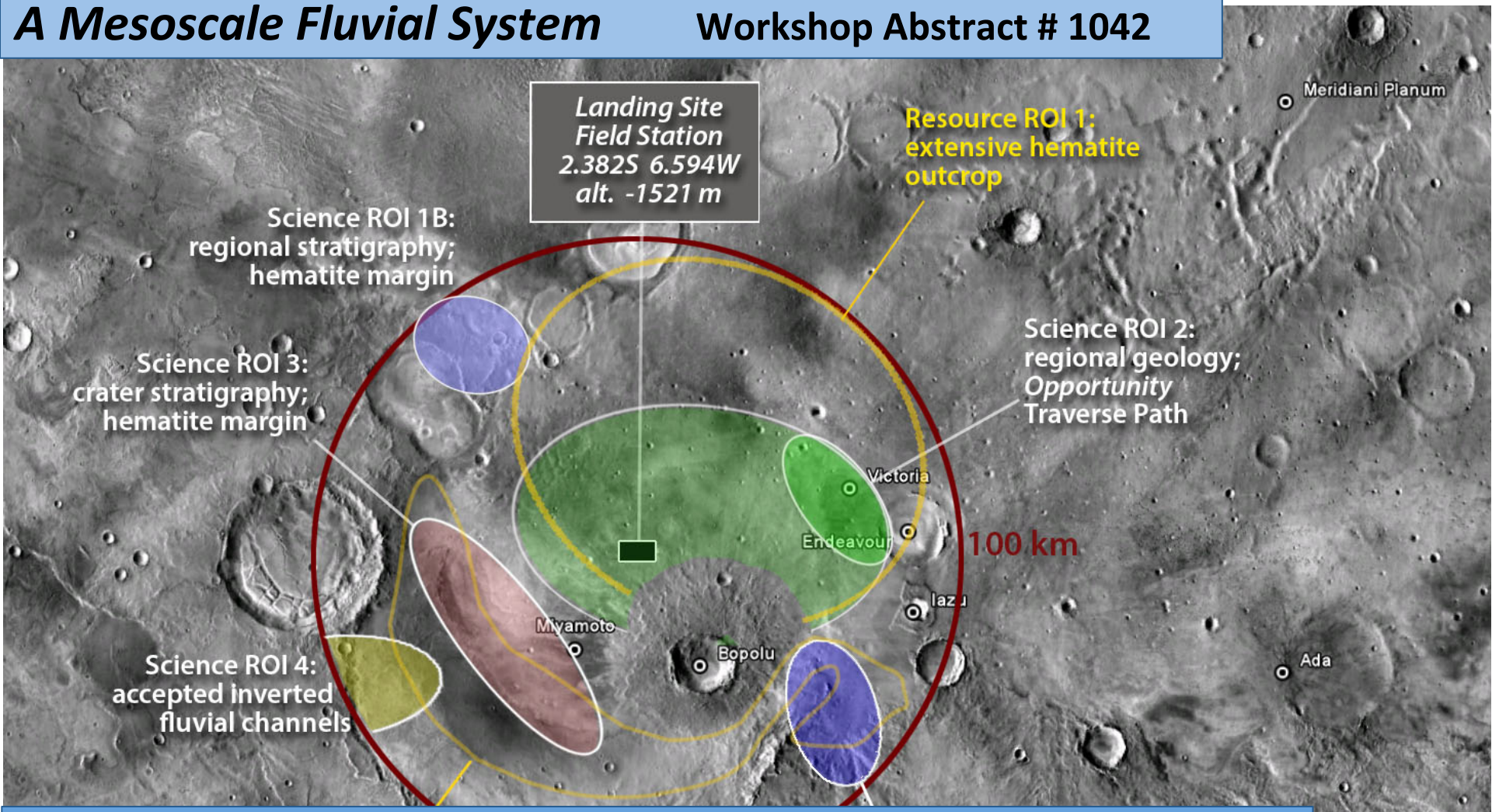
Sinus Meridiani Landing Site for Human Exploration — A Mesoscale Fluvial System

Workshop Abstract # 1042



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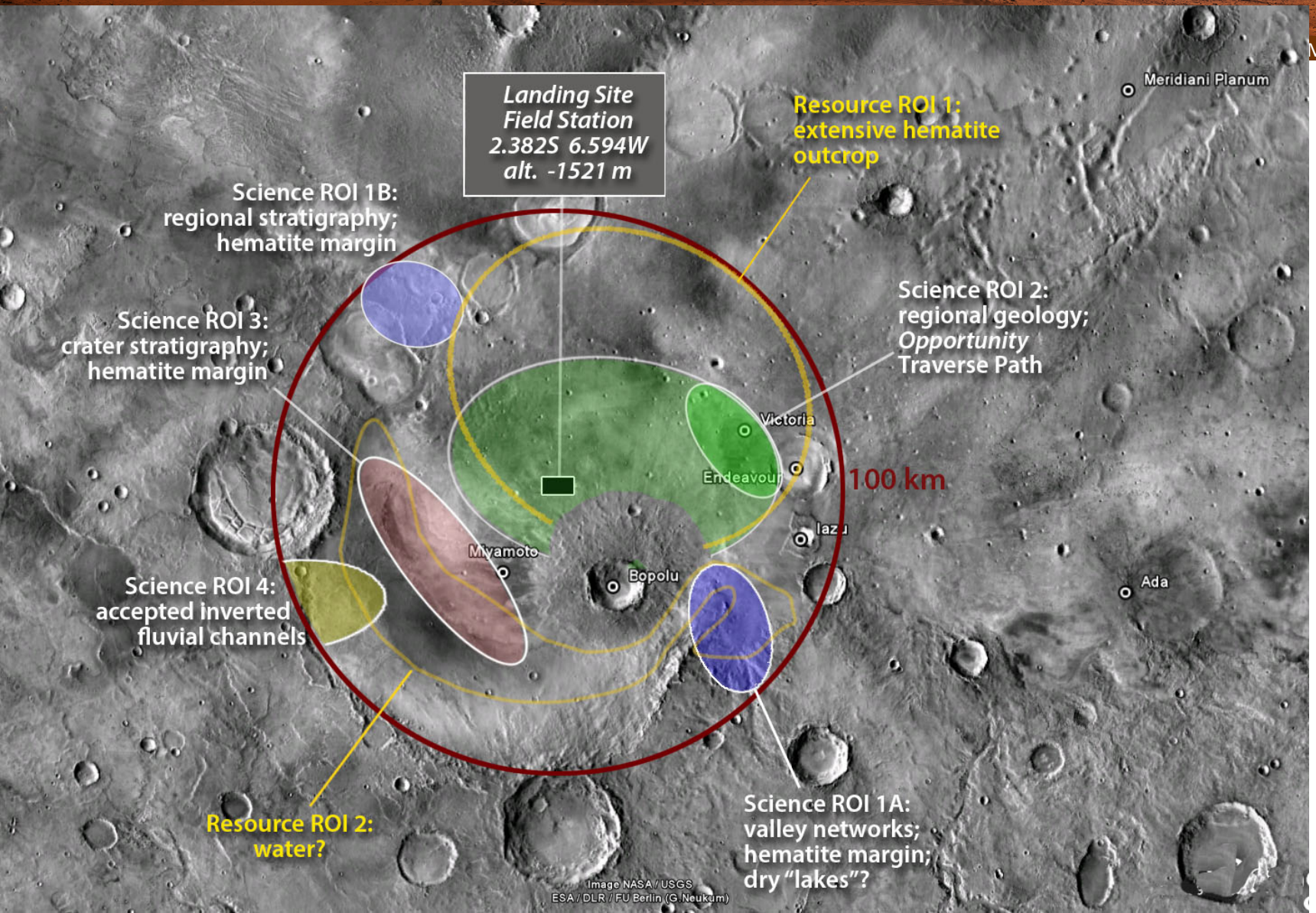
Patrick J. McGovern USRA, Lunar Planetary Institute, Houston, TX

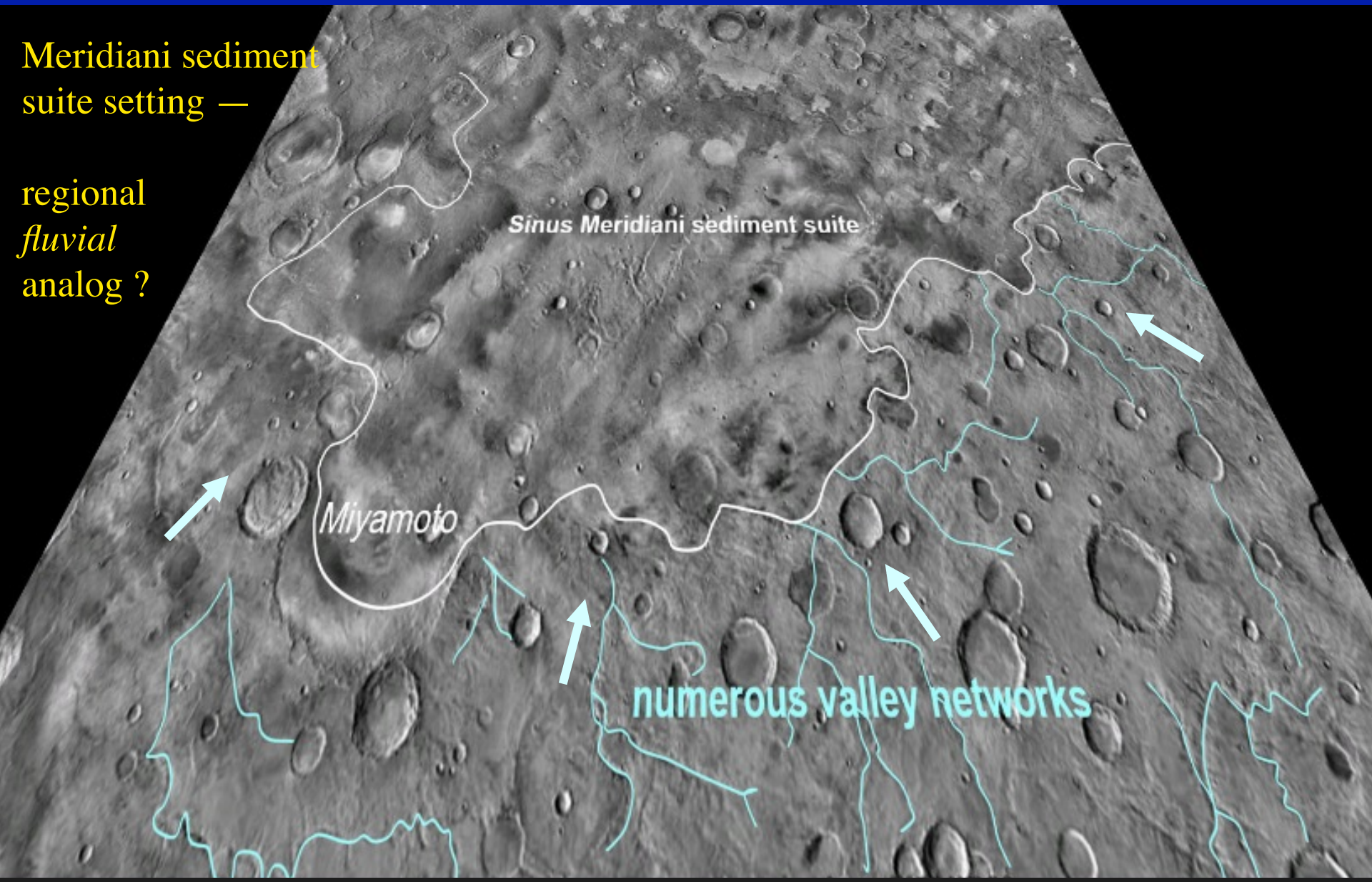
Heath Mills University of Houston-Clear Lake, Clear Lake, TX

Exploration Zone Map



Meridiani sediment suite setting —

regional *fluvial* analog ?



