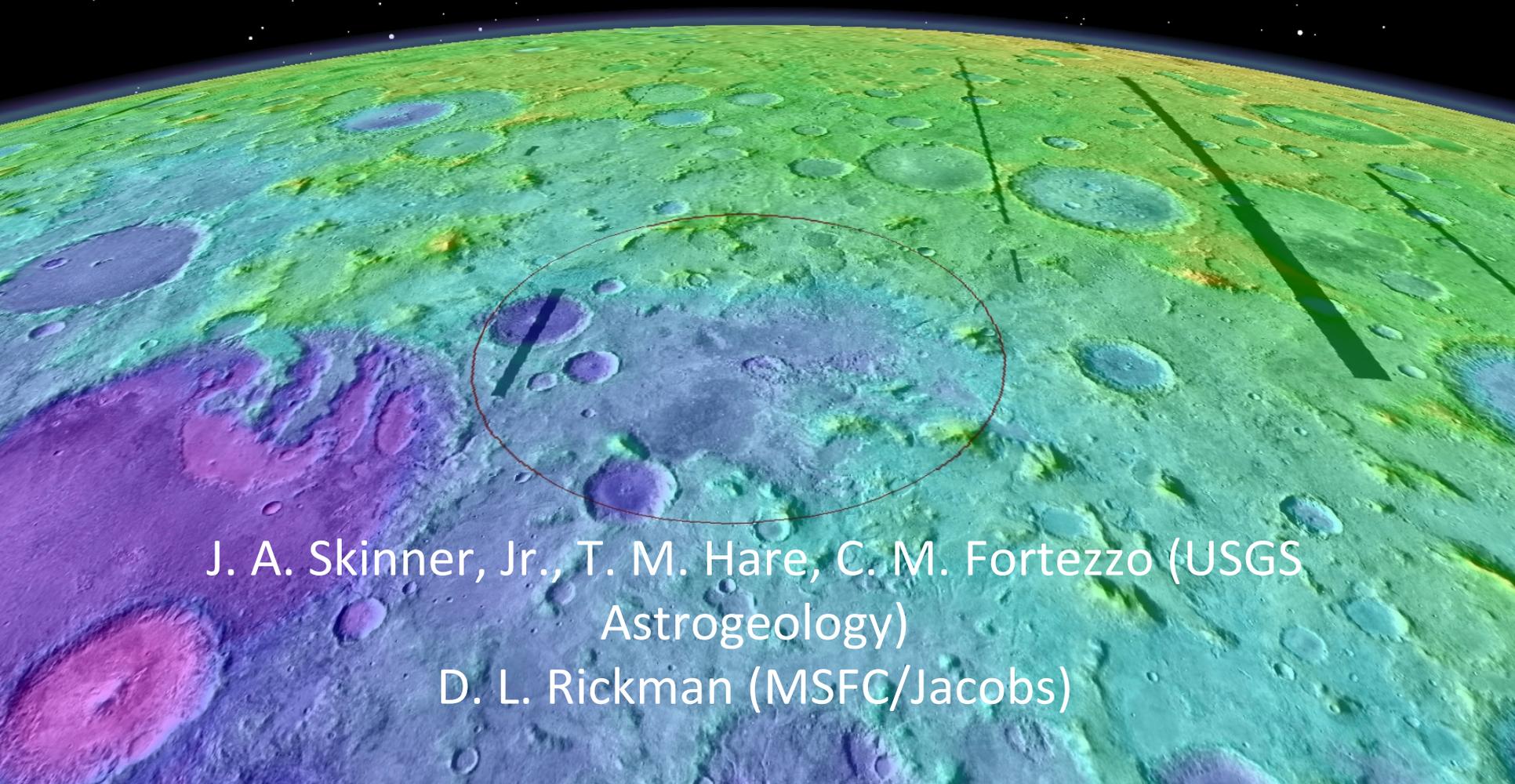


# EXPLORING AN EXHUMED, INTERCRATER BASIN IN MARTIAN CRATERED HIGHLANDS: THE HADRIACUS PALUS AND CAVI EXAMPLE



J. A. Skinner, Jr., T. M. Hare, C. M. Fortezzo (USGS  
Astrogeology)

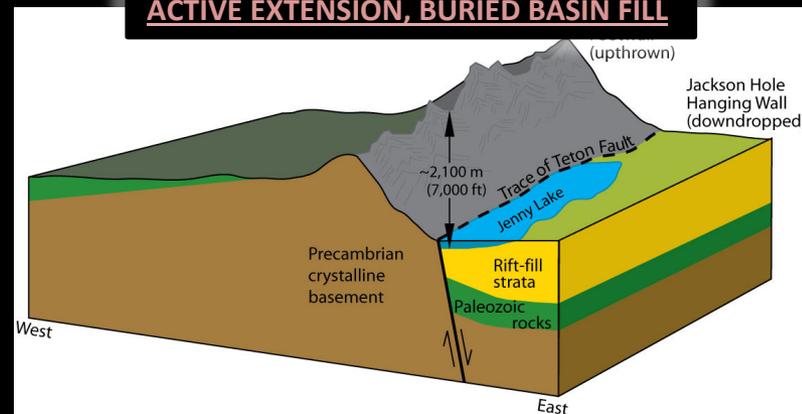
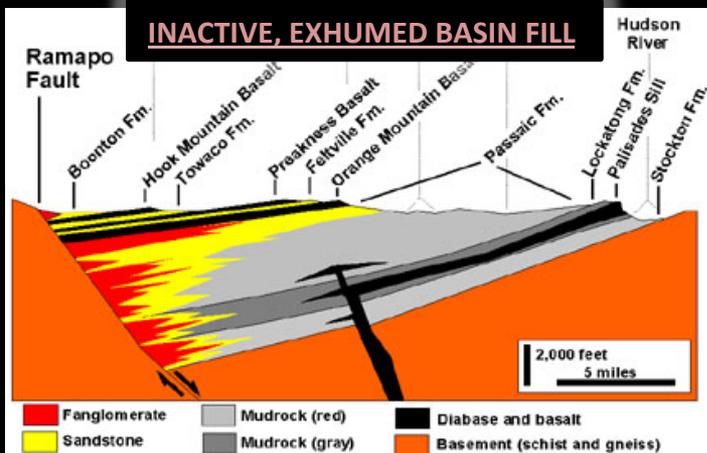
D. L. Rickman (MSFC/Jacobs)

# Rationale

- On Earth, basin strata detail pre-, syn-, and post-basin tectonism, depositional environments, and climate interactions
  - *Uplifted blocks ~ Basement material*
  - *Accommodation space ~ Sedimentary fill*
  - *Thinned crust ~ volcanism*
  - *Need lengthy core or exhumation*
- On Mars, expect similar...
  - *Basin impacts ~ instantaneous accommodation*
  - *Need exhumation to examine*
  - *“Typical” on Mars*

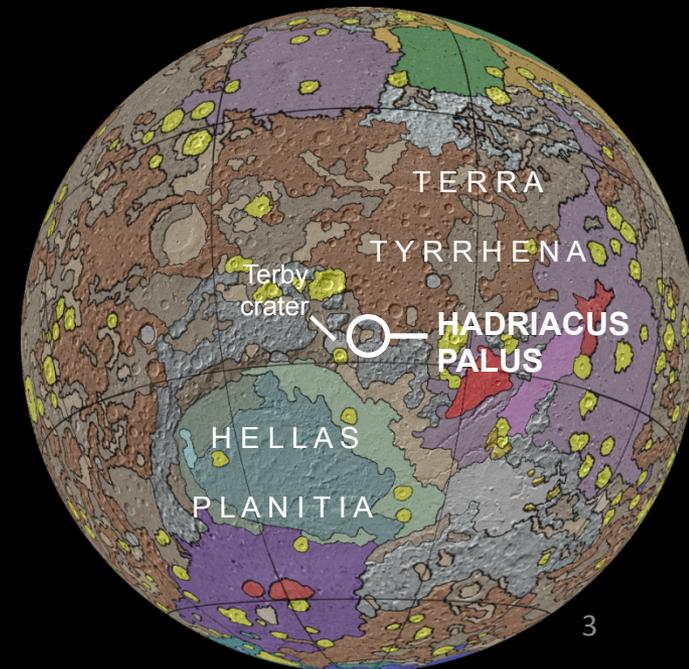
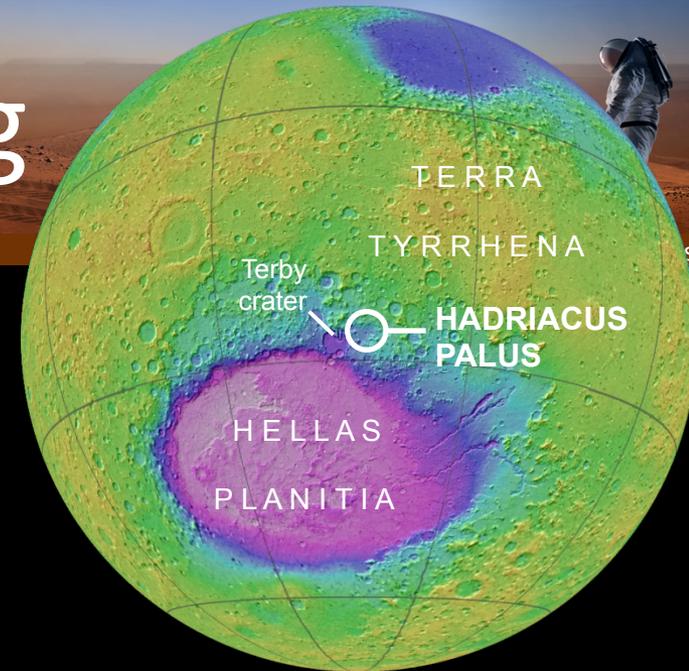


