Ausonia Cavus & Kasei Valles: Complementary Exploration Zones

Workshop Abstract **#1045**

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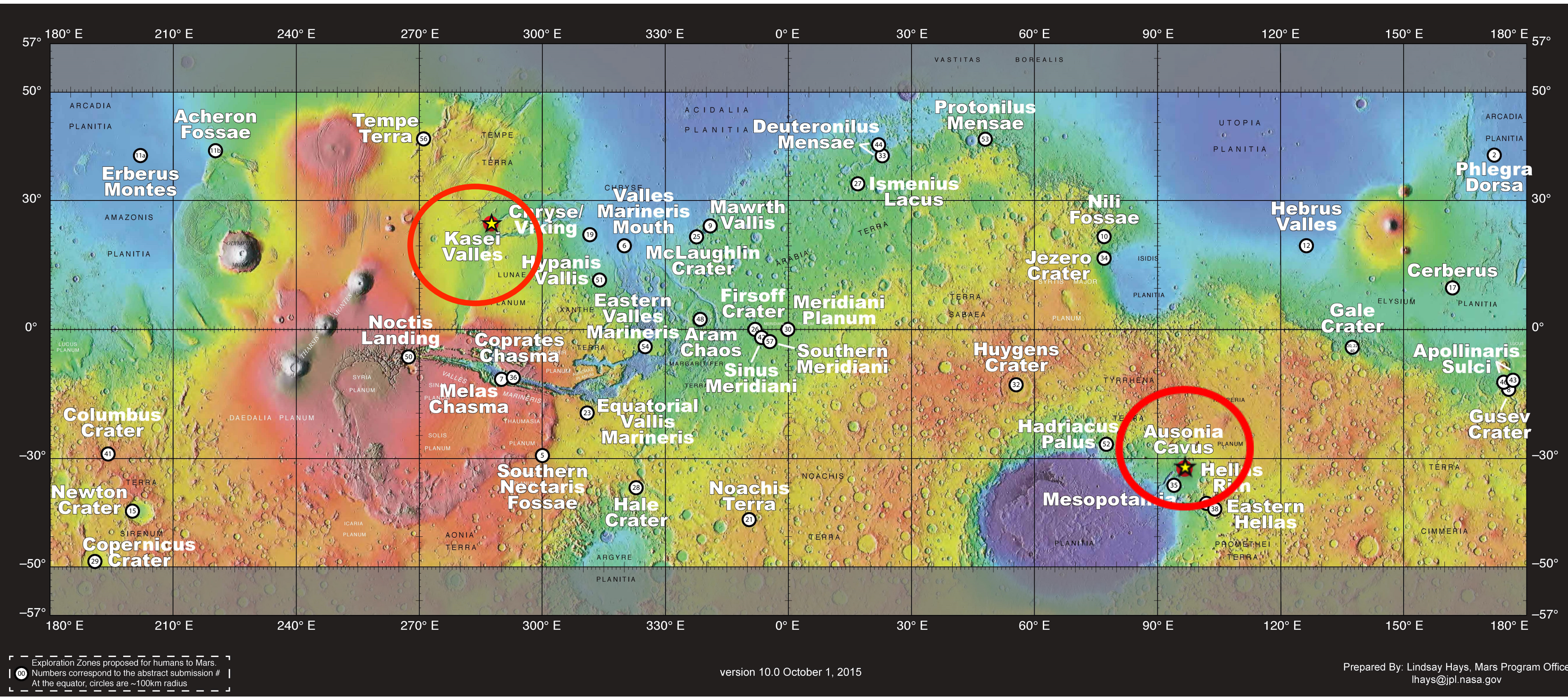
University of Hawai'i Hilo

PISCES Pacific International Space Center for Exploration Systems

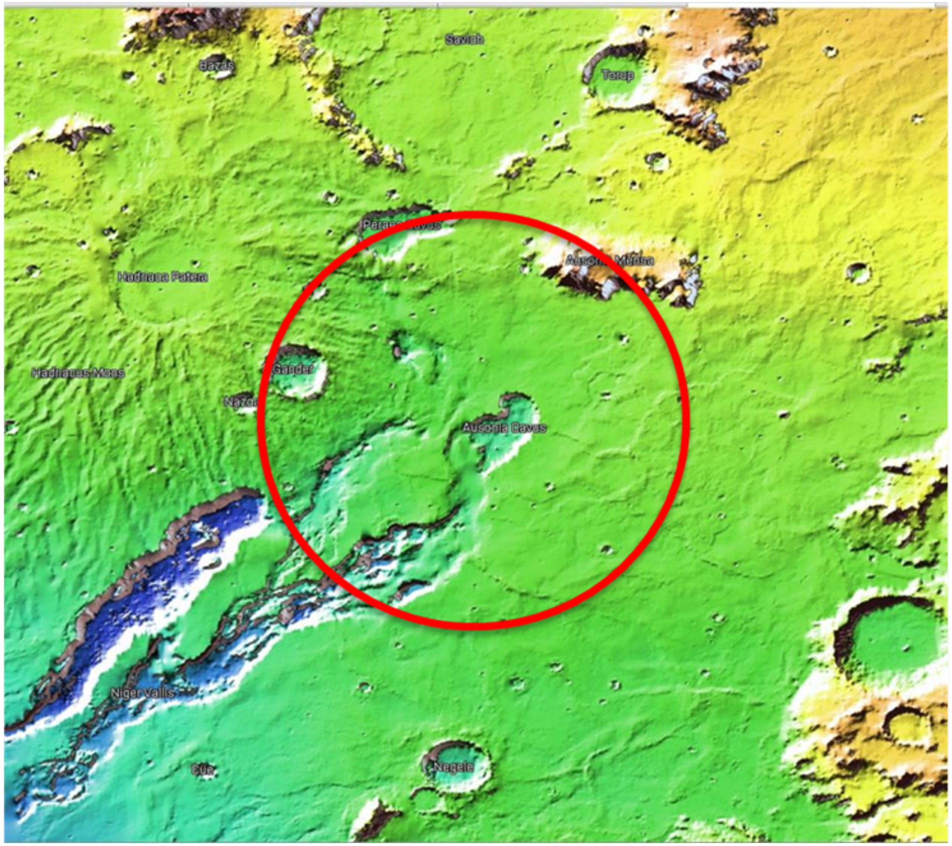
Exploration Zones

1st EZ Workshop for Human Missions to Mars

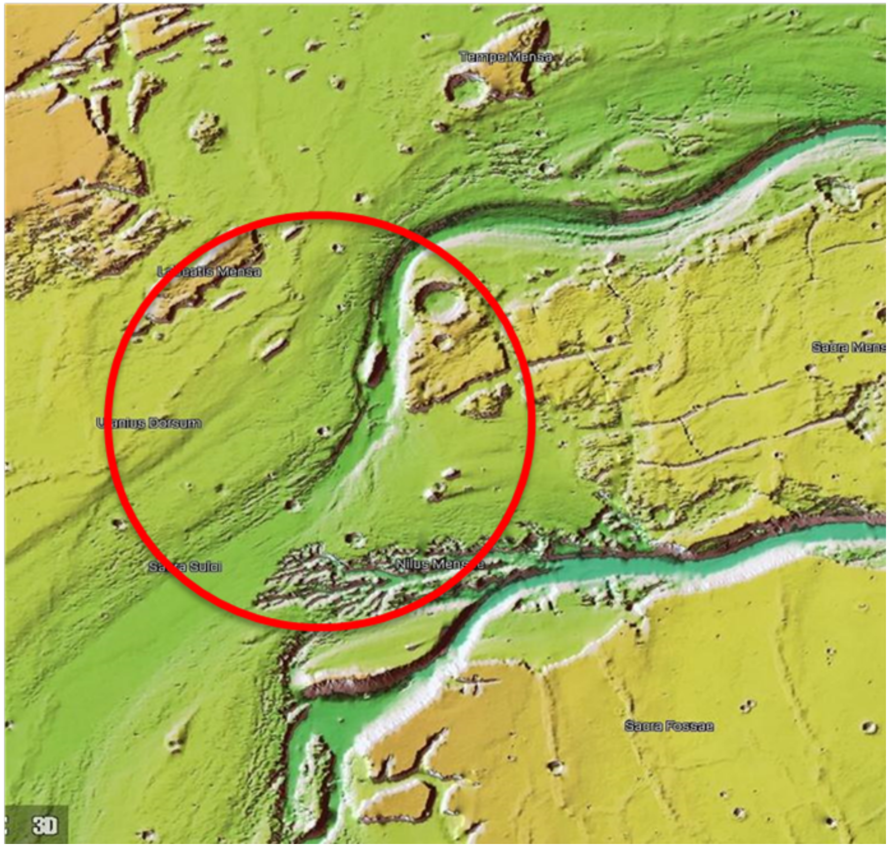


Exploration Zones

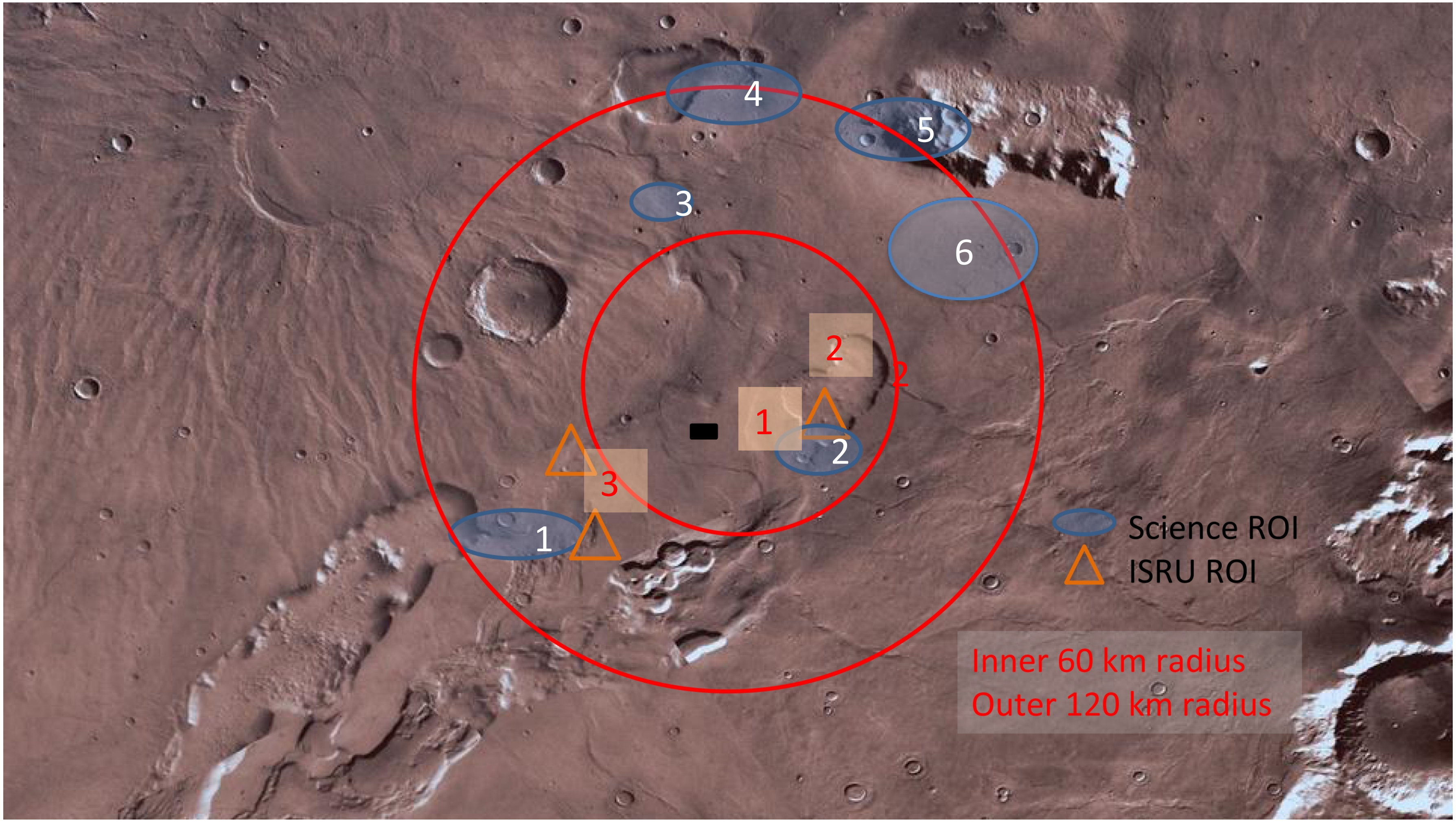
Ausonia Caves



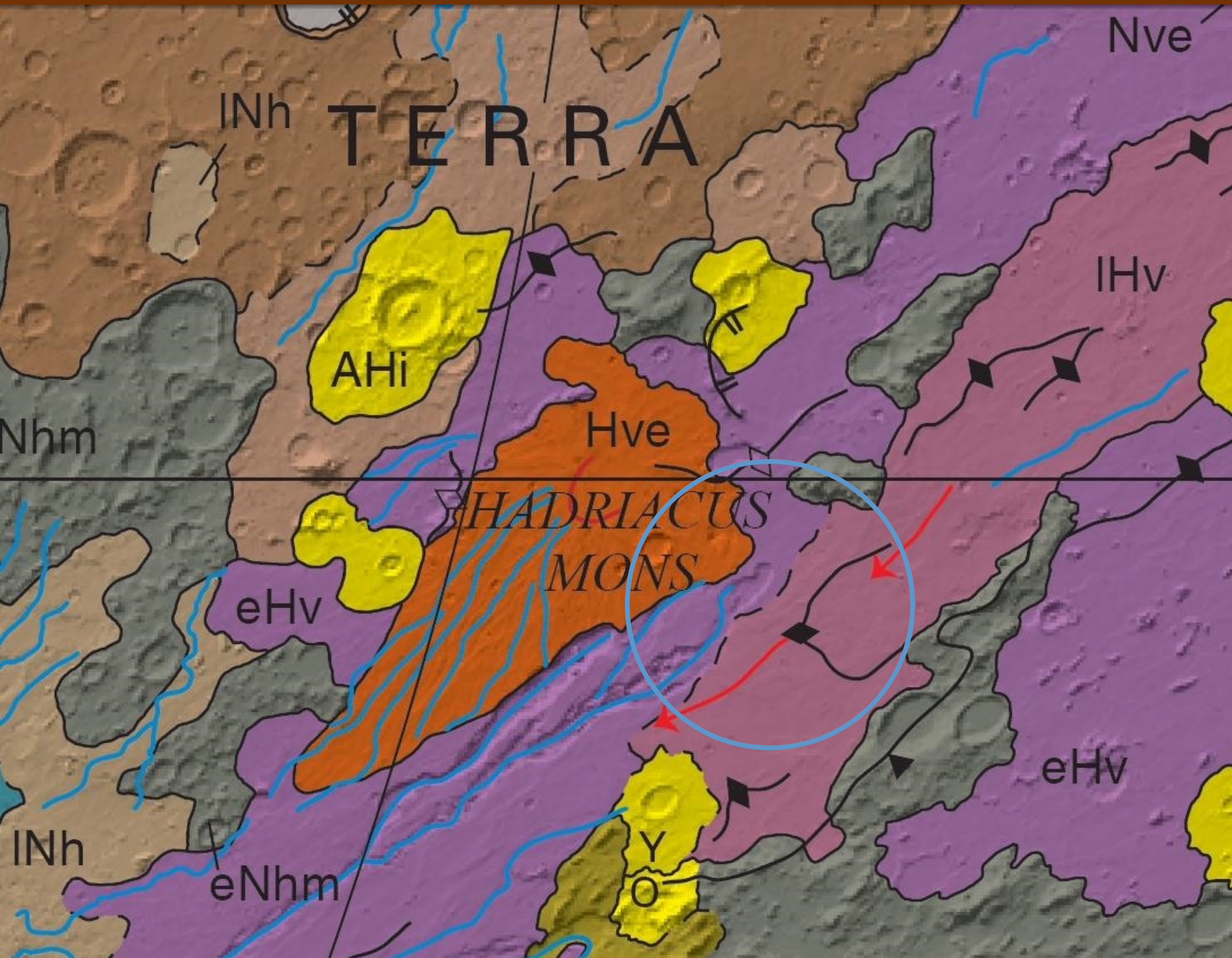
Kasei Valles



Exploration Zone Map: Ausonia Cavus



Ausonia Cavus



lHvf **Late Hesperian volcanic field unit**—Patches hundreds of kilometers across of lobate flows typically
Volcanocs and lava flows

eHv **Early Hesperian volcanic unit**—Planar deposits meters to tens of meters thick and tens to hundreds of kilometers across; lobate scarps common.
Flood lavas, undifferentiated, sourced from regional fissure and vent systems. Tectonically contracted

