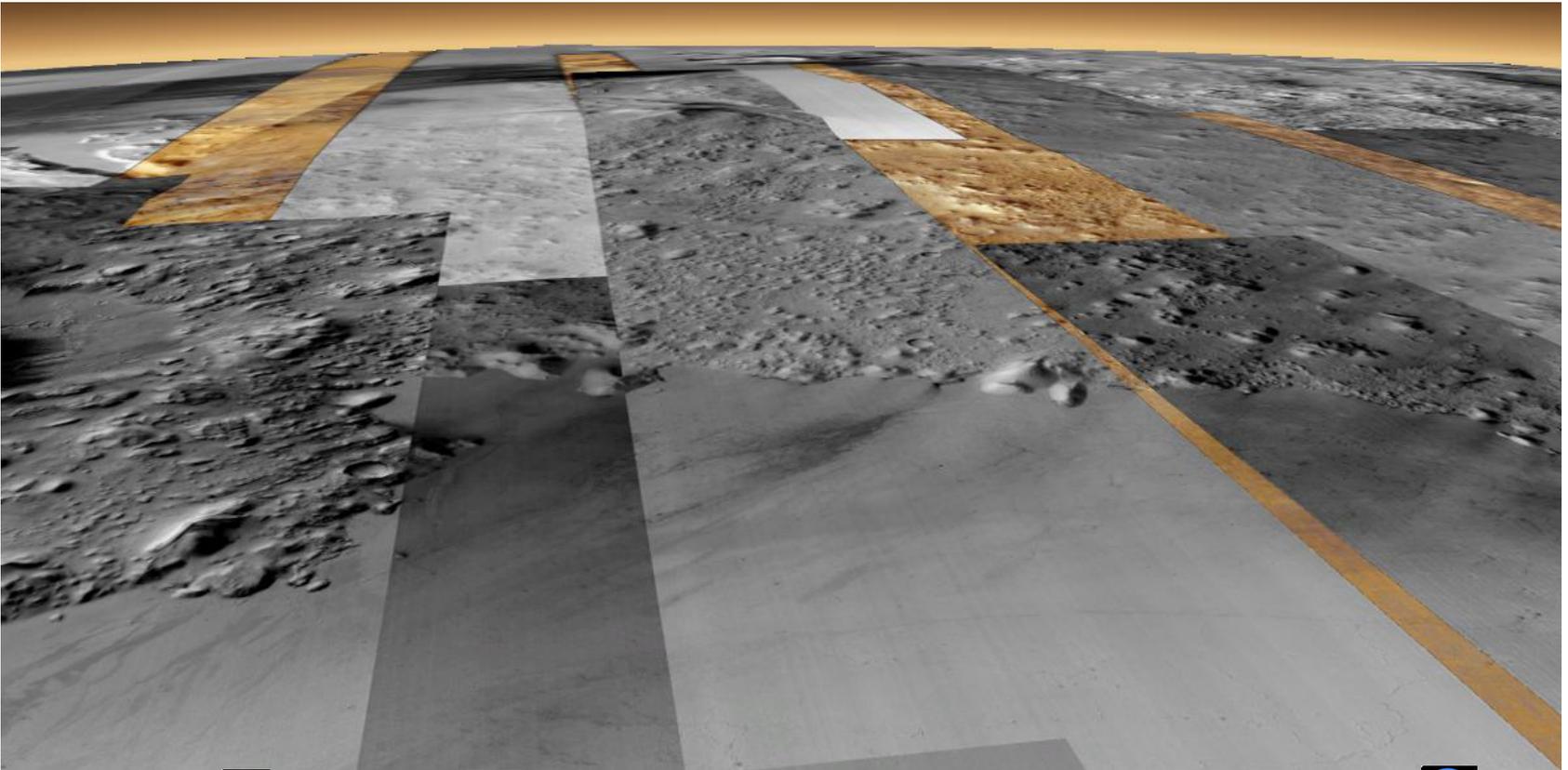


# An Exploration Zone in Cerberus Containing Young and Old Terrains, Including Fossae/Faults and Shergottite Distal Ejecta (abstract #1017)



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A.S. Burton , P.D. Archer, Jr. , E.B. Rampe , S. Piqueux 

# E2E-iSAG Mars Sample Return



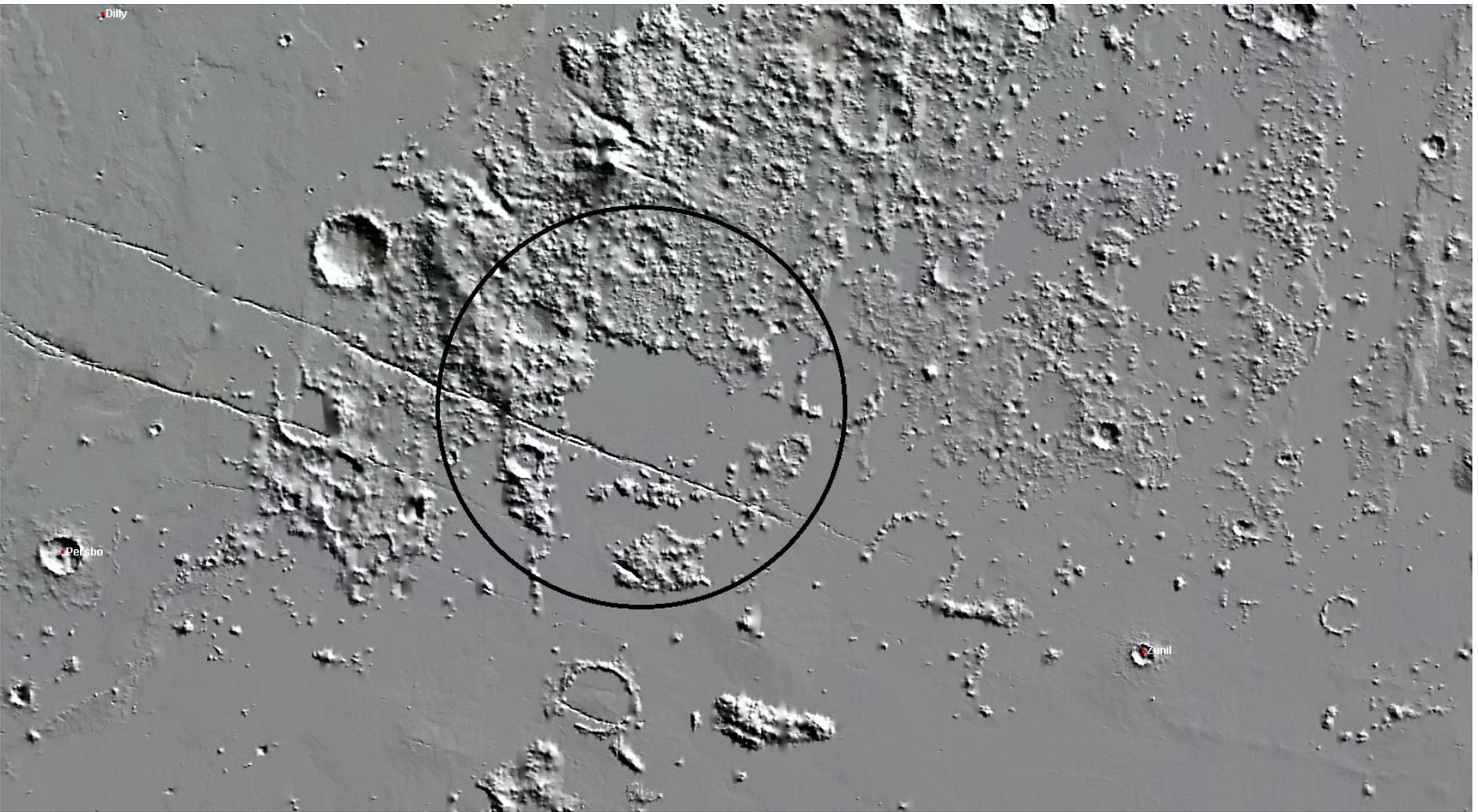
1<sup>st</sup> EZ Workshop for Human Missions to Mars

## **MEPAG report of the End-to-End international Science Analyses Group suggests:**

- Noachian – igneous and/or sedimentary
- igneous rocks – pristine and altered
- impactites and ejecta
- aeolian sediments
- soils / regolith
- airfall dust
- aqueously altered rocks
- hydrothermally altered rocks