**ACTIVE EXTENSION, BURIED BASIN FILL**



# Regional Setting

- SW Terra Tyrrhena, NE Hellas Planitia, E of Terby crater
- Early Noachian extensional basin sequence
- Noachian to Early Hesperian basin fill
- Late Hesperian basin exhumation
- Basement, sedimentary, volcanic, and impact rocks
- 2 channel systems, different provenance
- Representative highland plains units
- Comparative terrains (locally and globally)
- 800 m of exposed and accessible strata
- Tectonic history directly observable
- Well-placed for atmospheric science
- Adjacent to globally-inferred ice reservoirs
- Exceptional geologic and stratigraphic context
- Completely normal
- Type locality strata enabling broad extrapolation



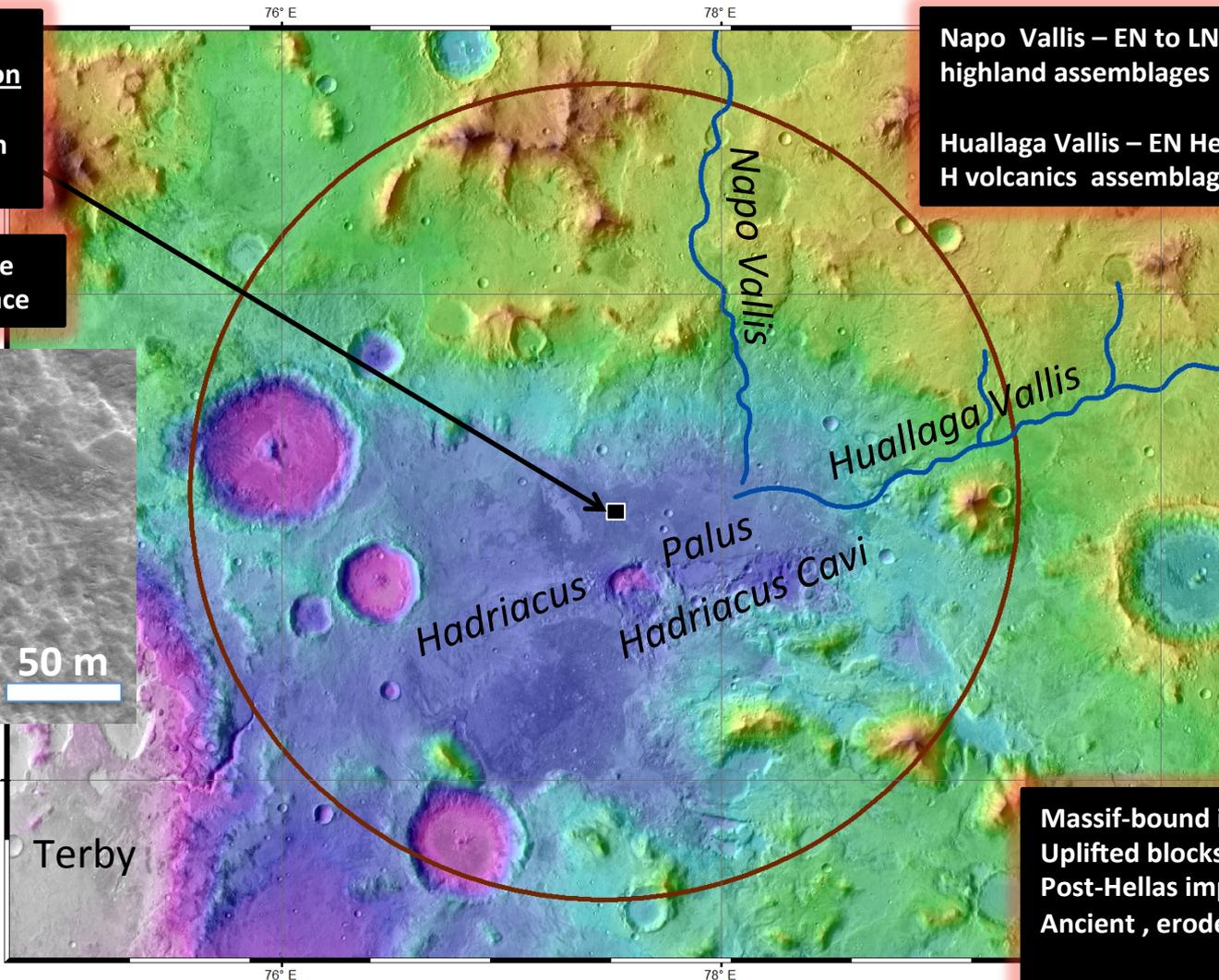
# Exploration Zone Map

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



**Landing Site and  
Surface Field Station**  
77.47E, -26.84N  
-2649 m elevation  
125 m / 70 km

- Rock free surface
- ~Sand free surface



**Napo Vallis – EN to LN “typical” cratered highland assemblages**

**Huallaga Vallis – EN Hellas massifs, H volcanics assemblages~ Hadriacus Mons**

50 m

Terby

**Massif-bound intercrater basin**  
**Uplifted blocks related to Hellas?**  
**Post-Hellas impacts?**  
**Ancient , eroded volcanic centers?**

# Exploration Zone Map



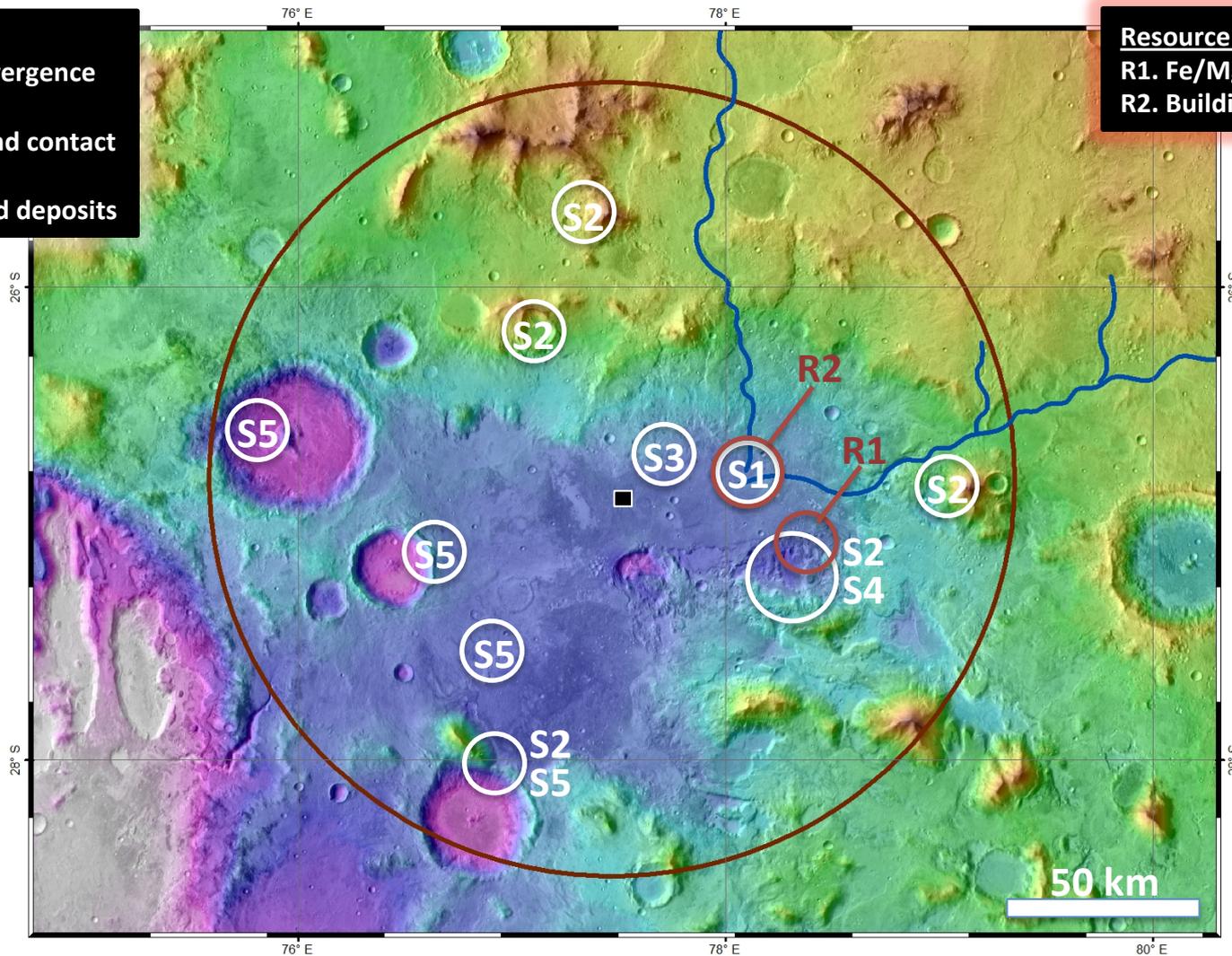
1<sup>st</sup> EZ Workshop for Human Missions to Mars

