Gusev Crater: A Geologically Diverse, Engineering Safe Site with Evidence for Past Habitable Environments and Potential Biosignatures

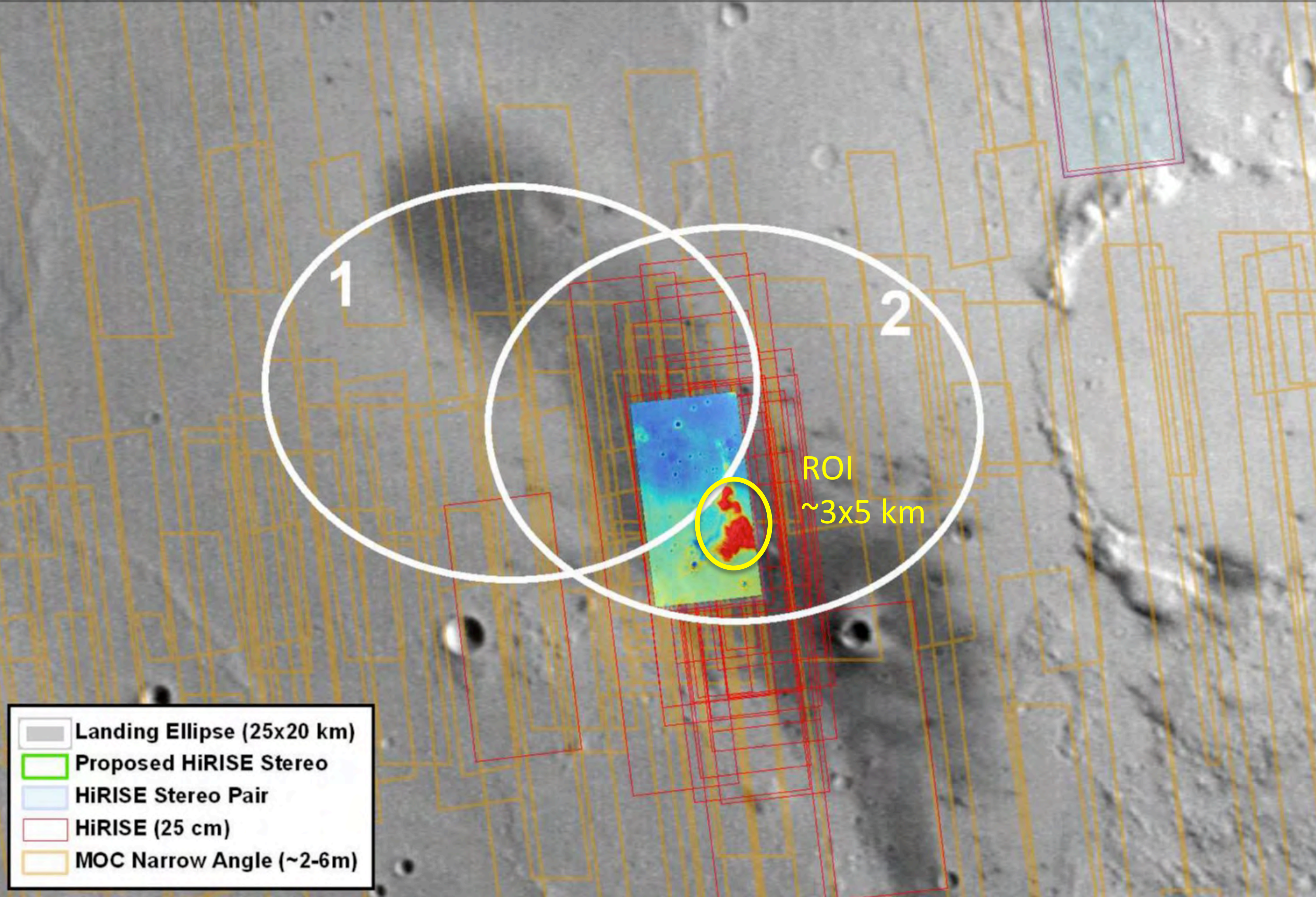
A potential biosignature is an object, substance and/or pattern that might have a biological origin and thus compels investigators to gather more data before reaching a conclusion as to the presence or absence of life.
Mars 2020 SDT Report

