	●	●	●	●	●	●	10.0
			Utilitarian terrain features				○	○		0.3
	Food Production	Qualifying	Low latitude							0.0
			No local terrain feature(s) that could shadow light collection facilities				●	●		3.0
			Access to water	●					●	2.0
			Access to dark, minimally altered basaltic sands	●						1.0
	Metal/Silicon Resource	**Threshold**	**Potential for metal/silicon**	○	○	○	○	○	○	0.10
			Potential to be minable by highly automated systems	○	○	○	○	○	○	0.10
			Located less than 3 km from processing equipment site						●	1.0
			Located no more than 3 meters below the surface	○	○	○	○	○	○	0.10
			Accessible by automated systems	○	○	○	○	○	○	0.10
		Qualifying	Potential for multiple sources of metals/silicon	○	○	○	○		○	0.9
			Distance to resource location can be >5 km	●					●	2.0
			Route to resource location must be (plausibly) traversable	●	●	●	●	●	●	10.0

Highest Priority EZ Data Needs

- RSL over all the central peaks?
  - HiRISE images
- Constrain RSL start
  - HiRISE images
- Topography over the entire central part of Hale and at the two passes
  - HiRISE or CTX DTMs
- More hydrothermal alteration?
  - CRISM

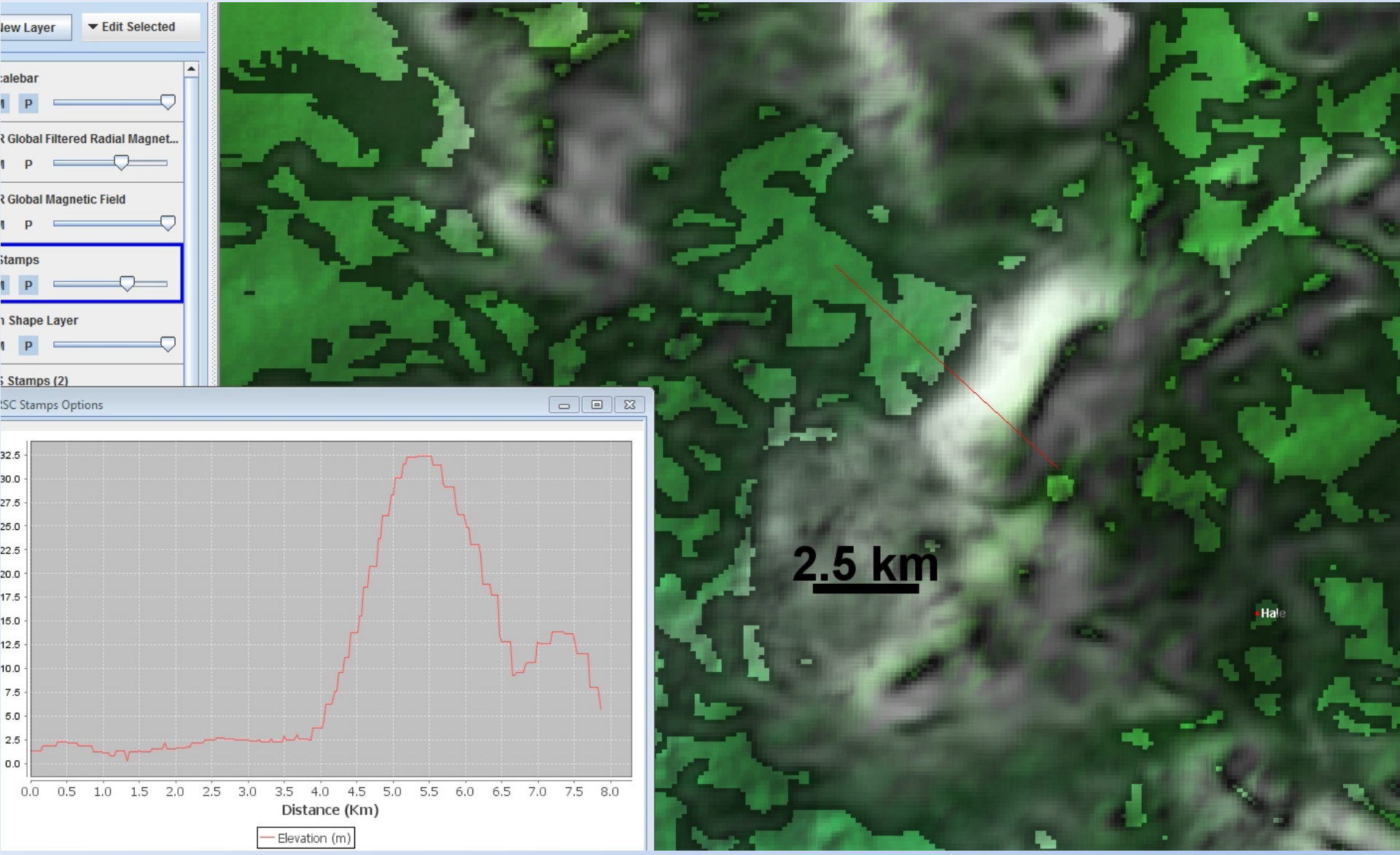
RSL as a resource?

