A photograph of an astronaut in a white spacesuit standing in a dark, rocky cave. The astronaut is positioned in the center of the frame, looking towards the camera. The cave walls are made of reddish-brown rock, and the floor is dark and uneven.

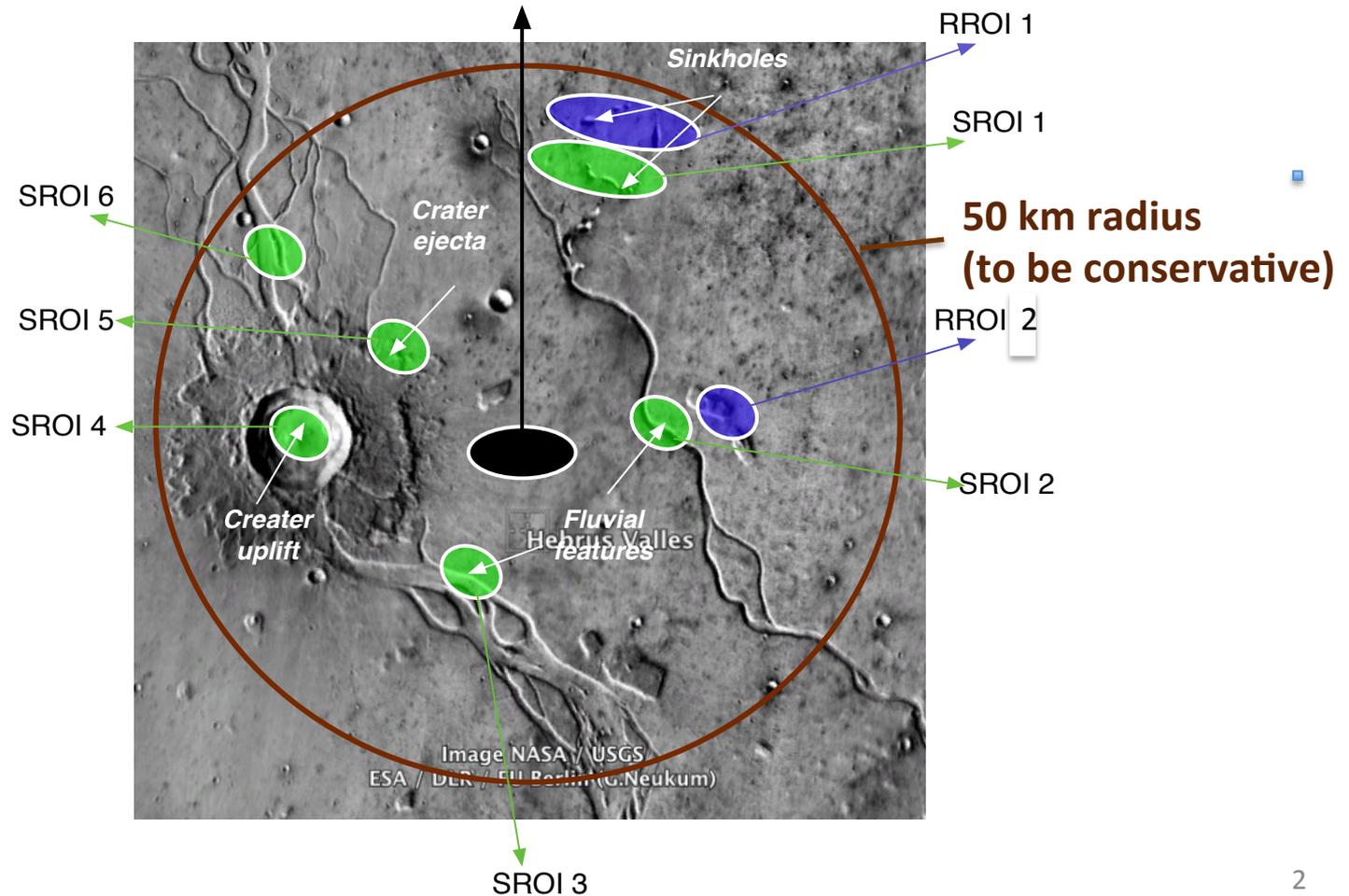
THE HEBRUS VALLES EXPLORATION ZONE: ACCESS TO THE MARTIAN SURFACE AND SUBSURFACE

**A. Davila, A.G. Fairén, A.P. Rodríguez,
D. Schulze-Makuch, J. Rask, J. Zavaleta**

Exploration Zone Map

1st EZ Workshop for Human Missions to Mars

Mars landing site and surface field station
20°05' N, 126°38' E / Elevation = -3600 m