## Science ROI

- S1. Channel convergence
- S2. Massifs
- S3. Basin-Highland contact
- S4. Cavi strata
- S5. Crater-related deposits

## Resource ROI

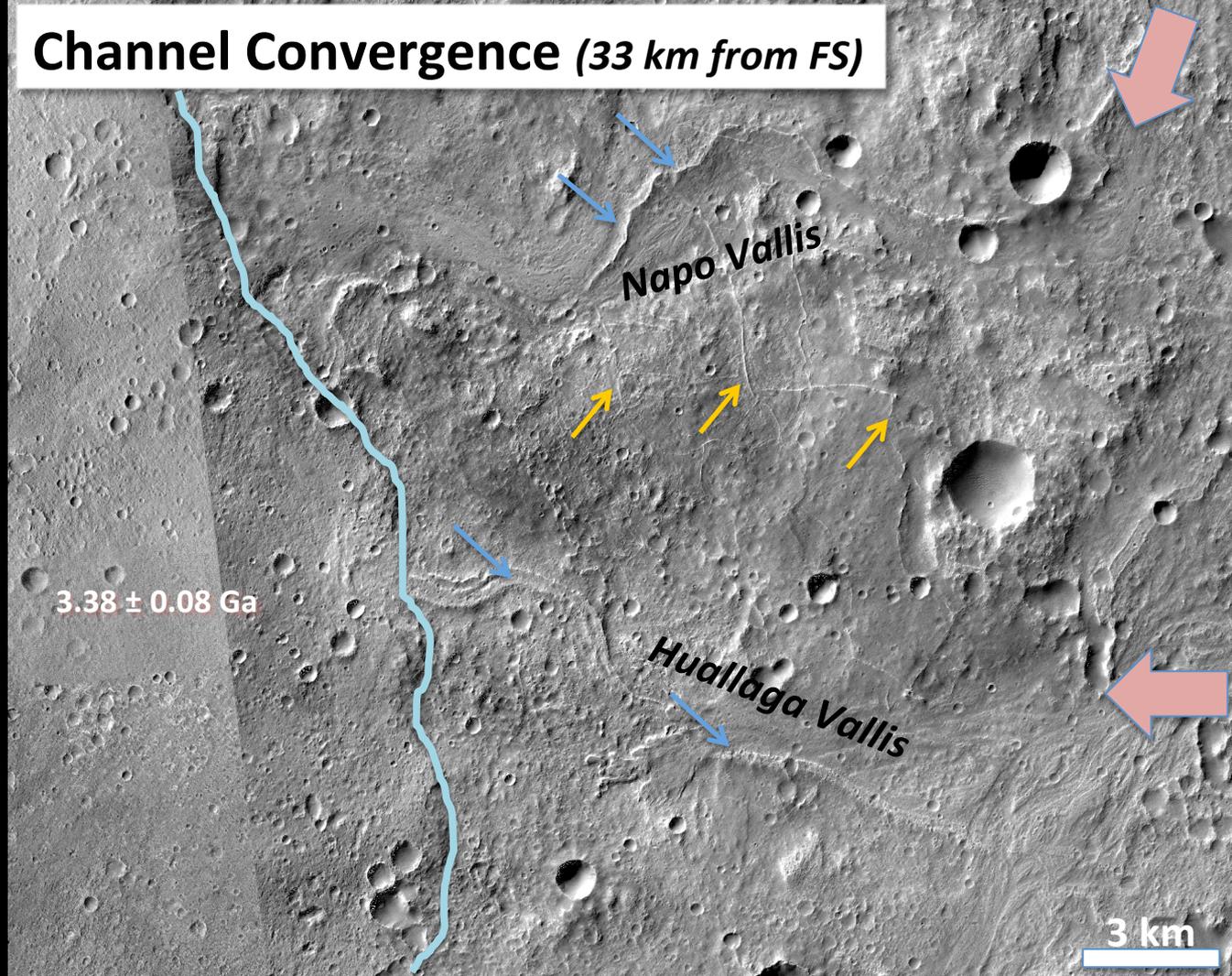
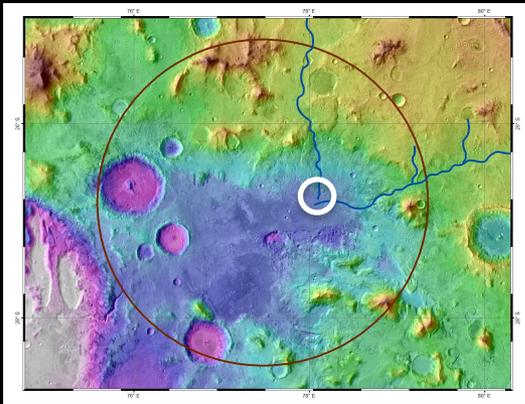
- R1. Fe/Mg phyllosilicates
- R2. Building materials



- S1. Channel convergence
- S2. Massifs
- S3. Basin-Highland contact
- S4. Cavi strata
- S5. Crater-related deposits

# Science ROIs

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

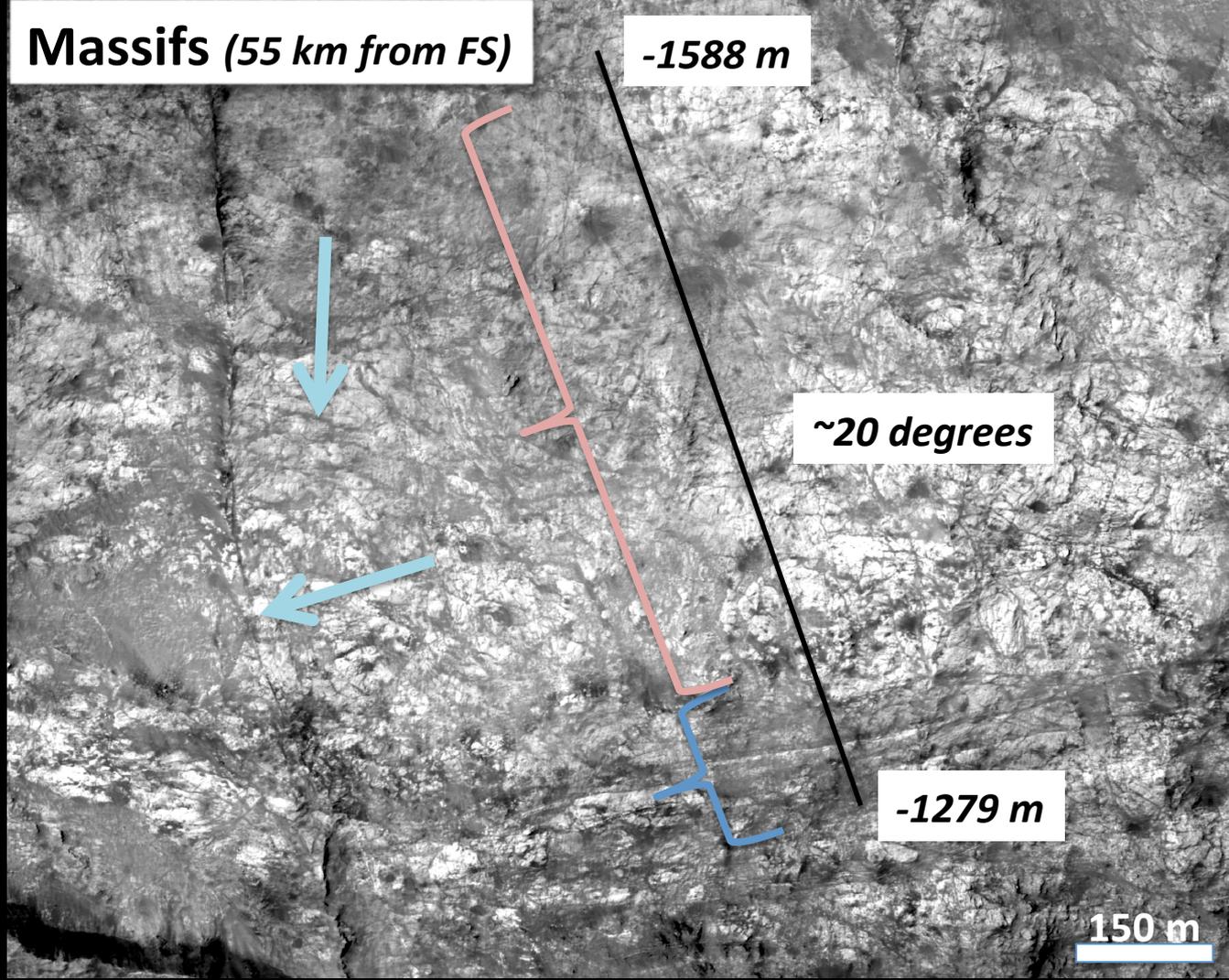
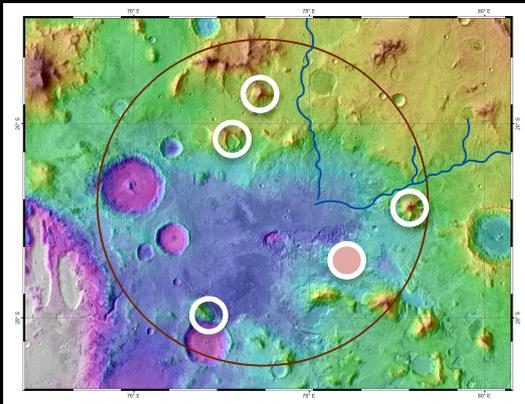