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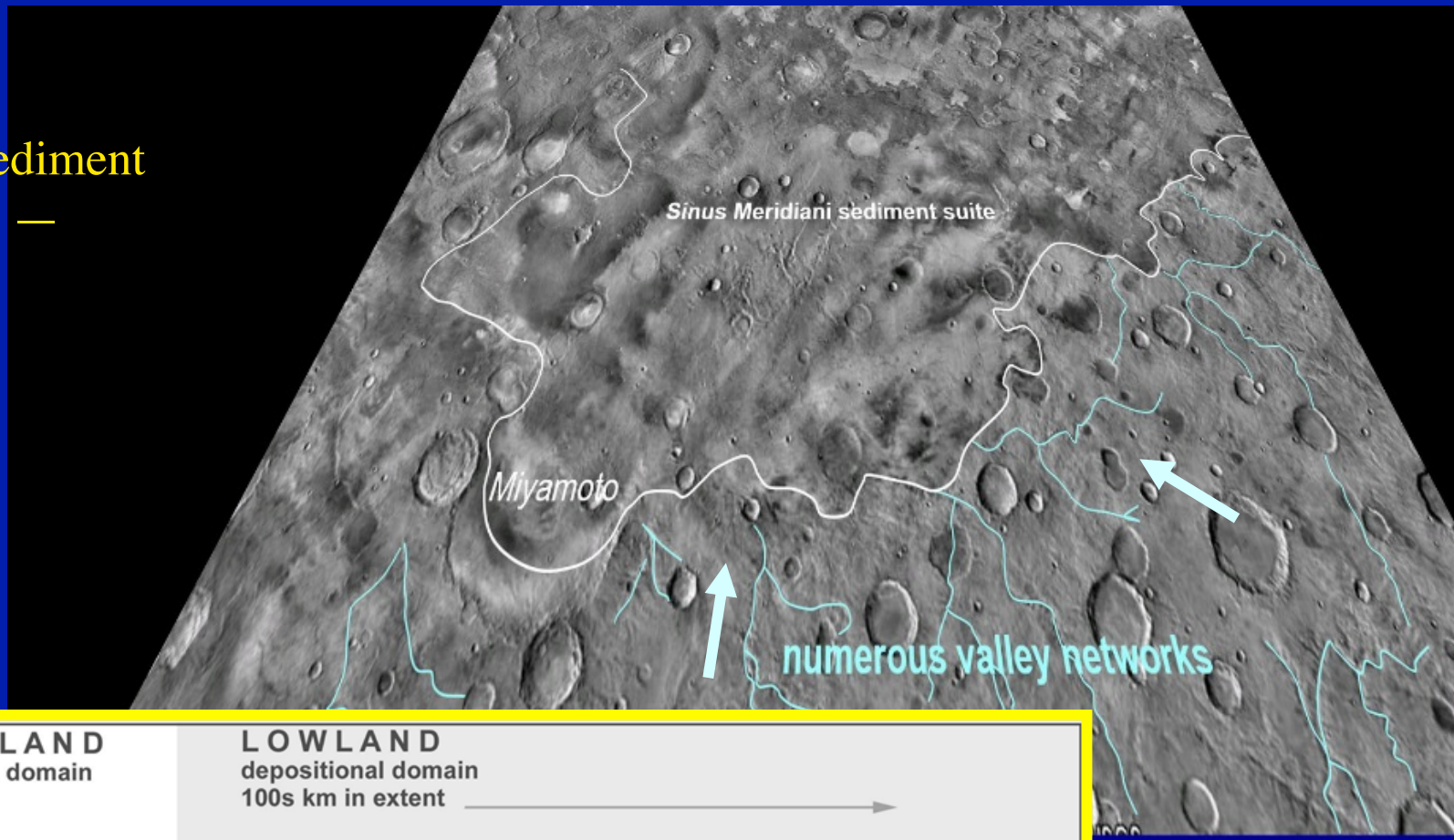
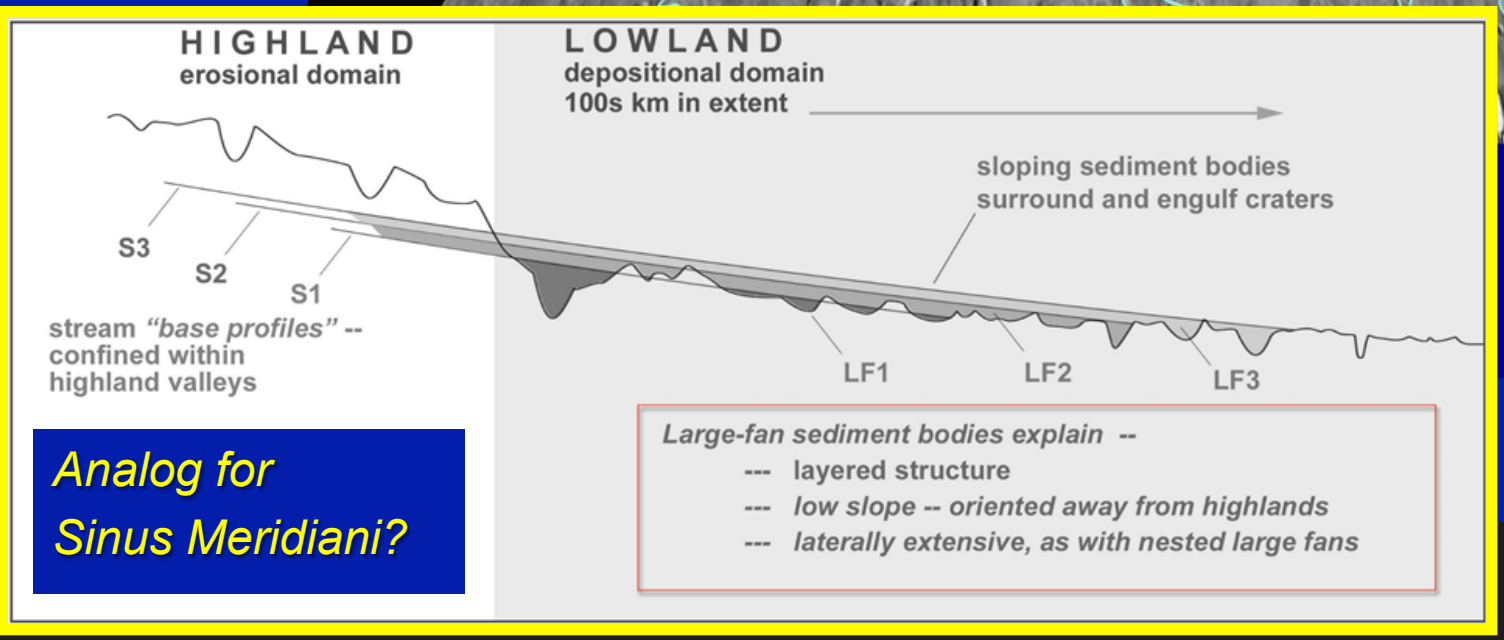
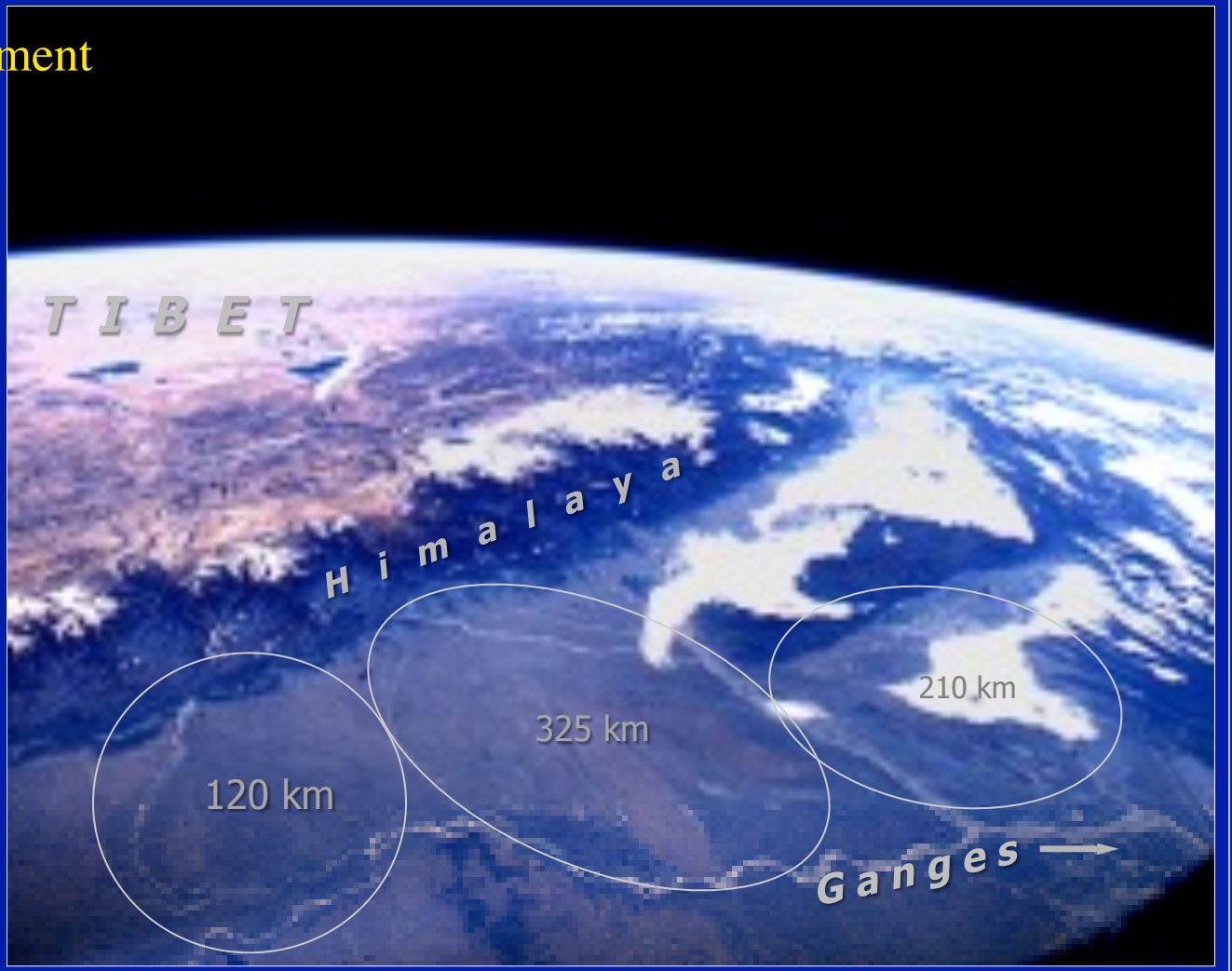




Analog for Sinus Meridiani?

Meridiani sediment suite setting —

regional *fluvial* analog ?