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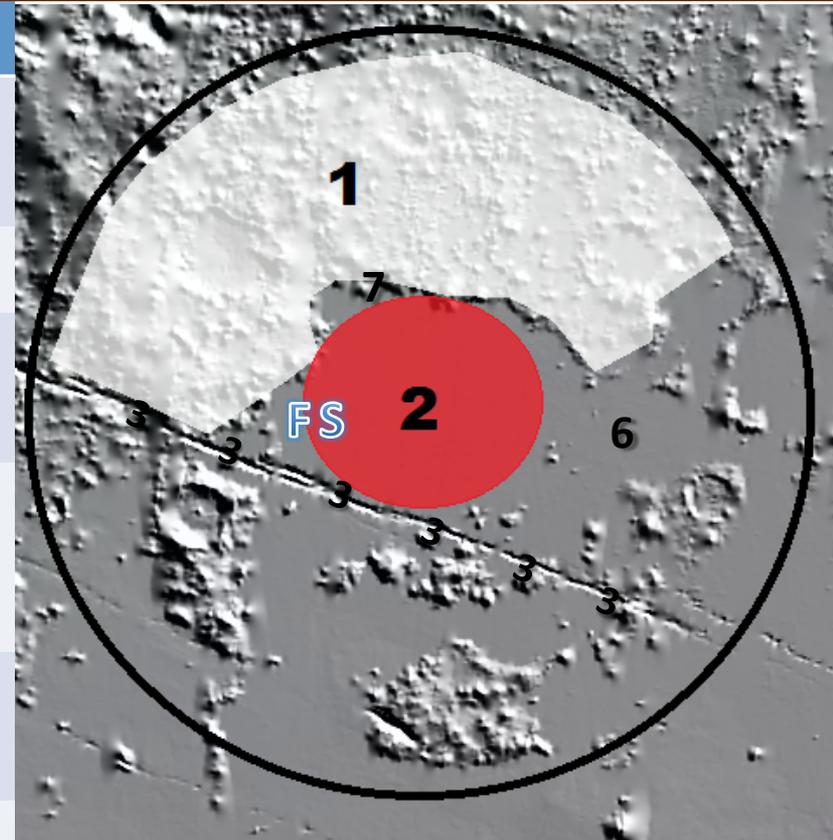


# Exploration Zone Map

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SROI	Label	Brief description
1	Noachian terrains	Knobbed, ridged – sedimentary rocks?
2	young flood basalts	For dating purposes
3	Fossae	Tectonic rifting? Subsidence?
4	ancient crater rims embayed; young craters	For geomorphology, mapping, context
5	Zunil rays / ejecta (throughout EZ)	Is Zunil 1 of 4 shergottite source craters?
6	(aqueous) flood features, deposits	Several authors
7	hydrated salts (RSL's)	contact/border of 1 & 2?



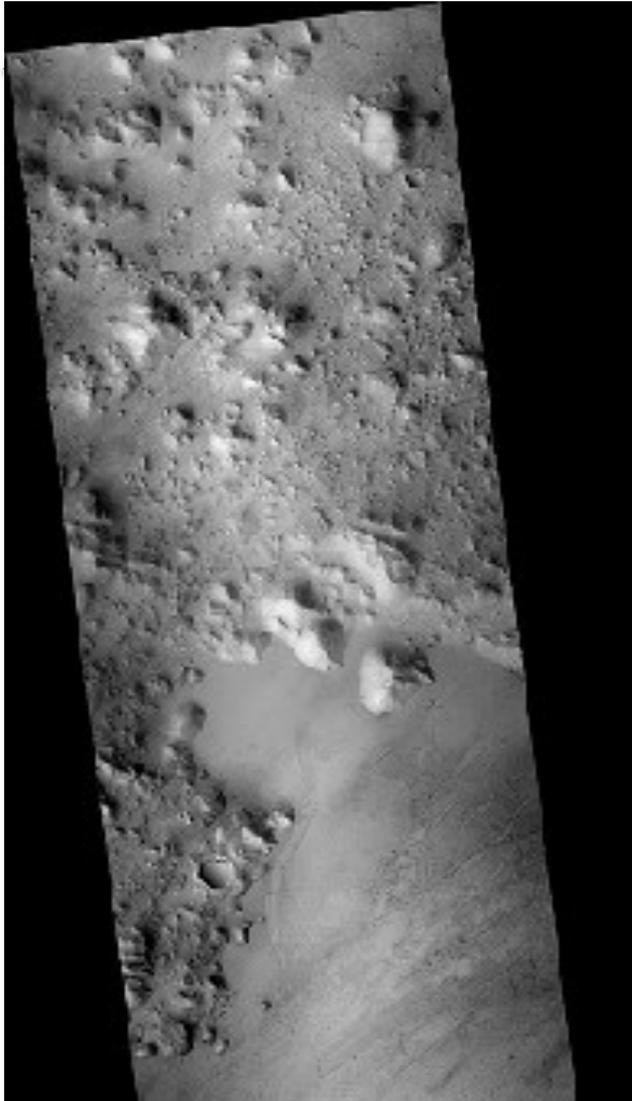
center: 161.9 E, 9.7 N, -2700 m

RROI1 – ice

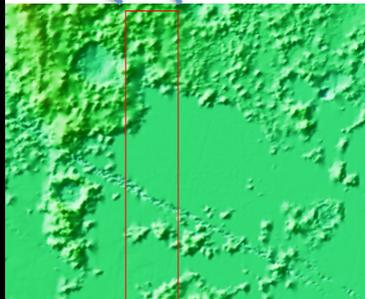
RROI2 – materials

# Science ROI 1: knobby terrain

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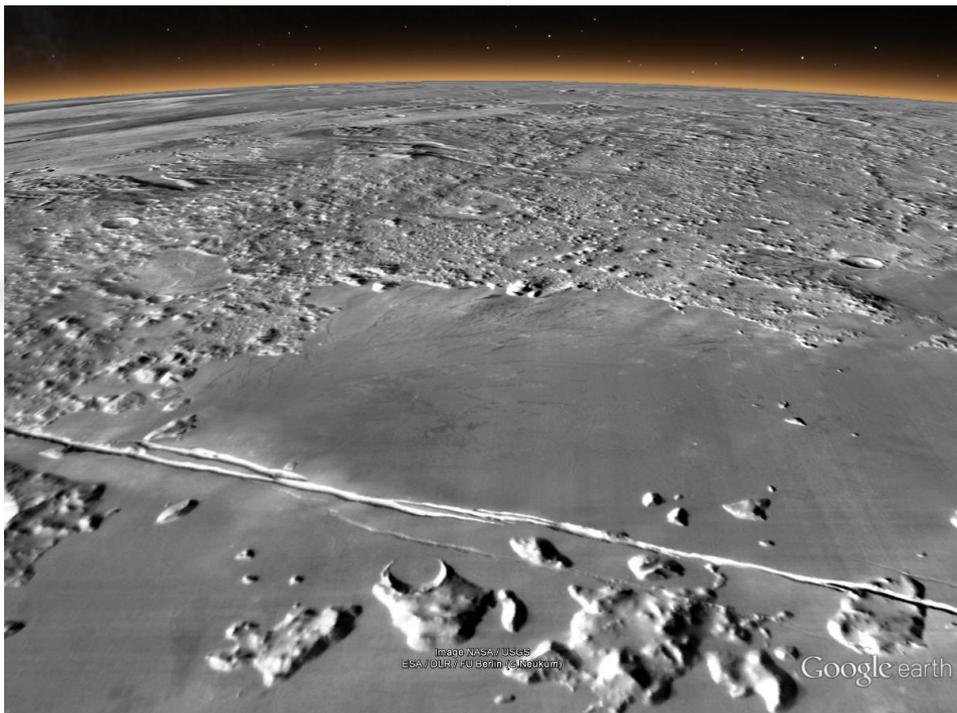


- Surrounds EZ; primarily N & W
- Early or Late Noachian
- A long history of geologic and atmospheric processes:
  - Original emplacement
  - Climate change
  - Hesperian/Amazonian volcanics
    - Hydrothermal alteration?
    - Ashes/tephras?