- **Inverted and abutted channels**  
*Fluvial dynamics?*  
*Process of inversion?*  
*Correlative timing?*
- **Two different source terrains**
- **eNh, mNh, lNh vs.**
- **eNhm, mNh, eHv, Hve**  
*Contrasting lithology?*  
*Changing fluvial systems?*
- **Palus scarp**  
*Erosion and deflation?*
- **Raised, curvilinear ridges**  
*Fracture cementation?*  
*Surface or subsurface?*

- S1. Channel convergence
- S2. Massifs
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- S5. Crater –related deposits

# Science ROIs

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

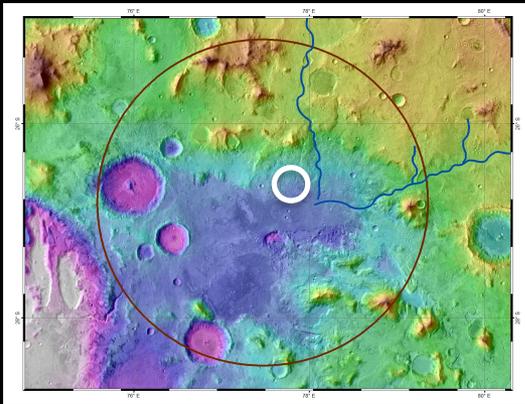


- Multiple sites enable cross-comparison of massif lithology and structure
- Layered upper
  - Ancient regolith?*
  - Hellas ejecta?*
- Massive lower
  - Xstalline basement?*
- Lineaments parallel and perp.
  - Pre-Hellas faulting?*
  - Post-Hellas faulting?*
- **DATABLE UNIT**

- S1. Channel convergence
- S2. Massifs
- S3. Basin-Highland contact**
- S4. Cavi strata
- S5. Crater-related deposits

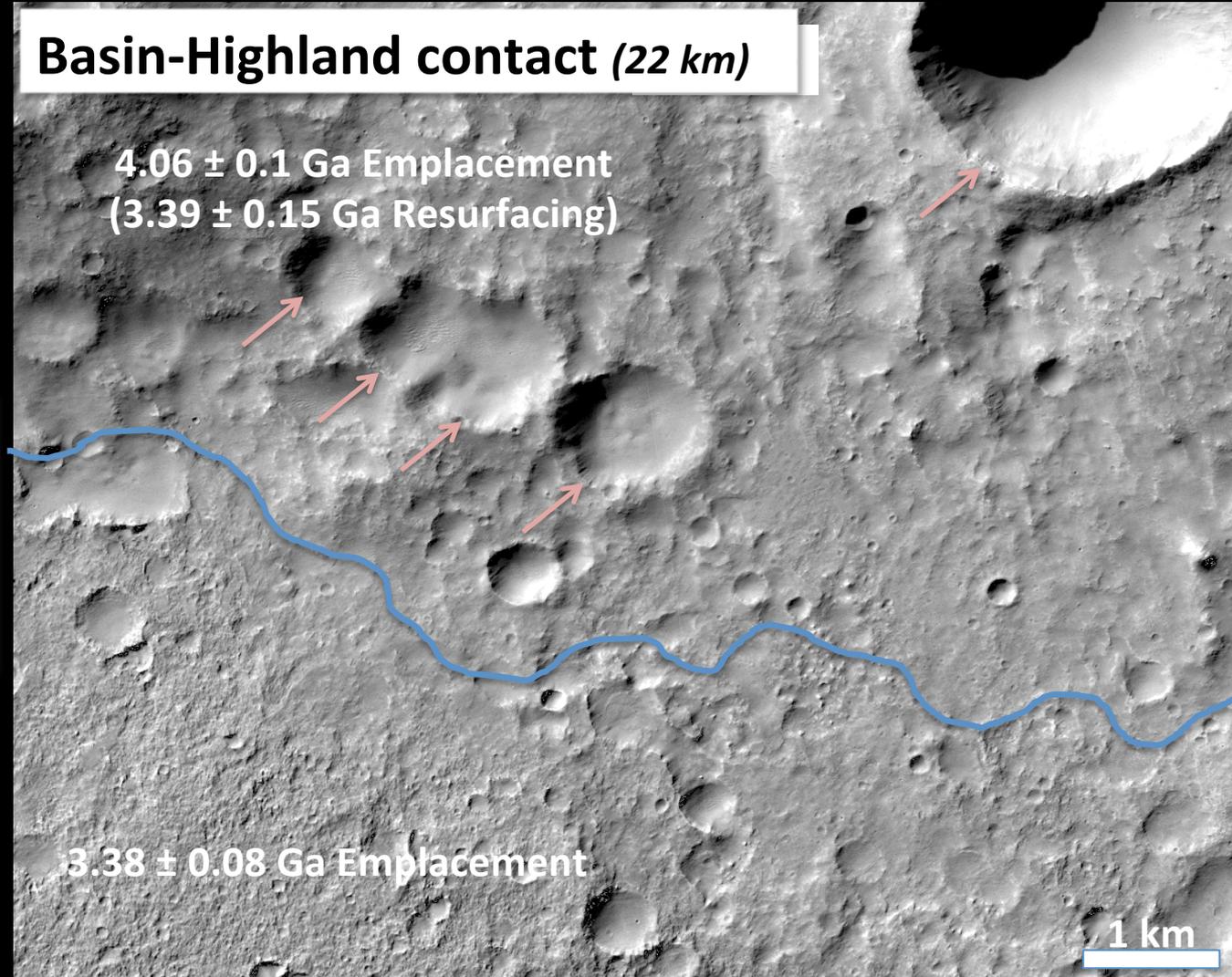
# Science ROIs

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



## Basin-Highland contact (22 km)

4.06 ± 0.1 Ga Emplacement  
(3.39 ± 0.15 Ga Resurfacing)

