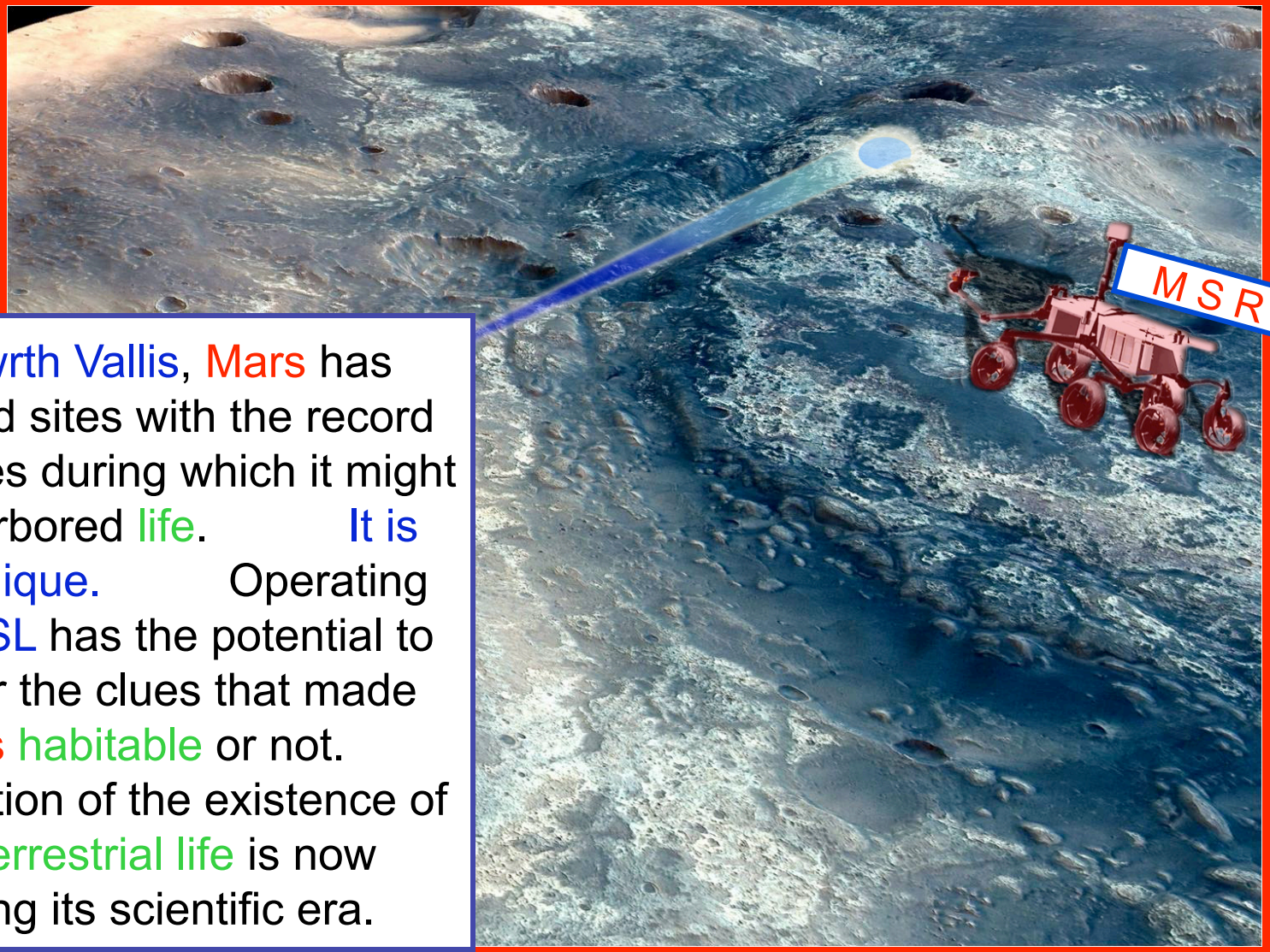
Mawrth Vallis

The dream is alive

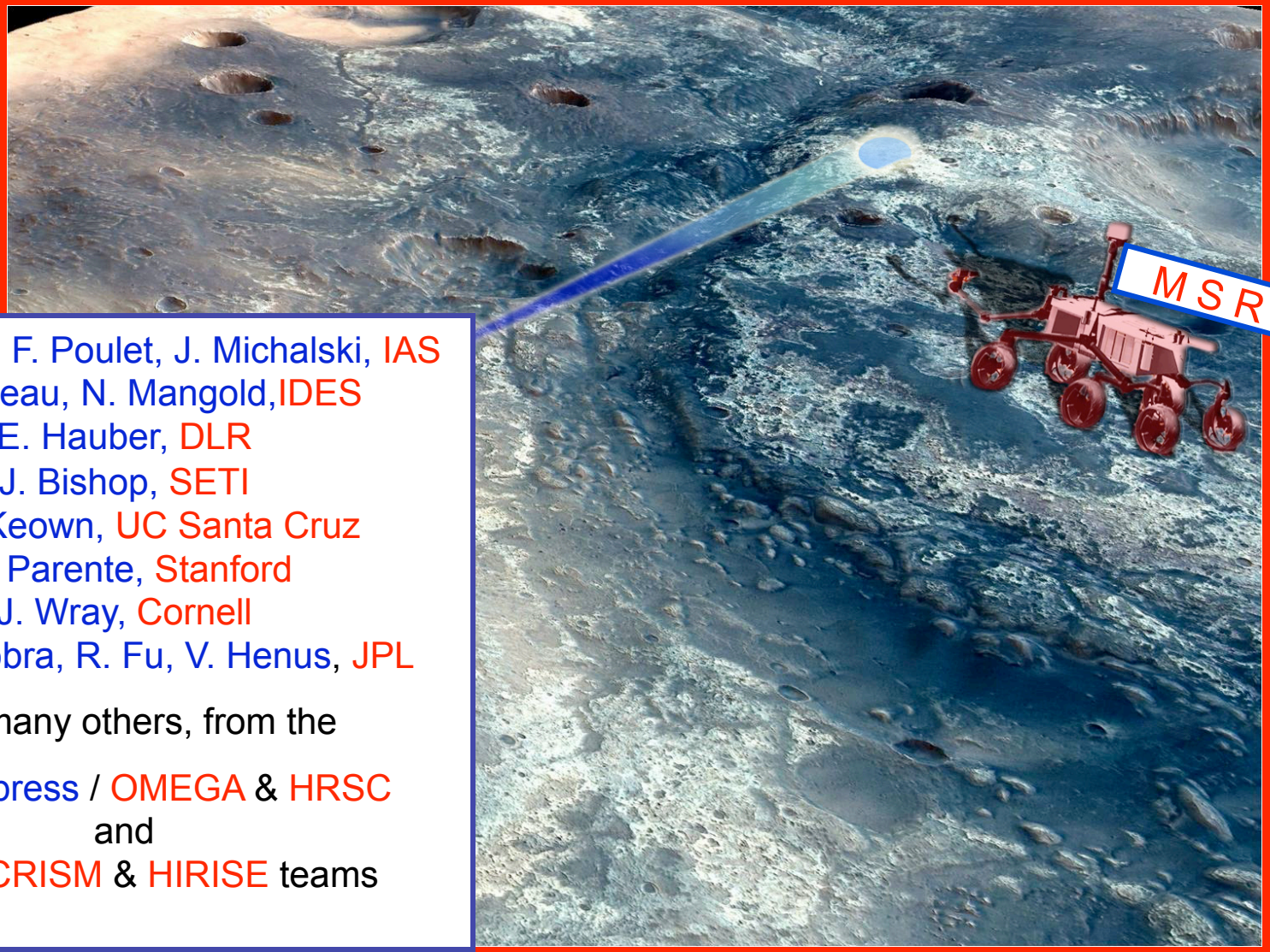


At Mawrth Vallis, Mars has preserved sites with the record of the times during which it might have harbored life. It is totally unique. Operating there, MSL has the potential to decipher the clues that made Mars habitable or not.

The question of the existence of extraterrestrial life is now entering its scientific era.

Mawrth Vallis

The dream is alive



J-P. Bibring, F. Poulet, J. Michalski, IAS
D. Loizeau, N. Mangold,IDES
E. Hauber, DLR
J. Bishop, SETI
N. McKeown, UC Santa Cruz
M. Parente, Stanford
J. Wray, Cornell
E. Noe Dobra, R. Fu, V. Henus, JPL

and many others, from the

Mars Express / OMEGA & HRSC
and
MRO / CRISM & HIRISE teams

Mawrth Vallis

The dream is alive

1. The OMEGA discovery of hydrated phyllosilicate-rich sites has opened a new window for Mars to have potentially harbored habitable conditions. 3 years of refined measurements by OMEGA/ MEx, then CRISM/MRO, coupled to HRSC/MEx and HIRISE/MRO have confirmed that,

   if ever Mars was habitable, it was at a time phyllosilicates formed.

Follow the water

⇓

Follow the phyllo

Mawrth Vallis

The dream is alive

2. This era is the most ancient one: it happened while the planet was heavily bombarded, and very likely when the dynamo was still active. It lasted within the Noachian, but likely ended prior the drop of the bombardment, which further modeled most of the surface and erased most of the record of the previous aqueous alteration.

3. This era, so critical for planetary evolution as it might have hosted, at least on the Earth, possibly at Mars, the emergence of life, has never been studied so far, as it was out of observational accessibility, both on the Earth and on the Moon.

- What was the environment at that time?
- How did it evolve?
- How could aqueous settings remain stable while bombarded?
- Did the bombardment slowly decrease, over half a billion years or
- Did it rapidly dropped, with further spikes until the late events

(which formed Hellas and most of the other large basins, together with craters of all sizes that remodeled the crust, after it had been altered with phyllosilicate-rich upper layers, over some hundreds of meters), leaving quiet episodes for standing bodies of water to host (bio)chemical evolution?

Mawrth Vallis
The dream is alive

4. Mars is unique in offering to address these questions.
   MSL has the capability to significantly contribute answering them.

   The phyllosilicate composition, coupled to the geomorphological context, is key to assess the environmental conditions prevailing at these times, and the processes in place with impact cratering a dominant one.

   ⇒ The variety of composition translates the evolution of the overall conditions, the deciphering of which constitutes a key goal for MSL.

   However: one need to access the best preserved site wrt this sequential evolution (in place alteration).

   Any phyllosilicate-rich site has the potential to contain rocks having preserved bio-relics, if ever life emerged at Mars. However, only very few have kept the stratification record of this very complex era in its integrity: in only one do we have direct access to it, within the MSL landing ellipse: Mawrth Vallis.

Mawrth Vallis

The dream is alive

5. The reasons why this happened at Mawrth Vallis are not fully understood yet: many controversial and exciting ideas have emerged. Nicolas and Eldar will address them. Very likely, we will not know the final answers prior to have landed and MSL operated there.

   However, what is known for sure and widely agreed, is that this era is totally unique for its potential to tell if, why, when and how, Mars evolution led to habitability.

   In exploring Mawrth Vallis we optimize the chances to be successful.

