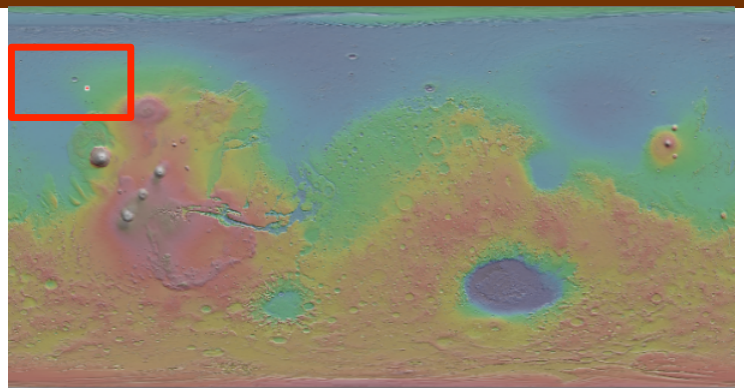
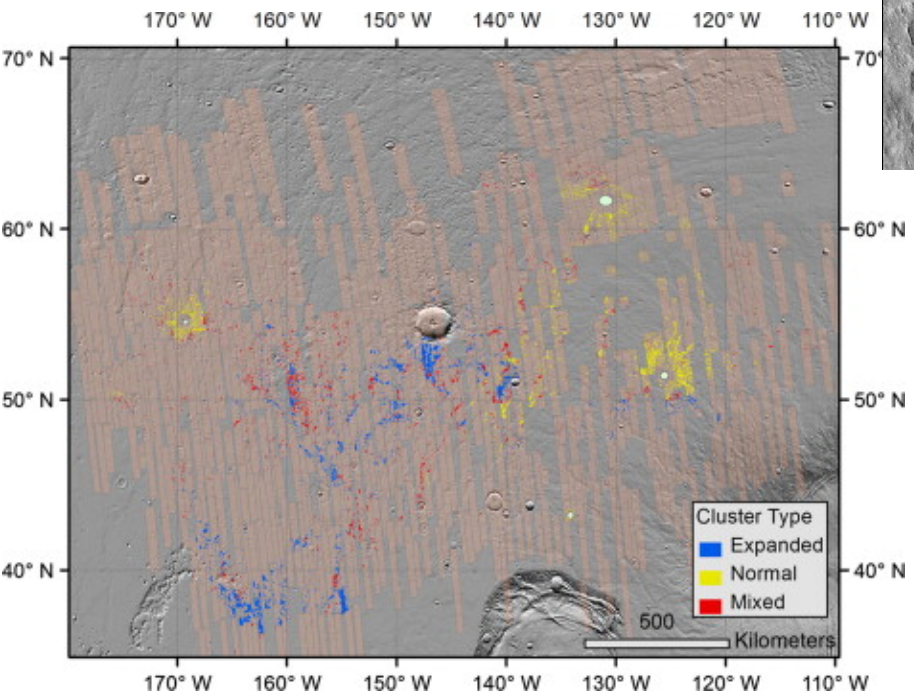
Arcadia Planitia: Acheron Fossae and Erebus Montes Workshop Abstract #1011

Donna Viola[1] (dviola@lpl.arizona.edu), Alfred S. McEwen[1], & Colin M. Dundas[2]

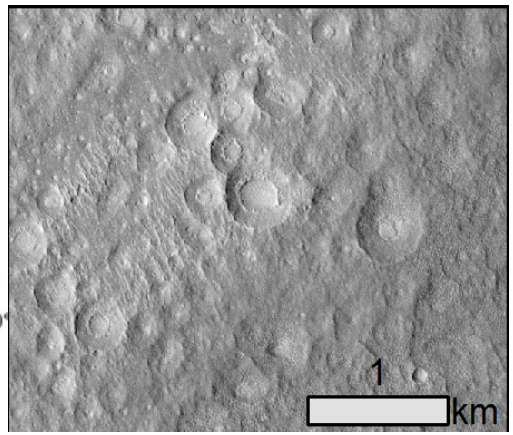
[1]University of Arizona, Department of Planetary Sciences, [2]USGS Astrogeology Science Center

Motivation: Shallow Subsurface Water Ice





Expanded Secondary Craters



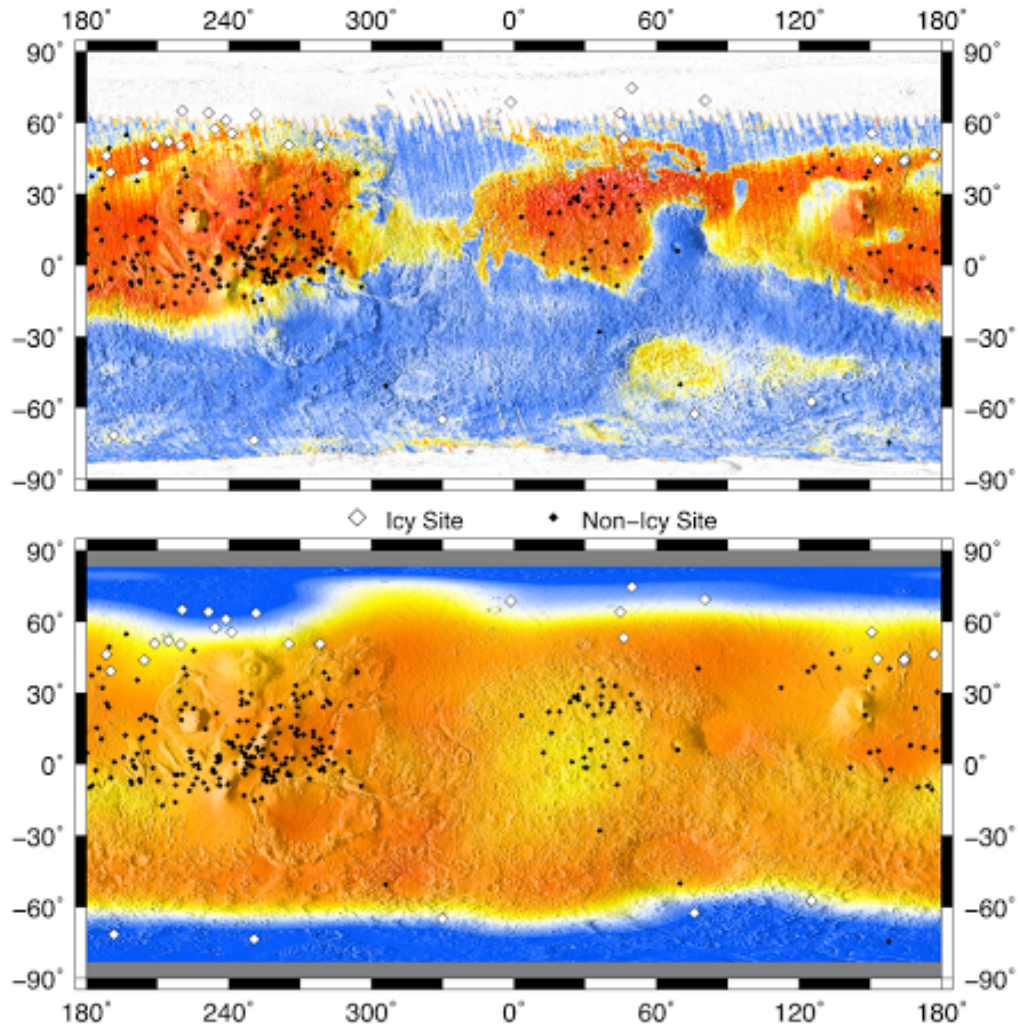
These craters require substantial **excess ice** in order to form. They suggest that the Arcadia Planitia ice sheet is tens of millions of years old.

Viola, et al. (2015). Icarus *248*: 190-204.

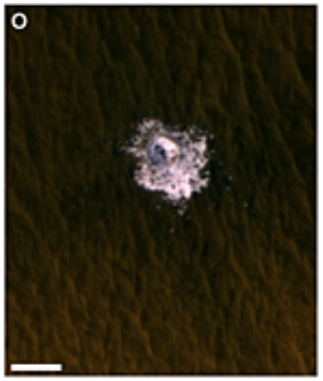
Arcadia Planitia is one of the few regions where abundant shallow ice is present at relatively low latitude.

Motivation: Shallow Subsurface Water Ice

Map of recent ice-exposing impact craters



Dust cover index basemap (red = dusty, blue = less dusty)



These craters expose **"excess" ice** (Dundas et al., 2015)– which is almost entirely free of dust (>99% water ice).

Water-equivalent hydrogen basemap (blue = more ice, orange = little/no ice)

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Motivation: Shallow Subsurface Water Ice

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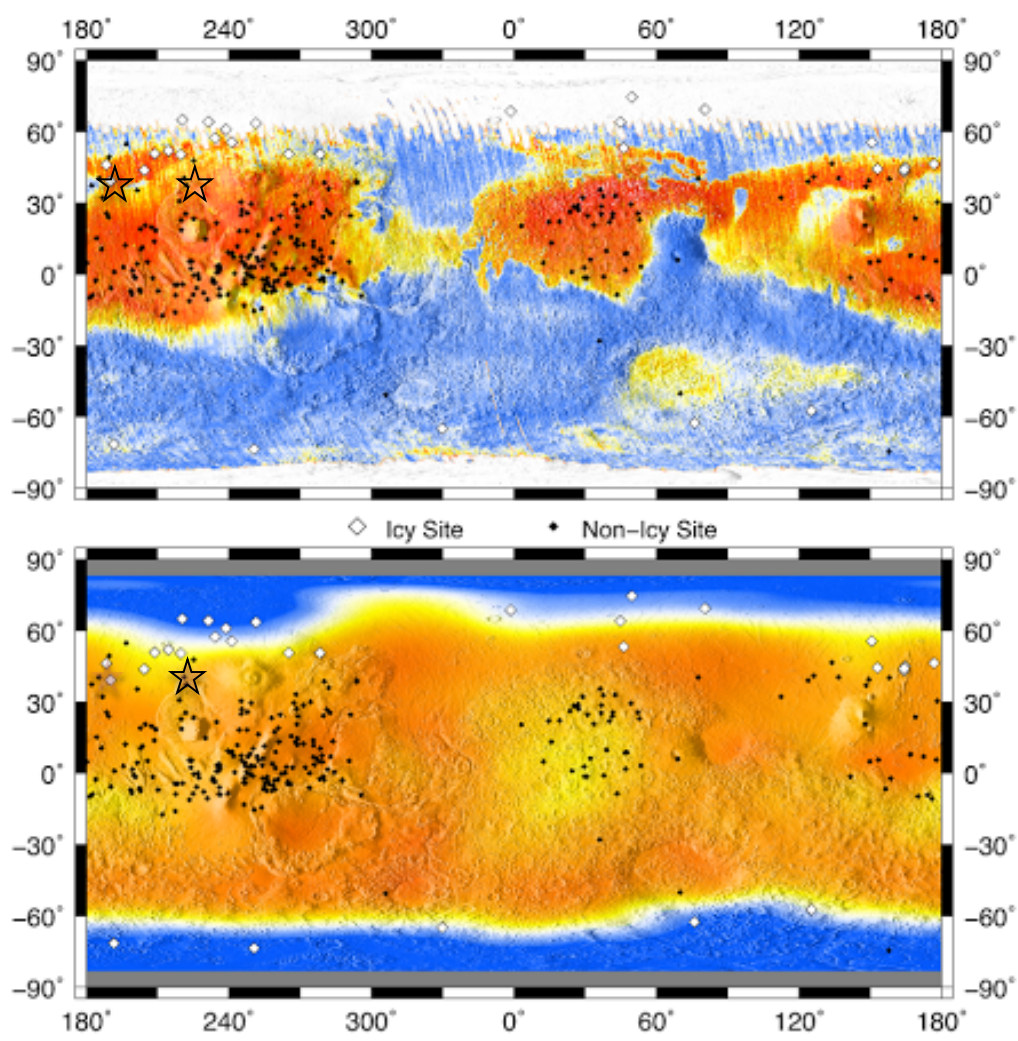

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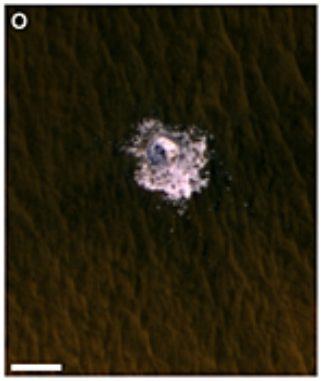