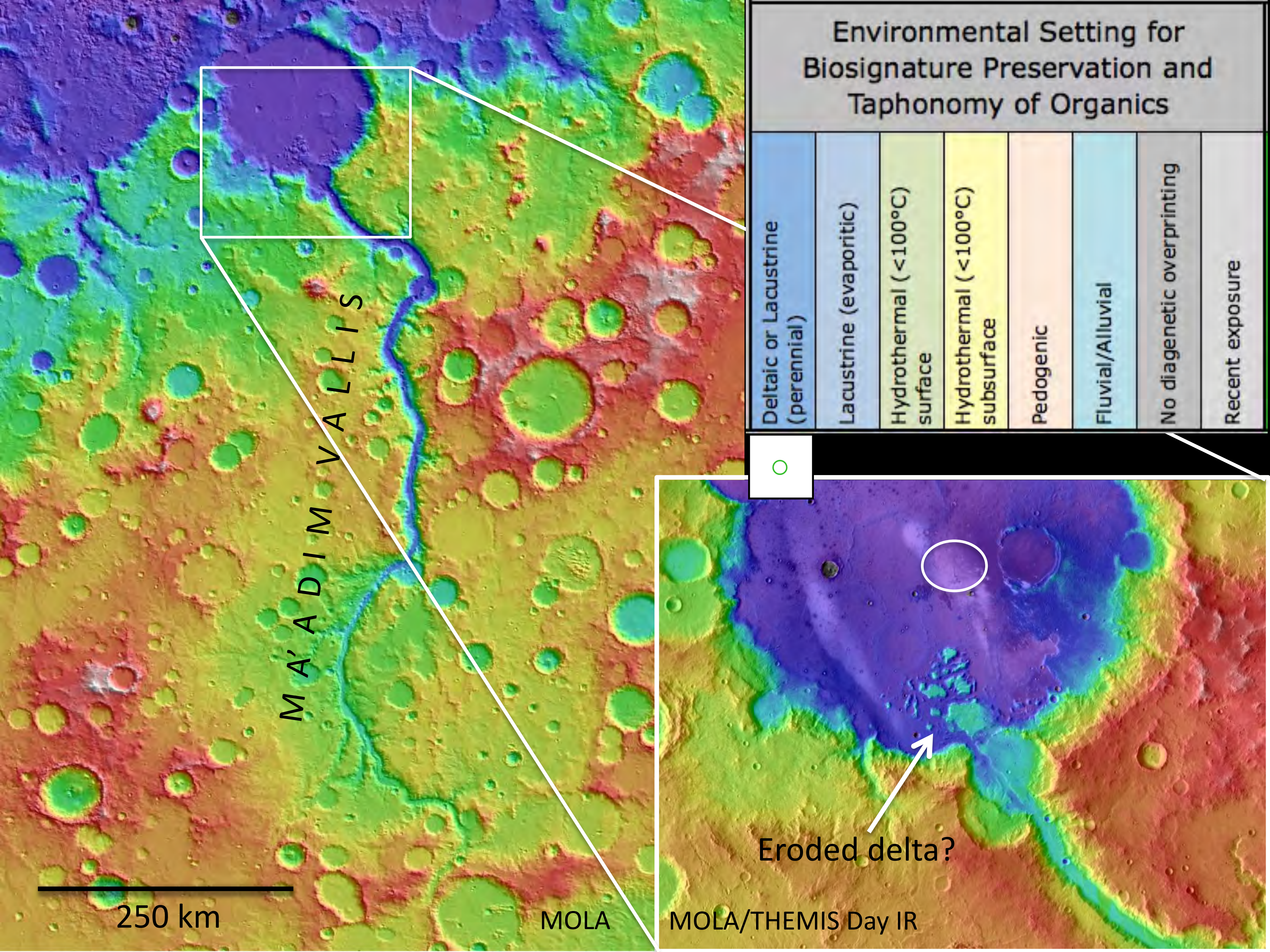
Steve Ruff, Jim Rice, and Alex Longo

with Jack Farmer

Opaline silica outcrops in Gusev crater
Pancam approximate true color image

Gusev Crater

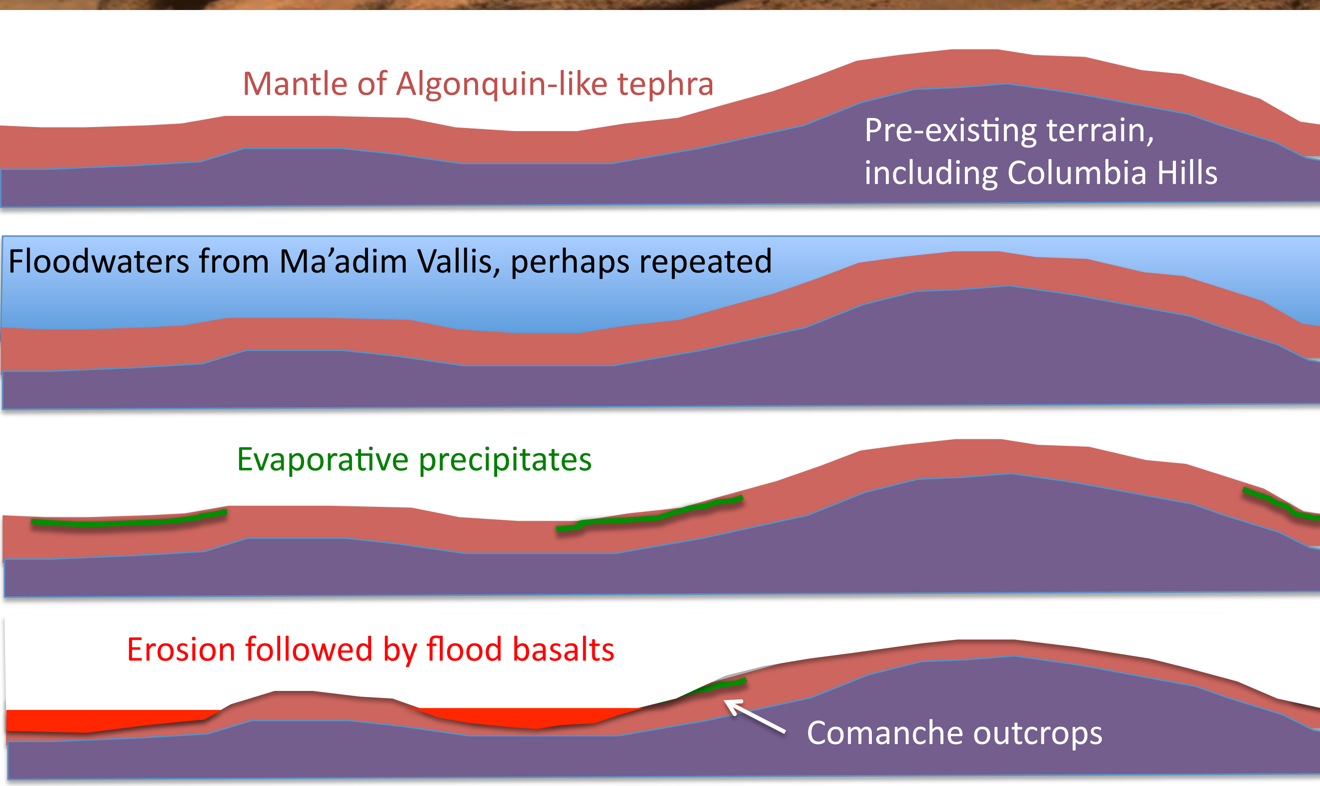




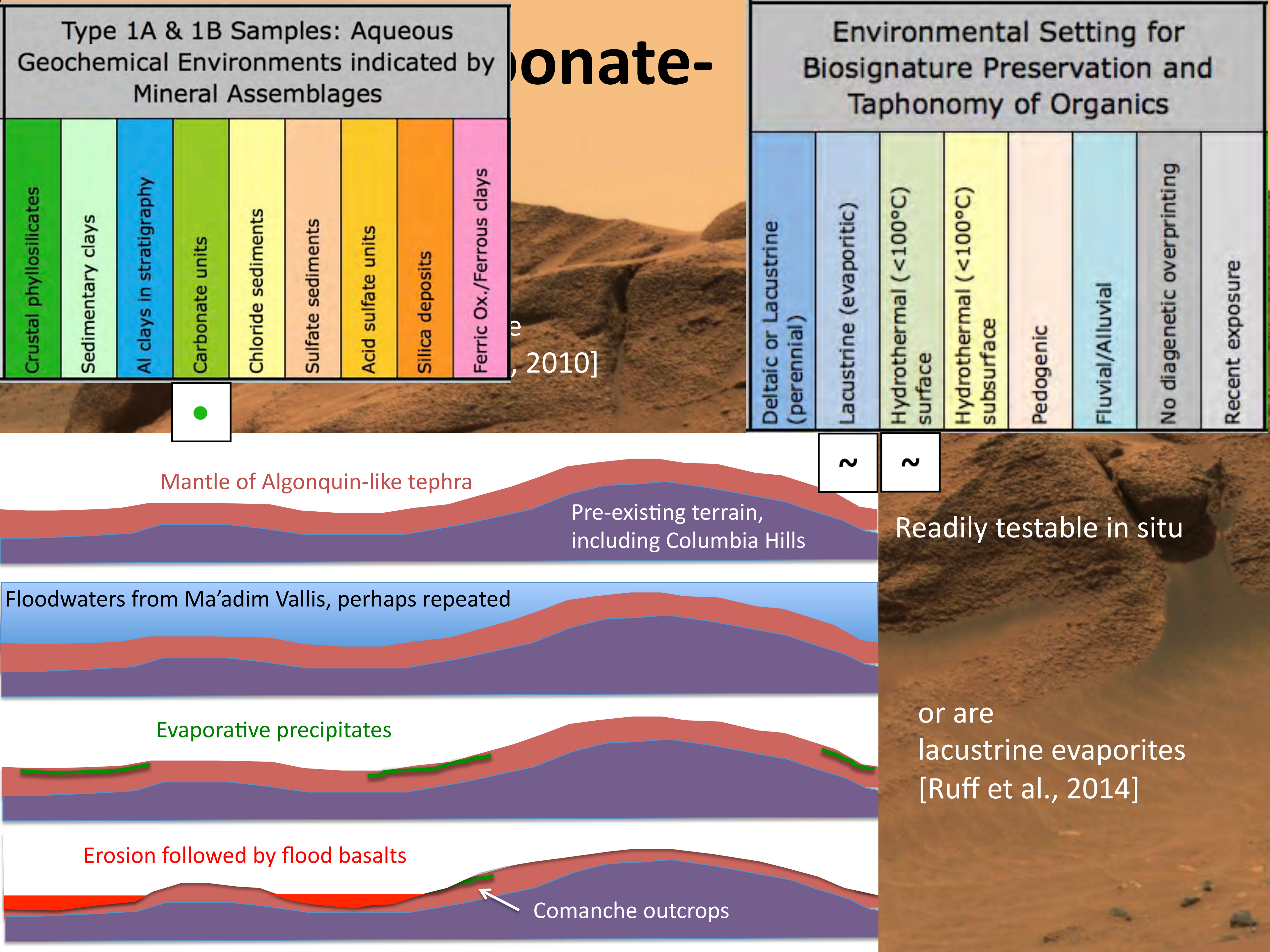
Environmental Setting for Biosignature Preservation and Taphonomy of Organics
Deltaic or Lacustrine (perennial)
Lacustrine (evaporitic)
Hydrothermal (<100°C) surface
Hydrothermal (<100°C) subsurface
Pedogenic
Fluvial/Alluvial
No diagenetic overprinting
Recent exposure
MA'ADIM VALLIS
Eroded delta?
250 km
MOLA
MOLA/THEMIS Day IR

Comanche Carbonate-rich Outcrops

Mg-Fe carbonates up to ~30 wt% are hydrothermal in origin [Morris et al., 2010]



or are lacustrine evaporites [Ruff et al., 2014]



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Type 1A & 1B Samples: Aqueous Geochemical Environments indicated by Mineral Assemblages
Crustal phyllosilicates
Sedimentary clays
Al clays in stratigraphy
Carbonate units
Chloride sediments
Sulfate sediments
Acid sulfate units
Silica deposits
Ferric Ox./Ferrous clays
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, 2010]
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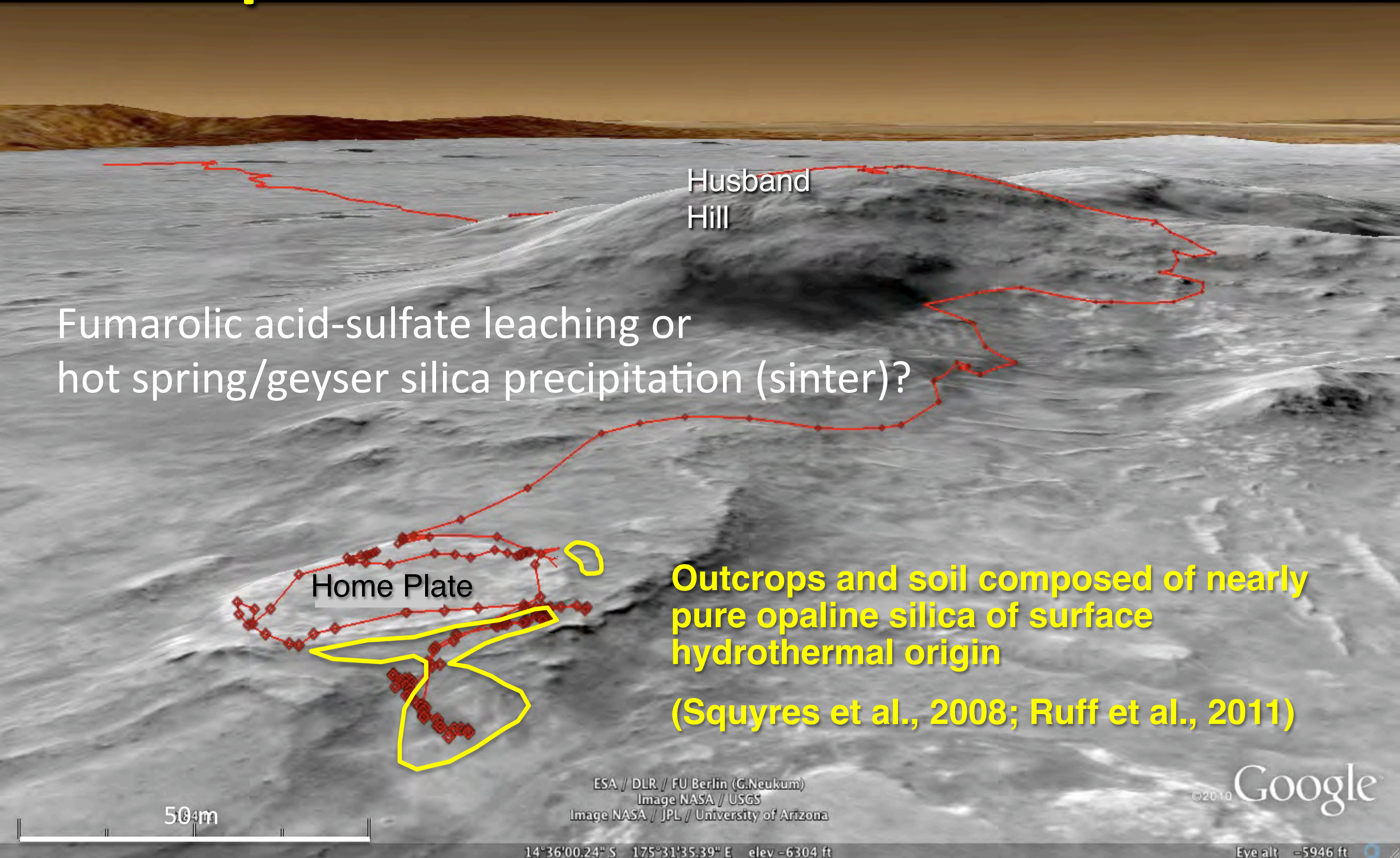
~
~
Mantle of Algonquin-like tephra
Pre-existing terrain, including Columbia Hills
Readily testable in situ
Floodwaters from Ma'adim Vallis, perhaps repeated
Evaporative precipitates
or are
lacustrine evaporites
[Ruff et al., 2014]
Erosion followed by flood basalts
Comanche outcrops

Home Plate Opaline Silica



Fumarolic acid-sulfate leaching or hot spring/geyser silica precipitation (sinter)?

Outcrops and soil composed of nearly pure opaline silica of surface hydrothermal origin

(Squyres et al., 2008; Ruff et al., 2011)

Type 1A & 1B Samples: Aqueous Geochemical Environments indicated by Mineral Assemblages								
Crustal phyllosilicates	Sedimentary clays	Al clays in stratigraphy	Carbonate units	Chloride sediments	Sulfate sediments	Acid sulfate units	Silica deposits	Ferric Ox./Ferrous clays
							●	

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		●					

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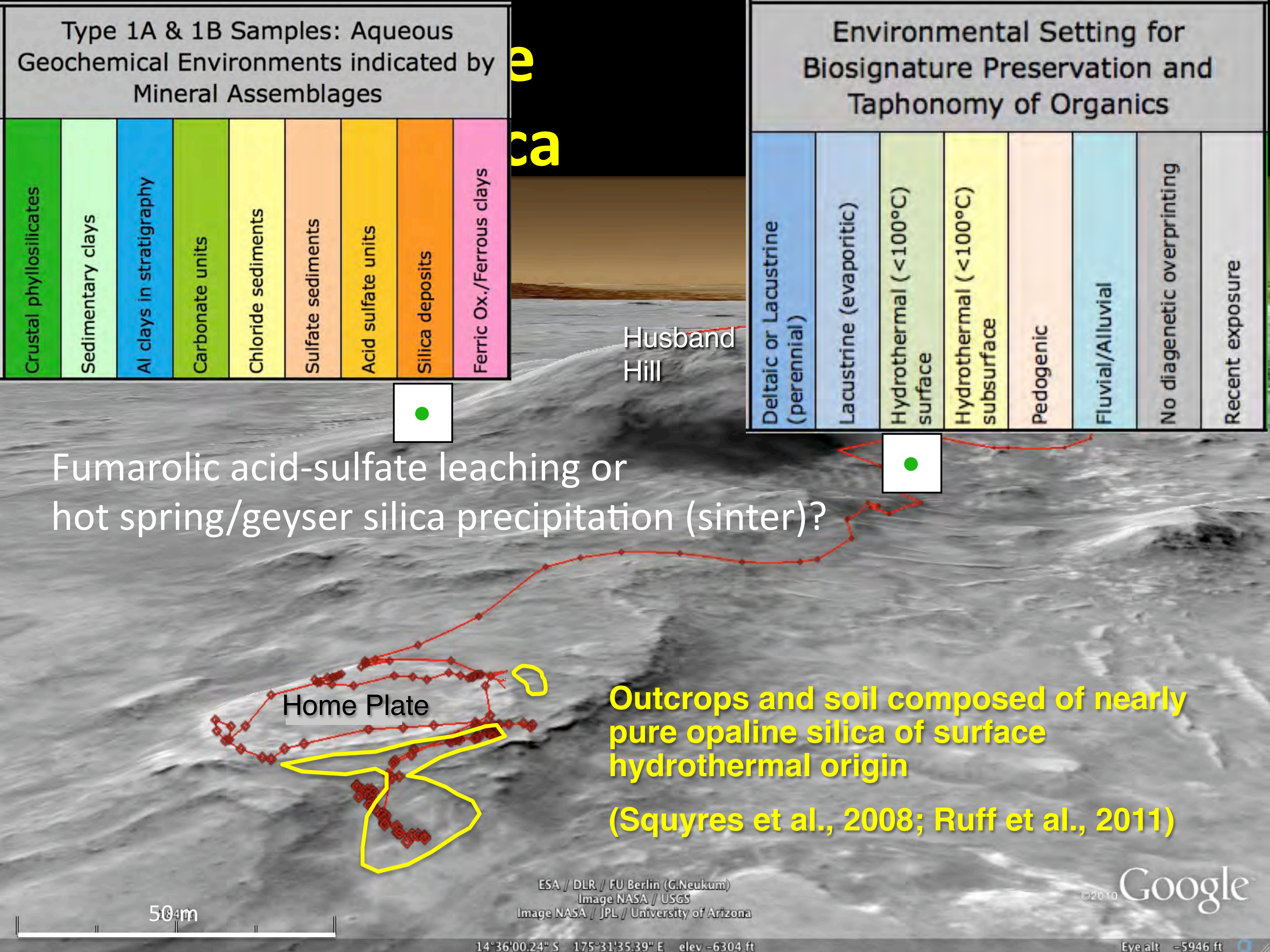
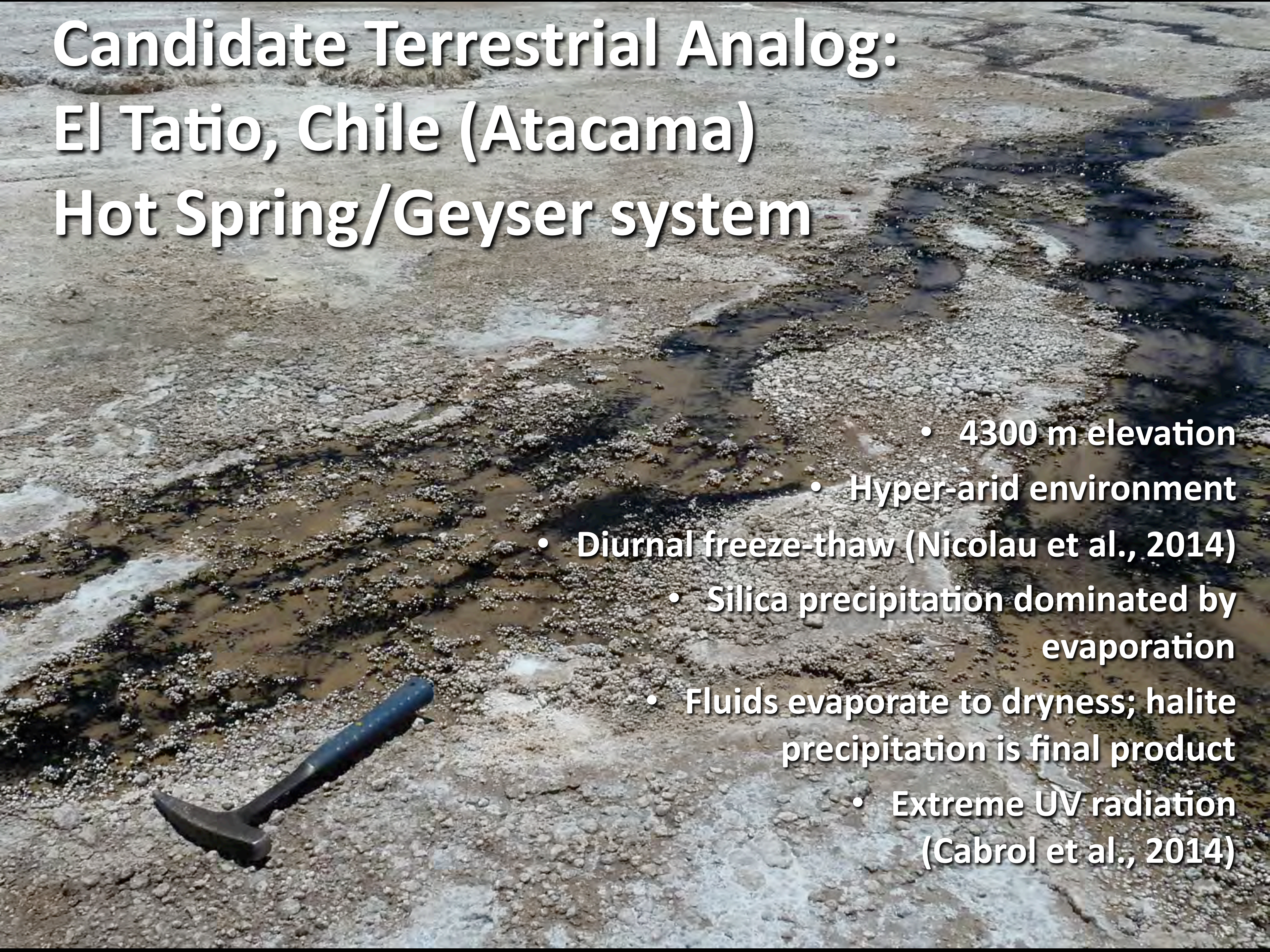