Science ROI(s) Rubric

1st EZ Workshop for Human Missions to Mars



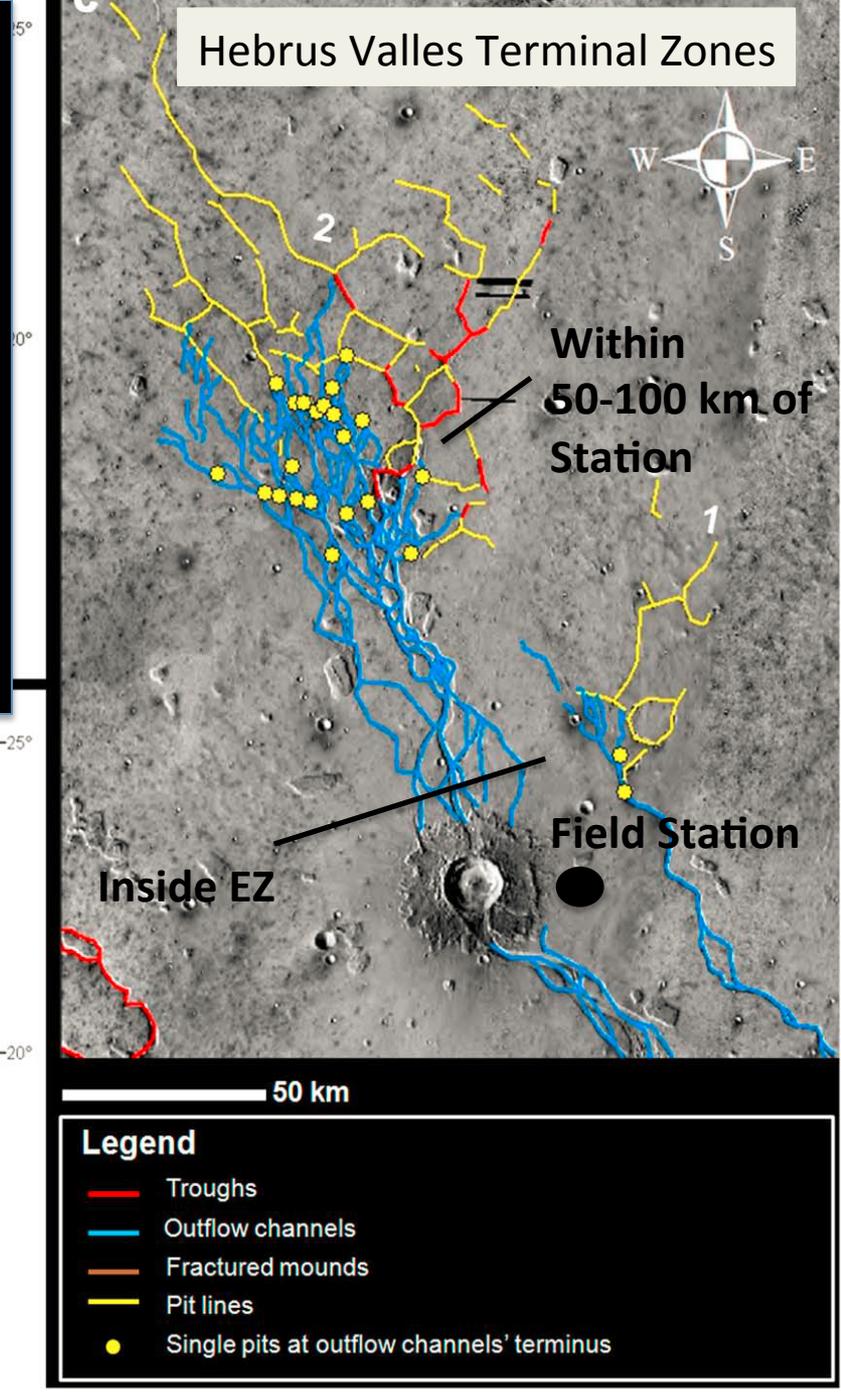
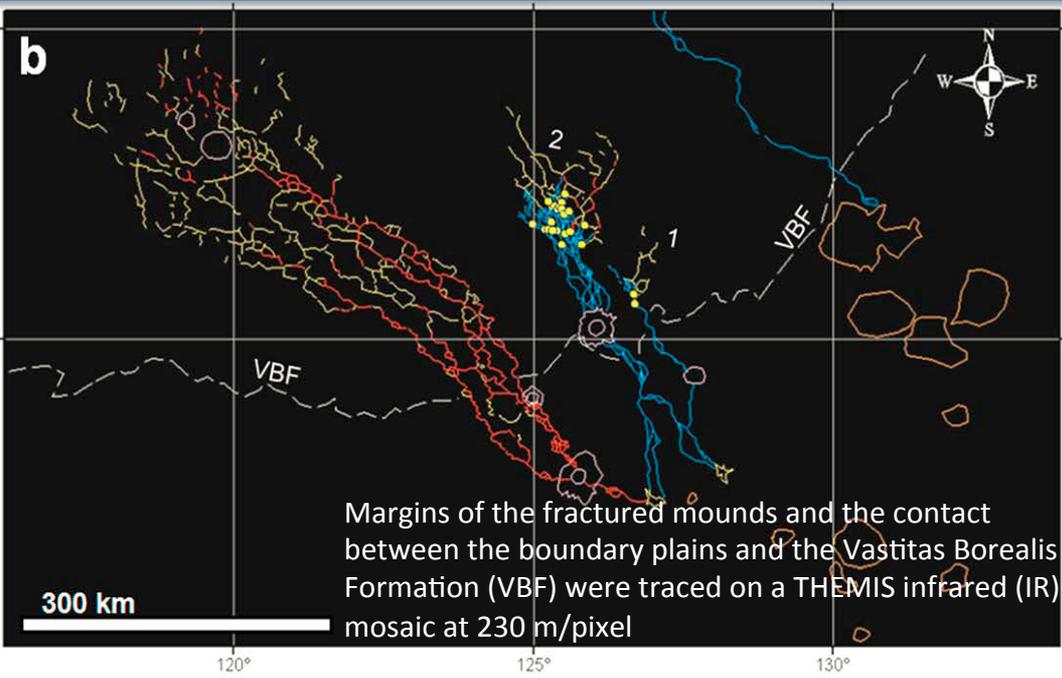
Science Site Criteria			Site Factors		SROI1	SROI2	SROI3	SROI4	SROI5	SROI6	RROI1	RROI2	EZ SUM	
			AND/OR											
Astrobio	Threshold	Potential for past habitability	●	●	●	●	●	●	●	●			5	
		Potential for present habitability/refugia	●								●			1
	Qualifying	Potential for organic matter, w/ surface exposure	●	●	●					●			4	
Atmospheric Science	Threshold	Noachian/Hesperian rocks w/ trapped atmospheric gases	●	●	●	●	●	●	●	●			6	
		Meteorological diversity in space and time	○	○	○	○	○	○	○	○			6	
	Qualifying	High likelihood of surface-atmosphere exchange	?	?	?	?	?	?	?	?				
		Amazonian subsurface or high-latitude ice or sediment	○											1
		High likelihood of active trace gas sources	?	?	?	?	?	?	?	?				
Geoscience	Threshold	Range of martian geologic time; datable surfaces	●	●	●	●	●	●	●	●			6	
		Evidence of aqueous processes	●	●	●	●	●	●	●	●			6	
		Potential for interpreting relative ages	●	●	●	●	●	●	●	●			6	
	Qualifying	Igneous Rocks tied to 1+ provinces or different times												
		Near-surface ice, glacial or permafrost		○		○				○	○			4
		Noachian or pre-Noachian bedrock units												
		Outcrops with remnant magnetization												
		Primary, secondary, and basin-forming impact deposits				●	●							2
		Structural features with regional or global context												
Diversity of aeolian sediments and/or landforms	?	?	?	?	?	?								

