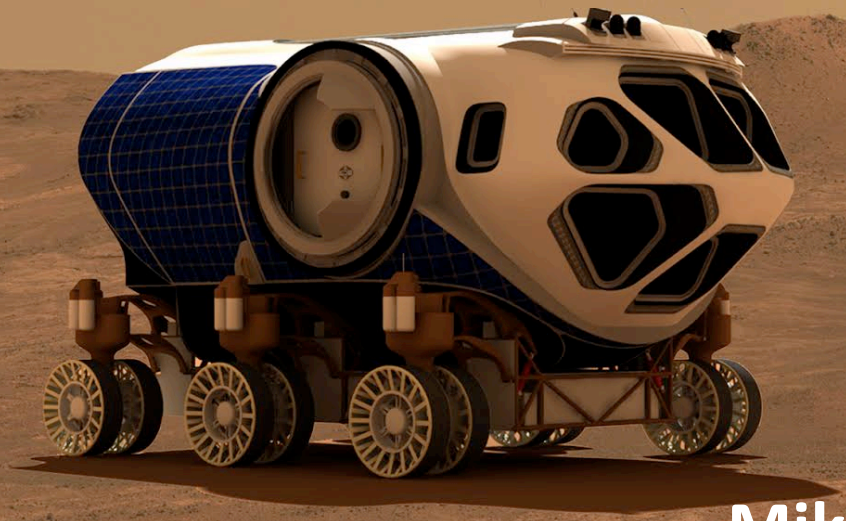
The Land Of Opportunity:
A Human Return To Meridiani Planum

Workshop Abstract 1030



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Jet Propulsion Laboratory

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NASA Marshall Space Flight Center

Why go back to Meridiani?

Safety

- Landing and trafficability:
  - Low, flat, and stable
  - Effectively no rock abundance
  - Shallow ripples over bedrock
  - Steep slopes only inside craters
  - Expansive benign terrain minimizes vehicle wear and tear on long traverses

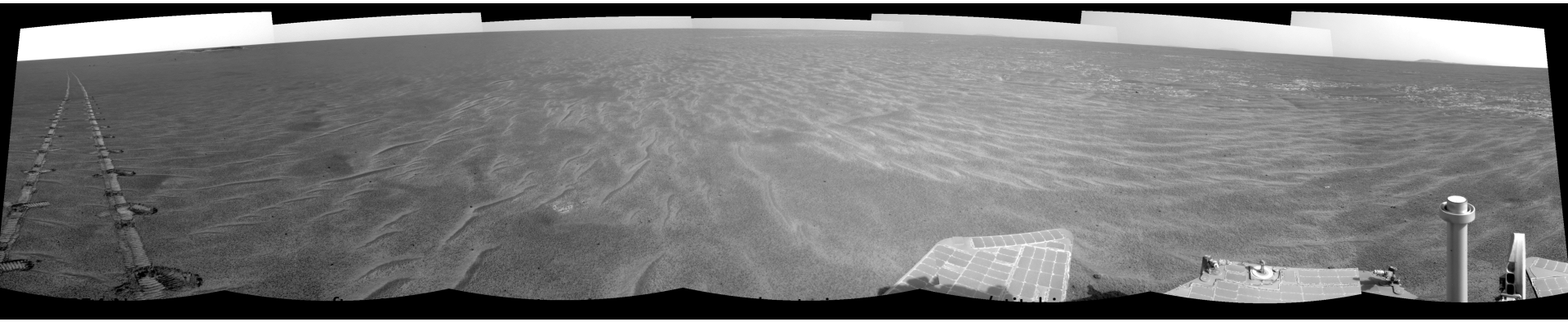
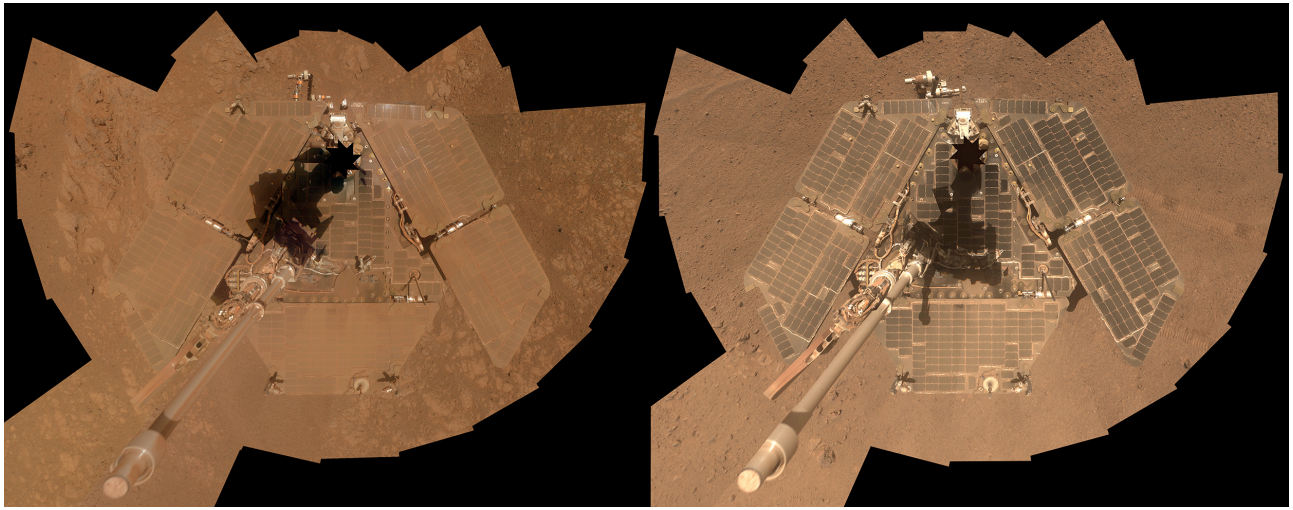


Image credit: NASA/JPL-CalTech

Why go back to Meridiani?

Safety

- Equatorial
  - Excellent solar insolation
  - Less seasonal thermal variation
  - Excellent lighting (glare, glint)
- Known dust environment
  - Daily tau measurements, known seasonal behavior
  - Known seasonal deposition & removal

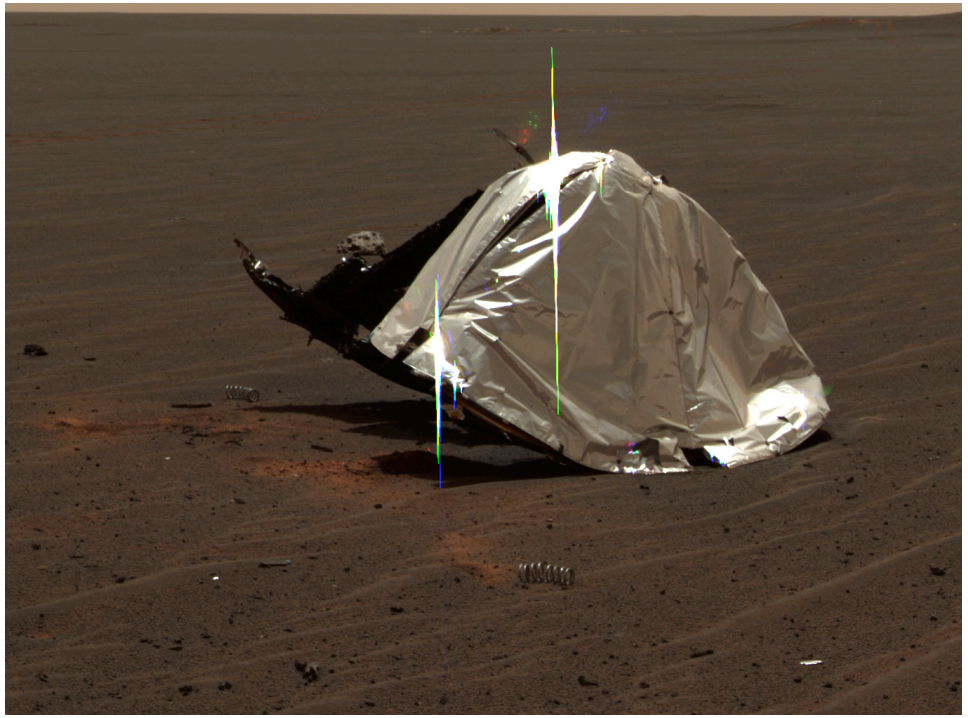


Dusty solar arrays in January 2014, Clean solar array in March 2014; 65% increase in array output
Image credit: NASA/JPL-Caltech/Cornell Univ./Arizona State Univ

Why go back to Meridiani?

Planetary Protection

- Forward contamination:
  - Large areas not possible habitats for extant life
  - Already contaminated (MER heat shield, backshell, parachute, lander, and Opportunity)
- Backwards contamination:
  - Large areas not possible habitats for extant life
  - Surface materials characterized with in-situ measurements (APXS & Mössbauer)