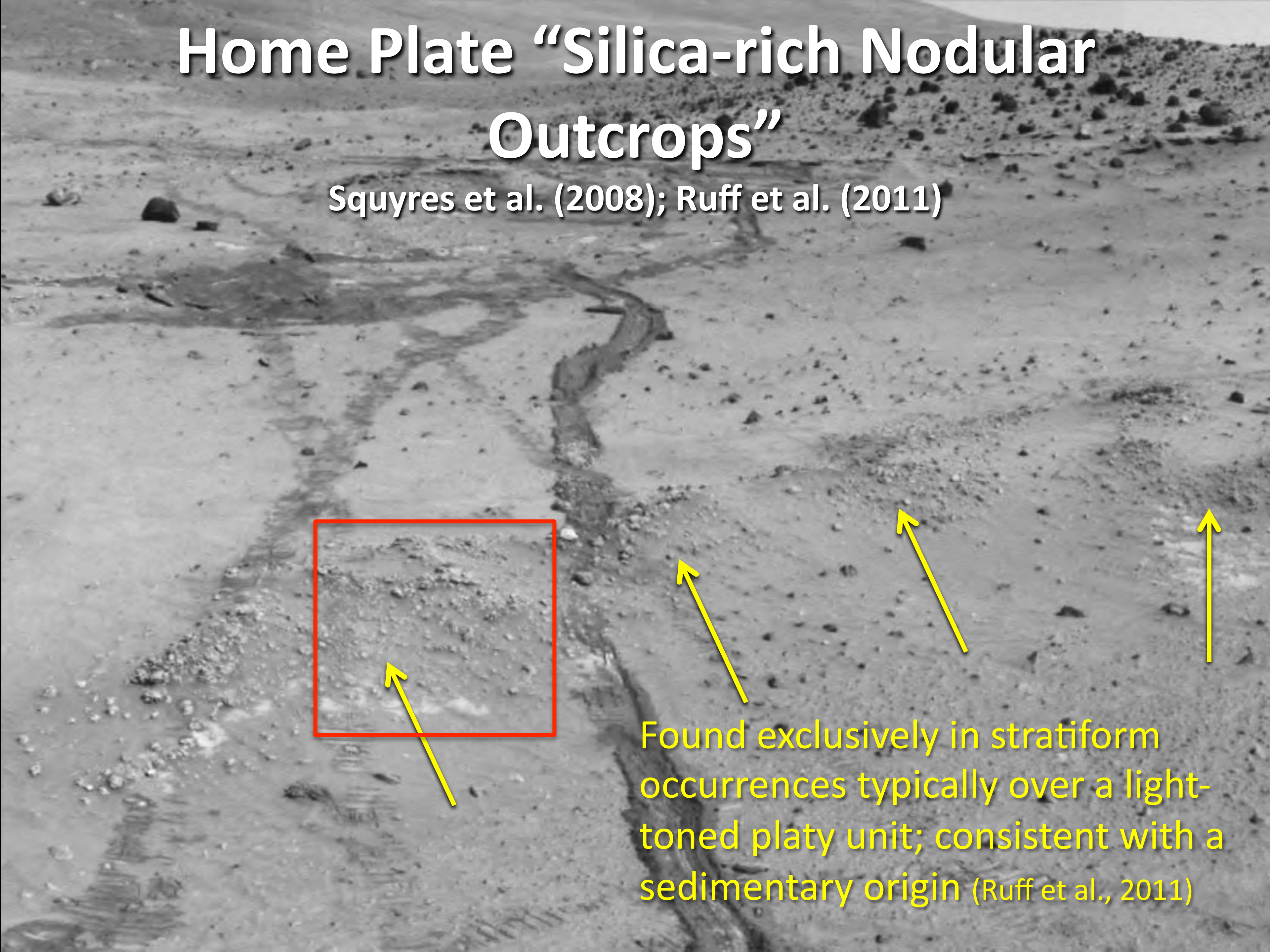
Outcrops and soil composed of nearly pure opaline silica of surface hydrothermal origin

(Squyres et al., 2008; Ruff et al., 2011)

Candidate Terrestrial Analog: El Tatio, Chile (Atacama) Hot Spring/Geyser system



- 4300 m elevation
- Hyper-arid environment
- Diurnal freeze-thaw (Nicolau et al., 2014)
- Silica precipitation dominated by evaporation
- Fluids evaporate to dryness; halite precipitation is final product
- Extreme UV radiation (Cabrol et al., 2014)


Home Plate "Silica-rich Nodular Outcrops"
Squyres et al. (2008); Ruff et al. (2011)
Found exclusively in stratiform occurrences typically over a light-toned platy unit; consistent with a sedimentary origin (Ruff et al., 2011)


Sol 778 Pancam approximate true color


El Tatio, Chile hot spring discharge apron

“Digitate protrusions”

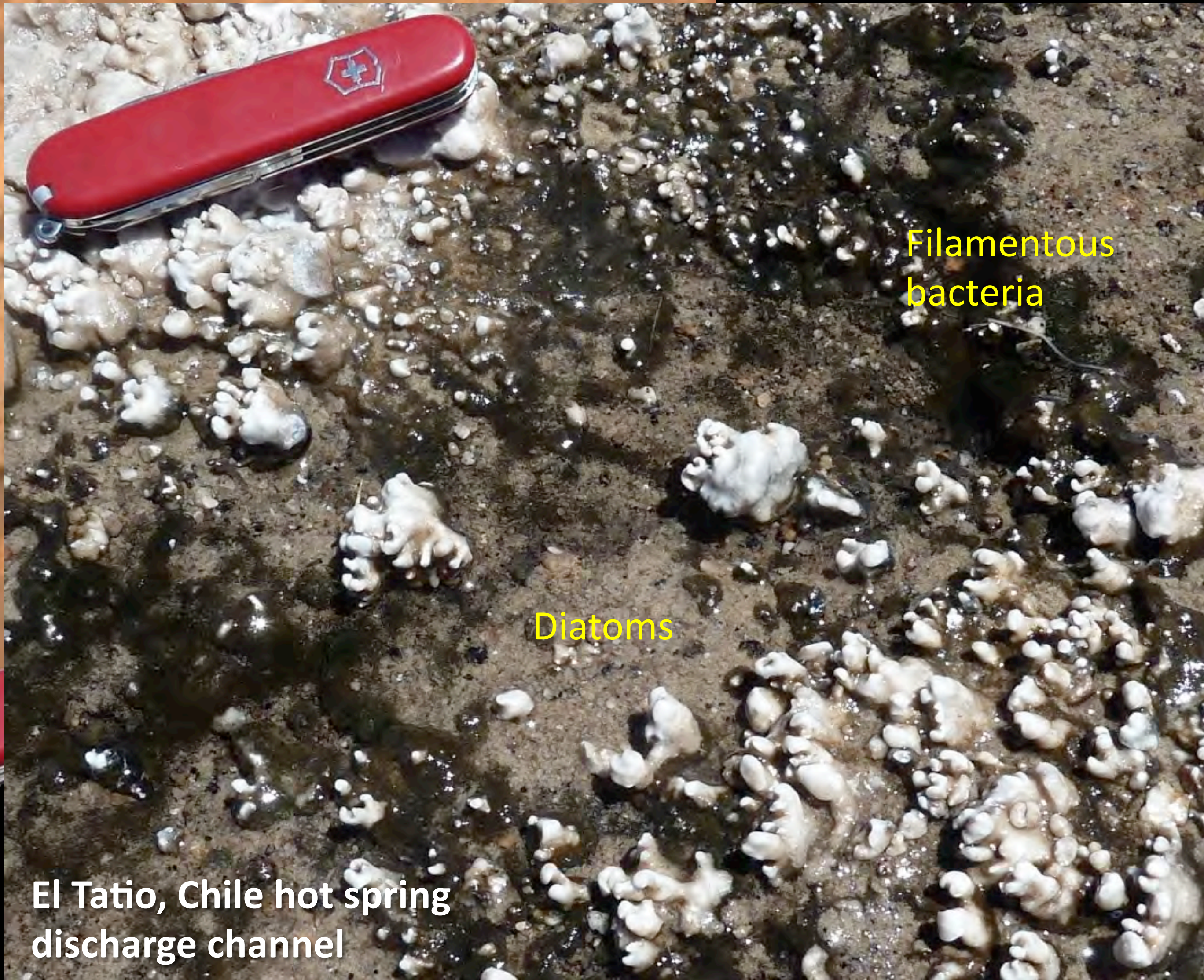
Ruff et al. (2011)

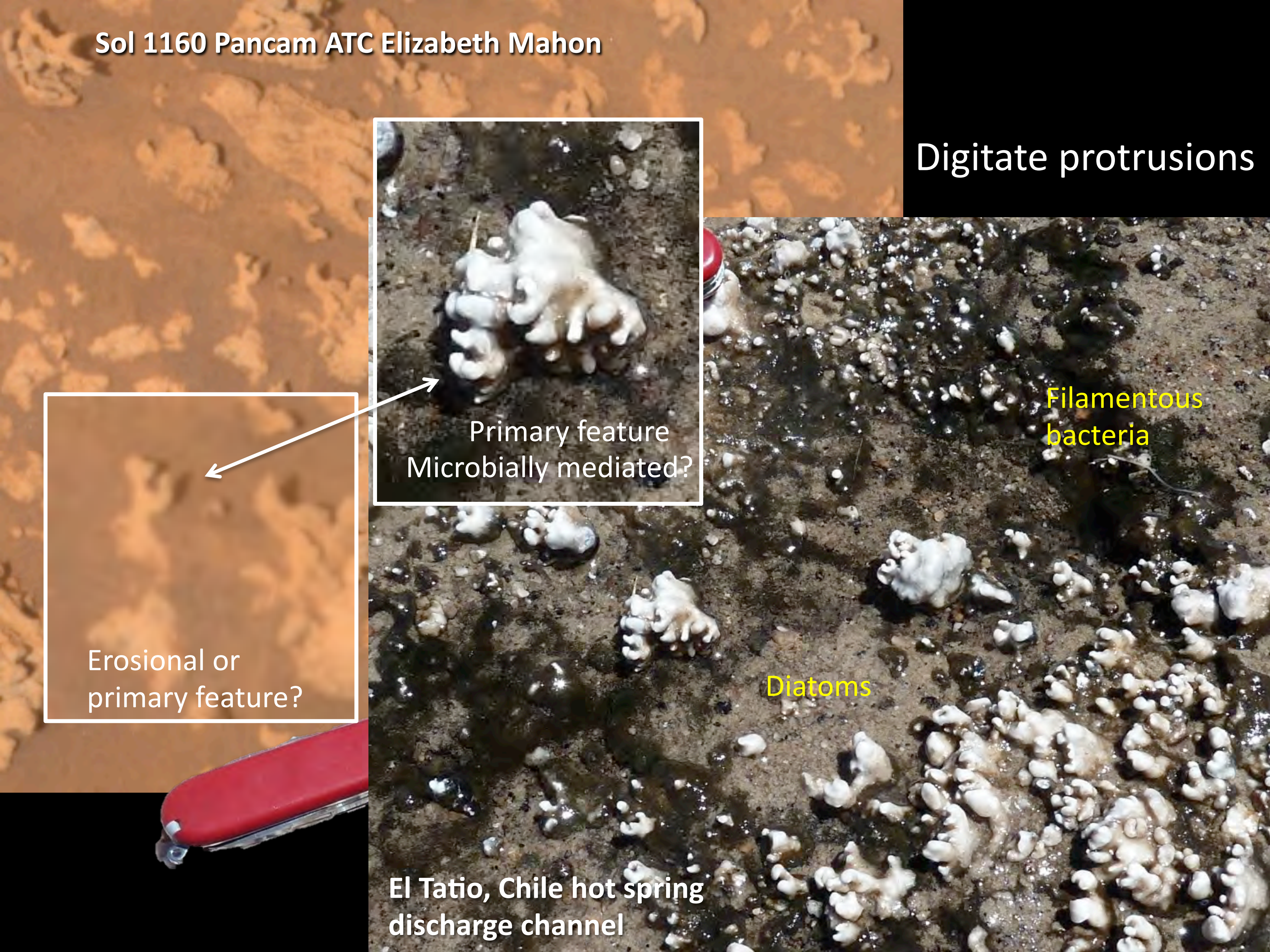
“Digitate protrusions”