# Science ROI 2

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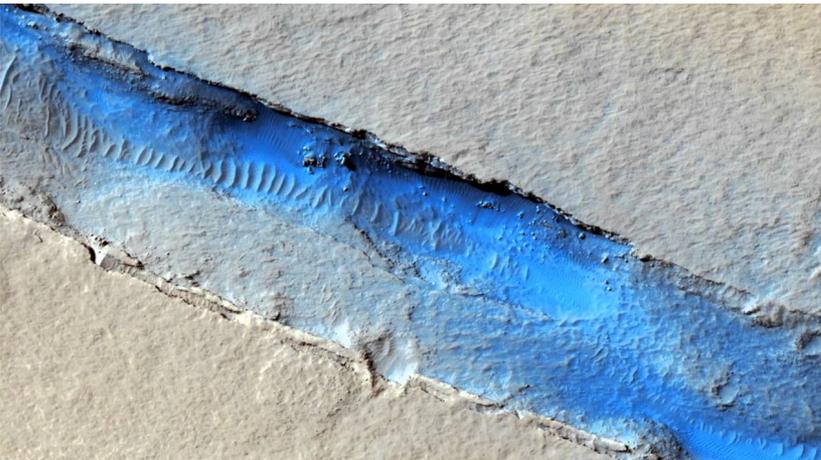
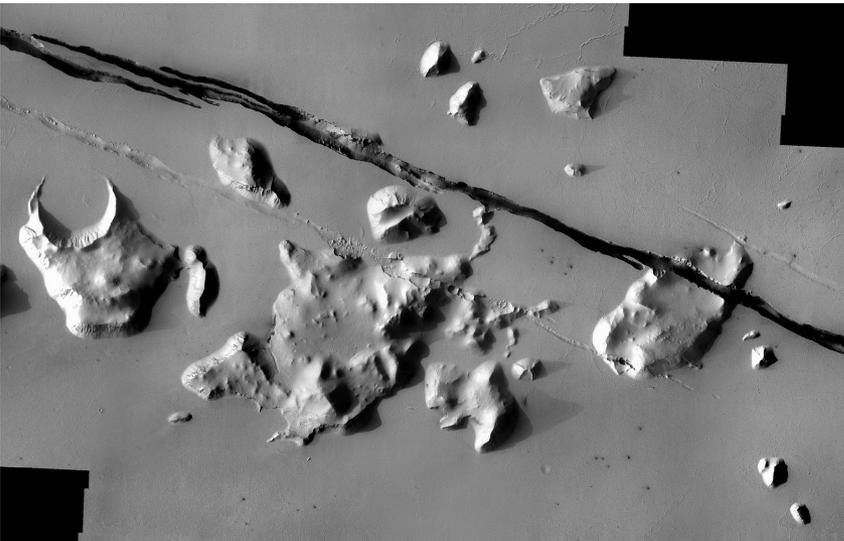
- Center of EZ at 9.9°N, 162° E; “mini-EZ” or “bullseye” w/ ~70 km diameter
- Igneous rock can be dated and compared to global crater counts of surfaces

# Science ROI 3: Fossae

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- Cause of Fossae can be investigated
  - tectonics or subsidence?
  - global implications
- Subsurface can be examined

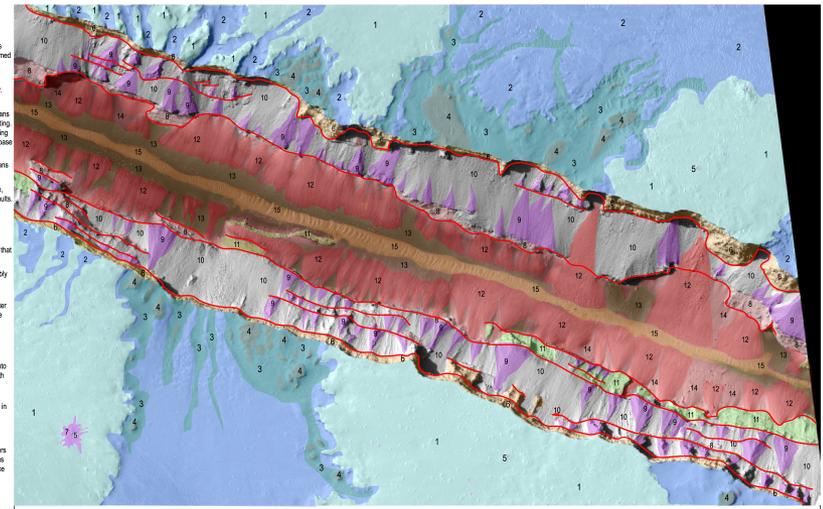


Geological Map of Cereberus Fossae with Offset Debris Fans and multiple layers exposed within possibly very young faulted fossae. Mars (PSP\_009824\_1900\_RED\_MRO\_HRISE)

Key:

- 15 Dunes formed of most likely dark and light sand. Sand formed from the grain-eroded material from fossae walls and dark sand on fossae floor. Local valley winds have formed dunes transverse to fossae floor length.
- 13 Dark, possibly basaltic sand, deposits on fossae floor and between some debris fans that extending onto fossae floor. Fallen boulders from cliffs above litter the sand.
- 12 Offset active debris fans leading down to floor of fossae. Fans offset from those above by possibly active extensional faulting. A few large boulders, fallen from cliff above can be seen lying on top of some fans. Debris fans appear to emanate from base of cliffs above.
- 14 Areas of fallen debris within deep fossae between debris fans likely where slope is steep.
- 10 Truncated scree slopes, covering shelf layers within fossae, between truncated debris fans. Truncated by extensional faults.
- 9 Truncated debris fans offset and truncated by multiple extensional faulting.
- 4 Areas of apparently higher ground within deeper channels that had been cut into larger fluvio channel.
- 3 Deeper channels of this larger channel floor. Again possibly covered in later lava flow. Similar to 2, dunes formed in deeper channels.
- 2 Extent of fluvio channels cut into lava plains, possibly at later date covered in later lava flow deposits. Some dunes made from light coloured dust, transverse to channel direction forming in some deeper channel floors.
- 5 Larger impact craters seen, some with well defined ejecta blankets. Many craters too small to resolve on map, these seen only on regional lava plains and fluvio channels cut into regional lava plains. No impact craters of any size seen with fossae fracture.
- 7 Lightly cratered regional lava plains. Cut by later fluvio channels as evidenced by fewer small impact craters seen in channel floors.
- 6 Multiple layers exposed in cliff at top of fossae fracture possibly formed by successive lava and fluvio flows.
- 8 Multiple layers exposed in cliffs of lower exposed shelf layers within fossae fracture. Multiple faulting within the fossae has exposed these layers. Possibly layers containing subsurface water ice have been exposed.
- 11 Shelf layer exposed, appearing not to be covered by debris fans of eroded scree deposits.

Traces of extensional fault lines, multiple faults within fossae offsetting debris fans.