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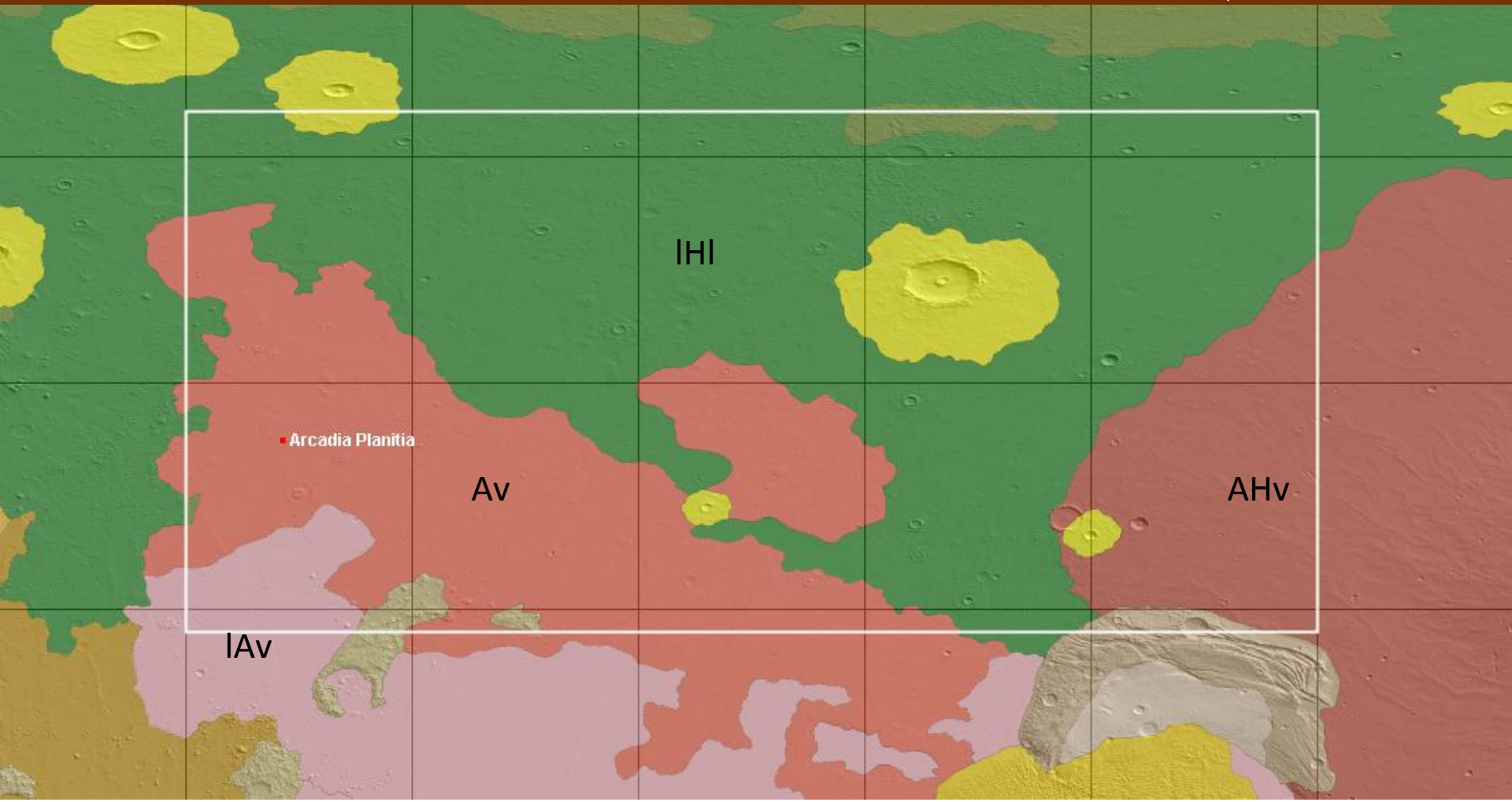
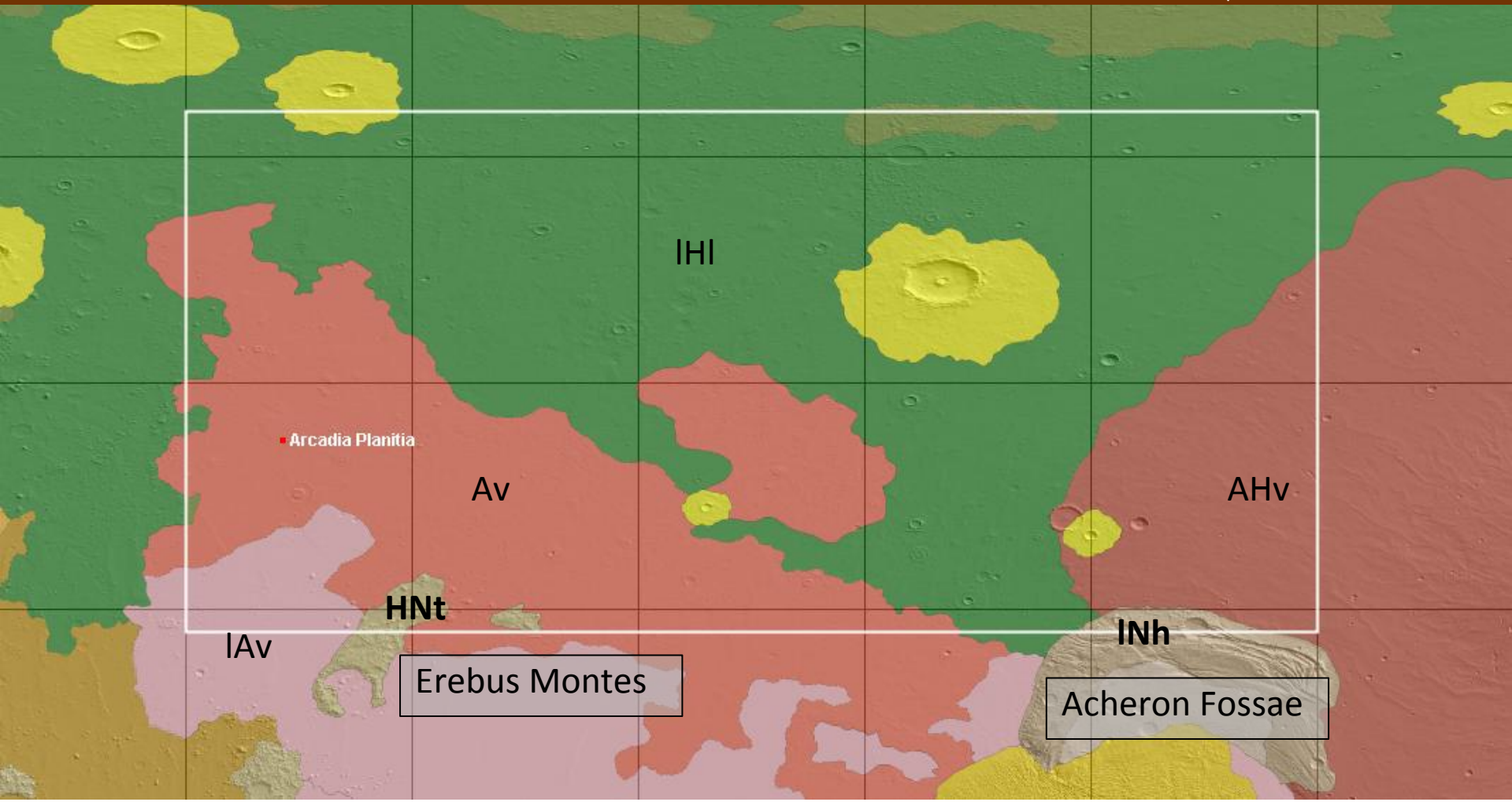
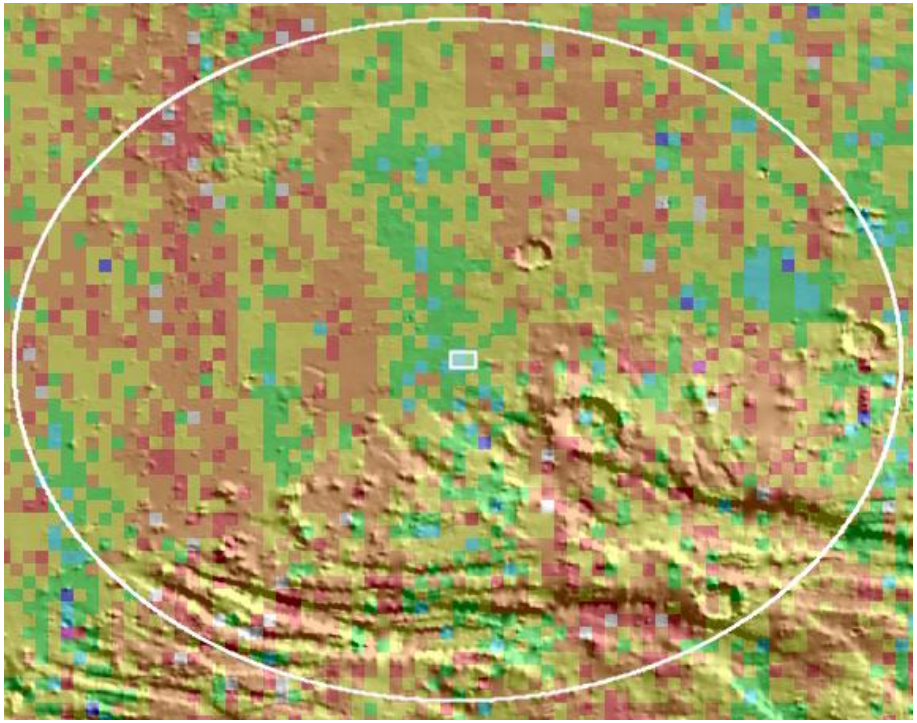
Arcadia Planitia: Geologic Context



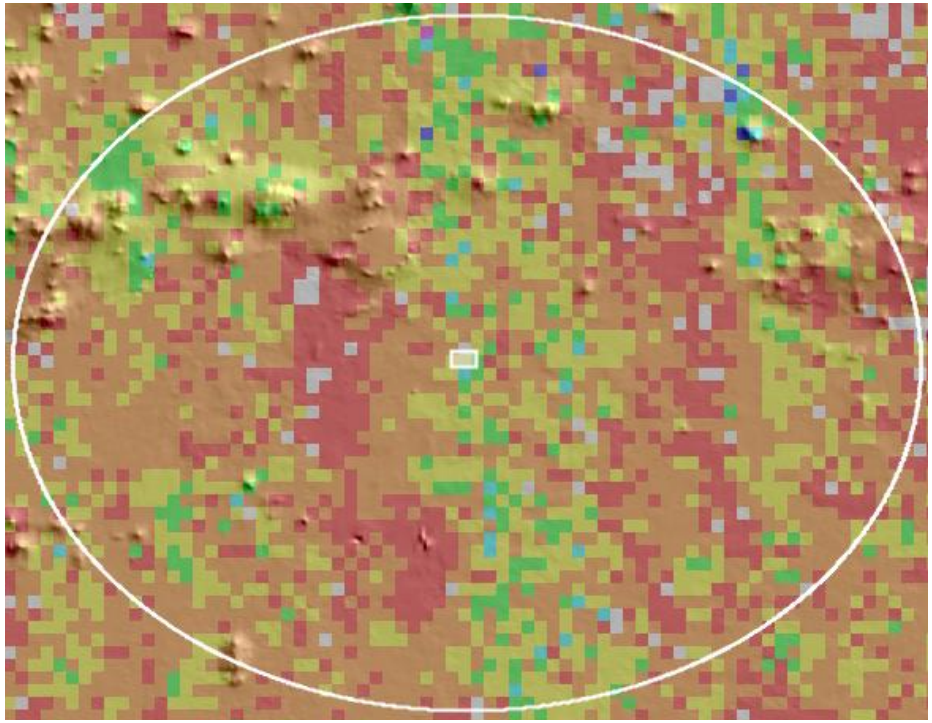
Arcadia Planitia: Geologic Context



Arcadia Planitia: Challenges



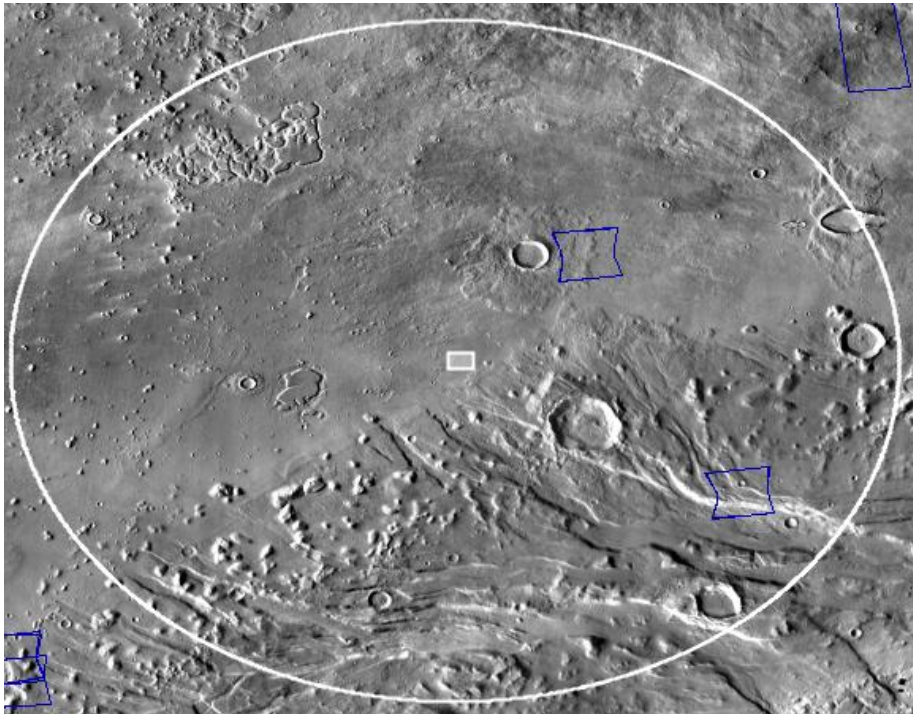
Acheron Fossae



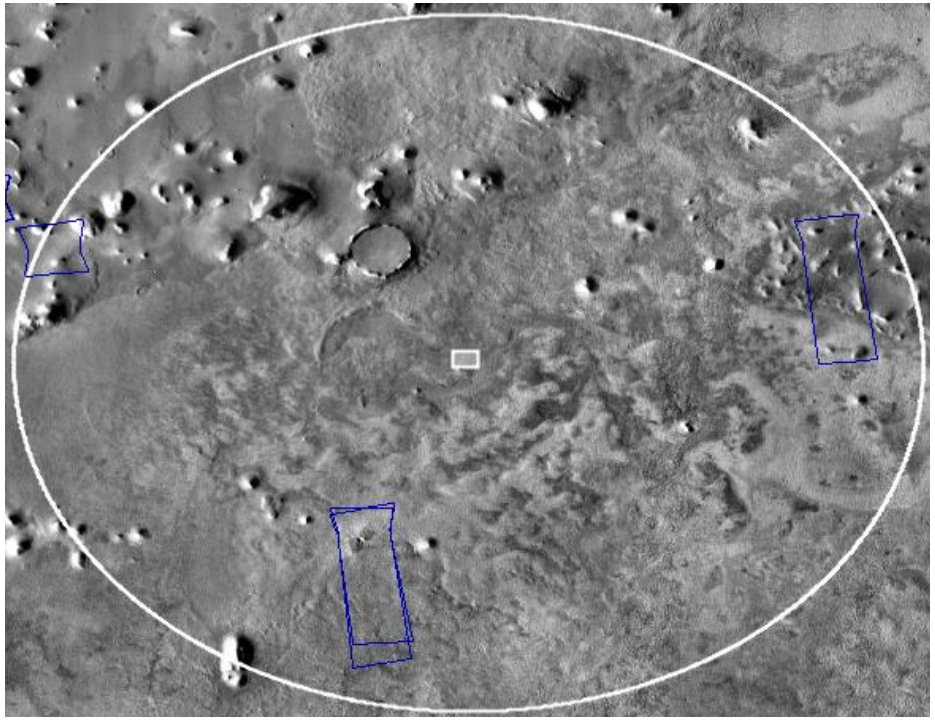
Erebus Montes

Dust: Arcadia Planitia is fairly dusty. Landing sites were chosen in areas that appear to minimize dust using the TES Dust Cover Index.