Hve **Hesperian volcanic edifice unit**—Shield-like edifices several tens to hundreds of kilometers across; made up of lobate flows meters

Volcanic edifices composed of different combinations of lava flows and pyroclastic and volcaniclastic deposits. Modified by summit collapse from magma withdrawal and fluvial dissection in places

Nve **Noachian volcanic edifice unit**—Shield-like edifices

Volcanic edifices composed of different combinations of lava flows, pyroclastic deposits, and volcaniclastic deposits sourced from degraded shields. Domed and fractured by local intrusions. Tectonically contracted

eNhm **Early Noachian highland massif unit**—Forms high-relief massifs tens of kilometers across separated by broad linear troughs and valleys. Kilometers thick.

Primitive, degraded crustal rocks uplifted by large, basin-forming impact. Dissected by basin-related fault structures and erosional valleys

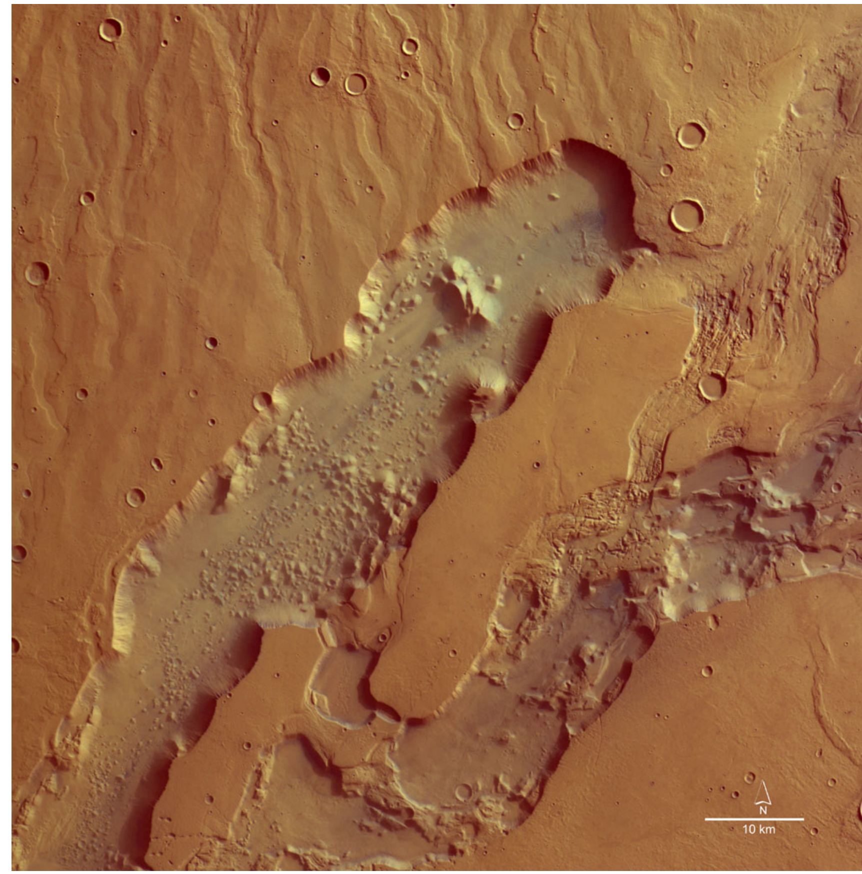
Wrinkle ridge—Ridge, sinuous, crenulated; tectonic contraction

Valles Formation

Two hypotheses for formation of fluvial system:

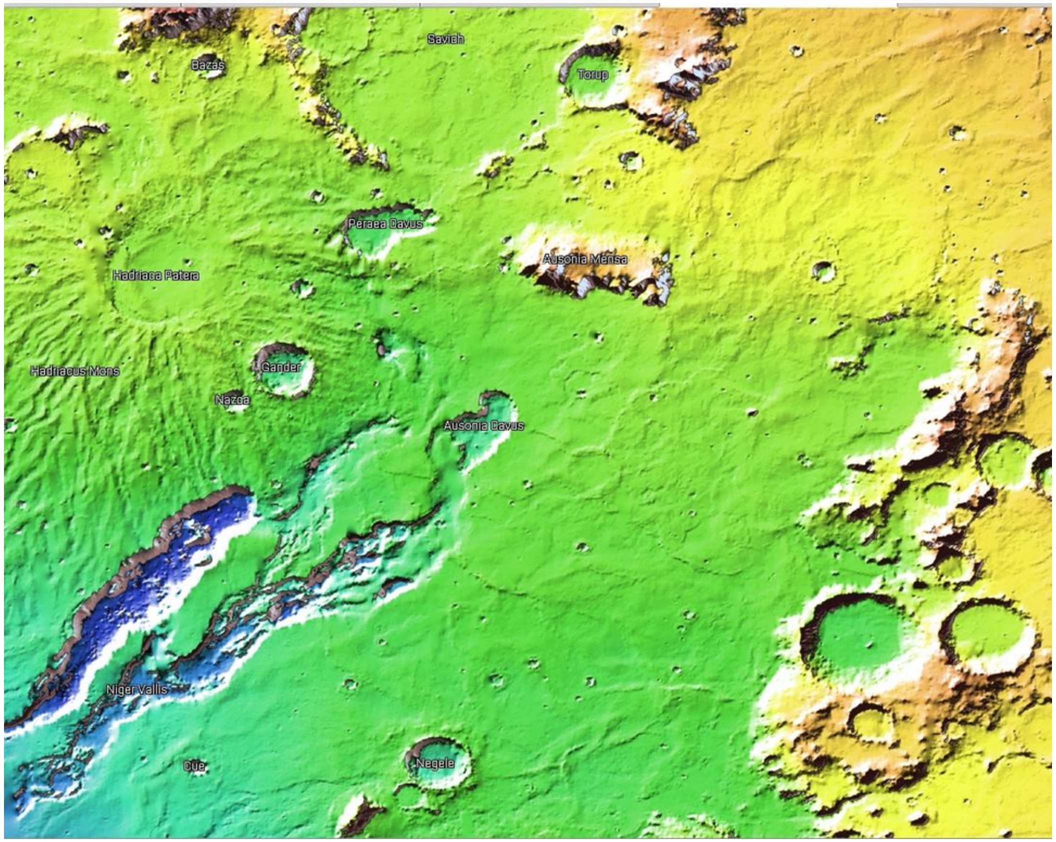
•Kostama et al. (2010): Accumulations of ice were buried by successive volcanic deposits from Hadriacus Mons and were later heated from below by magmatic intrusions that caused melting of the ice deposits, release of water, and formation of the fluvial structures.

•Musial et al. (2011): Emplacement of a volcanic load on a confined, overpressurized aquifer in the early Hesperian, fracturing around the load, possibly reactivated during various stages of volcanic activity, channeling of groundwater to the surface along fractures and outflow channel formation during several events in the Hesperian, and collapse, mass wasting and modification of depressions in the Amazonian.

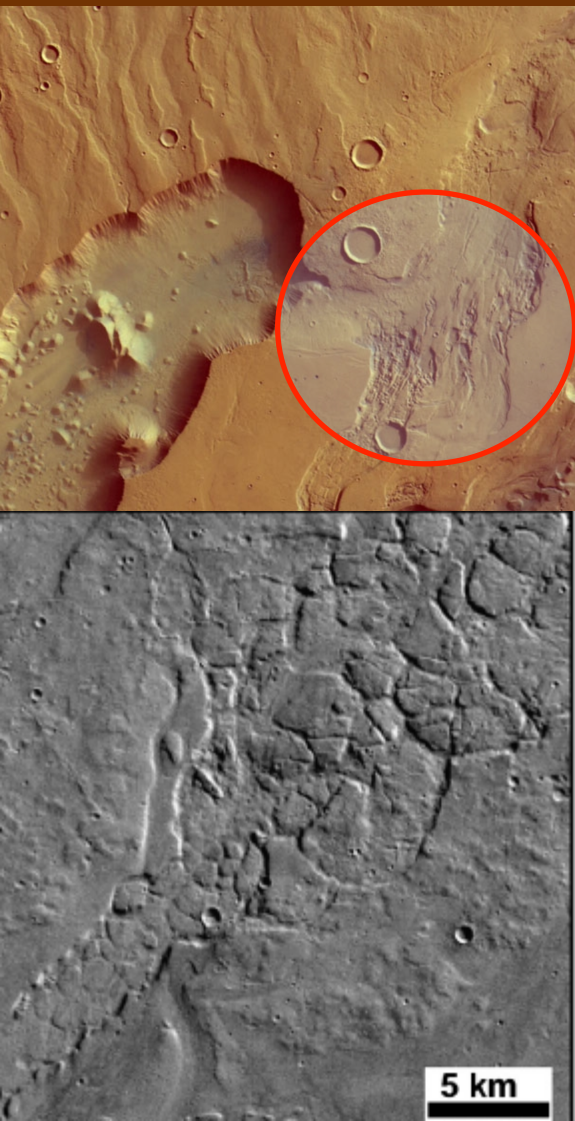


SCIENCE ROIs

1. Ausonia Cavus floor
2. Ausonia Mensa
3. Paraea Cavus floor
4. Hadriacus Mons (Hesperian) flow channel
5. Niger Vallis head
6. Tyrrhenus Mons (Naochian) flow



Science ROI 1



Head of Niger Valles Outflow Channel

Latitude: 33 S

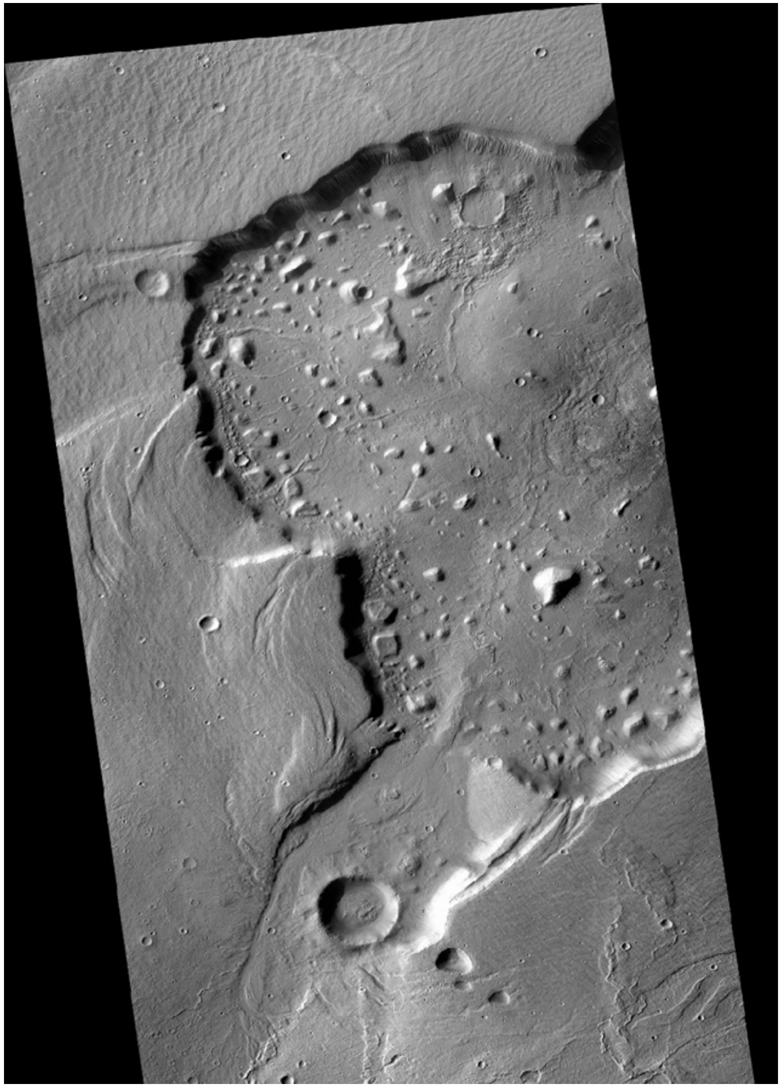
Longitude: 94.5 E

Altitude: -2800m

Head of Niger Valles outflow channel

- Chaos area
  - Fractured and faulted Basalt
  - Source of a system of small channels
  - Created by flooding and tectonic deformation
- Small well preserved craters