- Too uncertain right now
- Need more data and likely a new mission
- Are slopes just too steep?



Conclusion

- Minimize infrastructure for water extraction
  - Minimizes cost and risk


lew Layer
Edit Selected
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R Global Magnetic Field
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S Stamps (2)
SC Stamps Options
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15.0
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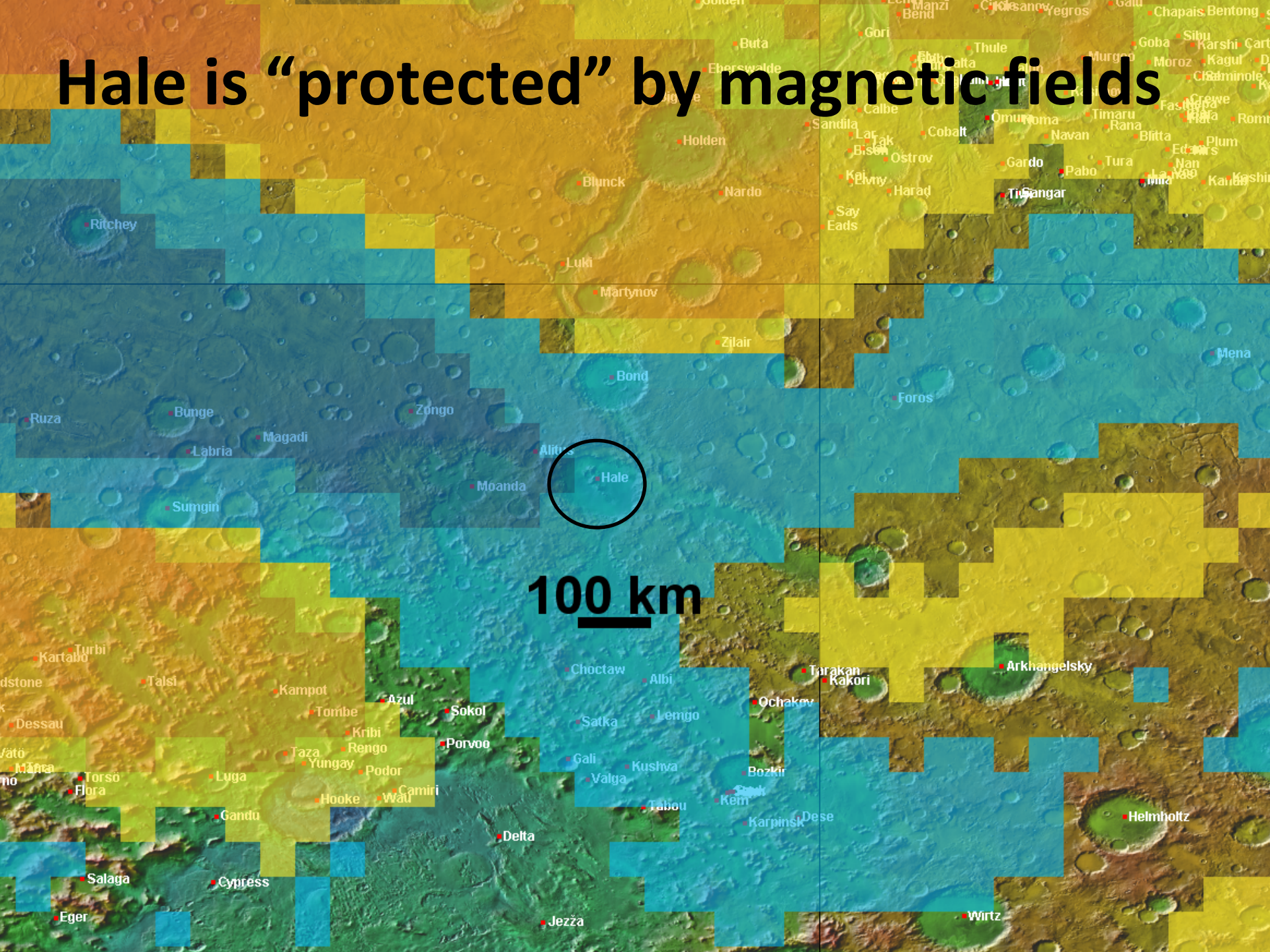
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0
Distance (Km)
Elevation (m)
2.5 km
Hale