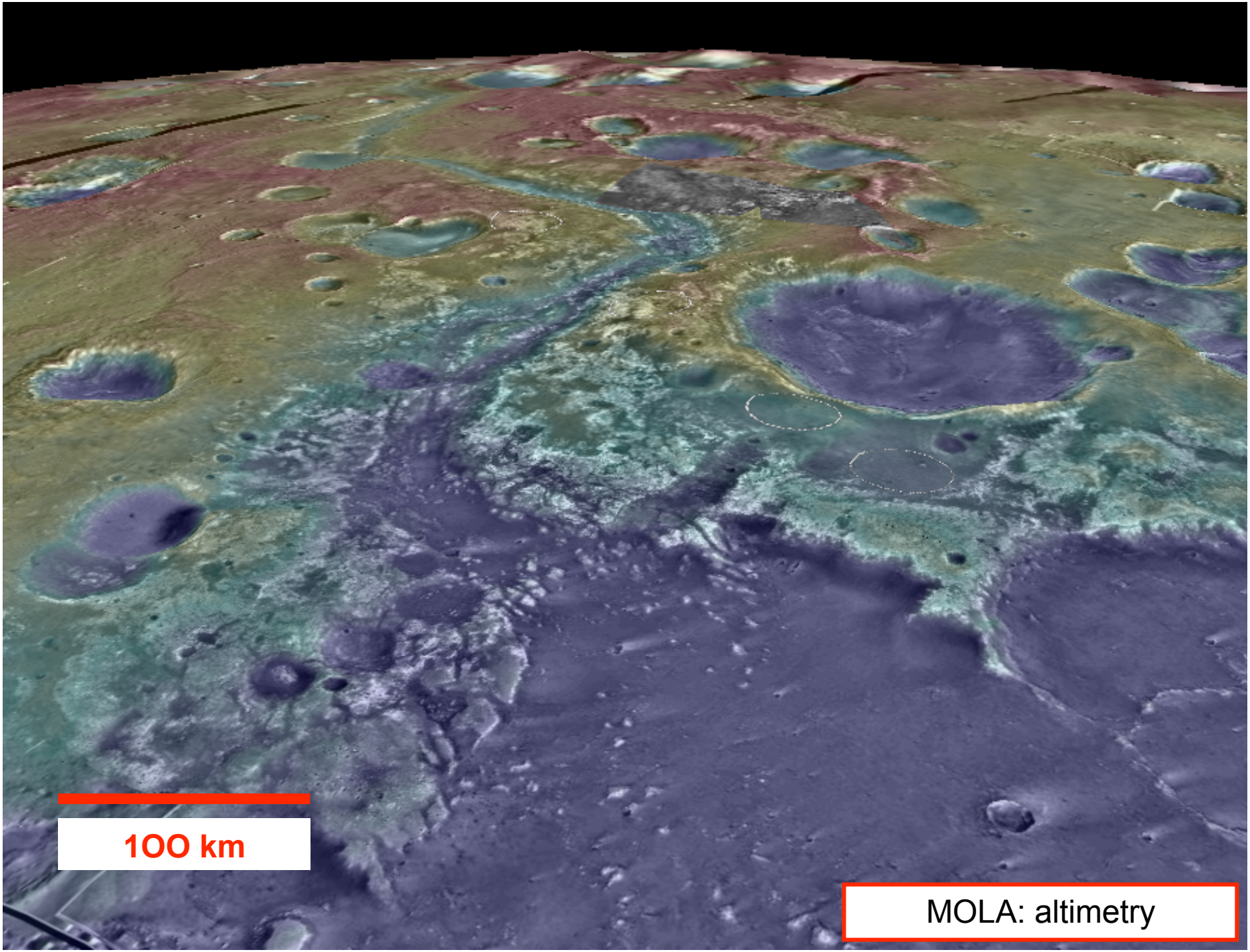
Mawrth Vallis

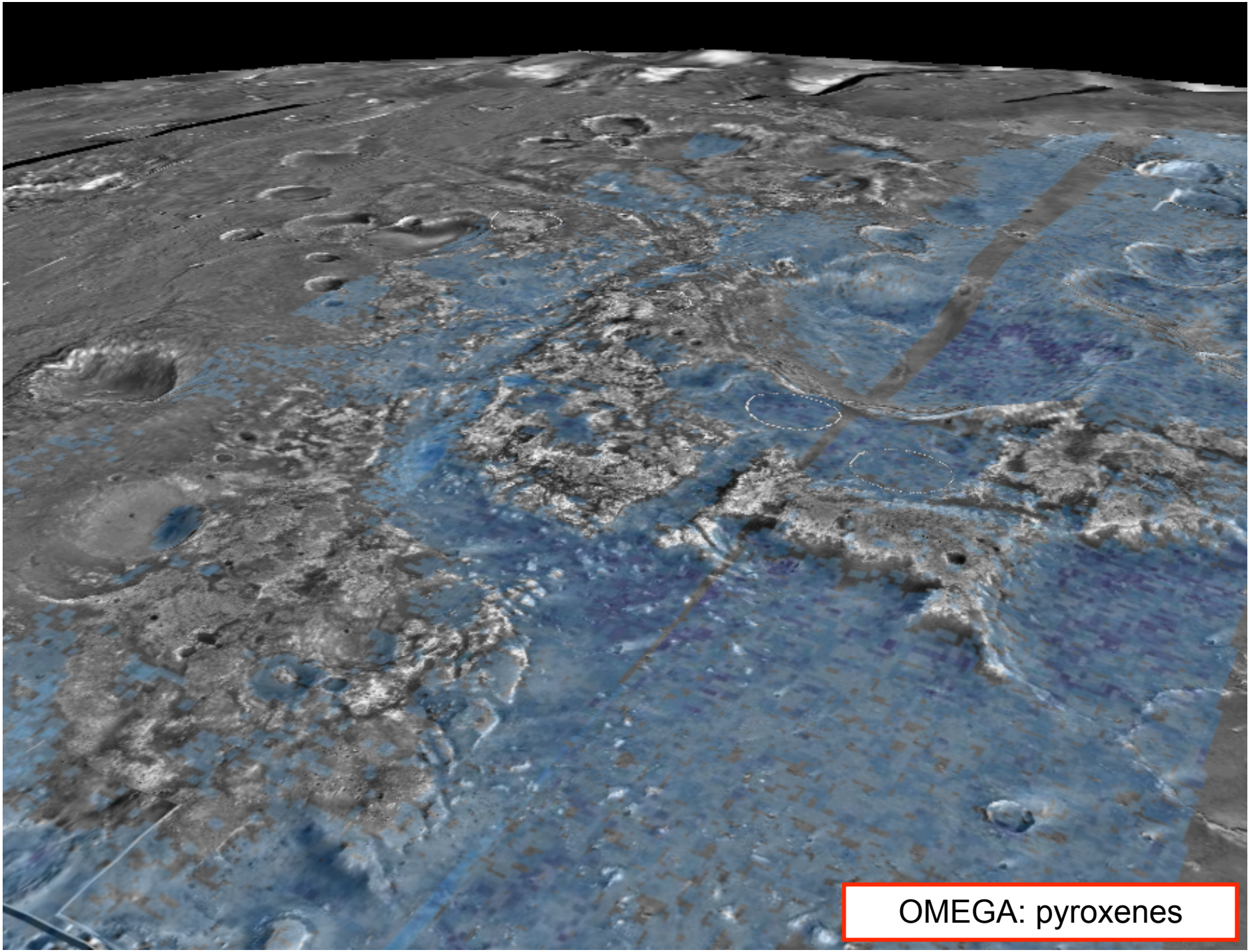
The dream is alive

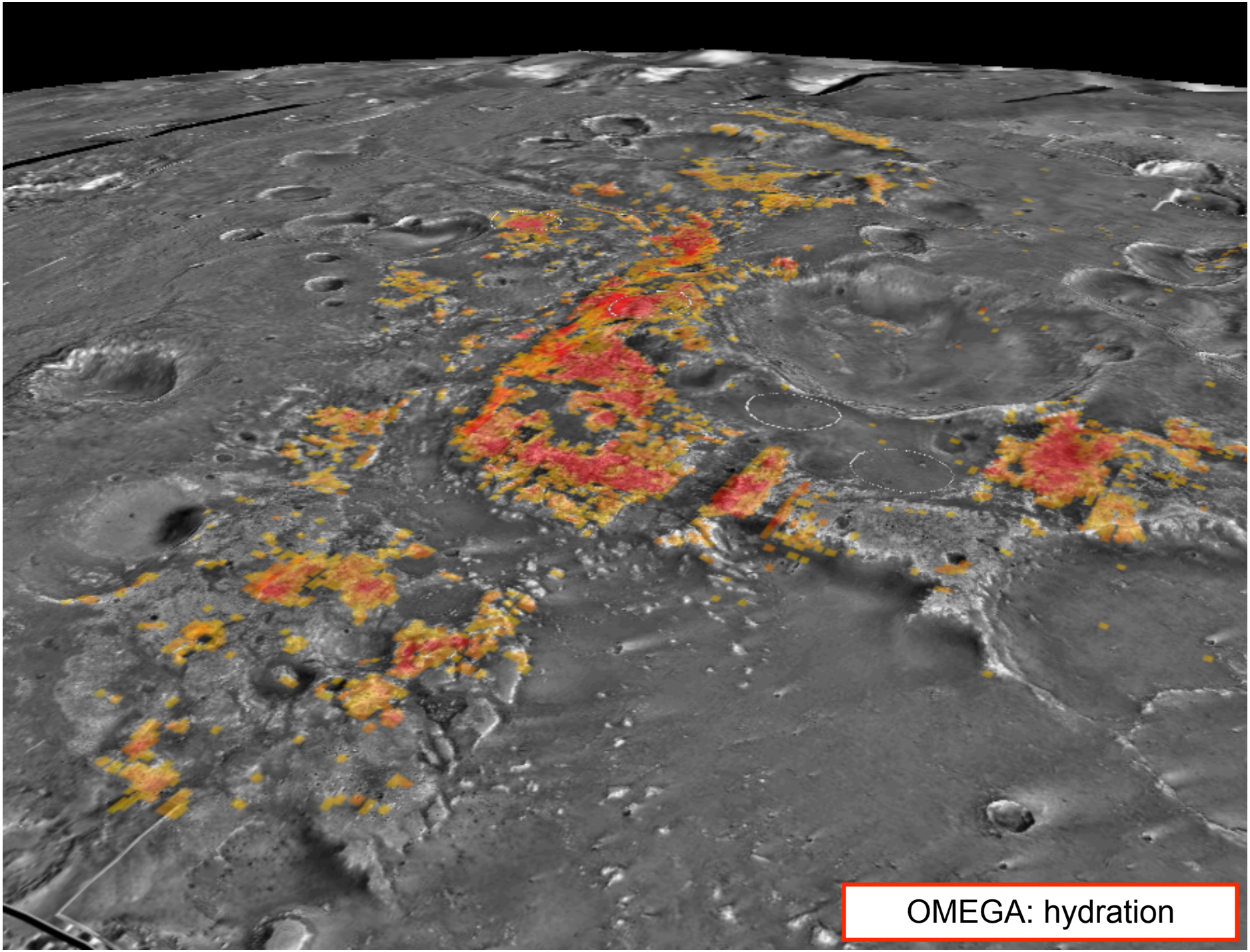
6. Amongst the uniquenesses of Mawrth Vallis:

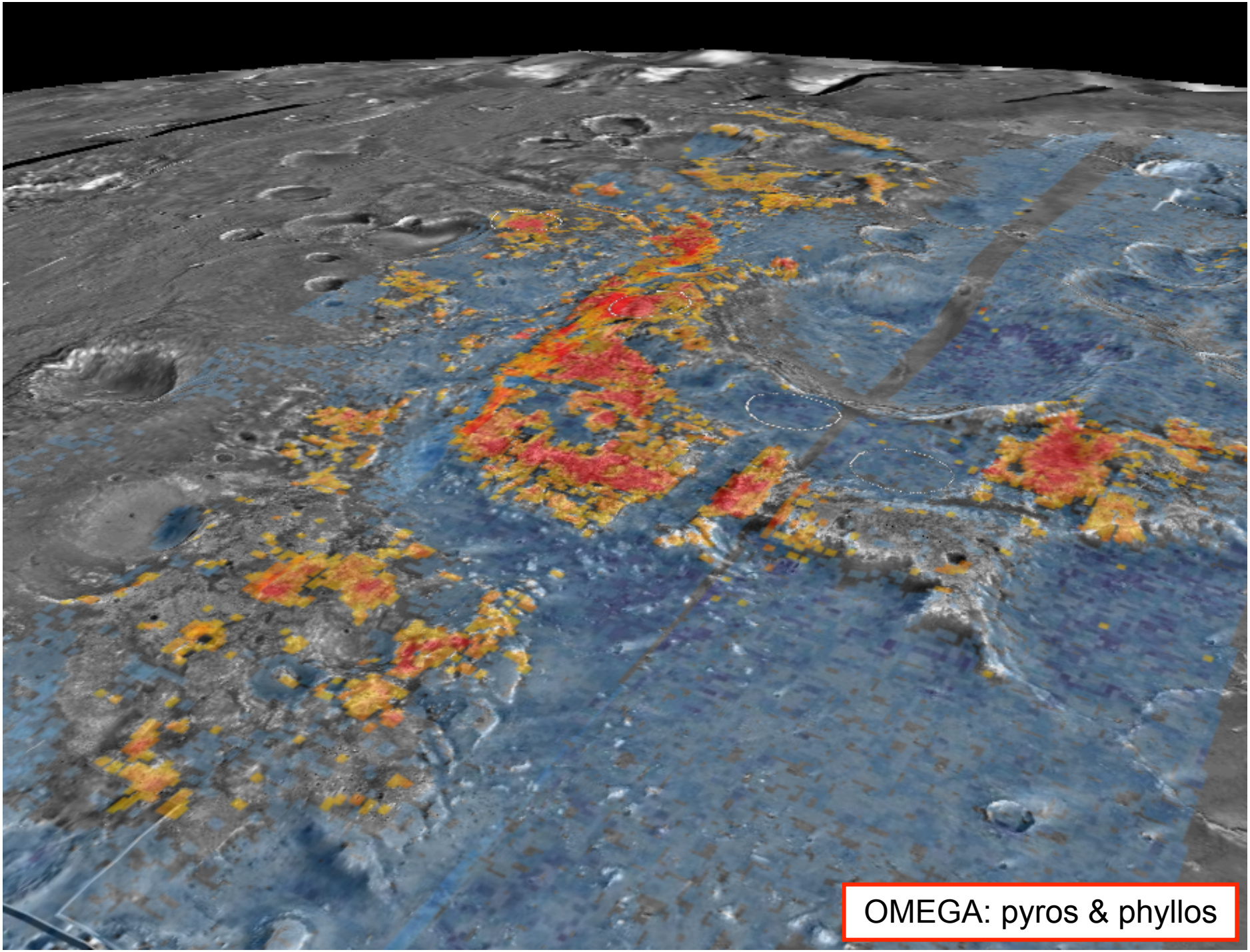
- its extension: it is so large that a number of candidate ellipses can and have been proposed, both as Go To and In Place exploration.

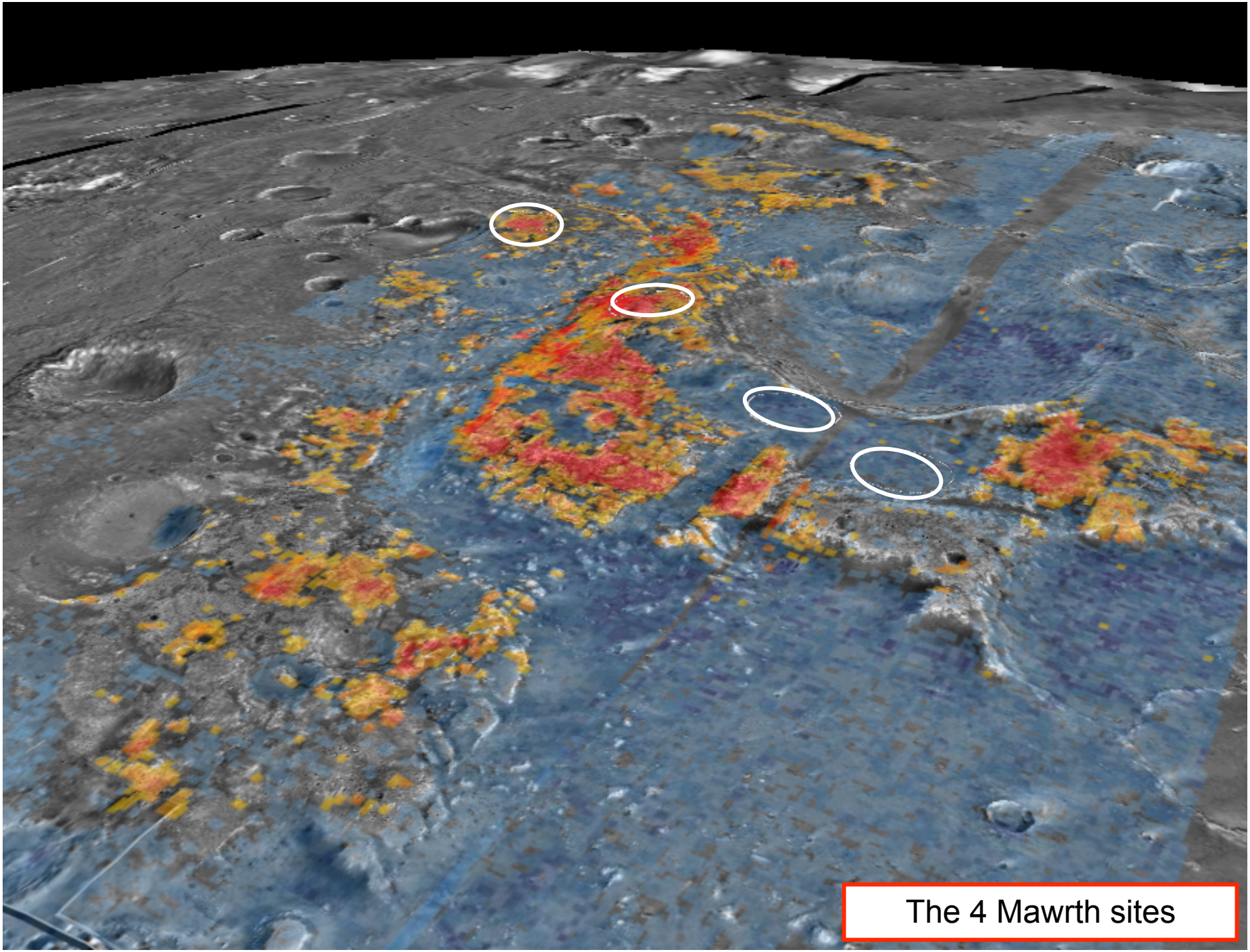
It emphasizes the value of this site. The penalty is that we have the same time slot to describe 4 sites. As a consequence, we followed a focused strategy:

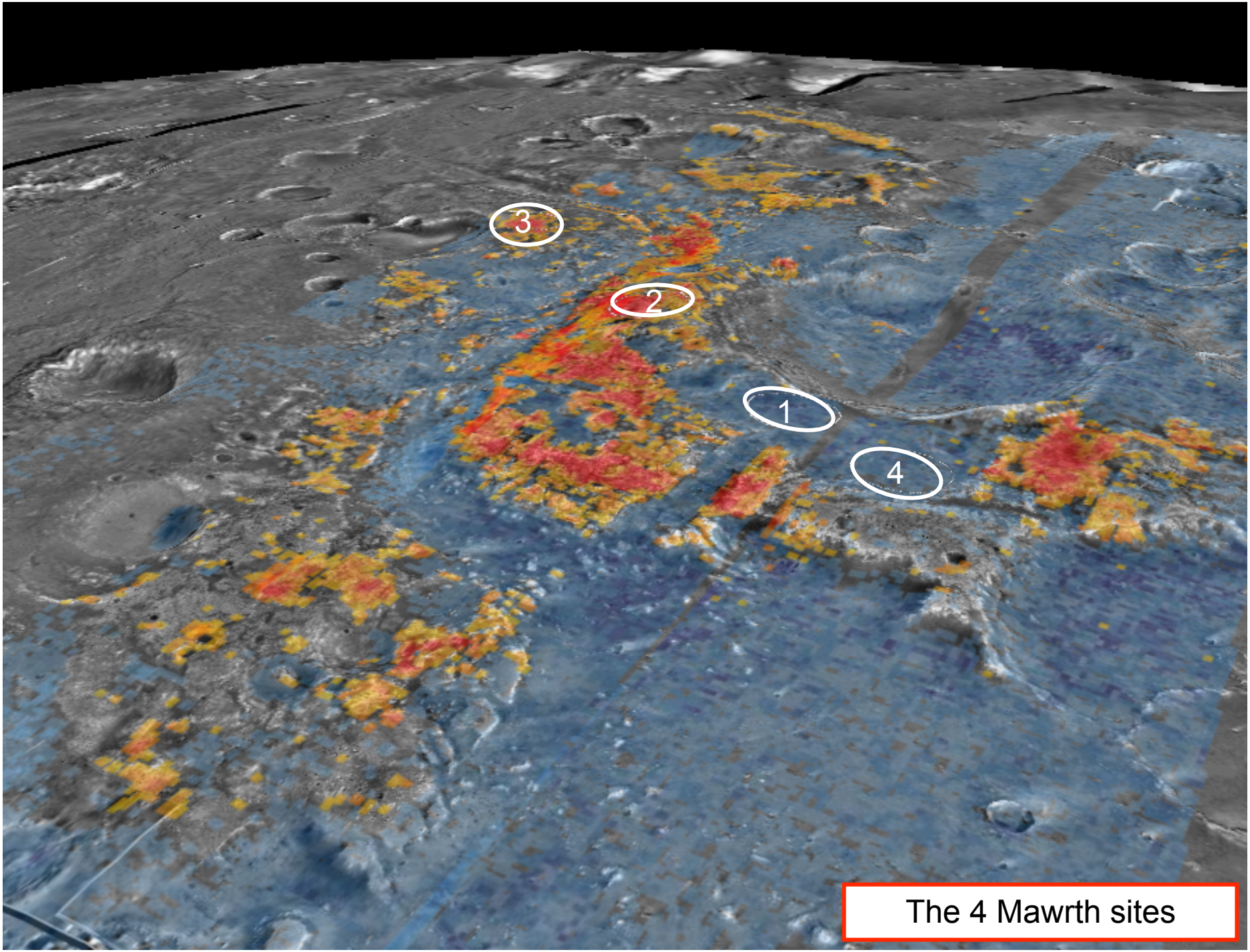

100 km
MOLA: altimetry

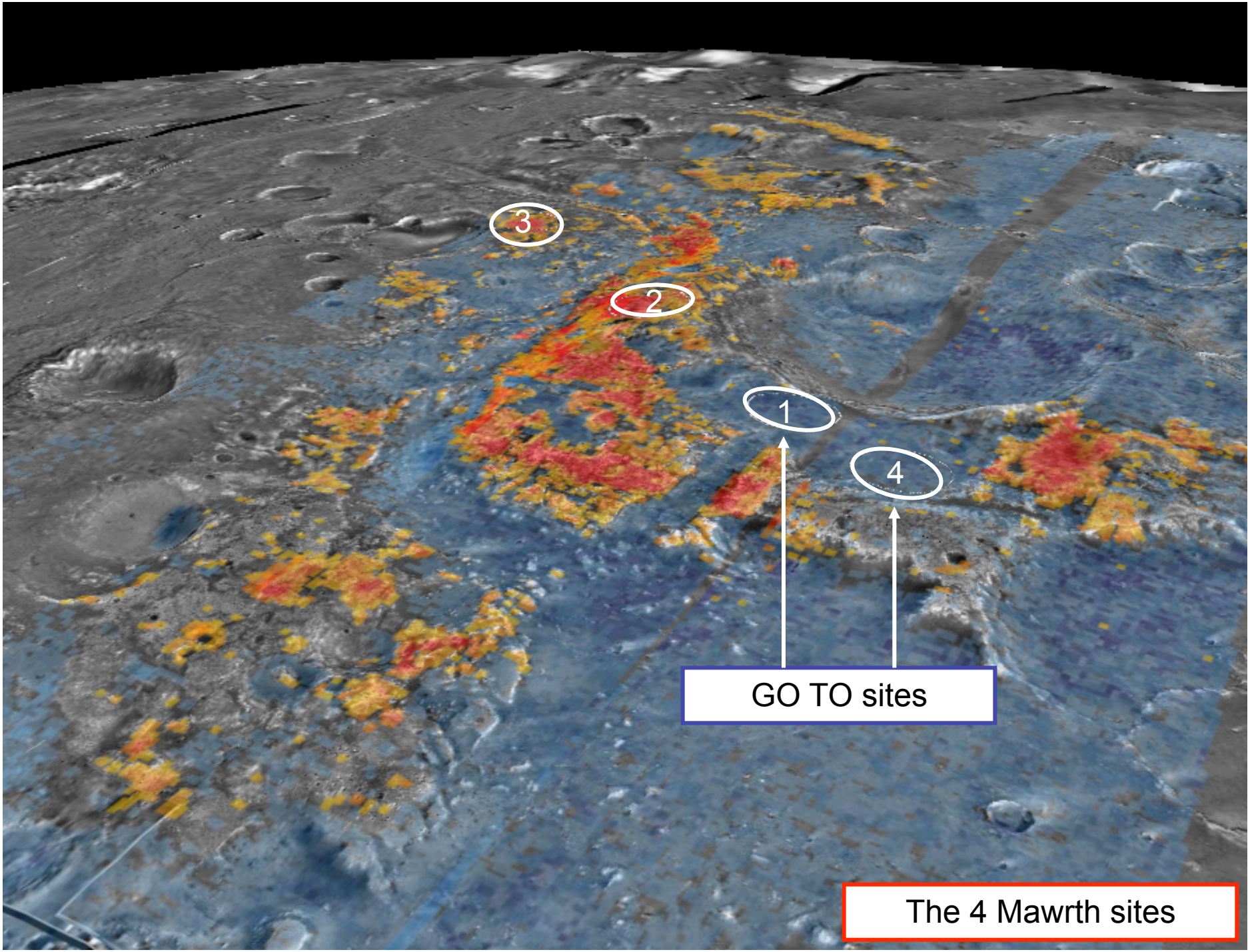

OMEGA: pyroxenes

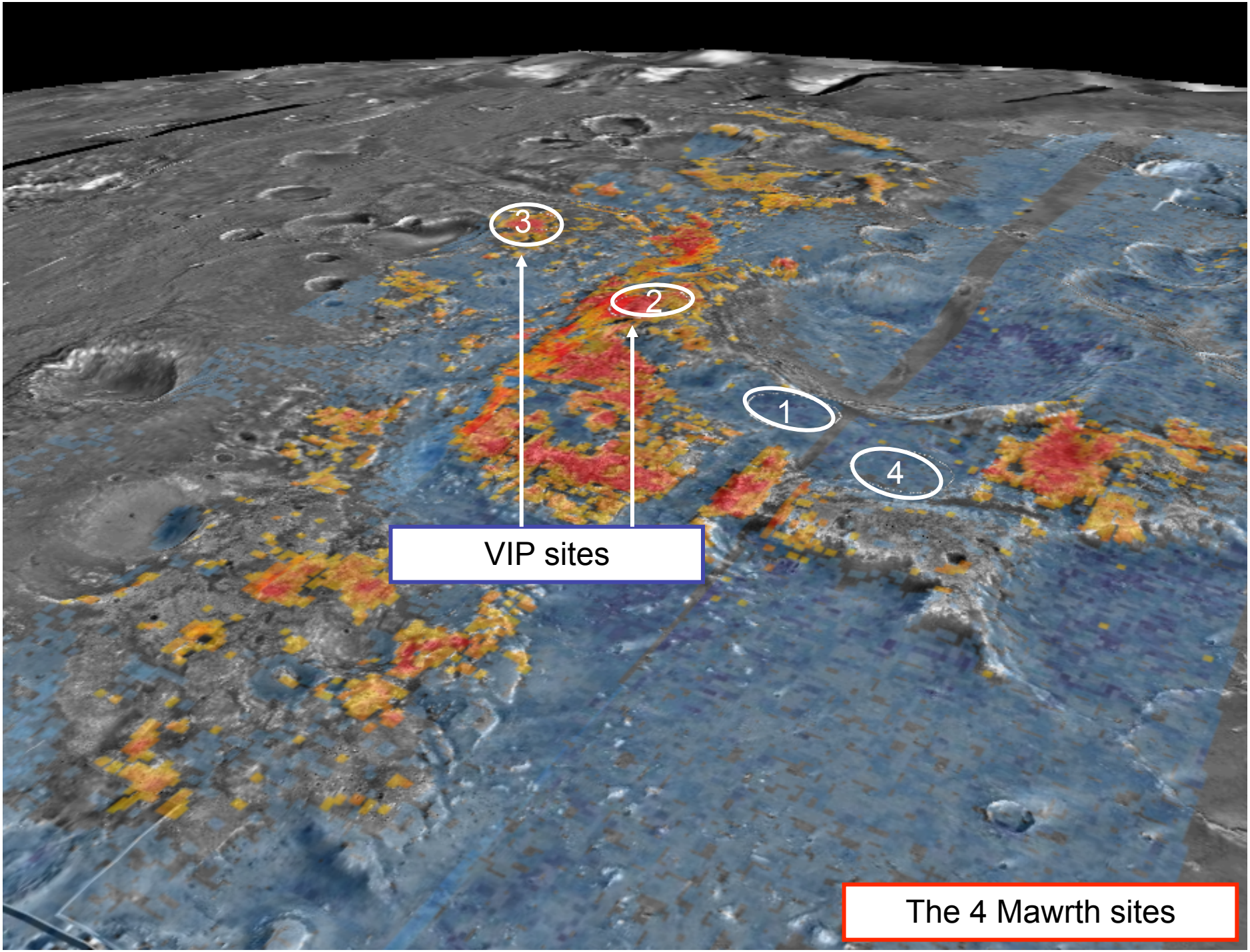

OMEGA: hydration

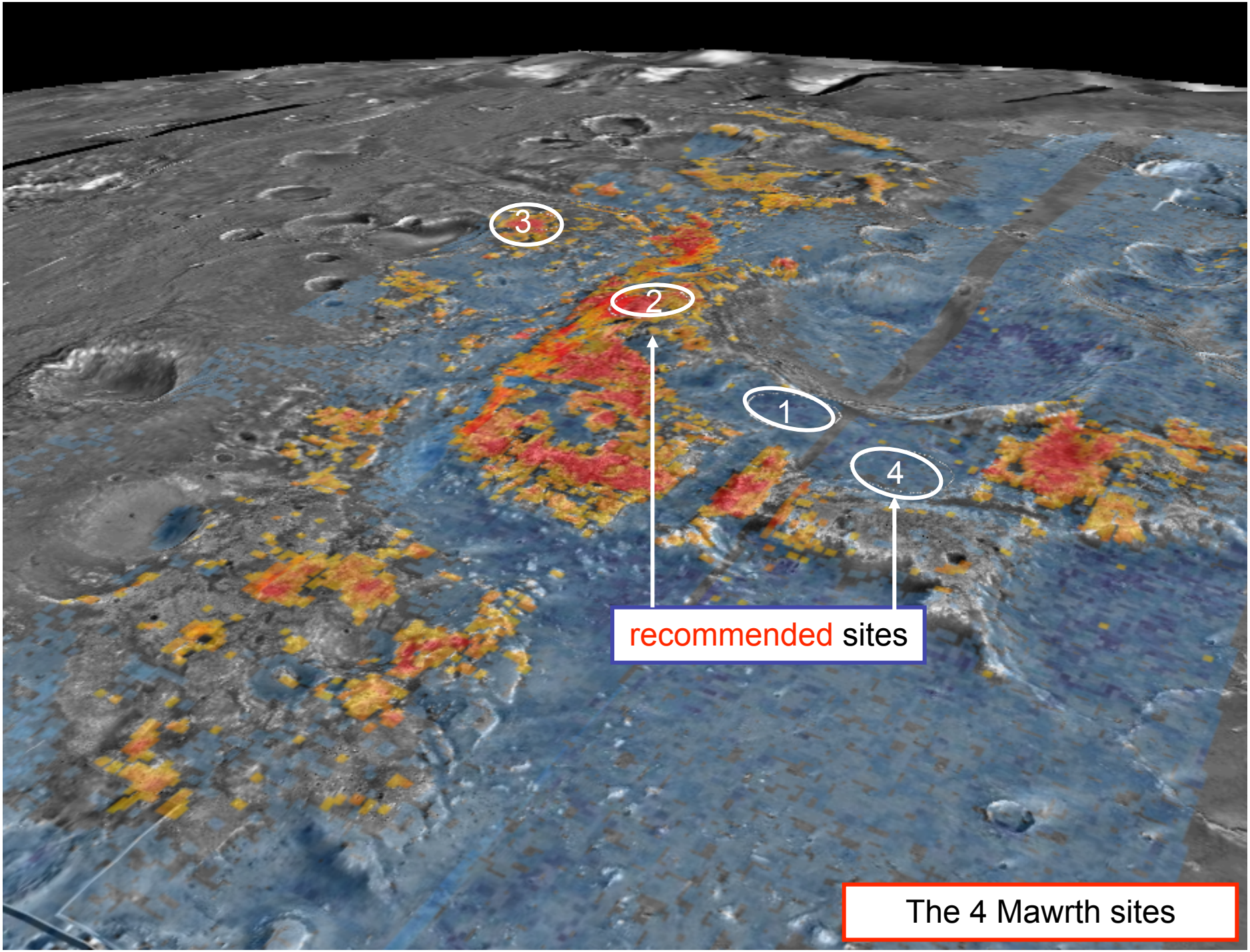

OMEGA: pyros & phyllos


The 4 Mawrth sites


3
2
1
4
The 4 Mawrth sites


3
2
1
4
GO TO sites
The 4 Mawrth sites


3
2
1
4
VIP sites
The 4 Mawrth sites



The 4 Mawrth sites

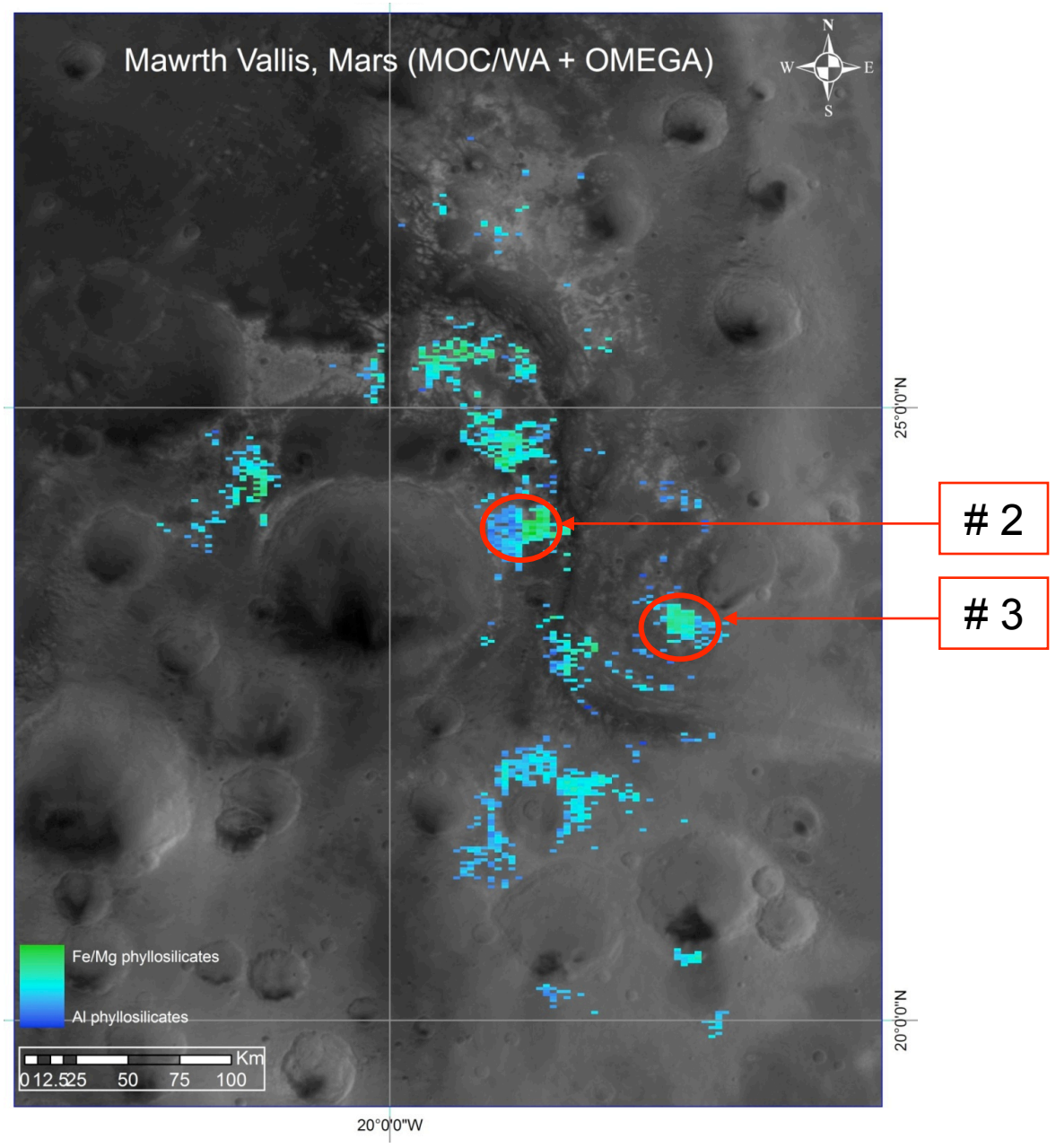
Mawrth Vallis
The dream is alive

6. Amongst the uniquenesses of Mawrth Vallis:

- its extension: it is so large that a number of candidate ellipses have been proposed, both as GO TO and In Place exploration.

- its compositional diversity

Mapping phyllosilicates with OMEGA



Mawrth Vallis

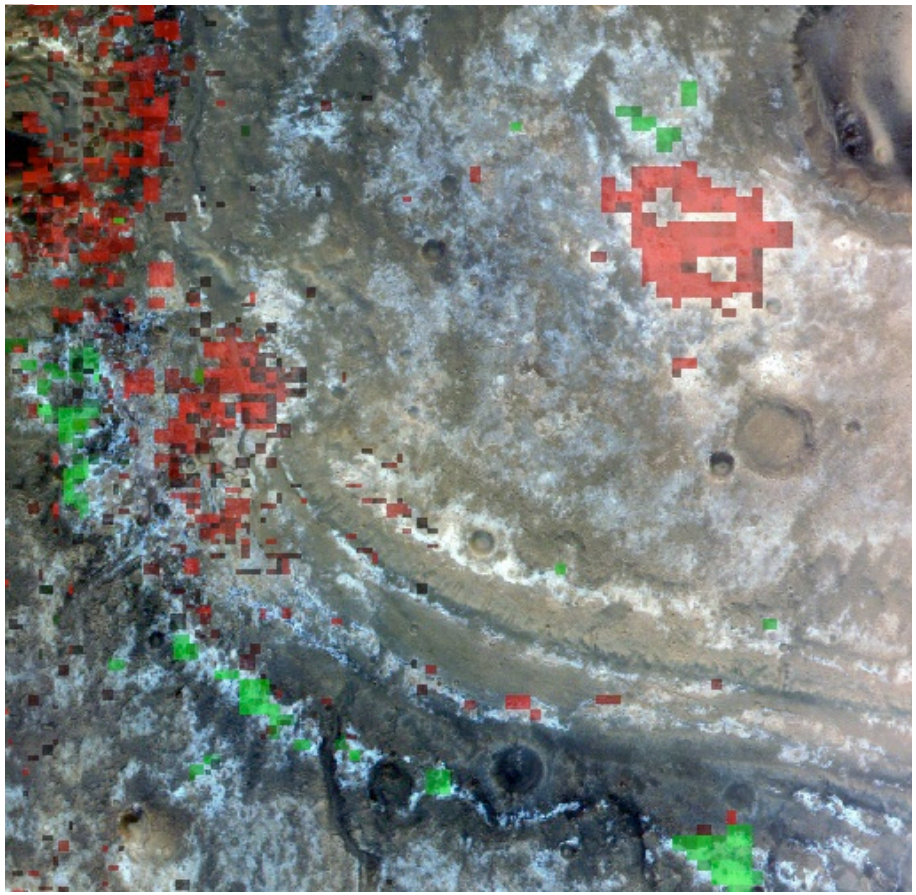
The dream is alive

6. Amongst the uniquenesses of Mawrth Vallis:

- its extension: it is so large that a number of candidate ellipses have been proposed, both as GO TO and In Place exploration.

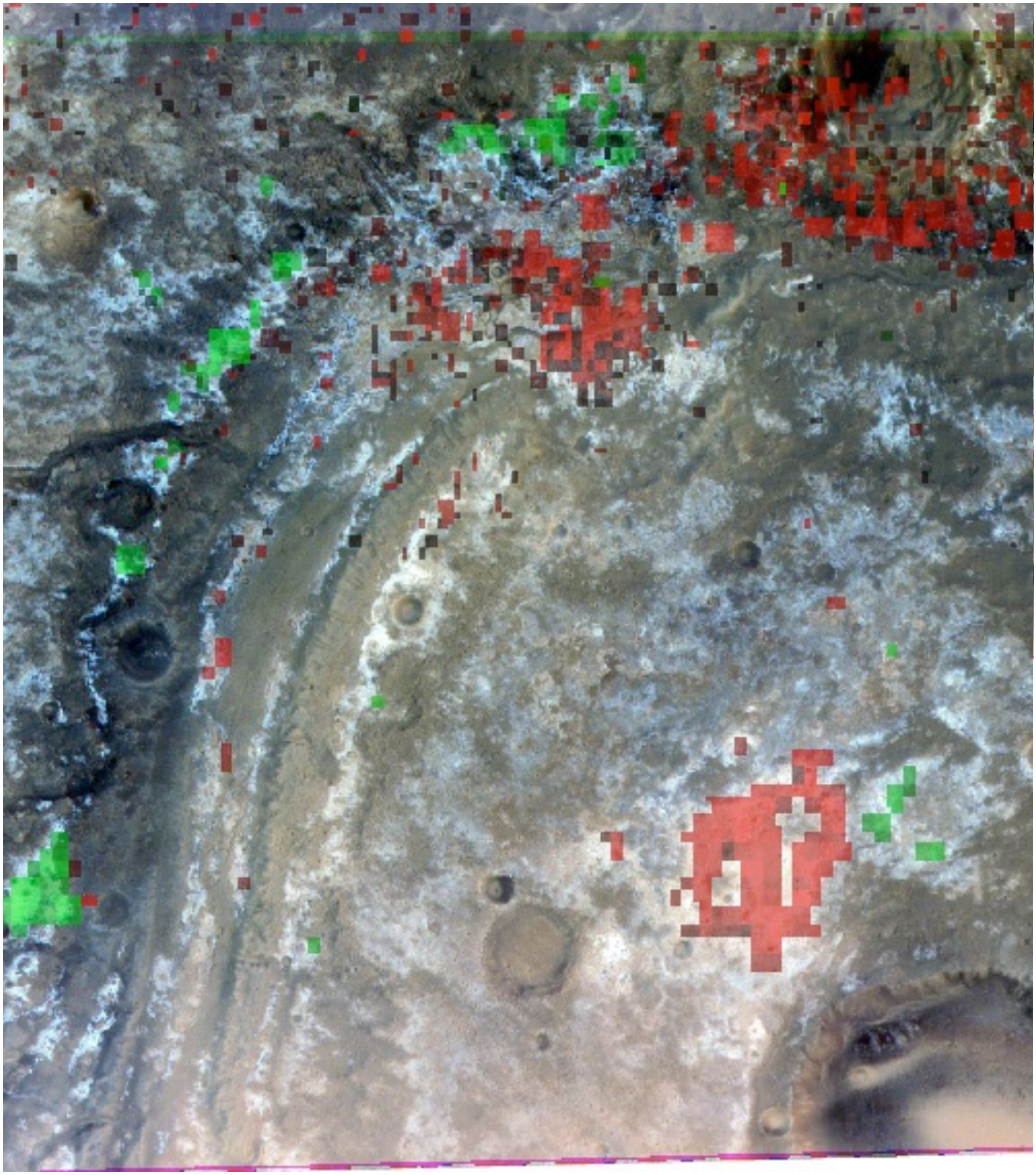
- its compositional diversity, coupled to clear stratifications, which translates the preservation of most if not all the Martian aqueous era and enables to study the evolution of the environmental conditions and climate.