Arcadia Planitia: Challenges



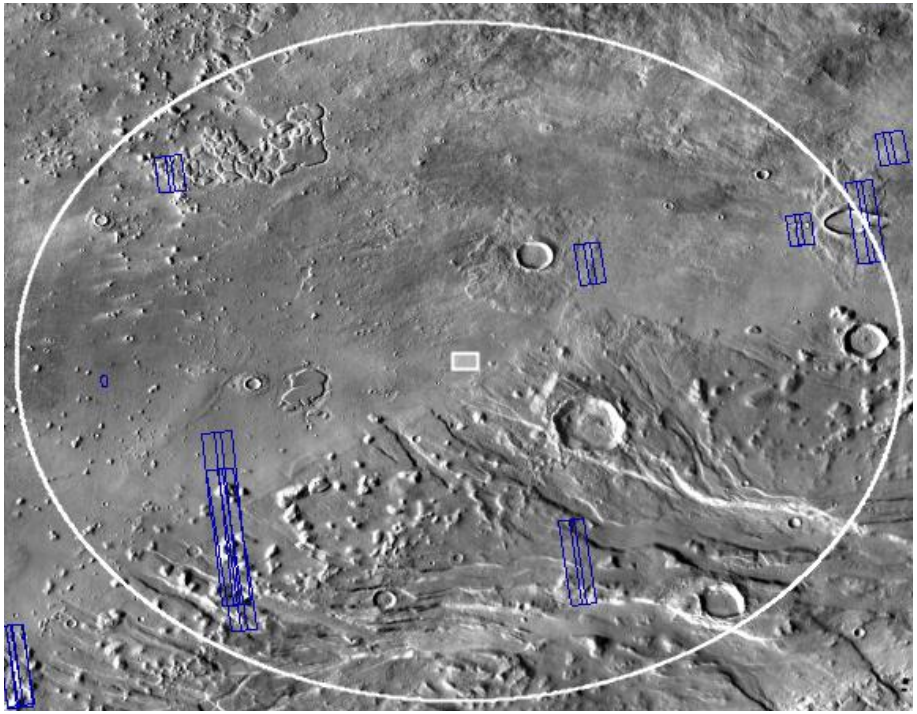
Acheron Fossae



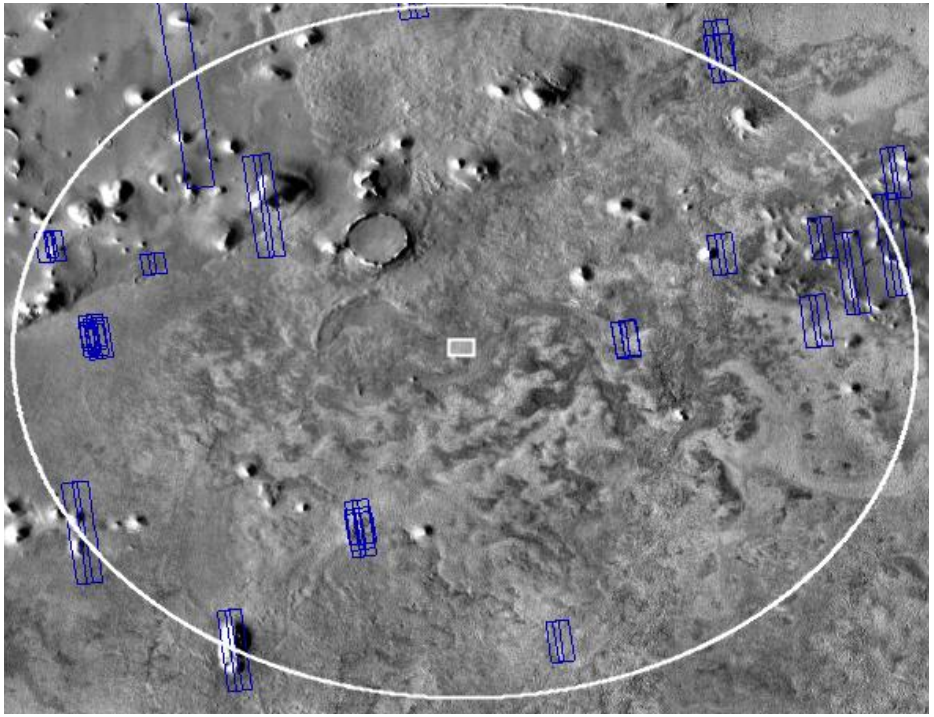
Erebus Montes

Composition: Very little CRISM data for either EZ.

Arcadia Planitia: Challenges



Acheron Fossae



Erebus Montes

High-resolution coverage: Some HiRISE coverage, but not much.

Arcadia Planitia: **Acheron Fossae** and Erebus Montes

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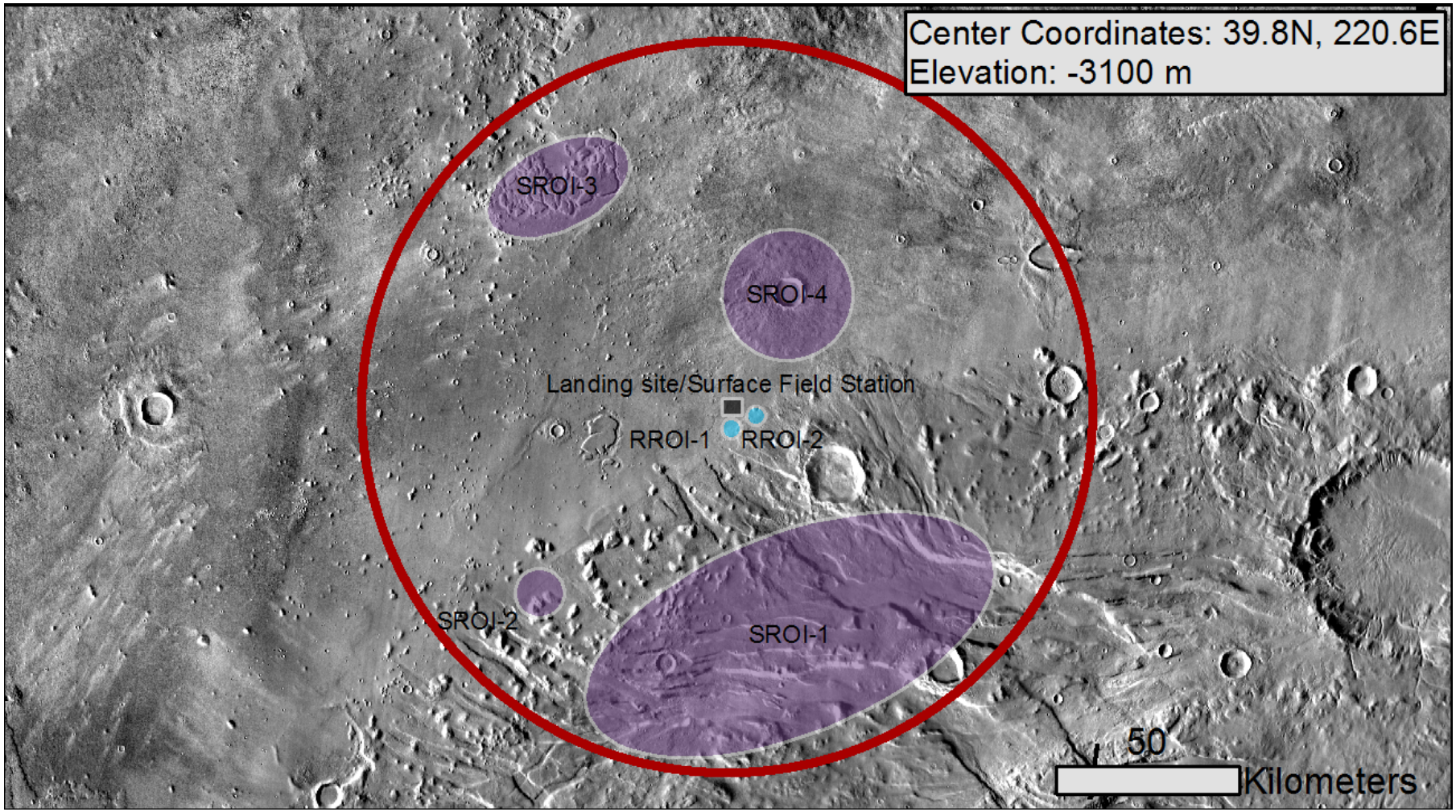
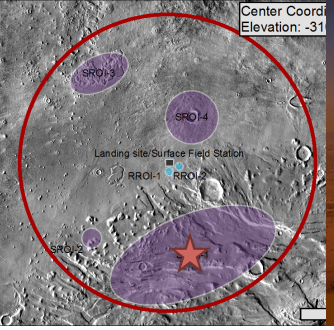
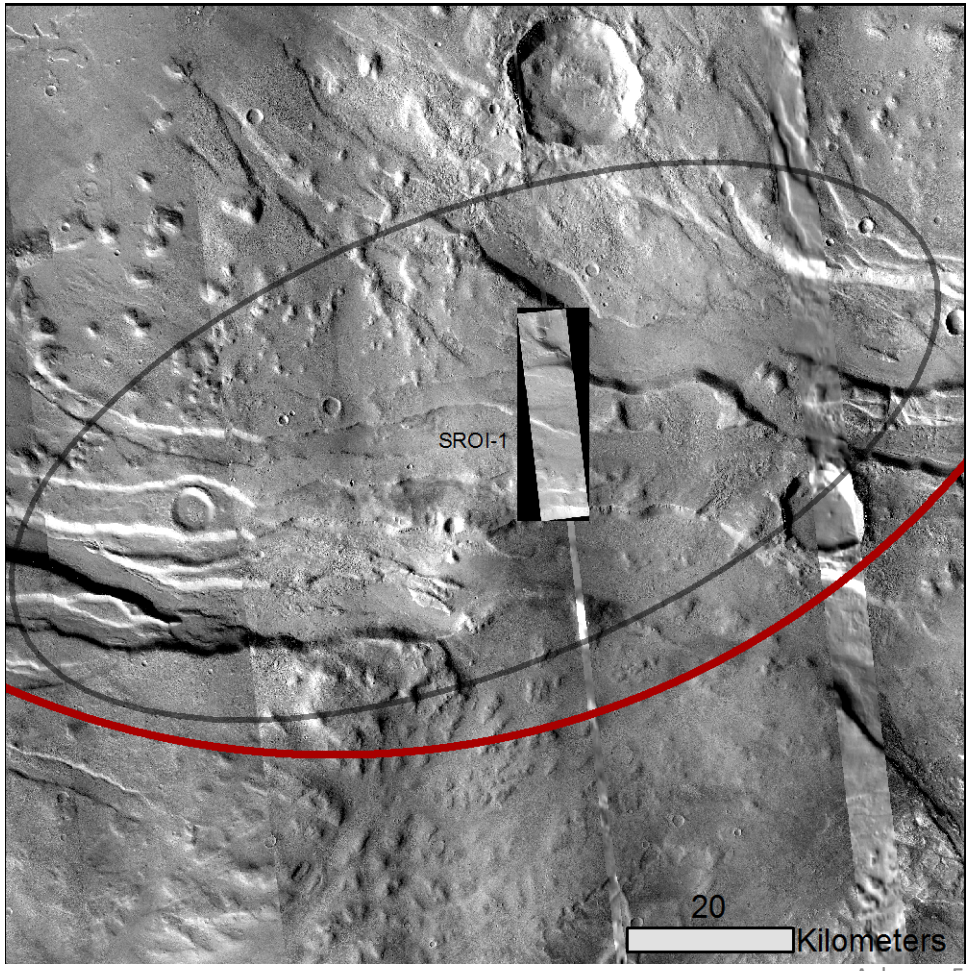
Exploration Zone Map



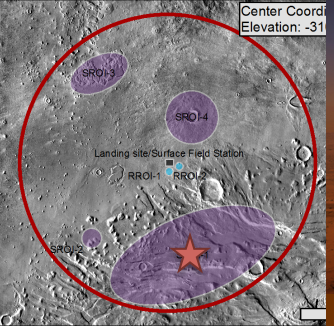
SCIENCE ROIs



Science ROI 1



- 38.7N, 221E. Well-covered in CTX, minimal HiRISE.
- Acheron Fossae graben system, late Noachian highlands terrain.
  - Presence of Noachian rocks.
  - Unit with regional/global extent.
  - Significant tectonic activity.
- Many different features of interest within this larger region.