Key	
●	Yes
○	Partial Support or Debated
	No
?	Indeterminate

Each of the two distributaries terminates within isolated pit and trough networks, suggesting drainage of floodwaters into the subsurface

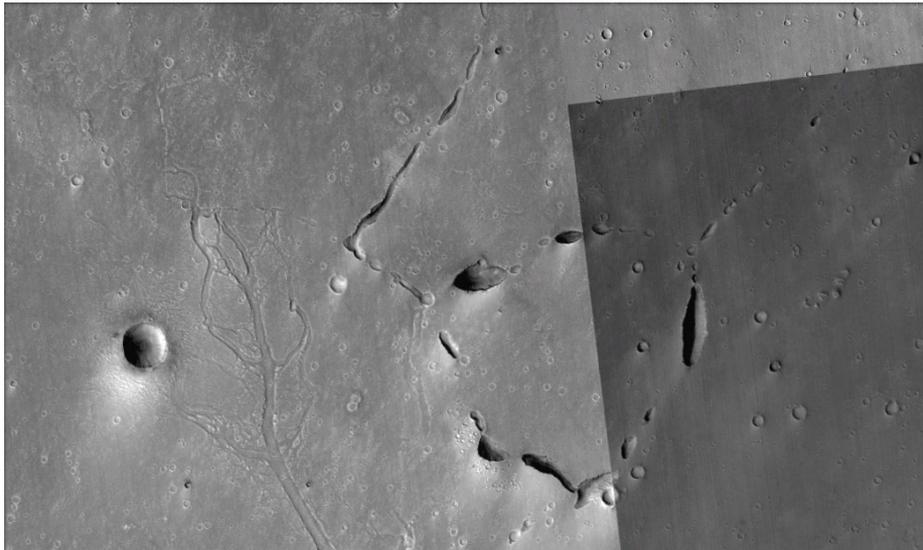
The absence of evidence for ponding upstream of pits and troughs and the presence of channel pendant bars that extend into troughs are indicative of rapid and unobstructed flow into the subsurface similar to sinkholes on Earth

(Rodriguez et al., 2012)



Science ROI 1

1st EZ Workshop for Human Missions to Mars



- N20° 46' 17"/ E126° 47' 46"
- Elevation = -3680m
- Multiple-point access to the subsurface with a high preservation potential for evidence of past habitability and biosignatures.

Science ROI 1 (continued)

1st EZ Workshop for Human Missions to Mars



- Rodriguez et al. (2012) suggested high hydraulic pressure associated with mud volcanism forming pseudo-karstic erosion along feeder conduits
- Carr and Malin (2000), on the other hand, suggested a subsurface karst landscape by dissolution of buried carbonates
- **Either way:** The inferred magnitude of floodwater infiltration points to the existence of structurally stable caverns with permafrost having a mechanical strength of limestone at the average temperatures at Hebrus Valles
- Since Martian gravity is 0.38 g, it allow for caves that are 2.5 x larger than Earth-equivalents (and up to 6 km deep)

Where should we look for Life ?

Cave Environments

Secondary mineral formations (speleothems)

Permanent or transient ices



(by P. Boston, 2003)