Ruff et al. (2011)

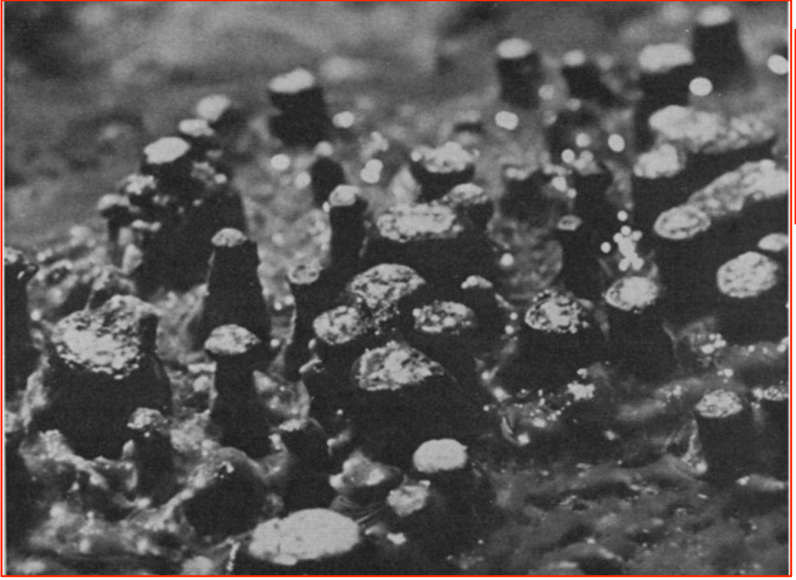
Digitate protrusions

Digitate protrusions

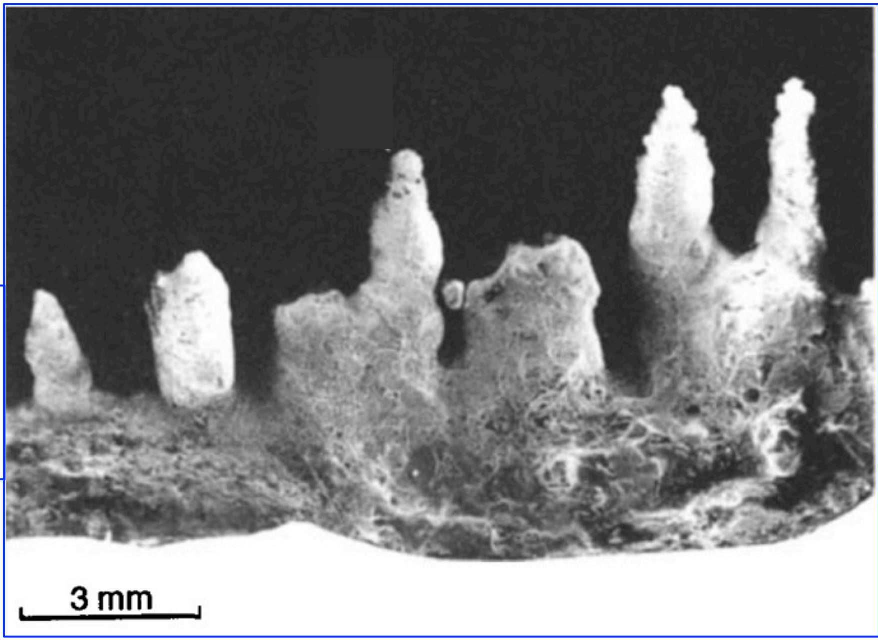




Sol 1160 Pancam ATC Elizabeth Mahon
Digitate protrusions
Primary feature
Microbially mediated?
Filamentous
bacteria
Erosional or
primary feature?
Diatoms
El Tatio, Chile hot spring
discharge channel



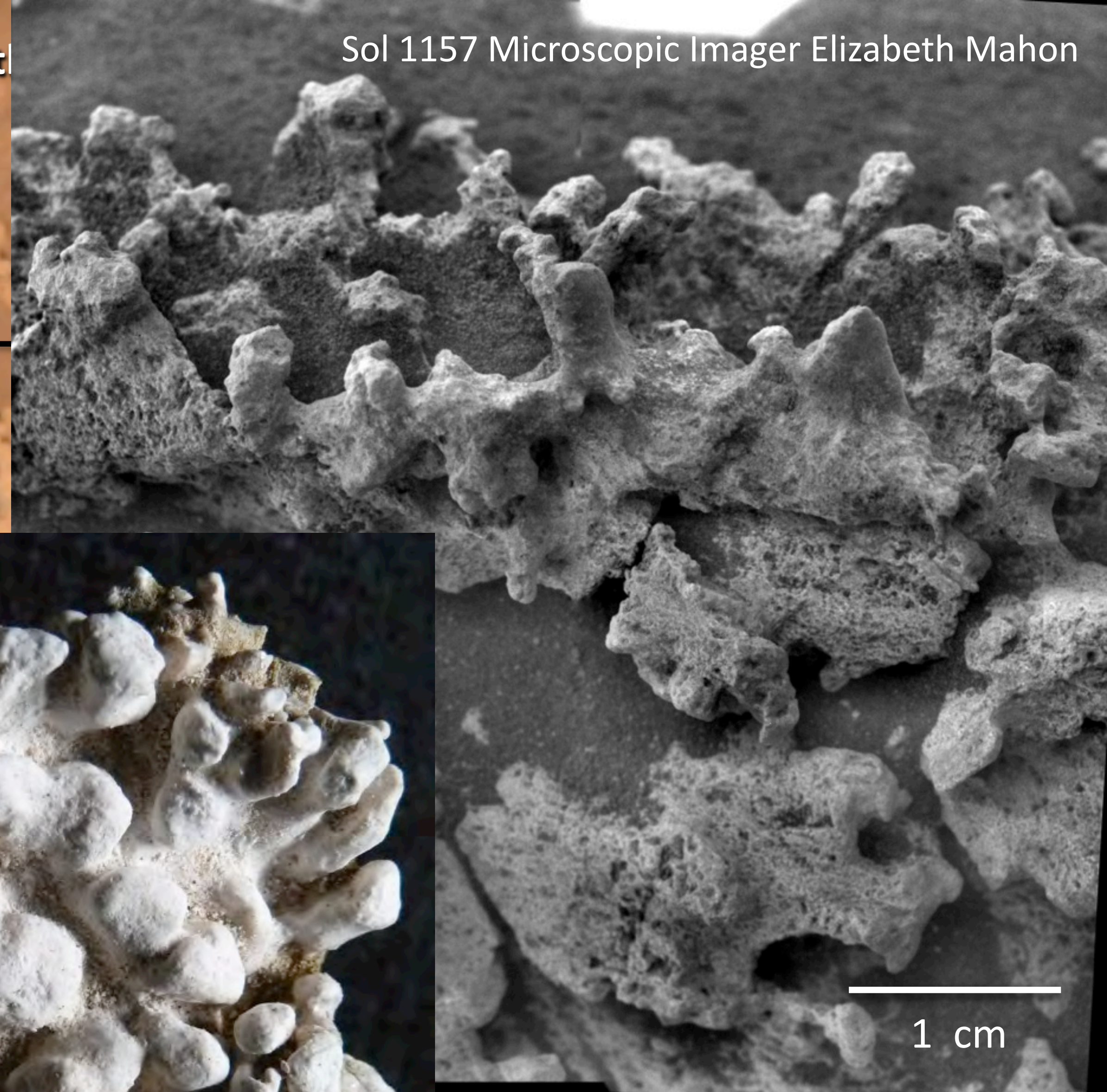
Siliceous Algal and Bacterial Stromatolites in Hot Spring and Geyser Effluents of Yellowstone National Park, Malcolm Walter et al., Science, 1972



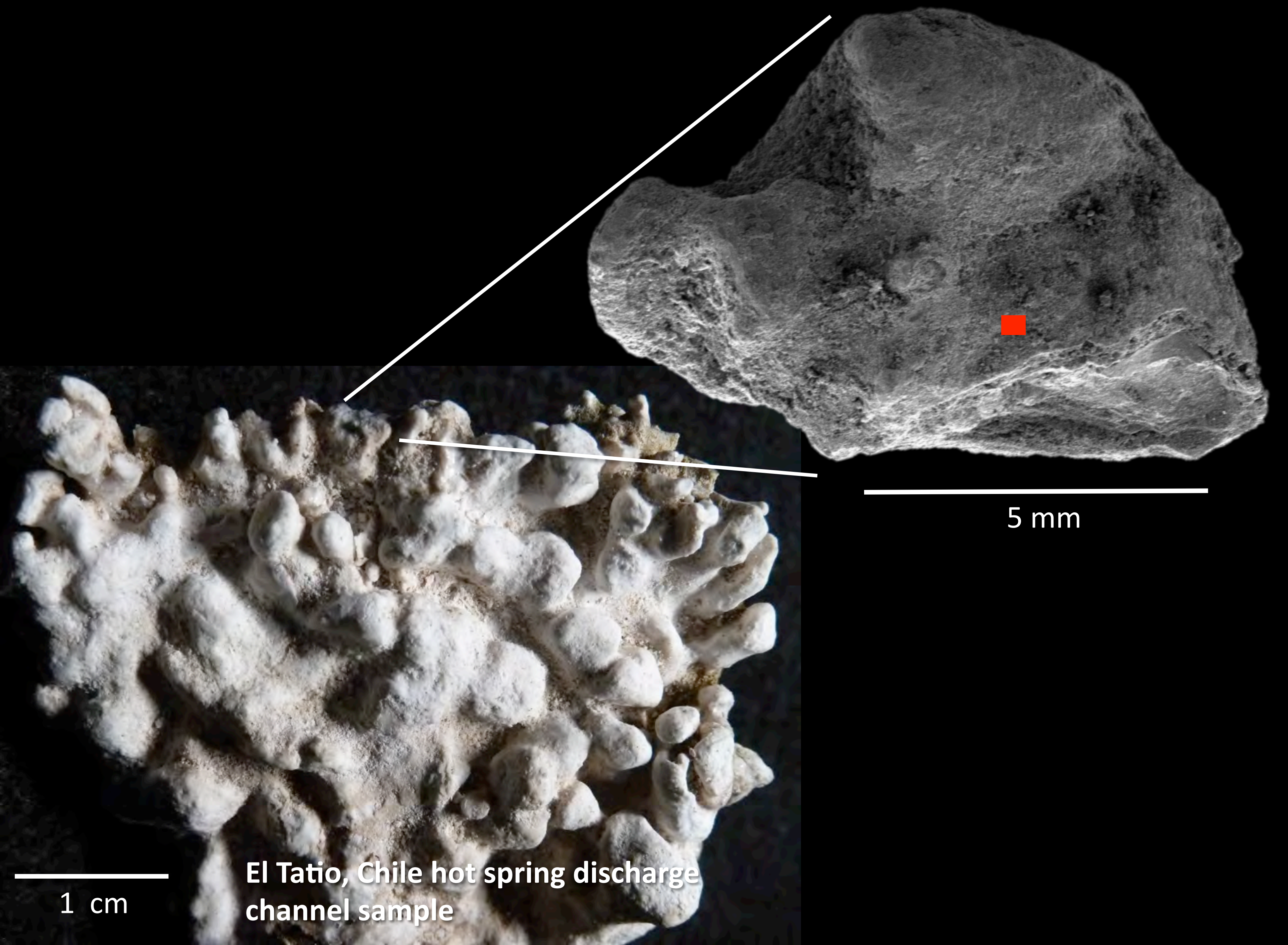
Vertical Zonation of Biota in Microstromatolites Associated with Hot Springs, North Island, New Zealand, Jones et al., Palaios, 1997