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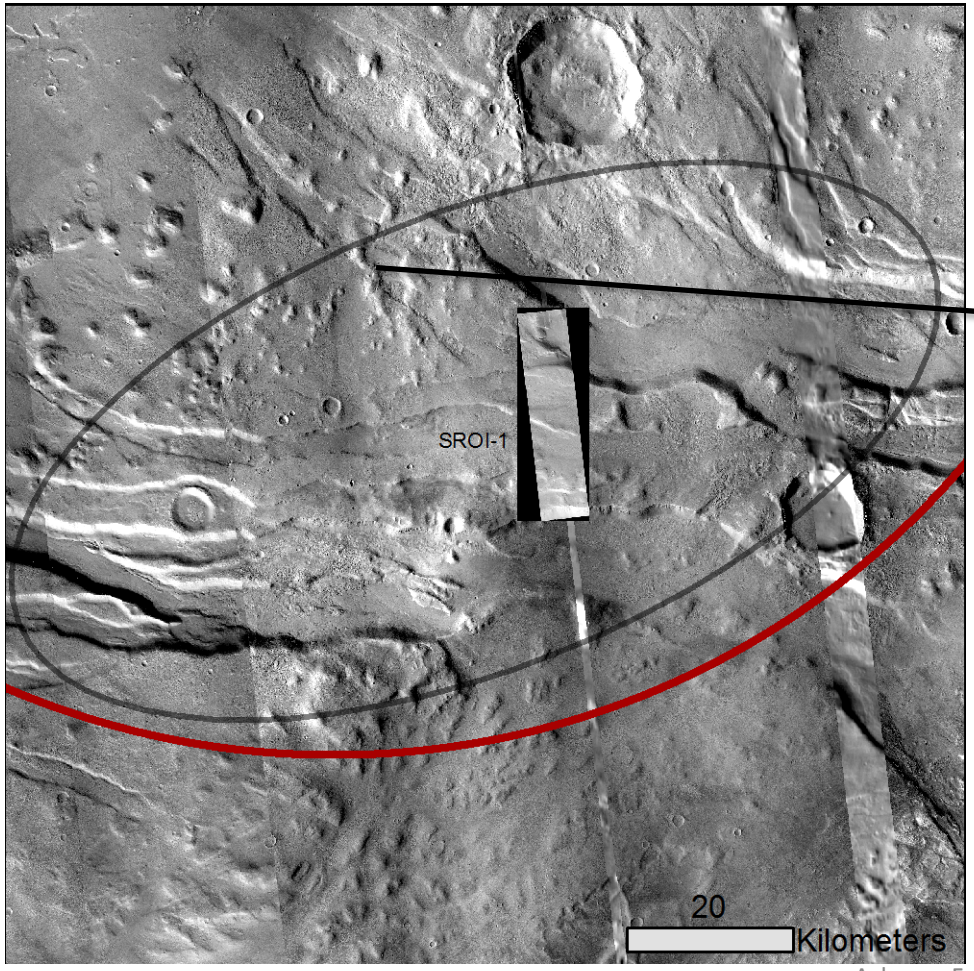
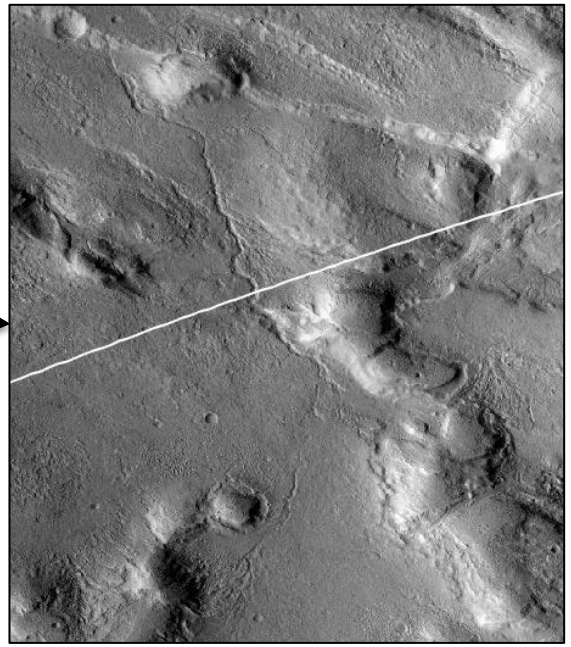
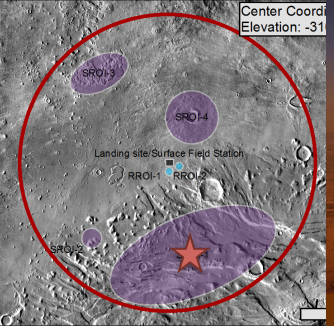
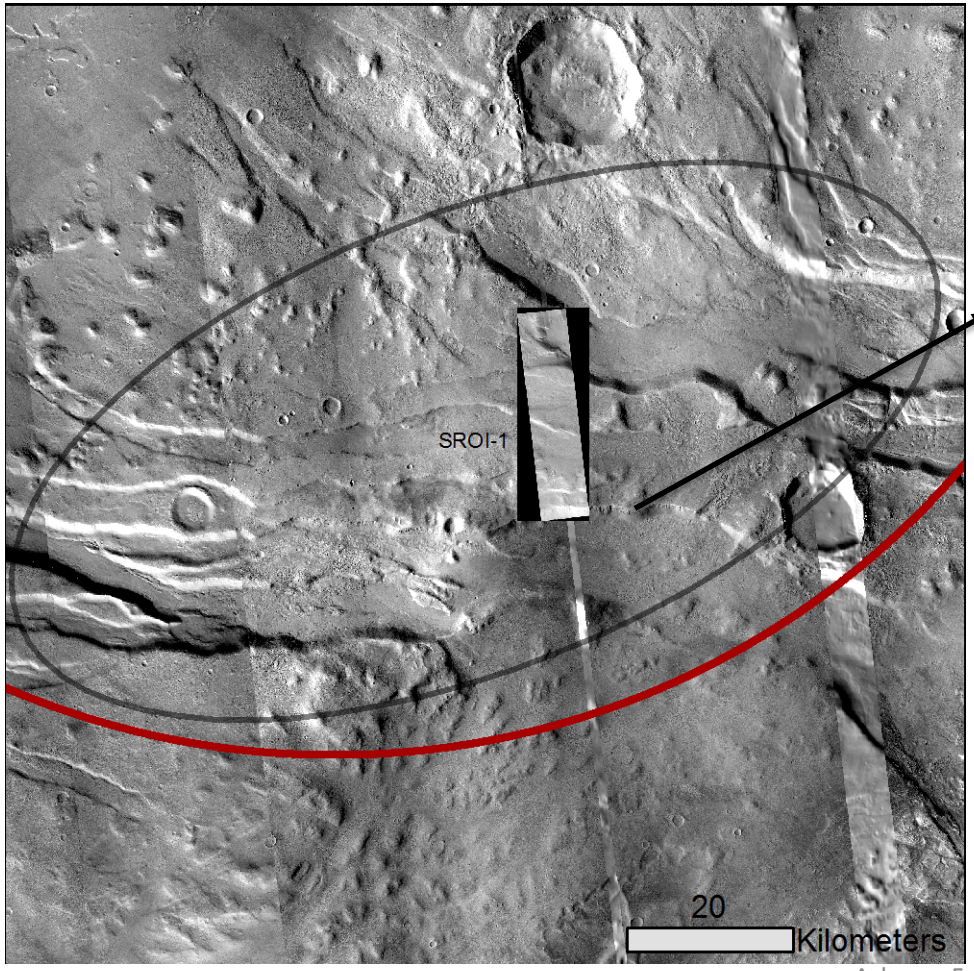


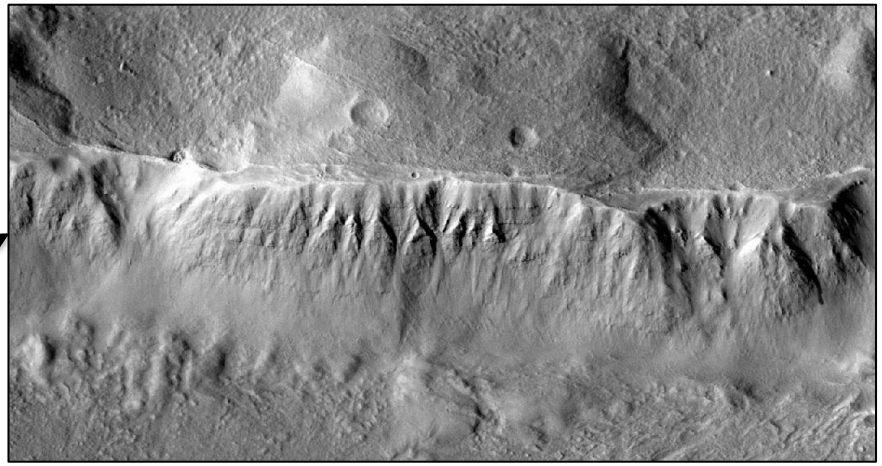


- Possible channel-like features in CTX:
  - Past aqueous activity?
  - Habitability potential?

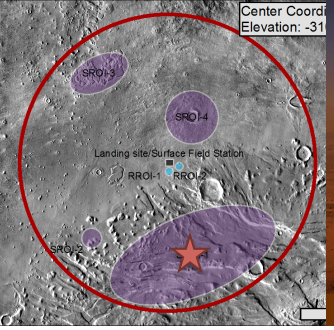


Science ROI 1





- Exposures along grabe walls (multiple locations).
  - Access to Noachian bedrock units?