HRSC context / OMEGA composition in ellipse 3

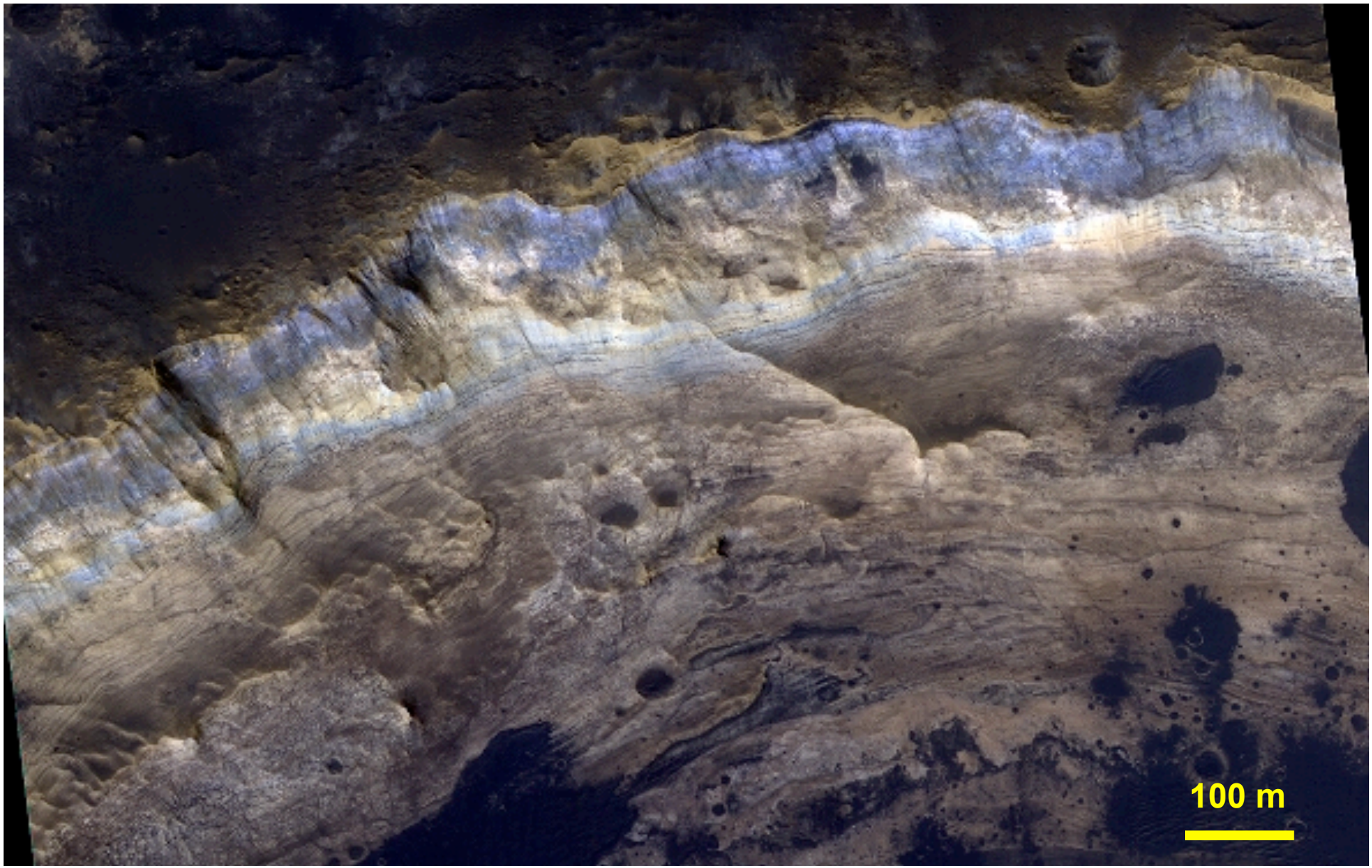


HRSC color composite

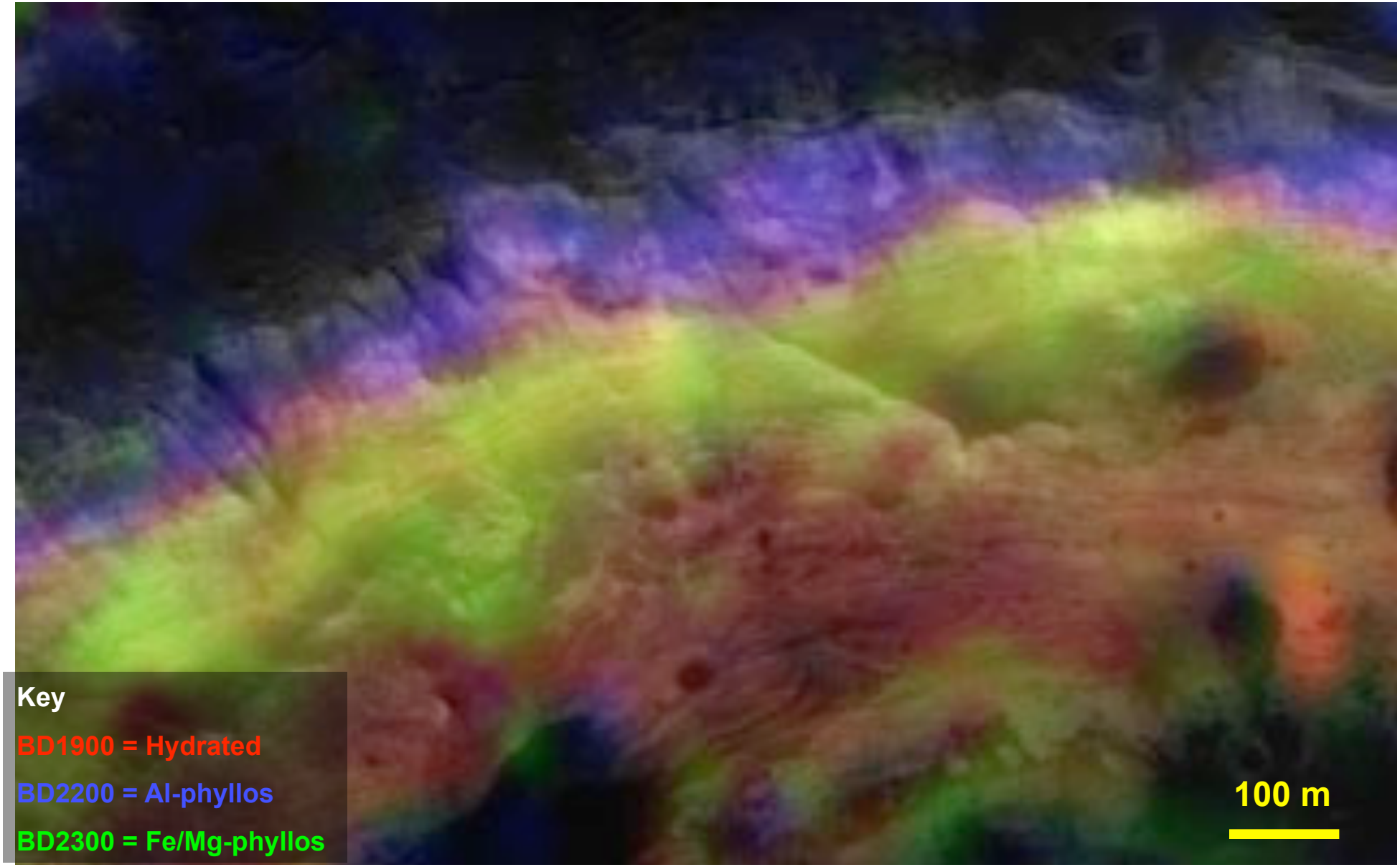
green: Al-OH rich phyllosilicate (2.20 μm)
red: Mg/Fe rich phyllosilicate (2.30 μm)



HIRISE color layering (near ellipse 2)



CRISM compositional layering (near ellipse 2)



Mawrth Vallis
The dream is alive

6. Amongst the uniquenesses of Mawrth Vallis:

- its extension: it is so large that a number of candidate ellipses have been proposed. It is an obvious plus, as it emphasizes the value of this site. The penalty is that we have the same time slot to describe 4 sites. As a consequence, we followed a focused strategy;

- its compositional diversity, coupled to clear stratifications, which translates the preservation of most if not all the Martian aqueous era and enables to study the evolution of the environmental conditions and climate.

- its phyllosilicate abundance; by far the highest over the entire planet, above 50%, as demonstrated by an accurate and refined modeling, performed for all sites in a similar way.

Mawrth Vallis

The dream is alive

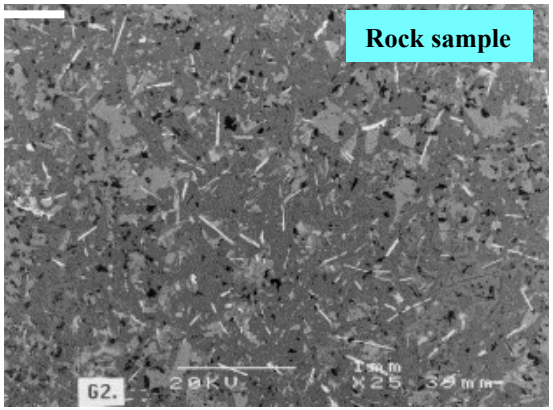
1. Introduction, context	J-P. Bibring
2. Abundances, modeling	F. Poulet, J. Bandfield, J. Michalski
3. Context, chronology,	N. Mangold
4. CRISM HR mineralogy	J. Bishop, N. McKeown, M. Parente
5. HIRISE stratigraphy	J. Wray
6. Regional context	E. NoeDobra
7. Phyllosilicate formation	J. Michalski
8. Summary	J-P. Bibring

Modal mineralogy of phyllosilicate-rich deposits

Surface model to deconvolve OMEGA spectra based on the Shkuratov radiative transfer theory

To derive the scattering properties:

- Microscopic Level (⇔ composition, grain size)
- Macroscopic Level (⇔ type of mixture)



Parameters of the model: Optical constants of each mineral

Modal Mineralogy:

- Mineral abundance
- Average grain size

Skhuratov et al. 1999; Poulet et al. 2002, 2004, 2008

END-MEMBERS : MINERALS AND SPECTRA

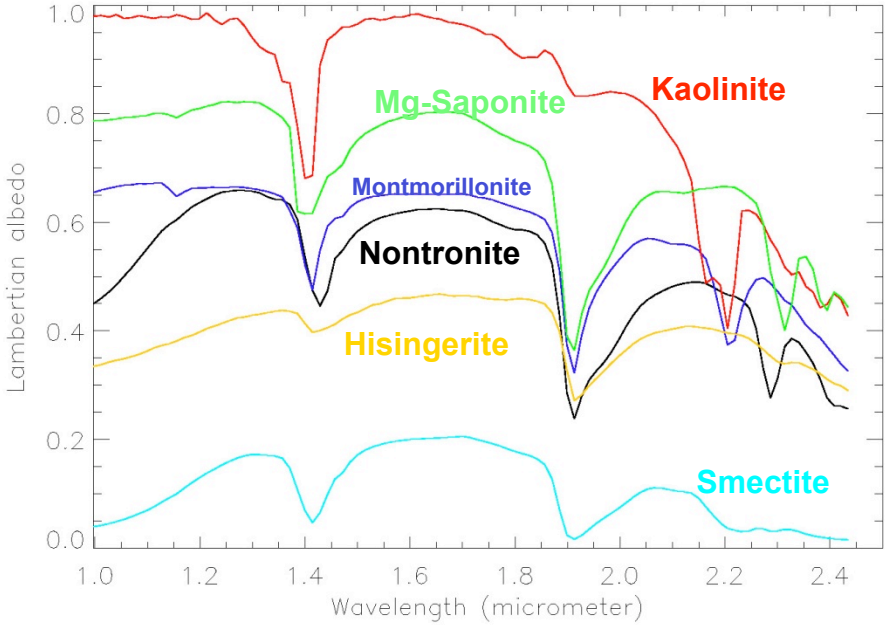
2:1 expansible Phyllosilicates:
- Nontronite (Fe^{3+},OH,H_20)
- Montmorillonite (Al,Fe,Mg,OH,H_20)
- Al/Fe/Mg-Smectite (Fe^{3+},Mg,Al,OH,H_20)
- Illite (Fe,Mg,Al,OH,H_20)
- Mg-Saponite (Mg, OH,H_20)

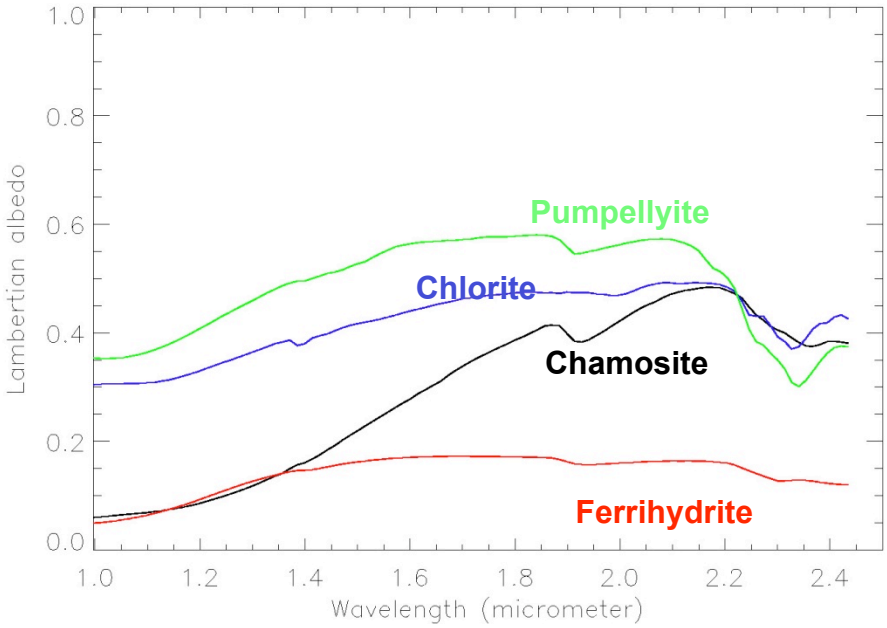
2:2 or 2:1:1 Phyllosilicates:
- Chamosite (Fe^{3+},Fe^{2+}, Mg,Al,OH)
- Chlorite (Fe^{3+},Fe^{2+},Mg,Al,OH)

1:1 Phyllosilicates:
- Hisingerite (Fe^{3+},OH,H_2O)
- Kaolinite (Al,OH)

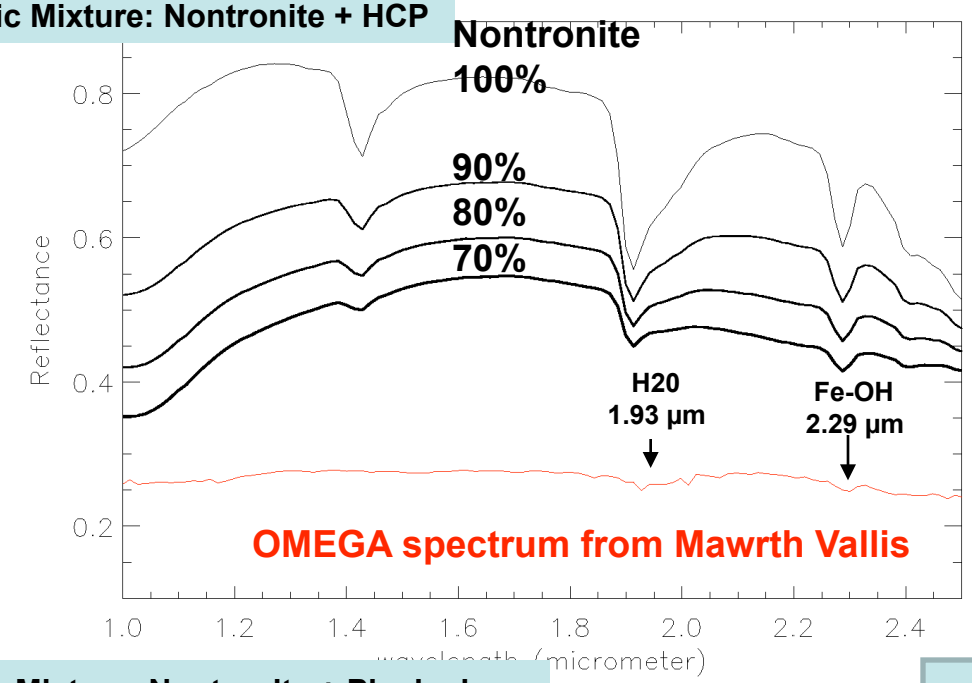
Hydrated minerals
- Ferrihydrite (Fe^{3+},OH, H_2O)
- Zeolites
- Pumpellyite (sorosilicate) (Mg,Al)(OH)(H_20)