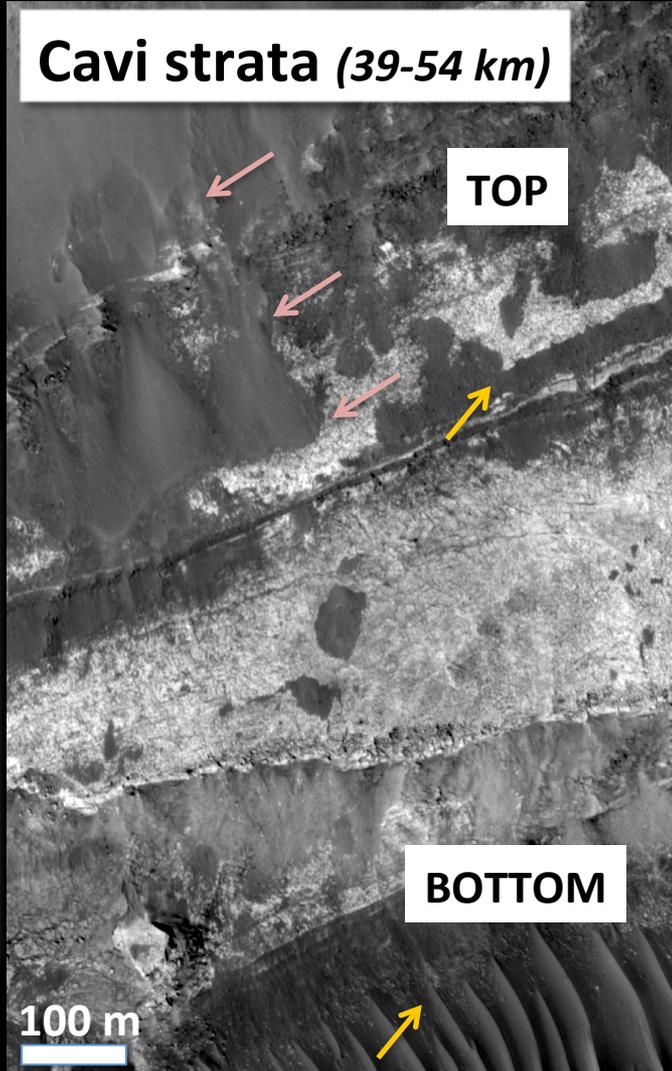
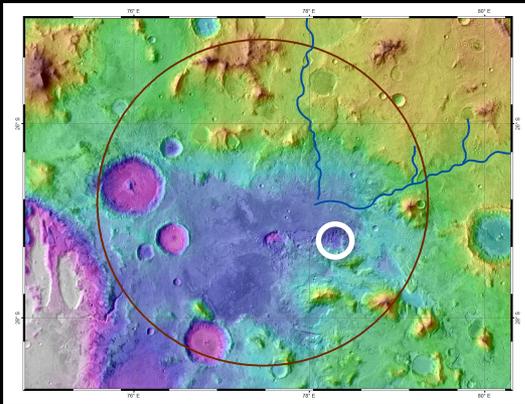
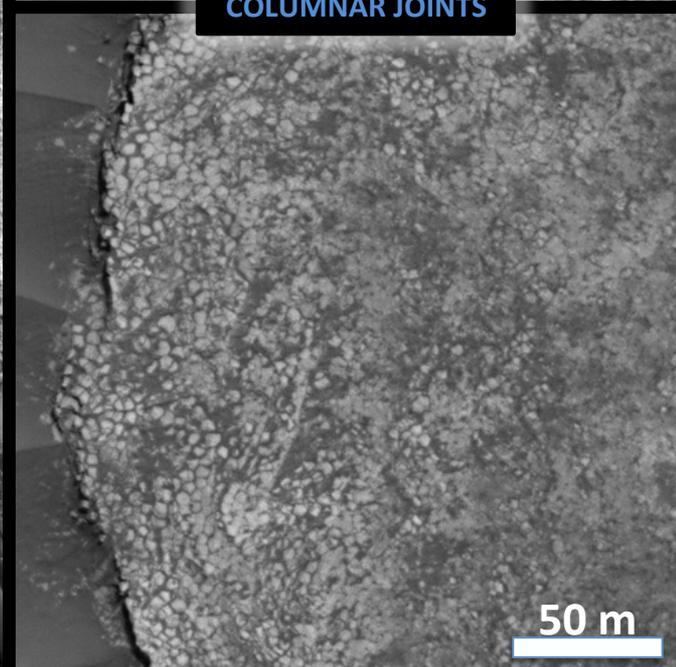
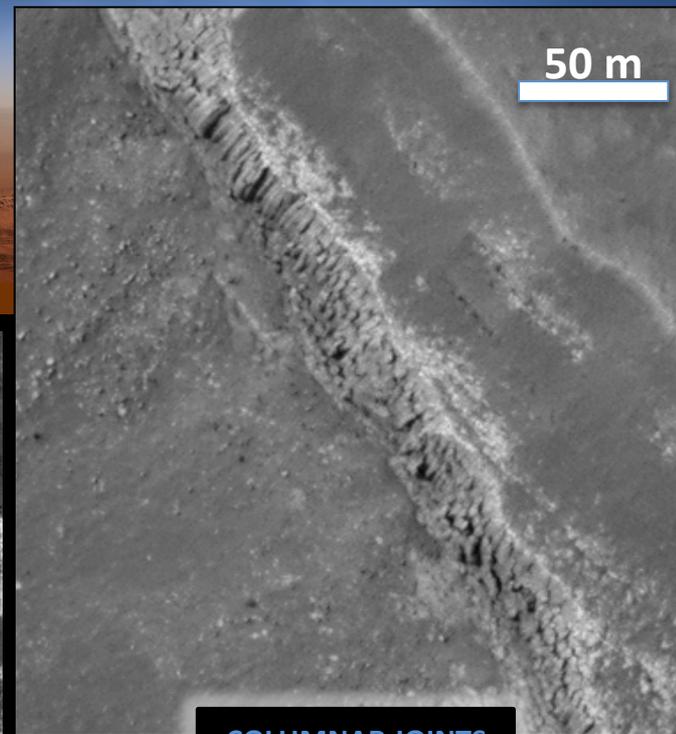


3.38 ± 0.08 Ga Emplacement

- **Palus margin**  
*Burial or interfingering?*  
*DEPO environment?*  
*Channel contributions?*
- **Impact craters**  
*Primary processes?*  
*Secondary processes?*

- S1. Channel convergence
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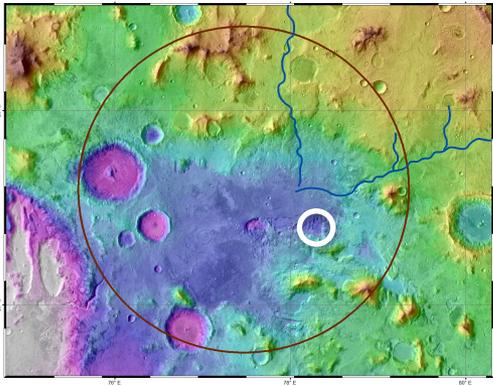
# Science ROIs



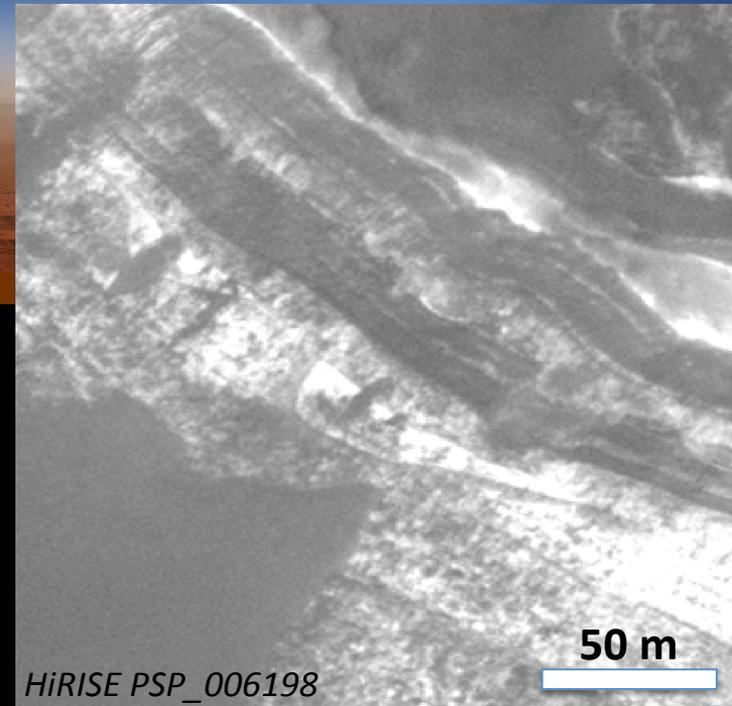
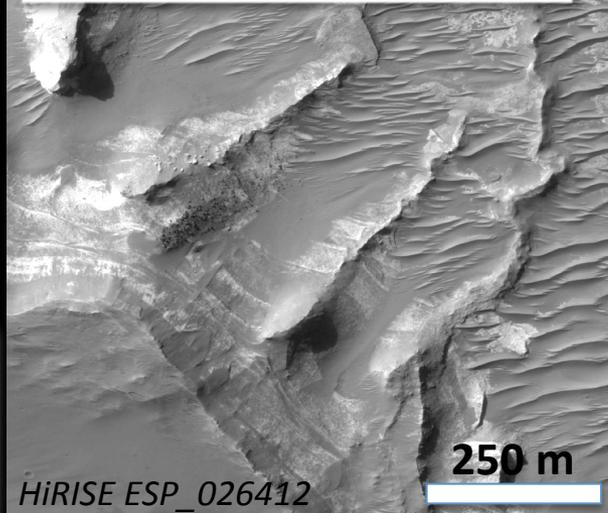
- Light/Dark stratification  
*Lithology? Facies?*
- Colluvium  
*Deposition v. erosion?*
- Duneform and mantle  
*Wind regimes?*  
*Source terrains?*
- Columnar joints  
*Lava? Welded tuff?*  
*Continuous section?*  
*Comparative samples?*  
*Relation to basin event?*
- DATABLE UNIT

- S1. Channel convergence
- S2. Massifs
- S3. Basin-Highland contact
- S4. Cavi strata
- S5. Crater-related deposits