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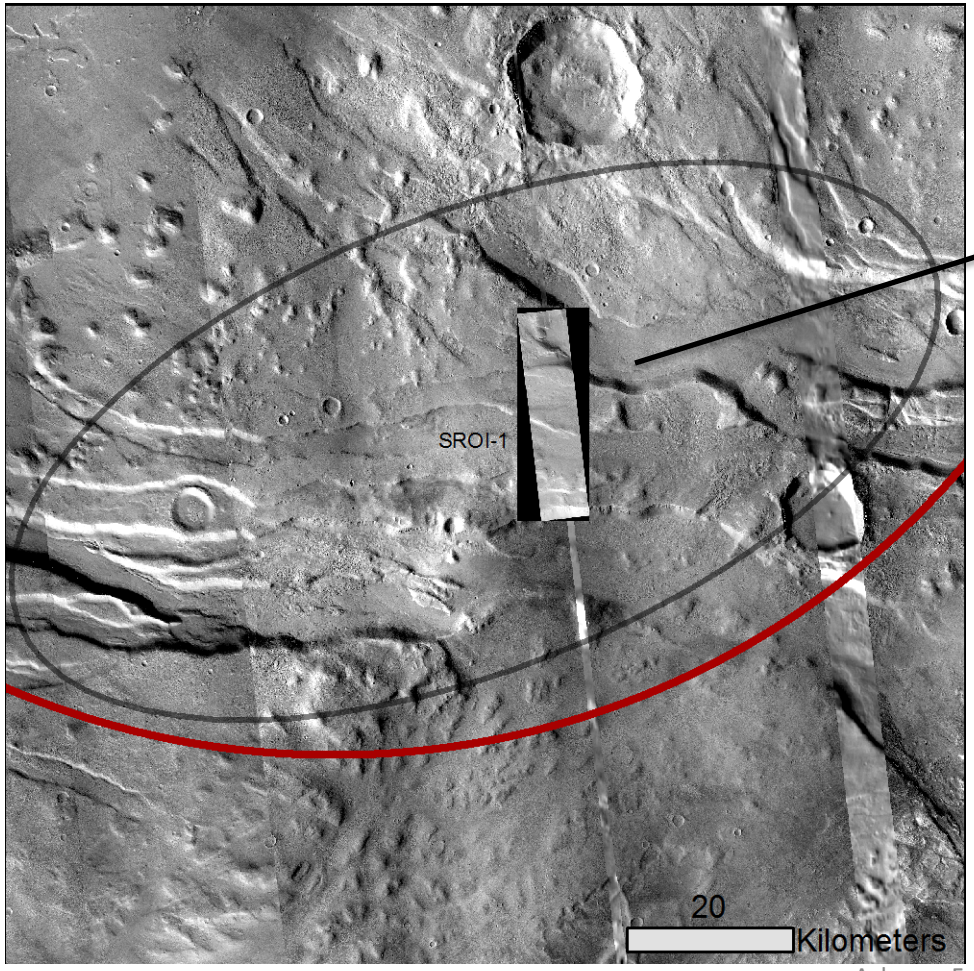
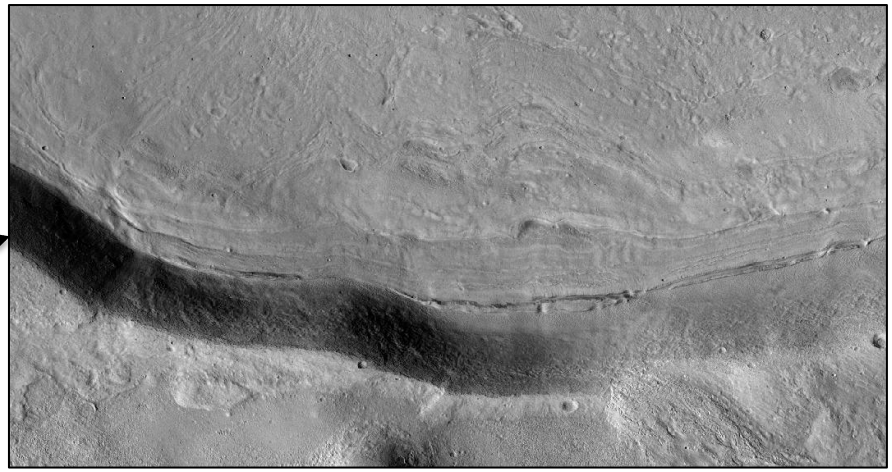
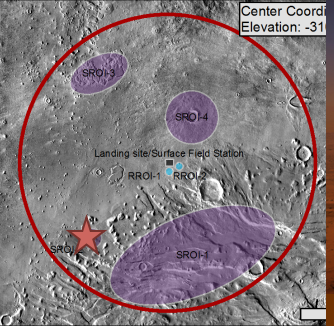
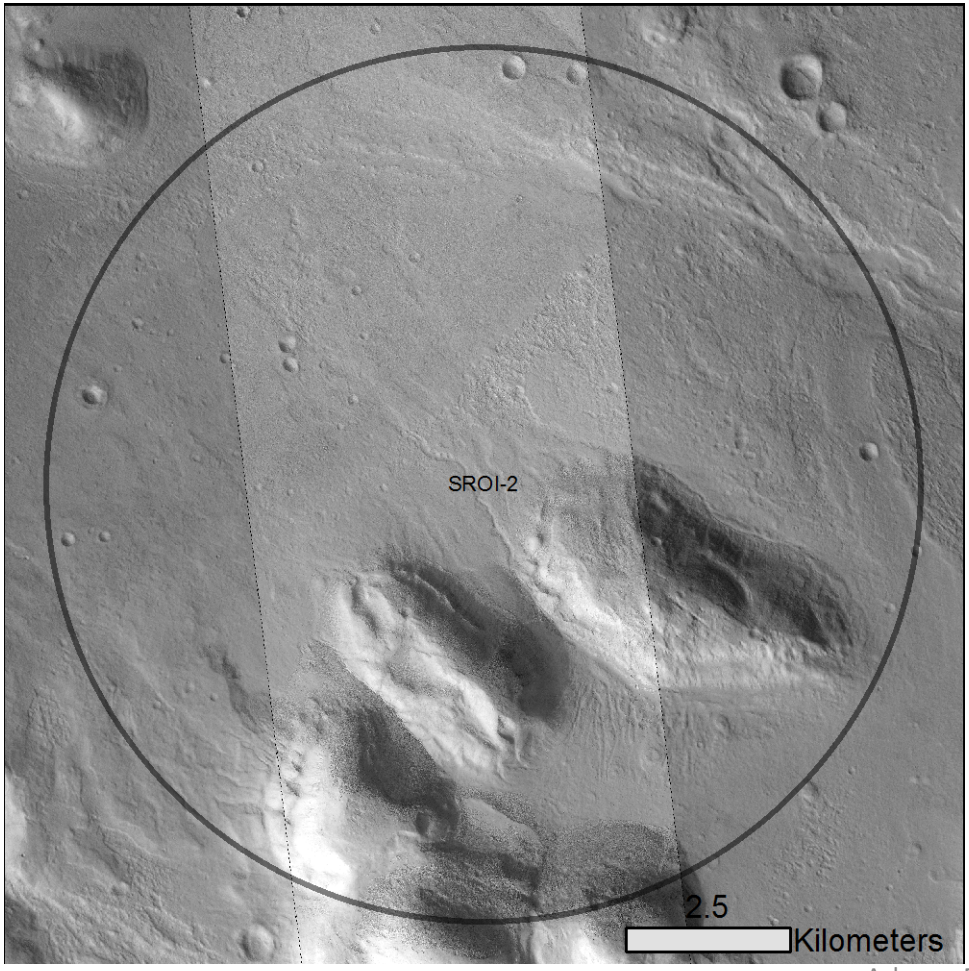




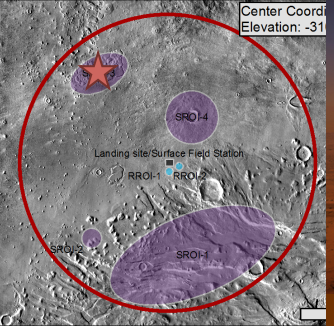
- Glacial fill on graben floors (likely Amazonian in age).
  - Range of surface ages (relative).
  - Access to Amazonian subsurface ice.



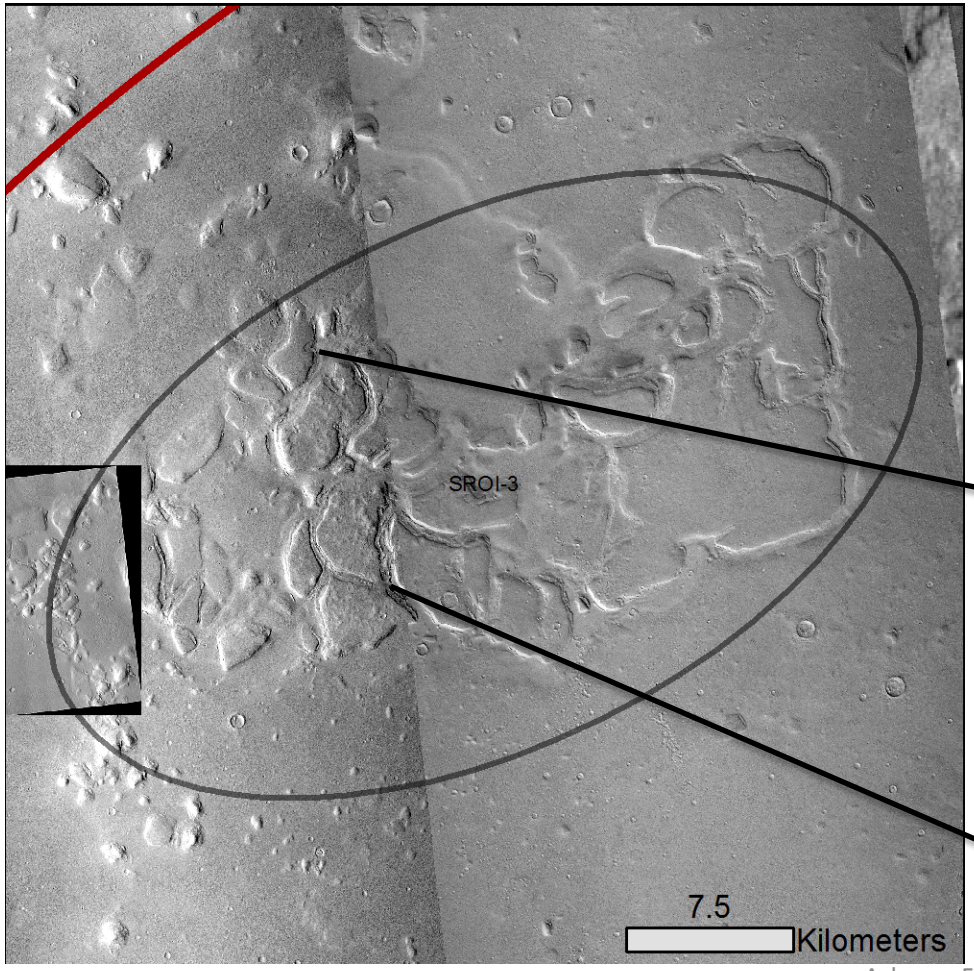
Science ROI 2



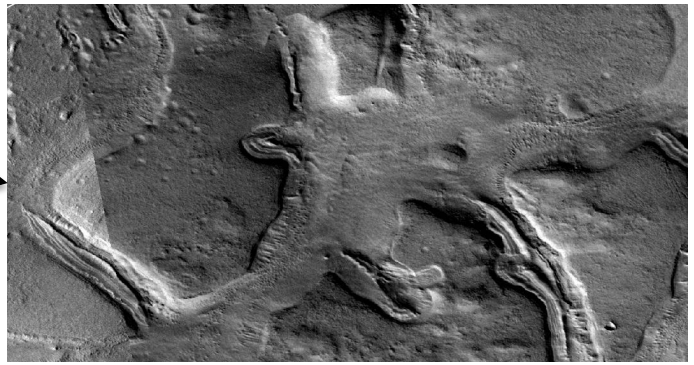
- 38.9N, 219.5E. Covered by CTX, HiRISE.
- Small channel-like feature, not in fluvial network – possible evidence of sub-glacial liquid water flow.
  - Aqueous activity
  - Potential habitability?

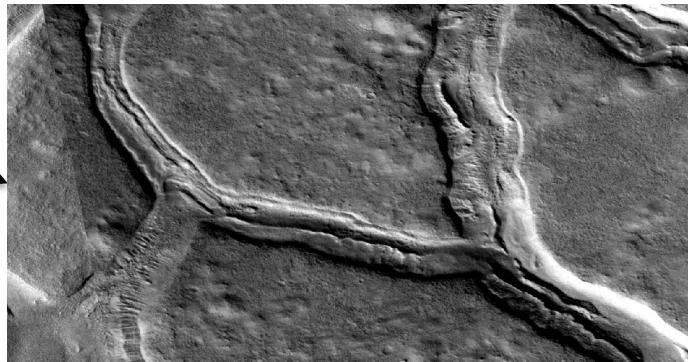


Science ROI 3

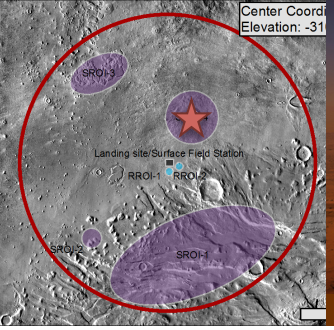


- 40.8N, 219.6E. CTX coverage, little HiRISE.
- Periglacial-type terrain; large block mesas
- Abundant subsurface ice (Amazonian), including glacial fill between blocks.