Latitude Centred 9.8 Degrees North

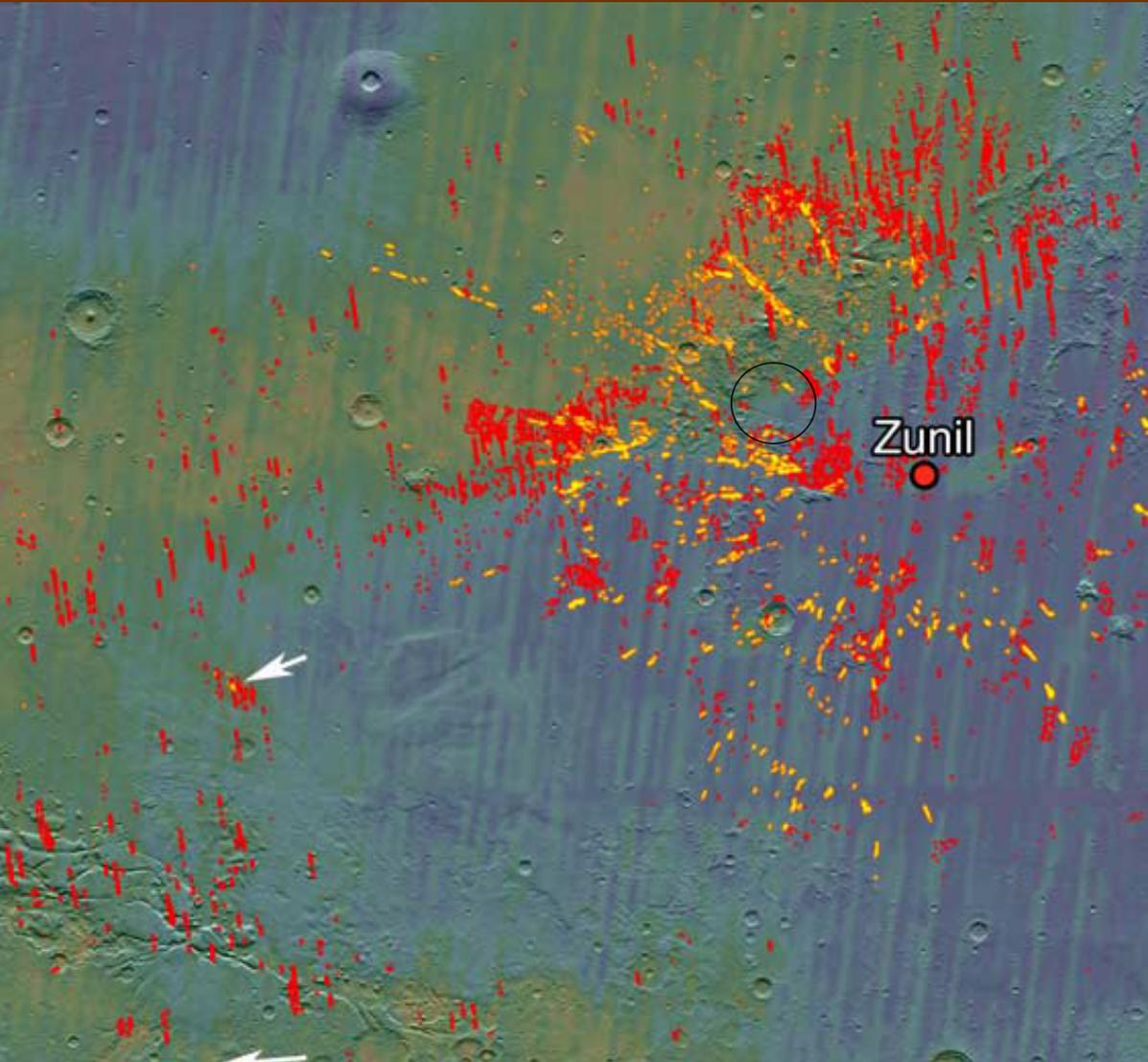
Alison Mulder

157.822 Degrees East



# Science ROI 5: Zunil ejecta/rays

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rays

bright ejecta craters

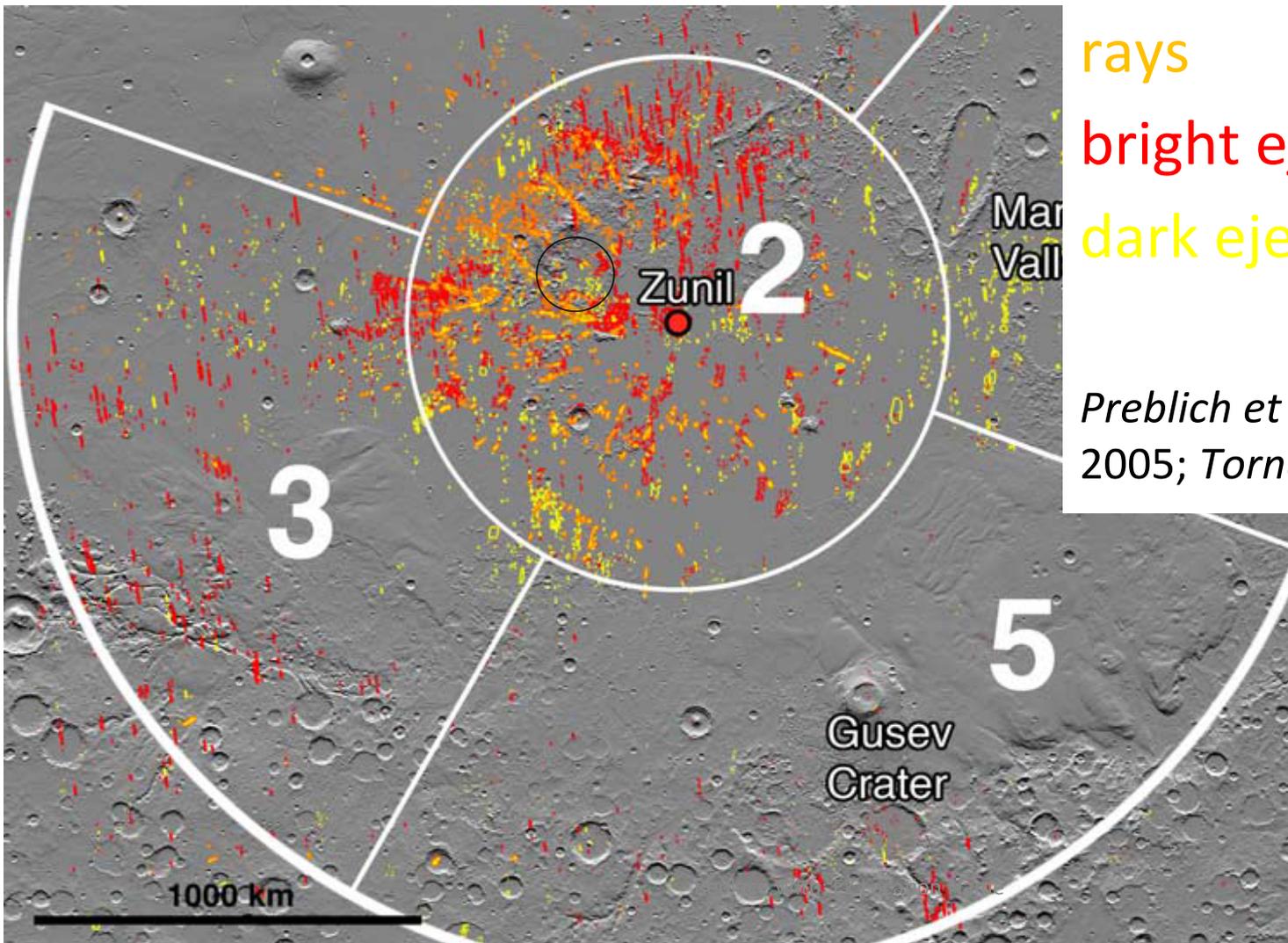
dark ejecta craters

*Preblich et al., 2007; McEwen et al., 2005; Tornabene et al., 2006*



# Science ROI 5: Zunil ejecta/rays

1<sup>st</sup> EZ Workshop for Human Missions to Mars



rays

bright ejecta craters

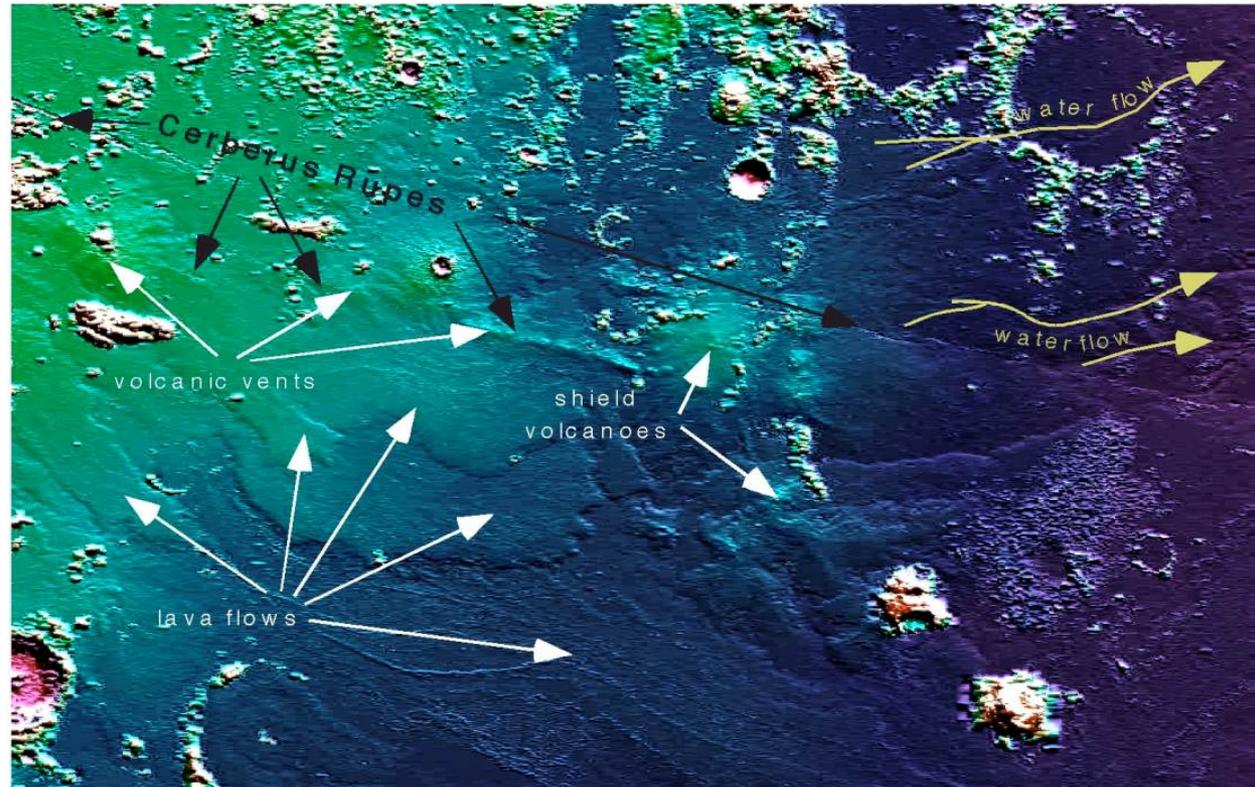
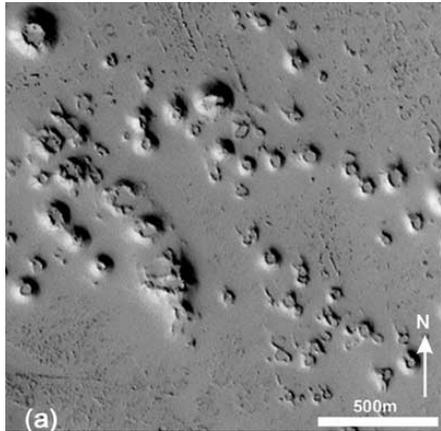