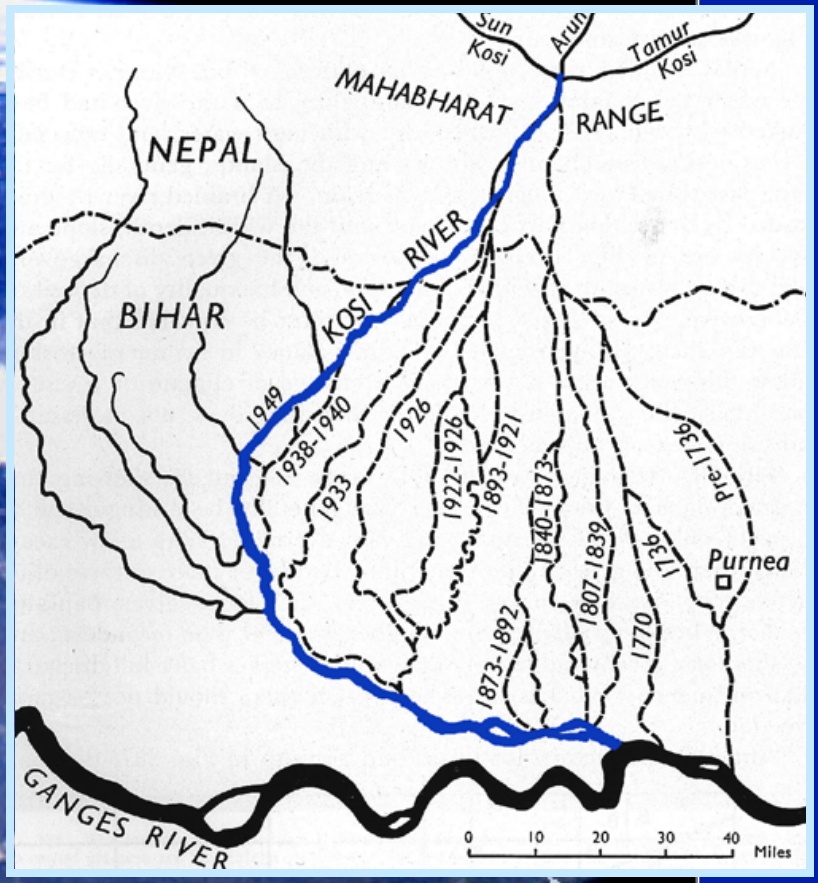
GANGES PLAIN — LARGE FANS

Kosi R. *Mahananda-Tista* *Brahmaputra*

Switching behavior —

Kosi River avulsions —

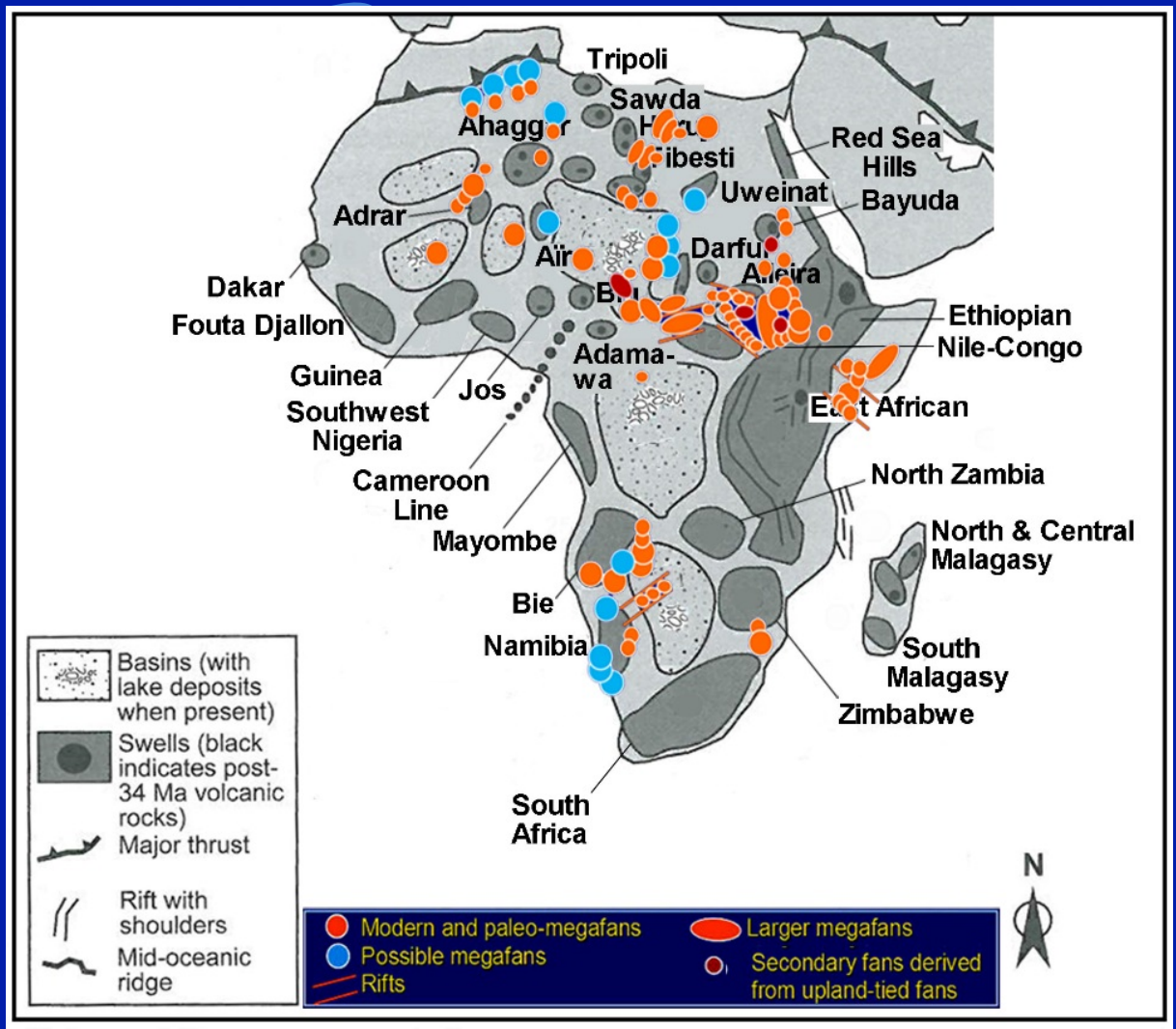
- cross entire surface of fan
- average rate ~19 yr between switching events



Kosi R. avulsions

Megafan distribution (n=88) on a Mars-like continent —

Megafan distribution in Africa's basin-swell context.



Swell margins: single-margin (i.e. larger) basins —

- fan distribution along basin circumferences
- large fans at variable altitudes
  - on swell flanks mainly
  - sometimes on basin floors
- *diamond-shaped fans* more frequent
- clusters of fans in the T/T pattern

Rifts: smaller double-margin basins —

- most fans and fan clusters within rifted lowlands
- occasionally on swell crests — Salamat fan (Central African Rep.)
- *triangle-shaped fans* more frequent

Unexpected conclusions —

Large fans are probably —

- *new class* of landform feature on the planet — not the freak end point in the alluvial fan continuum
- *the norm* in all filling continental basins --

Unexpected conclusions —

Large fans are probably —

- *new class* of landform feature on the planet — not the freak end point in the alluvial fan continuum
- *the norm* in all filling continental basins --
- at the poorly known middling scale

the new stuff

Table 1. Megafans and sets of megafans within Miall's (1996) hierarchical schema of fluvial sedimentary bodies (architectural elements). The mesoscale is italicised.

Group	Time scale (yr)	Abbreviated hierarchy of fluvial sedimentary bodies (architectural elements)	
		rivers and alluvial fans*	**megafan (radius >100 km) distributary systems**
6	10^2-10^3	shallow channels, large stream-bed macroforms	shallow channels, large stream-bed macroforms
7	10^3-10^4	fan trench backfill, channels	channels
8	10^4-10^5	alluvial fan, channel belt	channel belt; packet of channels (sector set or megafan subapex set)
9	***10^5-10^6***	***delta, alluvial fan tract, major depositional system axis (Gulf of Mexico coast depositional axes)***	***megafan***
10	10^{6-7}	smaller basin-fill complexes (Tertiary fms., Gulf of Mexico coast)	set of nested megafans
11	10^{7-8}	larger basin-fill complexes (Triassic Molteno Fm., Karoo basin)	

* adapted from Miall (1996) and DeCelles et al. (1991).

the middling scale

Unexpected conclusions —

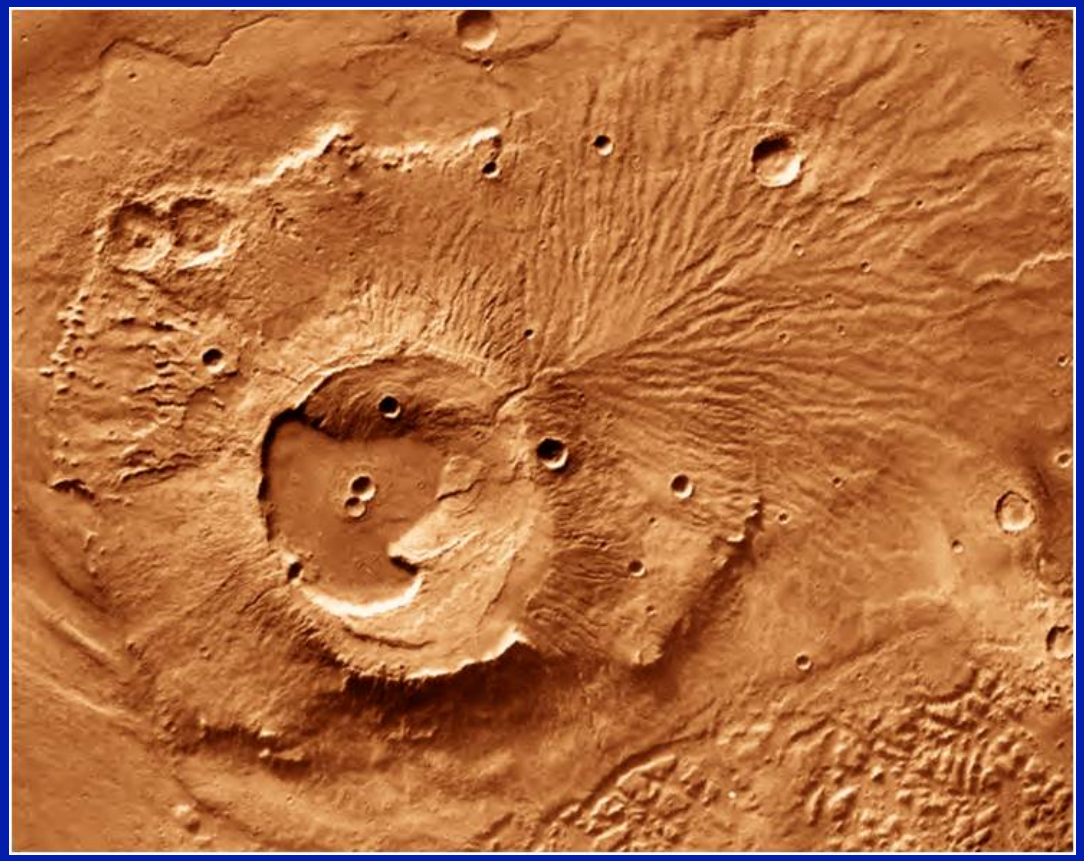
Large fans are probably —

- *new class* of landform feature on the planet — not the freak end point in the alluvial fan continuum
- *the norm* in all filling continental basins --
- at the poorly known middling scale

prediction — successful prediction of location is now being performed for Earth landscapes