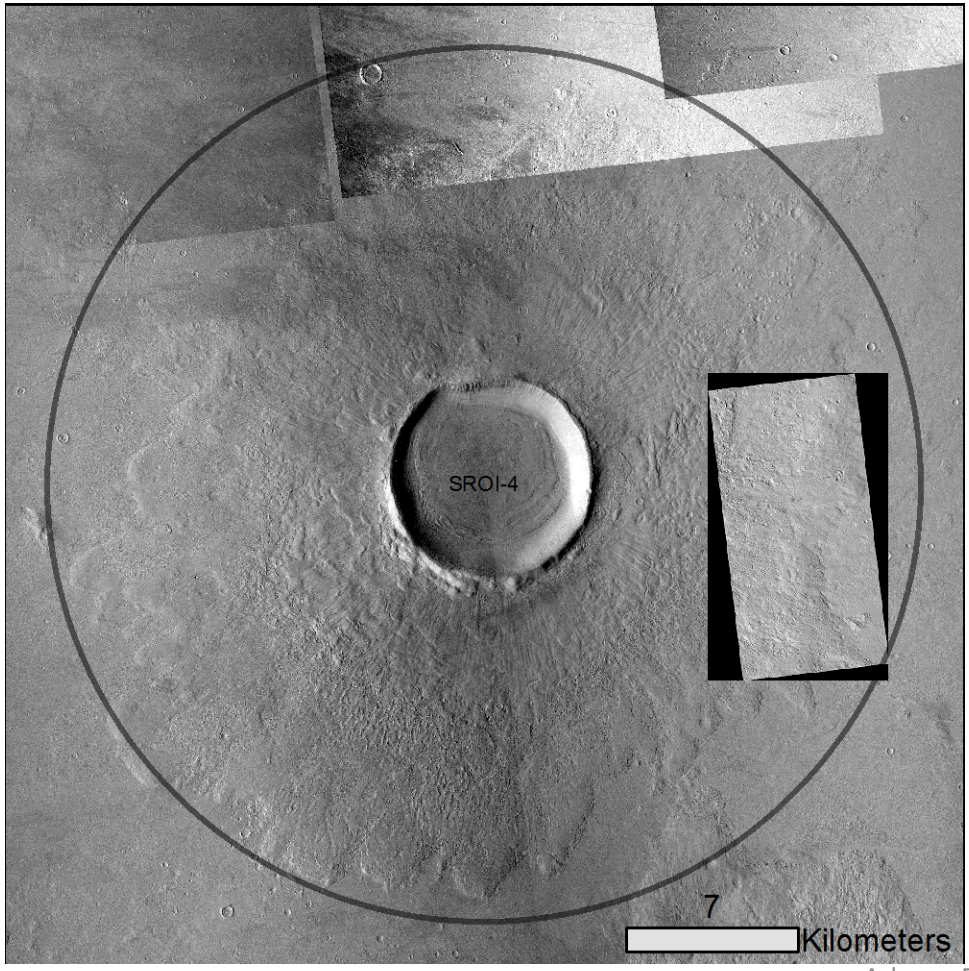




Acheron Fossae

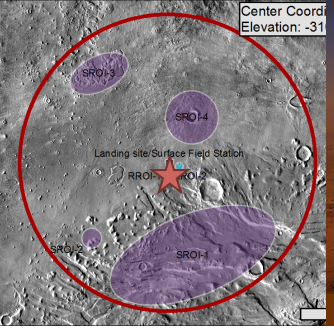


Science ROI 4

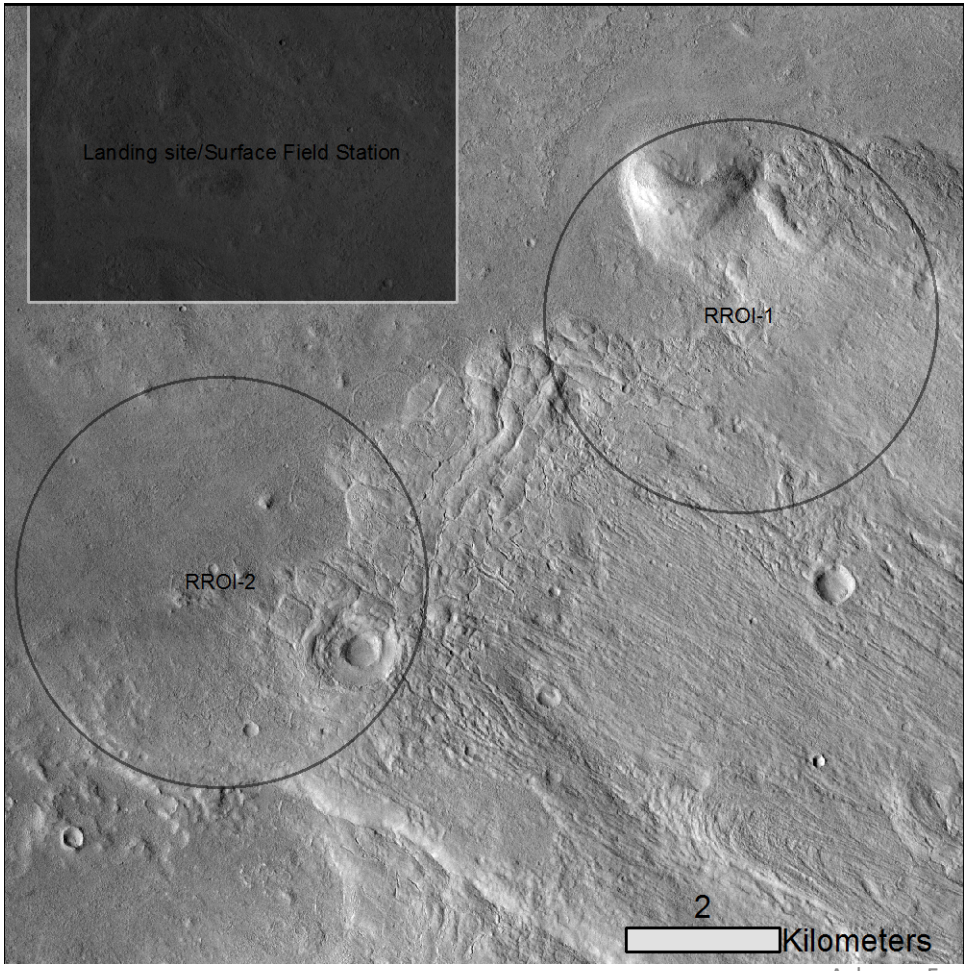


- 40.3N, 221E. CTX coverage, some HiRISE.
- Double layer ejecta impact crater, concentric crater fill, radial texture apparent in parts of ejecta.
  - Access to Amazonian-aged subsurface ice.
  - Primary crater deposits (with unique ejecta morphology).

RESOURCE ROIs



Resource ROIs



- RROI-1: 39.8N, 220.8E
  RROI-2: 39.7N, 220.6E
- Sample RROI locations near HZ, on the fringes of lobate, likely ice-rich, ejecta material.
- Excess water ice thought to be abundant throughout this entire region.

Science ROI(s) Rubric

Site Factors					SROI1	SROI2	SROI3	SROI4	RROI1	RROI2	EZ SUM
Science Site Criteria	Astrobio	Threshold	AND/OR	**Potential for past habitability**	○	○	?	?	?	?	0,2
				Potential for present habitability/refugia	○	○	○	○	○	○	0,6
		Qualifying		Potential for organic matter, w/ surface exposure	?	?	?	?	?	?	
	Atmospheric Science	Threshold		**Noachian/Hesperian rocks w/ trapped atmospheric gases**	○	○					0,2
		Qualifying		Meteorological diversity in space and time	?	?	?	?	?	?	
				High likelihood of surface-atmosphere exchange	●	●	●	●	●	●	6,0
				Amazonian subsurface or high-latitude ice or sediment	●	●	●	●	●	●	6,0
				High likelihood of active trace gas sources	?	?	?	?	?	?	
	Geoscience	Threshold		**Range of martian geologic time; datable surfaces**	●		●				2,0
				Evidence of aqueous processes	●	●					2,0
				Potential for interpreting relative ages	●	?	?	●			2,0
		Qualifying		Igneous Rocks tied to 1+ provinces or different times	?	?	?	?	?	?	
				Near-surface ice, glacial or permafrost	●	●	●	●	●	●	6,0
				Noachian or pre-Noachian bedrock units	●	●					2,0
				Outcrops with remnant magnetization	?	?	?	?	?	?	
				Primary, secondary, and basin-forming impact deposits	●	●	●	●			4,0
				Structural features with regional or global context	●						1,0
				Diversity of aeolian sediments and/or landforms	?	?	?	?	?	?	

Key	
●	Yes
○	Partial Support or Debated
	No
?	Indeterminate

Resource ROI(s) Rubric

1st EZ Workshop for Human Missions to Mars

Site Factors				SROI1	SROI2	SROI3	SROI4	RROI1	RROI2	EZ SUM
ISRU and Civil Engineering Criteria	Engineering		Meets First Order Criteria (Latitude, Elevation, Thermal Inertia)	●	●	●	●	●	●	6,0
	Water Resource	Threshold	**Potential for ice or ice/regolith mix**	●	●	●	●	●	●	6,0
			AND/OR **Potential for hydrated minerals**	?	?	?	?	?	?	
			Quantity for substantial production	●	●	●	●	●	●	6,0
			Potential to be minable by highly automated systems	●	●	●	●	●	●	6,0
			Located less than 3 km from processing equipment site					●	●	2,0
			Located no more than 3 meters below the surface	●	●	●	●	●	●	6,0
			Accessible by automated systems					●	●	2,0
		Qualifying	Potential for multiple sources of ice, ice/regolith mix **and** hydrated minerals							
			Distance to resource location can be >5 km							
			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°	○	○	●	○	●	●	3,3
			Located within 5 km of landing site location					●	●	2,0
		Qualifying	Located in the northern hemisphere	●	●	●	●	●	●	6,0
			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	●	●	●	●	●	●	6,0
			Access to dark, minimally altered basaltic sands	?	?	?	?	?	?	
	Metal/Silicon Resource	Threshold	**Potential for metal/silicon**	?	?	?	?	●	●	2,0
			Potential to be minable by highly automated systems					?	?	
			Located less than 3 km from processing equipment site					●	●	2,0
			Located no more than 3 meters below the surface					○	○	0,2
			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**

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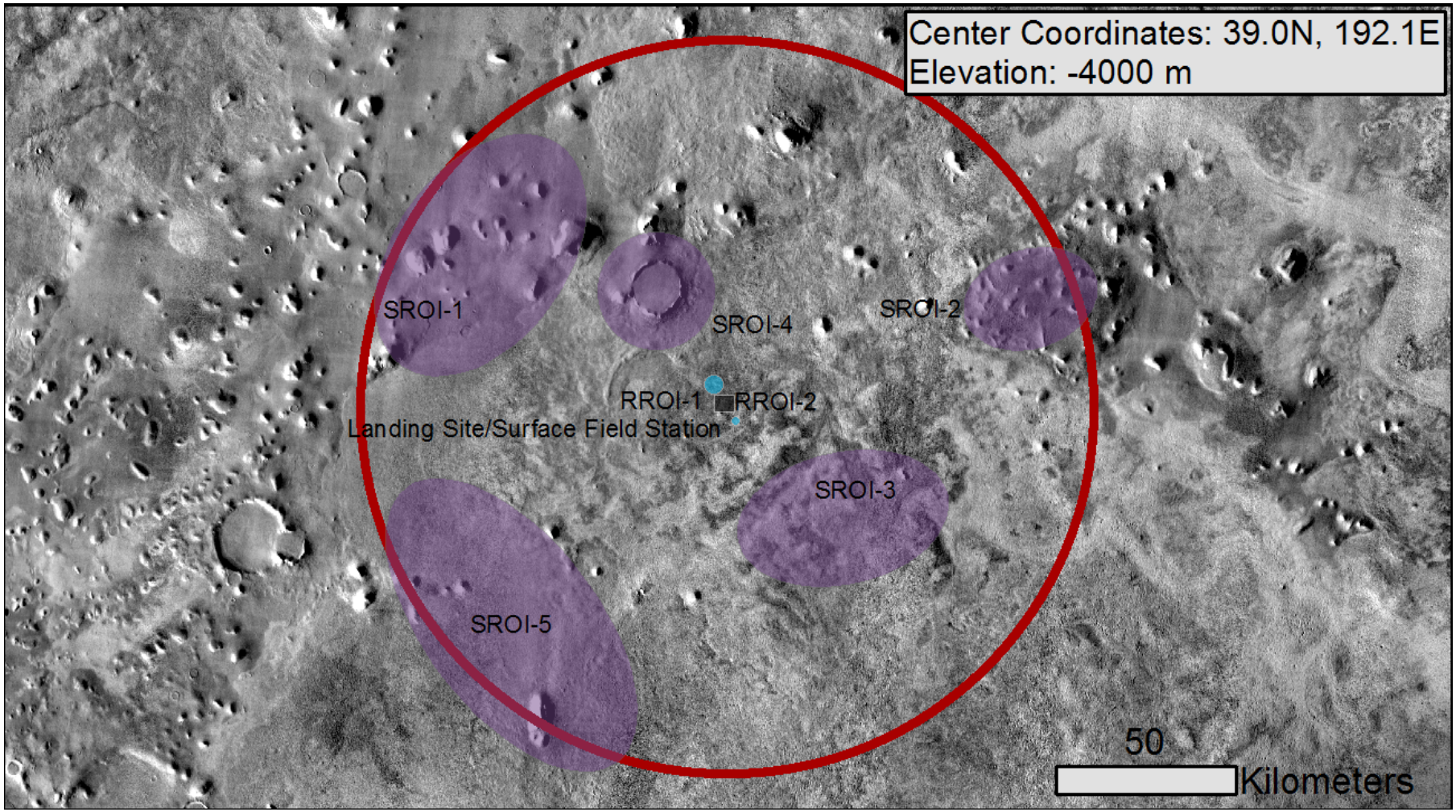
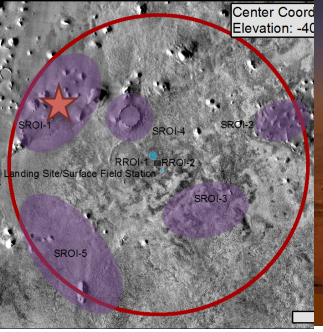
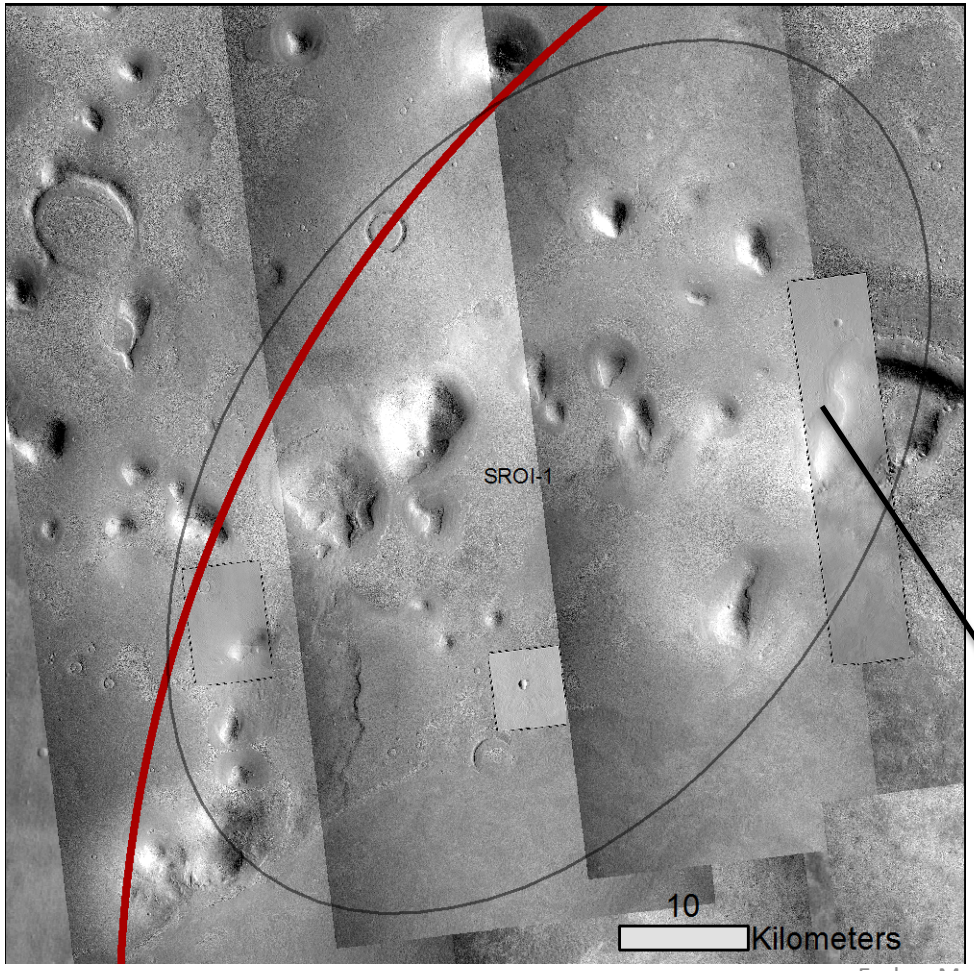
Exploration Zone Map