dark ejecta craters

*Preblich et al., 2007; McEwen et al., 2005; Tornabene et al., 2006*

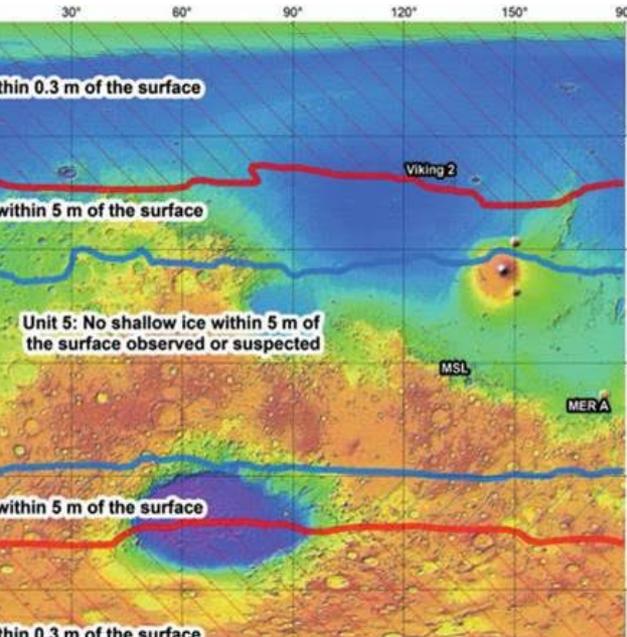
# Science ROI 6: aqueous flooding



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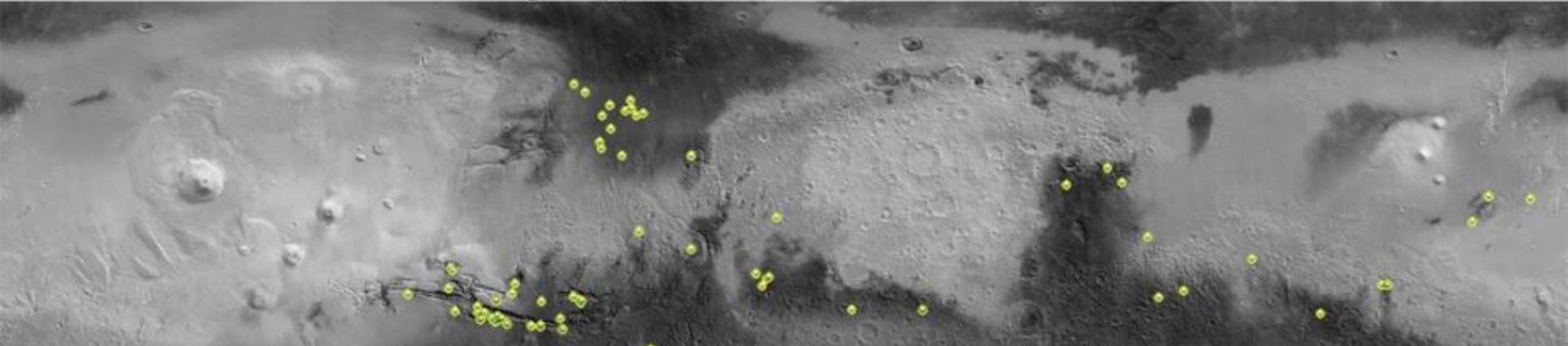
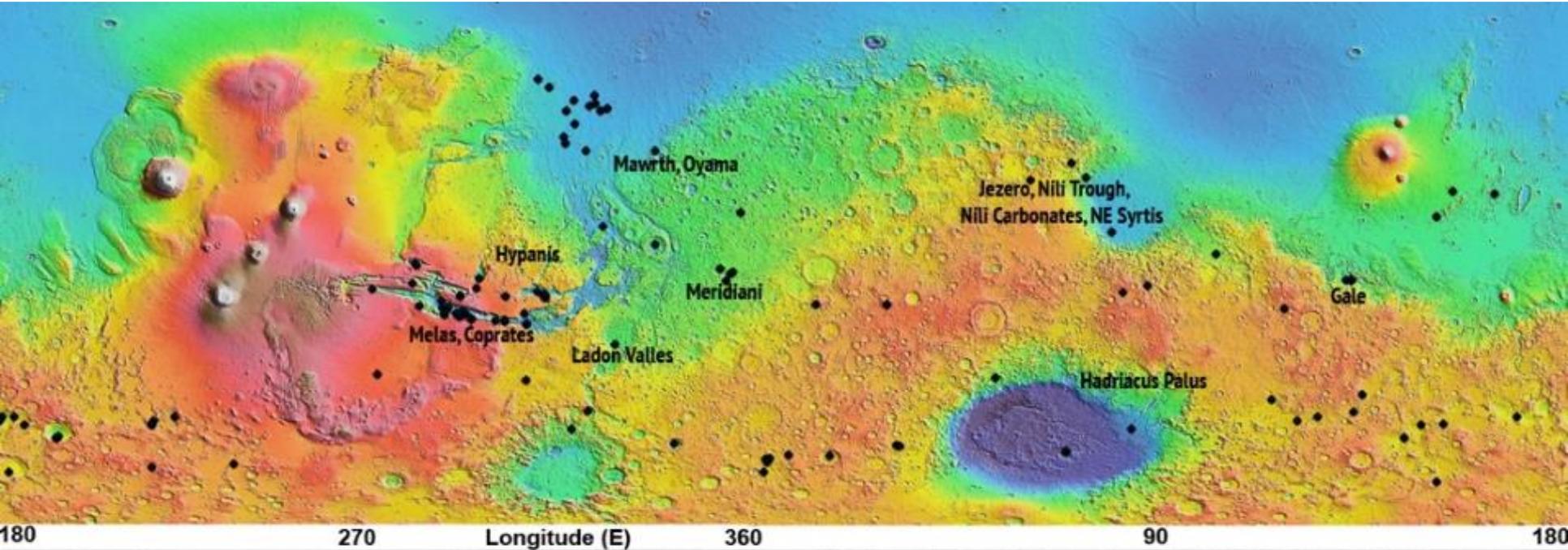
Cerberus Plains on Mars, showing fissures, vents, shield volcanoes, lava flows, fluvial channels and inferred directions of flows of both water and lava. Elevation shown by color (dark blues and purples are lows; greens are higher elevations).