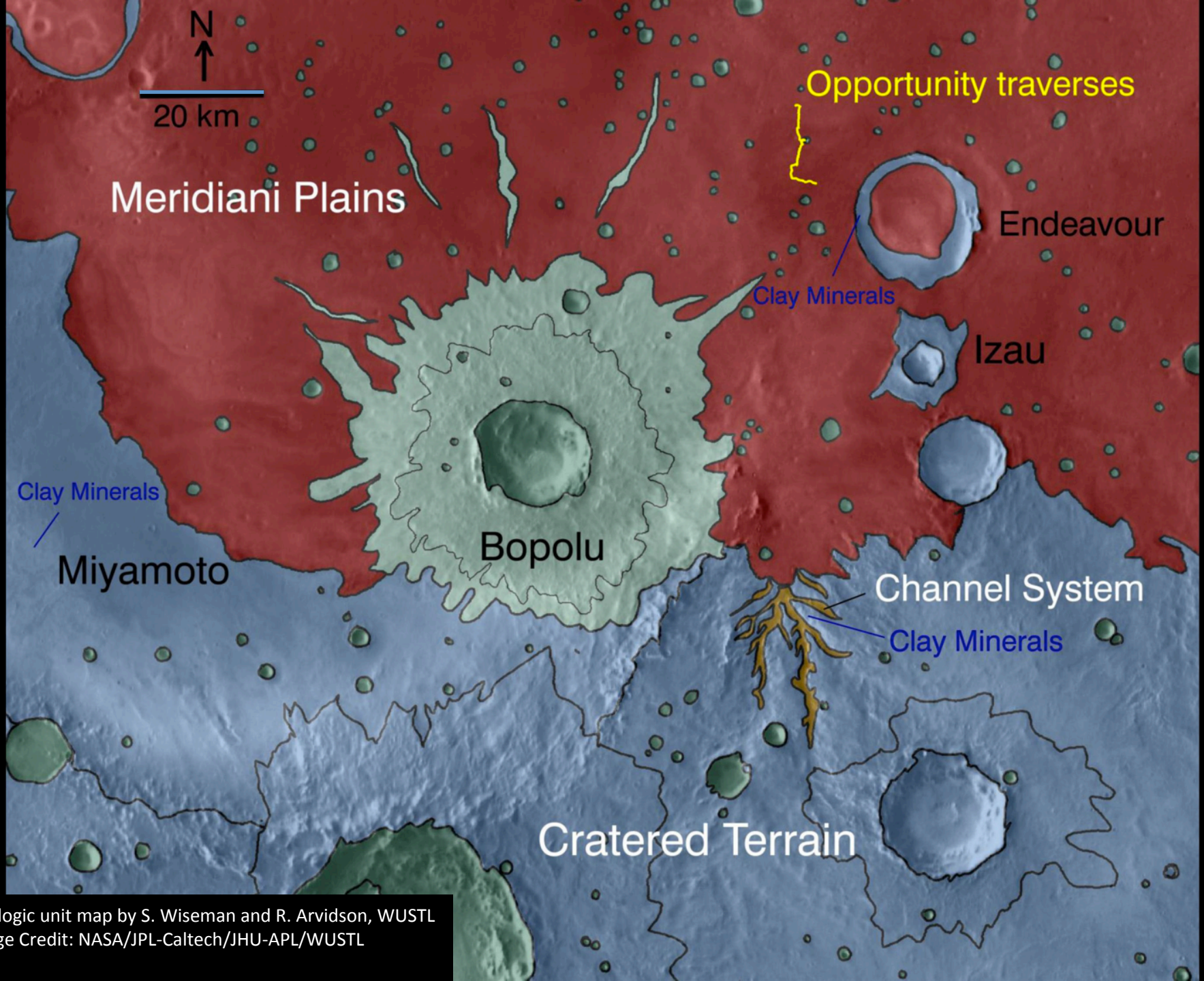
Opportunity's heatshield as seen on Sol 355, approximate true color
Image credit: NASA/JPL/Cornell

Why go back to Meridiani?

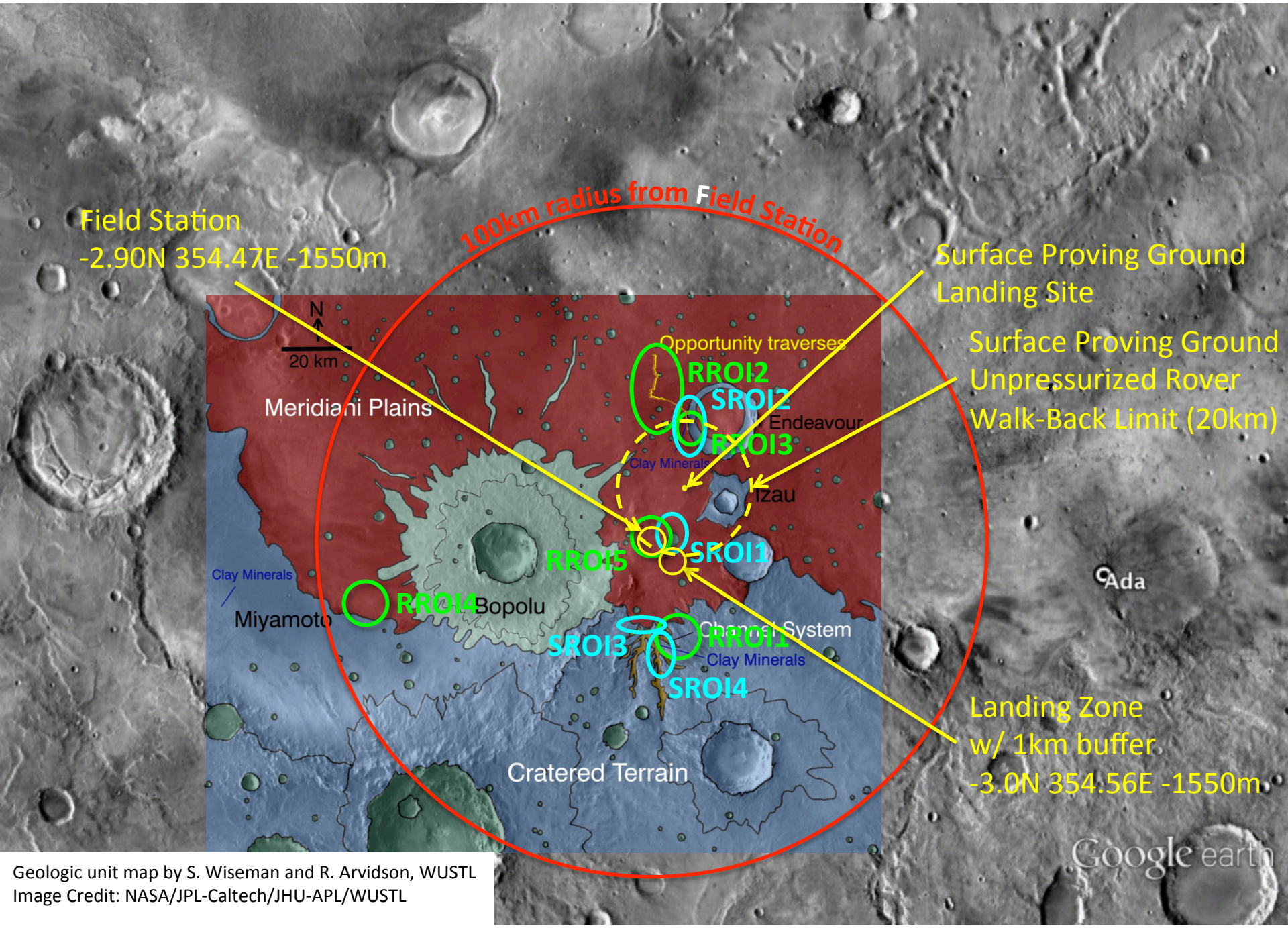
Follow Up Science

- Immediate follow up science with a surface proving ground mission:
  - Collection and return of high value targets
  - Enhanced context for existing measurements
- Long term follow-up science and continued exploration:
  - Perform new analyses on unreturnable science targets
  - Continue similar and expanded investigations past where Opportunity's mission ends*

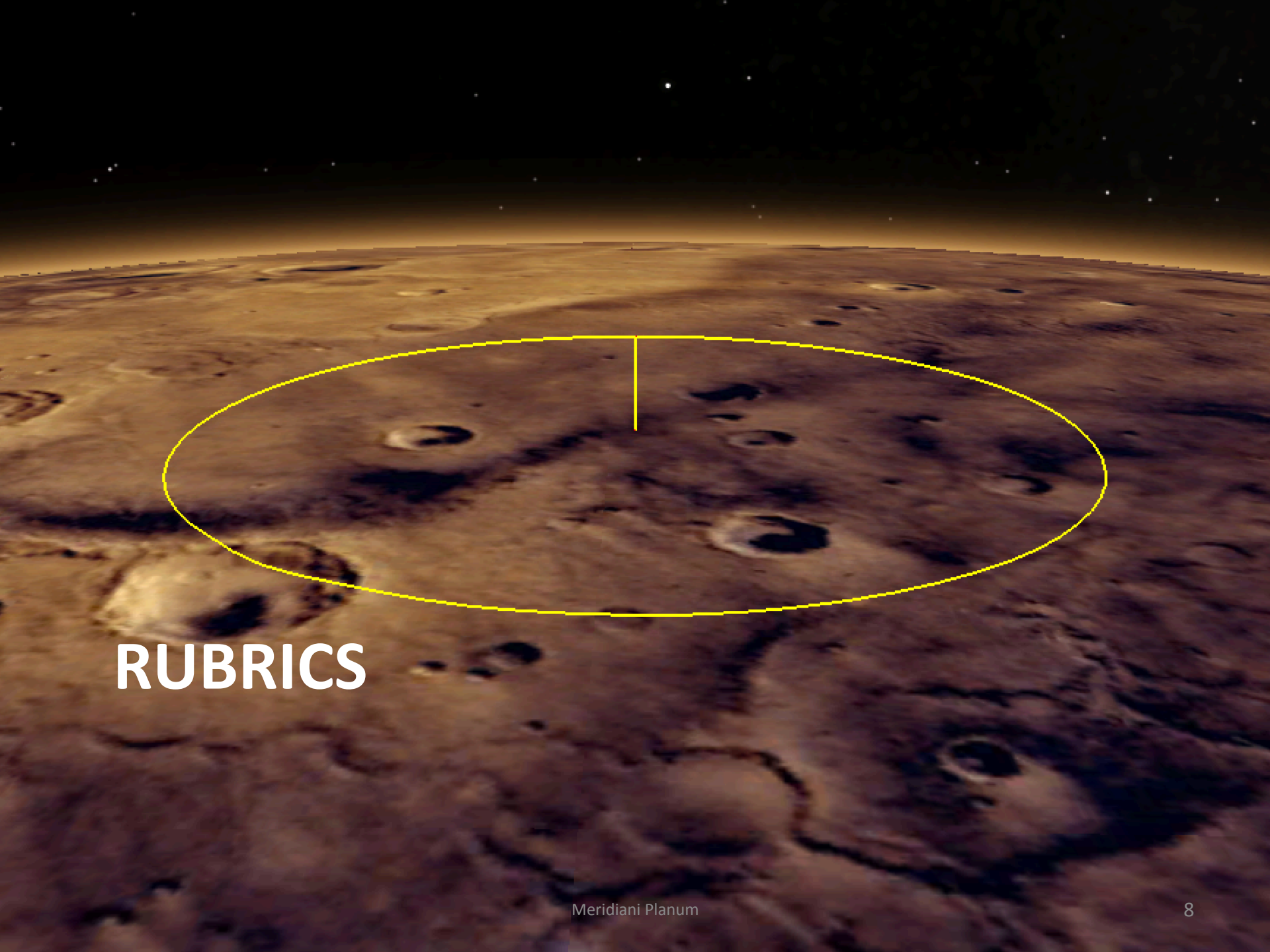
Pinnacle Island rock, Sol 3540
Image credit: NASA/JPL-Caltech/Cornell Univ./ Arizona State Univ.