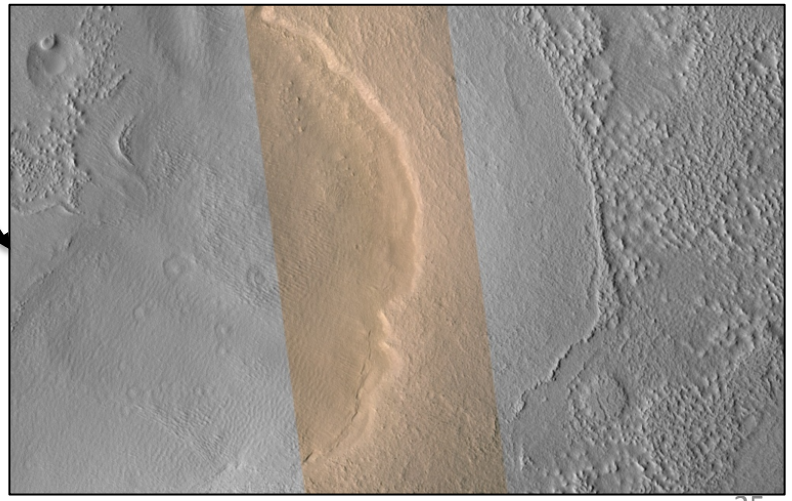
SCIENCE ROIs

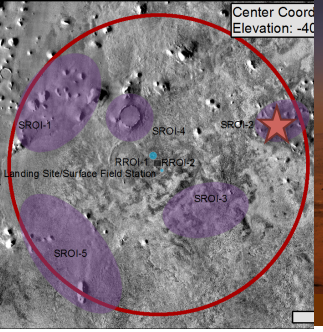


Science ROI 1

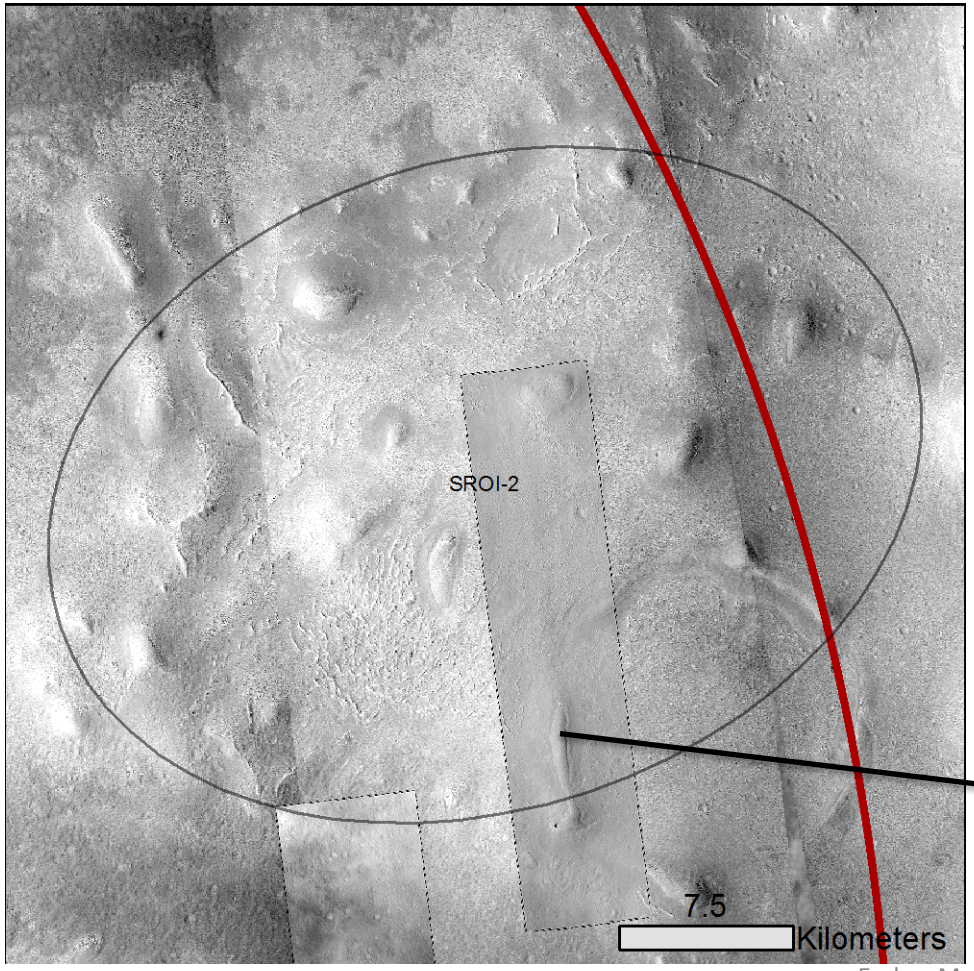


- 39.7N, 190.6E. Well-covered in CTX, some HiRISE.
- Exposures of Hesperian-Noachian transition terrain.
  - Noachian/Hesperian rocks?
- Some mounds of HNt material have ice-rich lobate debris aprons.
  - Amazonian-aged subsurface ice.
  - Relative ages.
- Located near a recent ice-exposing impact crater.
  - Subsurface ice.
  - Impact crater processes.

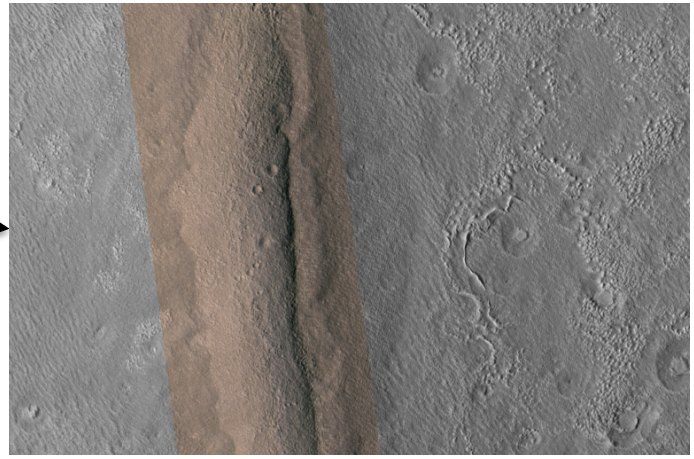


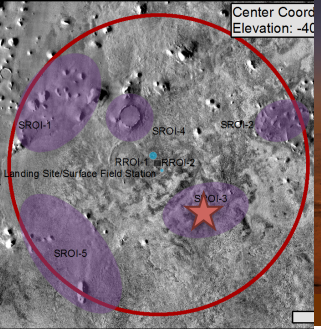


Science ROI 2

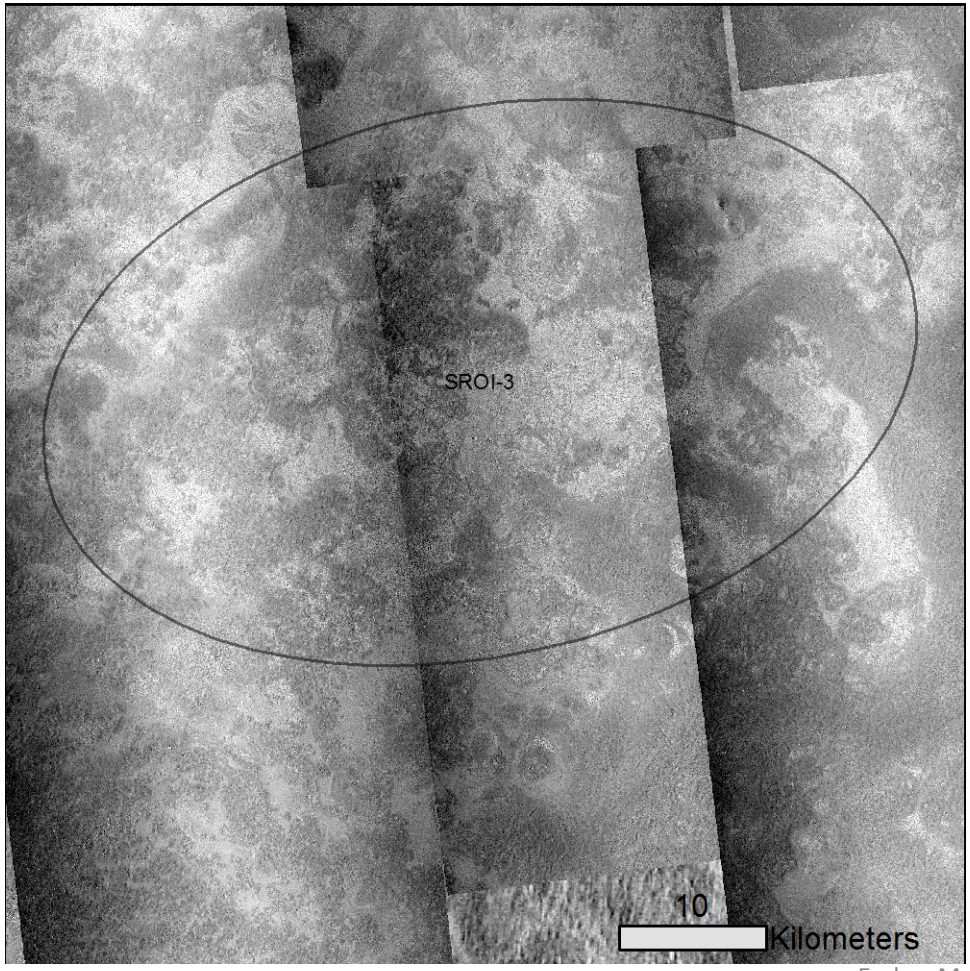


- 39.5N, 194E. Well-covered in CTX, some HiRISE.
- Additional exposures of Hesperian-Noachian transition terrain.
- Some mounds of HNt material have ice-rich lobate debris aprons. Filled/buried crater seen in SE region.
  - Impact processes, relative ages.

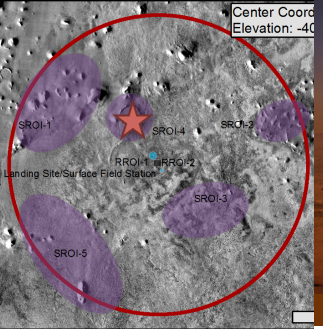




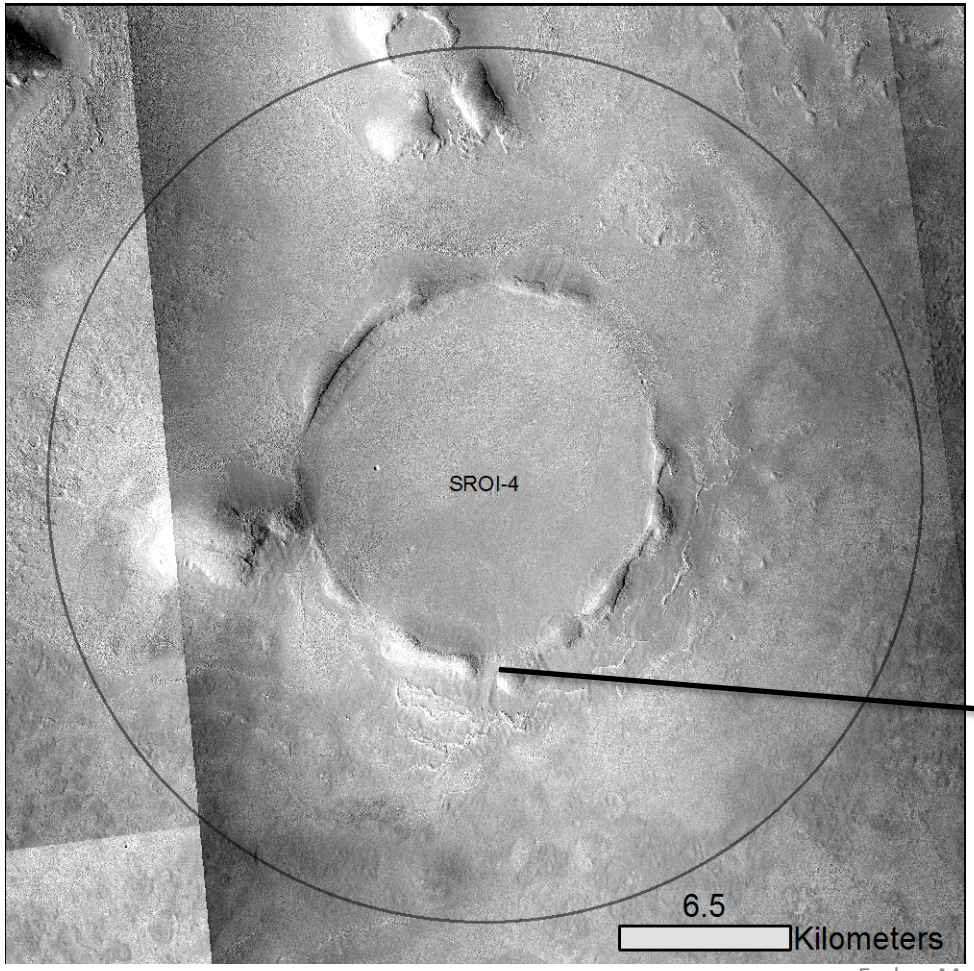
Science ROI 3



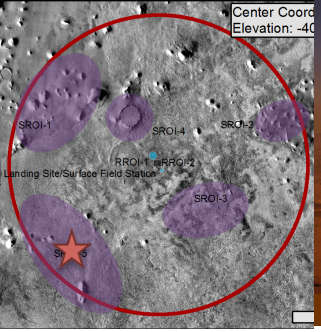
- 38.5N, 192.8E. Well-covered in CTX, no HiRISE.
- Contact between multiple episodes of Amazonian volcanism.
  - Relative surface ages.
  - Possibility for lava tube caves?
- Also includes some evidence for subsurface ice.