Megafans on Mars ? —

Apollinaris Patera — fan feature with radius of 200 km on the southern slopes (top right quadrant). Fan interpreted as an "alluvial fan" (Ghail and Hutchison, 2003). 7ºS, 173ºE,Viking image



ROCKIES

Rockies-derived sedimentaries

NORTH

remnant of original continuous slope from highland to depositional lowland -- without erosional trench

PECOS TRENCH

Analog tweak: Common eroded upland-lowland margin — landscape sequence

upland sediment source ⇒ eroded "trench" ⇒ upland-derived sediments

Rocky Mts ⇒ Pecos trench ⇒ Ogallala sedimentaries

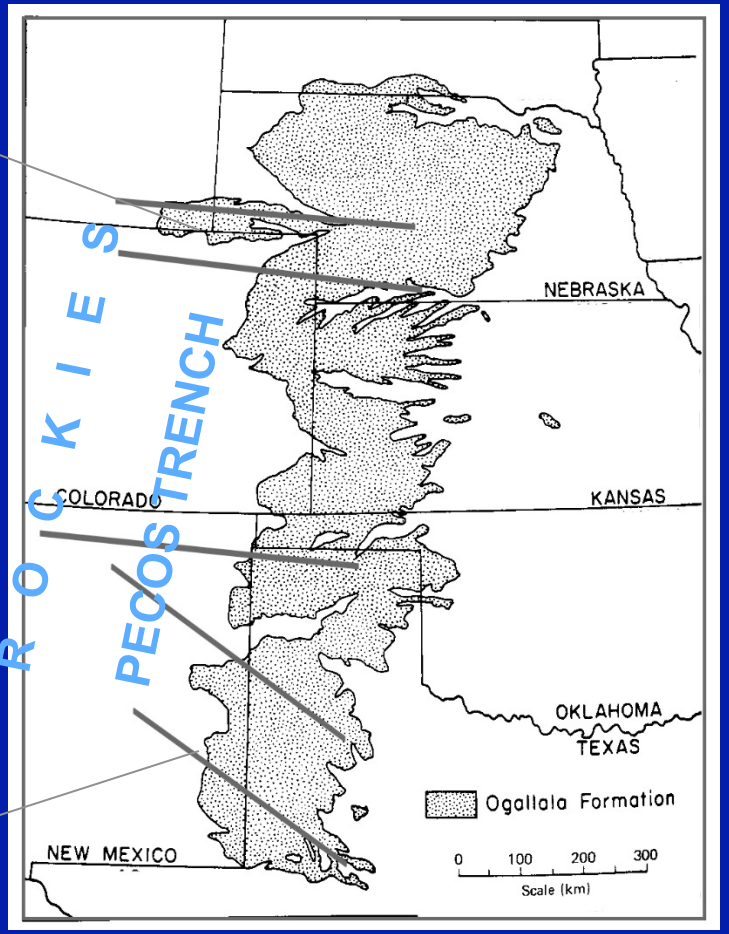
1

2

3

4

5



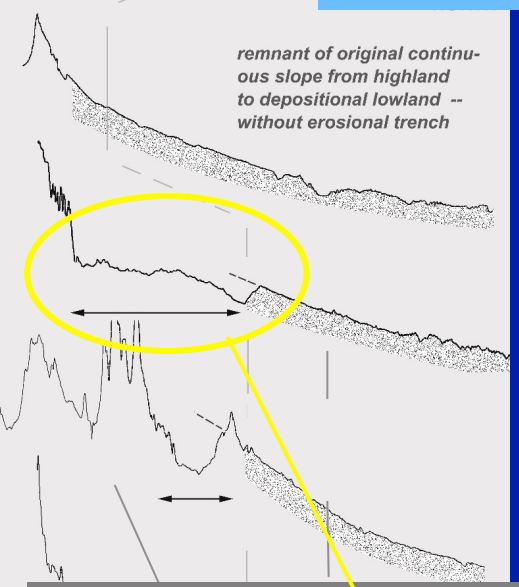
Ogallala Formation, Great Plains (Frye 1971)

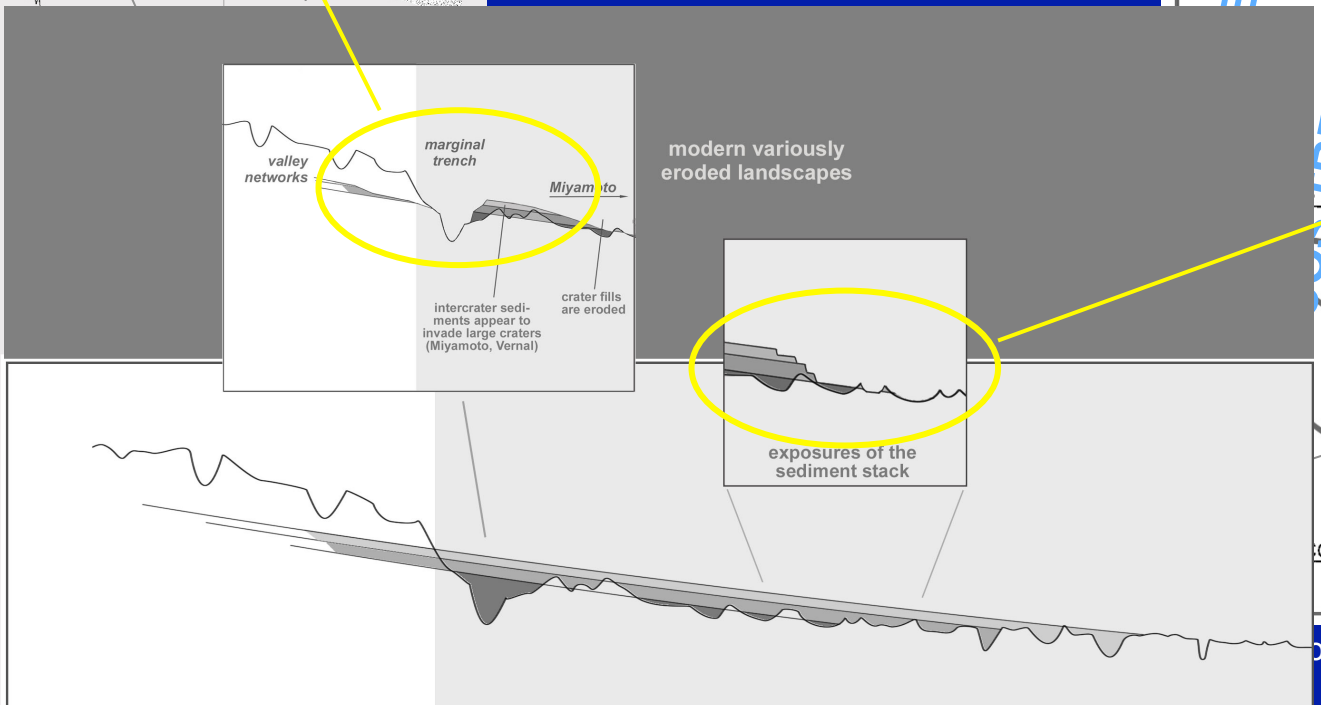
ROCKIES

Rockies-derived sedimentaries

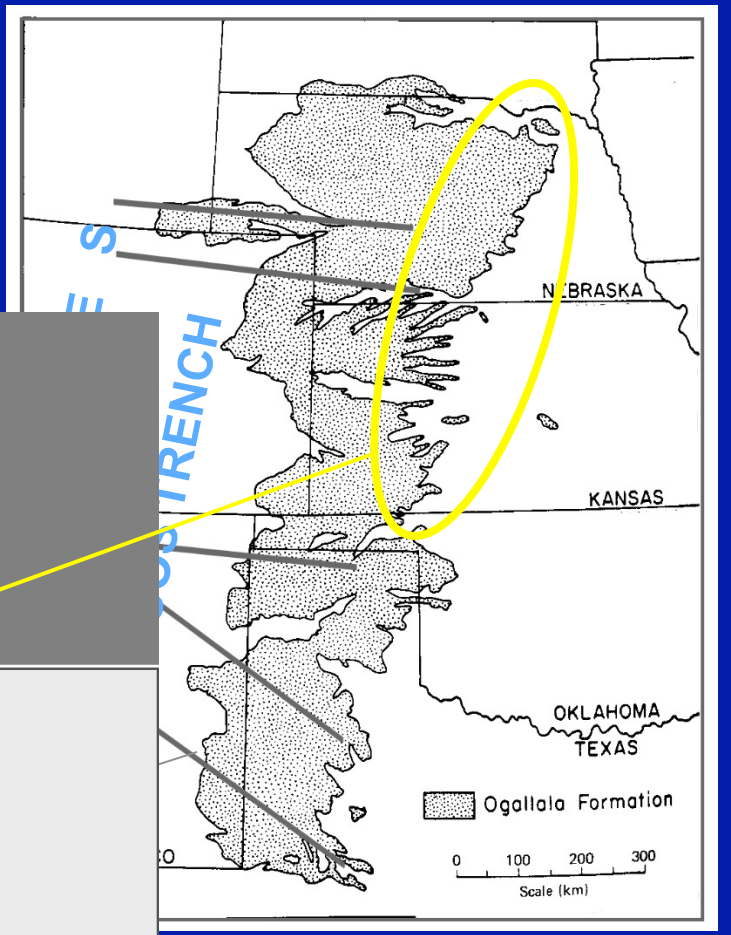
Analog tweak: Common eroded upland-lowland margin — landscape sequence