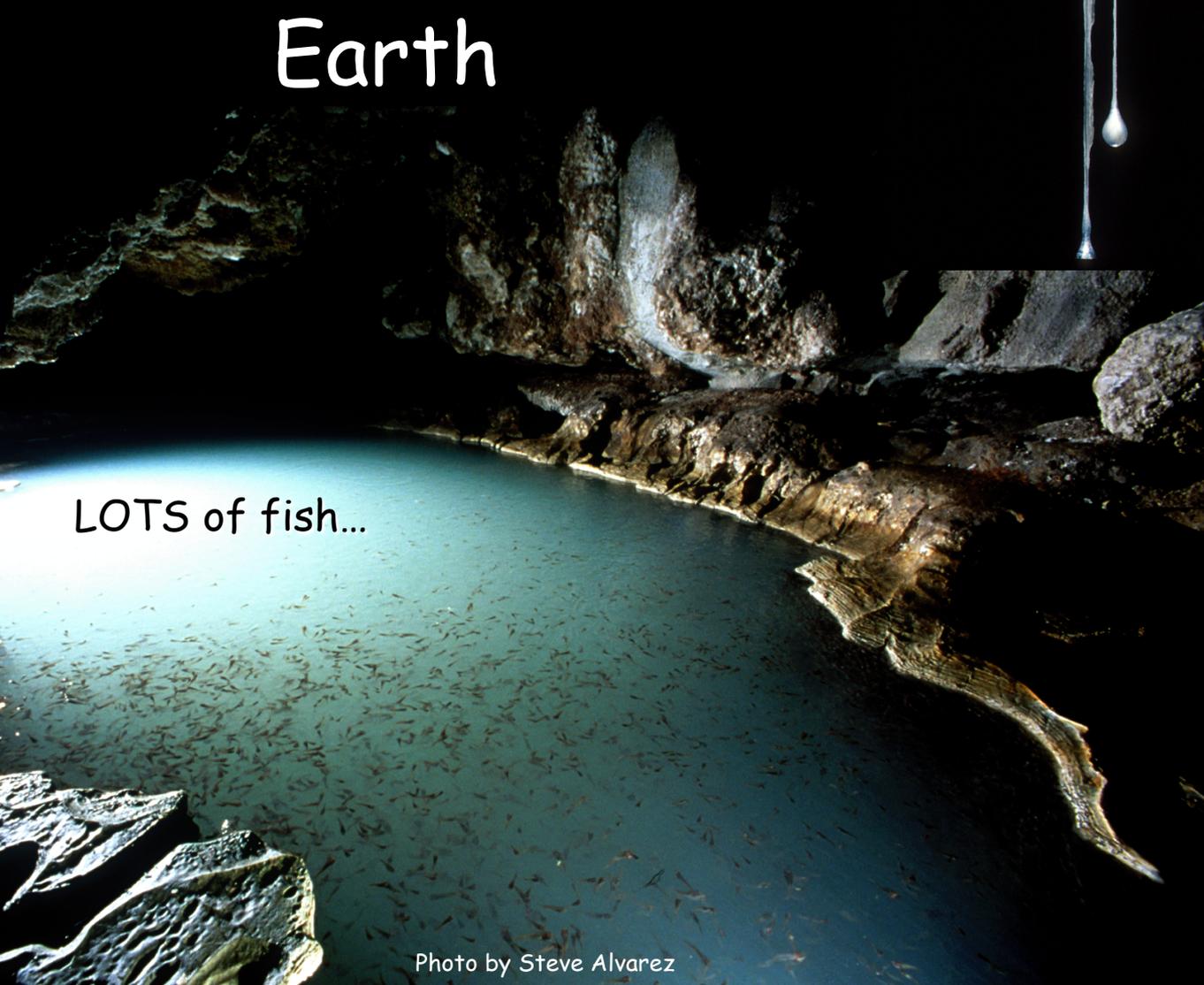




Mars?

Photo by K. Ingham

In situ microbially mediated mineral formation ?



LOTS of fish...

Photo by Steve Alvarez

Investigation of a potential long-term stable habitat

Preservation of potential biosignatures in caves

Science ROI 2

1st EZ Workshop for Human Missions to Mars



- N19° 46' 37" / E126°31'49"
- Elevation = -3641
- Fluvial features indicative of aqueous processes and potential habitability



Science ROI 3

1st EZ Workshop for Human Missions to Mars

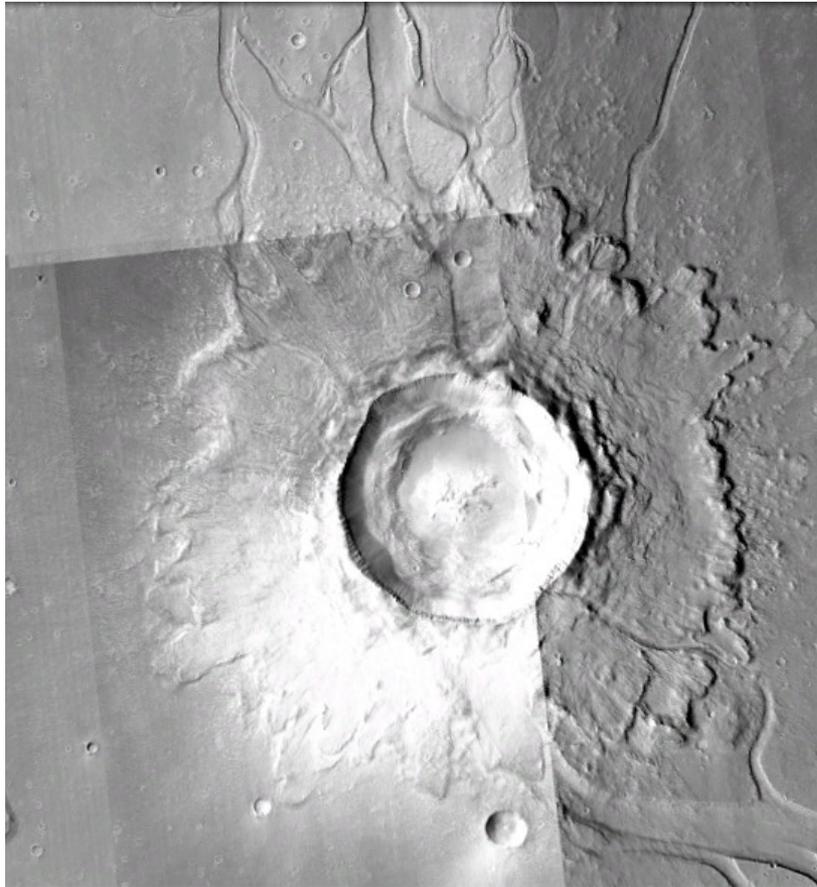


- N19° 44' 69" / E126° 31' 39"
- Elevation = -3695
- Fluvial features indicative of aqueous processes and potential habitability



Science ROI 4&5

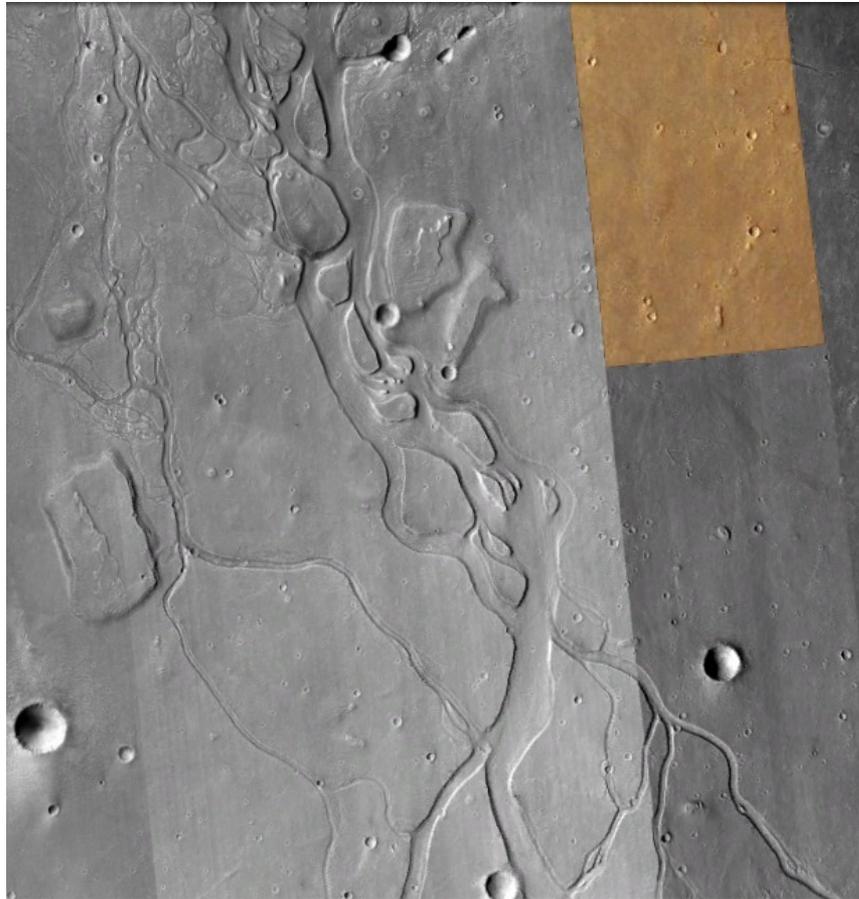
1st EZ Workshop for Human Missions to Mars