Geologic unit map by S. Wiseman and R. Arvidson, WUSTL
Image Credit: NASA/JPL-Caltech/JHU-APL/WUSTL



Geologic unit map by S. Wiseman and R. Arvidson, WUSTL
Image Credit: NASA/JPL-Caltech/JHU-APL/WUSTL



RUBRICS

Science ROI(s) Rubric

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

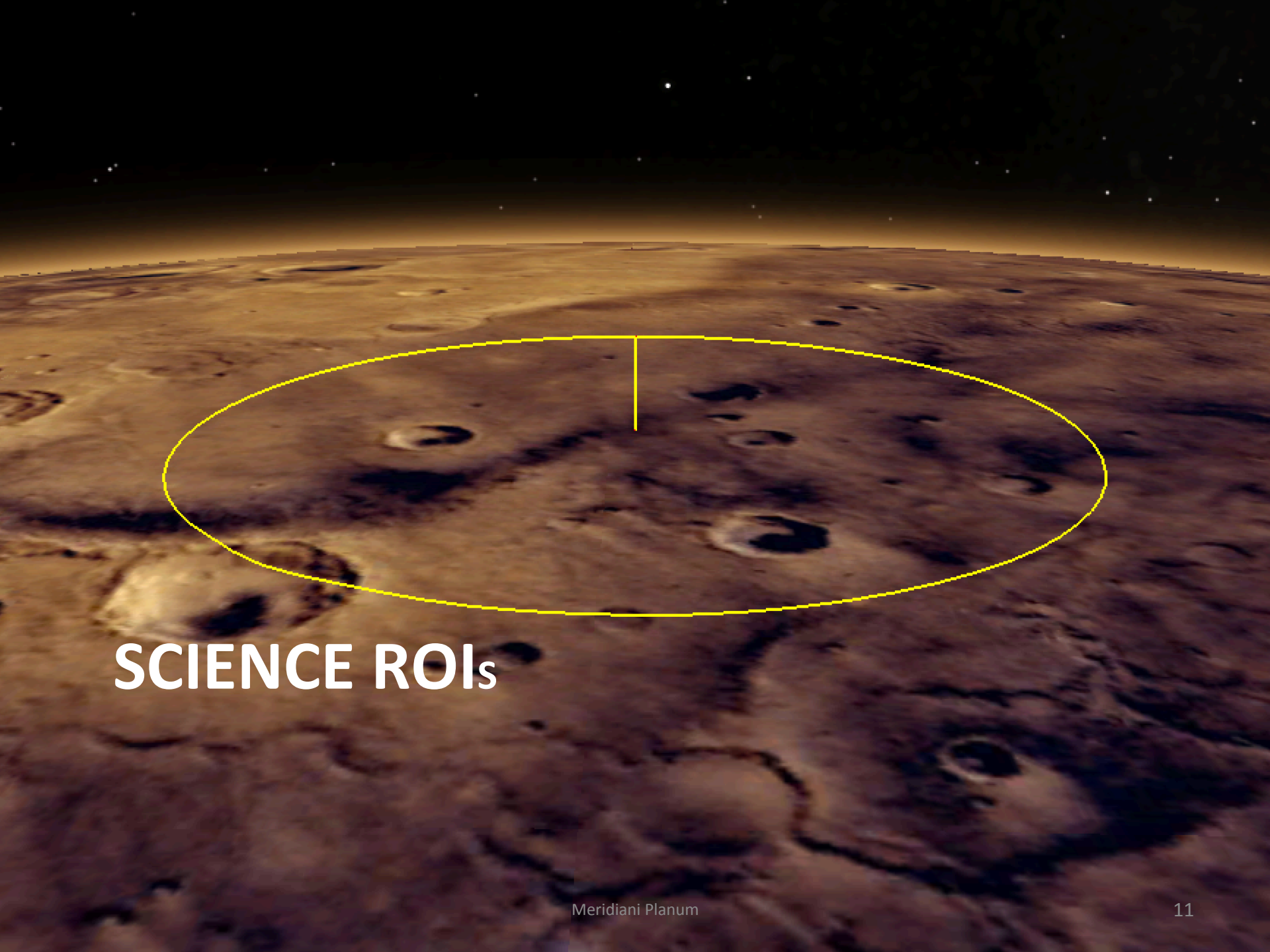
Complete this rubric and the one on the next slide for all ROIs (science and resource) in the proposed EZ. For each ROI, indicate whether the criteria is met fully or partially met using the key below. In the EZ SUM column, tally how many ROIs meet each criteria fully (n) and how many are met only partially (m) in the format n,m.

Key	
●	Yes
○	Partial Support or Debated
	No
?	Indeterminate

Resource ROI(s) Rubric

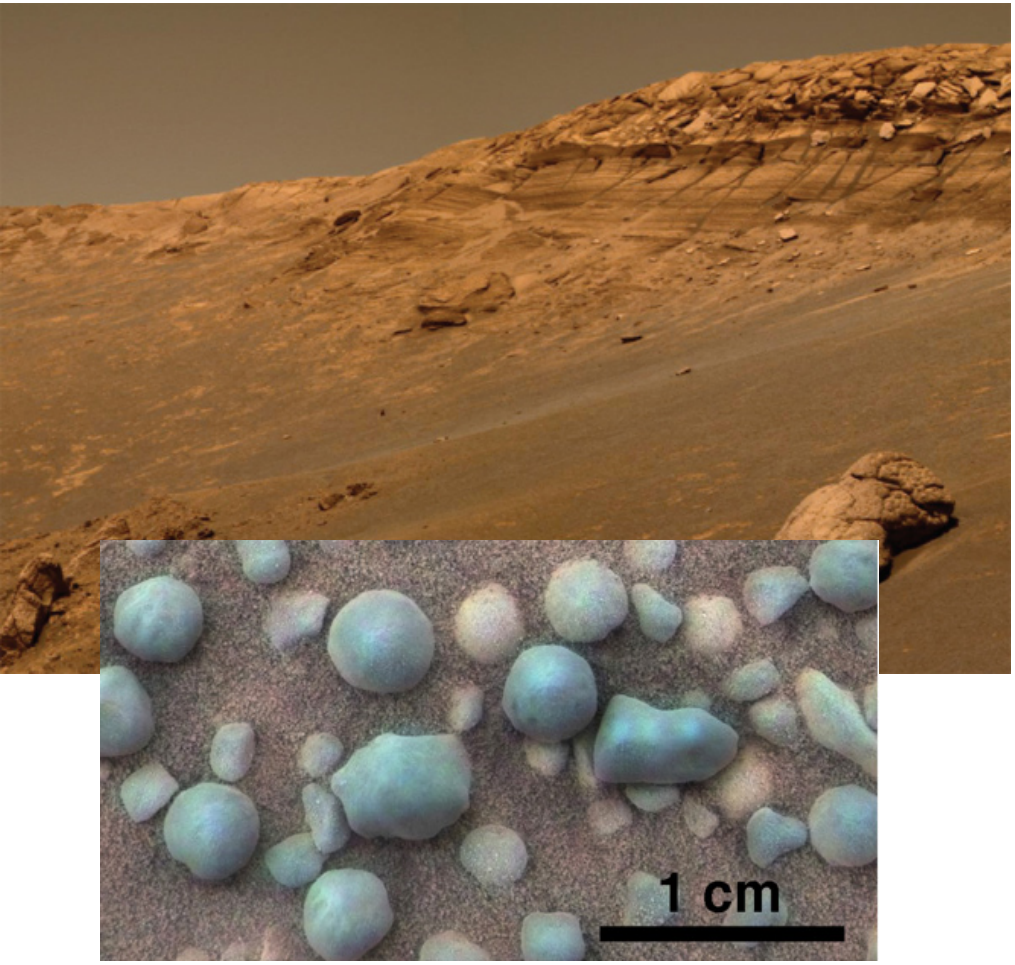
Site Factors				SROI1	SROI2	SROI3	RROI1	RROI2	RROI3	RROI4	RROI5	EZ SUM
ISRU and Civil Engineering Criteria	Engineering		Meets First Order Criteria (Latitude, Elevation, Thermal Inertia)	●	●	●	●	●	●	●	●	8,0
	Water Resource	Threshold	**Potential for ice or ice/regolith mix**									0,0
			AND/OR **Potential for hydrated minerals**	●	●	●	●		●	●		6,0
			Quantity for substantial production	○		○	●		●	○		2,3
			Potential to be minable by highly automated systems	○			○		○	○		0,4
			Located less than 3 km from processing equipment site	●			○		○	○		1,3
			Located no more than 3 meters below the surface	●		○	○		●	○		2,3
			Accessible by automated systems	●			●		●	○		3,1
		Qualifying	Potential for multiple sources of ice, ice/regolith mix **and** hydrated minerals									0,0
			Distance to resource location can be >5 km	●		○	○		○	○		1,4
			Route to resource location must be (plausibly) traversable	●	●	●	●		●	●		6,0
	Civil Engineering	Threshold	**~50 sq km region of flat and stable terrain with sparse rock distribution**	●	●	●		●	●	●	●	7,0
			1–10 km length scale: <10°	●	●	●	●	●	●	●	●	8,0
			Located within 5 km of landing site location	●							●	2,0
		Qualifying	Located in the northern hemisphere	●	●	●	●	●	●	●	●	8,0
			Evidence of abundant cobble sized or smaller rocks and bulk, loose regolith	●	●	●	●	●	●	●	●	8,0
			Utilitarian terrain features	●	●	●	●	●	●	●	●	8,0
	Food Production	Qualifying	Low latitude	●	●	●	●	●	●	●	●	8,0
			No local terrain feature(s) that could shadow light collection facilities	●	●	○	●	●	○	●	●	6,2
			Access to water									0,0
			Access to dark, minimally altered basaltic sands	●	○	○	○	●	○	○	●	3,5
	Metal/Silicon Resource	Threshold	**Potential for metal/silicon**	●	●	●	●	●	●	●	●	8,0
			Potential to be minable by highly automated systems	●	●	○	○	●	○	○	●	4,4
			Located less than 3 km from processing equipment site	●			○	●	○	○	●	3,3
			Located no more than 3 meters below the surface	●		○	○	●	○	○	●	3,4
			Accessible by automated systems	●		○	○	●	●	●	●	5,2
		Qualifying	Potential for multiple sources of metals/silicon	●		○	○	●	○	○	●	3,4
			Distance to resource location can be >5 km	●			●	●	●	●	●	6,0
			Route to resource location must be (plausibly) traversable	●	●	○	○	●	●	○	●	5,3