upland sediment source ⇨ eroded "trench" ⇨ upland-derived sediments



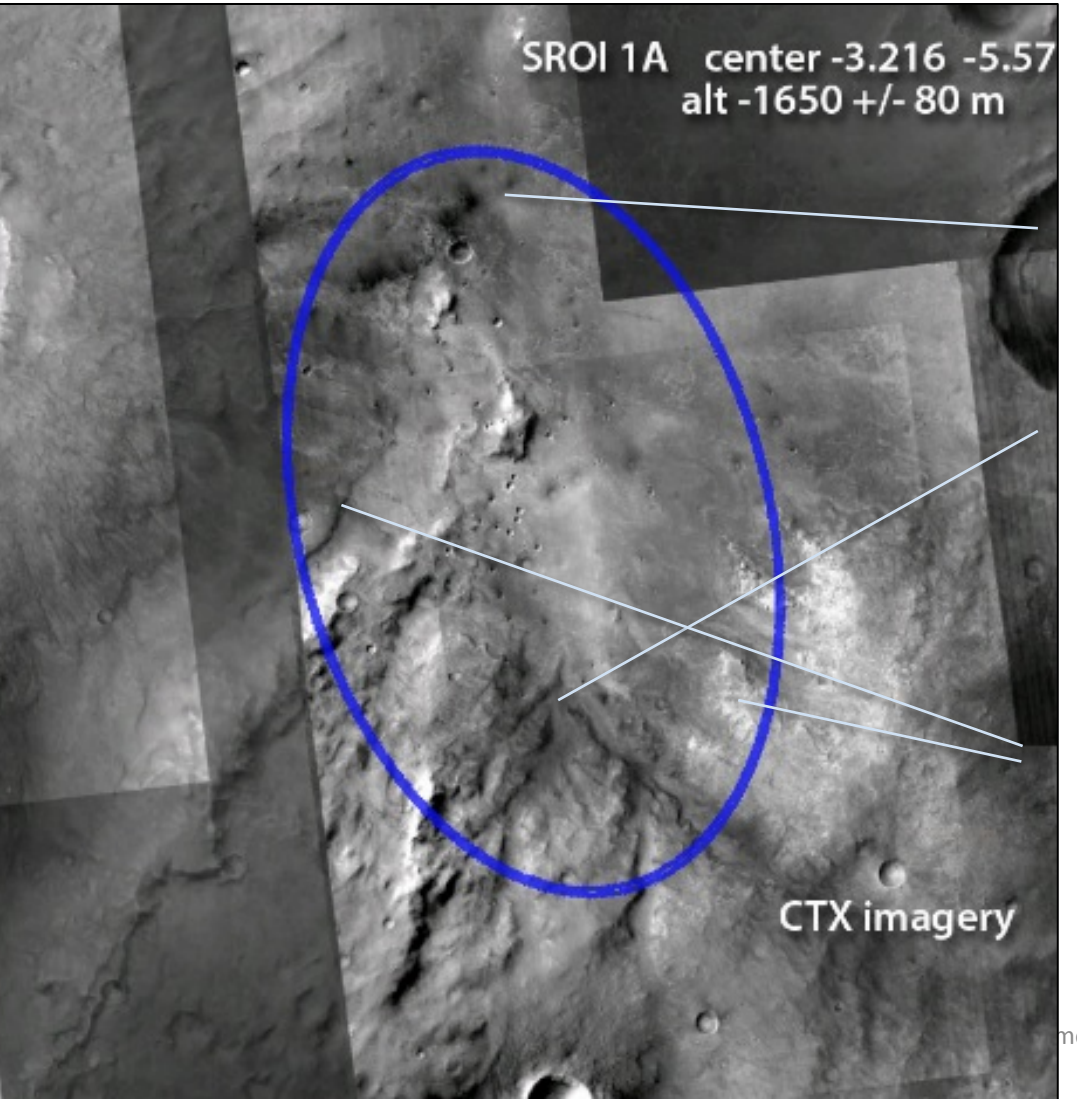


Rocky Mts | Pecos trench | Ogallala sedimentaries



ormation, Great Plains (Frye 1971)

Science ROI 1A -- stratigraphy



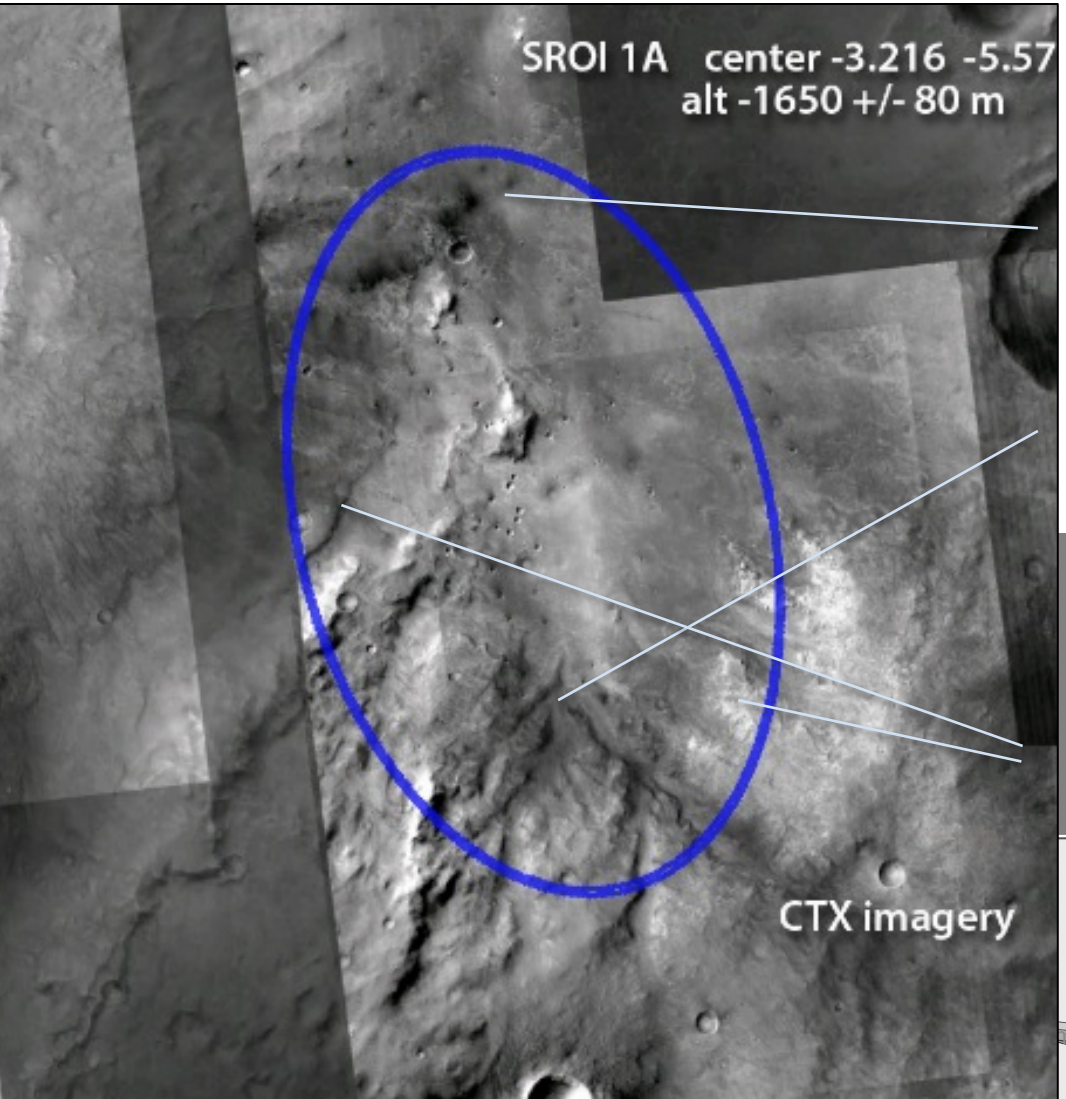
Stratigraphic relationships between —

- Units of the Sinus Meridiani sediment suite, especially the hematite Ph unit margin
- Valley Networks

Habitability —

- Hematite Ph unit potential for habitability
- Possible lake sediments (Newsom et al. 2003), with potential for habitability

Science ROI 1A -- stratigraphy



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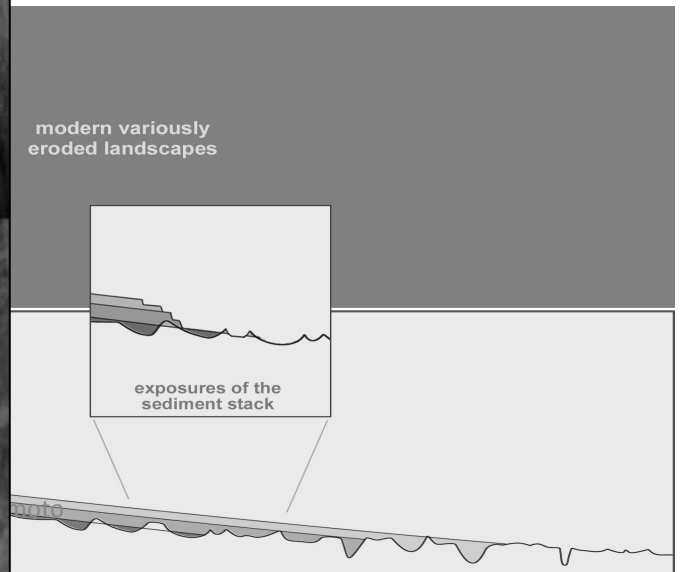
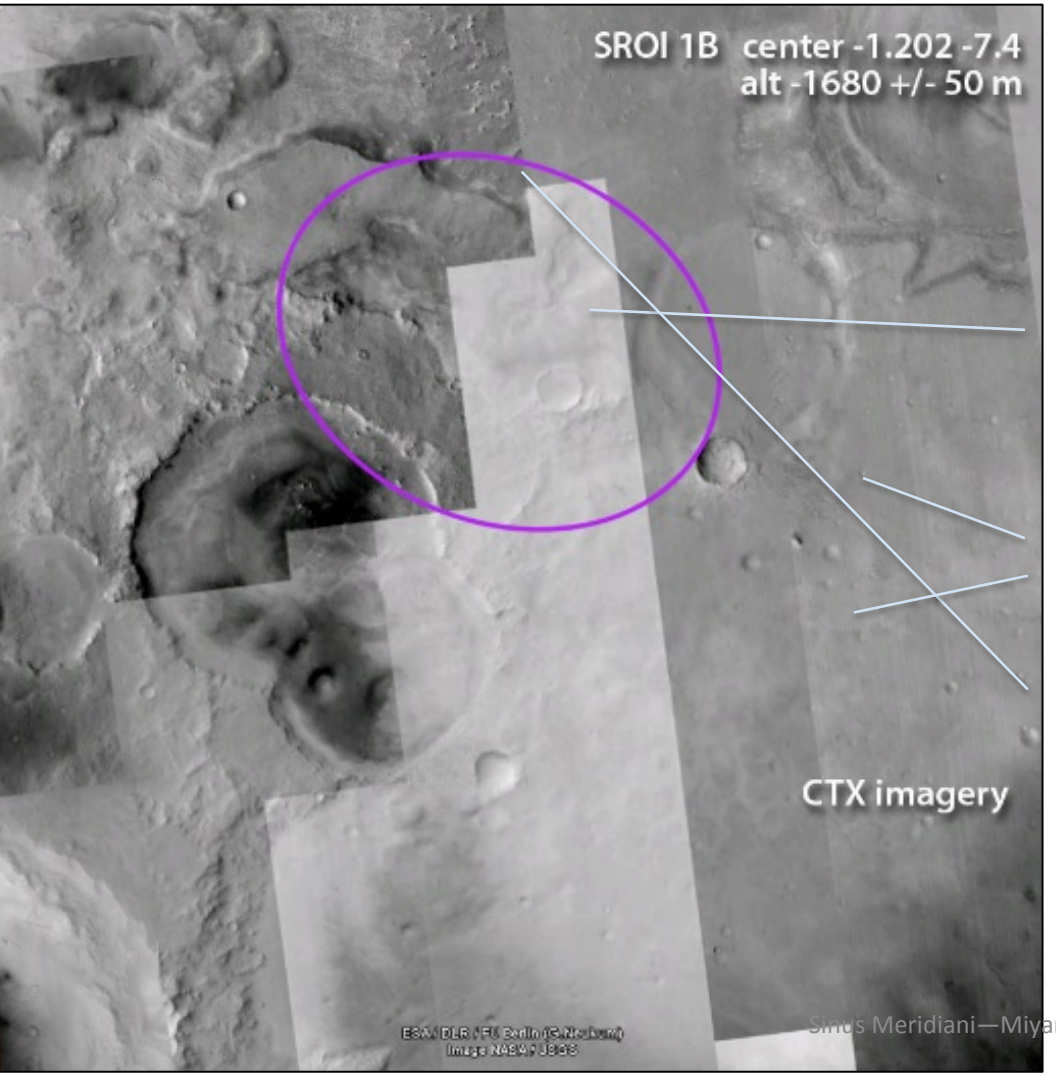