Anhydrous silicates:
- Pyroxenes
- Plagioclase
- Martian dust

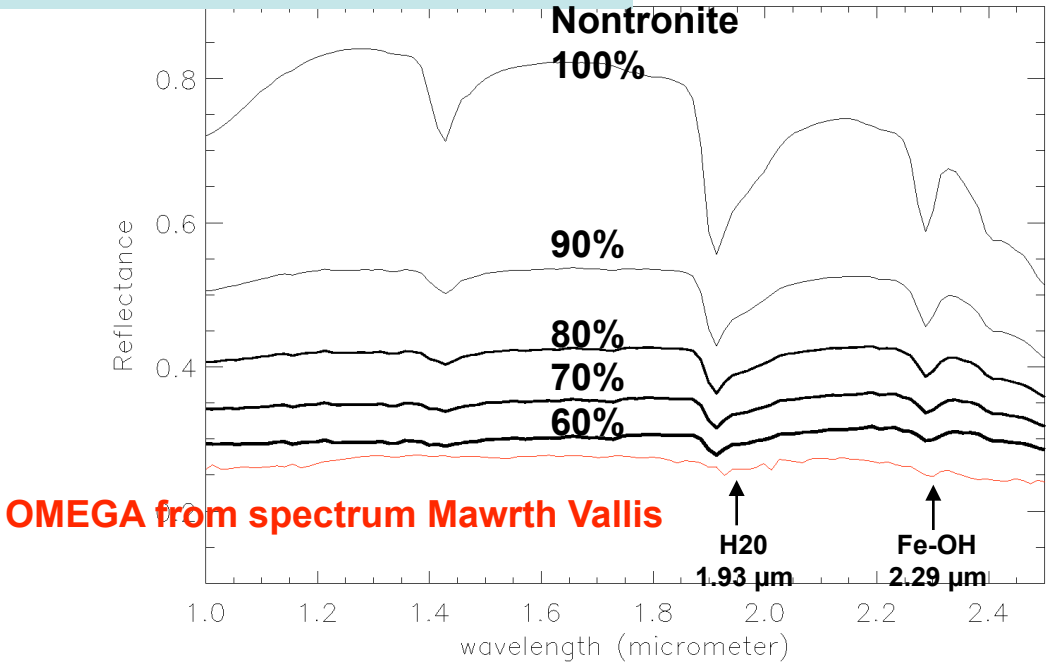




Synthetic Mixture: Nontronite + HCP

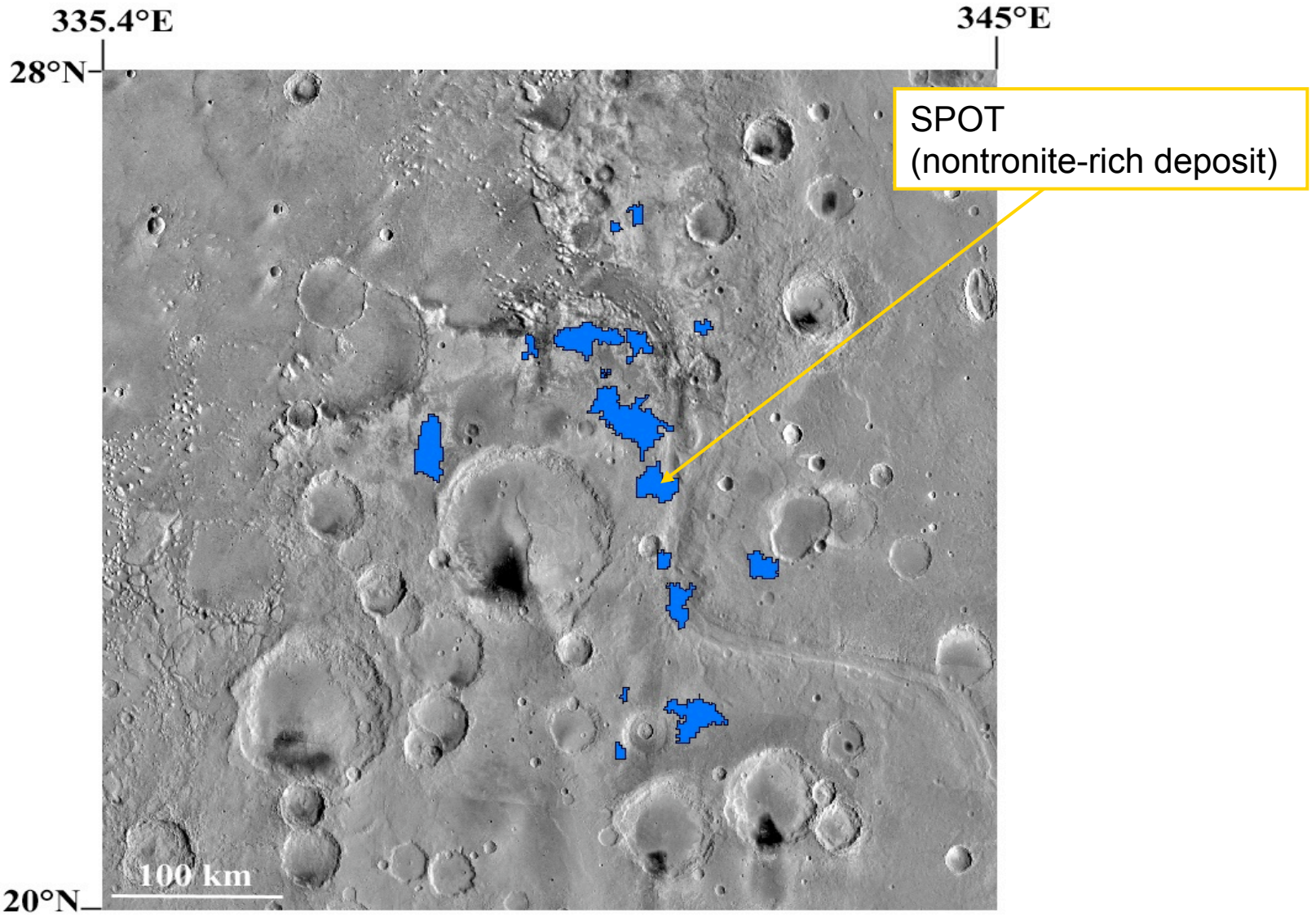


Synthetic Mixture: Nontronite + Plagioclase

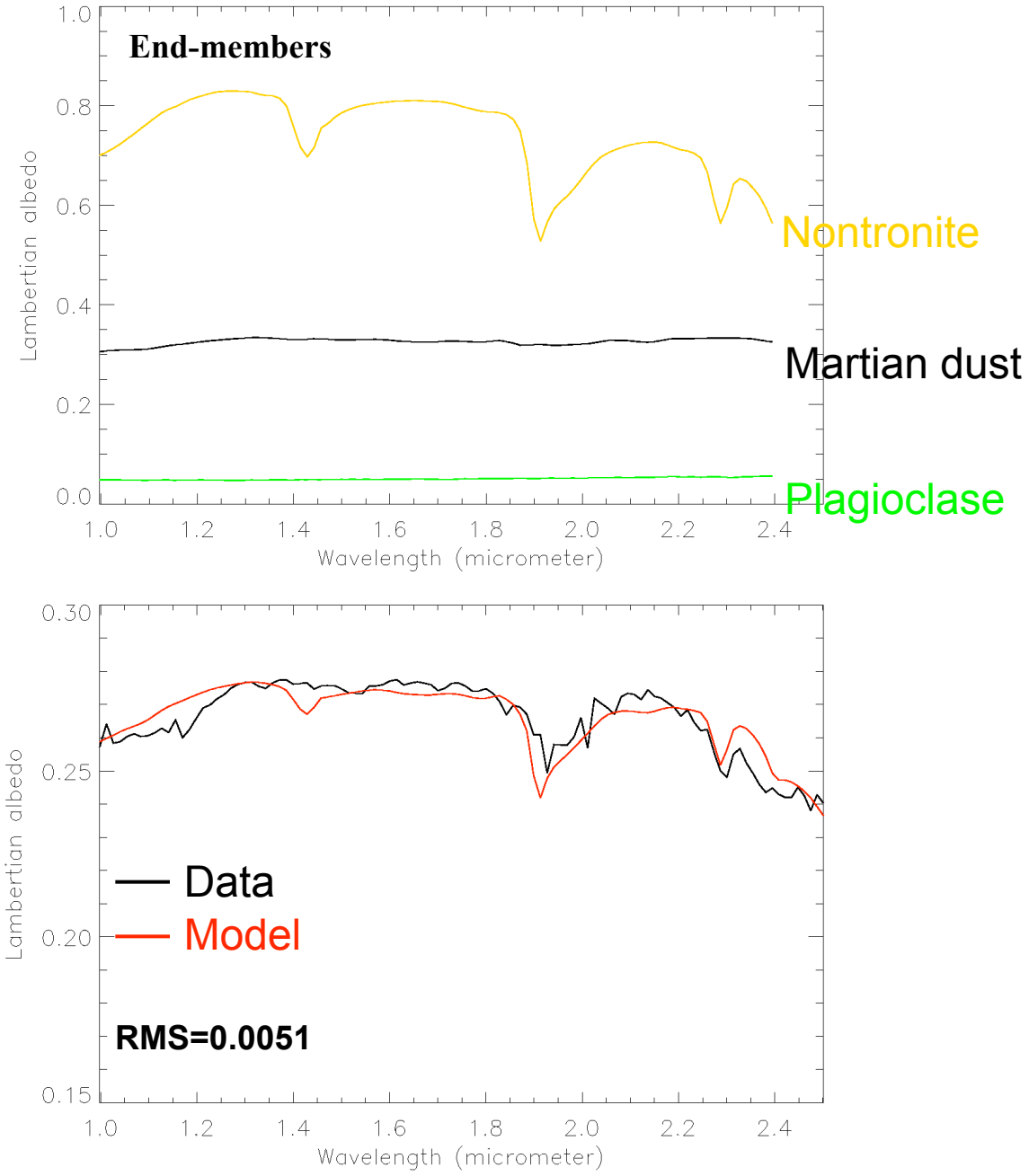


ADMIXTURE OF
NON-PHYLLOSILICATE
ANHYDROUS COMPONENT(S)

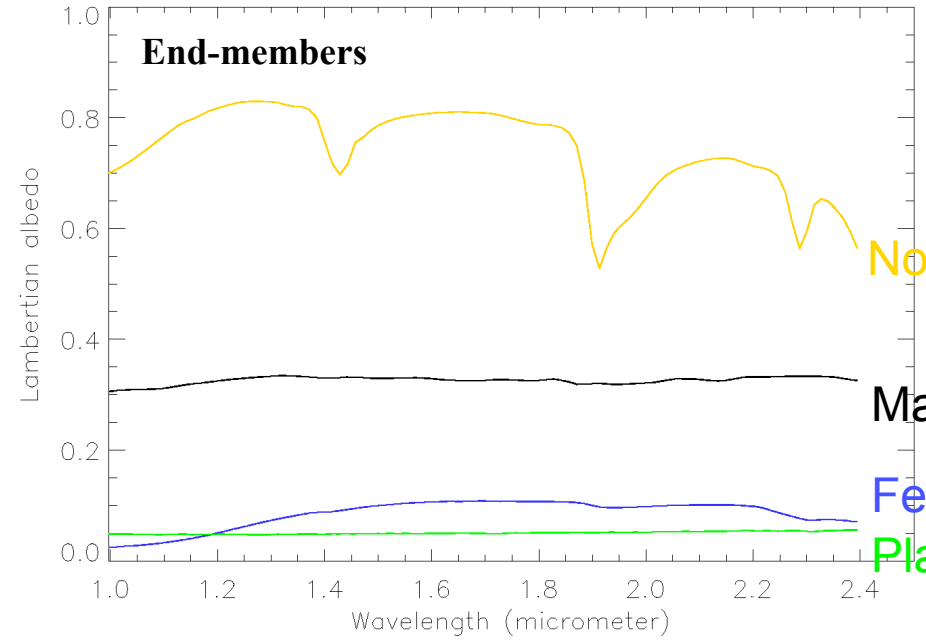
Phyllosilicate-rich deposits in Mawrth vallis

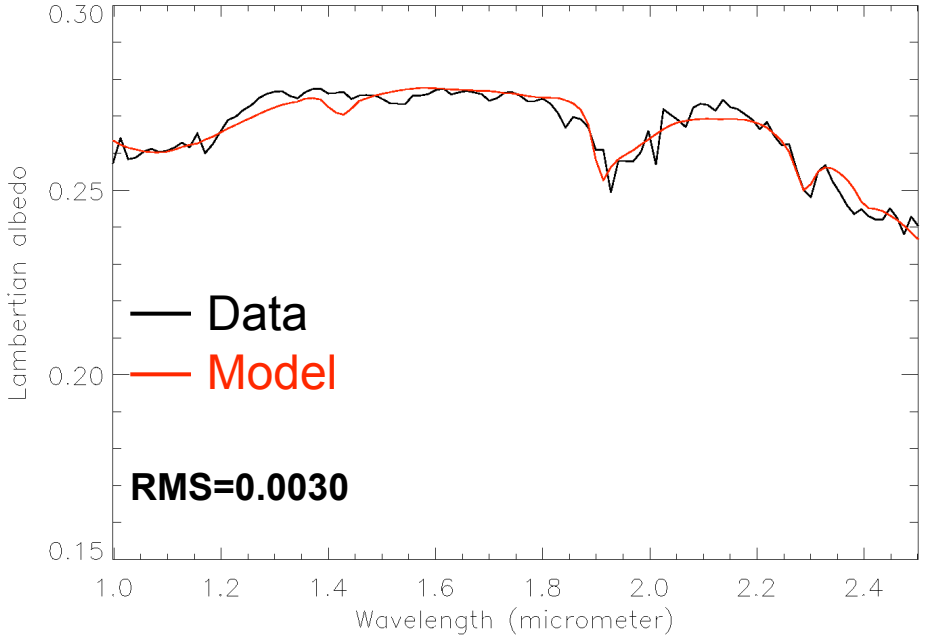


Nontronite-rich deposit



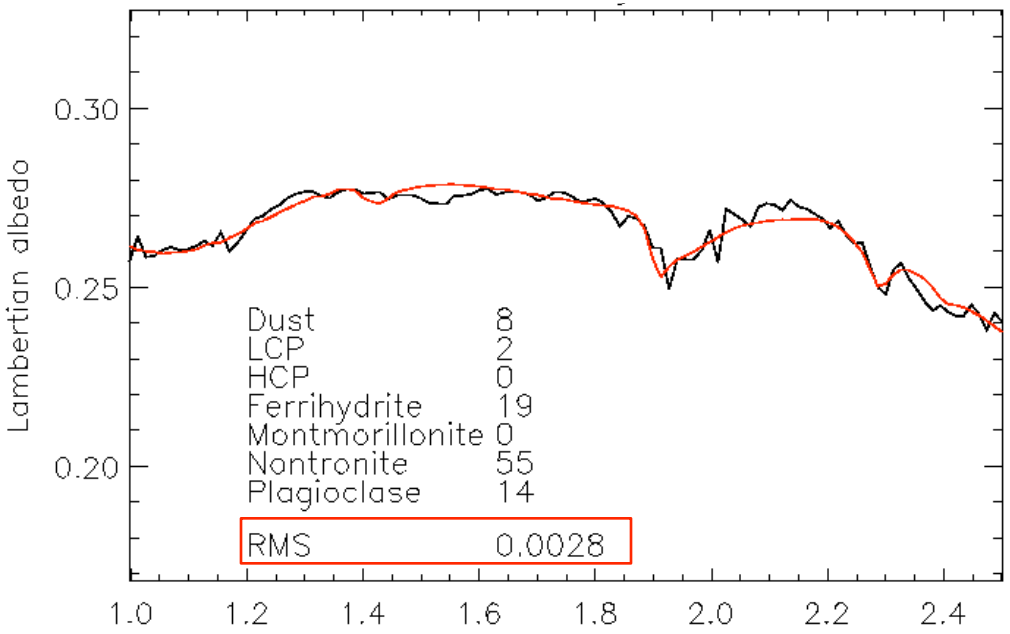
Nontronite-rich deposit



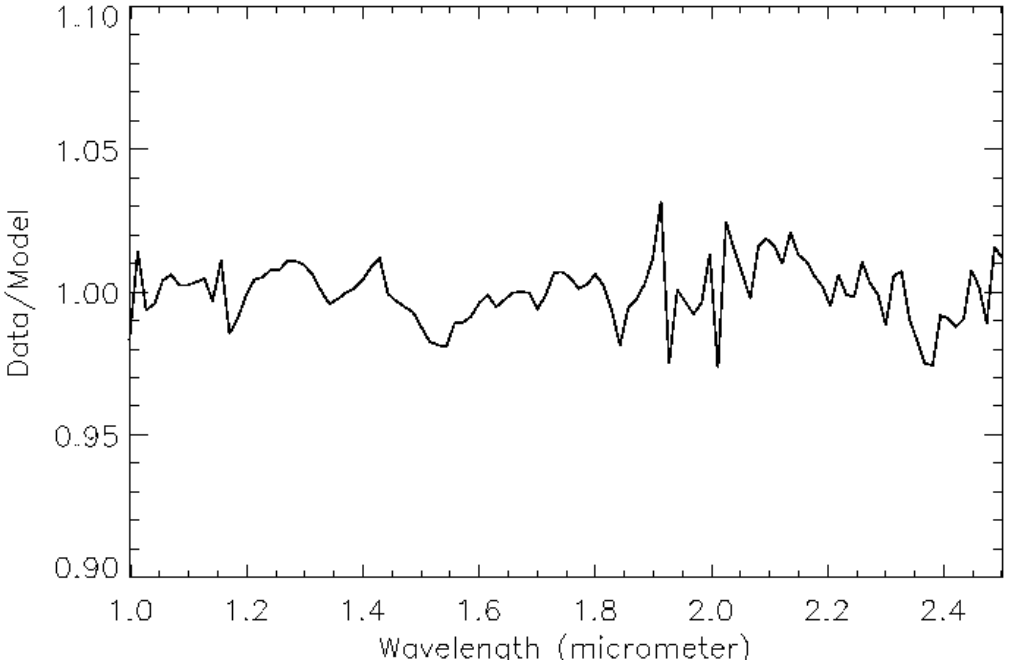


Nontronite 60%
Ferrihydrite 15%
Martian dust 10%
Plagioclase 15%

Nontronite-rich deposit (best fit)