Key	
●	Yes
○	Partial Support or Debated
	No
?	Indeterminate



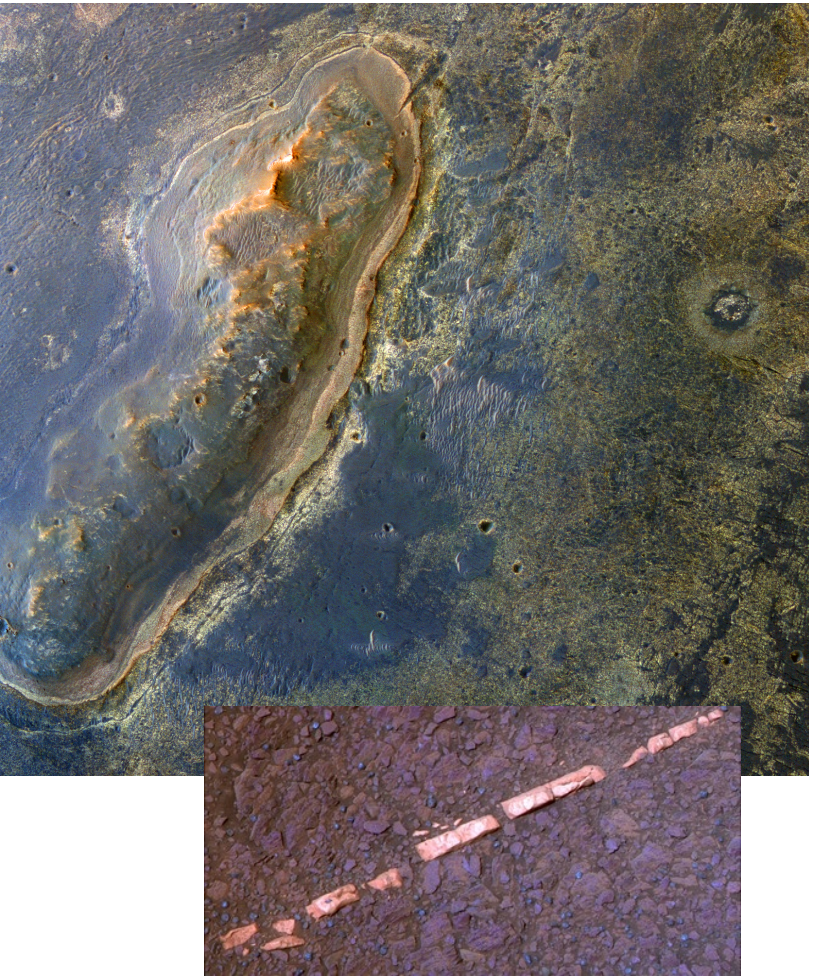
SCIENCE ROIs

Science ROI 1



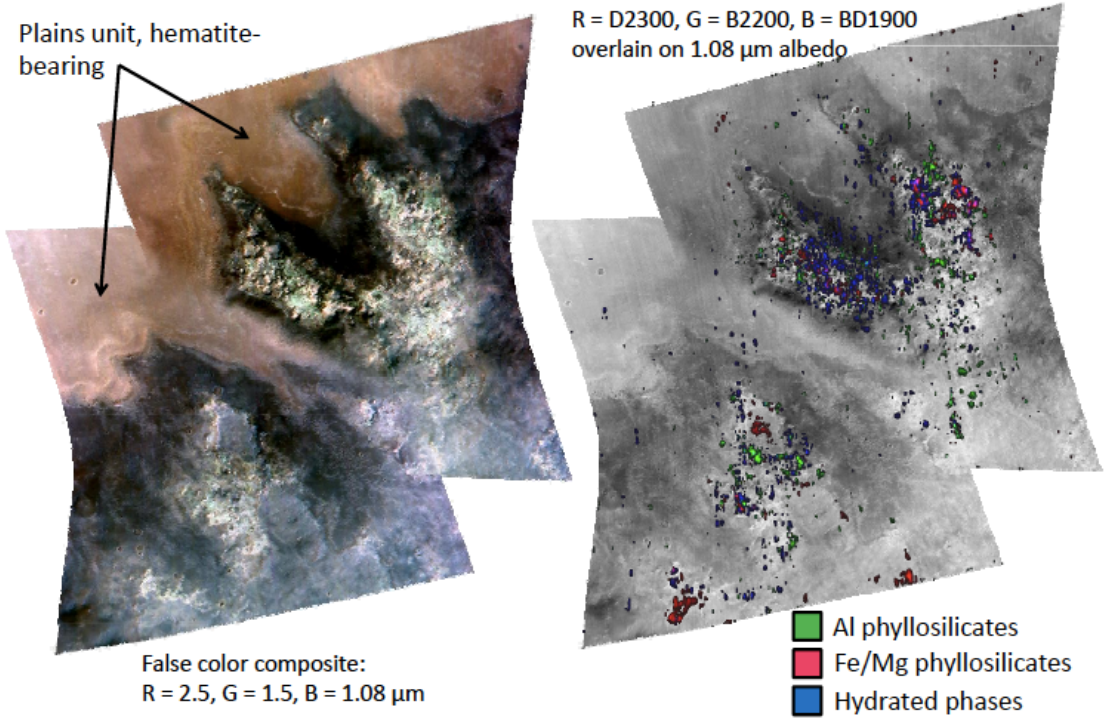
- **Meridiani Plains unit**; this is just an example ROI – the unit is widespread in the EZ
- (c) *Exposures of at least two crustal units that have regional or global extents, that are suitable for radiometric dating*: regionally extensive, contiguous units that contain datable minerals (K-rich sulfate)
- d) *Access to outcrops with morphological and/or geochemical signatures (with preference for sites that link the two) indicative of aqueous or groundwater/mineral interactions*: sedimentary sulfate-rich deposits with gypsum veins and hematite concretions

Science ROI 2



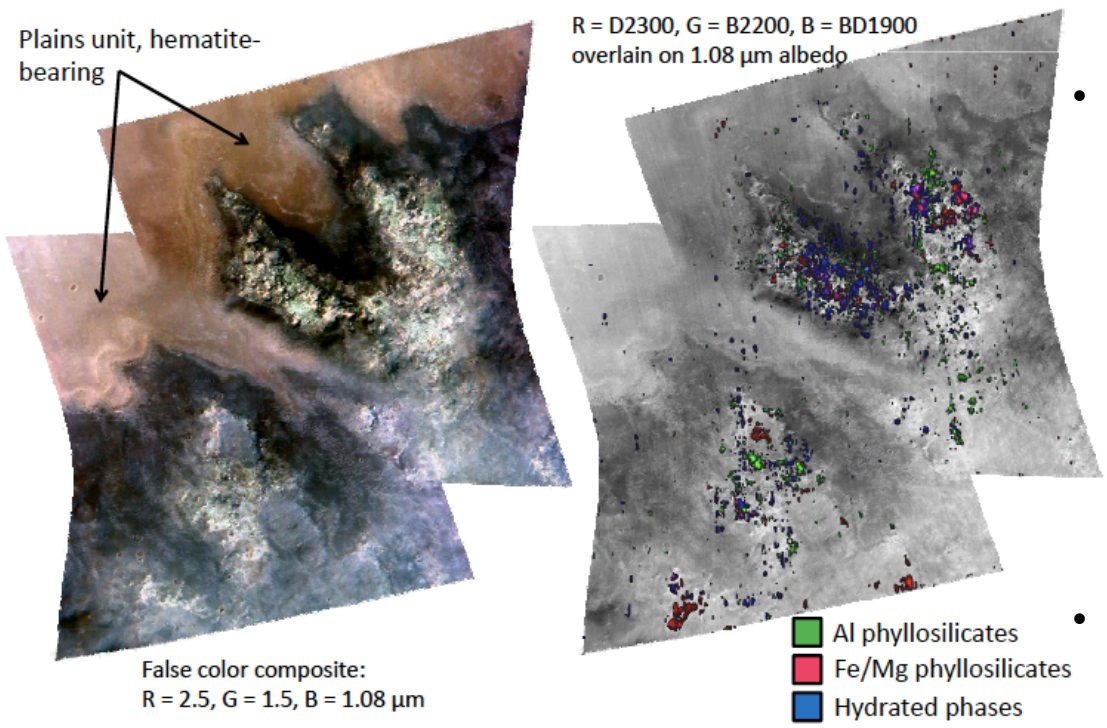
- **Endeavour Crater rim**
- (a) *Access to deposits with a high preservation potential for evidence of past habitability and fossil biosignatures and/or sites that are promising for present habitability*: phyllosilicates and sulfates detected at Endeavour Crater
- (b) *Noachian and/or Hesperian rocks in a stratigraphic context that have a high likelihood of containing trapped atmospheric gases:* CRISM phyllosilicate spectral signatures correlate with polygonally-fractured bedrock in HiRISE, meaning that the phyllosilicates are in place and have appropriate stratigraphic context
- (d) *Access to outcrops with morphological and/or geochemical signatures (with preference for sites that link the two) indicative of aqueous or groundwater/mineral interactions*: gypsum veins found on the rim of Endeavor