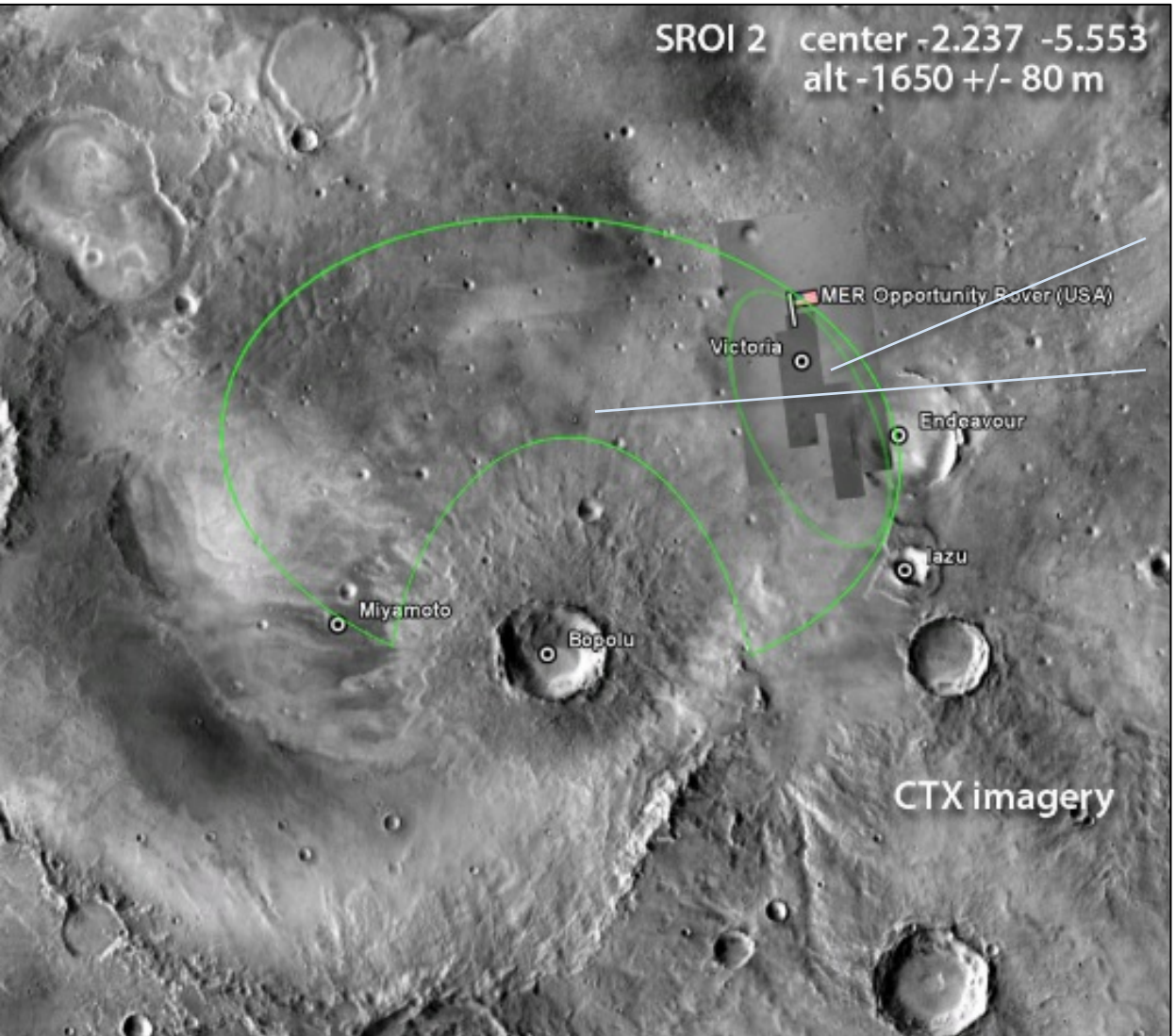
Science ROI 1B -- stratigraphy



Stratigraphic relationships between (contd.) —

- Units of the Sinus Meridiani sediment suite, especially the hematite margin
- Hematite *Ph* unit potential for habitability
- Meridiani suite and underlying "MCT" *(Mantled Cratered Terrain)*
- *current imaging available—CTX, HiRISE complete coverage*

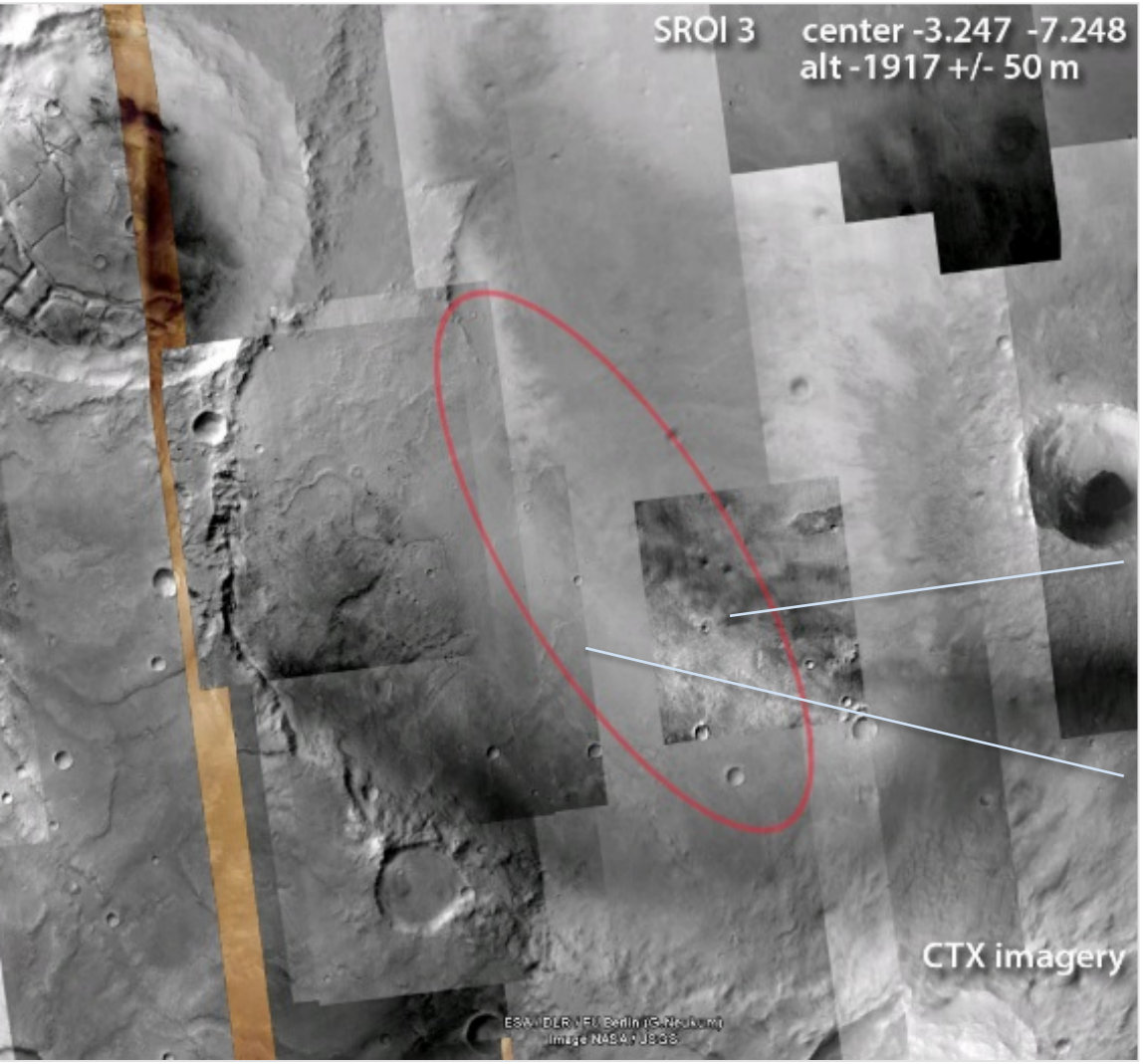
Science ROI 2 – Burns Fm & hematite



Burns Fm context —

- Field access to sites along *Opportunity's* Traverse Path
- Extend perspectives gained from *Opportunity's* operations (small ellipse) far to the west (large ellipse)
  - mineralogy
  - sedimentology
  - Stratigraphy
- *current imaging available— CTX, HiRISE complete coverage*

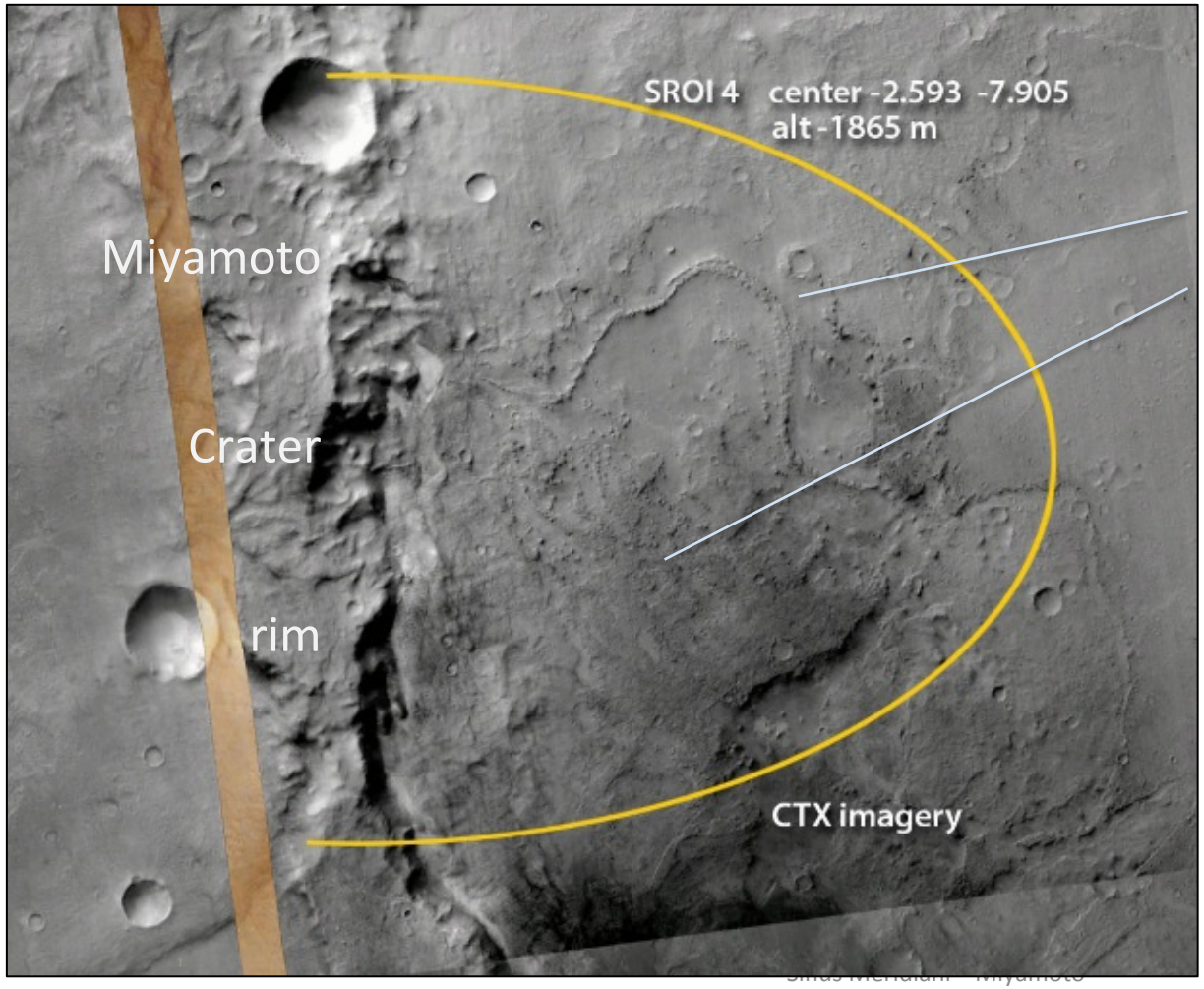
Science ROI 3 – Miyamoto crater -- plains stratigraphy