# Science ROI 7: ~~RSL's~~ hydrated salts

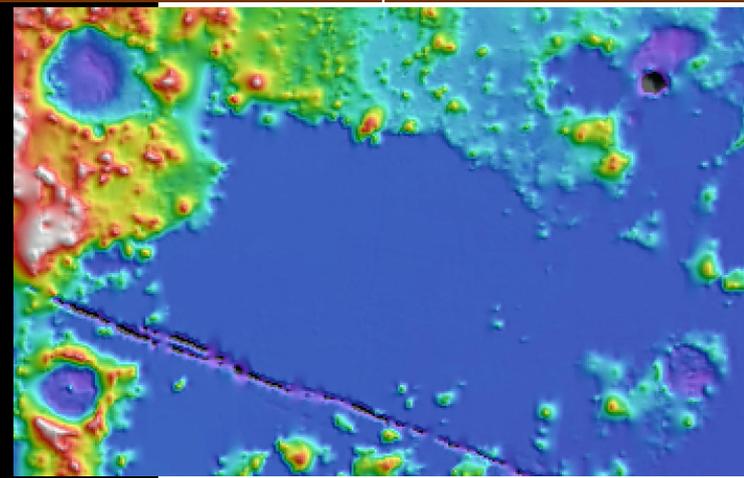
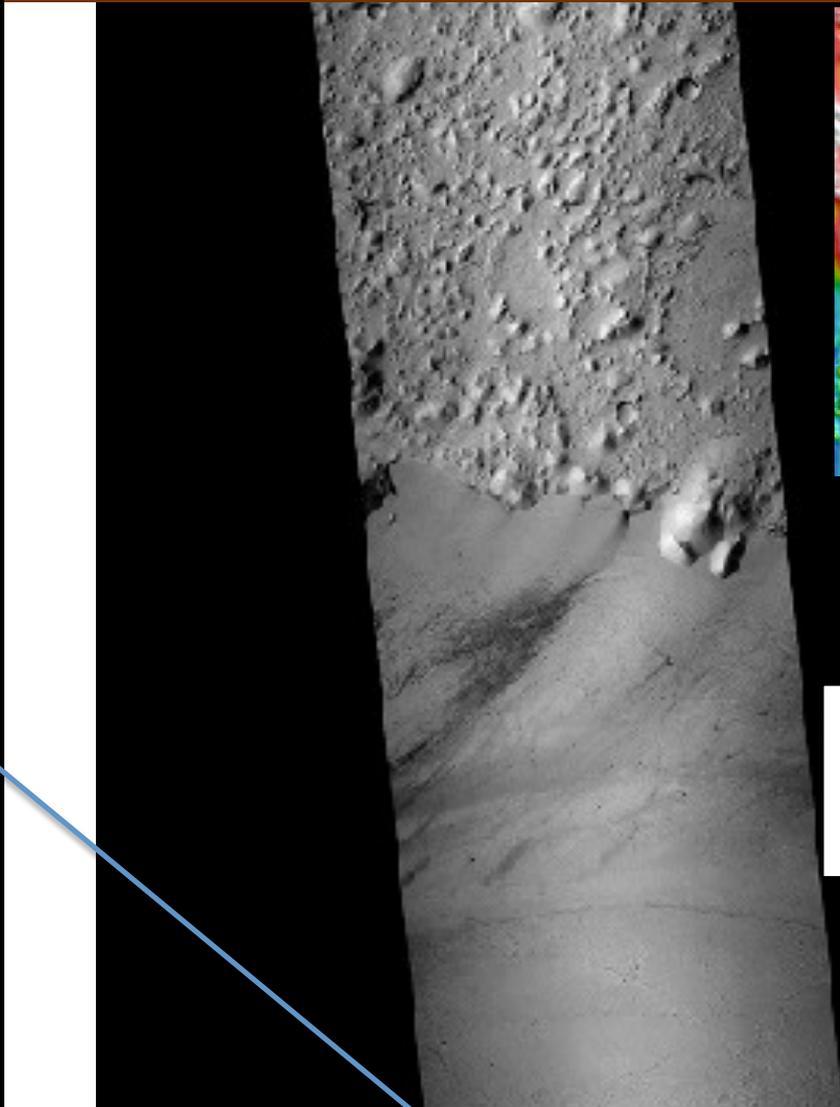
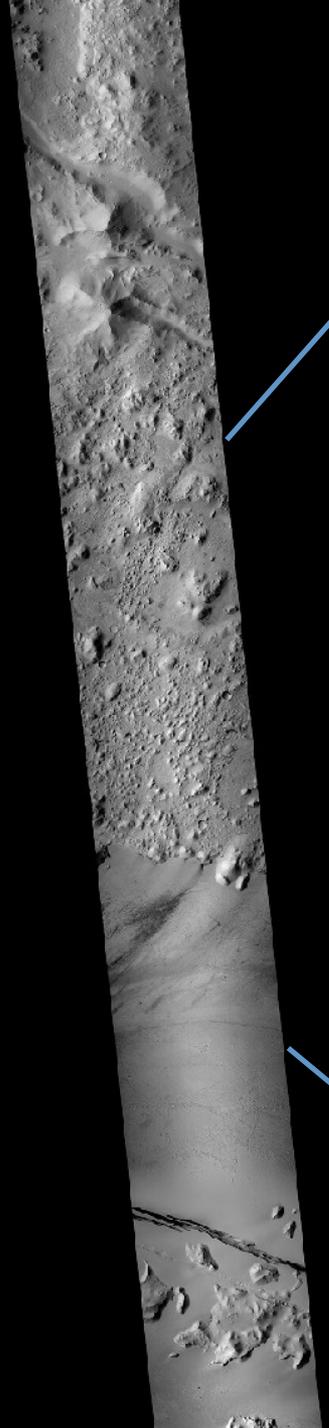


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1<sup>st</sup> EZ Workshop for Human Missions to Mars