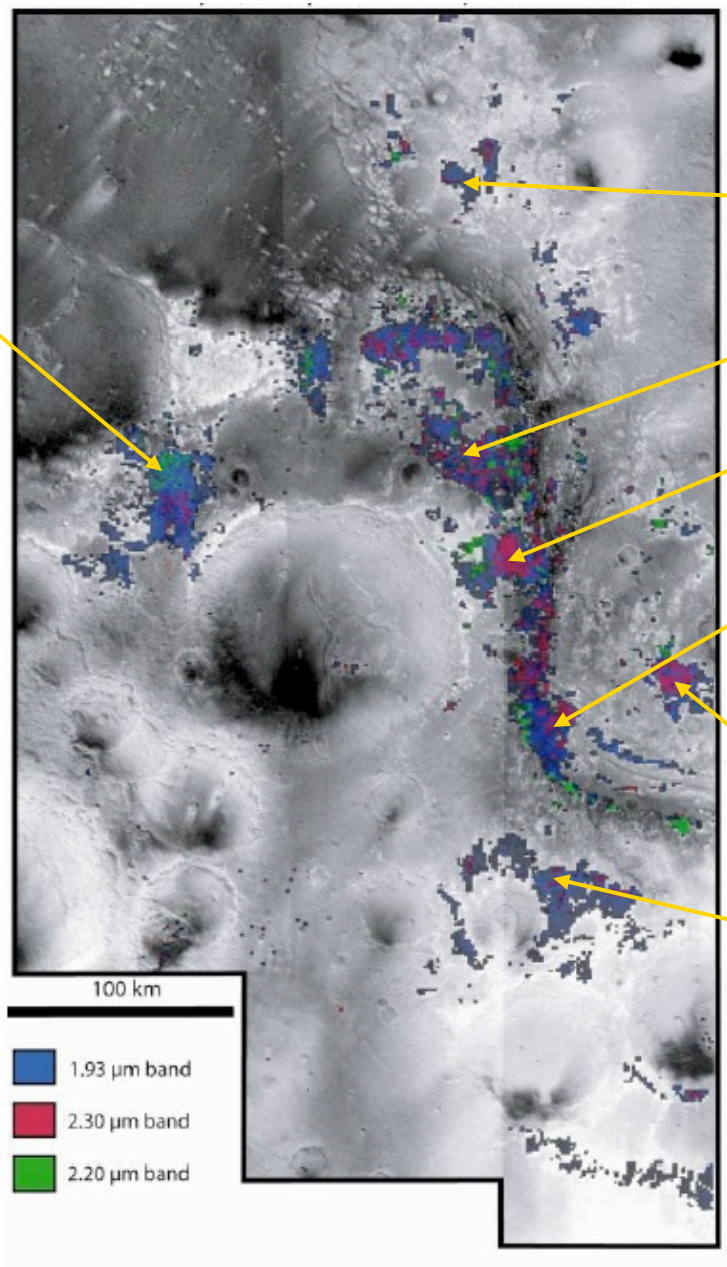


Hydrated mineral abundance : ~70%



+/- 2%

Mawrth Vallis: Phyllosilicate Map



SPOT 7: MSL Ellipse 4

SPOT 6

SPOT 5

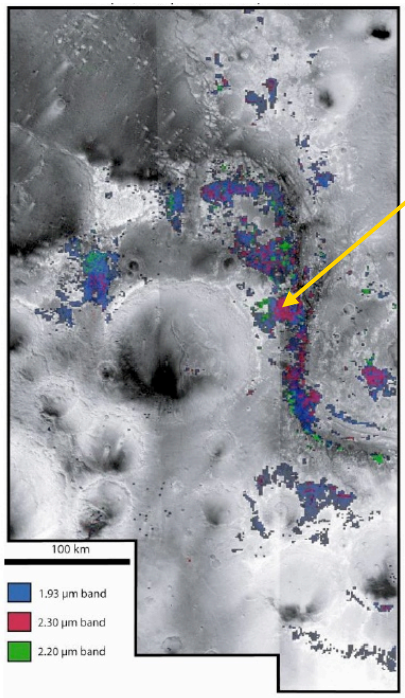
SPOT 4: MSL Ellipse 2

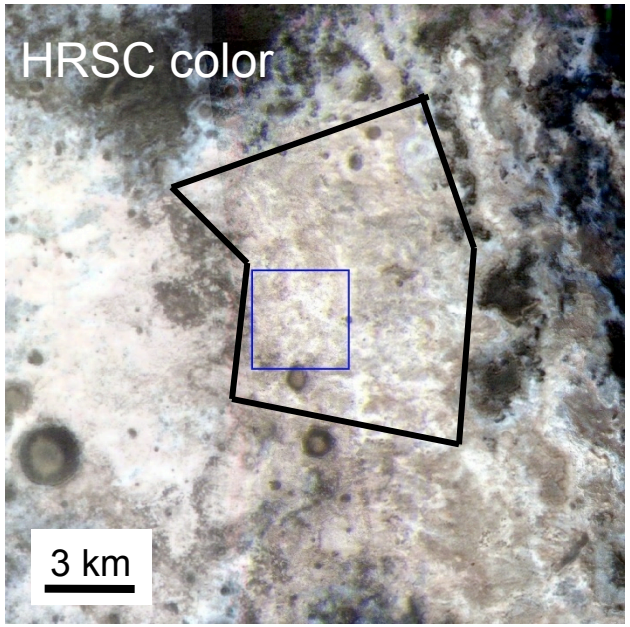
SPOT 3

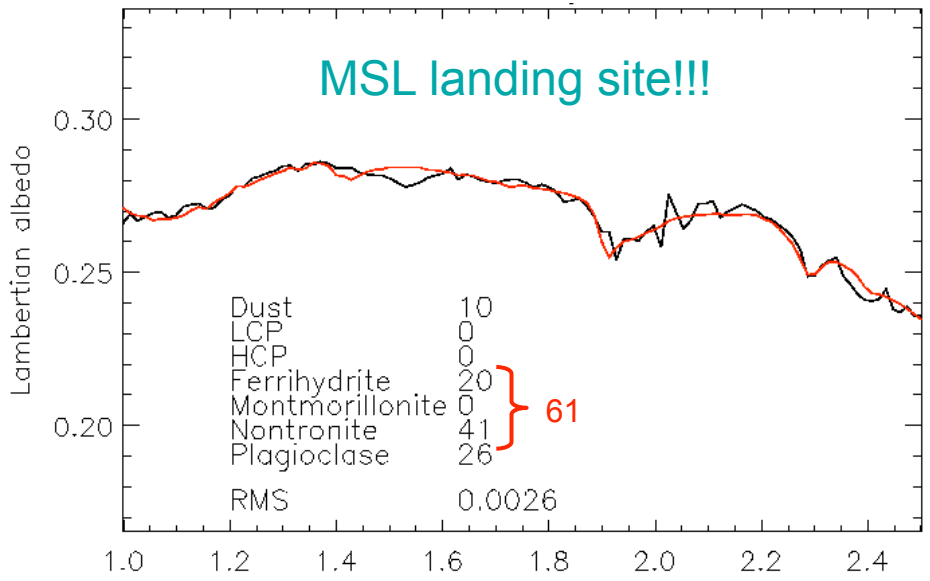
SPOT 2: MSL Ellipse 3

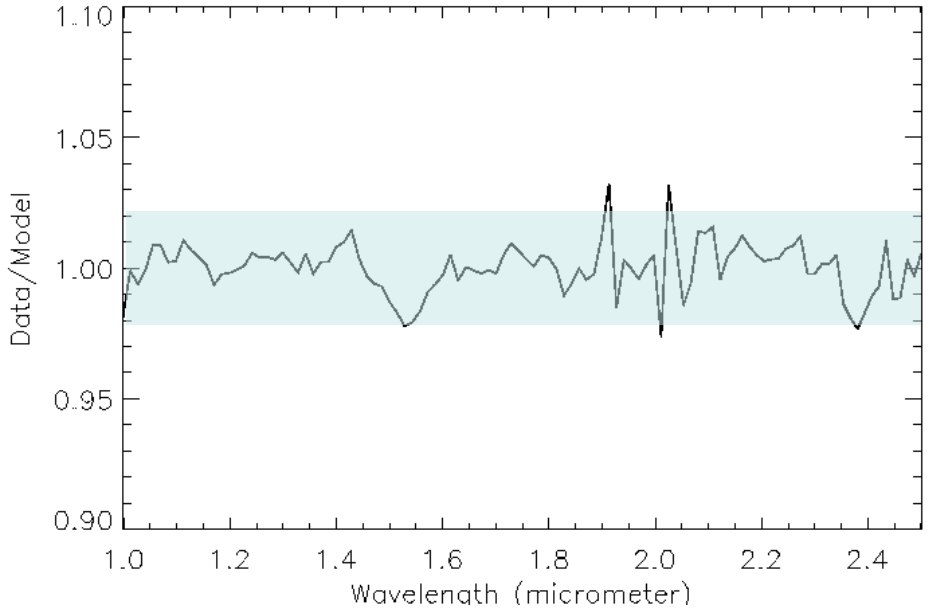
SPOT 1

MSL Ellipse 2

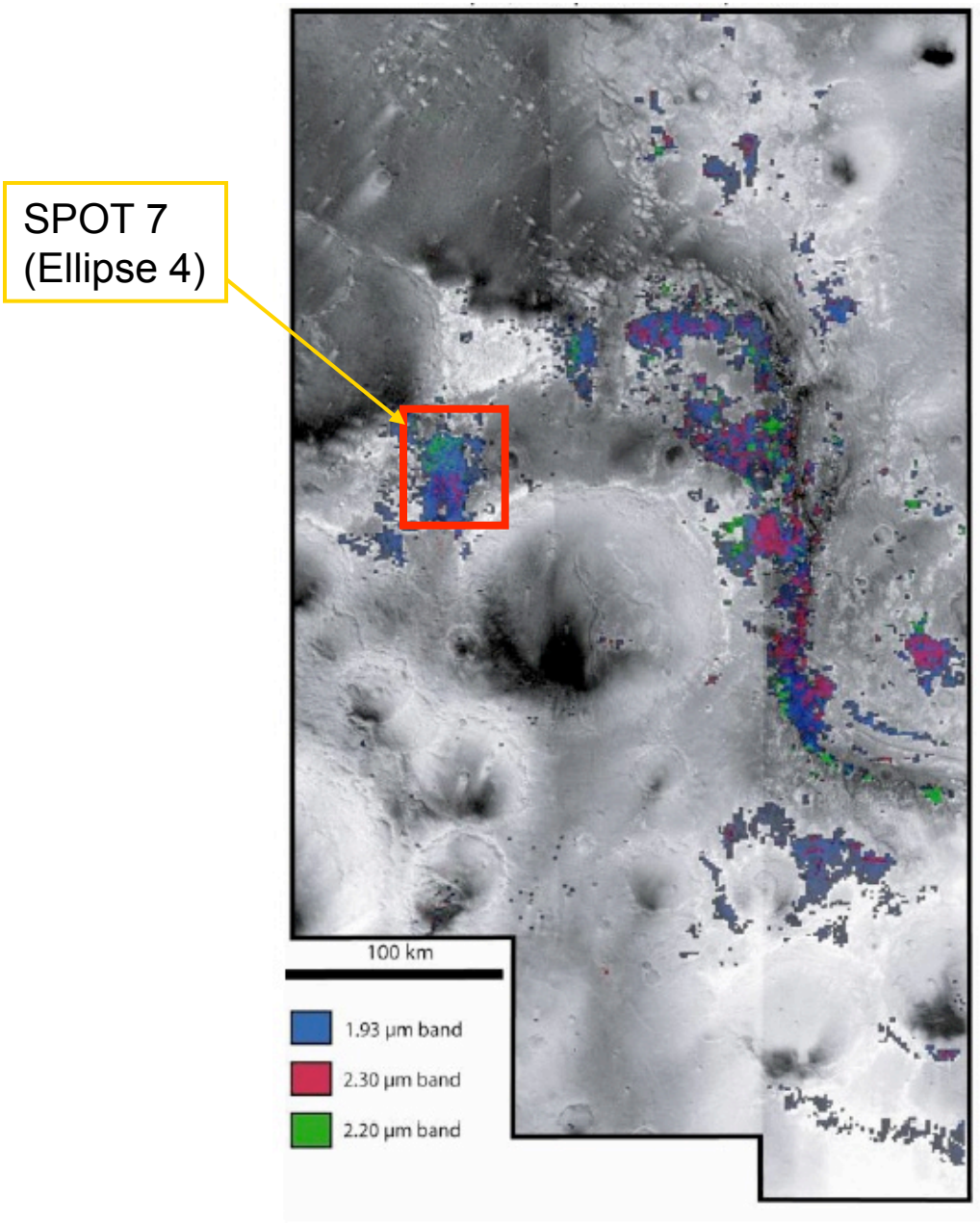


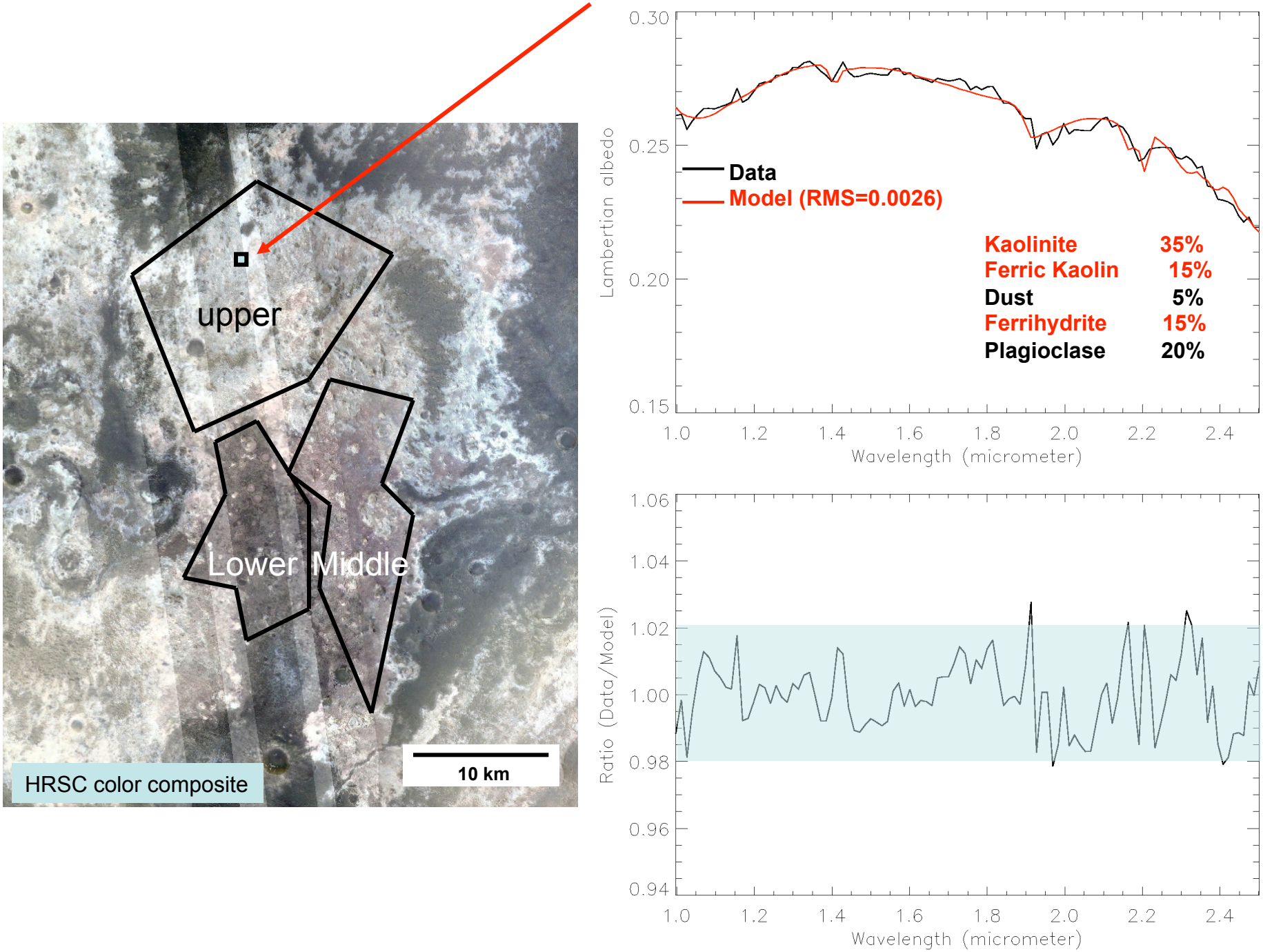


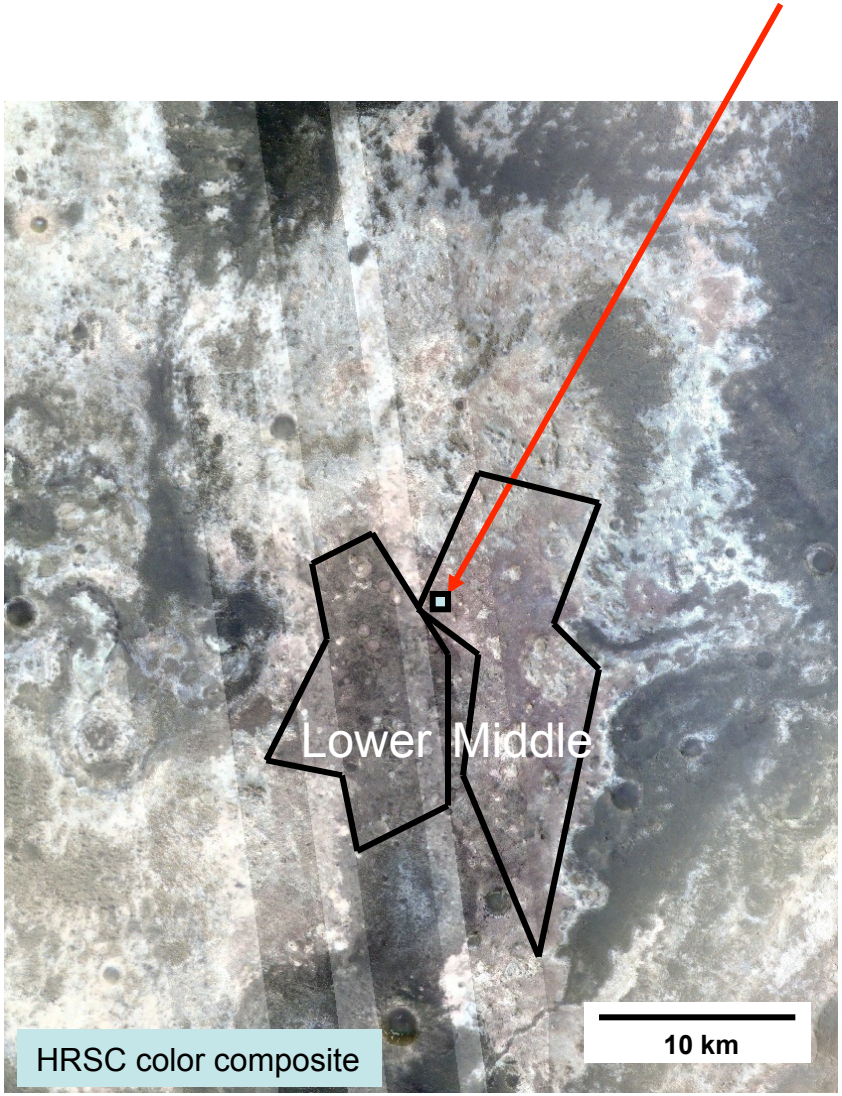


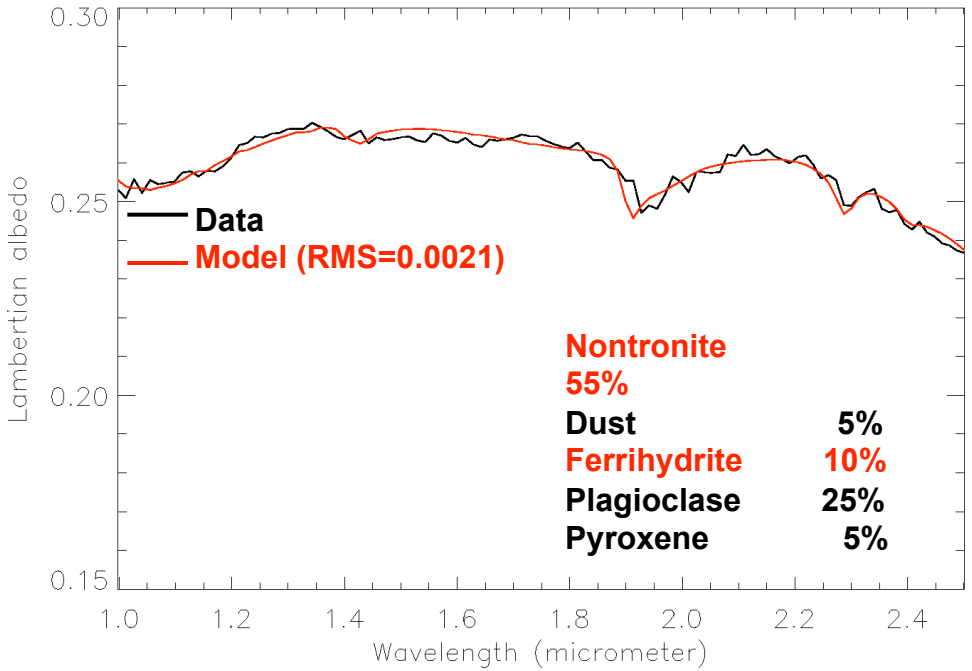


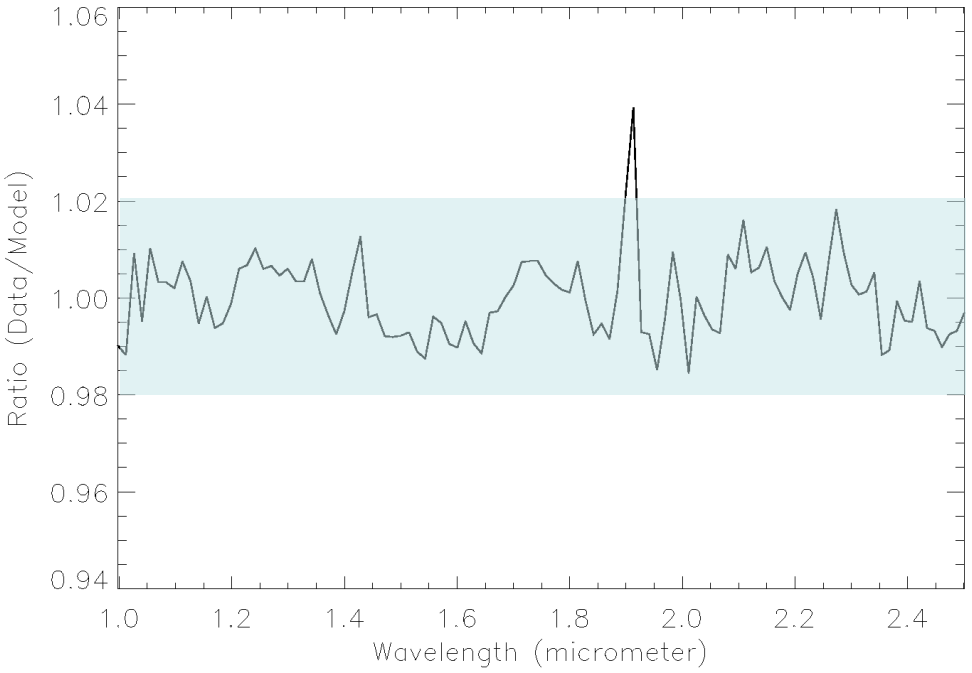
Mawrth Vallis: Phyllosilicate Map

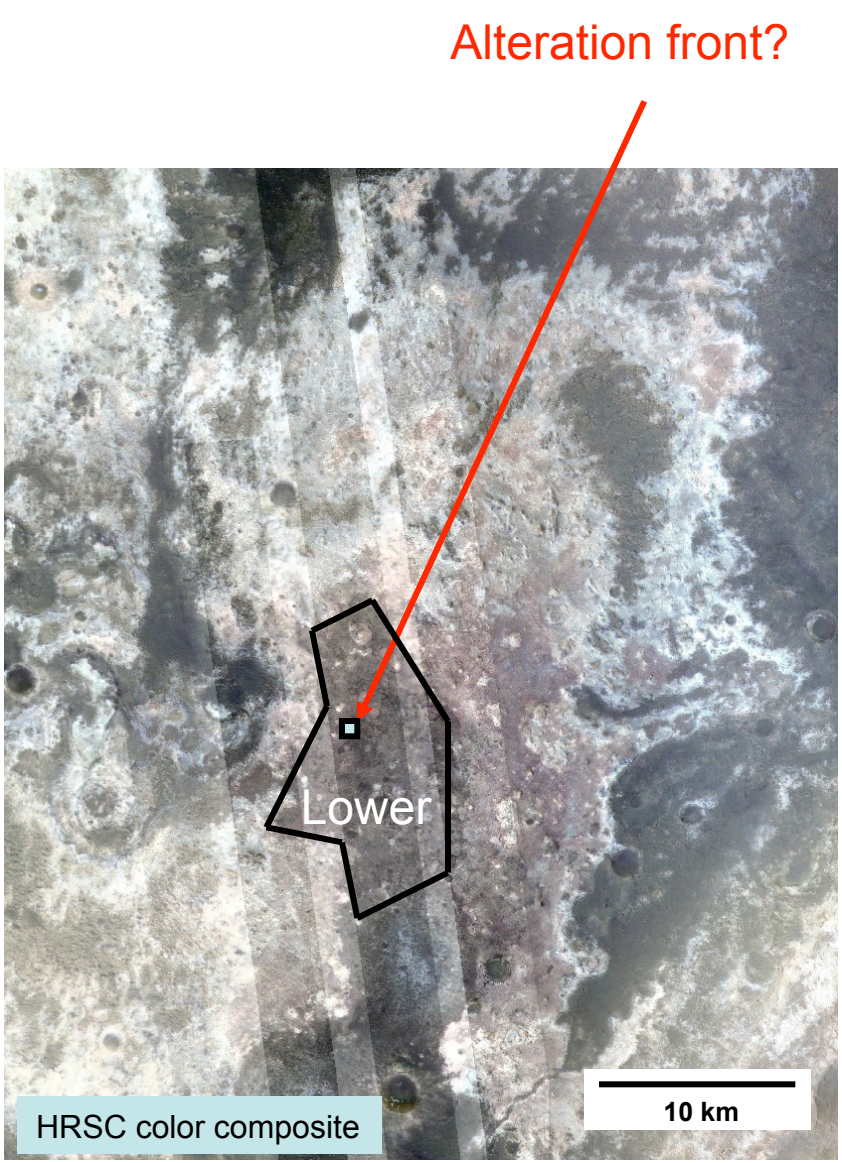


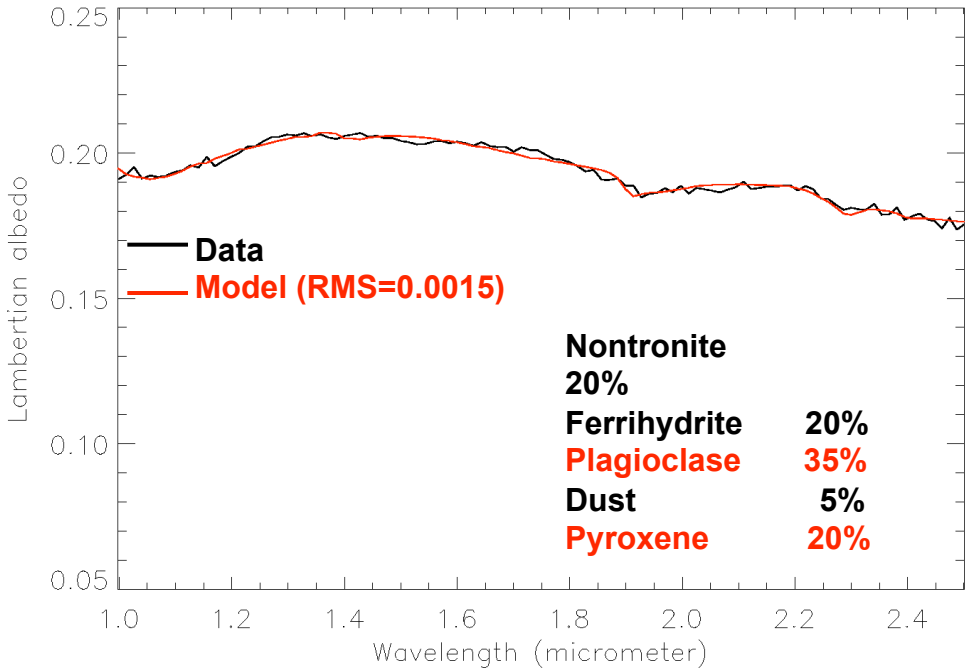

upper
Lower
Middle
10 km
HRSC color composite
Lambertian albedo
0.30
0.25
0.20
0.15
Data
Model (RMS=0.0026)
Kaolinite 35%
Ferric Kaolin 15%
Dust 5%
Ferrihydrite 15%
Plagioclase 20%
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
Wavelength (micrometer)
Ratio (Data/Model)
1.06
1.04
1.02
1.00
0.98
0.96
0.94
Wavelength (micrometer)

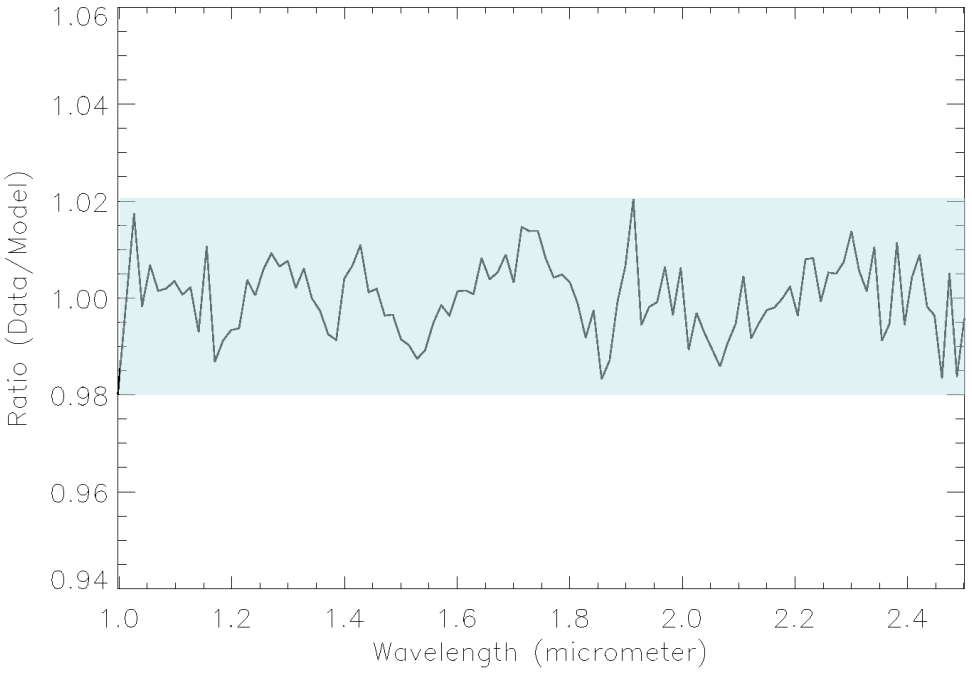

Lower
Middle
10 km
HRSC color composite


0.30
0.25
0.20
0.15
Lambertian albedo
Data
Model (RMS=0.0021)
Nontronite
55%
Dust 5%
Ferrihydrite 10%
Plagioclase 25%
Pyroxene 5%
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
Wavelength (micrometer)


1.06
1.04
1.02
1.00
0.98
0.96
0.94
Ratio (Data/Model)
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
Wavelength (micrometer)


Alteration front?
Lower
10 km
HRSC color composite


Lambertian albedo
Wavelength (micrometer)
Data
Model (RMS=0.0015)
Nontronite 20%
Ferrihydrite 20%
Plagioclase 35%
Dust 5%
Pyroxene 20%


Ratio (Data/Model)
Wavelength (micrometer)

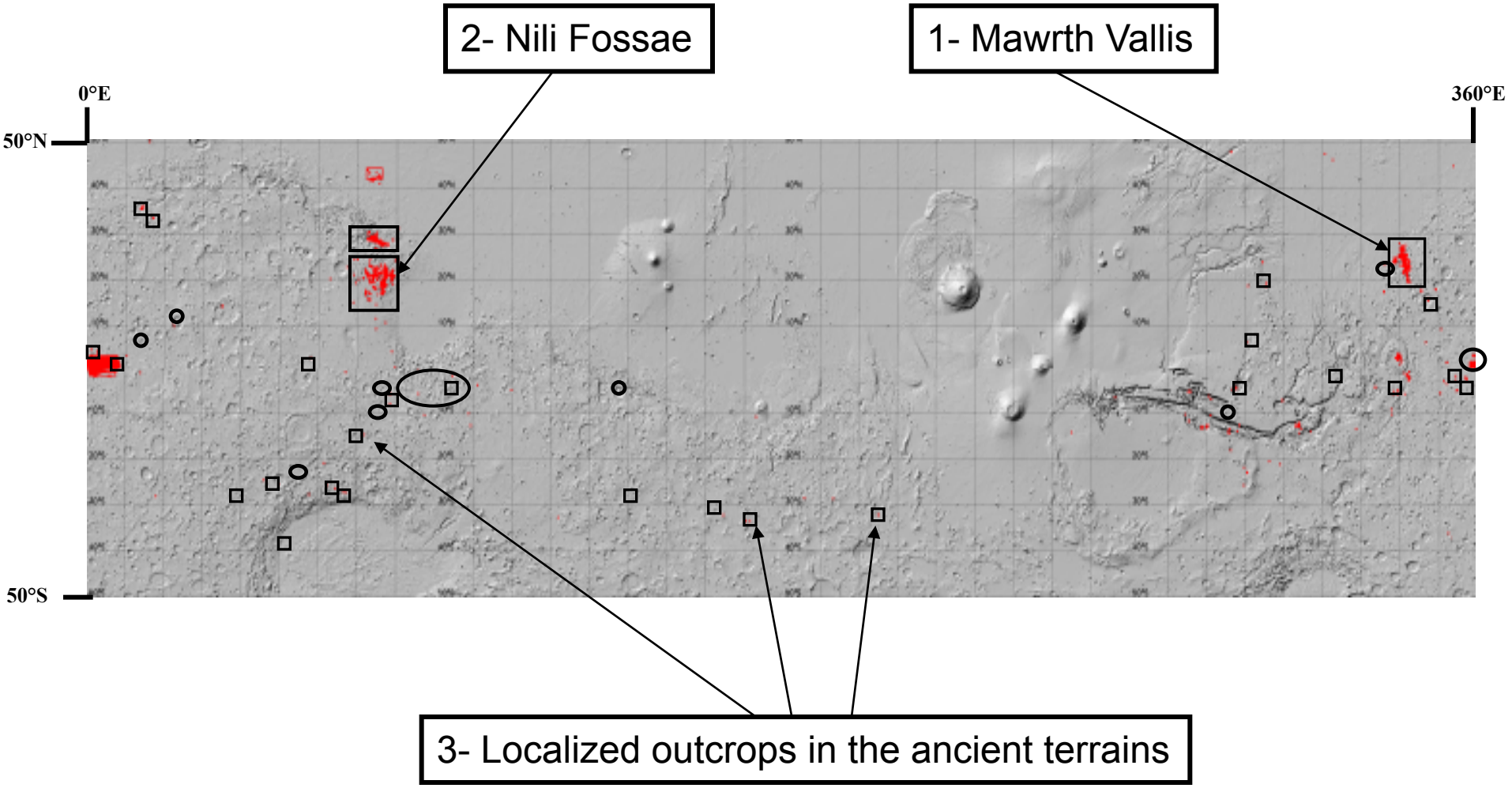
Modal mineralogy of phyllosilicate-rich deposits in Mawrth Vallis

- Hydrated minerals (Fe- and Al-phyllosilicate+ iron hydroxide) > 60% in Vol
- Anhydrous component (Plagioclase) <25%
- No pyroxene

- Lower unit dominated by anhydrous silicates (plagioclase, pyroxenes)

Spatial distribution

OMEGA hydrated mineral global map (Phyllosilicates, Sulfates)



Comparison of modal analyses

	Mawrth Vallis	Others (including Nili Fossa
Hydrated Minerals	> 60%	< 35%
Anhydrous minerals (Primary igneous)	< 25%	> 60%
Martian Dust	~10%	~10%

Modal mineralogy of the Mawrth Vallis deposits indicates a larger and/or different degree of alteration + phyllosilicate-rich layers deposited above a less altered surface

Anydrous minerals are the most abundant minerals

Mawrth Vallis

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1. Introduction, context	J-P. Bibring
2. Abundances, modeling	F. Poulet, J. Bendfield, J. Michalski
3. Context, chronology,	N. Mangold
4. CRISM HR mineralogy	J. Bishop, N. McKeown, M. Parente
5. HIRISE stratigraphy	J. Wray
6. Regional context	E. NoeDobra
7. Phyllosilicate formation	J. Michalski