Science ROI 2



Latitude: 31.97 S
Longitude: 95.55 E
Altitude: -2600m

Ausonia Cavus

• Walls show undeformed stratigraphic section extending into Noachian

•Mg-Fe Phyllosilicates

•Potentially large deposit of groundwater or subterranean ice

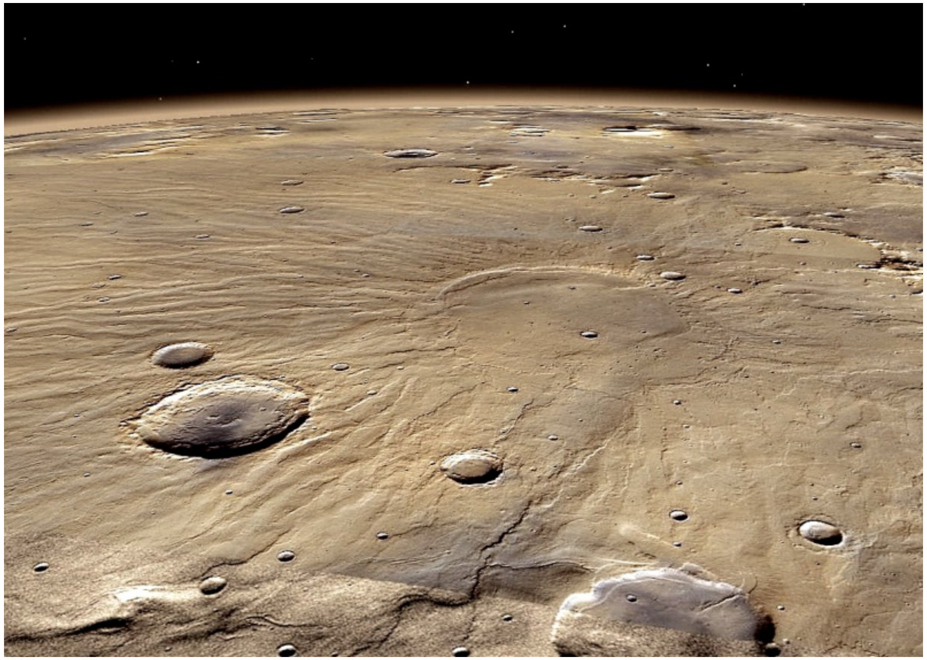
•Large blocks excavated by flood events

•Mass wasting from walls and rim

  – Easy access to diverse rock types and ages

AUSONIA CAVUS

Science ROI 3

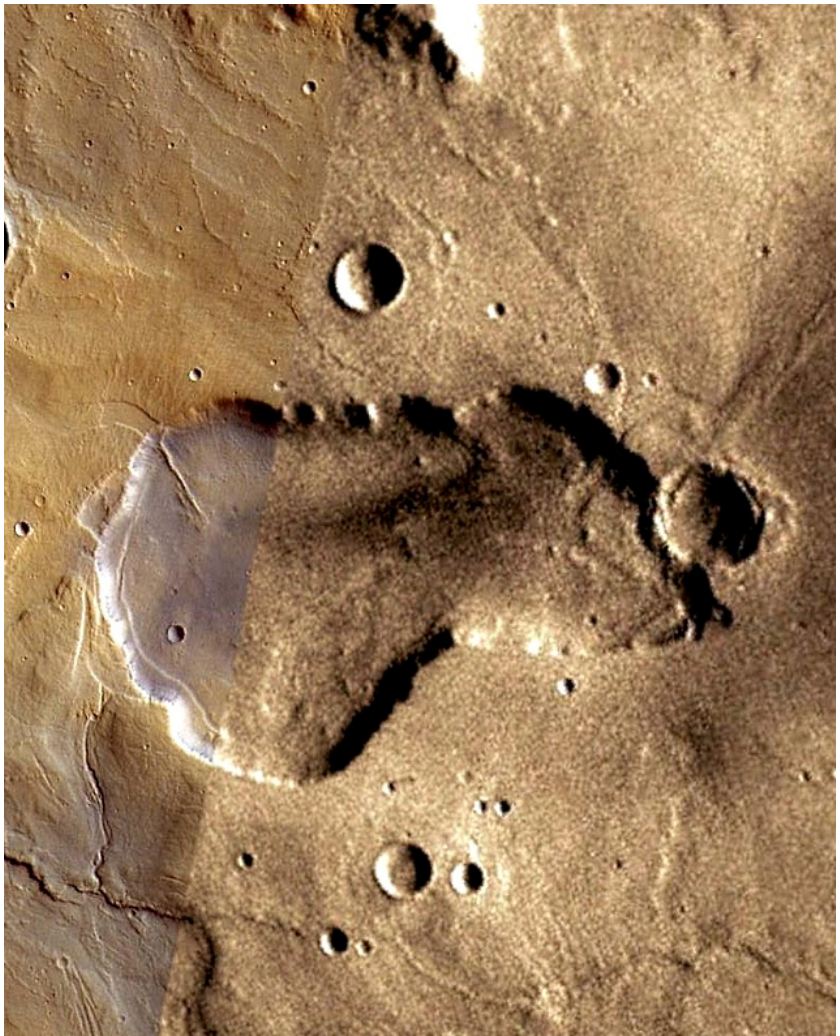


Coordinates: 31.34S, 91.86E

Altitude: -1750m

- Hadriacus Mons
- Hesperian shield volcano
- 450 km dia.

Science ROI 4

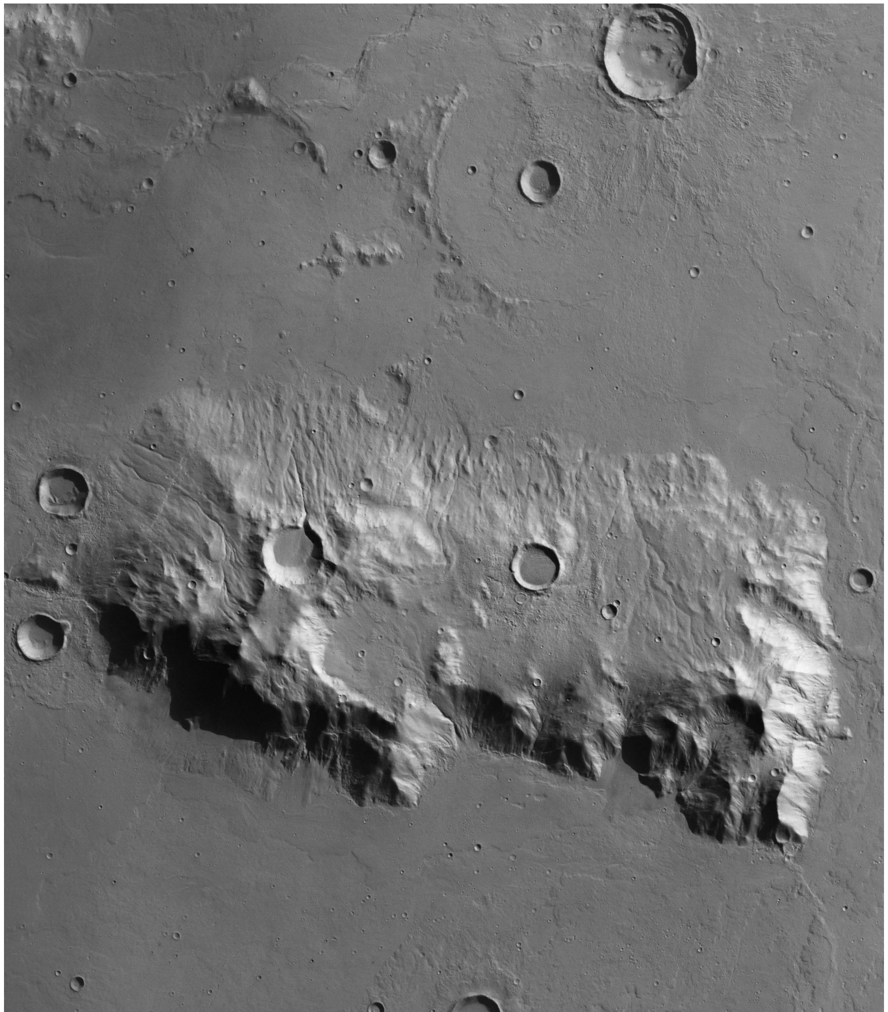


AUSONIA CAVUS

Paraea Cavus

- 56.2 km diameter
- Paleolake
- Relatively undisturbed lacustrine sediments, clays
- Exposed stratigraphic section in walls
- HiRISE Obs PSP010311-1500 Thermally distinct material
- Large landslide on east side

Science ROI 5



Ausonia Cavus

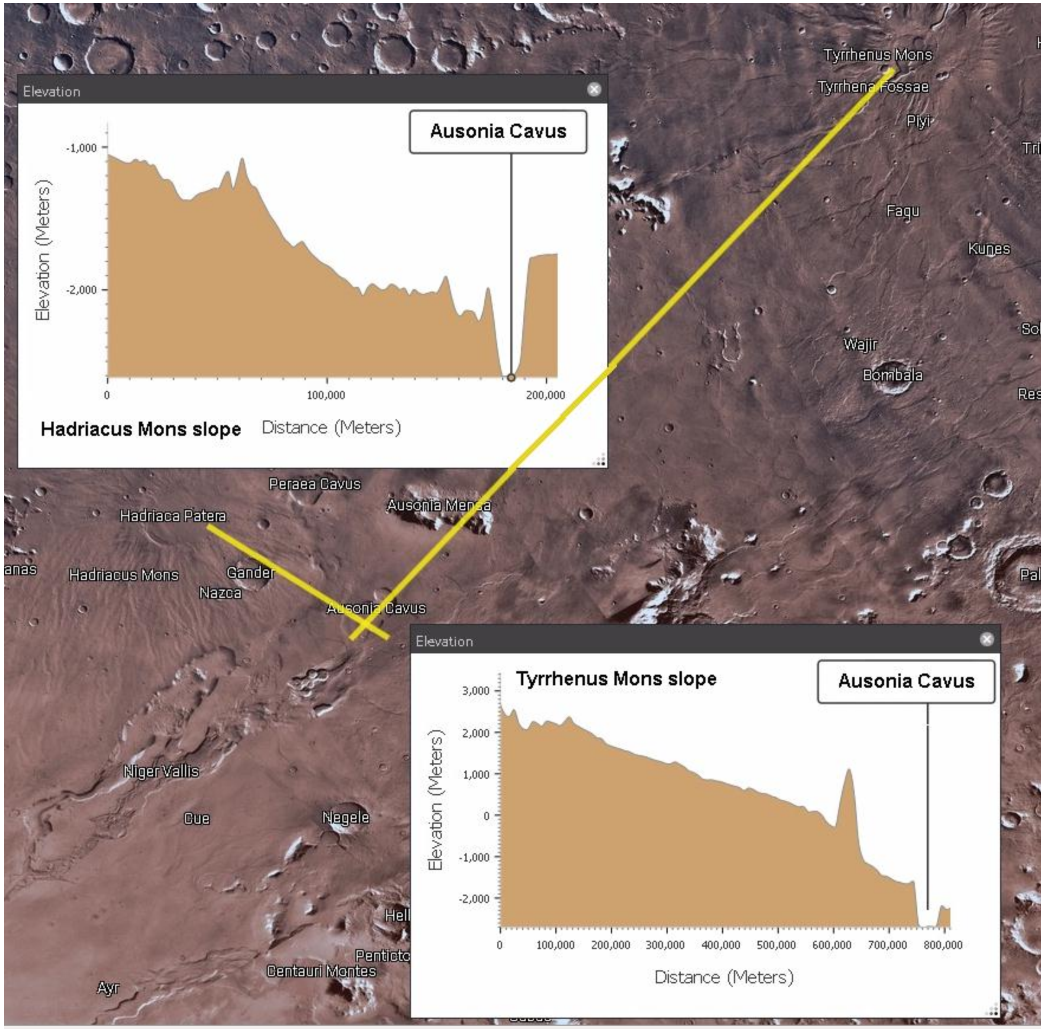
Latitude: 30.06 S

Longitude: 97.72 E

Altitude: -900m

- Ausonia Mensa
- Early Noachian Highland massif
- Primitive, crustal block upthrusted by Hellas impact
- Possible small fluvial structures on North and West side
- 102.5 km diameter
- Datable material

Science ROI 6



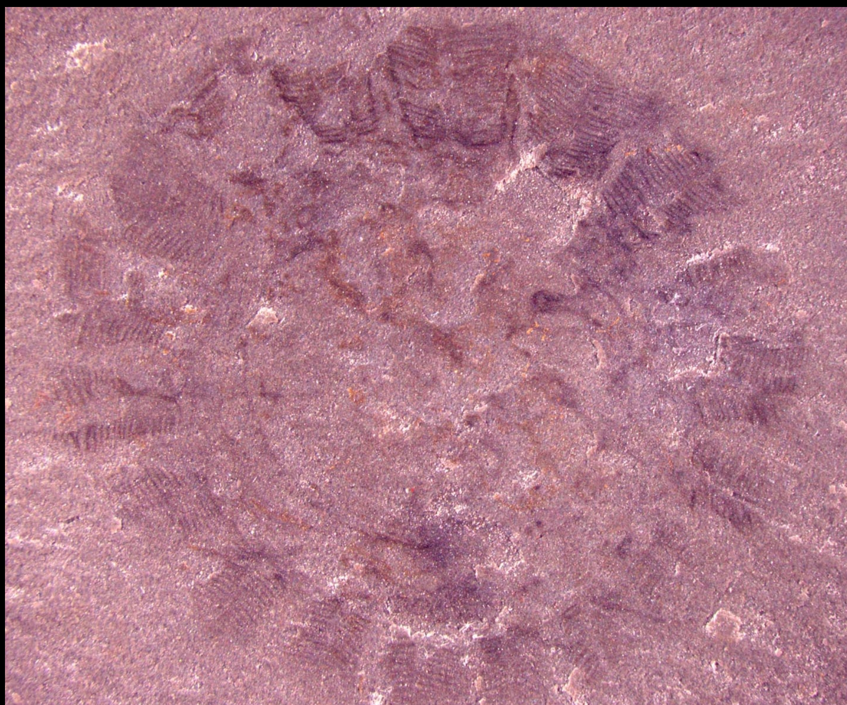
Ausonia Cavus

Latitude: 31.97 S

Longitude: 96.55 E

- Confluence of Noachian (Tyrrhenus Mons) and Hesperian (Hadriacus Mons) Volcanic slopes

EZ Astrobiological Potential



Fossilized jellyfish. Citation: Cartwright P. et al, *Exceptionally Preserved Jellyfishes from the Middle Cambrian*

- The data from the strata on the early Noachian highland massif could provide insight into potential biosignatures in ancient Martian atmospheric compositions.
- Sediment deposits and lack of material disturbance make lakes on Earth high fidelity biosignature conservation sites. The lake in this region, Paraea Cavus, may have also been capable of biosignature preservation.
  - As an example, soft bodied organism impressions can be preserved in sedimentary rock.