Hale is “protected” by magnetic fields

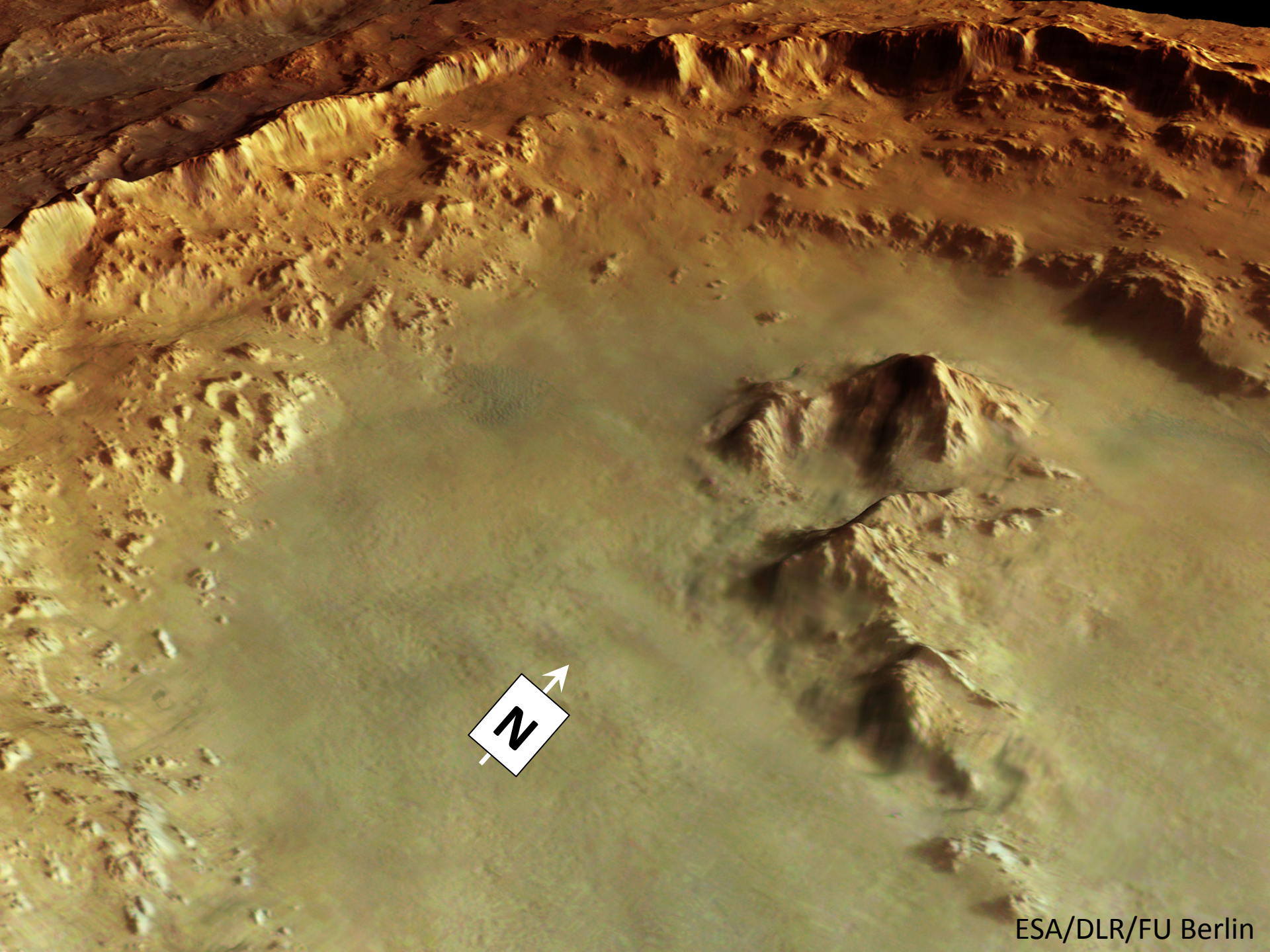


Astrobiology

- Extant life – RSL ROI (A3)
- Characterize modern environment with high habitability – RSL ROI (A4)
- Past Life – RSL, Gullies, Hydrothermal, Ancient channels ROI (A1, A2)
- Characterize the exchange and cycling of H2O between the subsurface, surface, and atmosphere – RSL ROI (A5)