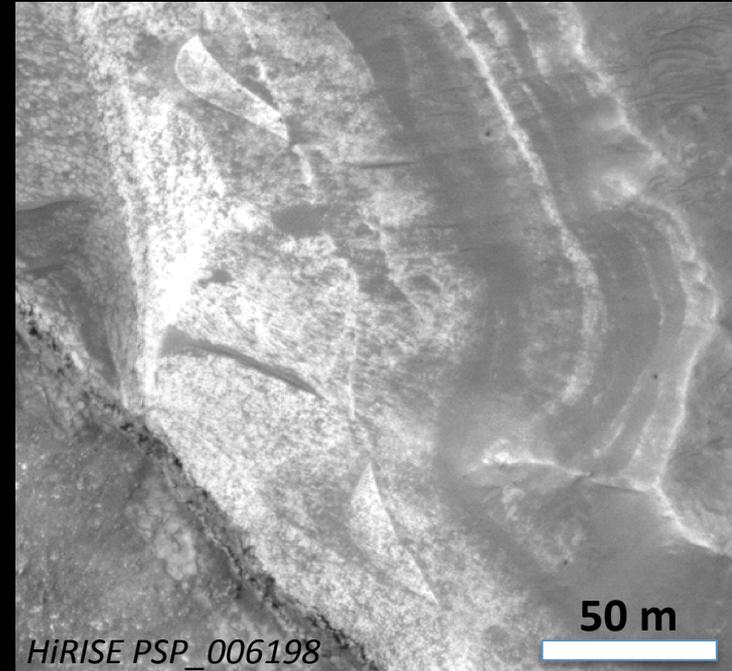
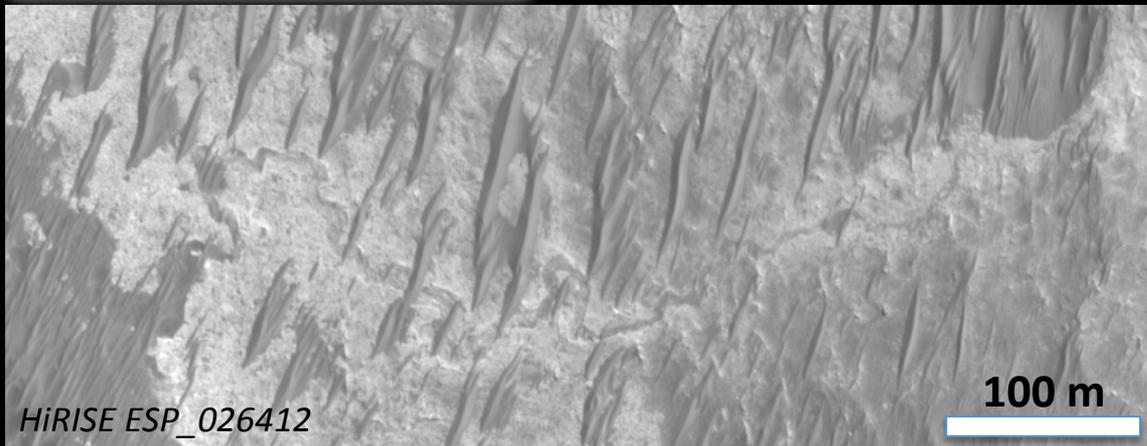
# Science ROIs



**Cavi strata (39-54 km)**



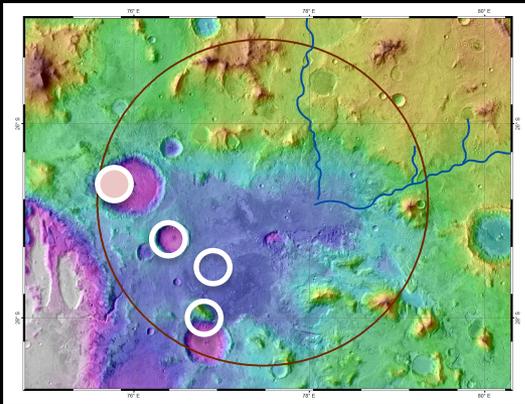
- Channels
  - Intermittency?*
  - Changing environment?*
  - Lateral continuity?*



- S1. Channel convergence
- S2. Massifs
- S3. Basin-Highland contact
- S4. Cavi strata
- S5. Crater-related deposits

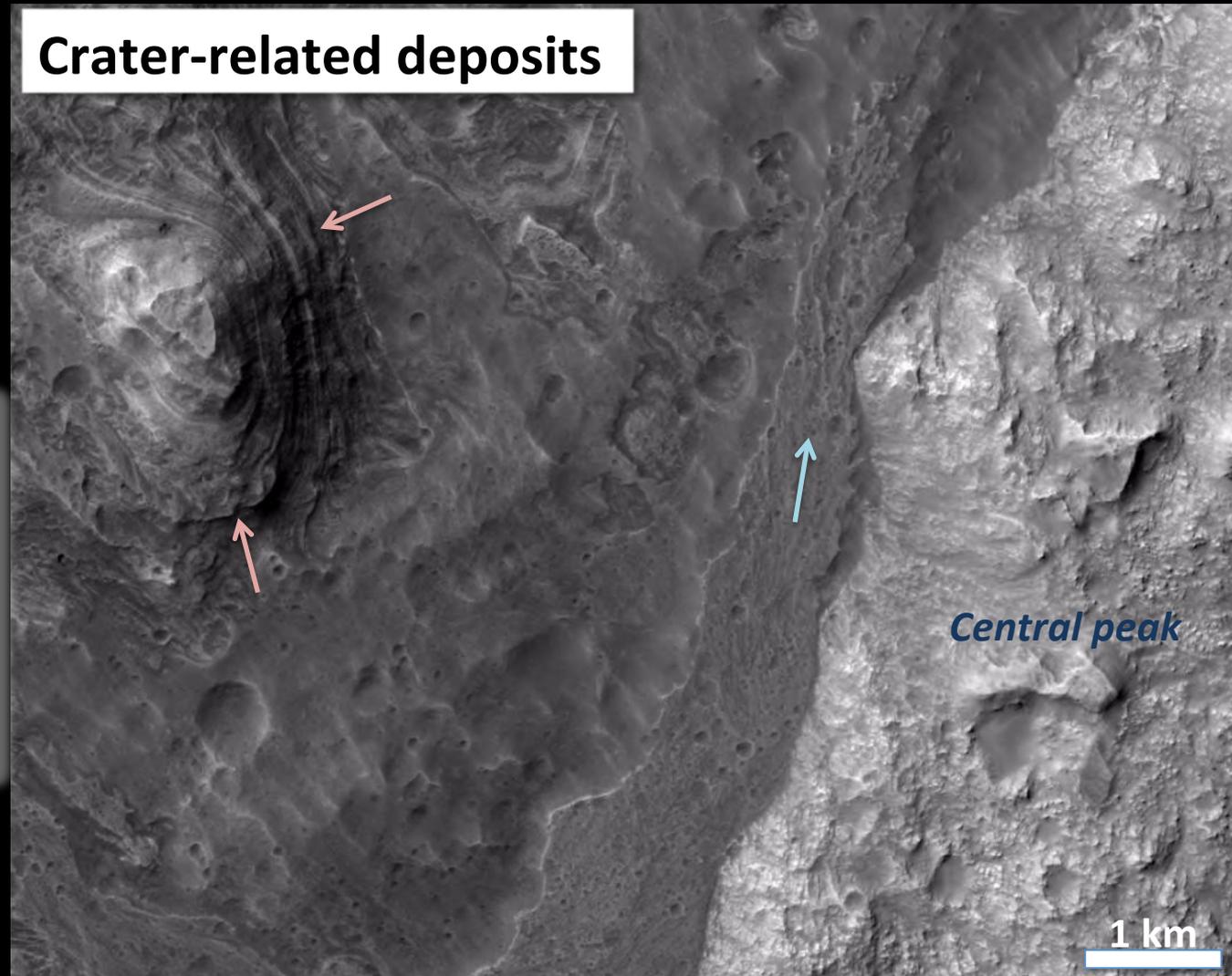
# Science ROIs

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## Crater-related deposits

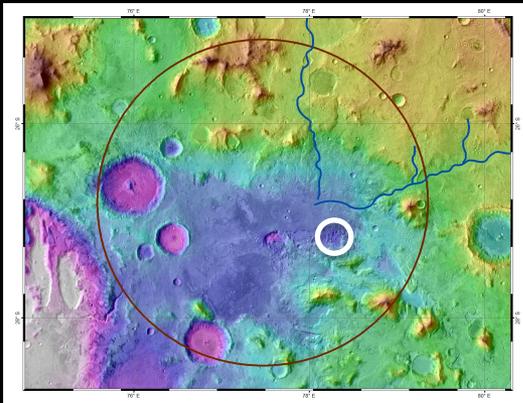
- **Central peak**  
*Compare to massifs?*
- **DATEABLE UNIT**
- **Finely stratified units**  
*Aqueous environment?*  
*Compare to MSL?*
- **Exhumation and lobate flows**  
*Compare cavi exhumation?*  
*Debris flows?*
- **Crater rim, wall, ejecta facies**