- N20° 06' 30" / E126° 03' 59"
- Elevation = -3913
- Access to Hesperian subsurface materials:
 - Trapped gases
 - Dating geologic units
 - Interpreting relative ages
 - Primary and secondary impacts

Science ROI 6

1st EZ Workshop for Human Missions to Mars



- $N21^{\circ} 01' 29''$ / $E125^{\circ} 54' 52''$
- Elevation = -3774
- Fluvial features indicative of aqueous processes and potential habitability

Resource ROI(s) Rubric



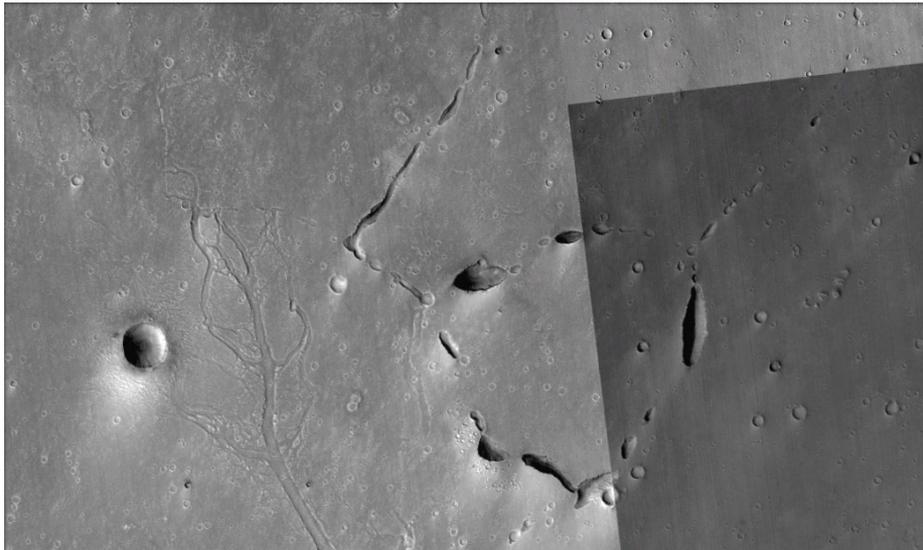
EZ Workshop for Human Missions to Mars

Site Factors			SROI1	SROI2	SROI3	SROI4	SROI5	SROI6	RR011	RR012	EZ SUM	
ISRU and Civil Engineering Criteria	Engineering	Meets First Order Criteria (Latitude, Elevation, Thermal Inertia)	●	●	●	●	●	●	●	●		
	Water Resource	AND/OR	Potential for ice or ice/regolith mix	●	●	●			●	●		
			Potential for hydrated minerals		●	●	●		●			
		Threshold	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		●	●			●	●			
		Route to resource location must be (plausibly) traversable		●	●			●	●			
	Civil Engineering	Threshold	~50 sq km region of flat and stable terrain with sparse rock distribution	Multiple sites								
			1-10 km length scale: <10°	Multiple sites								
			Located within 5 km of landing site location	Multiple sites								
		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

Resource ROI 1

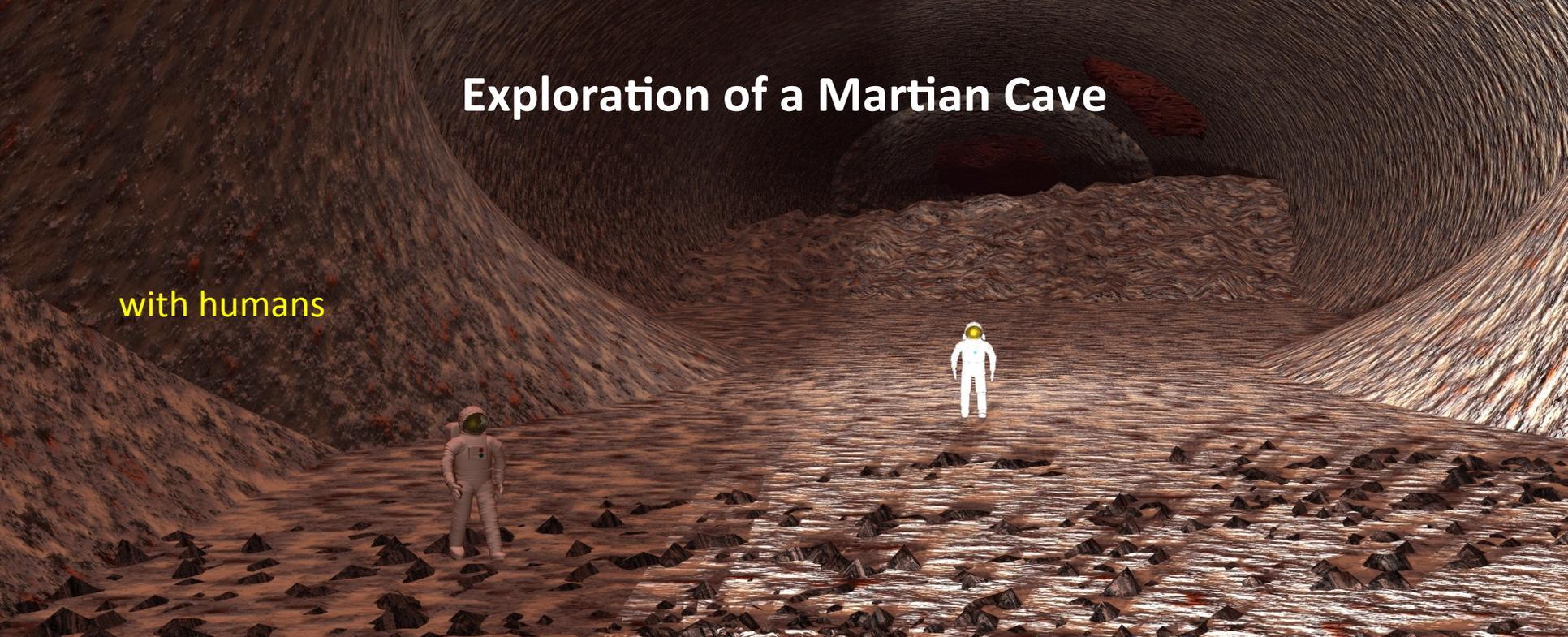
1st EZ Workshop for Human Missions to Mars