Resource ROI 1

eHv **Early Hesperian volcanic unit**—
Planar deposits meters to tens of meters thick and tens to hundreds of kilometers across; lobate scarps common.
Flood lavas, undifferentiated, sourced from regional fissure and vent systems. Tectonically contracted

Ausonia Cavus southern outflow

Latitude: 31.97 S

Longitude: 96.55 E

Altitude: -2700m

- Chaotic terrain
- Hydrated minerals
- Possible subsurface ice

Resource ROI 2

Floor of Ausonia Caves

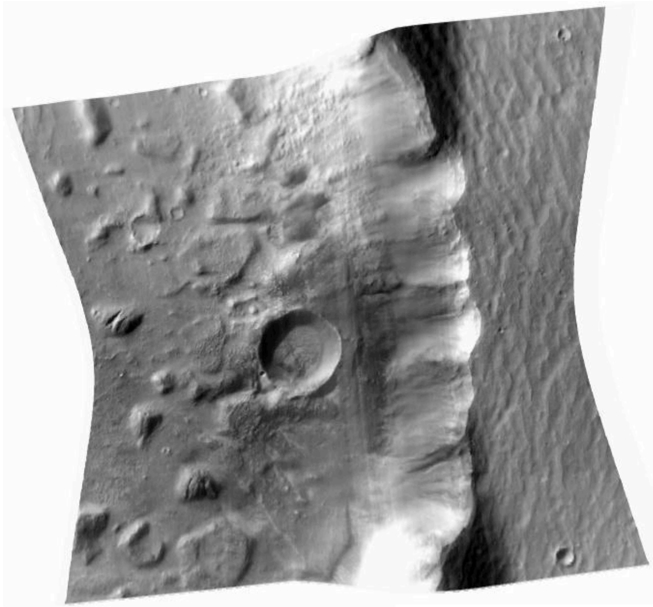
Latitude: 31.97 S

Longitude: 96.55 E

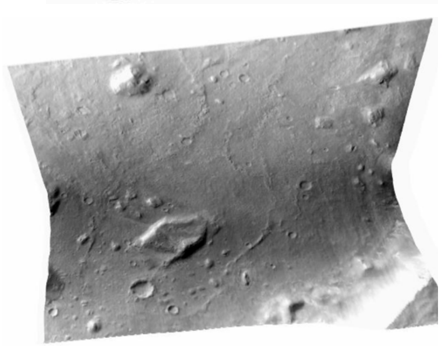
Altitude: -2600m

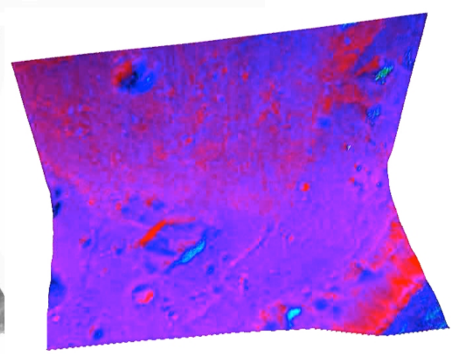
- Southern Floor of Ausonia Cavus, outflow channel
- PSP_001648_1475 Red
- Dust, small dunes
- Sand, clays

Resource ROI 2



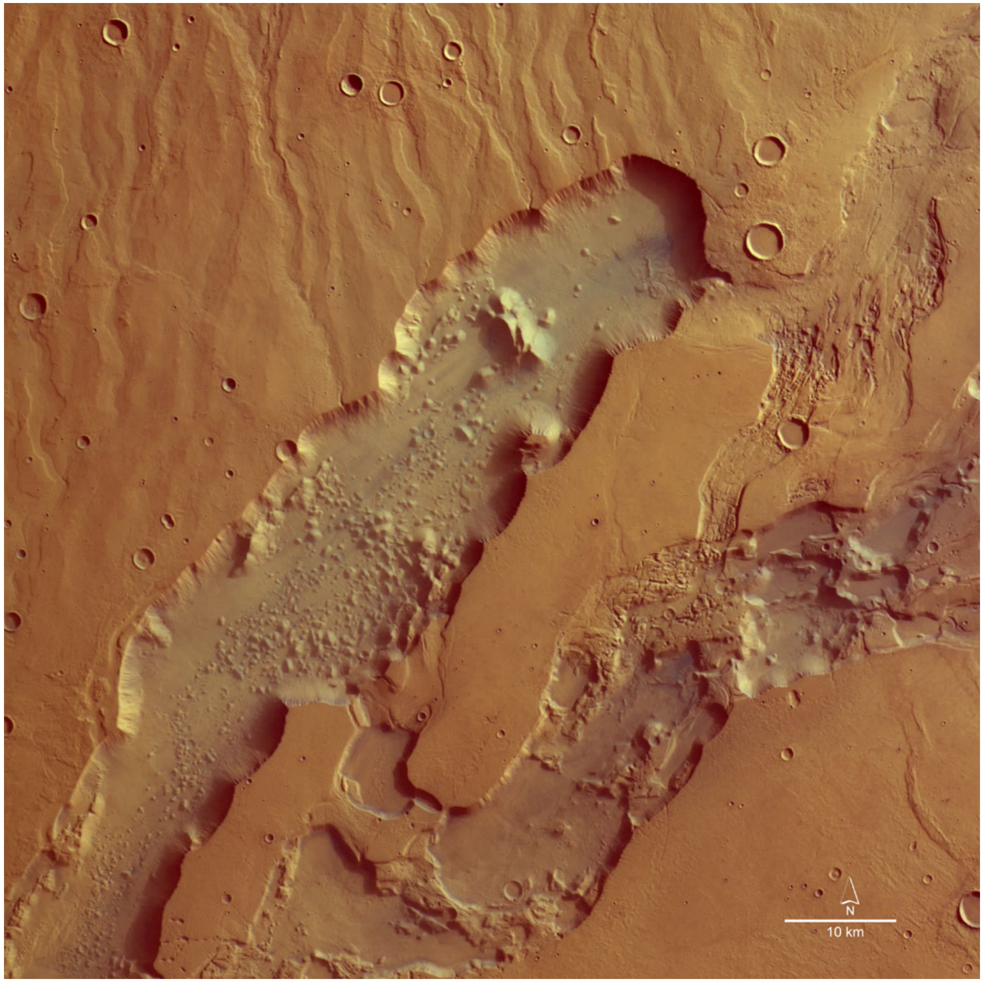
- Walls of Cavus likely to have RSL with potential pooling at bottom of slope





- Fe/Mg Phylosilicates
- CRISM image

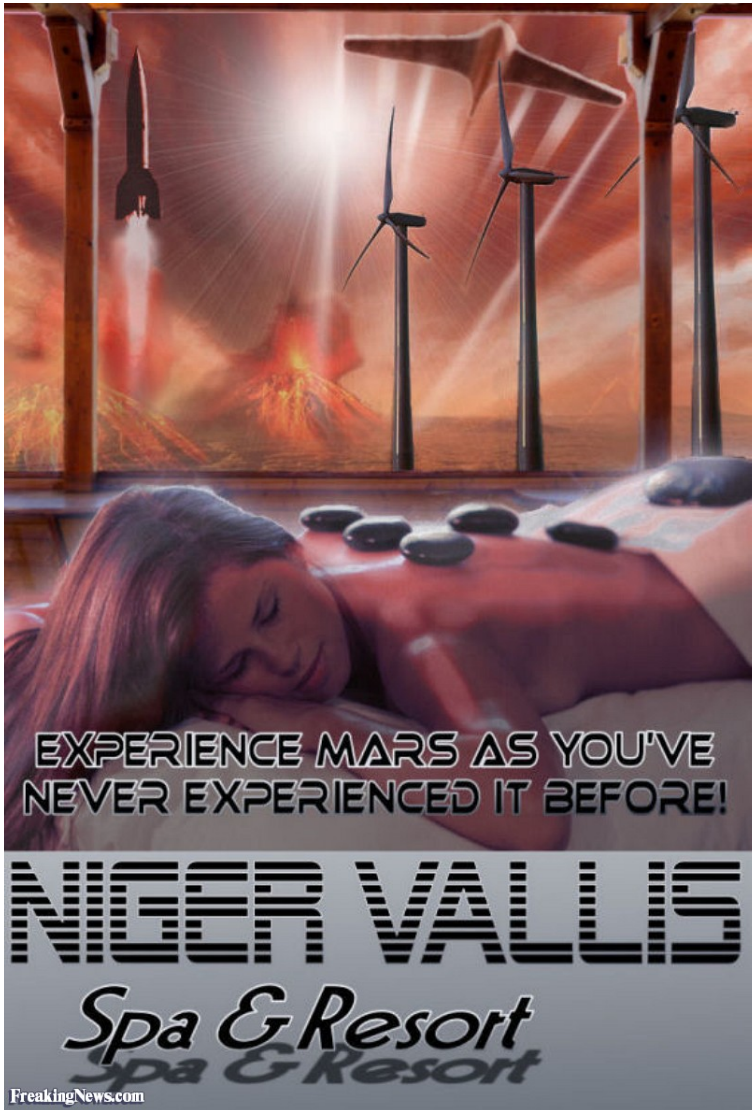
Resource ROI 3



Head of Niger Valles outflow channel
Latitude: 33.00 S
Longitude: 94.5 E

- Fractures surrounded by concentric fractures. These would allow ice to sublimate into the atmosphere from the subsurface materials causing progressive collapse of the crater walls and resulting in the formation of the interior hummocky terrain.
- Fine-grained sediments trapped by the hummocky terrain get reworked by local winds forming dunes on the lower floors.

Resource ROI 3



- Head of Niger Valles outflow channel
- Tourism!

Science ROI(s) Rubric: Ausonia Cavus

Science Site Criteria				Site Factors	SROI 1	SROI 2	SROI 3	SROI 4	SROI 5	SROI 6	EZ SUM
Astrobio	Threshold	AND/OR		Potential for past habitability	●	●	●	●	●	●	6,0
				Potential for present habitability/refugia	●	●	○	○	○	○	2,4
	Qualifying			Potential for organic matter, w/ surface exposure	○	○	○	○	○	○	0,6
Atmospheric Science	Threshold			Noachian/Hesperian rocks w/ trapped atmospheric gases	○	●	●	●	●	○	4,0
	Qualifying			Meteorological diversity in space and time	○	○	○	○	○	○	0,6
				High likelihood of surface-atmosphere exchange	○	○	○	○	○	○	0,6
				Amazonian subsurface or high-latitude ice or sediment	●	●	●	●	●	●	6,0
				High likelihood of active trace gas sources	○	○	○	○	○	○	0,6
Geoscience	Threshold			Range of martian geologic time; datable surfaces	●	●	●	○	●	●	5,1
				Evidence of aqueous processes	●	●	●	○	●	○	4,2
				Potential for interpreting relative ages	●	●	●	●	●	●	6,0
	Qualifying			Igneous Rocks tied to 1+ provinces or different times	●	●	●	○	●	●	5,1
				Near-surface ice, glacial or permafrost	○	●	○	○	○	○	1,5
				Noachian or pre-Noachian bedrock units	○	○	○	○	●	○	1,5
				Outcrops with remnant magnetization	●	●	●	●	●	●	6,0
				Primary, secondary, and basin-forming impact deposits	●	●	●	●	●	●	6,0
				Structural features with regional or global context	○	○	○	○	●	○	1,5
				Diversity of aeolian sediments and/or landforms	●	●	●	●	●	●	6,0

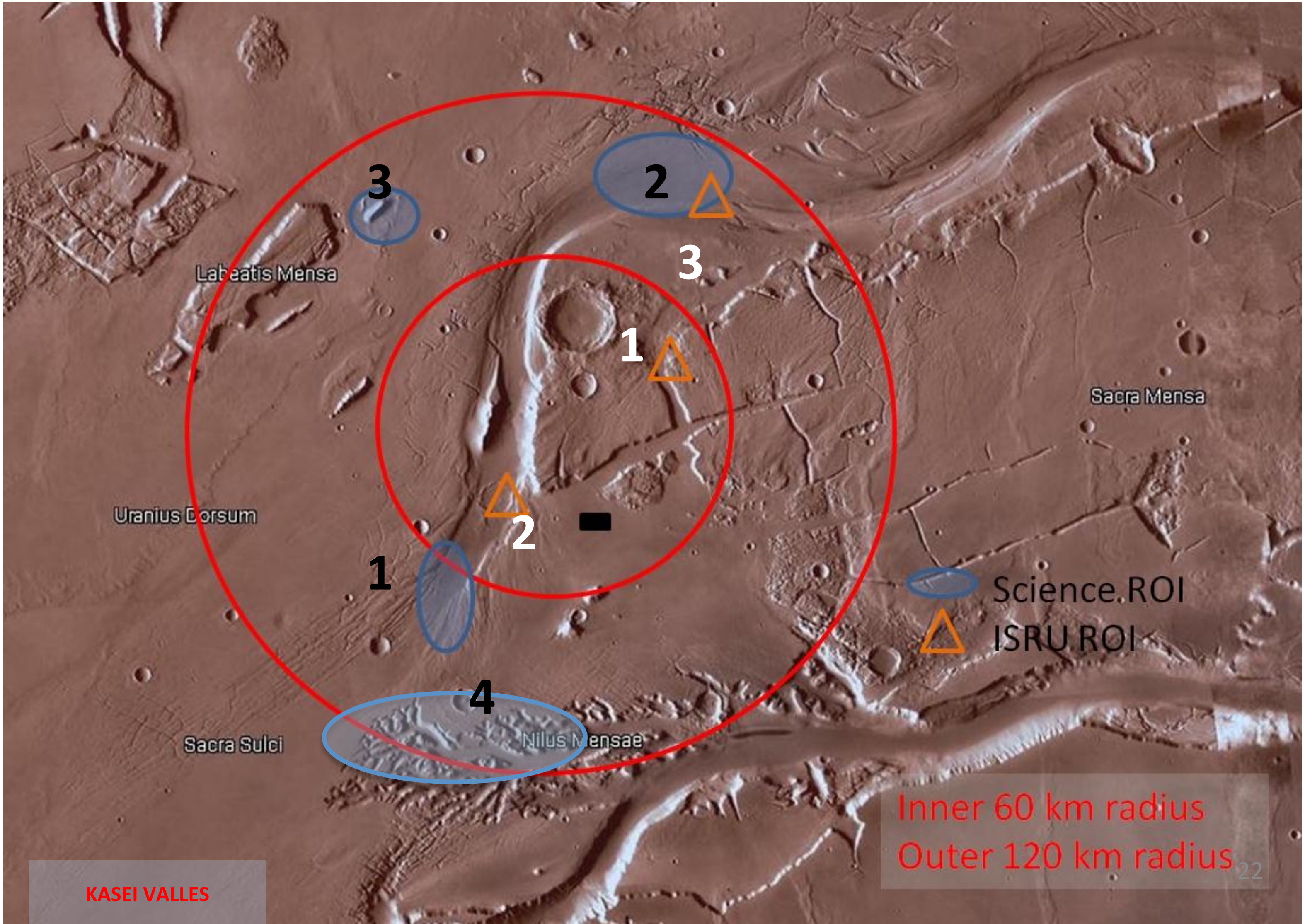
Key	
●	Yes
○	Partial Support or Debated
	No
?	Indeterminate