MOLA -1500 to -3000

CTX image of knobs-plains contact

# Science ROI(s) Rubric

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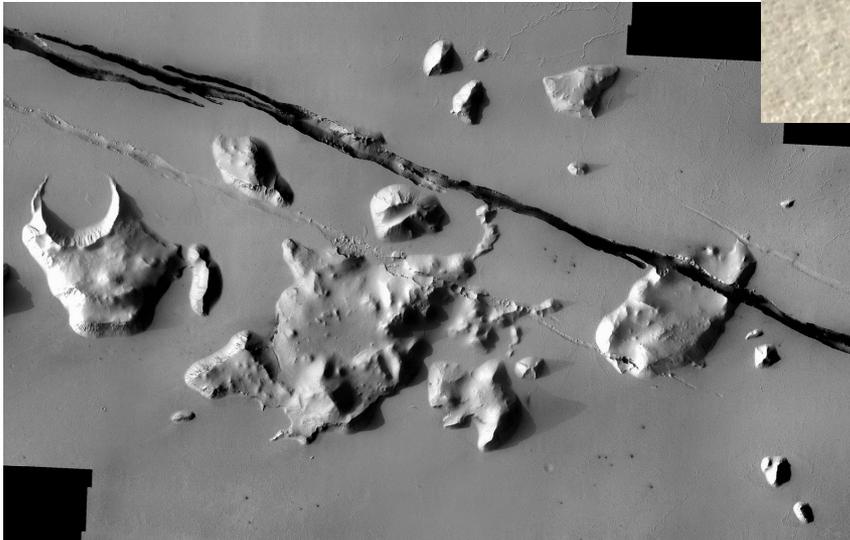
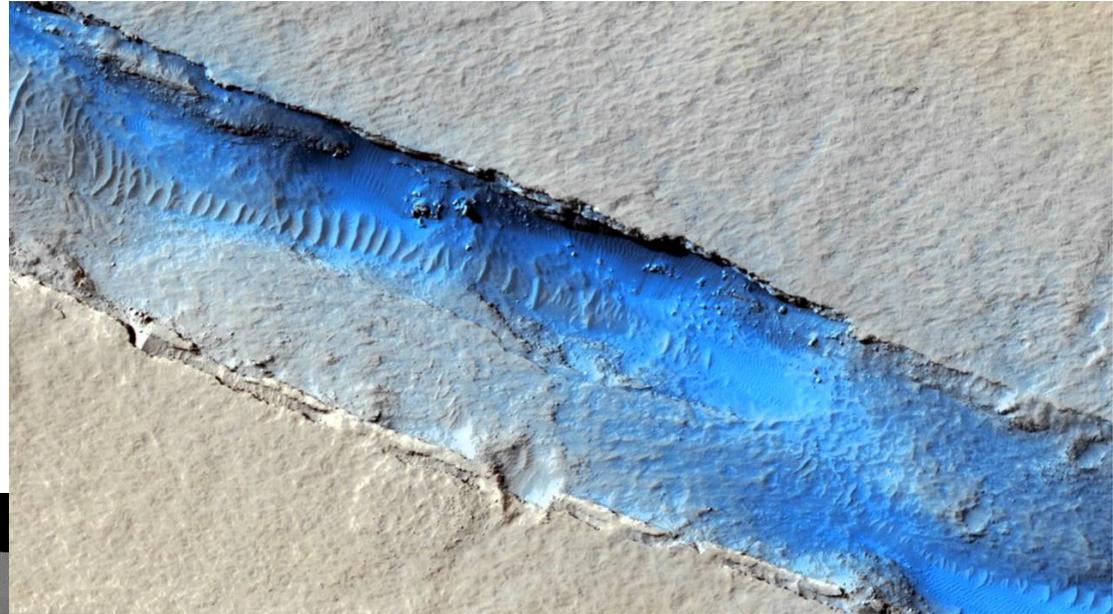
Site Factors			SROI1	SROI2	SROI3	SROI4	SROI5	SROI6	SROI7	RROI1	RROI2	RROI3	EZ SUM											
Science Site Criteria	Astrobio	Threshold	AND/OR	Potential for past habitability										●										
			Potential for present habitability/refugia										●	●					●					
		Qualifying	Potential for organic matter, 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

# Resource ROI 1: ice

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**Fossae and aqueous  
flooding –  
contemporaneous  
at 2-10 Ma ?**



ROI 1: ground ice

# Resource ROI 2: materials

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- dust
- cobbles of basalt
- sedimentary rocks – “cherty”  
silica?

# Resource ROI(s) Rubric

1<sup>st</sup> EZ Workshop for Human Missions to Mars



Site Factors			SROI1	SROI2	SROI3	SROI4	SROI6	SROI7		RROI1	RROI2		EZ SUM		
<b>ISRU and Civil Engineering Criteria</b>	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 <b>and</b> 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°			●									
			Located within 5 km of landing site location			●	X					?	?		
		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

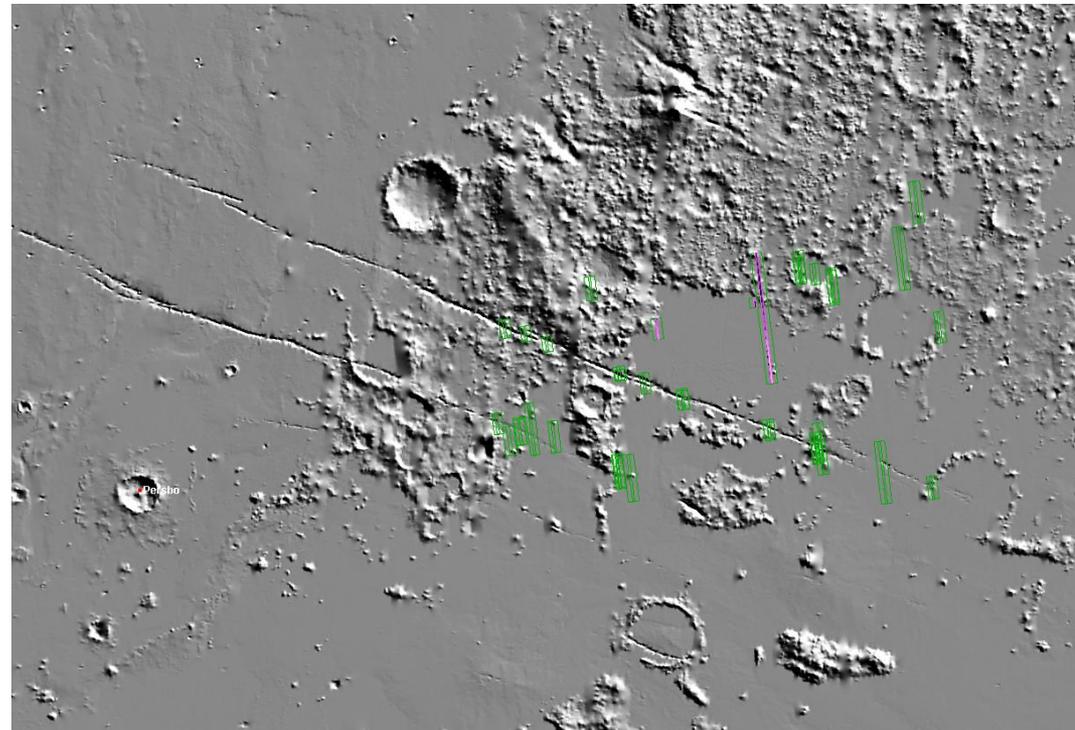
- Yes
- Partial Support or Debated
- No
- ? Indeterminate

# Prioritization List of EZ Data Needs

1<sup>st</sup> EZ Workshop for Human Missions to Mars



- Science:
  - Instrument: HiRISE
  - Lat/Long: 10.5° N, 161.3° to 162.1° E
  - ~40 km embayment contact between lava plains and Noachian knobby terrain ... hydrated salts/RSL's?