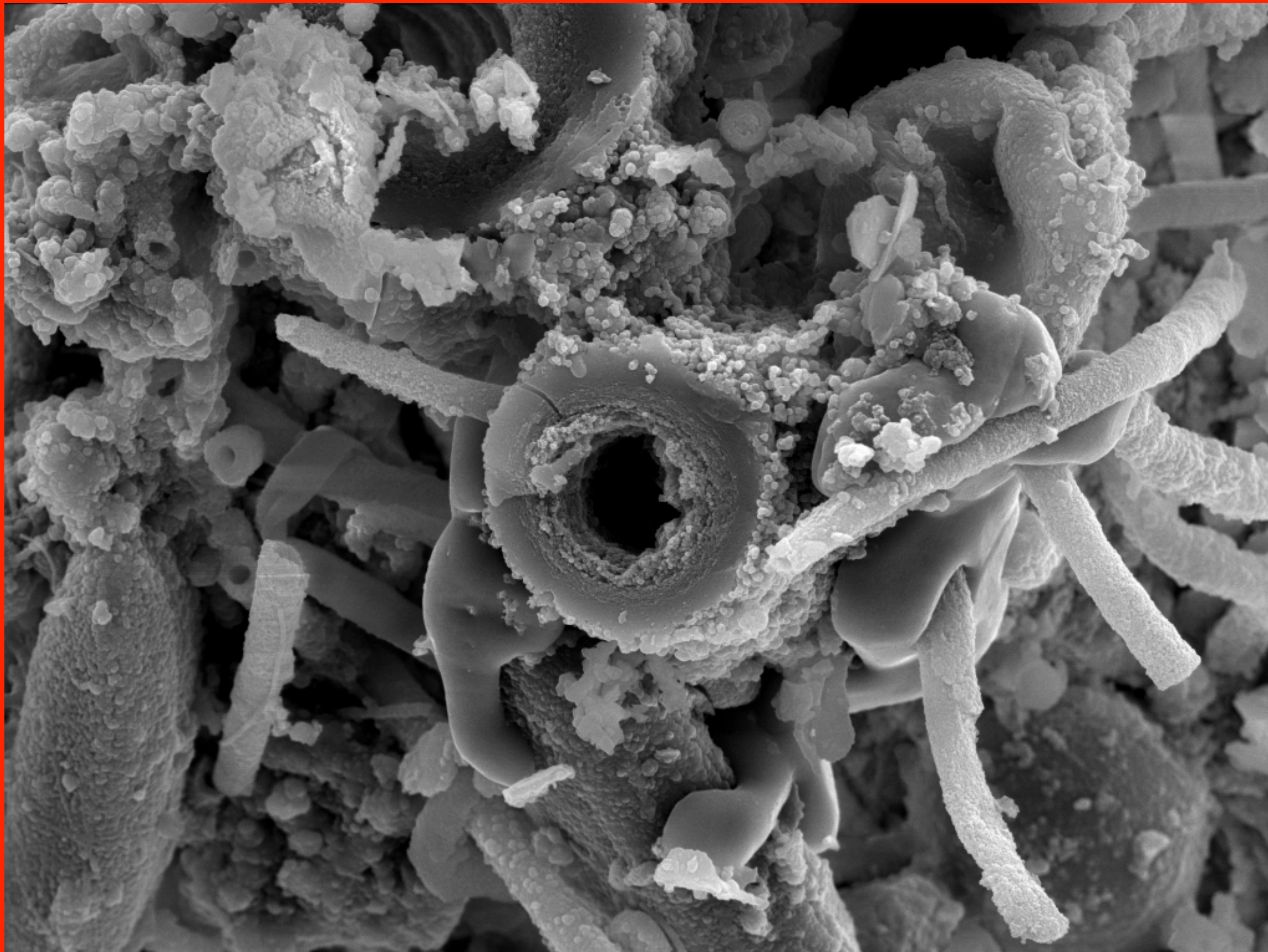
Microbial-silica interactions in Icelandic hot spring sinter: possible analogues for some Precambrian siliceous stromatolites, Konhauser et al., Sedimentology, 2001

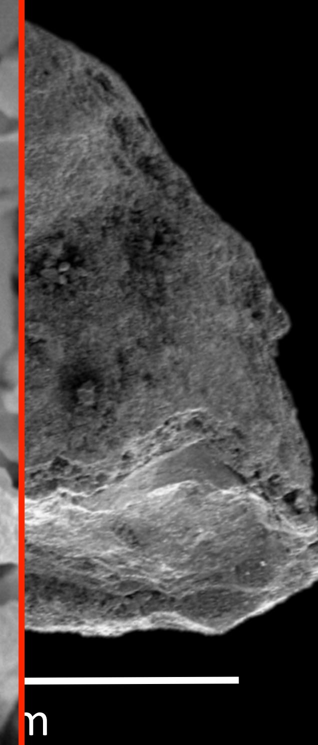

Sol 1160 Pancam ATC Elizabet


Sol 1157 Microscopic Imager Elizabeth Mahon
1 cm


1 cm
El Tatio, Chile hot spring discharge channel sample


5 mm
1 cm
El Tatio, Chile hot spring discharge channel sample



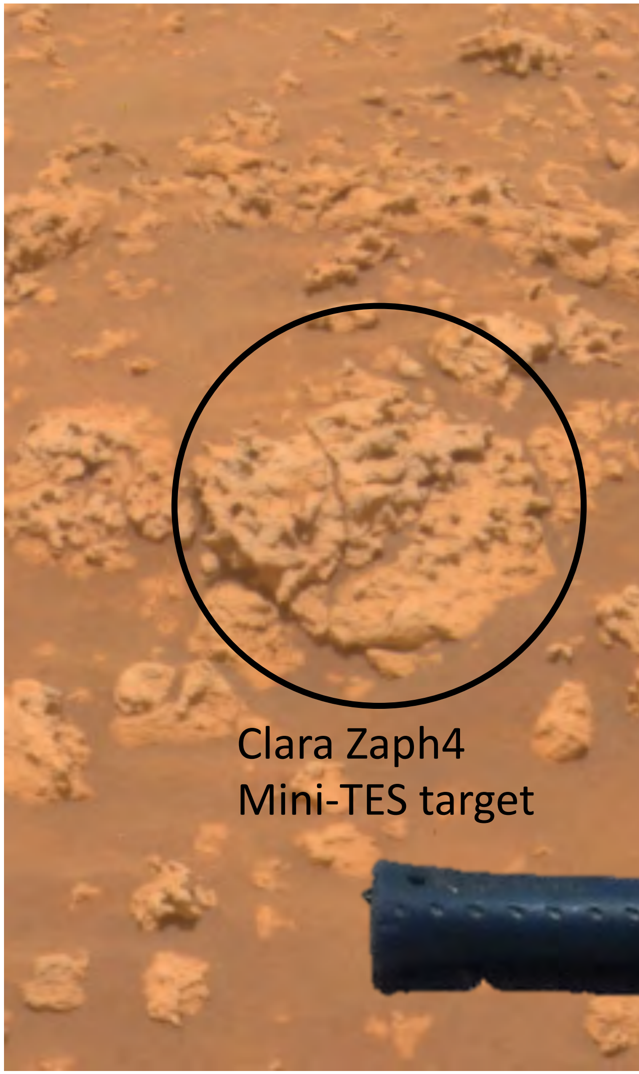


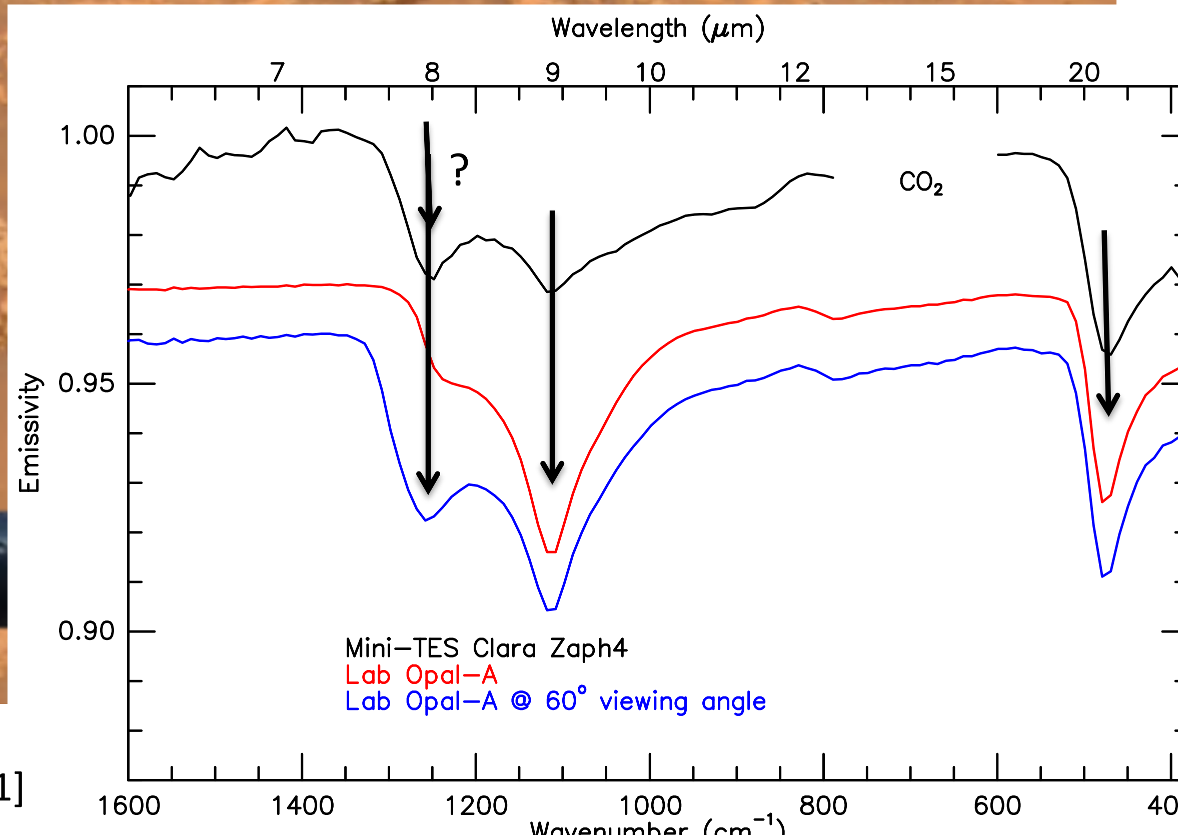
View field: 50.67 um DET: SE Detector
HV: 15.0 kV DATE: 03/09/15
20 um Vega ©Tescan

Mike Kraft Western Washington University

Near lower center of a5

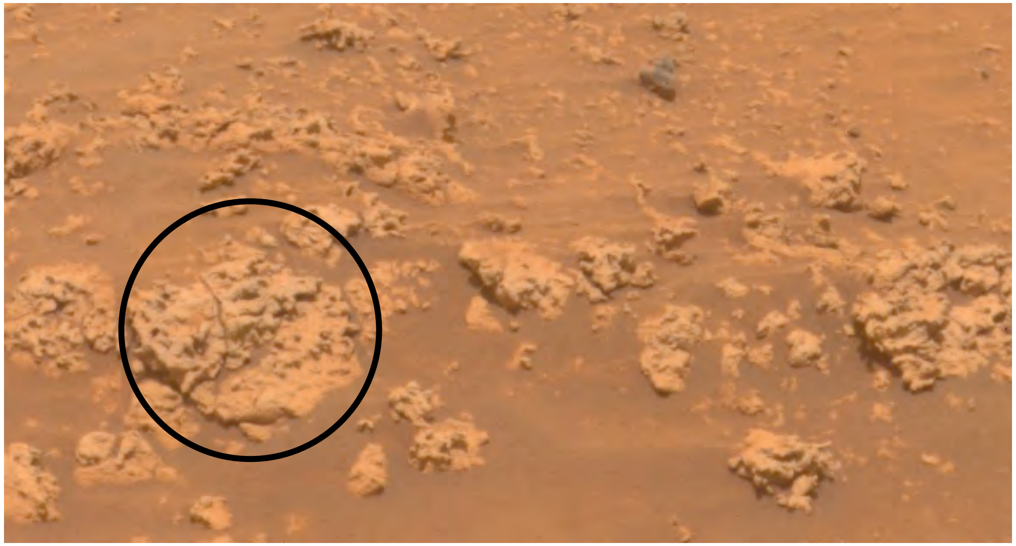
Thermal Emission Spectroscopy

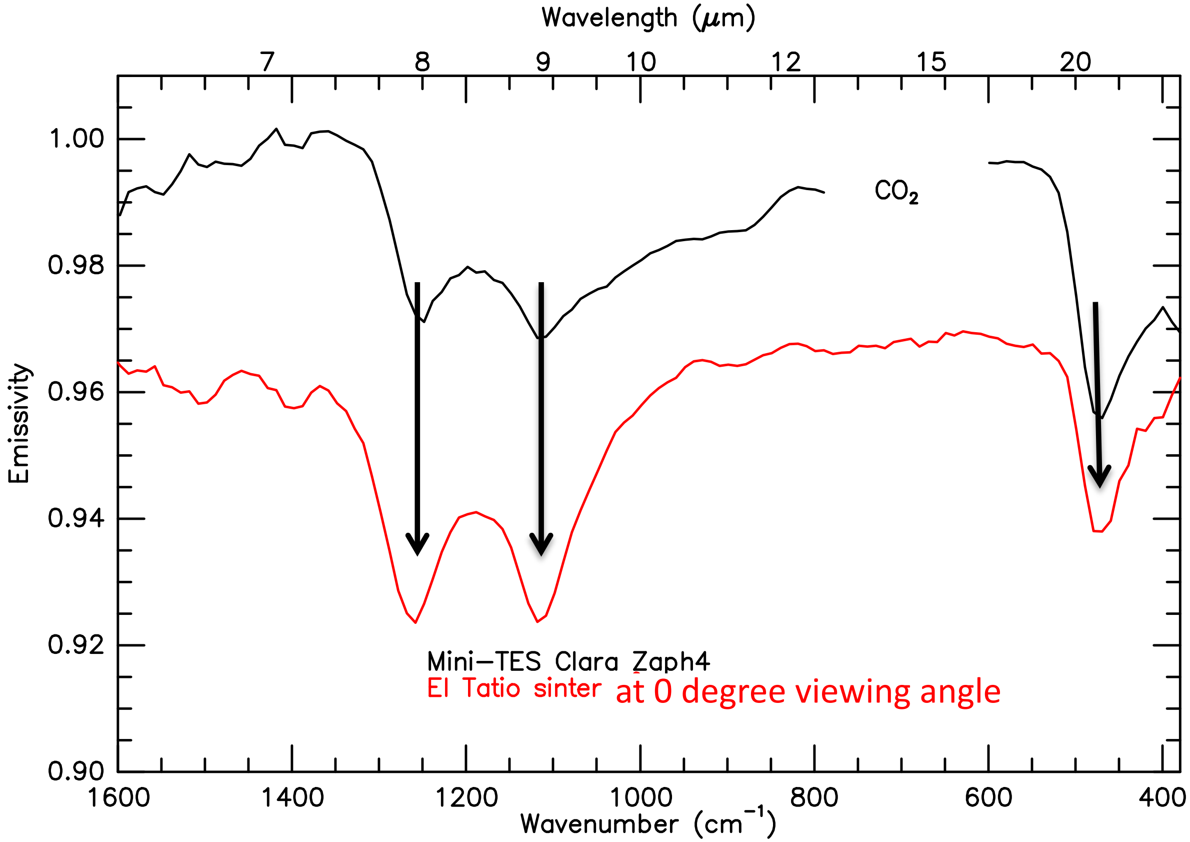




After Ruff et al. [2011]

Viewing Angle Effects Or Something Else?