8. Summary	J-P. Bibring

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Context

- Hydrated phyllosilicates are present with very high abundances (throughout the ellipse # 2 and 3); the MSL lack of remote sensing ways to drive towards minerals of relevance is not a major issue.
- Landing site # 2 exhibits abundant and varied outcrops of phyllosilicates and aqueous materials within the ellipse.
- Phyllosilicates are found where were formed, over large depths (> 150 m).
- Context characterized by discrete stratigraphic sequences, straightforwardly recognizable (from orbit & in situ).

⇒ The coupling between compositional and context information will enable to decipher the sequential formation processes.

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Diversity

- Fe/Mg-smectite the most common phyllosilicates throughout Mawrth Vallis; occur in thick and broad deposits, cracked polygonal texture; apparently resistant to alteration.
- Abundant Al-phyllosilicates (montmorillonite and kaolinite) present, preferentially at higher elevations; primarily smaller 20-50 m outcrops but few larger 100-200 m outcrops.
- Al-phyllosilicates frequently accompanied by hydrated silica.
- Ferrous component often observed at transition boundaries from Fe-rich to Al-rich phyllosilicates.
- Mafics from various origins present, in varying (wrt phyllosilicate compositional) composition and abundance : access to igneous petrology.

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Habitability / preservation

- Phyllosilicate transitions over elevation (translating a time evolution?) indicate changes in formation / environmental conditions
- Recent exposure, and very limited oxidation (almost no peroxidic reddening).
- Heavy bombardment, RCS and RCG have not altered the hydration state nor modified the sequential compositional evolution.
- Phyllosilicates provide surfaces for binding / trapping organics. Silica is good preserving agent for fossils and organic biosignatures. Rocks appear to be largely undisturbed, so high chance of rocks to retain original record of organics or life, if present.

⇒ optimized samples for having preserved potential fossils, biosignatures or evidence of organics key for life

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at Mawrth Vallis, MSL will (can / should)

address the diversity

- in the composition of the variety of minerals/types/lithologies, tracing the sequential evolution of the environment
- in the coupled stratification of the context structures, translating the sedimentary processes

and search for preserved habitability footprints

- in imbedded grains within clays (e.g. carbonates, pCO2 tracers)
- in coupled C-rich phases, diagnostic of environmental conditions
- in the various strata, accessible within the ellipse: their variation along the stratification will assess that of habitability.