Science ROIs 3 & 4

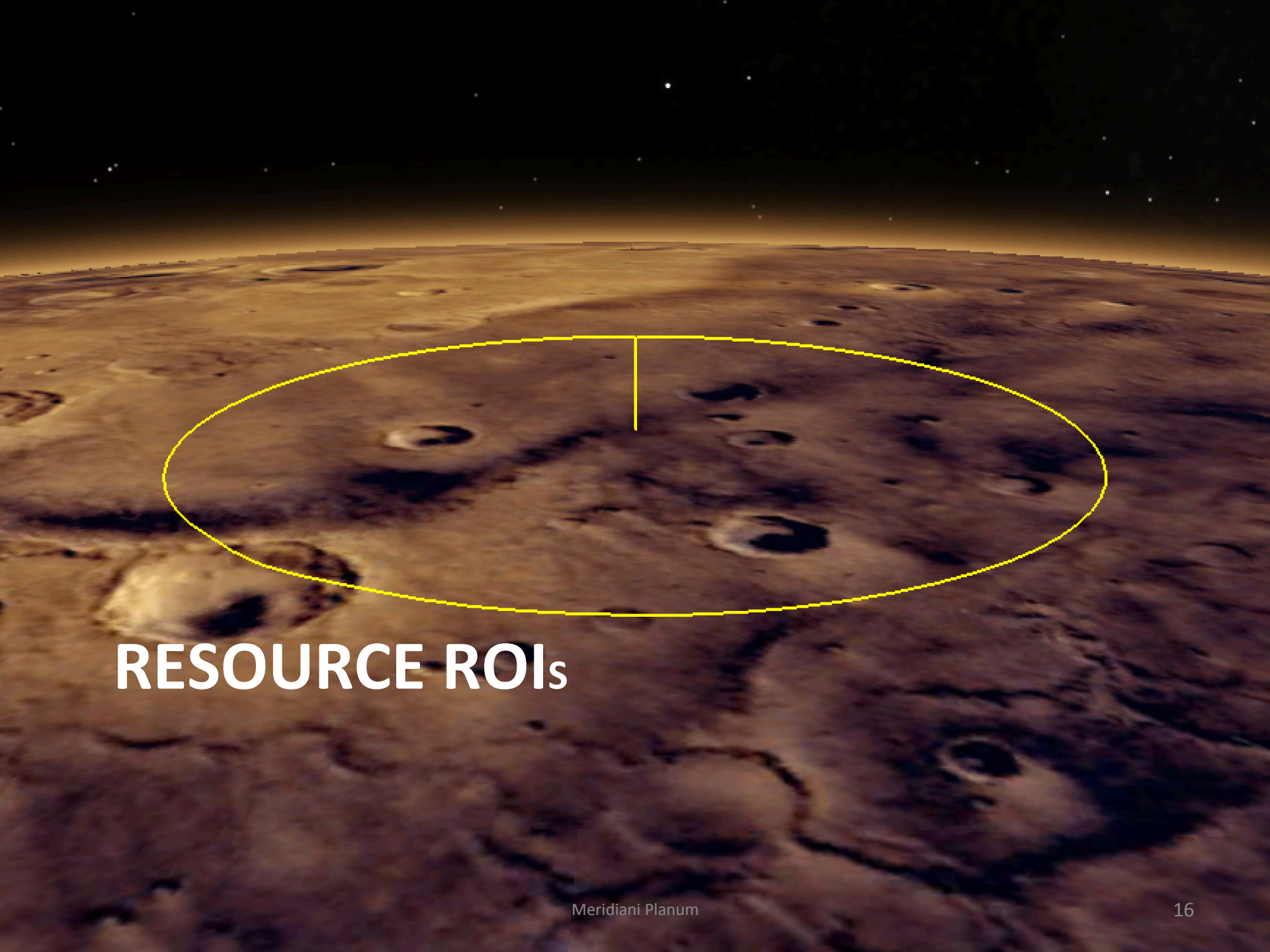


- **Channeled terrain into Hesperian basement**
- (a) *Access to deposits with a high preservation potential for evidence of past habitability and fossil biosignatures and/or sites that are promising for present habitability*: phyllosilicates buried in the walls of craters preserved by overlying burden
- (b) *Noachian and/or Hesperian rocks in a stratigraphic context that have a high likelihood of containing trapped atmospheric gases:* CRISM phyllosilicate spectral signatures correlate with polygonally-fractured bedrock in HiRISE, meaning that the phyllosilicates are in place and have appropriate stratigraphic context

Science ROIs 3 & 4

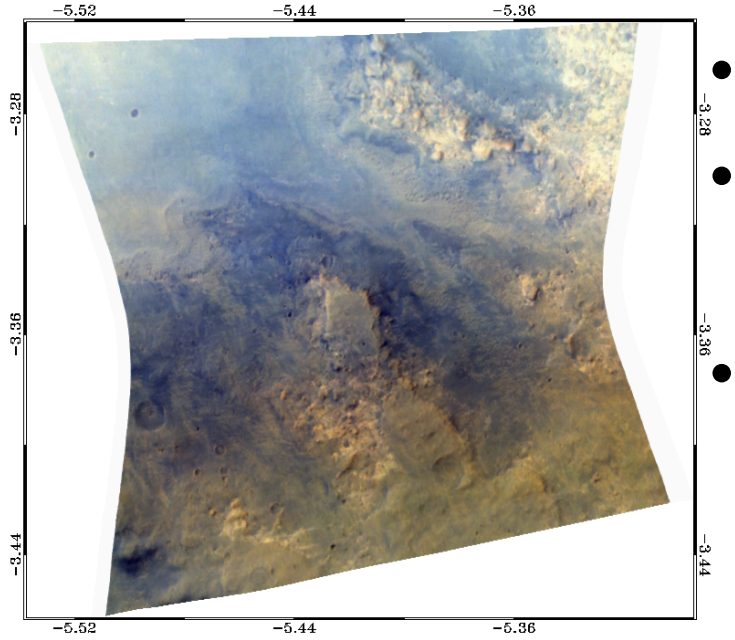


- **Channeled terrain into Hesperian basement**
- (c) *Exposures of at least two crustal units that have regional or global extents, that are suitable for radiometric dating, and that have relative ages that sample a significant range of Martian geological time*. Intact Noachian / Hesperian contact; phyllosilicates are datable minerals (though date alteration), but unaltered basalt may also be present
- (e) *Identifiable stratigraphic contacts and cross-cutting relationships from which relative ages can be determined*: identifiable contact between the plains and cratered terrain, conveniently cut by a channel for access.



RESOURCE ROIs

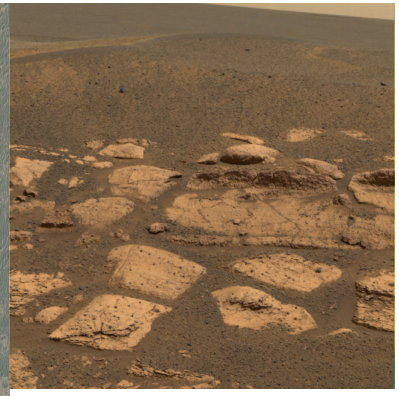
Resource ROI 1



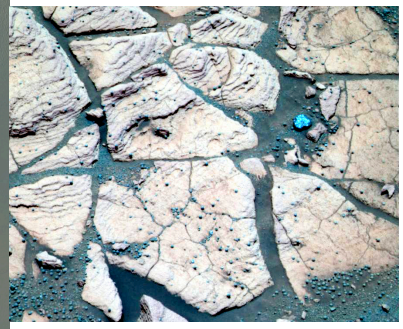
Enhanced Visible Color (592nm, 533nm, 492nm). CRISM observation 000091C5Image credit: NASA/Johns Hopkins University Applied Physics Laboratory

- 3.35°S 354.59°E -1625m;
- Existing imagery: CRISM FRT, HiRISE, CTX, partial MOC
- Water resource
  - Hydrated minerals (phylosillicates)
  - Route to RROI1 is traversable based on CTX & HiRISE

Resource ROI 2



Opportunity Pancam RGB Sol 17
Image credit: NASA/JPL/Cornell



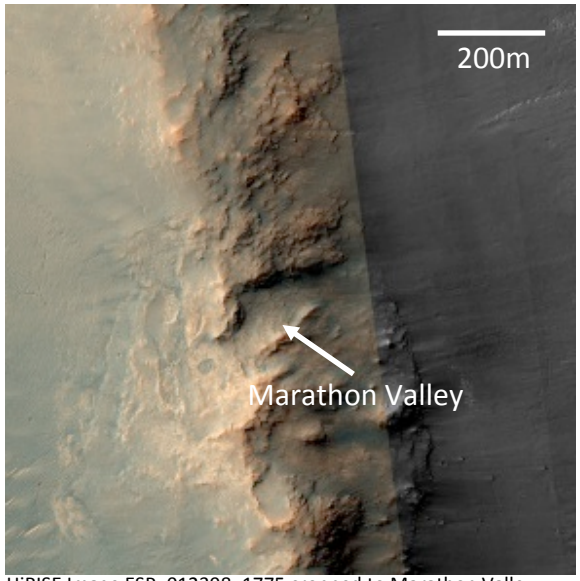
Opportunity Pancam False Color Sol 50
Image credit: NASA/JPL/Cornell

- -2.044°N, 354.497°E, -1364m; extends across substantial portion of EZ including Field Station site
- Existing imagery: CRISM FTR, HiRISE, HRSC, CTX, MOC, Opportunity Pancam, Microscopic Imager, Mössbauer, APXS & MiniTES
- Food Production
  - Surface covering predominantly basaltic sand
- Metal/Silicon Resource
  - Hematite spherules mixed in surface covering and embedded in bedrock[1]
  - Easily accessible by automated systems due loose nature of material on surface
  - Outcrop materials are high silica content magnesium and calcium sulfates[1]

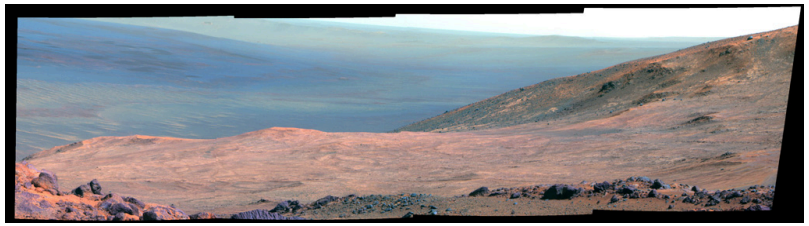
HiRISE Image TRA_000873_1780 cropped Victoria Crater region
Image credit: NASA/JPL-CalTech/University of Arizona

1Christensen, P., et al. Mineralogy at Meridiani Planum from the Mini-TES Experiment on the Opportunity Rover. Science: 306. 1733-1739.

Resource ROI 3



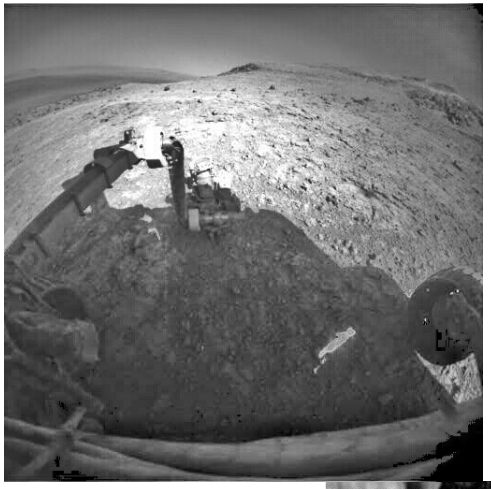
HiRISE Image ESP_012398_1775 cropped to Marathon Valley
Image credit: NASA/JPL-CalTech/University of Arizona

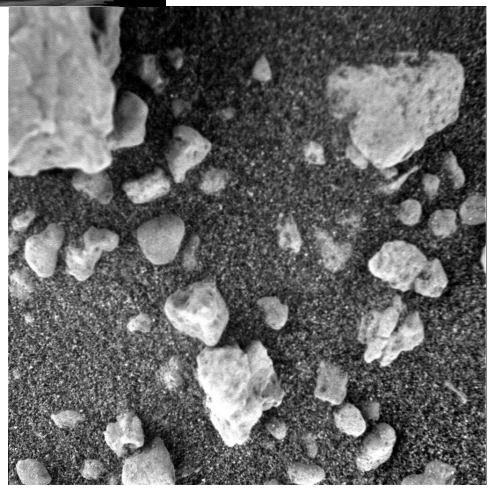


Marathon Valley overlook. False color (753nm, 535nm, 432nm). JPL image number: PIA19152
Image credit: NASA/JPL-CalTech/Cornell Univ./Arizona State Univ.