R1. Fe/Mg Phyllosilicates  
R2. Building materials

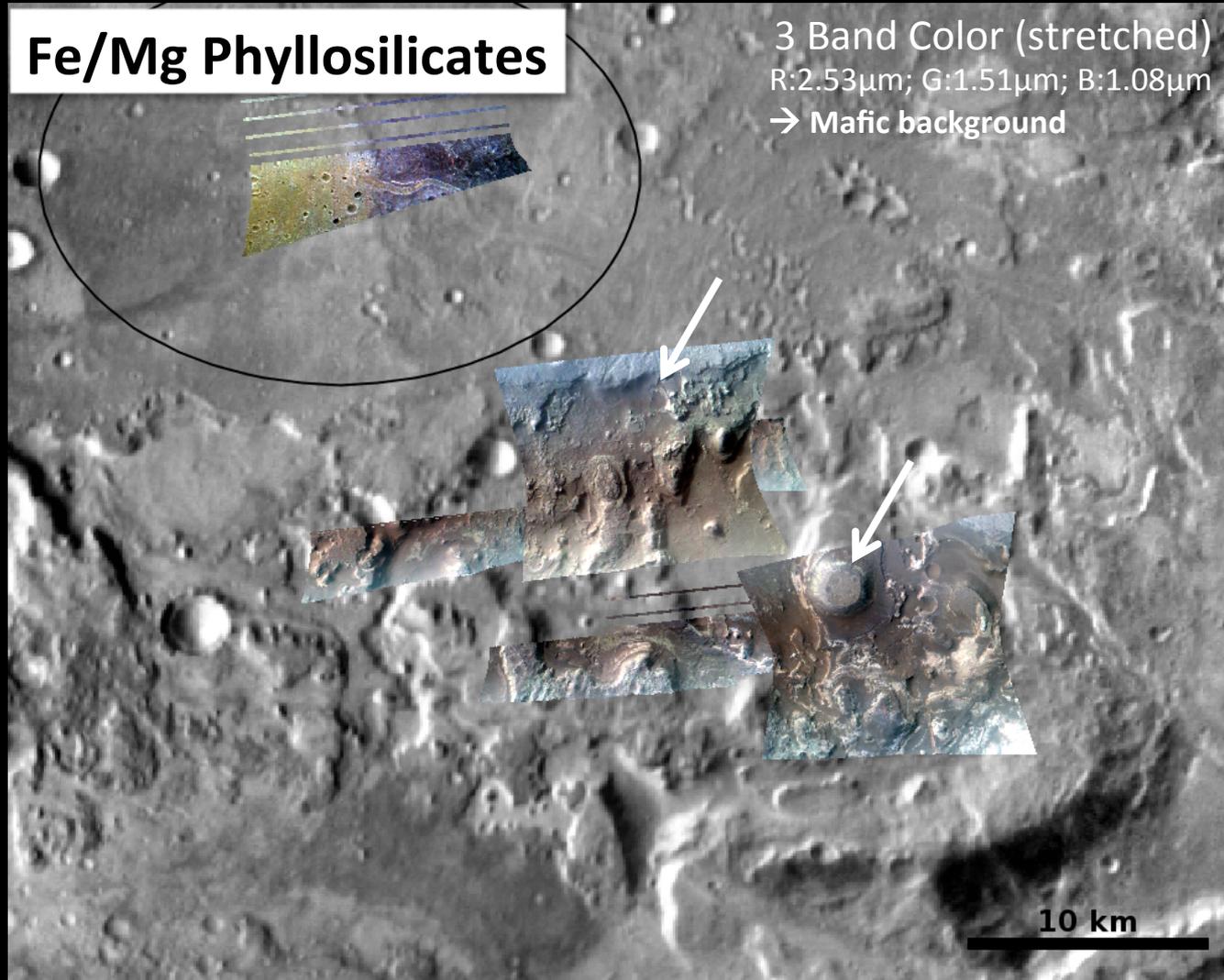
# Resource ROIs

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



## Fe/Mg Phyllosilicates

3 Band Color (stretched)  
R:2.53 $\mu$ m; G:1.51 $\mu$ m; B:1.08 $\mu$ m  
→ Mafic background

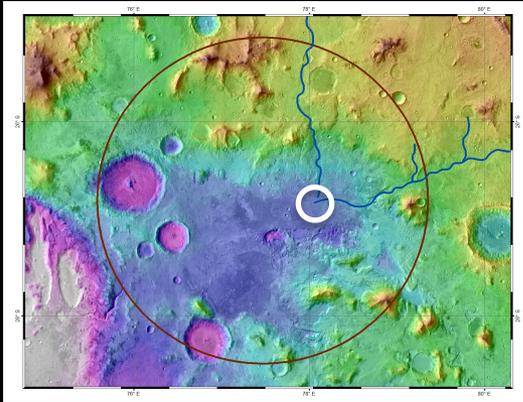


- Observed in particular sections of cavi strata
- Correlated to other sections
- Not imaged along the cavi margin
- Can (should) make use of mapping campaign images
- Mafic background pervasive