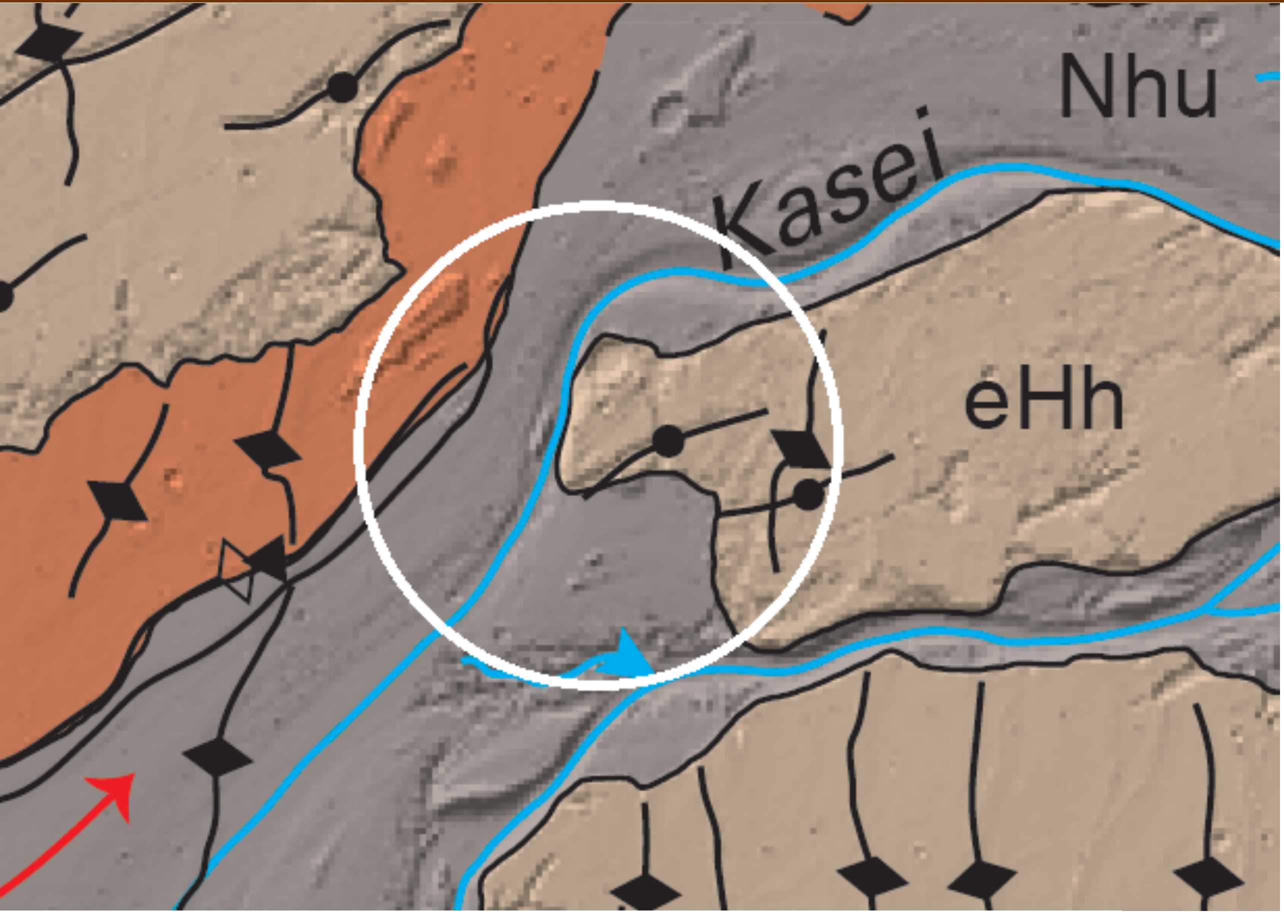
Site Factors					RROI1	RROI2	RROI3	EZ SUM
ISRU and Civil Engineering Criteria	Engineering			Meets First Order Criteria (Latitude, Elevation, Thermal Inertia)	●	●	●	
					●	●	●	
	Water Resource	Threshold	AND/OR	**Potential for ice or ice/regolith mix**	●	●	●	
				Potential for hydrated minerals	●	●	●	
				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 **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°	○	○	○	
				Located within 5 km of landing site location	●	●	●	
		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	●	●	●	

Workshop for Human Missions to Mars

Key	
●	**Yes**
○	**Partial Support or Debated**
	No
?	**Indeterminate**

Kasei Valles





Scarp—Sinuous, crenulated or scalloped; erosional, also tectonic or volcanic

Ridge—Simple form; erosional or volcanic

Wrinkle ridge—Ridge, sinuous, crenulated; tectonic contraction

Graben—Trough, linear or sinuous, en echelon; tectonic extension

Outflow channel—Long, wide, sinuous channel floors, often braided with bars and islands along the reach; catastrophic flooding, local collapse, and mass wasting

Nhu **Noachian highland undivided unit**—Forms canyon walls and some high plains and channel floors. Layered. Hundreds of meters to several kilometers thick in exposures.

Undifferentiated, friable (likely fine grained) sedimentary, volcanic, and impact rocks. Altered by weathering

eHh **Early Hesperian highland unit**—High plains-forming, relatively smooth outcrops extending hundreds of kilometers. May be hundreds of meters thick.

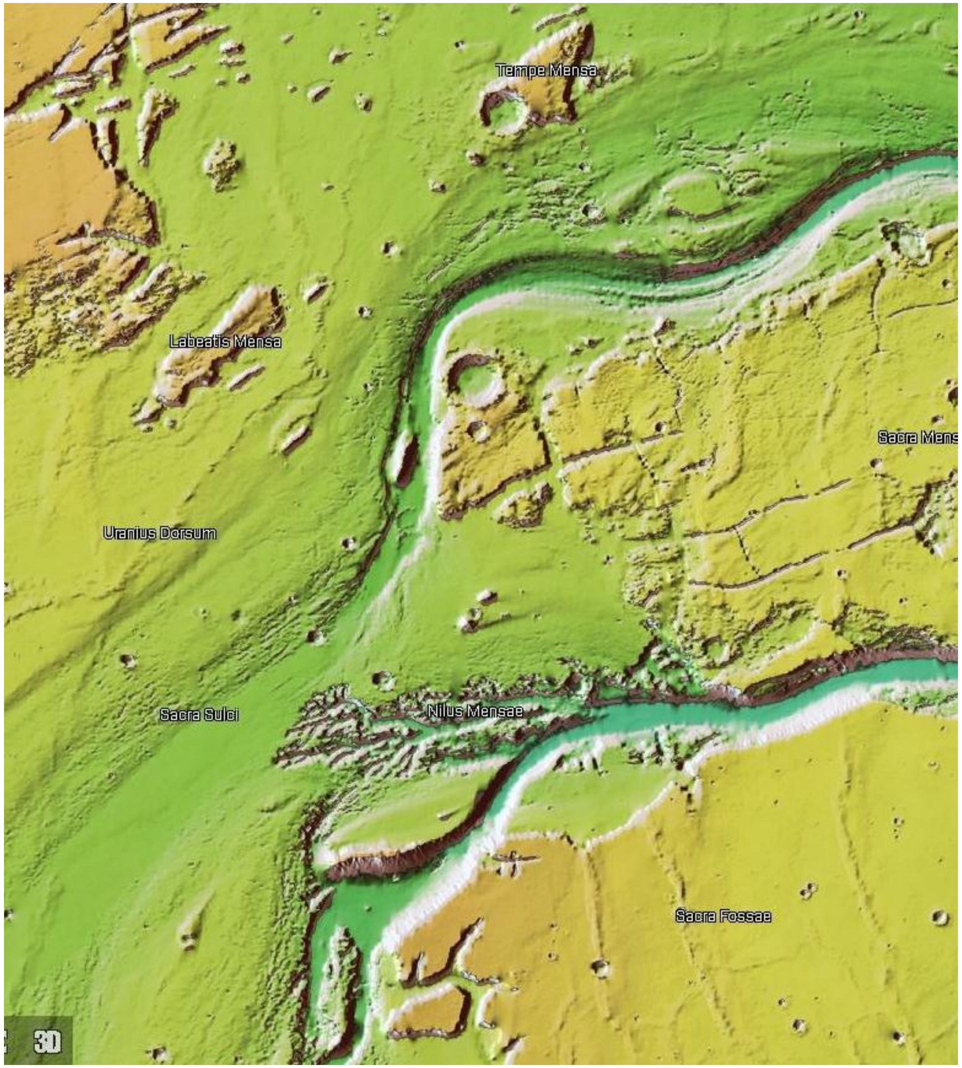
Undifferentiated impact, volcanic, eolian, fluvial/lacustrine materials. Locally degraded and (or) deformed

AHv **Amazonian and Hesperian volcanic unit**—Stacked, gently sloping lobate flows meters to tens of meters thick and hundreds of kilometers long. Variable daytime IR brightness in places. Cumulative thicknesses reach hundreds of meters to several kilometers.

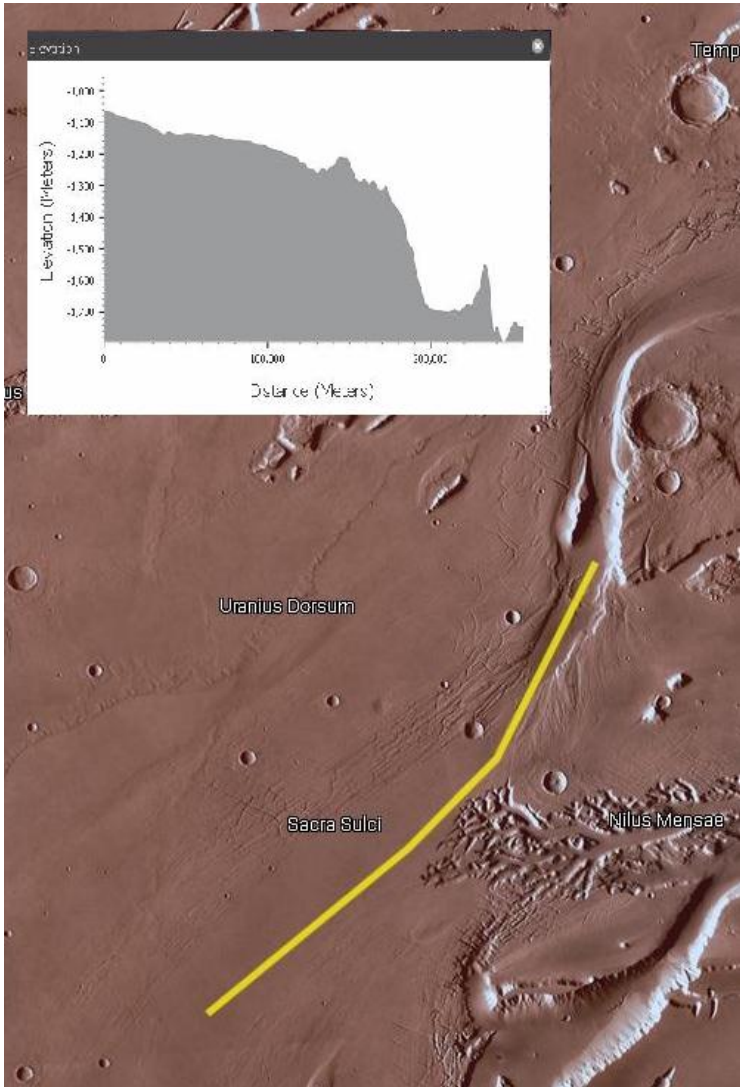
Flood lavas and large lava flows, undifferentiated, sourced from regional fissure and vent systems. Highly variable ages of individual flows, although generally younger in central parts of Tharsis rise

SCIENCE ROIs

1. Head of outflow channel
2. Outside bend of outflow channel
3. Older massif feature
   NE of Labeatis Mensa
4. Head of Nilus Mensae



Science ROI 1

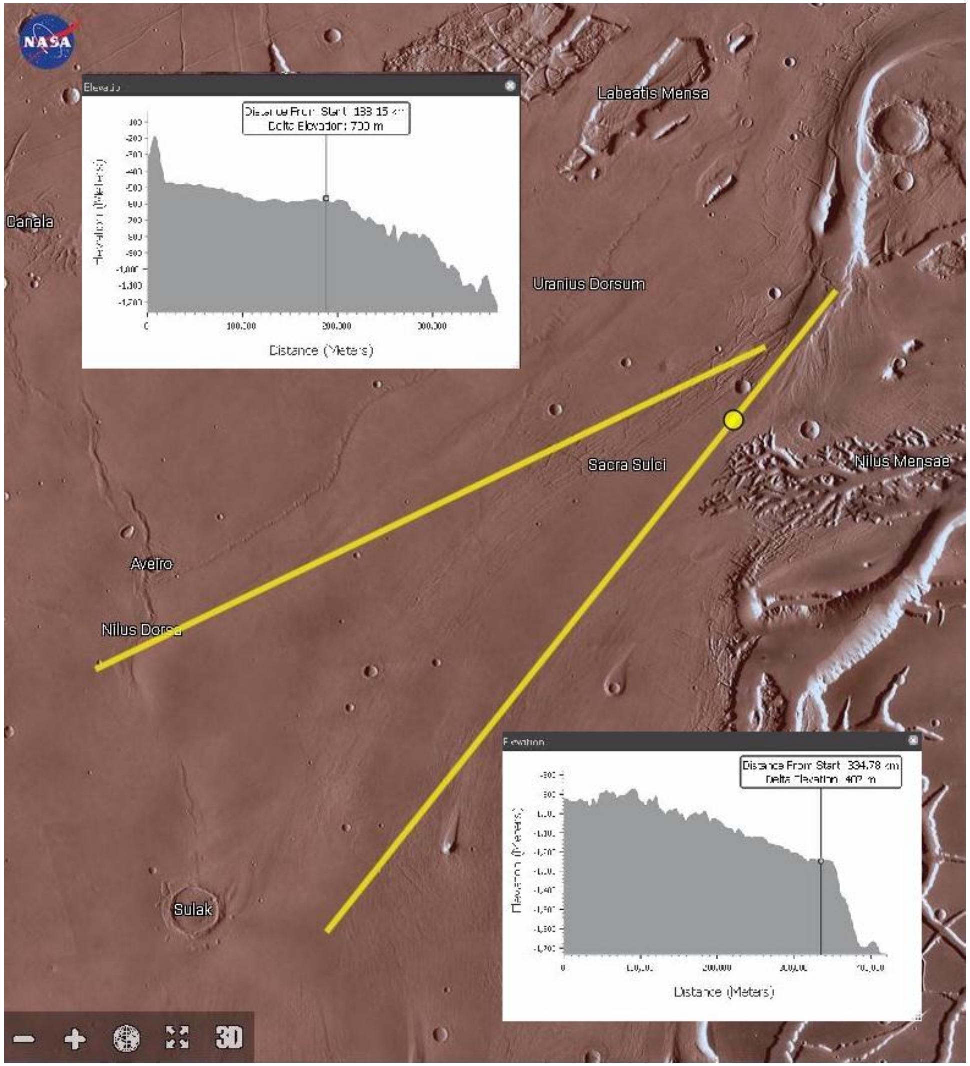


Latitude: 23.23 N
Longitude: 73.28 W
Altitude: -1690m

- Head of Kasei Valles
- Outflow channel formed from large flood events that transported a diverse array of eroded material downslope
- Floods created from volcanic interaction with glaciers on Tharsis Montes
- Drainage slopes into Kasei Valles from Sacra Sulci. Contains erosional deposits from Sacra Sulci and areas further upslope. Allows a geologic sampling from a large area in the Valles.