- -2.312°, 354.653°, -1450m
- Existing imagery: HiRISE; CTX; CRISM; MER-B Pancam, Microscopic Imager, & APXS
- Water Resource
  - Hydrated minerals (phylosillicates)
  - Route proven traversable

Resource ROI 3

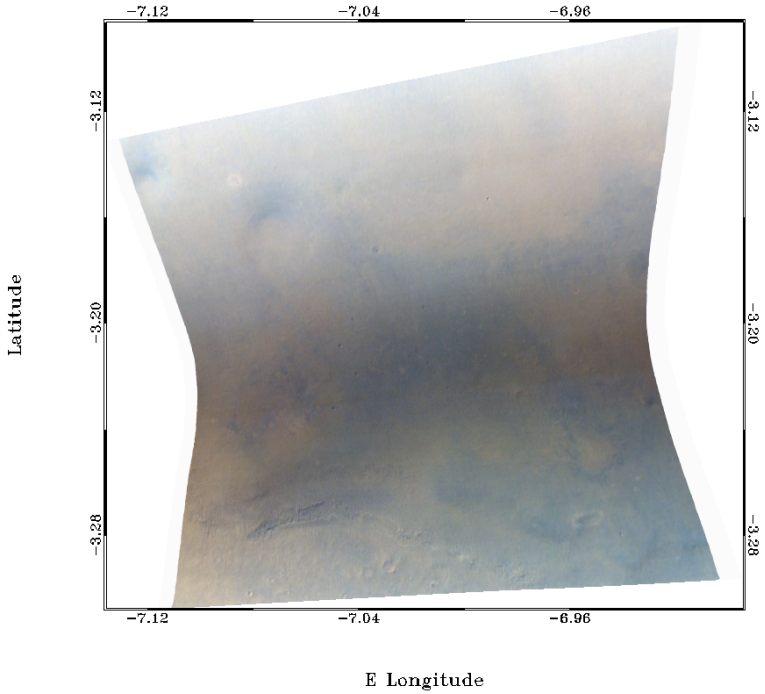




- -2.312°, 354.653°, -1450m
- Existing imagery: HiRISE; CTX; CRISM; MER-B Pancam, Microscopic Imager, & APXS
- Water Resource
  - Hydrated minerals (phylosillicates)
  - Route proven traversable

Sol 4180 IDD MI in Marathon Valley
Image credit: NASA/JPL-CalTech, Sourced from Mars Images App

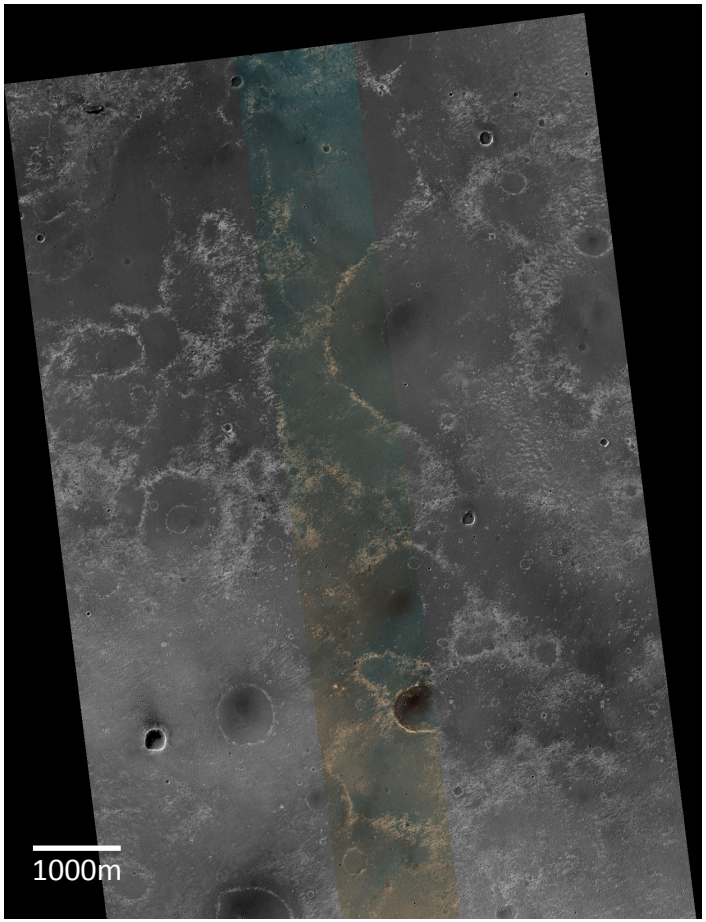
Resource ROI 4



Enhanced Visible Color (592nm, 533nm, 492nm). CRISM observation 0000B410
Image credit: NASA/Johns Hopkins University Applied Physics Laboratory

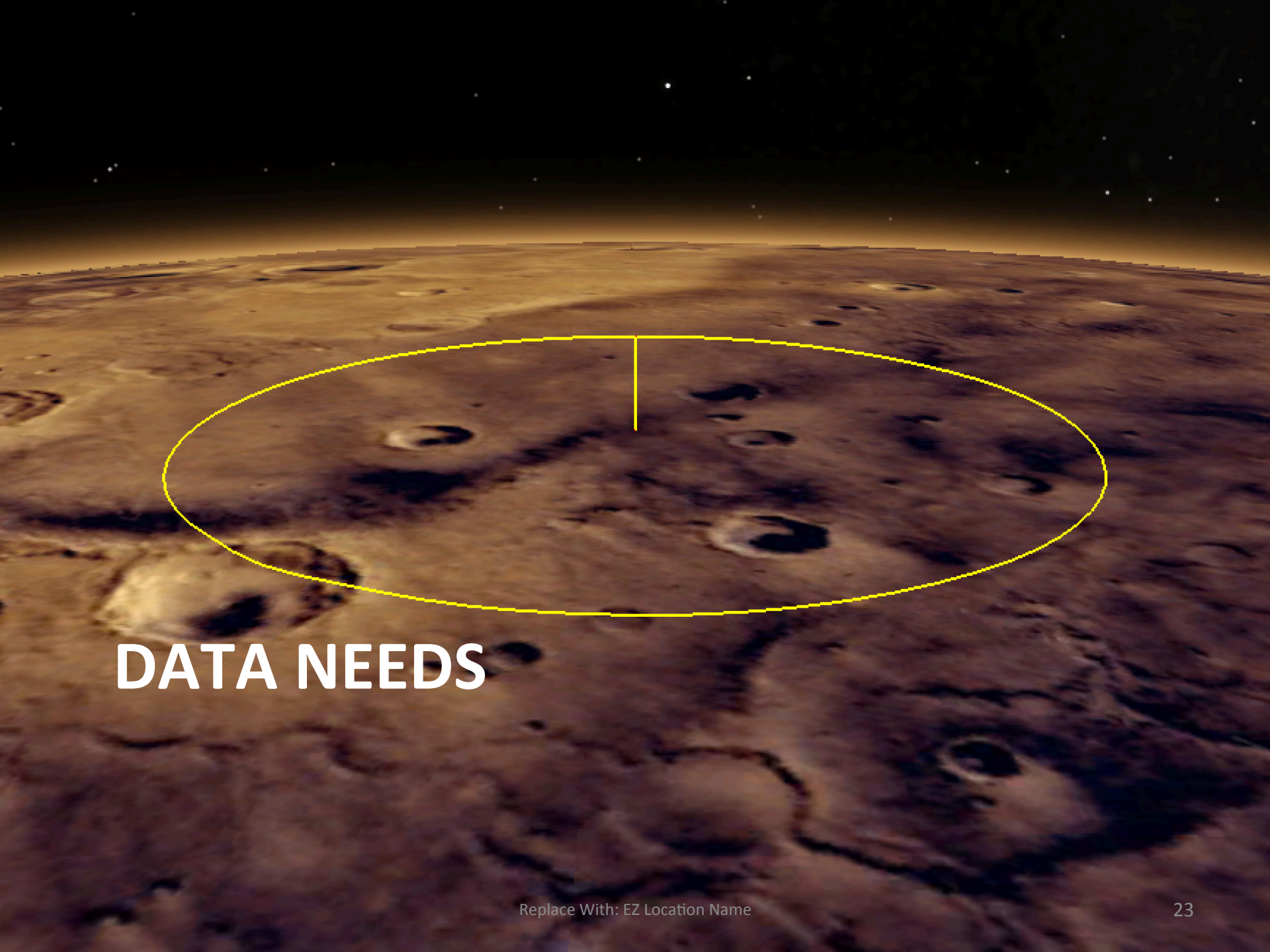
- 3.20°S 352.99°E -1820m,
- Existing imagery: CRISM FRT, HiRISE, CTX
- Phyllosilicates, unaltered basaltic sands
- Water resource
  - Probable hydrated minerals (phyllosilicates) based on CRISM
- Food Production:
  - Probable surface covering predominantly bassltic sands
- Metal/Silicon Resource
  - Probable
  - Easily accessible by automated systems due loose nature of material on surface
  - Outcrop materials are likely Burns formation with high silica content magnesium and calcium sulfates (similar to RROI2)