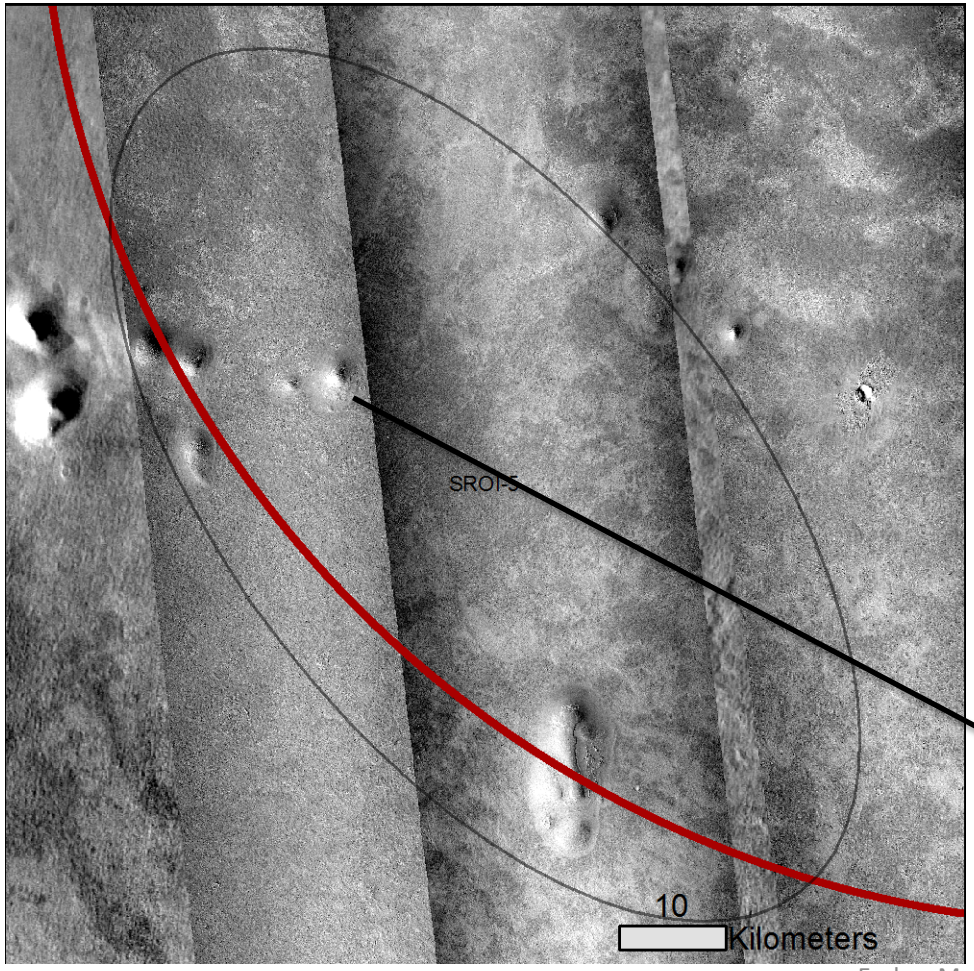
Science ROI 4



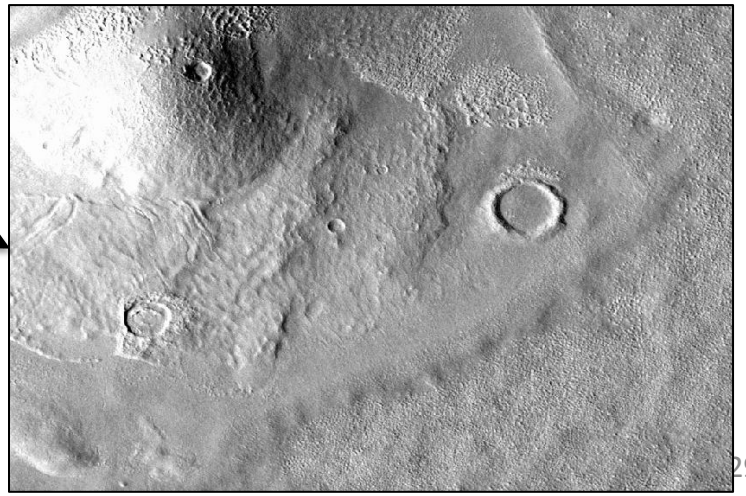
- 39.5N, 191.5E. Well-covered in CTX, no HiRISE.
- Filled/buried impact crater, evidence for glacial/ periglacial processes.



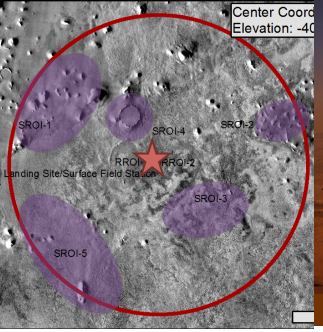
Science ROI 5



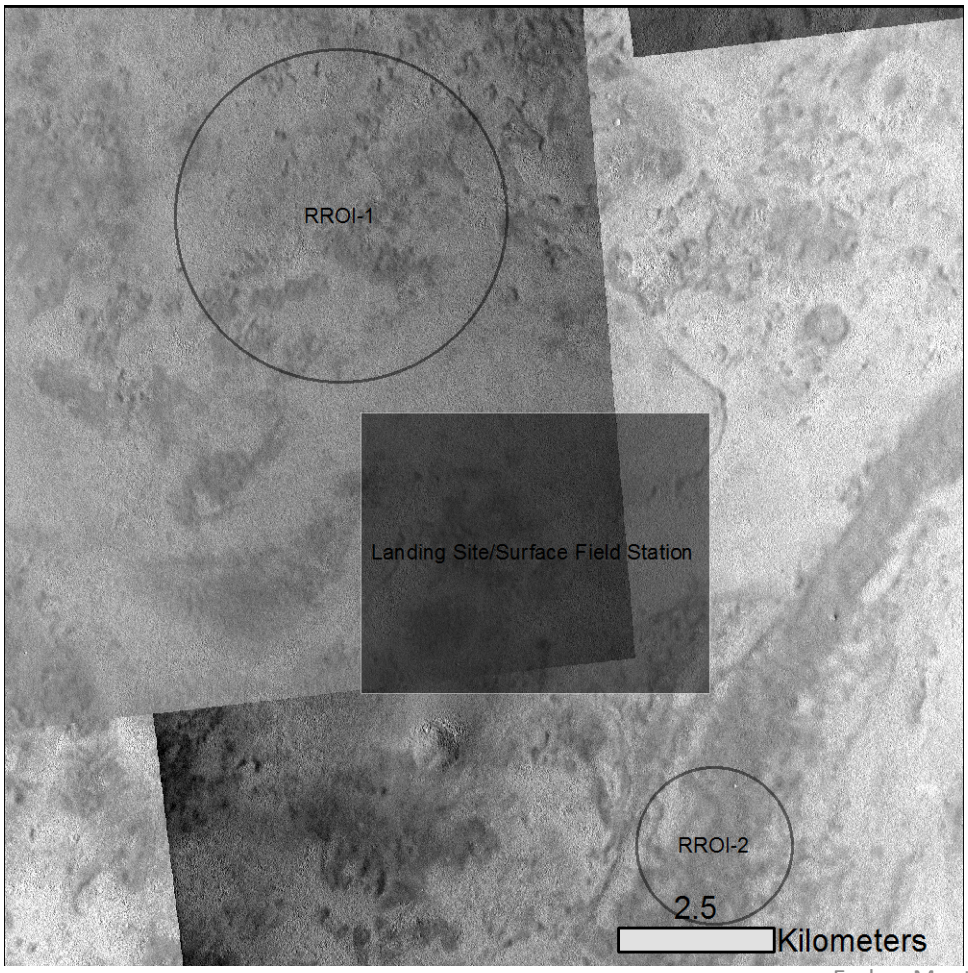
- 37.9N, 190.8E. Well-covered in CTX, some HiRISE.
- Mounds with lobate debris aprons, surrounded by Amazonian lava flows. Evidence for glacial/ periglacial activity.



RESOURCE ROIs



Resource ROIs



- RROI-1: 39.1N, 192E
  RROI-2: 38.9N, 192.2E
- Sample RROI locations near HZ. Both contain evidence for excess subsurface water ice (thought to be abundant throughout this entire region).

Science ROI(s) Rubric

1st EZ Workshop for Human Missions to Mars

Site Factors					SROI1	SROI2	SROI3	SROI4	SROI5	RROI1	RROI2	EZ SUM
Science Site Criteria	Astrobio	Threshold	AND/OR	**Potential for past habitability**	?	?	?	?	?	?	?	
				Potential for present habitability/refugia	○	○	○	○	○	○	○	0,7
		Qualifying		Potential for organic matter, w/ surface exposure	?	?	?	?	?	?	?	
	Atmospheric Science	**Threshold**		**Noachian/Hesperian rocks w/ trapped atmospheric gases**	○	○			○			0,3
		Qualifying		Meteorological diversity in space and time	?	?	?	?	?	?	?	
				High likelihood of surface-atmosphere exchange	●	●	●	●	●	●	●	7,0
				Amazonian subsurface or high-latitude ice or sediment	●	●	●	●	●	●	●	7,0
				High likelihood of active trace gas sources								
	Geoscience	**Threshold**		**Range of martian geologic time; datable surfaces**	●	●	●	●	●			5,0
				Evidence of aqueous processes								
				Potential for interpreting relative ages	●	●	●	●	●			5,0
		Qualifying		Igneous Rocks tied to 1+ provinces or different times	?	?	?	?	?	?	?	
				Near-surface ice, glacial or permafrost	●	●	●	●	●	●	●	7,0
				Noachian or pre-Noachian bedrock units	○	○			○			0,3
				Outcrops with remnant magnetization	?	?	?	?	?	?	?	
				Primary, secondary, and basin-forming impact deposits	●	●	●	●	●			5,0
				Structural features with regional or global context	●	●			●			3,0
				Diversity of aeolian sediments and/or landforms	?	?	?	?	?	?	?	

Key	
●	Yes
○	Partial Support or Debated
	No
?	Indeterminate

Resource ROI(s) Rubric

1st EZ Workshop for Human Missions to Mars

				Site Factors	SROI1	SROI2	SROI3	SROI4	SROI5	RROI1	RROI2	EZ SUM
ISRU and Civil Engineering Criteria	Engineering			Meets First Order Criteria (Latitude, Elevation, Thermal Inertia)	●	●	●	●	●	●	●	7,0
	Water Resource	Threshold		**Potential for ice or ice/regolith mix**	●	●	●	●	●	●	●	7,0
			AND/OR	**Potential for hydrated minerals**	?	?	?	?	?	?	?	
				Quantity for substantial production	●	●	●	●	●	●	●	7,0
				Potential to be minable by highly automated systems	●	●	●	●	●	●	●	7,0
				Located less than 3 km from processing equipment site						●	●	2,0
				Located no more than 3 meters below the surface	●	●	●	●	●	●	●	7,0
				Accessible by automated systems						●	●	2,0
		Qualifying		Potential for multiple sources of ice, ice/regolith mix **and** hydrated minerals								
				Distance to resource location can be >5 km								
				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°	○	●	●	○	●	●	●	5,2
				Located within 5 km of landing site location						●	●	2,0
		Qualifying		Located in the northern hemisphere	●	●	●	●	●	●	●	7,0
				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	●	●	●	●	●	●	●	7,0
				Access to dark, minimally altered basaltic sands	?	?	?	?	?	?	?	
	Metal/Silicon Resource	Threshold		**Potential for metal/silicon**	?	?	?	?	?	●	●	2,0
				Potential to be minable by highly automated systems						●	●	2,0
				Located less than 3 km from processing equipment site						●	●	2,0
				Located no more than 3 meters below the surface						○	○	0,2
				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

BONUS Science ROI

For both Acheron Fossae and Erebus Montes: The Arcadia Planitia Ice Sheet

- Easy access to subsurface ice means that it should be easy to sample and study as well.
- Science questions:
  - How did the ice sheet form?
  - How long did the ice deposition take, and how long has it existed?
  - How thick is the ice sheet?
  - How is the ice interacting with the atmosphere?
  - Did the ice preserve organics or other biosignatures?
  - Could the ice have contained habitable microenvironments now or in the past?

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Water, water (ice) everywhere – but not all of it's to drink!

Highest Priority EZ Data Needs

- Science Priority: surface composition data
  - Surface dust affects CRISM observations.
  - Strategy: Target CRISM observations in regions with slightly less dust.
- Resource Priority: higher resolution of near-surface ice deposits, including spatial distribution
  - SAR RADAR, higher resolution neutron spectrometer