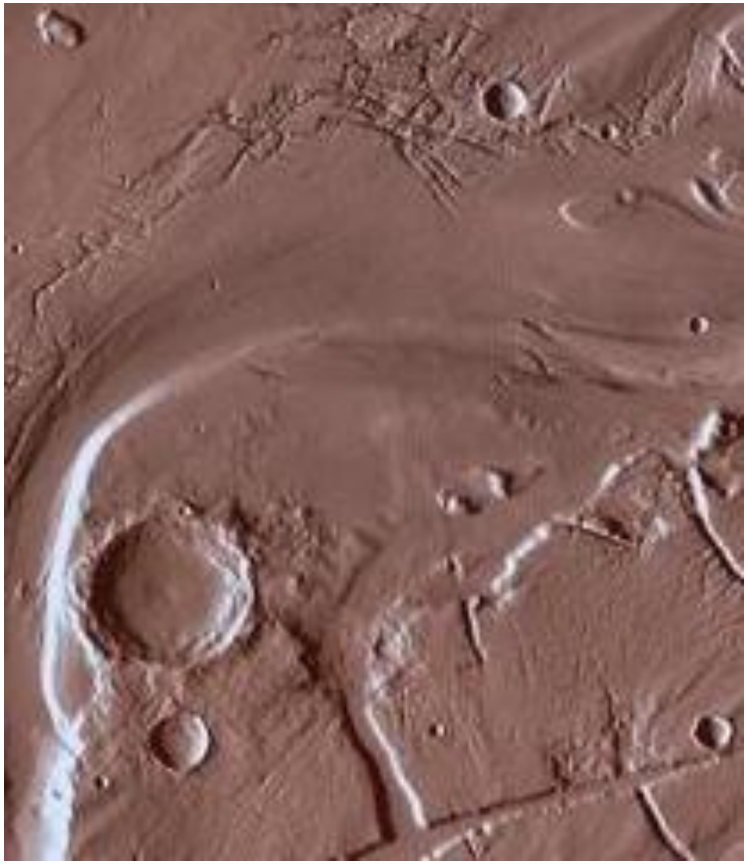
Kasei Valles

Science ROI 1



- Layered Noachian material exposed in walls and on channel floor
- Glaciers and near-surface ice may have persisted through Amazonian time in local areas over the entire length of Kasei Valles

Science ROI 2

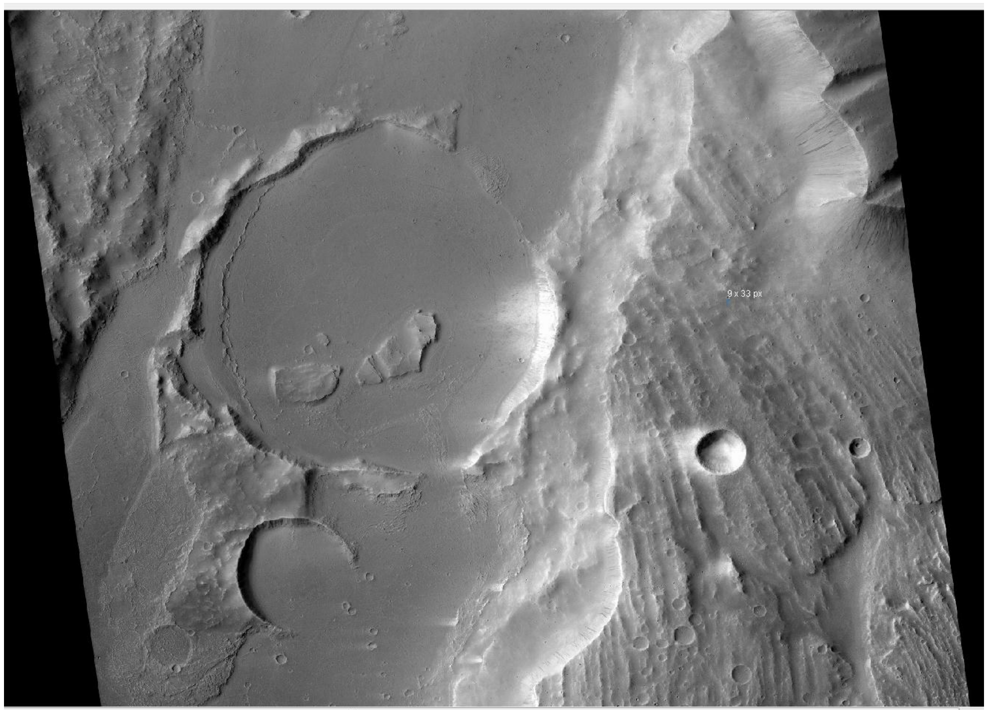


Latitude: 26.43 N
Longitude: 71.72 W
Altitude: -2200m

- Outside bend of outflow channel
- Outside bend will have material scoured out of sidewalls, exposing strata and possible frozen ground water deposits
- Multiple narrow, inner channels indicating multiple floods over a significant period of time

Kasei Valles

Science ROI 3



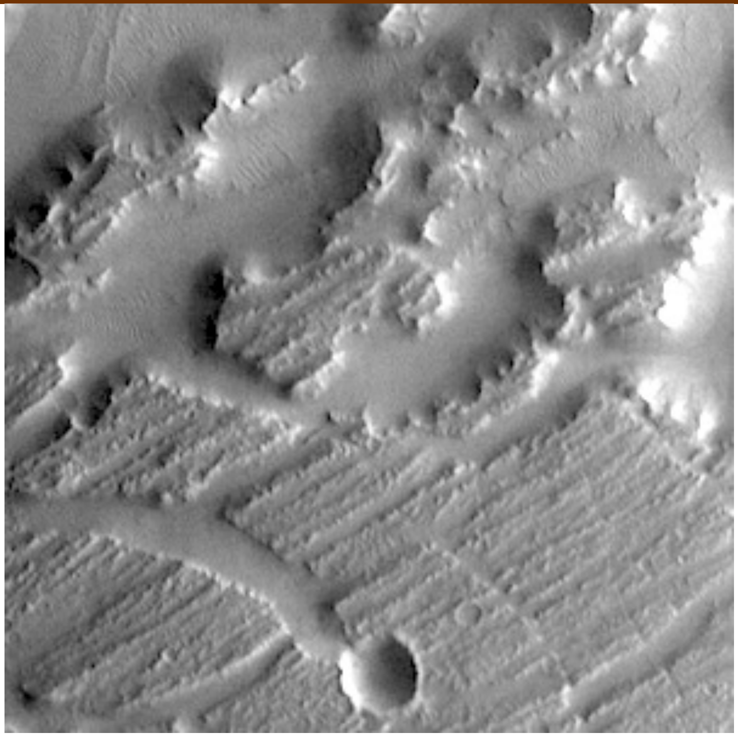
Latitude: 23.95 N

Longitude: 72.84 W

Altitude: -1800m

- Degraded crater infilled with hydrated minerals, sedimentary mix
- Channel dating

Science ROI 4



Latitude: 22.18 N

Longitude: 72.23 W

Altitude: -2300m

Head of Nilus Mensae

- Amazonian theater-headed channels formed by groundwater sapping
- System is feeding into North Kasei Valles gorges
- Themis IOTD_20140904

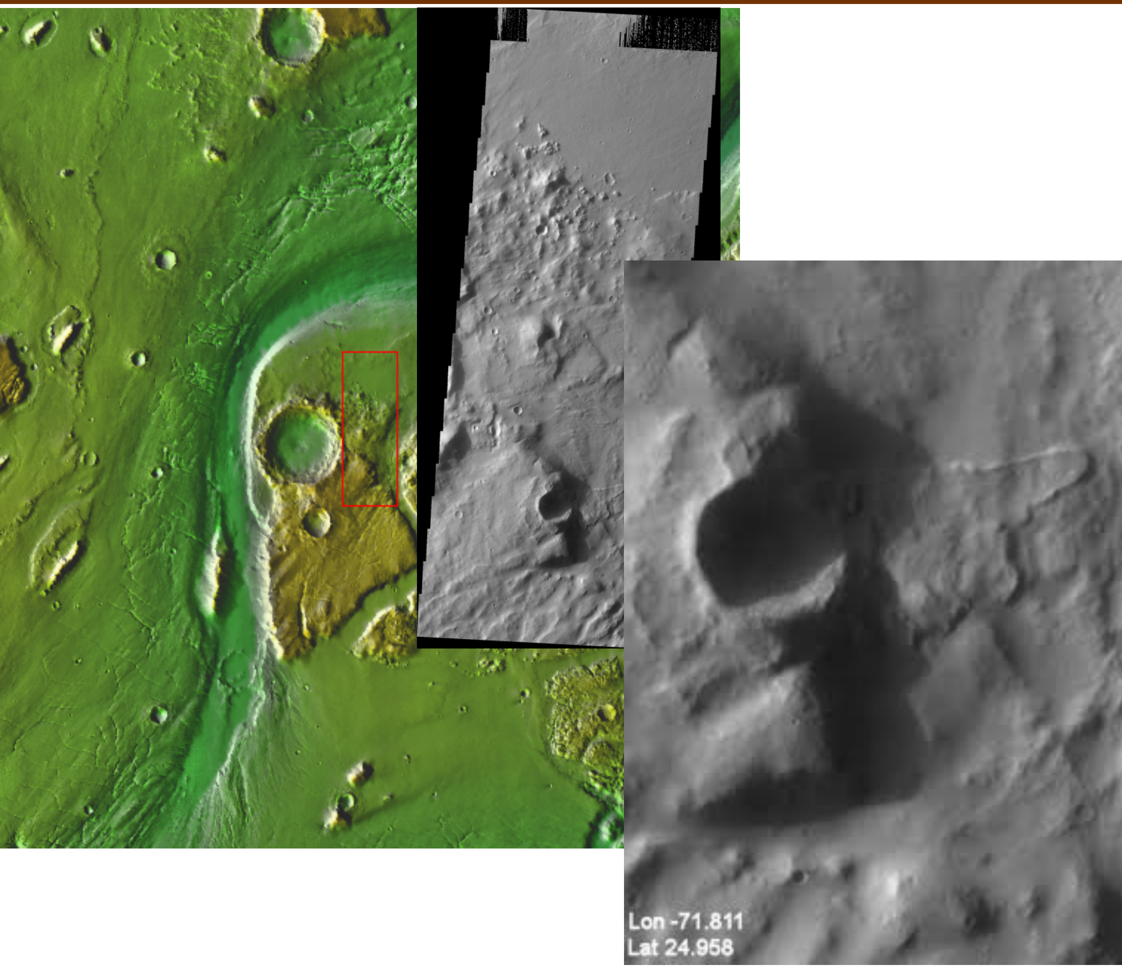
KASEI VALLES

EZ Astrobiological Potential

- The exposure of Noachian terrains could indicate potential mechanisms of biosignature preservation.
  - As an example: Flood events in this region, during potentially habitable times in Martian history, moved enough sediment to be able to preserve hard bodied organisms if any existed at the time (ex. silica walled diatoms).
- Amazonian-era fluvial processes indicating a potential groundwater reservoir and the proximity of the site to the remnants of the Martian oceans are promising characteristics.

Citations: Tanaka K.L. et al, *Geologic Map of Mars.*

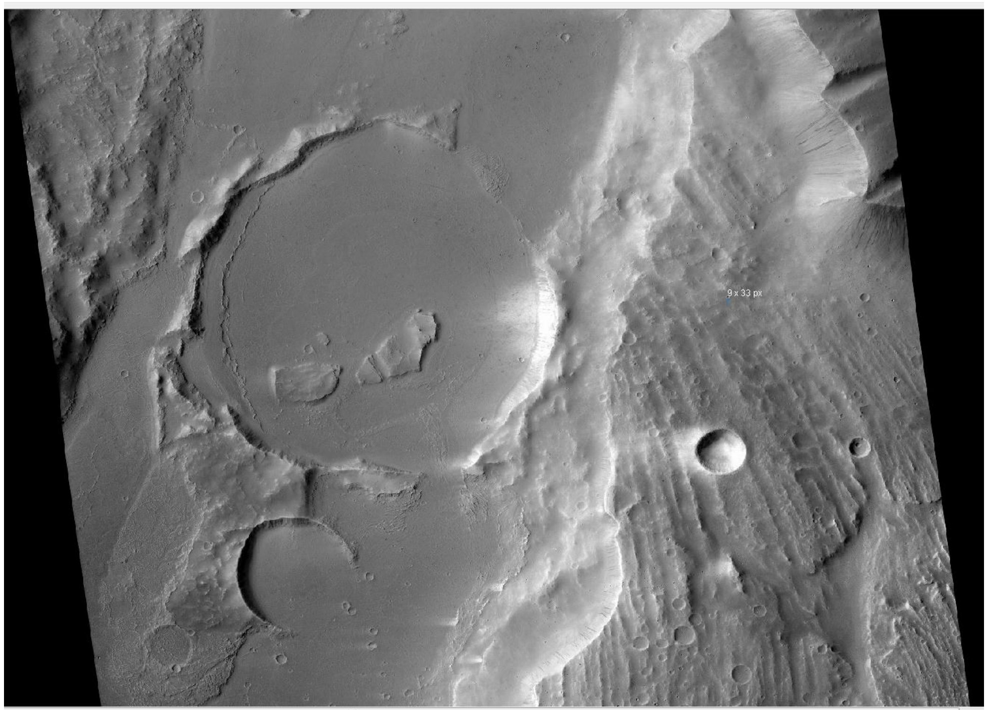
Resource ROI 1



- Outflow from crater wall collapse
- Latitude, longitude
- altitude
- Aqueous flow
- Possible Ice Flow