Miyamoto Crater stratigraphic relationships where the following formations meet —

- Meridiani suite to the east (probably externally derived)
- Intracrater-derived sediments to the west
- *current imaging available— CTX, HiRISE complete coverage*

Science ROI 4 – fluvial features

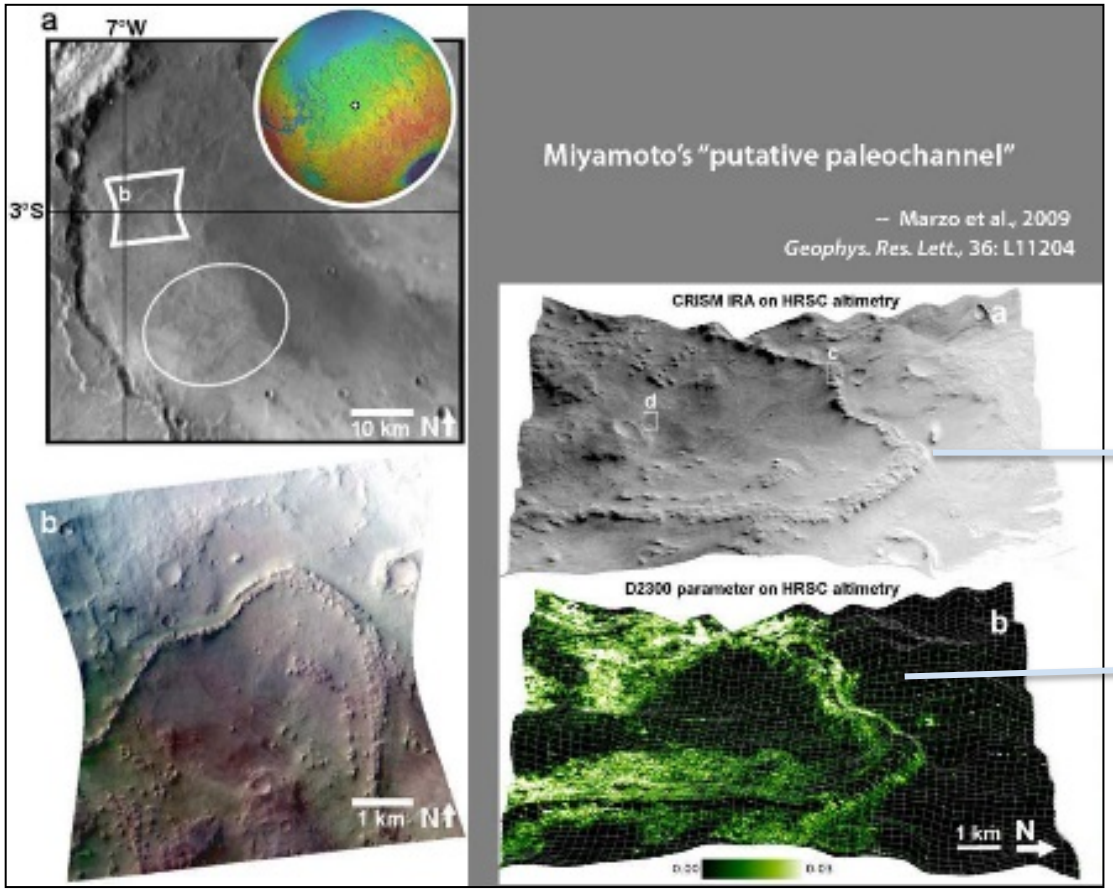


SW Miyamoto Crater fluvial features

—

- Access to well documented inverted fluvial channel, and other smaller channels
- Inverted channel appears to be a precise analog for widespread intercrater ridged terrain of the Meridiani units (“ridge-forming unit”) to the northeast
- CRISM response — evidence for phyllosilicates, plus water, plus hematite upslope → *ideal terrestrial conditions for microbial activity*
- *current imaging available—CTX, HiRISE complete coverage*

Science ROI 4 – fluvial features



Miyamoto Crater fluvial features —

- 3D DEM
- CRISM response

Evidence for phyllosilicates, plus water, plus hematite
upslope ⟶ *ideal conditions for microbial activity*

Meridiani units —

Large Fluvial Fan hypothesis

" … any hypothesis to explain their origin must be consistent with :

1. coherent deposition over at least the hundred kilometer scale ✓
2. exposures of these units over hundreds of thousands of square kilometers ✓
3. generally planar strata ✓
4. developed conformally to the (likely) preexisting shallow regional slope ✓
5. formation beginning toward the end of the Noachian epoch and continuing into the Hesperian ✓
6. geographical association with both older and younger valley networks ✓ ?
7. lack of evidence that deposition took place in closed basins **N/A**
8. significant physical compositional differences between layers ✓

— *Hynek and Phillips 2008*

From: Wilkinson MJ, 2010, Fluvial Sediment Accommodation and Mesoscale Architecture — Some Neglected Perspectives, *First Mars Sedimentology Conf., El Paso, TX,* April 18-21, 2010.

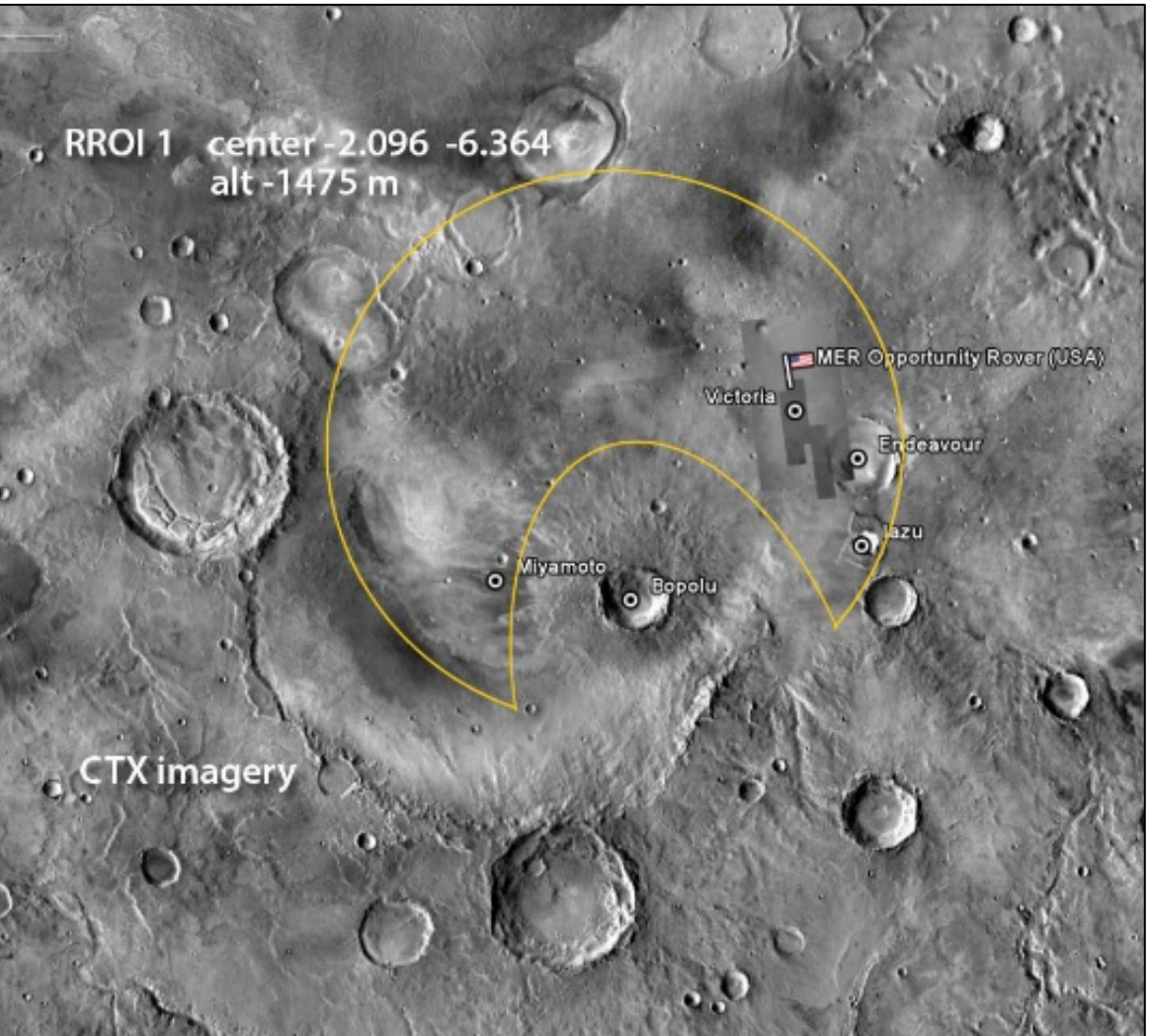
Science Rubric Total

Workshop for Human Missions to Mars

Science Site Criteria				Site Factors	SROI 1A	SROI 1B	SROI 2	SROI 3	SROI 4	RROI 1	RROI 2	RROI(n)	EZ SUM
	Astrobio	**Threshold**	AND/OR	**Potential for past habitability**	●	●	●	●	●	●	●		**(7,0)**
				Potential for present habitability/refugia	?	?	?	?	?	?	?		**(0,0)**
		Qualifying		Potential for organic matter, w/ surface exposure	●	●	●	●	●	●	●		**(7,0)**
	Atmospheric Science	**Threshold**		**Noachian/Hesperian rocks w/ trapped atmospheric gases**	?	?	?	?	?	?	?		**(0,0)**
		Qualifying		Meteorological diversity in space and time									**(0,0)**
				High likelihood of surface-atmosphere exchange									**(0,0)**
				Amazonian subsurface or high-latitude ice or sediment									**(0,0)**
				High likelihood of active trace gas sources									**(0,0)**
	Geoscience	**Threshold**		**Range of martian geologic time; datable surfaces**	●	●				●	●		**(4,0)**
				Evidence of aqueous processes	●	●	●	●	●	●	●		**(7,0)**
				Potential for interpreting relative ages	●	●	●	●	●	●	●		**(7,0)**
		Qualifying		Igneous Rocks tied to 1+ provinces or different times					?				**(0,0)**
				Near-surface ice, glacial or permafrost									**(0,0)**
				Noachian or pre-Noachian bedrock units	●	●							**(2,0)**
				Outcrops with remnant magnetization									**(0,0)**
				Primary, secondary, and basin-forming impact deposits	●	●							**(2,0)**
				Structural features with regional or global context	●		●	●		●	●		**(5,0)**
				Diversity of aeolian sediments and/or landforms	●		●	●	●	●	●		**(6,0)**
				fluvial sediments/structures					●				