Environmental Setting for Biosignature Preservation and Taphonomy of Organics							
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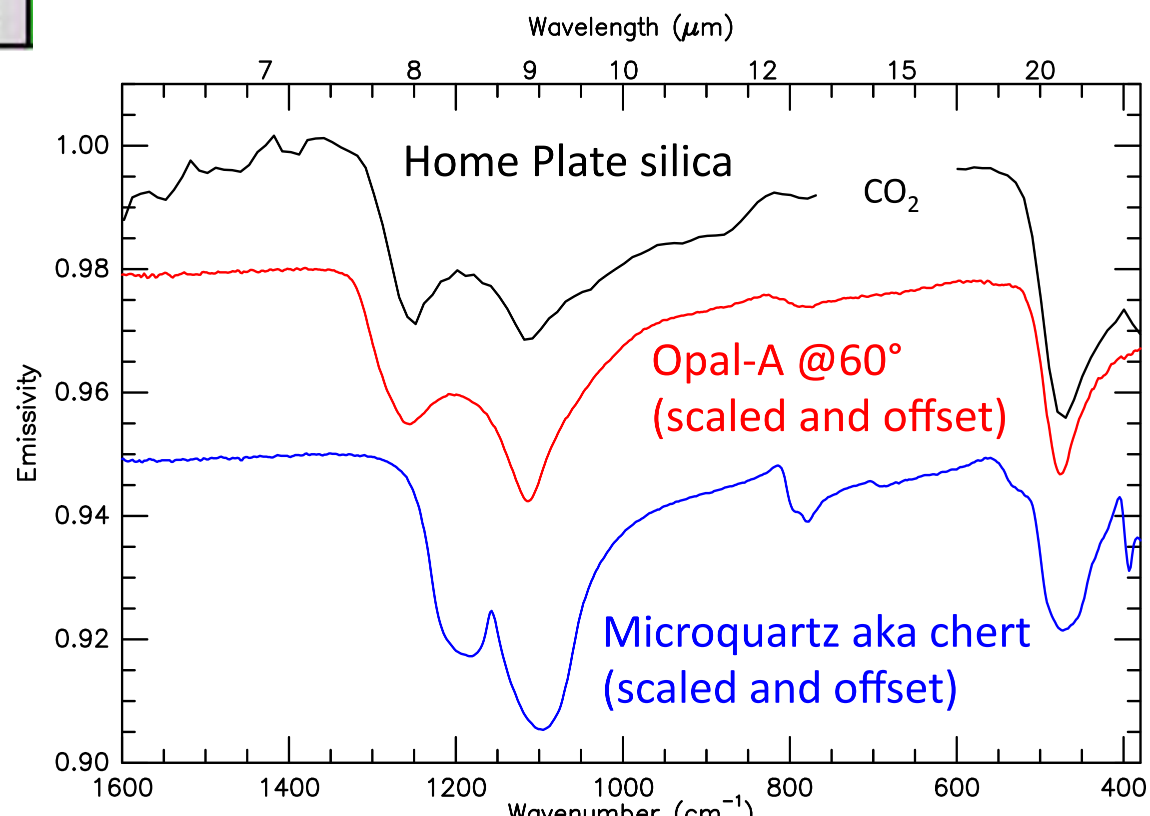
						●	

No Diagenesis



Does This Constitute a Recent Exposure?

Environmental Setting for Biosignature Preservation and Taphonomy of Organics							
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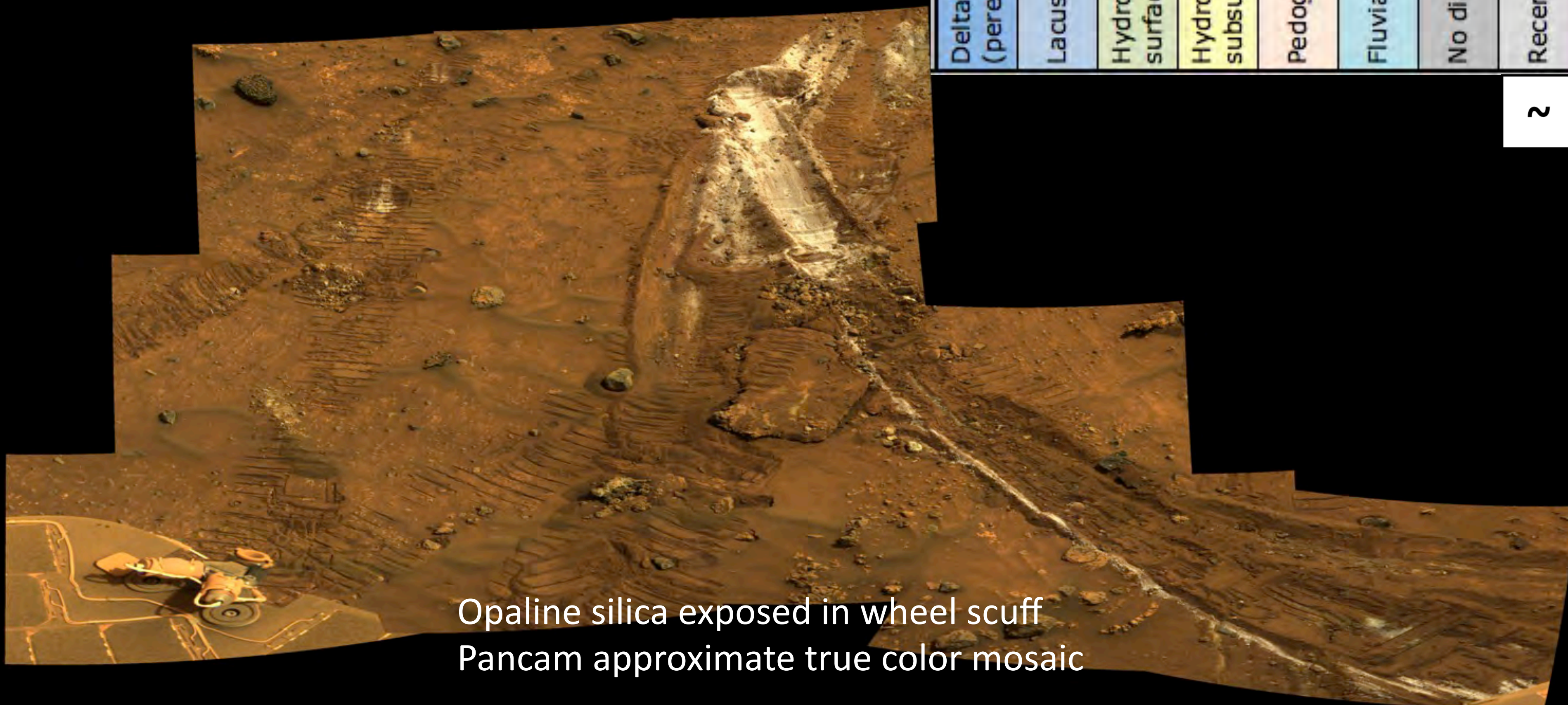
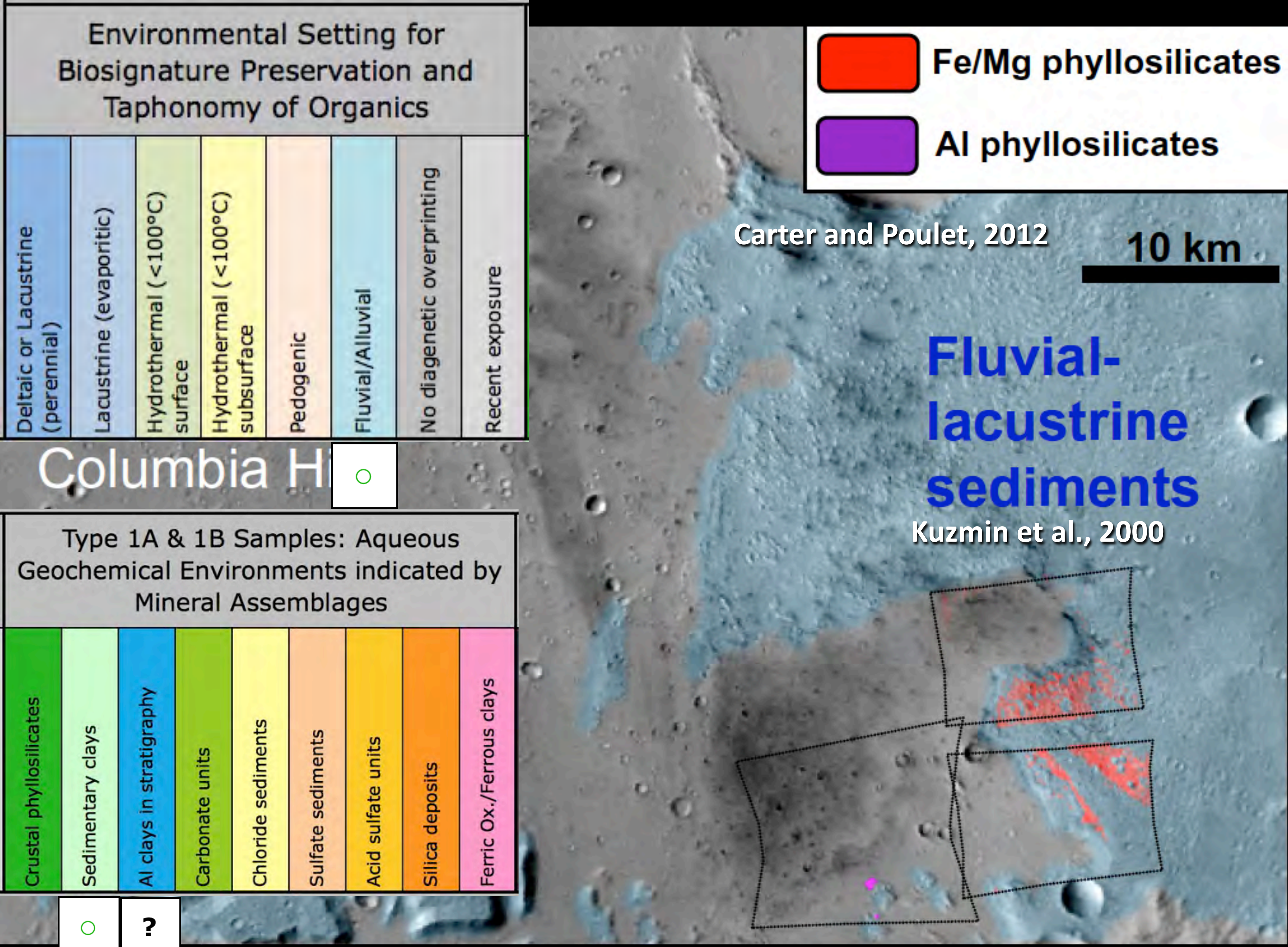


Opaline silica exposed in wheel scuff
Pancam approximate true color mosaic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Recent exposure
Columbia Hi
○
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Crustal phyllosilicates
Sedimentary clays
Al clays in stratigraphy
Carbonate units
Chloride sediments
Sulfate sediments
Acid sulfate units
Silica deposits
Ferric Ox./Ferrous clays
○
?
Fe/Mg phyllosilicates
Al phyllosilicates
Carter and Poulet, 2012
10 km
Fluvial-lacustrine sediments
Kuzmin et al., 2000

Type 1A & 1B Samples: Aqueous Geochemical Environments indicated by Mineral Assemblages

Crustal phyllosilicates	Sedimentary clays	Al clays in stratigraphy	Carbonate units	Chloride sediments	Sulfate sediments	Acid sulfate units	Silica deposits	Ferric Ox./Ferrous clays