- $N20^{\circ} 46' 17'' / E126^{\circ} 47' 46''$
- Elevation = -3680m
- Multiple-point access to the subsurface:
 - High potential for water
 - Shelter

Exploration of a Martian Cave

with humans



or robotic



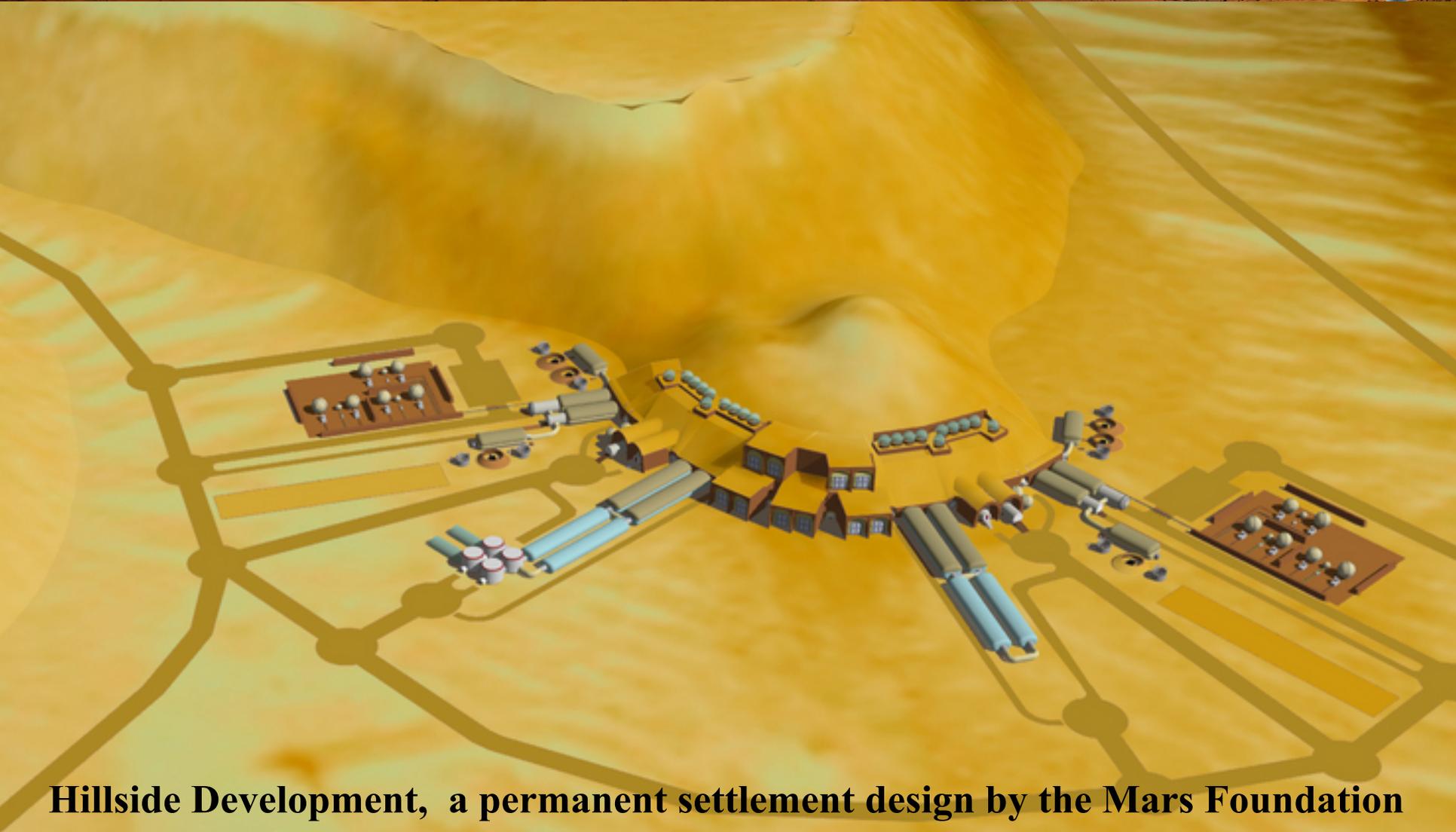
Possible Discovery of a Lake within a Martian Cave

Cave Advantages as a Resource:

- Protection from Radiation Environment
- Constant temperatures maintained by internal heat
- Higher amounts of water vapor may allow liquid water to persist