KASEI VALLES

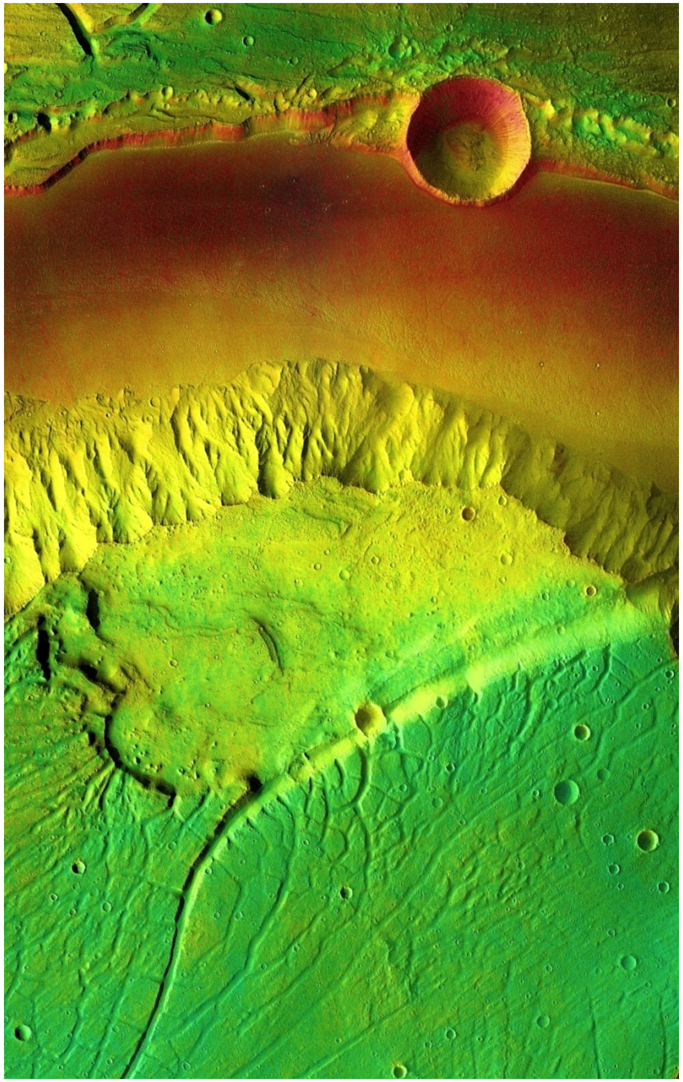
Resource ROI 2



- Filled in Crater
- Latitude: 23.95N
  Longitude: 72.84W
- Altitude: -1800m
- Sand and erosional depositions
- Water-altered minerals

KASEI VALLES

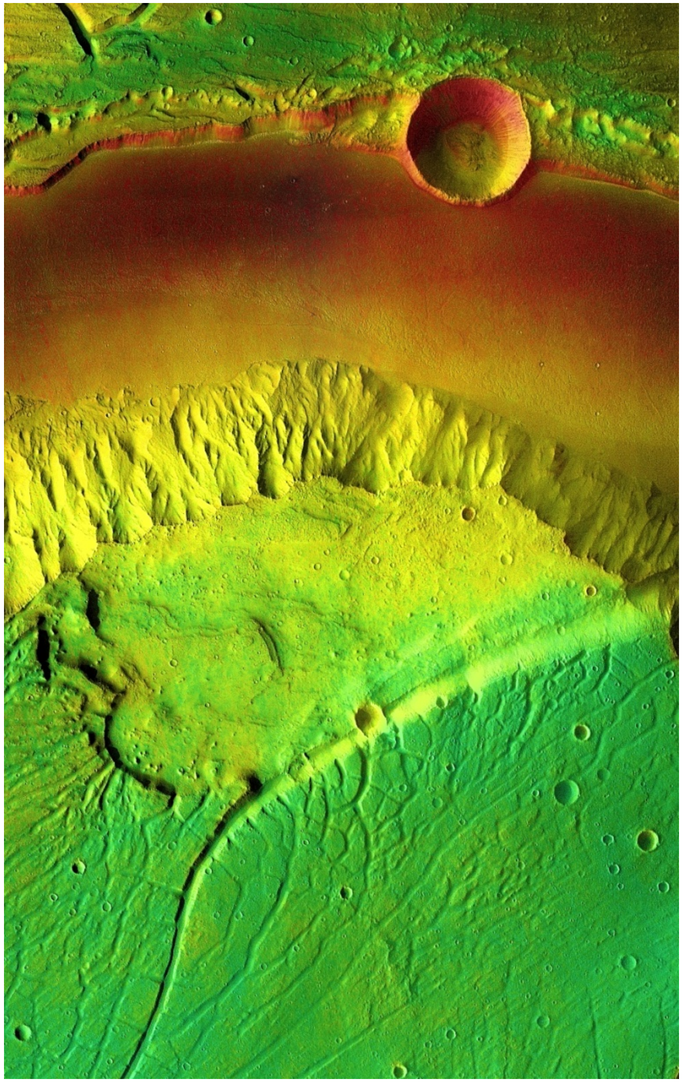
Resource ROI 3



- Latitude: 25.9N
- Longitude: 72.1W
- Altitude: -2100m
- Inside bend of outflow channel
- This side of the channel will have the erosional deposits from upslope, many fines
- Water altered minerals and clays – 3-6%

KASEI VALLES

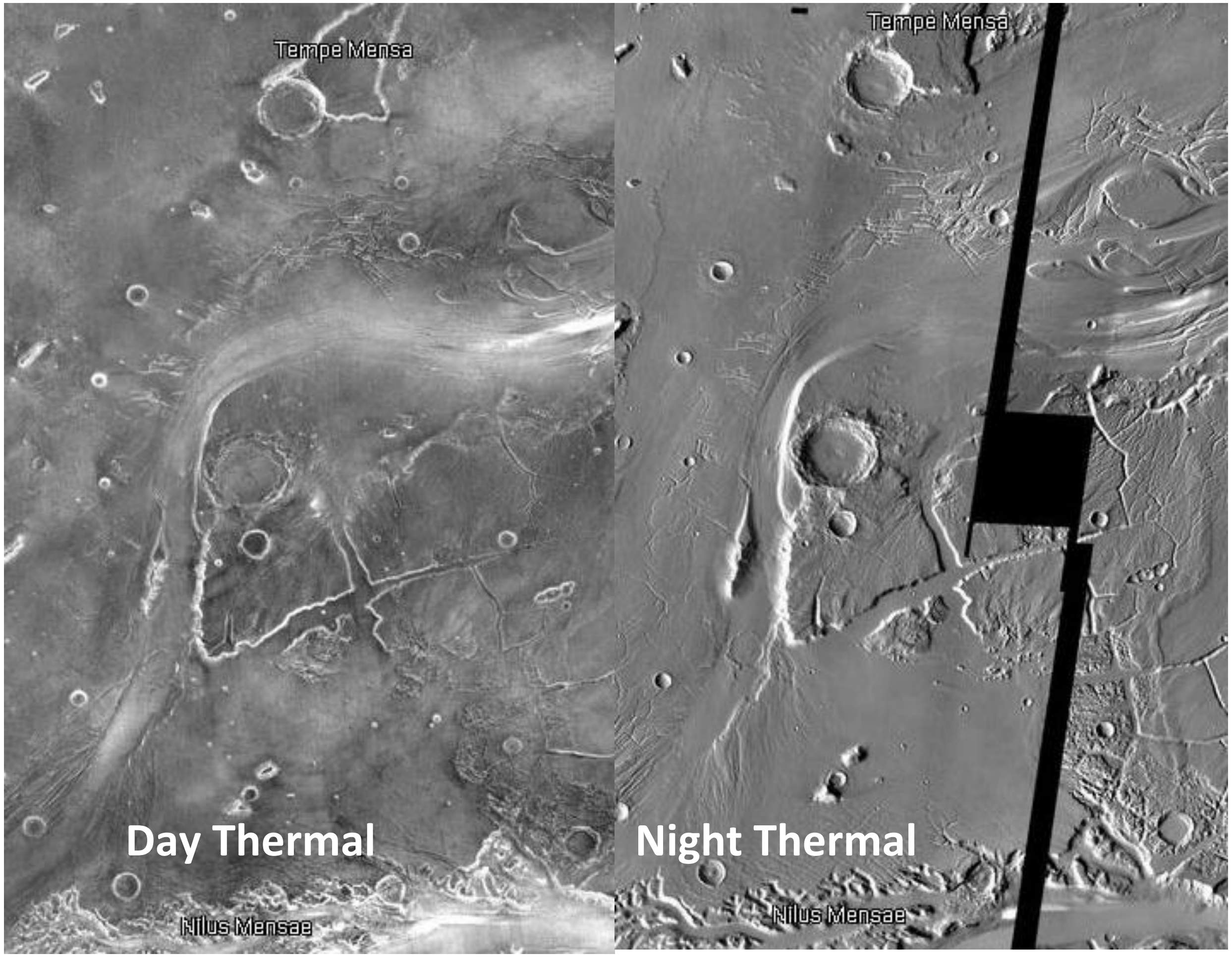
Resource ROI 3



- Exposed walls/cliffs
- Exposed subground strata allowing access to frozen water

KASEI VALLES

Resource ROI 4



KASEI VALLES

- Regolith dust deposits

Science ROI(s) Rubric: Kasei Valles

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

Key	
●	Yes
○	Partial Support or Debated
	No
?	Indeterminate

				Site Factors	RROI 1	RROI 2	RROI 3	RROI 4	EZ SUM
ISRU and Civil Engineering Criteria	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 **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°	●	●	●	●	
				Located within 5 km of landing site location	○	○	○	○	
		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

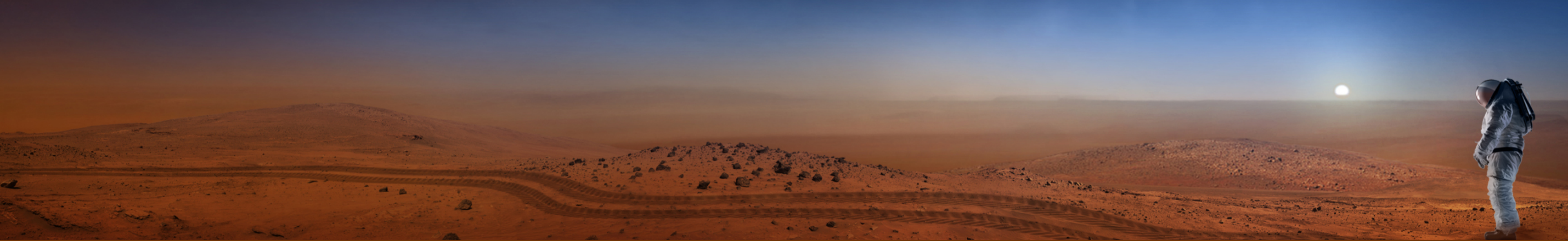
EZ Data Needs for Both Sites

Practical Needs:

- CRISM data to better understand the mineralogy (both Ausonia Cavus and Kasei Valles).
- HiRise imagery to identify more regions of interest at high-resolution (both Ausonia Cavus and Kasei Valles).

If Dreams Came True:

- Ground penetrating radar imagery of Ausonia Cavus to confirm the presence of water or water ice.
- Cores