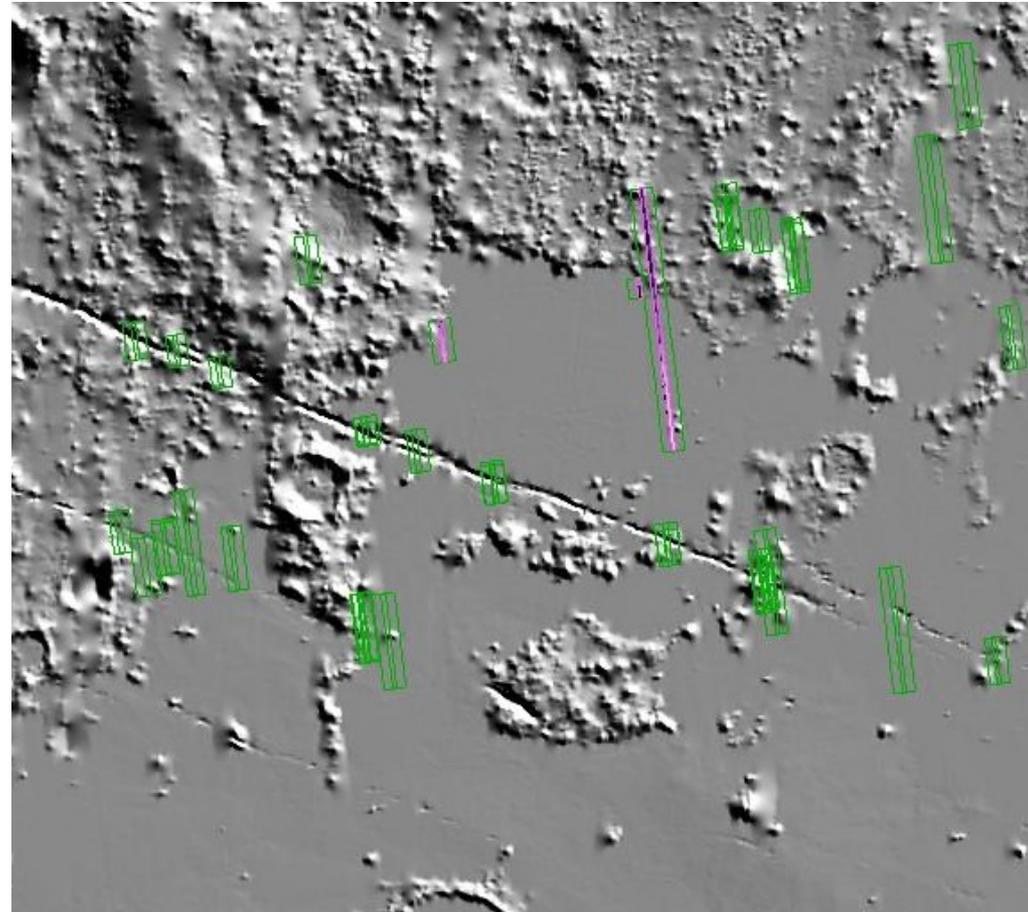


# Prioritization List of EZ Data Needs

1<sup>st</sup> EZ Workshop for Human Missions to Mars

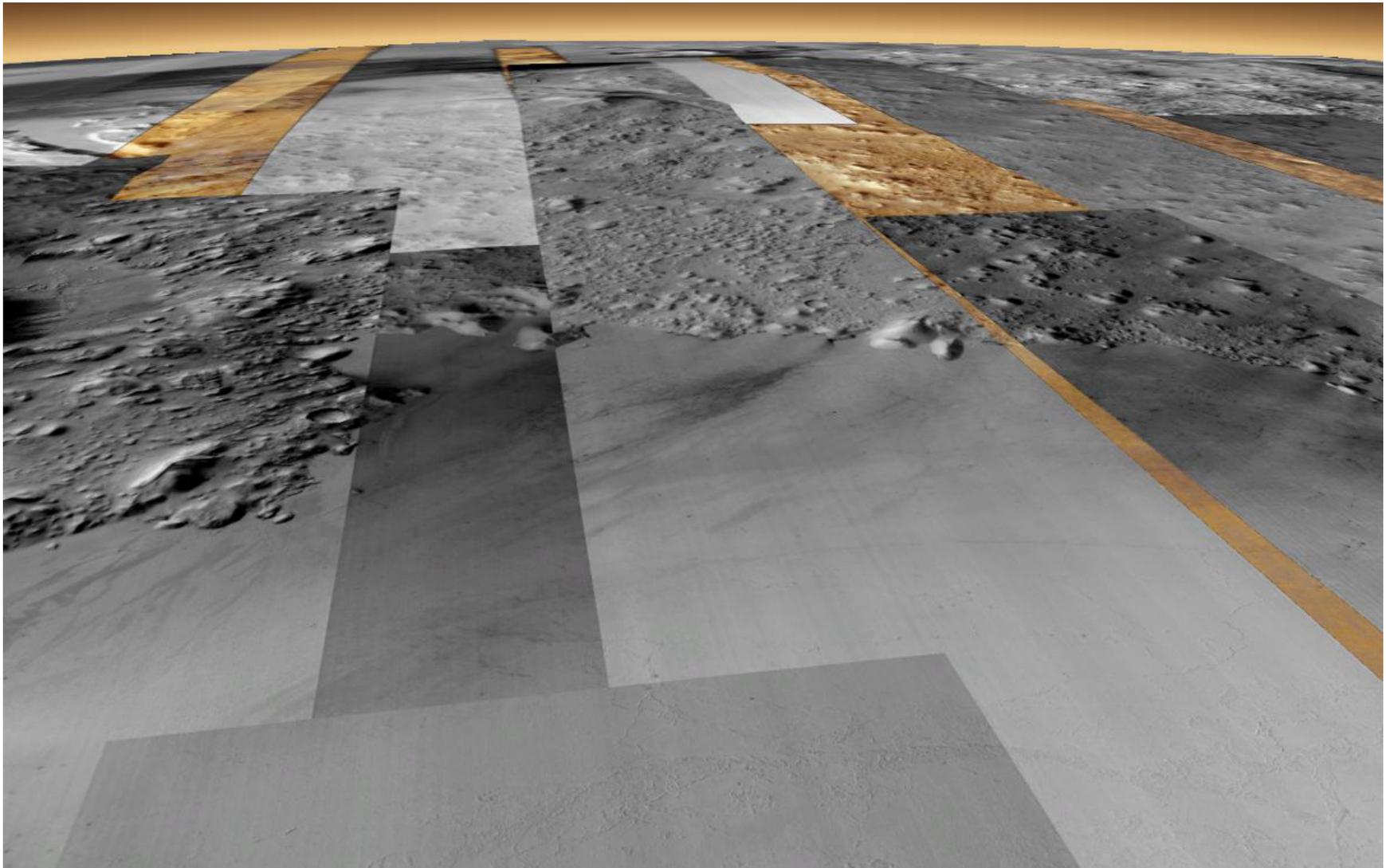


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# Priority: HiRISE of contact

1<sup>st</sup> EZ Workshop for Human Missions to Mars



# Conclusions

1<sup>st</sup> EZ Workshop for Human Missions to Mars



- Science
  - Old Noachian, younger Hesp-Amaz lava flows
  - 2-10 Ma Fossae faults
  - ~1 Ma distal ejecta/rays from 500+ km
  - Evidence of aqueous flooding 2-10 Ma
  - *Nearby* Formations: Medusa Fossae, southern Highlands
- Resources
  - Ice?
  - Safe, flat landing site on basalt flood plains
    - caves or skylights?
  - Materials: dust, basalt in plains (silica in knobs?)

# Available orbital datasets

Dataset	Instrument	Coverage	Spatial Res./Footprint	Where to look at
Surface images	HiRISE	2.4%	Res- 0.25-1 m/px Width- Red: 6km wide, Color: 1.2 km wide, Nominal length- 35km;	<a href="http://hirise.lpl.arizona.edu/">http://hirise.lpl.arizona.edu/</a>
	CTX	95%	Res- 5 m/px Width- 30 km	<a href="http://global-data.mars.asu.edu/bin/ctx.pl">http://global-data.mars.asu.edu/bin/ctx.pl</a>
	MOC (-2006)	6%	Res- <12 m/px	<a href="http://www.msss.com/moc_gallery/">http://www.msss.com/moc_gallery/</a>
	HRSC	>90%	Res- 10-60 m/px Swath width- 60 km	<a href="http://www.rssd.esa.int/PSA">http://www.rssd.esa.int/PSA</a> , <a href="http://ode.rsl.wustl.edu/mars/">http://ode.rsl.wustl.edu/mars/</a>
NIR spectral data (e.g., composition)	CRISM	97% msp VNIR, to 36% hsp IR	Res- 20-200 (msp) m/px msp Footprint: 10 km x 45-540 km	<a href="http://crism.jhuapl.edu/gallery/featuredImage/index.php">http://crism.jhuapl.edu/gallery/featuredImage/index.php</a>
TIR spectral data (e.g, thermal inertia for rock counting, surface texture/ type, subsurface cavities)	TES (-2006)	Near global	Res- 3 km Width- 5.3, Length- 8.3 km	<a href="http://tes.asu.edu/data_archive.html">http://tes.asu.edu/data_archive.html</a>
	THEMIS	Near global	Res- 100 m Width- 20 km	<a href="https://themis.asu.edu/gallery">https://themis.asu.edu/gallery</a>
Digital Terrain Models/slope maps	HiRISE	274 (there are more stereo images)	Meter-scale	<a href="http://www.uahirise.org/dtm/">http://www.uahirise.org/dtm/</a>
	HRSC	75%	~50 m/px	<a href="http://hrscview.fu-berlin.de/">http://hrscview.fu-berlin.de/</a>
	MOLA (-2001 as altimeter)	global	100s m spacing of points	<a href="http://mola.gsfc.nasa.gov/">http://mola.gsfc.nasa.gov/</a>
Radar	SHARAD	40%	Swath width- 3km, Depth res.- 10m, Depth pen.- 300m	<a href="http://pds-geosciences.wustl.edu/missions/mro/sharad.htm">http://pds-geosciences.wustl.edu/missions/mro/sharad.htm</a>
	MARSIS	80%	Swath width- 10km, Depth res.- 100m, Depth pen.- 1km	<a href="http://pds-geosciences.wustl.edu/missions/mars_express/marsis.htm">http://pds-geosciences.wustl.edu/missions/mars_express/marsis.htm</a>

**Notes:** Rows in orange are those that can be requested. Atmospheric datasets (not listed) are also available. Global maps can be found at: <http://www.mars.asu.edu/data/>. A useful tool for looking at and analyzing multiple datasets: <http://jmars.asu.edu/>