A Vision of a Human Settlement on Mars



Hillside Development, a permanent settlement design by the Mars Foundation

Resource ROI 2

1st EZ Workshop for Human Missions to Mars



- N20° 12' 07" / E127° 03' 04"
- Elevation = -3680m
- Flat and stable terrain near the LS. Slopes <math><5^\circ</math> over most of the EZ.
- Access to silicate materials over the entire EZ, including sediments
- Low latitude, plenty of sunlight
- Access to surface shelter



EZ Data Needs

1st EZ Workshop for Human Missions to Mars

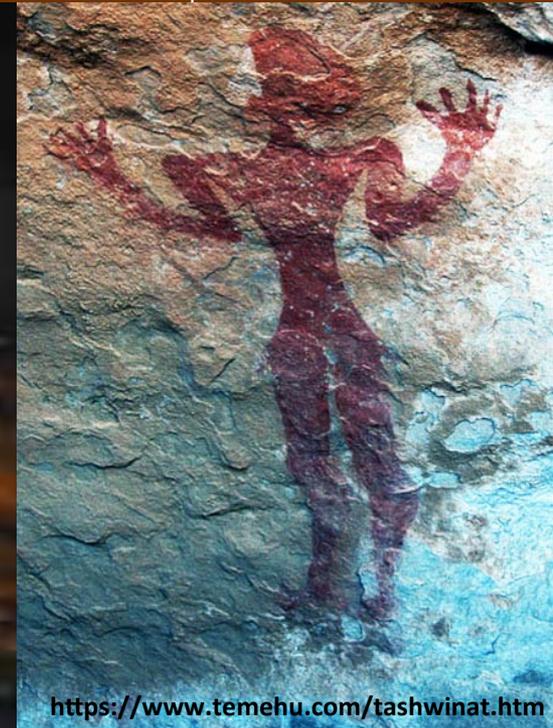


- The single most important additional data set needed to assess the science potential of the EZ would be high-resolution mapping of the terrain and its composition (MRO-HiRISE and CRISM, MEx-OMEGA, or similar). This is the highest priority because it would be necessary a previous good understanding of landforms and surface composition to ensure high-quality science return.
- The single most important additional data set needed to assess the resource potential of the EZ would be probing the subsurface using radar measurements with high depth resolution (MRO-SHARAD or similar). This is the highest priority because a previous good knowledge of the actual extension and geometry of the subsurface caverns available for habitation would be required.

First Permanent Human Habitation on Earth: Caves



1st EZ Workshop for Human Missions to Mars



<https://www.temehu.com/tashwinat.htm>

**A Human Field
Station should
utilize this great
resource on Mars**

BACKUP SLIDES

Prioritization List of EZ Data Needs

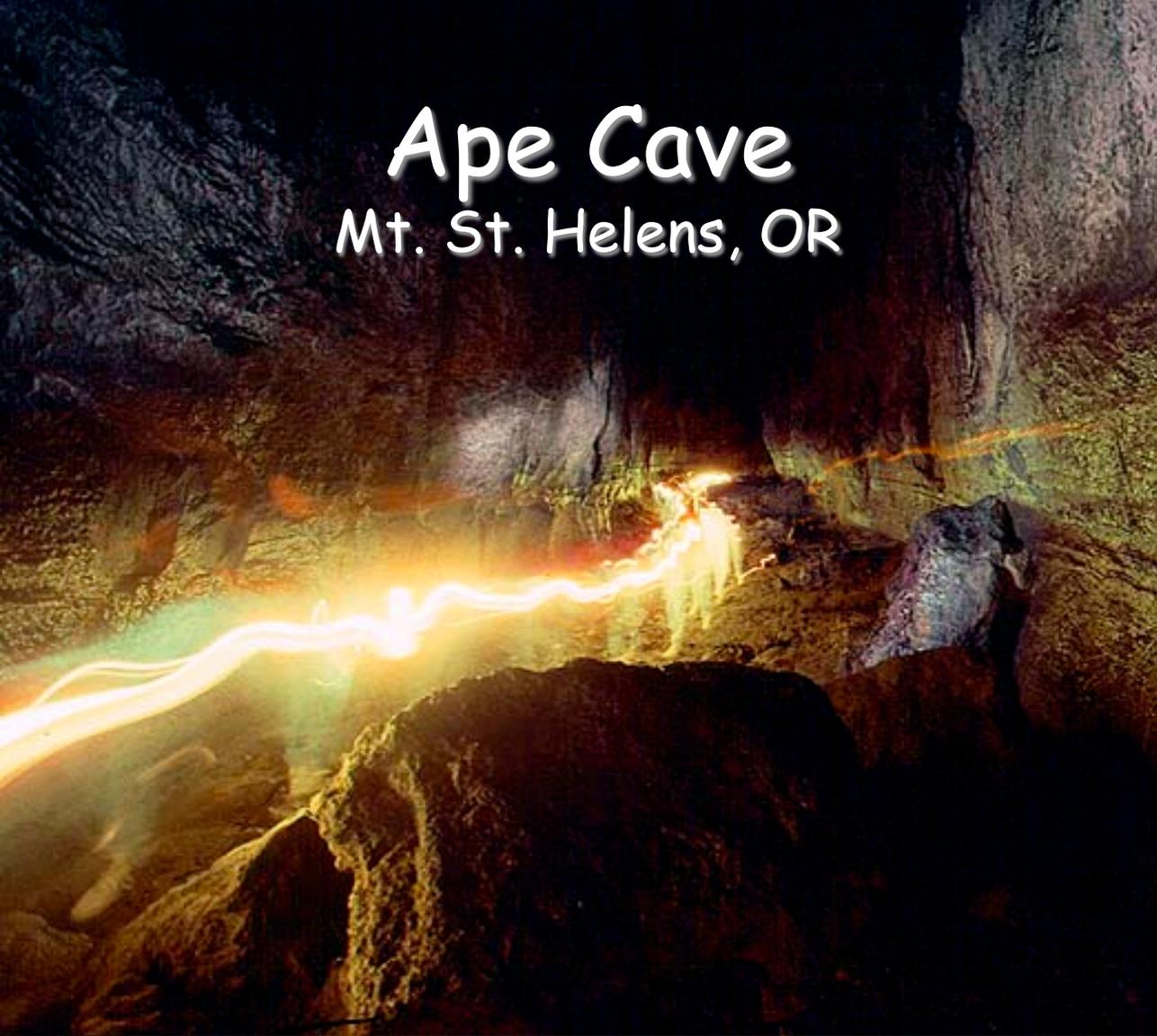
1st EZ Workshop for Human Missions to Mars