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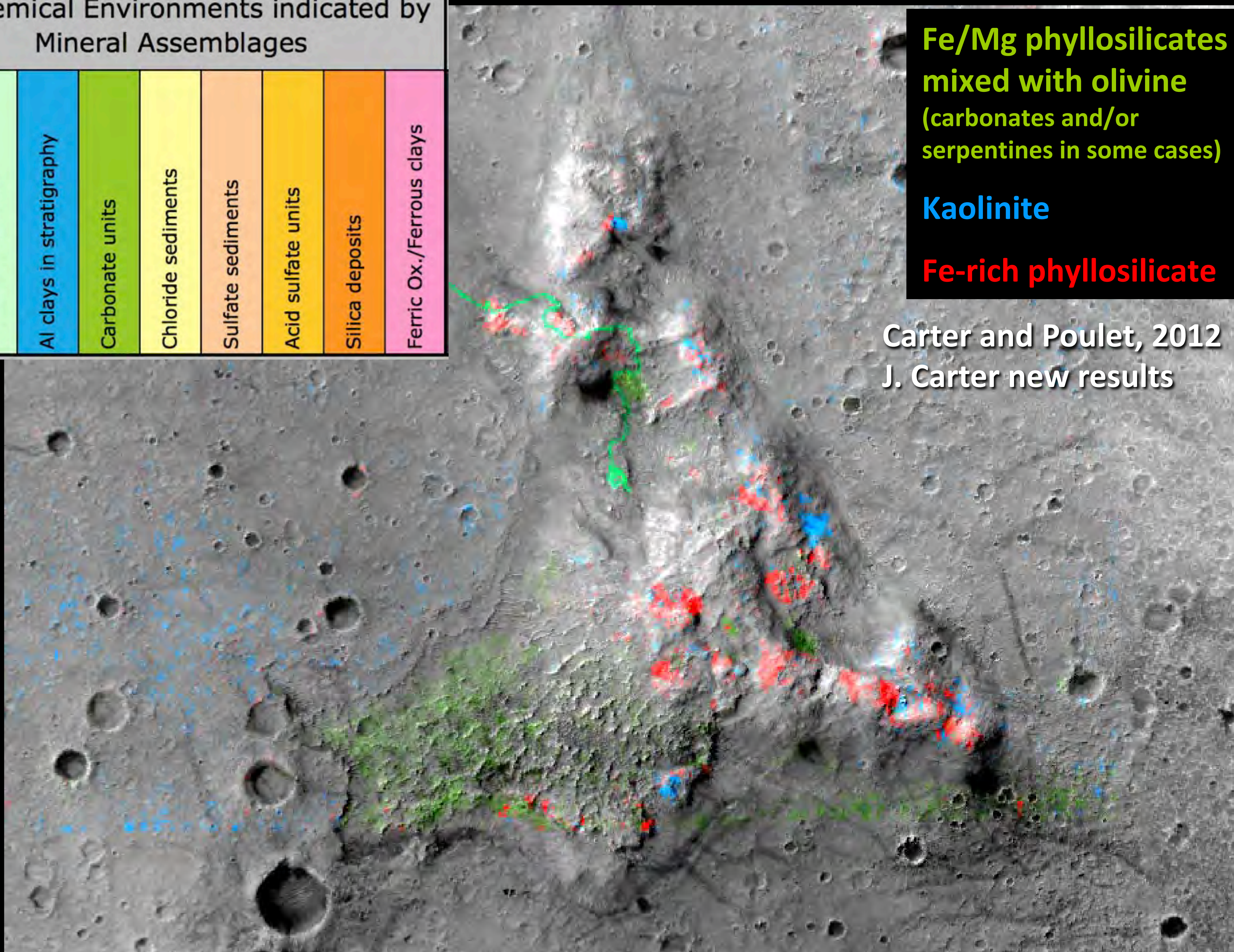

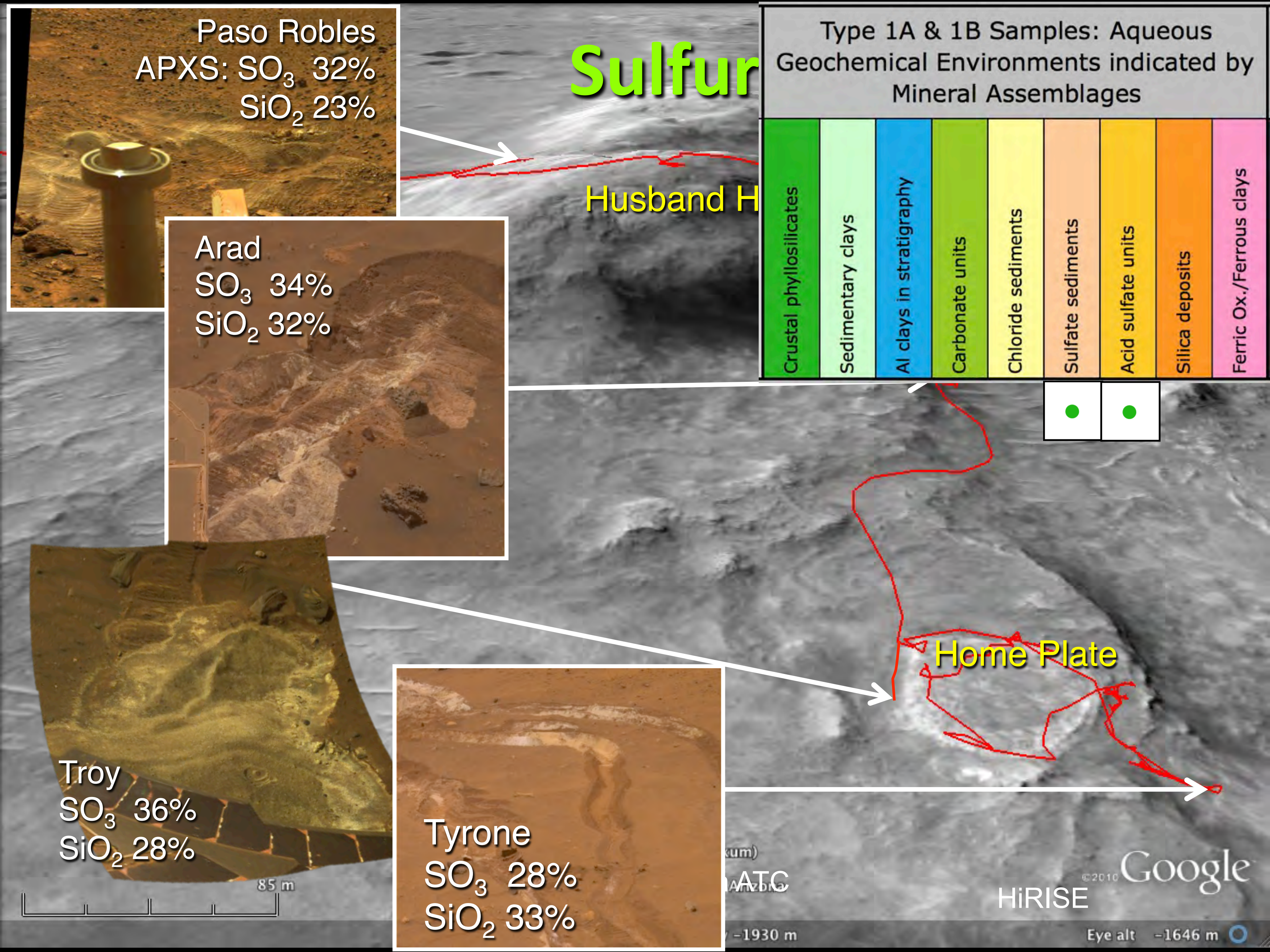

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Crustal phyllosilicates	Sedimentary clays	Al clays in stratigraphy	Carbonate units	Chloride sediments	Sulfate sediments	Acid sulfate units	Silica deposits	Ferric Ox./Ferrous clays
					●	●		

Halley Subclass Unit

Type 1A & 1B Samples: Aqueous Geochemical Environments indicated by Mineral Assemblages								
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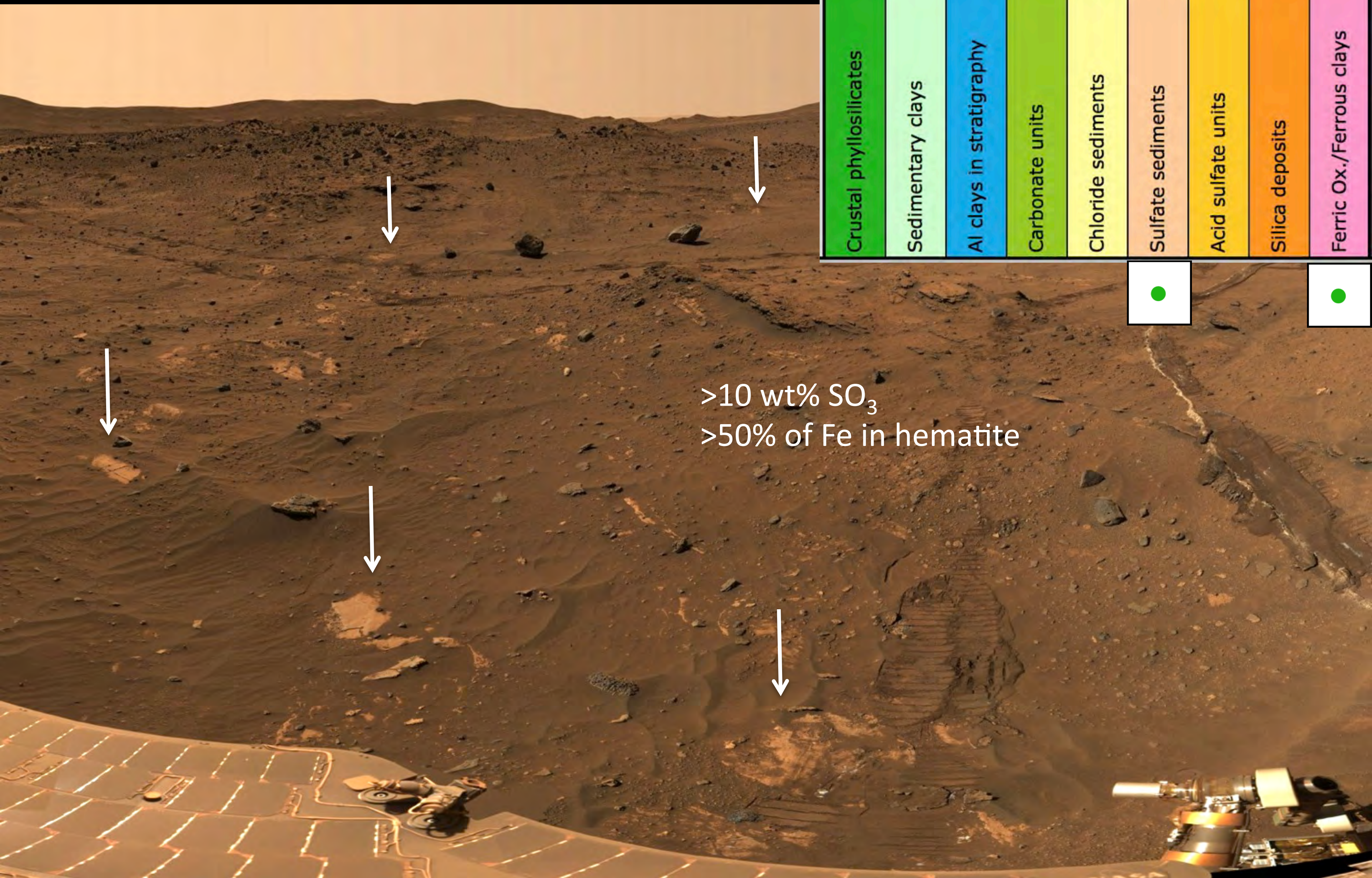
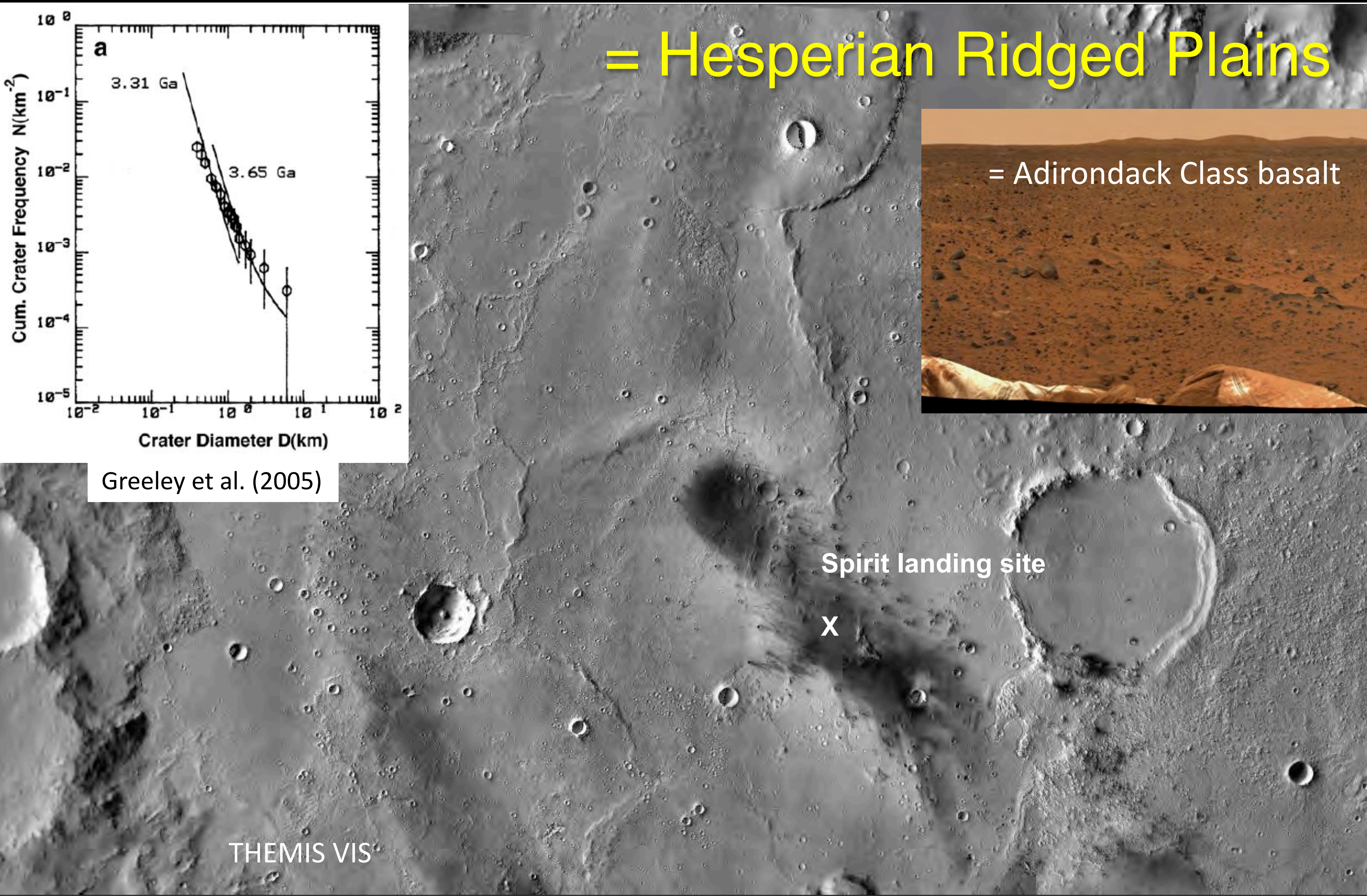
					●			●