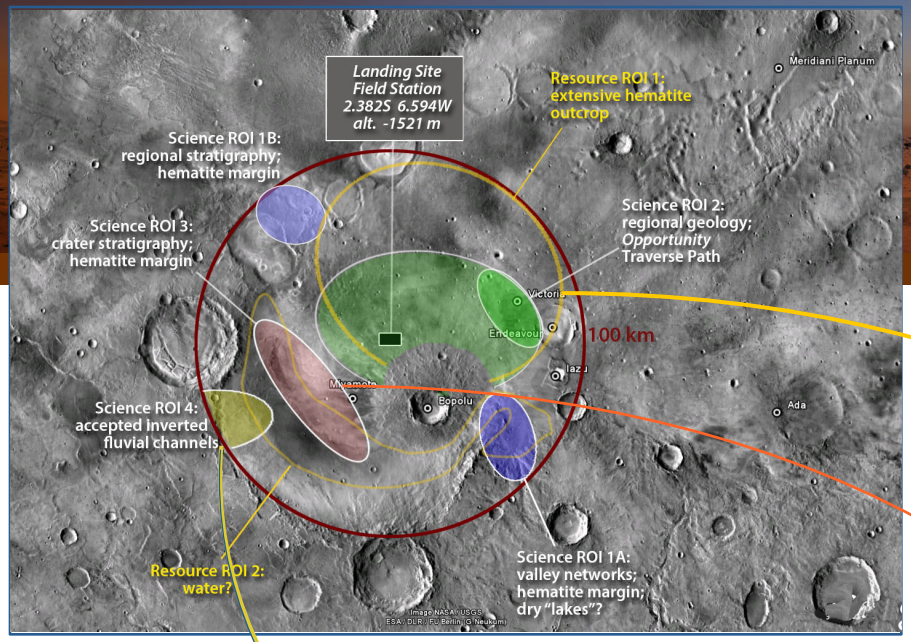
Key	
●	**Yes**
○	**Partial Support or Debated**
	No
?	**Indeterminate**

Resource ROI 1

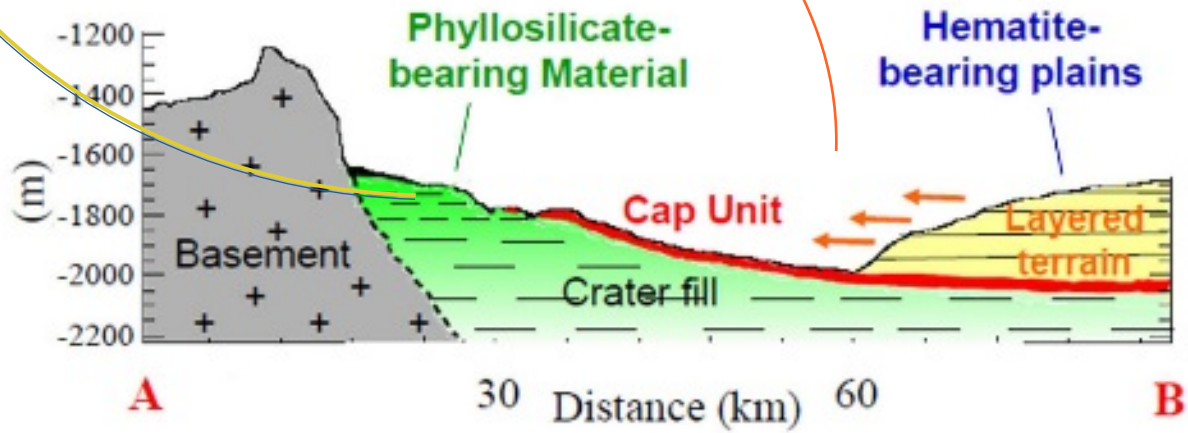


Hematite resource —

- Widespread, near-surface availability in friable host rock
- *current imaging available—CTX and HiRISE*



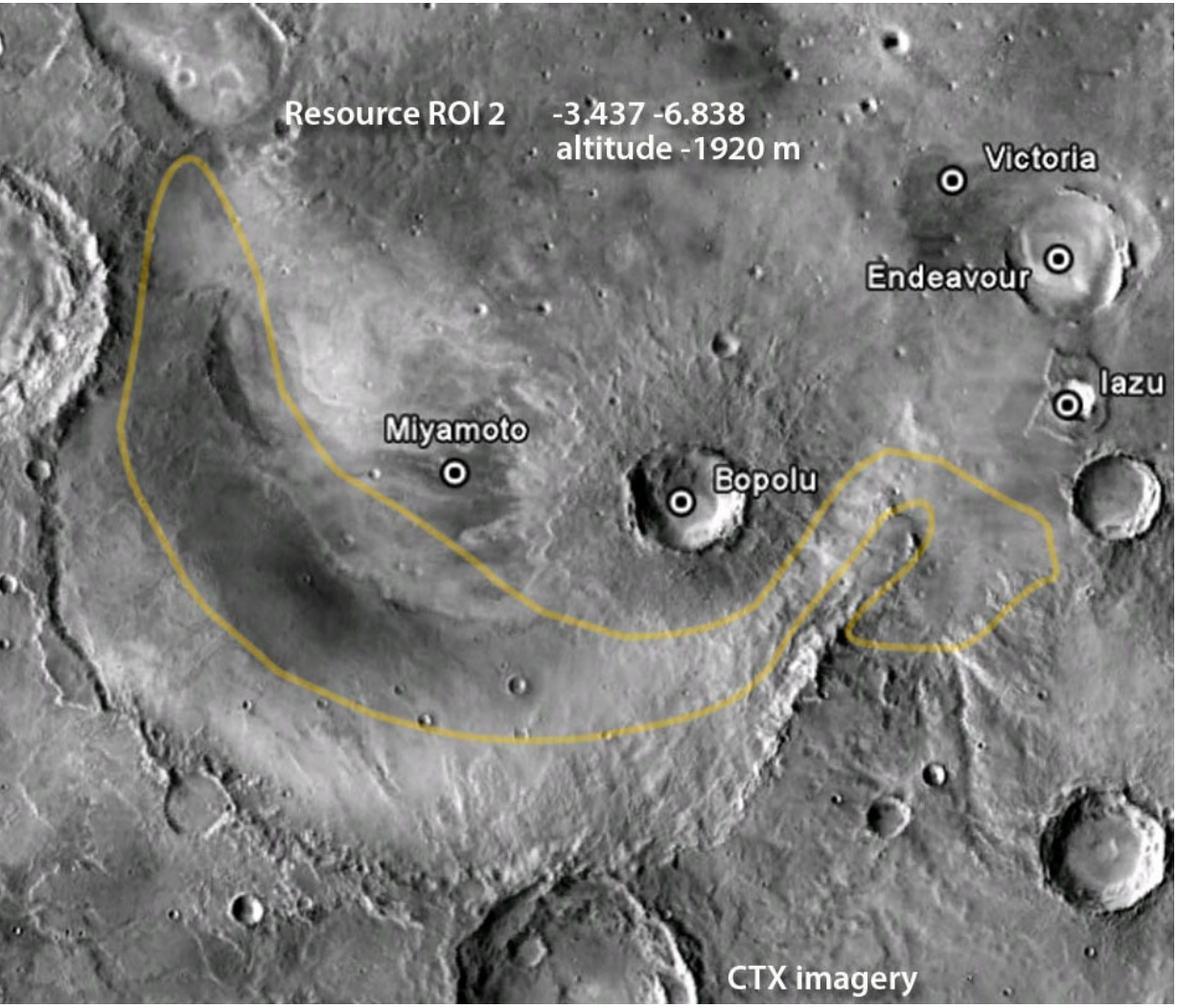
Resource: hematite



MOLA cross section.

Adapted from Wiseman et al., 2008, *LPSC XXXIX*, Abstract 1806

Resource ROI 2



Possible Water resource —

- in lowest areas of Miyamoto and "trench" between S Highlands and Meridiani sediments
- identified as possible lake basins by Newsom et al. (2003) — may contain near-surface water
- this RROI overlaps with mapped Ph hematite unit's southwest margin (see RROI 1)
- *current imaging available—CTX and HiRISE*

Resource Rubric Total

1st EZ Workshop for Human Missions to Mars

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

Key	
●	Yes
○	Partial Support or Debated
	No
?	Indeterminate

Highest Priority EZ Data Needs

- Widen the existing CRISM dataset in targeted mode within the proposed EZ
- Gamma ray spectrometer and neutron detection instrument (e.g., FREND on TGO) for characterization of water signatures in the proposed EZ – more complete coverage at the greatest possible resolution (to explore correlations between neutron signatures and geologic features)

BACKUP SLIDES

Science ROI 1A Rubric

1st EZ Workshop for Human Missions to Mars

Science Site Criteria				Site Factors	SROI 1A	SROI 1B	SROI 2	SROI 3	SROI 4	RROI 1	RROI 2	RROI(n)	EZ SUM
	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**

Science ROI 1B -- stratigraphy

Science Site Criteria				Site Factors	SROI 1A	SROI 1B	SROI 2	SROI 3	SROI 4	RROI 1	RROI 2	RROI(n)	EZ SUM
	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**

Science ROI 2 Rubric

1st EZ Workshop for Human Missions to Mars

Science Site Criteria				Site Factors	SROI 1A	SROI 1B	SROI 2	SROI 3	SROI 4	RROI 1	RROI 2	RROI(n)	EZ SUM
	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**

Science ROI 3 Rubric

1st EZ Workshop for Human Missions to Mars

Science Site Criteria				Site Factors	SROI 1A	SROI 1B	SROI 2	SROI 3	SROI 4	RROI 1	RROI 2	RROI(n)	EZ SUM
	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**

Science ROI 4 Rubric

1st EZ Workshop for Human Missions to Mars

Science Site Criteria				Site Factors	SROI 1A	SROI 1B	SROI 2	SROI 3	SROI 4	RROI 1	RROI 2	RROI(n)	EZ SUM
	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					●				
				fluvial sediments/structures					●				

Key	
●	Yes
○	Partial Support or Debated
	No
?	Indeterminate

Resource ROI 1 Rubric

1st EZ Workshop for Human Missions to Mars

			Site Factors	SROI 1A	SROI 1B	SROI 2	SROI 3	SROI 4	RROI 1	RROI 2	RROI(n)	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**									
			AND / OR **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

Resource ROI 2 Rubric

1st EZ Workshop for Human Missions to Mars

			Site Factors	SROI 1A	SROI 1B	SROI 2	SROI 3	SROI 4	RROI 1	RROI 2	RROI(n)	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**							○		
			AND/OR **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

Prioritization List of EZ Data Needs

- Rover examination of exposed stratigraphic sequences — as in SROIs 1A, 1B and 3

- Provide a prioritized list of orbiter/rover data to be collected to assess the resource potential of the EZ.

Exploration Zone Map