Resource ROI 5

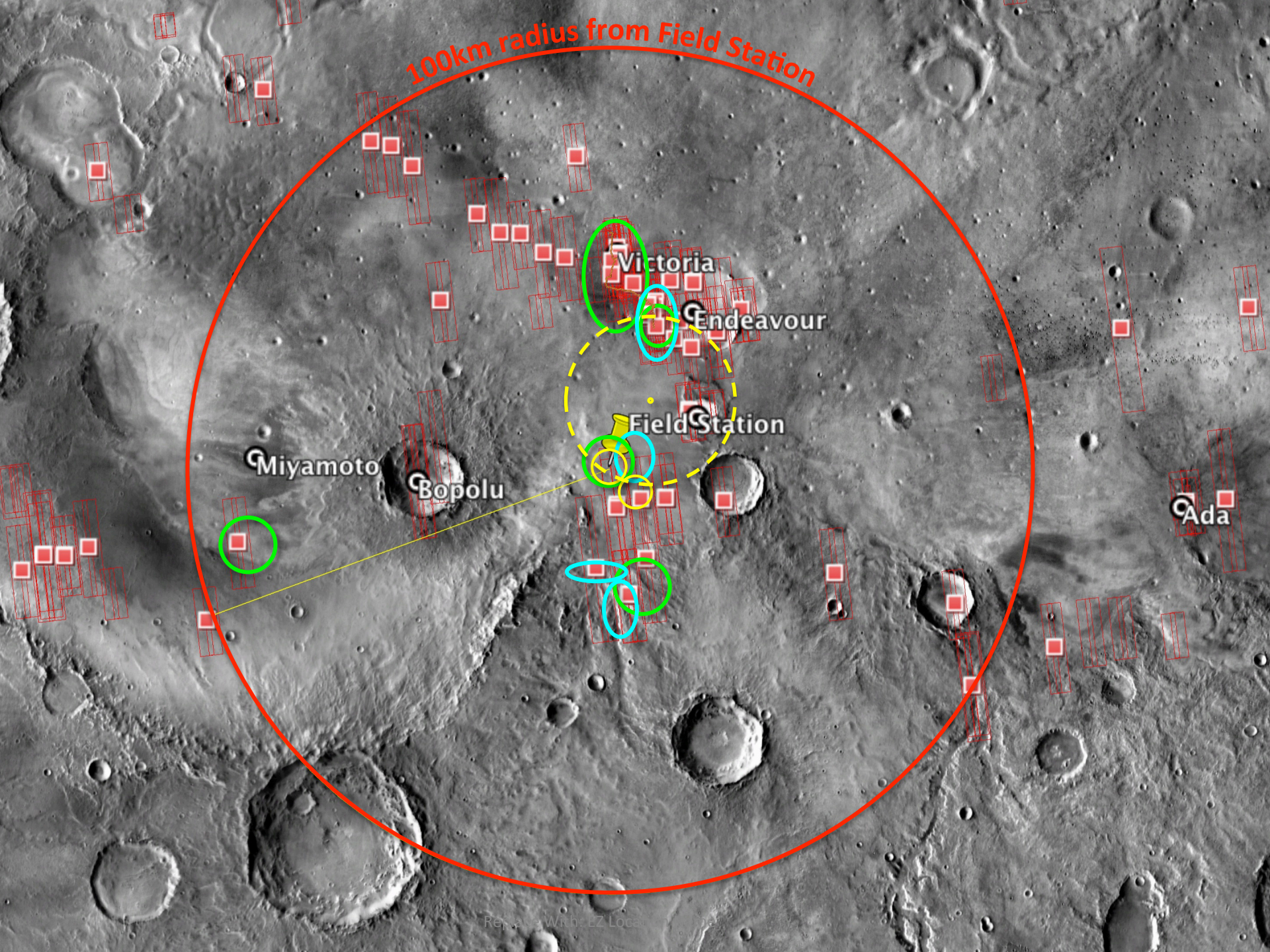


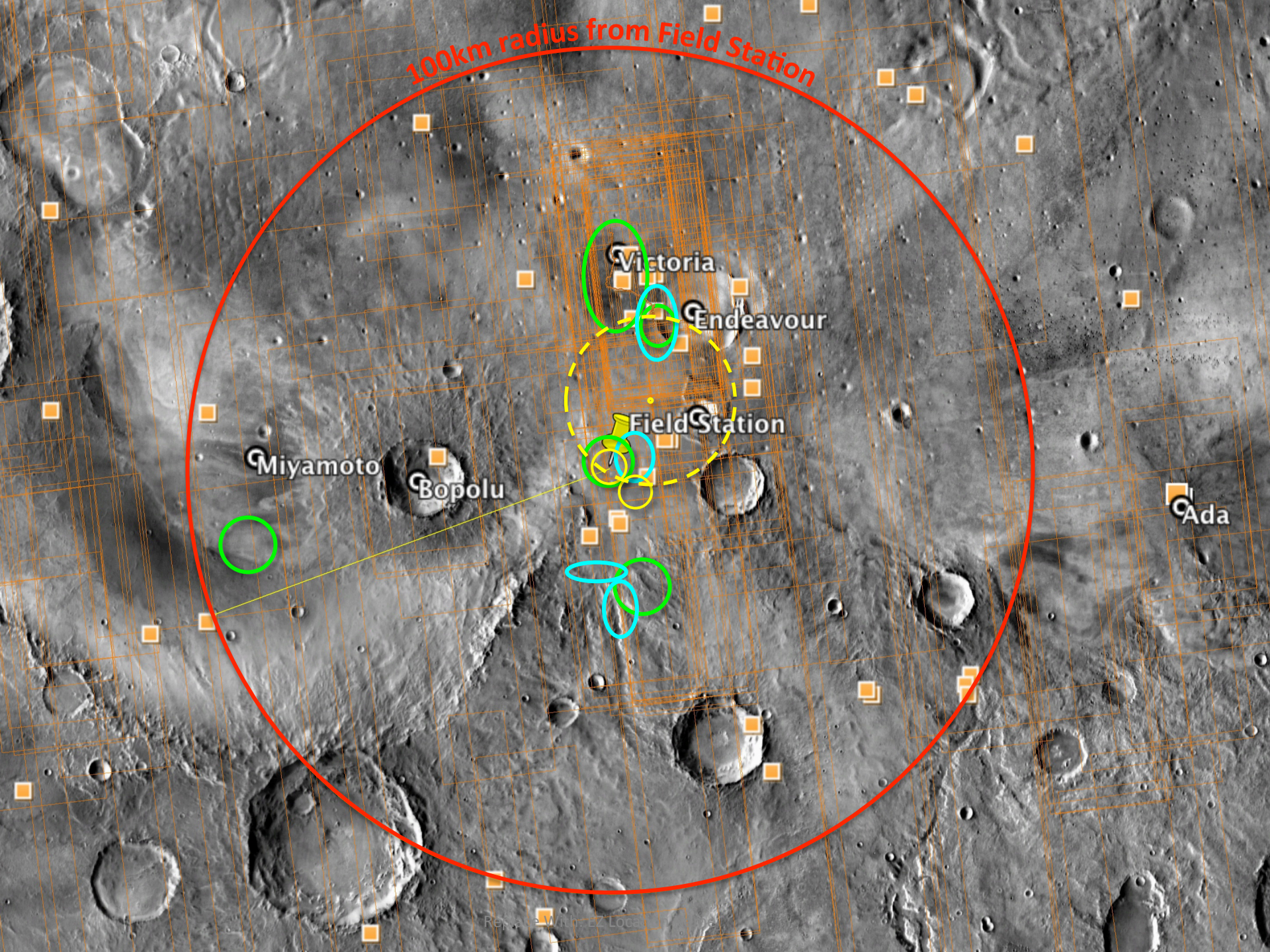
HiRISE Image PSP_009563_1770 cropped to proposed field station
Image credit: NASA/JPL-CalTech/University of Arizona

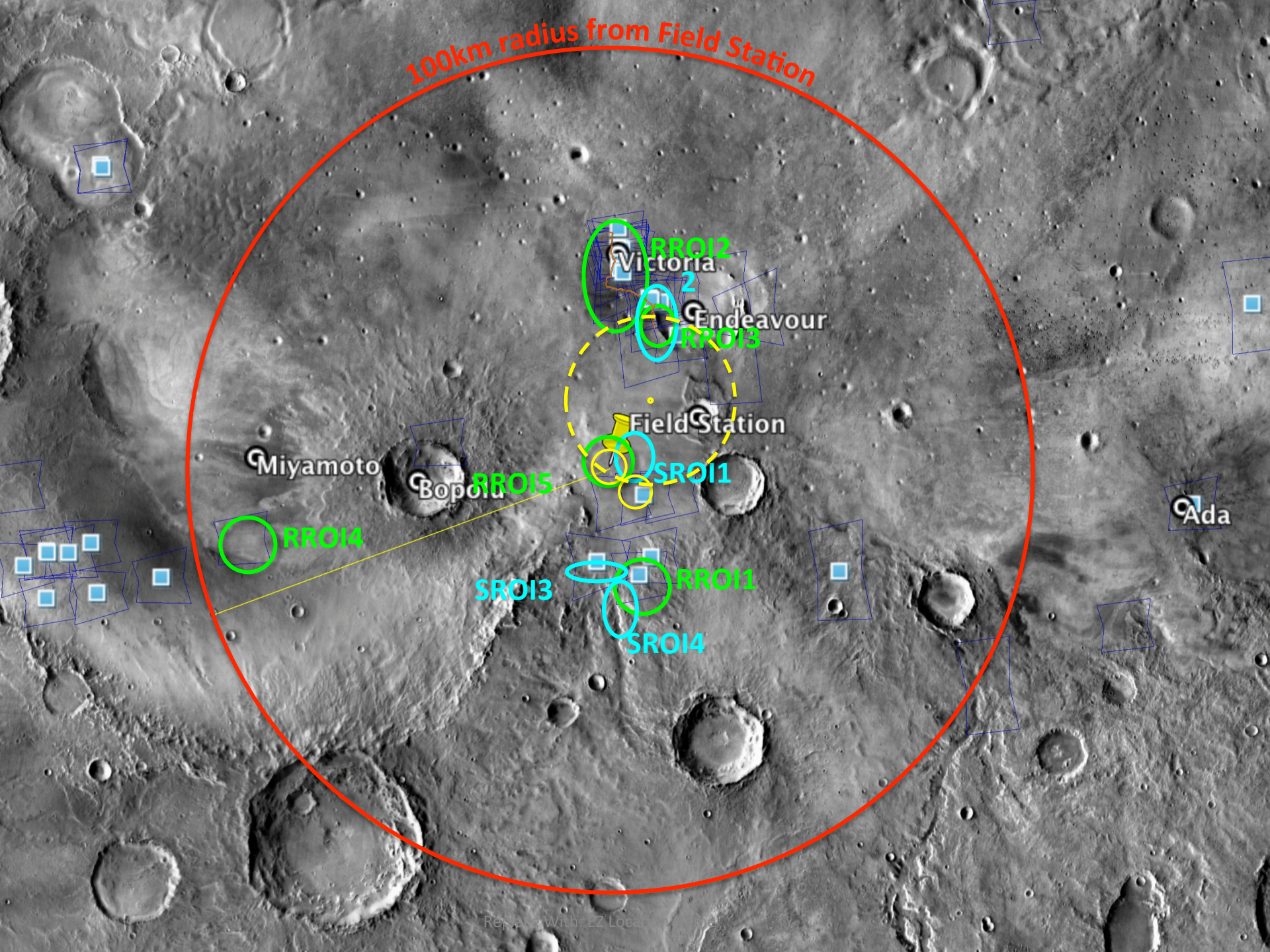
- -2.90N 354.47E -1550m (Field Station)
- Partial CRISM FRT, HiRISE, CTX, MOC
- Food Production:
  - Low latitude, no shadowing features
  - Probable surface covering of predominantly basaltic sands
- Metal/Silicon Resource
  - Probable hematite spherules
  - Easily accessible by automated systems due loose nature of material on surface
  - Outcrop materials are likely Burns formation with high silica content magnesium and calcium sulfates (similar to RROI2)