- Prioritized list of orbiter/rover data to be collected to assess the science potential of the EZ:
 1. High-resolution imagery (HiRISE-like) to characterize terrains for rover traverses and EVAs.
 2. Compositional data (CRISM and OMEGA-like) to prepare for in situ analyses.
 3. Mineralogical data (THEMIS-like) to understand mineral distribution before human exploration.
- Prioritized list of orbiter/rover data to be collected to assess the resource potential of the EZ:
 1. Subsurface radar data (SHARAD-like) to understand the extent and geometry of the subsurface conduits.
 2. Compositional data (CRISM and OMEGA-like) to characterize the availability of resources (ice/water, clays, perchlorates).
 3. THEMIS-like to search for and identify thermal hotspots in the subsurface.

Ape Cave

Mt. St. Helens, OR



Scablands, WA

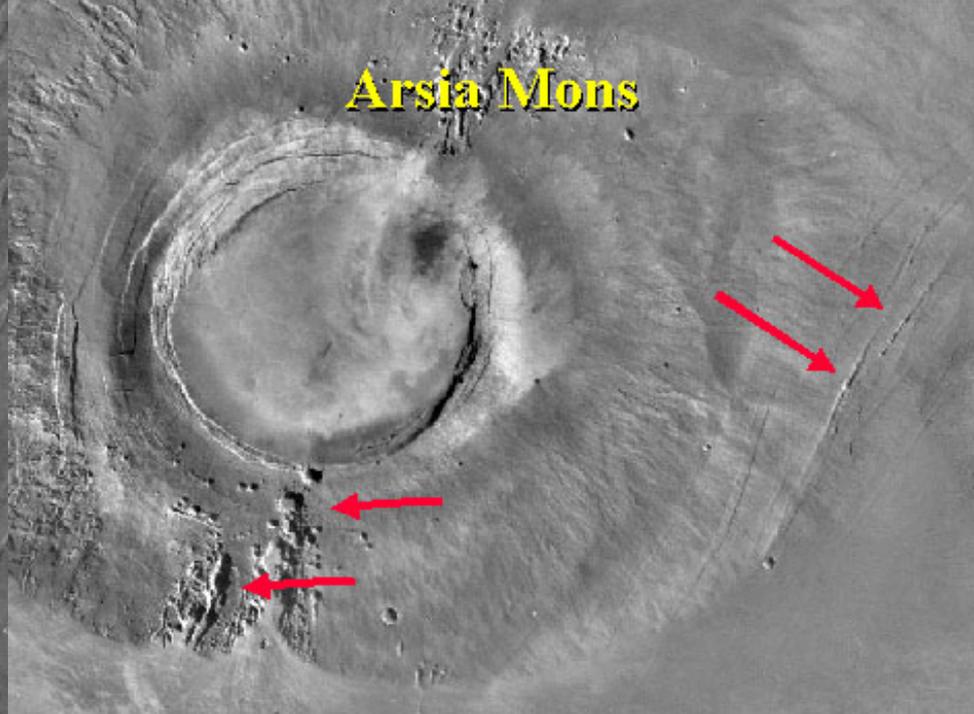


Alba Patera

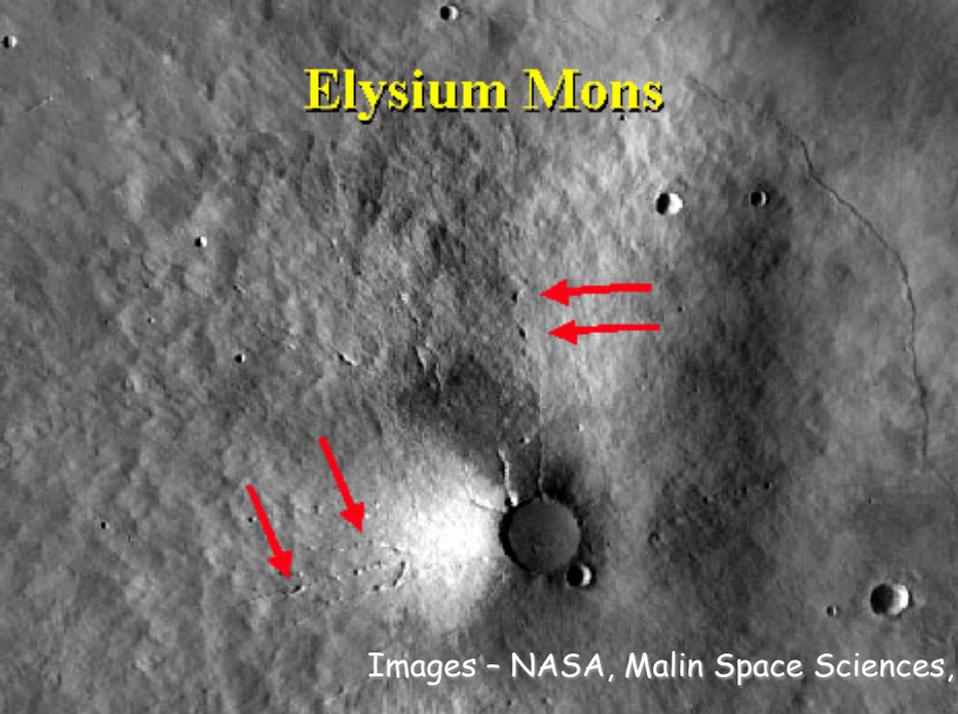
Lavatubes on Mars



Arsia Mons



Elysium Mons



Olympus Mons