R1. Fe/Mg Phyllosilicates  
R2. Building materials

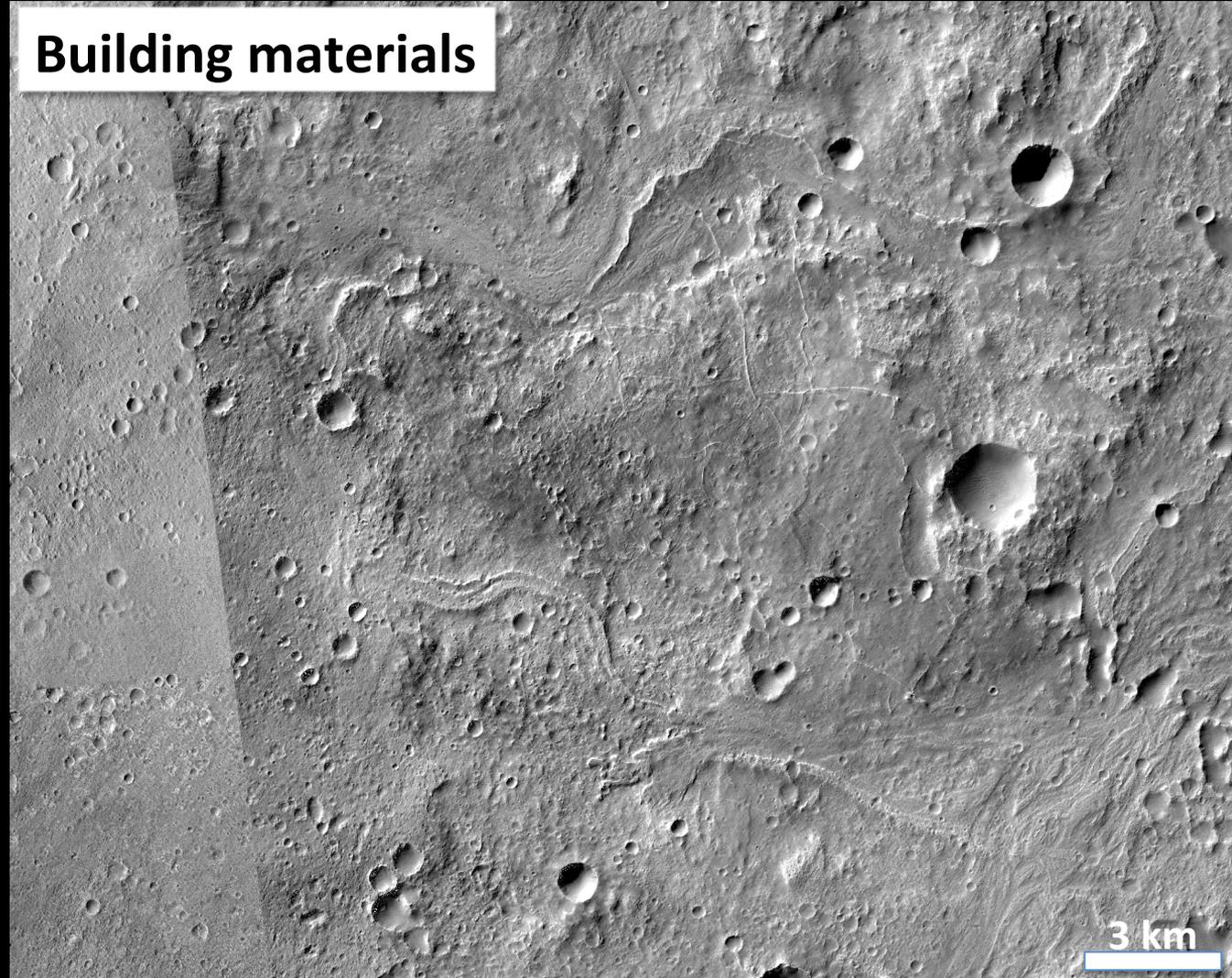
# Resource ROIs

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



## Building materials

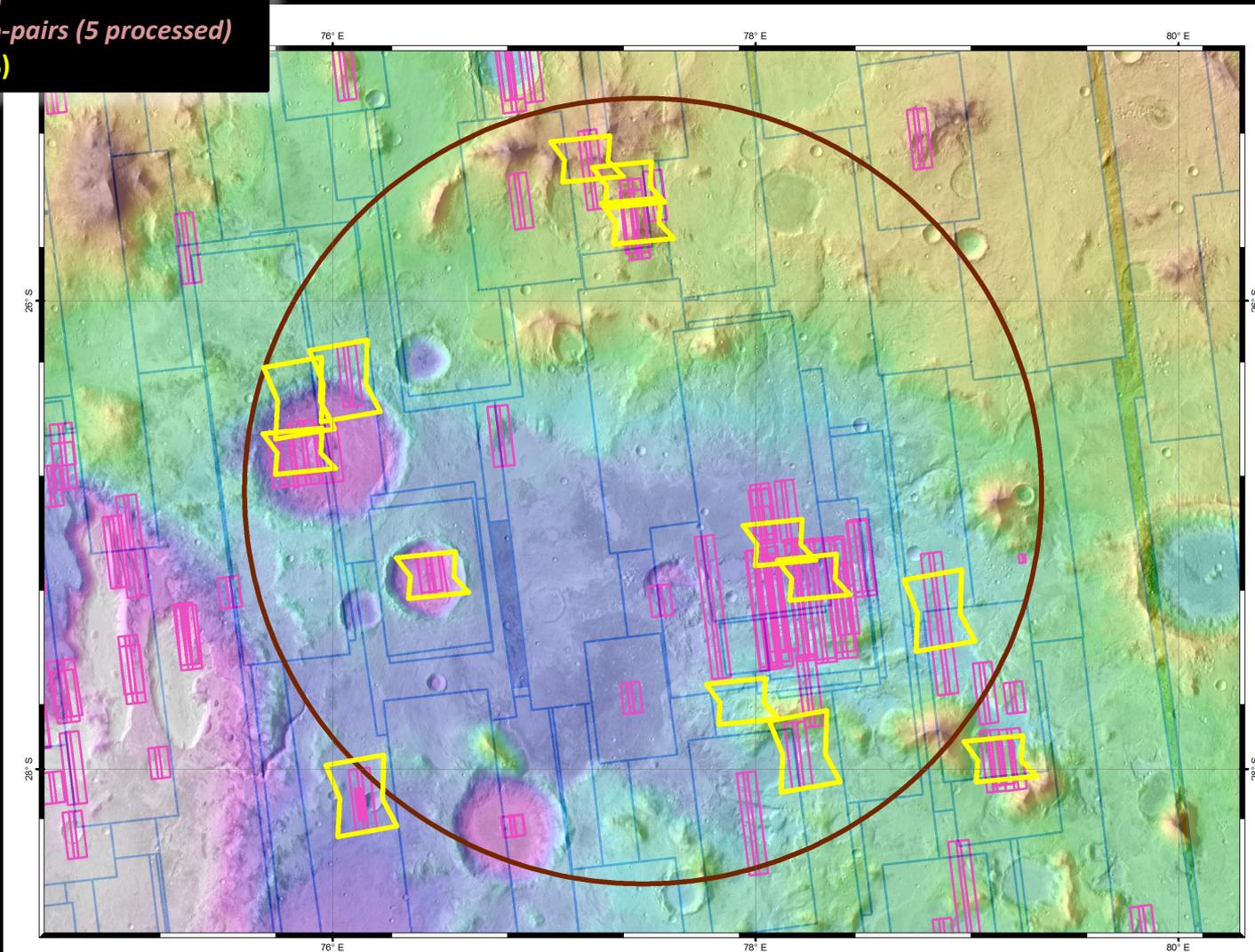
- Pervasively level terrain
- No shading topography
- Material interpreted to be laterally variable
  - Inferred loose*
  - Inferred variable size*
- Mafic background pervasive



# Data Coverage

- CTX complete (99%)
- HiRISE (~6%)  
*6 stereo-pairs (5 processed)*
- CRISM (~6%)

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



# Science ROI(s) Rubric

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



Site Factors				SROI1	SROI2	SROI3	SROI4	SROI5	RR011	RR012	RR013	EZ SUM		
Science Site Criteria	Astrobio	Threshold	AND/OR	Potential for past habitability	○			●	●				2,1	
				Potential for present habitability/refugia										0
		Qualifying		Potential for organic matter, w/ surface exposure									0	
	Atmospheric Science	Threshold		Noachian/Hesperian rocks w/ trapped atmospheric gases	○	●		●	○					2,2
				Meteorological diversity in space and time				●						1
		Qualifying		High likelihood of surface-atmosphere exchange										0
				Amazonian subsurface or high-latitude ice or sediment										0
				High likelihood of active trace gas sources										0
	Geoscience	Threshold		Range of martian geologic time; datable surfaces	○	●		●						2,1
				Evidence of aqueous processes	●		●	●	●					4
				Potential for interpreting relative ages	●	●	●	●	●					5
		Qualifying		Igneous Rocks tied to 1+ provinces or different times	○	○		●						1,2
				Near-surface ice, glacial or permafrost										0
			Noachian or pre-Noachian bedrock units	○	●	●	●	○					3,2	
			Outcrops with remnant magnetization		?		?							
			Primary, secondary, and basin-forming impact deposits	●	●	●	●	●					5	
			Structural features with regional or global context	●	●	●	●						4	
			Diversity of aeolian sediments and/or landforms	○		○		●					1,2	

- S1. Channel convergence
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- S5. Crater-related deposits

- R1. Fe/Mg Phyllosilicates
- R2. Building materials
- R3. Refuge

Key	
●	Yes
○	Partial Support or Debated
	No
?	Indeterminate

# Resource ROI(s) Rubric

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



Site Factors			SROI1	SROI2	SROI3	SROI4	SROI5	RROI1	RROI2	RROI3	EZ SUM	
ISRU and Civil Engineering Criteria	Engineering	Meets First Order Criteria (Latitude, Elevation, Thermal Inertia)	●	●	●	○	●	●	●	●	7,1	
	Water Resource	Threshold	AND/OR Potential for ice or ice/regolith mix									0
			Potential for hydrated minerals	○			○		○			0,3
			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										0
		Distance to resource location can be >5 km										0
		Route to resource location must be (plausibly) traversable	●			●			●			3
	Civil Engineering	Threshold	~50 sq km region of flat and stable terrain with sparse rock distribution	●		●				●	●	4
			1-10 km length scale: <10°	●		●				●	●	4
			Located within 5 km of landing site location									0
	Qualifying	Located in the northern hemisphere										0
		Evidence of abundant cobble sized or smaller rocks and bulk, loose regolith	○	○	○	○	○	○	○	○	○	8
	Food Production	Qualifying	Utilitarian terrain features	●		●			●	●	●	5
			Low latitude	●	●	●	●	●	●	●	●	8
			No local terrain feature(s) that could shadow light collection facilities	●		●				●	●	4
			Access to water									0
	Metal/Silicon Resource	Threshold	Access to dark, minimally altered basaltic sands	●	●	●	●	●	●	●	●	8
			Potential for metal/silicon	●	●	●	●	●	●	●	●	8
			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												

- S1. Channel convergence
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- 
- R1. Fe/Mg Phyllosilicates
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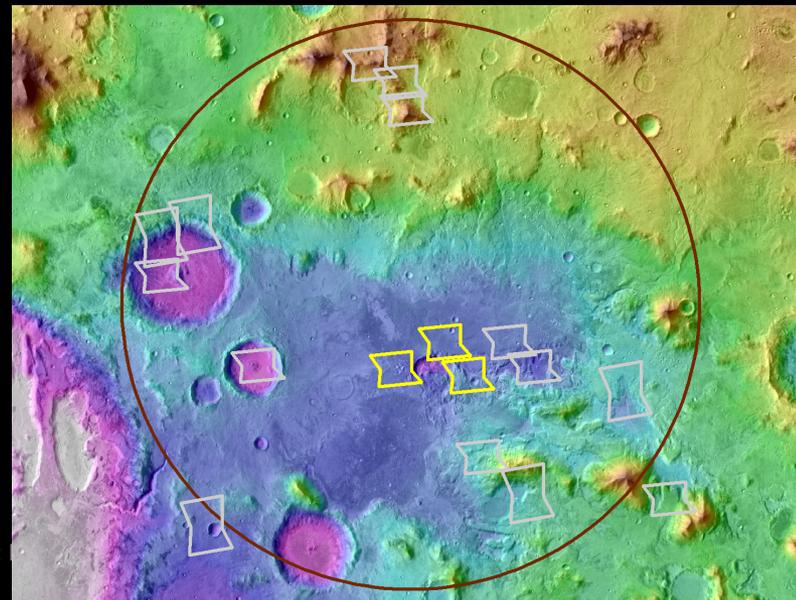
Key	
●	Yes
○	Partial Support or Debated
	No
?	Indeterminate

# Highest Priority EZ Data Needs

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- For reinforcing science potential
  - None needed (?!)
- For establishing resource potential:
  - CRISM on palus floor, margin, and crater ejecta
    - 77.58E, -26.93N
    - 77.72E, -27.13N
    - 77.27E, -27.08N



Inter crater Basin:

# Parting Words

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- Tectonic (non-crater) basins optimal exploration sites
  - Unparalleled access to geologic units and structures, demonstrably assist understanding Mars' crustal evolution
  - Traceable regionally to globally ... **context is critical**
- However, Hadriacus Palus might be “resource limited” ...
  - Limited observation? (Observations don't exist)
  - Limited contextual understanding?
  - Limited ability of instruments? (Observations not able)
- Good type example to ascertain what data could bring resources into focus