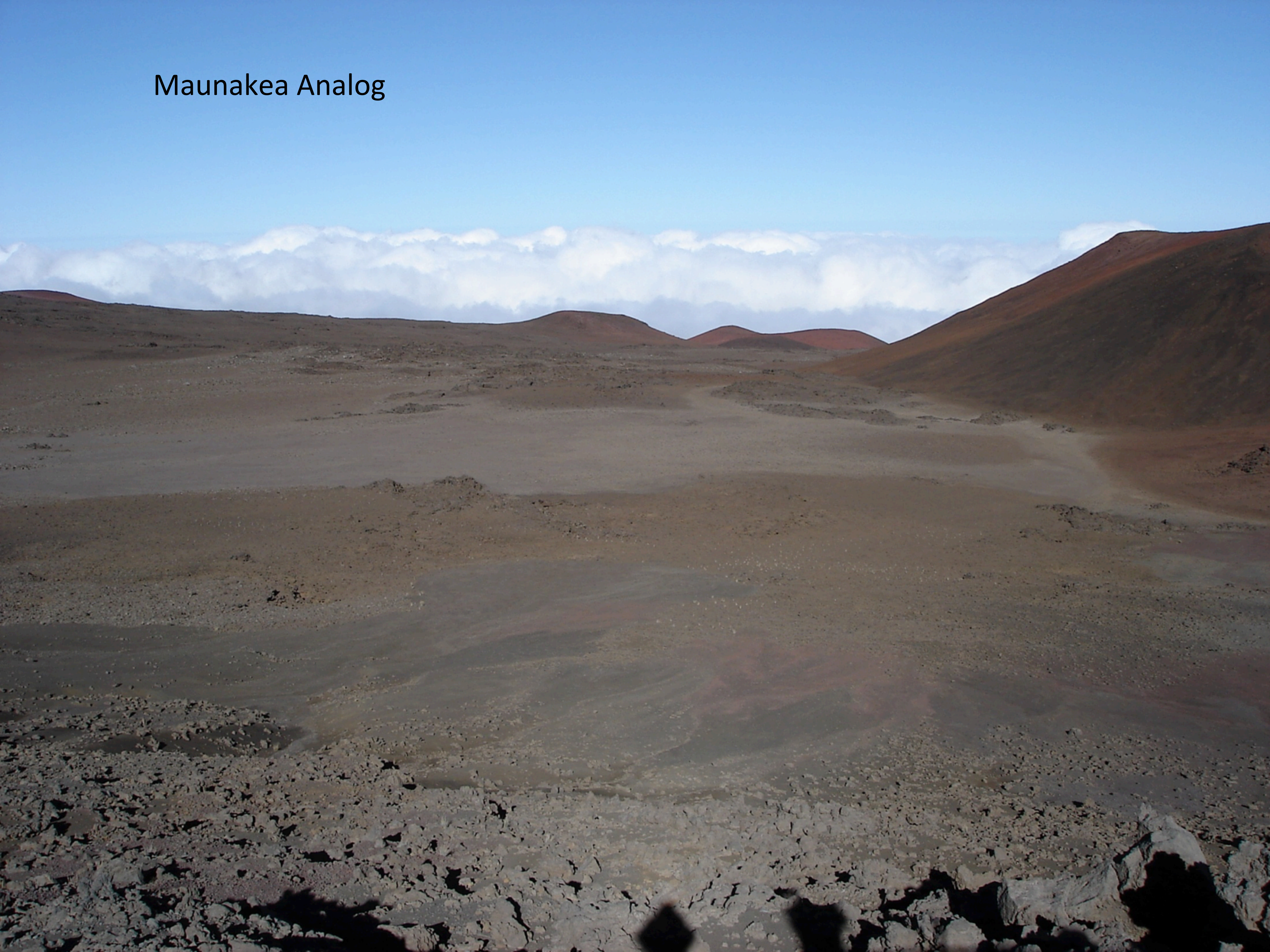


Backup slides

Hawai`i as Mars Analog

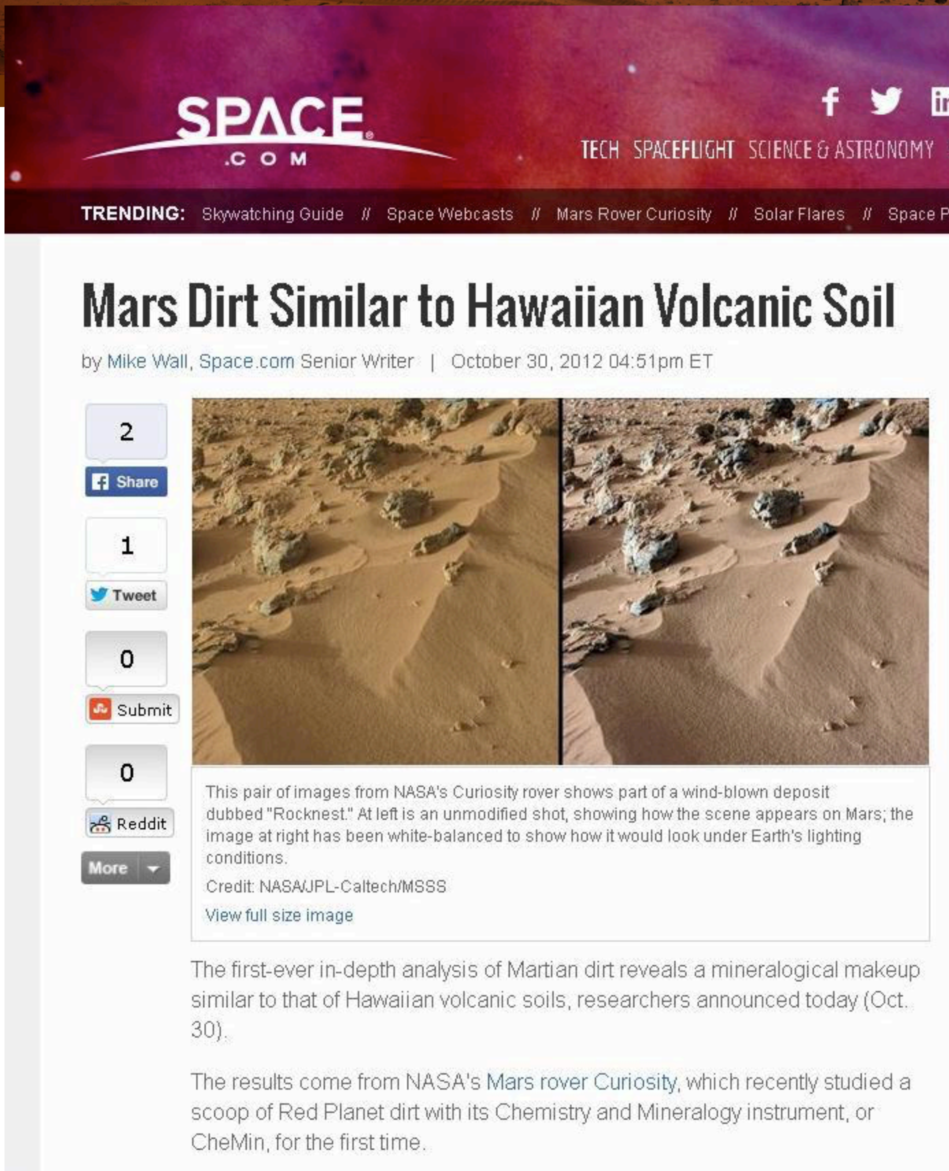
- High-Fidelity Planetary Analog sites
- Basaltic Terrain
- Geochemical similarity
- Water altered basalts
- Year round testing season
- Affordable access worldwide

Gale Crater Rim (sol 50 mastcam)


Maunakea Analog


Moon And Mars Analog Missions Activities (MMAMA)
roving at Apollo Valley, Mauna Kea 2012

Curiosity – Mars Science Laboratory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Mars Dirt Similar to Hawaiian Volcanic Soil

by Mike Wall, Space.com Senior Writer | October 30, 2012 04:51pm ET

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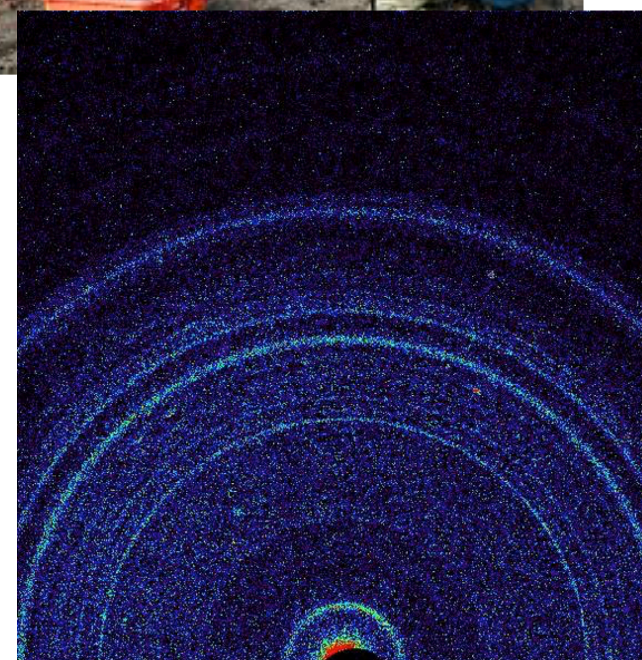
This pair of images from NASA's Curiosity rover shows part of a wind-blown deposit dubbed "Rocknest." At left is an unmodified shot, showing how the scene appears on Mars; the image at right has been white-balanced to show how it would look under Earth's lighting conditions.

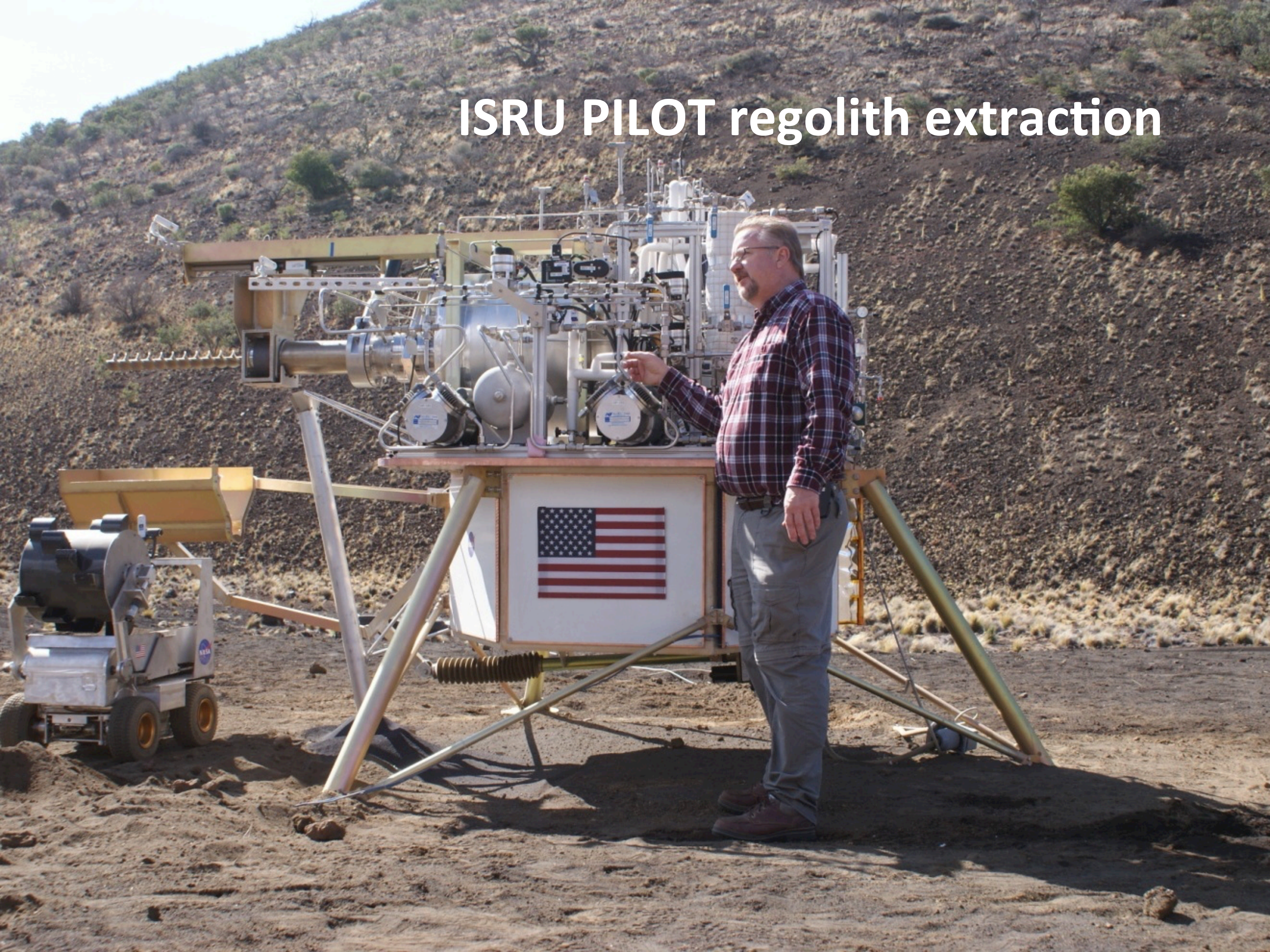
Credit: NASA/JPL-Caltech/MSSS

View full size image

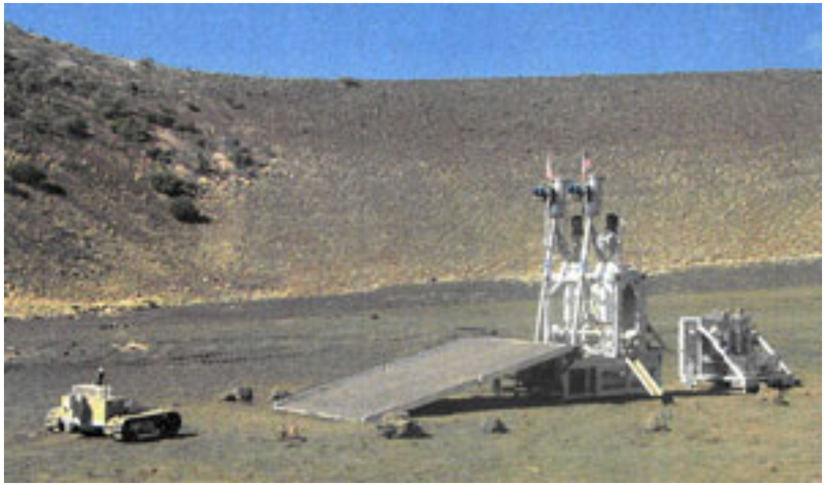
The first-ever in-depth analysis of Martian dirt reveals a mineralogical makeup similar to that of Hawaiian volcanic soils, researchers announced today (Oct. 30).

The results come from NASA's Mars rover Curiosity, which recently studied a scoop of Red Planet dirt with its Chemistry and Mineralogy instrument, or CheMin, for the first time.



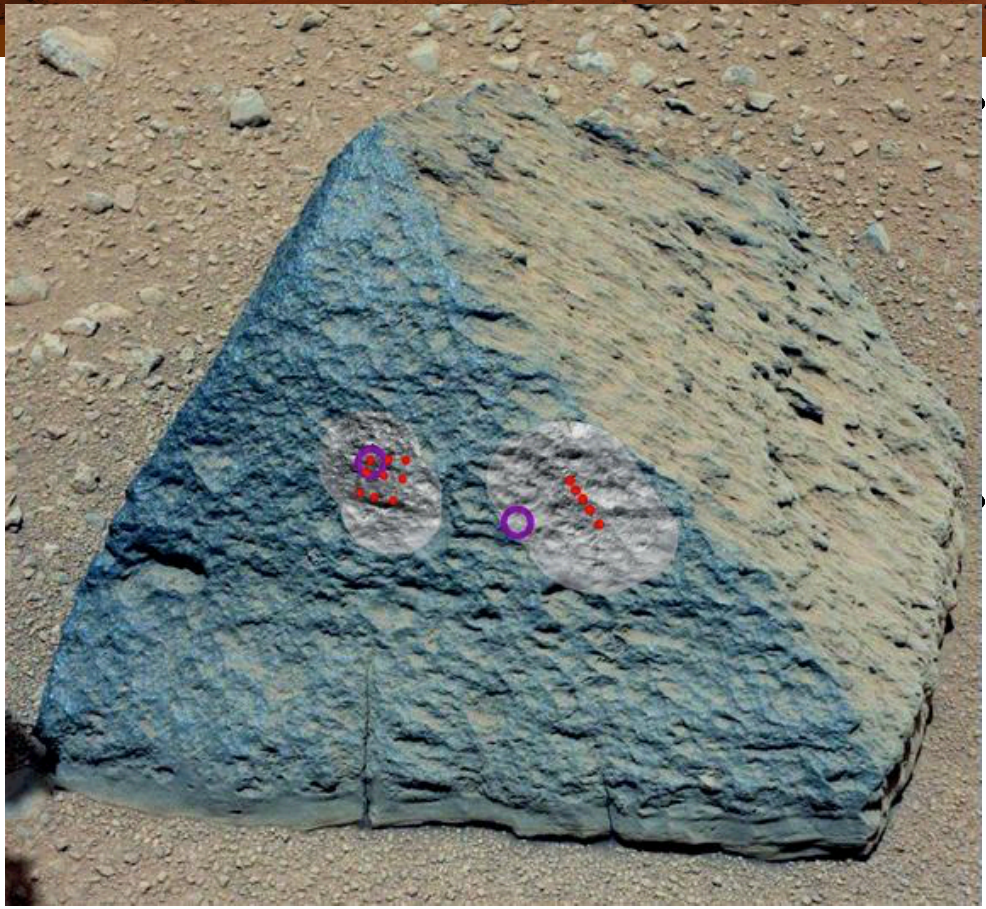

ISRU PILOT regolith extraction

ROxygen in operation



Heated tephra used in ROxygen reactor pouring out after reaction with hydrogen

Martian Rock "Jake Matijevic"



- Earth igneous rocks with this composition come from crystallization of relatively water-rich magma at elevated pressure. Such specimens are found on oceanic islands such as Hawai`i.
- 1st rock analyzed by the rover's arm-mounted Alpha Particle X-Ray Spectrometer (APXS) instrument and about the thirtieth rock examined by the Chemistry and Camera (ChemCam) instrument.

HI-SEAS Mars Analog Habitat

Pu`u Nene