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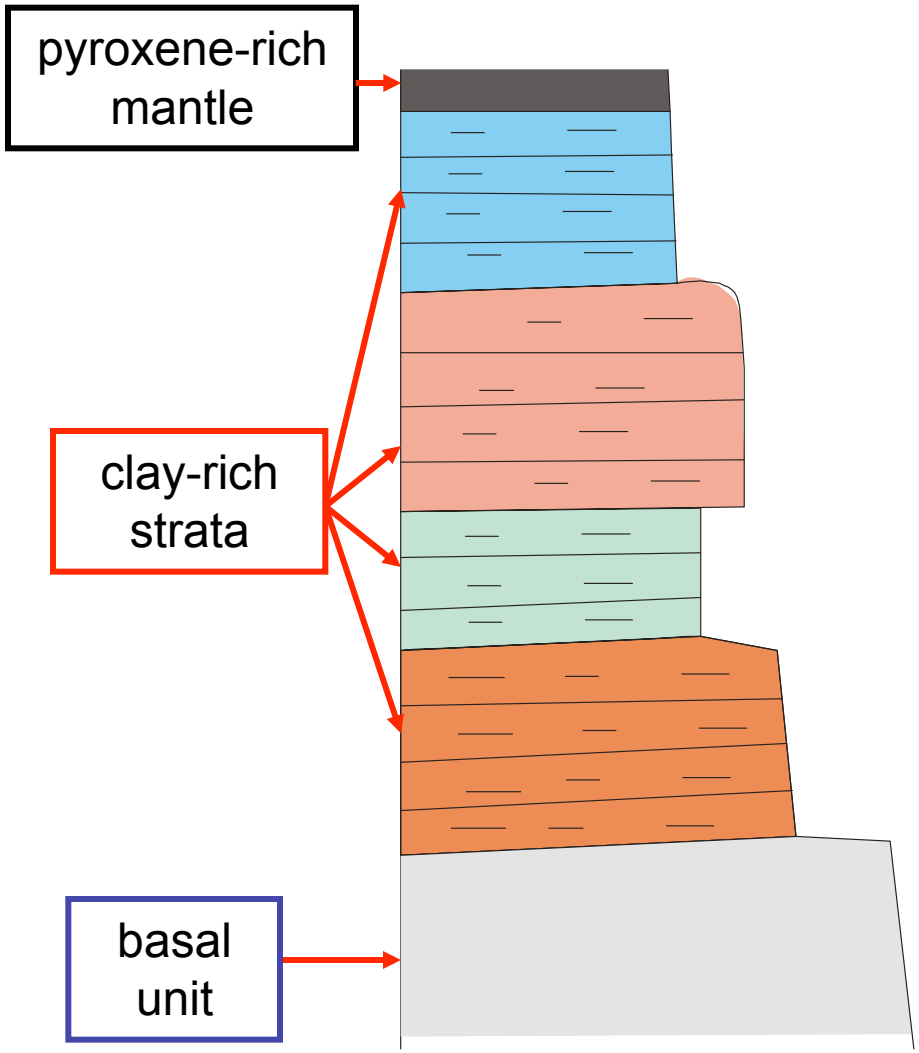
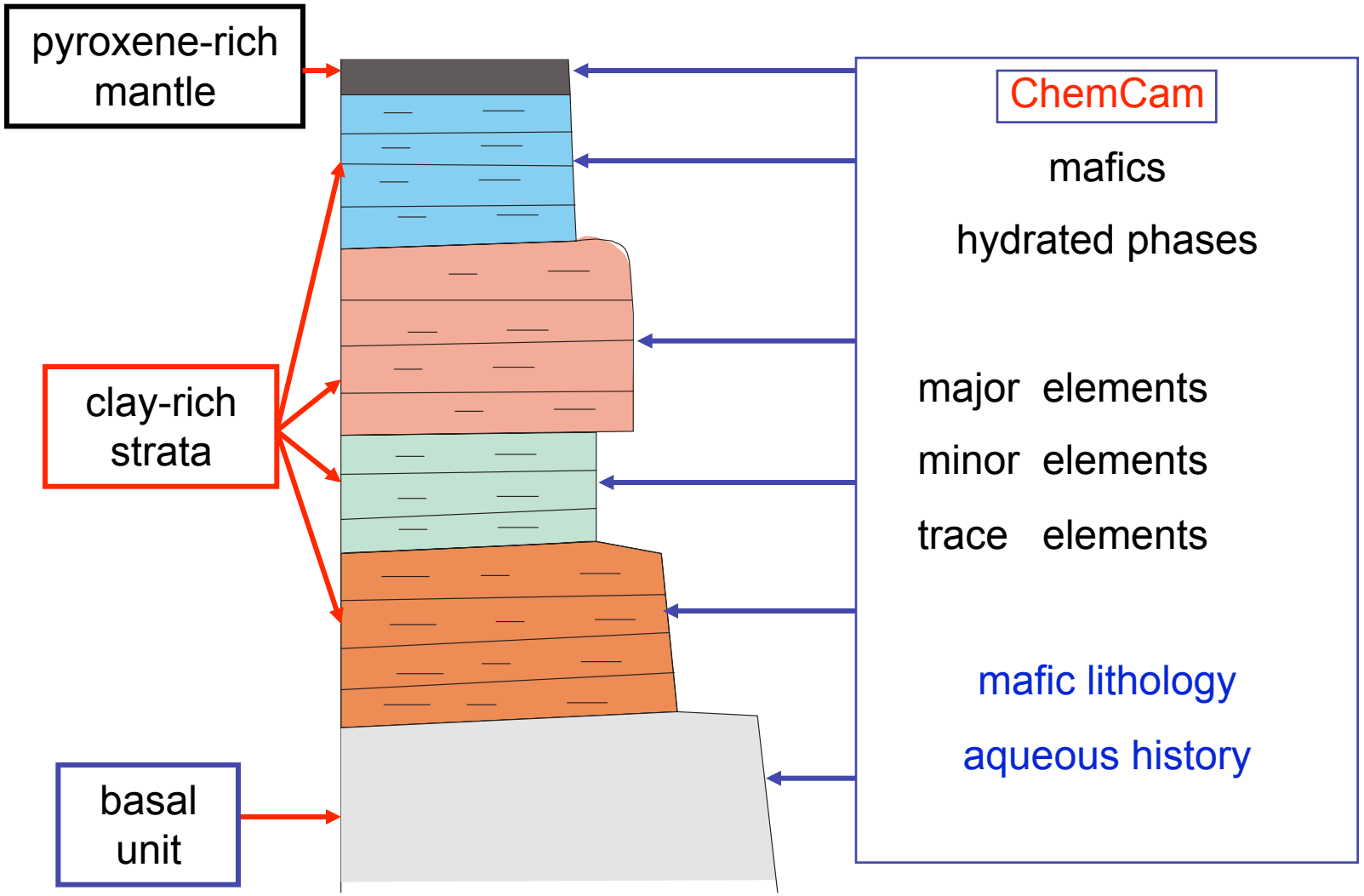


Mawrth Science Laboratory



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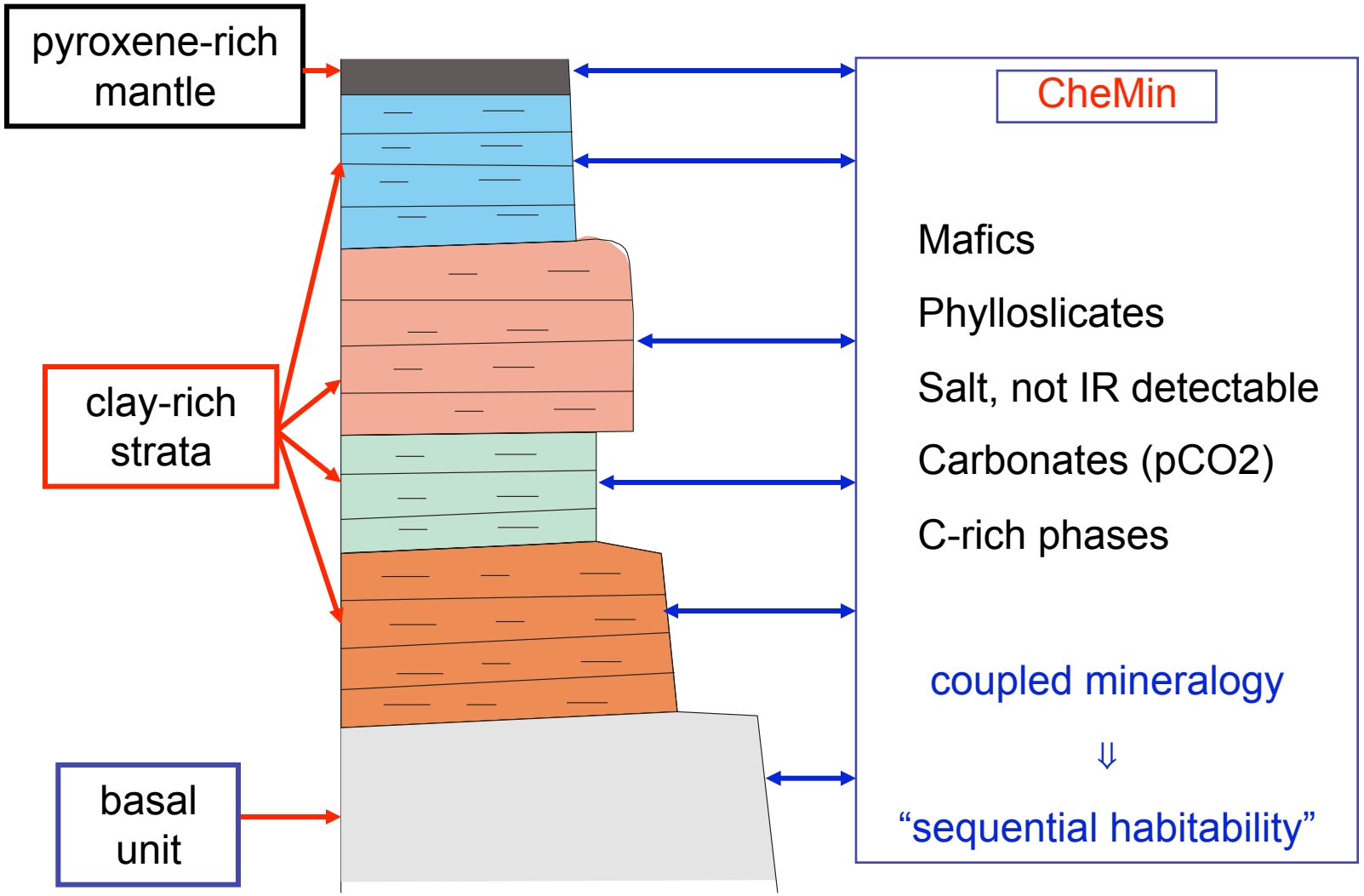

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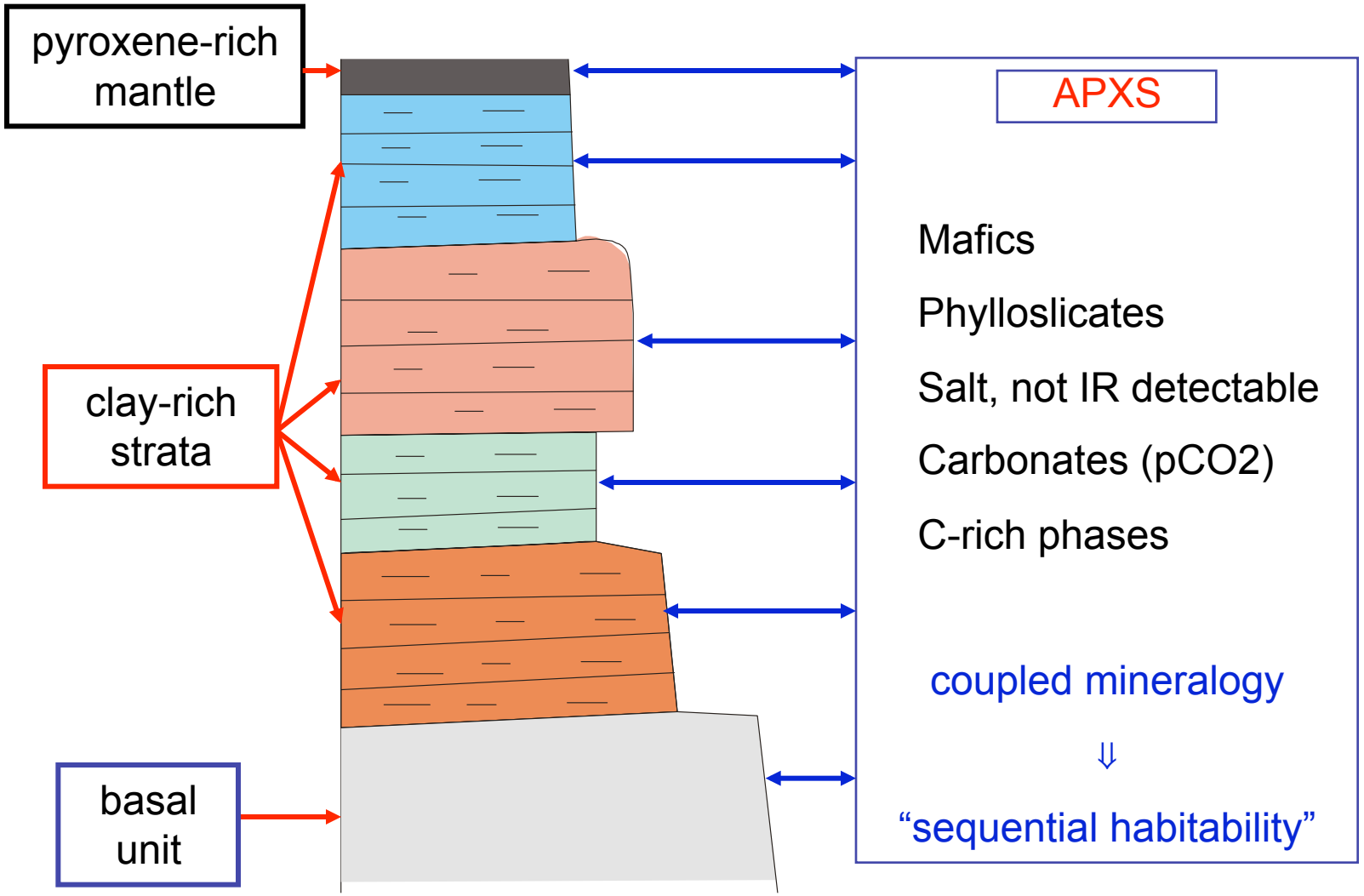

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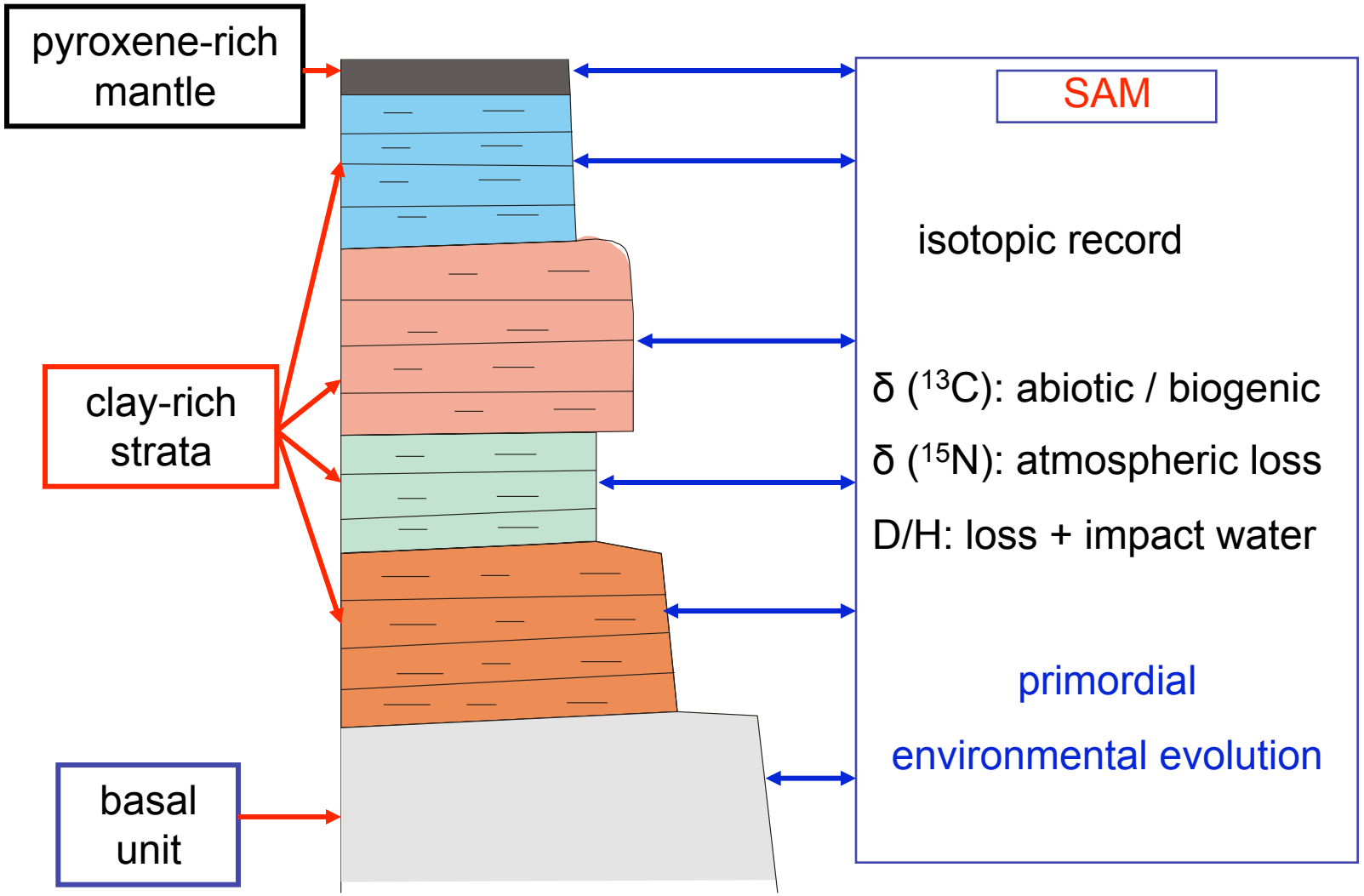

Mawrth Vallis

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Major weaknesses

1. We have not fully followed John Grotzinger's request, received yesterday morning:

"…I hope this will not result in a lawyerly (and overpassionate) defense of the Mawrth site, but an honest assessment of its strengths and weakness…"

Mawrth Vallis

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Major weaknesses

2. All 4 Mawrth Vallis sites are of utmost potential, with similar but not identical values. Investigating all necessarily led to less focused effort. We are sensitive to the fact that the activity is far from being completed.

It is trivial to state that provided Mawrth Vallis passes this WS, if one site is favored system- or science-wise (at this point, site 2 is our favored), we will proceed with a targeted activity in the coming weeks/months.

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Major weaknesses

3. Ideally, the exploration would enable to study the evolution of Mars through the global climatic change that led to the specific era during sulfate formation occurred, after the atmosphere had escaped. We hoped we would find at Mars areas 20 km in diameter in which distinct and unambiguous stratigraphy recording the entire first billion years of Mars History be preserved. They are none. Sites with mixture of phyllosilicates and sulfates exist: the material has been subjected to transportation, precluding to assess the true habitability history. Consequently, one has to choose between exploring the phyllosilicate or the sulfate era. No doubt that the habitability goal imposes the first; Opportunity has covered the second. However, Mawrth Vallis itself might have transported sulfate-rich grains: Spirit type exhume process might make them accessible, towards the very end of the mission…

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Major weaknesses

4. Given the unique potential of this site, if biorelics exist, the likelihood is high that MSL will identify them, in at least one specific strata, recording a specific time, climate and overall environment. We might even understand why Mawrth Vallis has preserved them, and why no other sites have.

⇒ Unfortunately, the ESA/ExoMars EDL does not seem sufficient to land in Mawrth Vallis: besides the outstanding ExoMars P/L suite, we might be severely frustrated …

⇒ and we will, for decades, be stuck to this fascinating site: we will need to send MSR back to this site…

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It is remarkable that the Mars evolution has preserved such a site at its surface: although heavily bombarded, it maintained the record of its most ancient era during which liquid water was persistent over long durations.

It is also remarkable that this site is accessible to MSL, being at low altitudes, with a consolidated texture.

In Mawrth Vallis, Mars offers to study this fascinating era of critical astrobiological relevance and planetary importance.

Supposedly MSL confirms its capability to explore Mawrth Vallis, we should not miss the opportunity.

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We all
thank you !