Geoscience

- What was the source of ULM? – Ancient Channels ROI (C1)
- What is the date of the Hale Crater impact event and why was the subsurface so wet? – Ancient Channels and Age Dating ROIs (C1, C2)
- Date of Argyre, Hale and Bond craters (C1, C2)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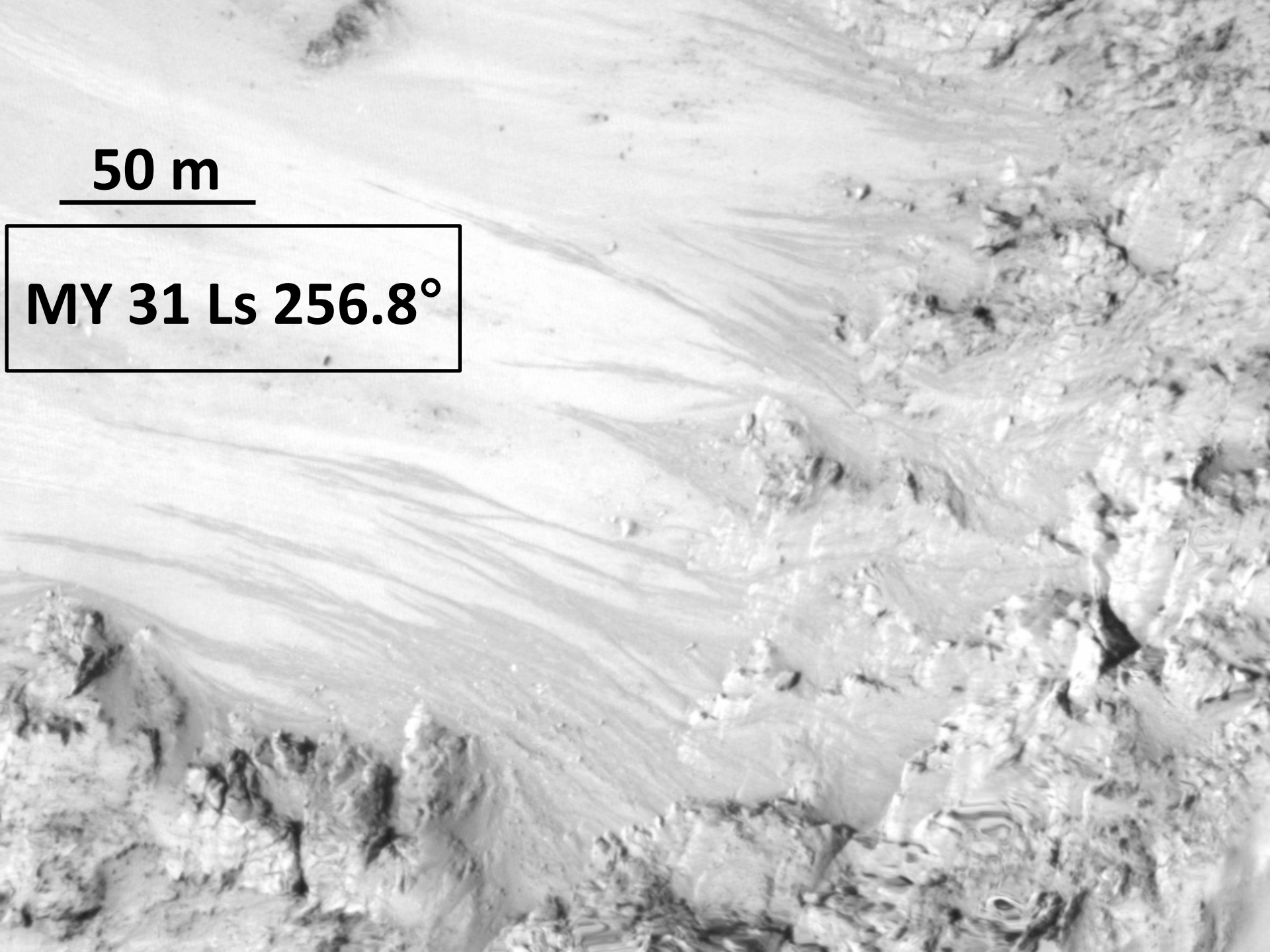
ESA/DLR/FU Berlin


50 m
MY 31 Ls 256.8°

50 m
MY 31 Ls 264°
11 sols later