DATA NEEDS

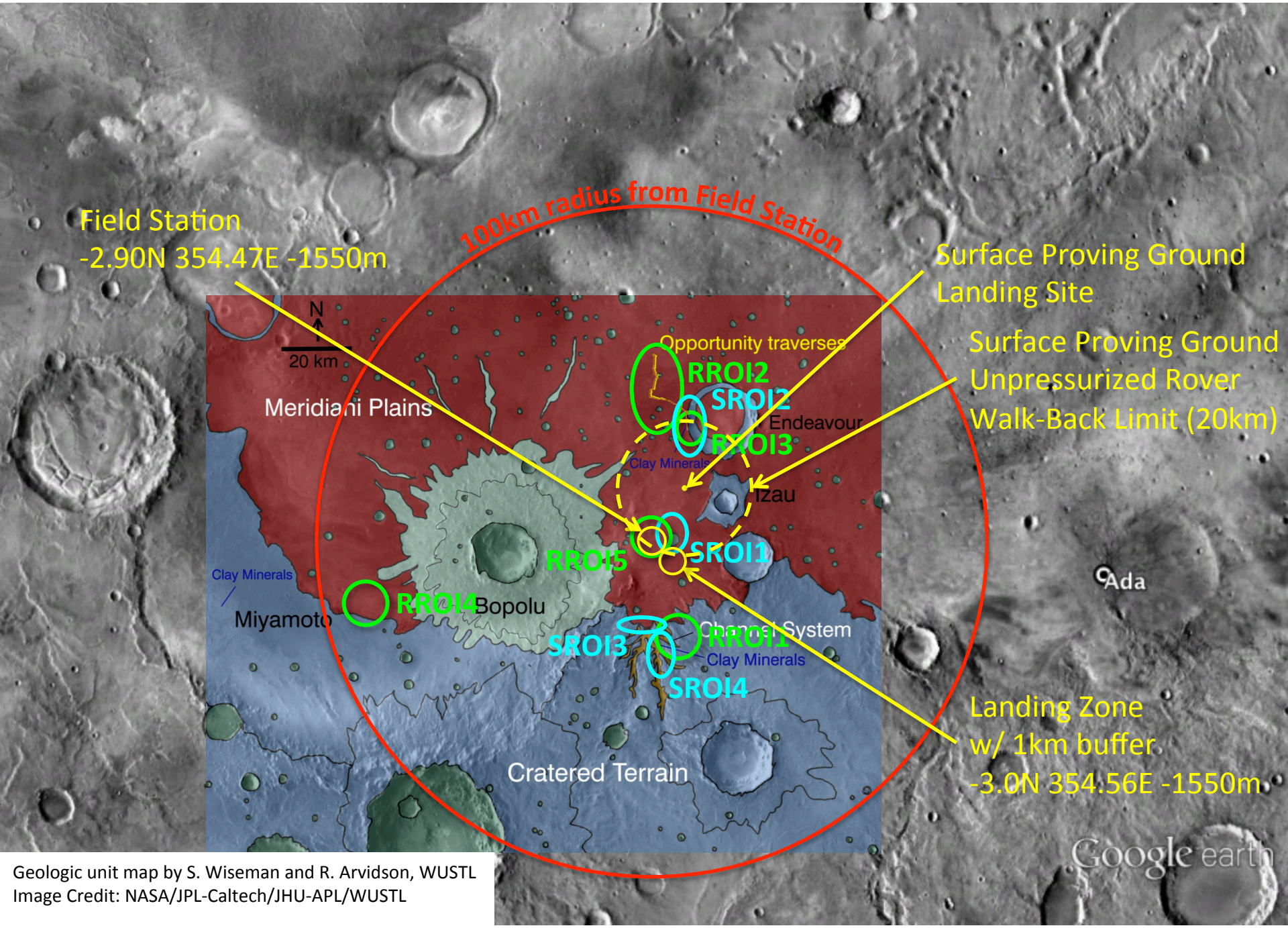

100km radius from Field Station
Victoria
Endeavour
Field Station
Miyamoto
Bopolu
Ada


100km radius from Field Station
Victoria
Endeavour
Field Station
Miyamoto
Bopolu
Ada

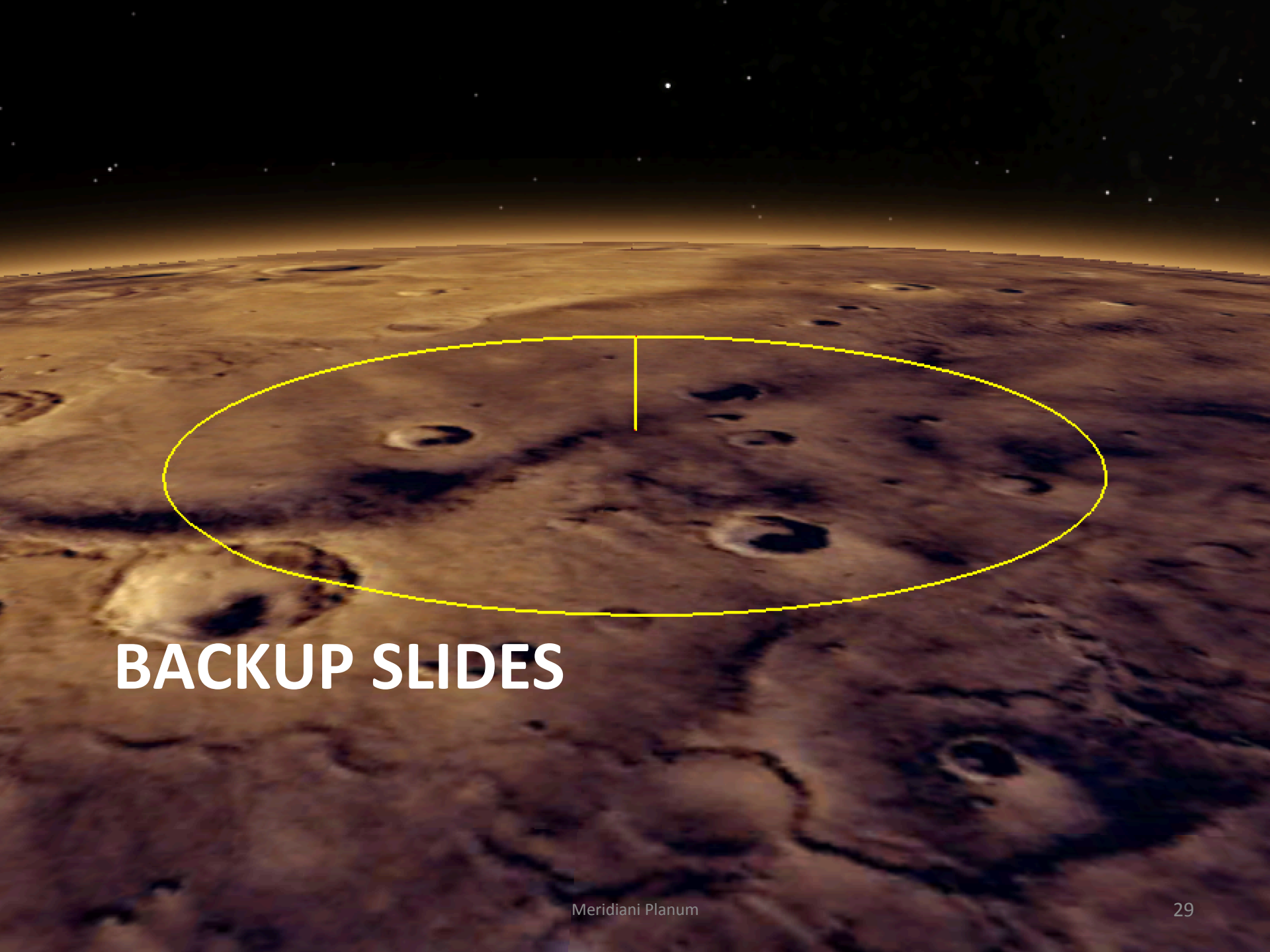

100km radius from Field Station
RROI2
Victoria
2
Endeavour
RROI3
Field Station
Miyamoto
Bopolu
RROI5
SROI1
RROI4
Ada
SROI3
RROI1
SROI4

Highest Priority EZ Data Needs

- Science Potential Assessment
  - Expanded CRISM coverage over the SROI3 & SROI4 area.
- Resource Potential Assessment
  - CRISM oversampling of the RROI1 region to establish the spatial extent of and strength of the phylloysillicate signal. This will be used to improve estimates of water output from ISRU processing of these materials.



Geologic unit map by S. Wiseman and R. Arvidson, WUSTL
Image Credit: NASA/JPL-Caltech/JHU-APL/WUSTL



BACKUP SLIDES

Prioritization List of EZ Data Needs

Science Imaging:

- SROI3&4 Phyllosilicate Assessment:
  - CRISM targeted oversampling
  - -3.28°N 354.52°E
  - Establish extent of hydrated minerals
- SROI3&4 Slope/Trafficability Assessment:
  - HiRISE DTM and slope map
  - -3.28°N 354.48°E
  - Verify that channels between Meridiani and cratered terrain is trafficable

Prioritization List of EZ Data Needs

- RROI1 Phyllosilicate Assessment:
  - CRISM targeted oversampling
  - -3.35°N 354.59°E, -3.27°N 354.64°E, and -3.35°N 354.72°E
  - Establish spatial extent and abundance of hydrated minerals
- RROI1 Slope/Trafficability Assessment:
  - HiRISE DTM and slope map
  - -3.33°N 354.63°E
  - Verify that channels between Meridiani and cratered terrain is trafficable
- RROI4 Phyllosilicate Assessment:
  - CRISM targeted oversampling
  - -3.20°N 352.99°E
  - Establish spatial extent and abundance of hydrated minerals
- HiRISE Slope Maps of Field Station Site
  - HiRISE stereo to cover a 5km radius around specified center
  - -2.90N 354.47E
  - Verify that the Field Station site meets slope and civil engineering requirements