3.65 Ga Wrinkle-ridged Plains of Gusev

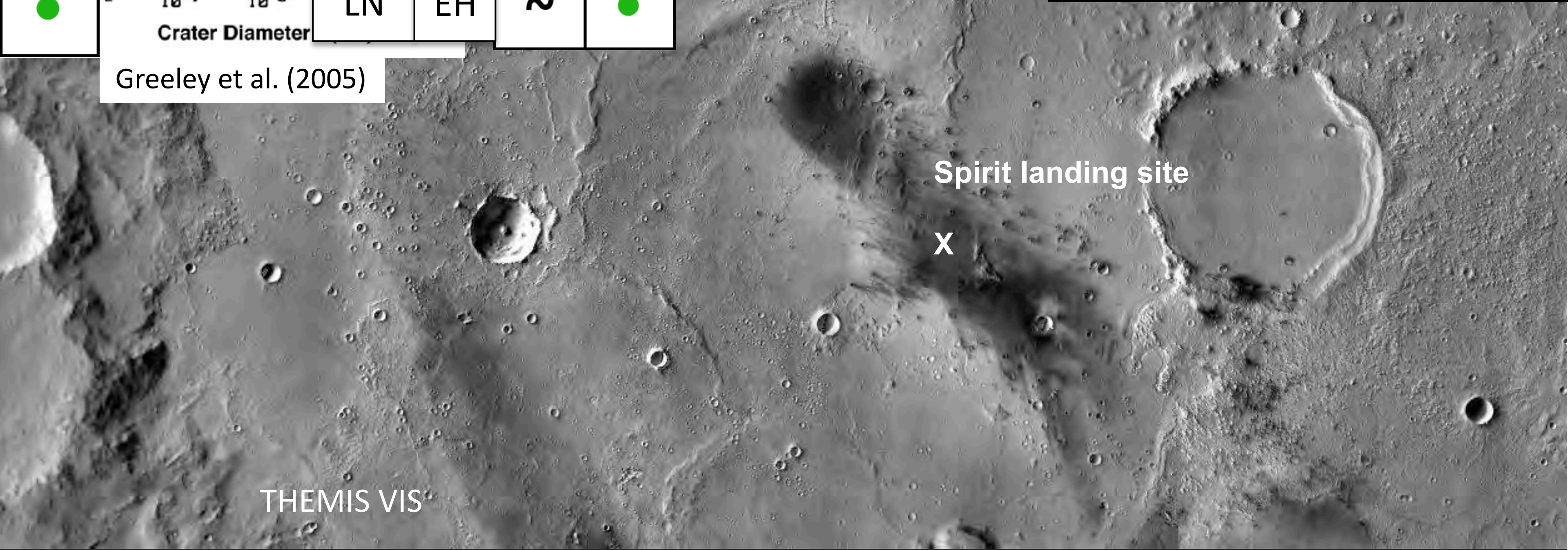


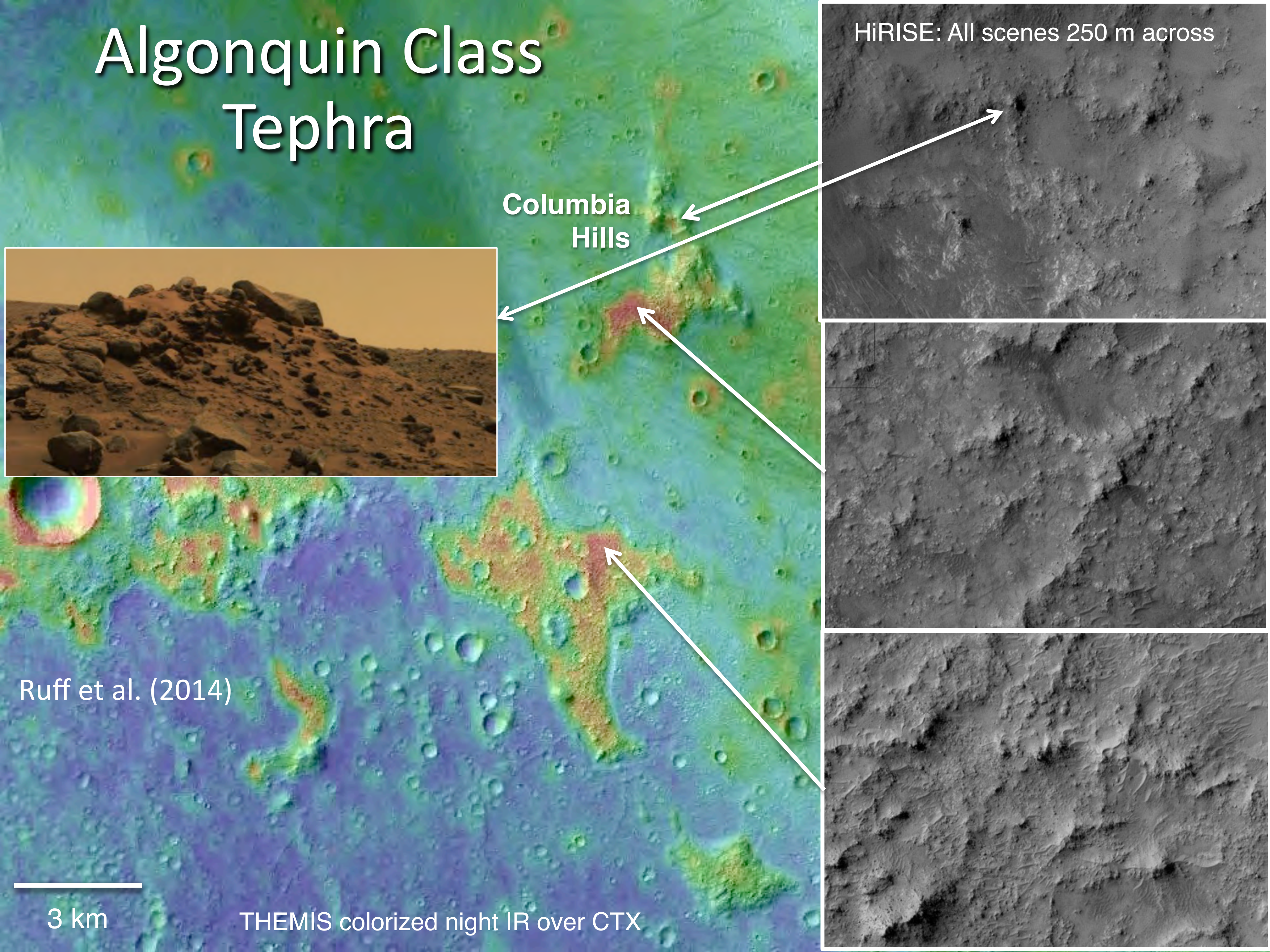
-ridged Plains of Gusev

= Hesperian Ridged Plains

Type 2 Samples: Igneous		Context: Martian History Sampled, Timing Constraints				
Igneous unit (e.g, lava flow, pyroclastic, intrusive)	2nd Igneous unit	Pre- or Early-Noachian Megabreccia	Oldest stratigraphic constraint	Youngest stratigraphic constraint	Stratigrapy of units well-defined	Dateable surface, volcanic (unmodified crater SFD)
●			LN	EH	~	●

Greeley et al. (2005)




Algonquin Class
Tephra
HiRISE: All scenes 250 m across
Columbia
Hills
Ruff et al. (2014)
3 km
THEMIS colorized night IR over CTX

Algonquin Class Tephra

Type 2 Samples: Igneous		Context: Martian History Sampled, Timing Constraints				
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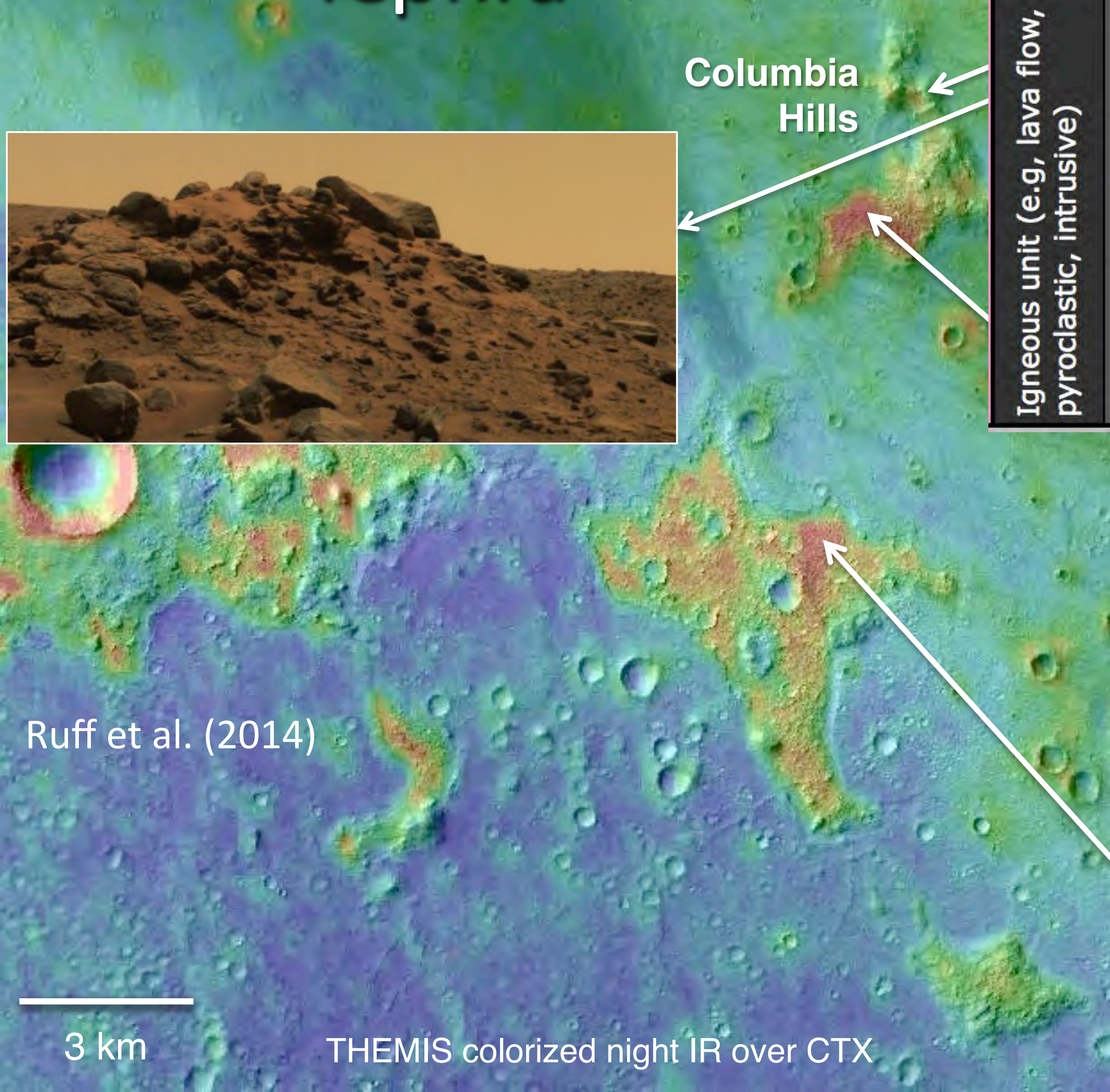

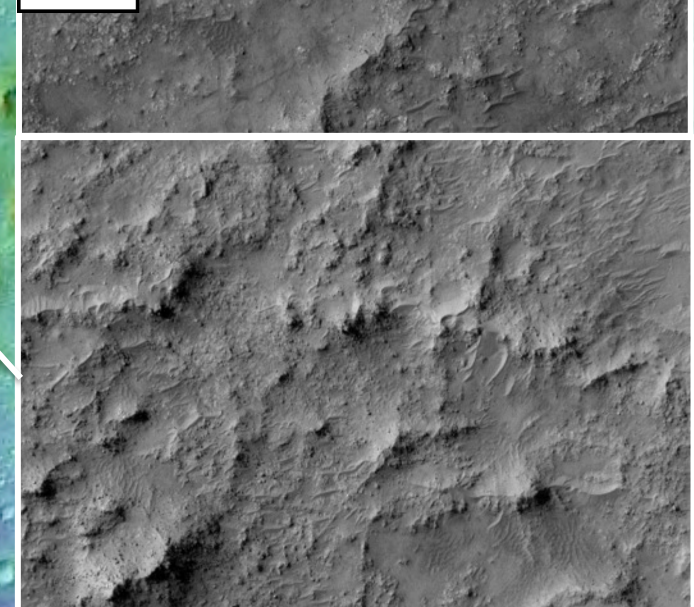

Landing Site Factor	Mars 2020 Mission and Decadal Priority Science Factors																							
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Gusev	○	~	●			○	●	~	~	○	?	●		●	●	●	●	●	●		LN	EH	~	●

Landing Site Scientific Selection Criteria:

Objective A.

1. The geologic setting and history of the landing site can be characterized and understood through a combination of orbital and in-situ observations. YES

Objective B

2a. The landing site offers an ancient habitable environment. YES

2b. Rocks with high biosignature preservation potential are available and are accessible to investigation for astrobiological purposes with instruments on board the rover. YES

Objective C

3a. The landing site offers an adequate abundance, diversity, and quality of samples suitable for addressing key astrobiological questions if and when they are returned to Earth. YES

3b. The landing site offers an adequate abundance, diversity, and quality of samples suitable for addressing key planetary evolution questions if and when they are returned to Earth. YES