OMEGA : science introduction

1. OMEGA primary goals

2. Science designed specifications

3. Instrument overview

4. Outline of major science outcomes

OMEGA

O bservatoire, pour la	⇒	Observatory
M inéralogie, l'		Mineralogy
E au, les		Water
G laces, et l'		Ices
A ctivité		Activity

P.I.: J-P. Bibring, Institut d'Astrophysique Spatiale d'Orsay
40 col's

OMEGA : science introduction

OMEGA was selected in 1988, to fly onboard the Mars 96 Russian mission. Its design was made soon after, to achieve the goals conceived as prime at that time, with the available flight qualified technology.

At this time, almost no surface compositional data were available, except from those derived from the two Viking Lander APXS sets of measurements : our understanding of Mars state, history and evolution was essentially based on optical imaging.

The goal for a large community was thus to produce compositional data to be coupled with imaging data already acquired or to be acquired (inferring the geomorphological context).

Together with US colleagues (VIMS/Mars Observer) we considered that NIR spectral imaging was the right answer to achieve the above quoted goal. For planetary objects of temperature ~ 300K, NIR is the domain of reflectance spectroscopy (crossover to thermal emission: 3 to 4 µm).

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OMEGA was decided at the time ISM / Phobos was launched, in 1988. ISM constituted the first ever designed and flown NIR spectral imager. For transfer of technology constraints, it was highly limited technically. However, it demonstrated the potential of NIR reflectance spectrometry to derive atmospheric and surface composition, and the benefit of coupling imaging and spectrometry to acquire the composition of each resolved pixel.

Consequently, OMEGA specifications were derived for:

imaging:	space sampling (IFOV) and FOV
spectrometry:	spectral sampling and spectral range
radiometry:	SNR

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imaging:

ISM demonstrated that surface diversity exists at all observed space scales (down to a few km). Thus, the goal for OMEGA was to get as high as possible a sampling. Trade off is thus between sampling and coverage. Given the lack of Mars compositional knowledge at that time, we wanted to have the capability to acquire the global coverage of the surface. With the envisioned downlink profile and mission duration, km-scale coverage was a realistic goal. For a given orbit, this drives the IFOV, thus the surface sampling. We chose an

IFOV of 1.2 mrad (~ 4.1 arcmin).

The associated surface sampling depends on the altitude of observation (along the elliptical orbit):

300 m from 250 km

4.8 km from 4000 km

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spectrometry:

NIR reflectance spectrometry is the means to derive composition from specific quantum transition to excited states through (solar) photon absorption.

Identification is made by comparison with library spectra (potential bias and limitation).

1. Spectral domain

VIS + NIR corresponds to electronic states (marginally), and primarily to vibration modes (radical and molecules). Most non symmetrical species (permanent dipole) have diagnostic transitions in the NIR, which constitutes the reflectance domain ($\lambda_m T$ = 2900 µm.K → reflectance/thermal crossover @ ~3 µm, thermal dominates above 5 µm). For OMEGA, we chose:

0.35 – 5.1 µm

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2. Spectral sampling

2.1. Atmospheric (gaseous) transitions lead to very narrow (rotational) lines (<< 1 nm width): FS is the means to achieve such a sampling over a wide spectral range. However, it requires moving parts, and is difficult to couple to imagery (in particular too large spectral sampling over a large spectral domain precludes large spatial sampling, for data volume constraint). Grating spectroscopy is easier to implement in an imaging mode. However, given the achievable resolution (typically $\lambda/\Delta\lambda$ ~100 to 500), sampling of a ~10 nm is achievable. We chose for OMEGA:

7nm	from	0.35 to 1 µm
13 nm	from	1 to 2.5 µm
20 nm	from	2.5 to 5.1 µm

With such a reduced sampling, individual lines are summed, which reduces sensitivity, but enables (in a few cases) to unambiguously identify species: Martian CO_2, CO, H_2O and O_2 can be identified along a nadir line, and even along limb sounding.

OMEGA : science introduction

2. Spectral sampling

2.2. Surface (solid) transitions lead to rather broad features, summing up a diversity of environments at a microscopic scale: 10 to 20 nm is adequate. Other solid compounds (aerosols, even clouds) do exhibit diagnostic signatures.

The position of the maximum absorption is diagnostic of the bounding, while the shape gives potentially access to other parameters, such as : mean grain size, temperature etc…Most vibration transitions in this domain are not fundamental modes, but combination of harmonics: in a few cases, several transitions are present in the NIR domain.

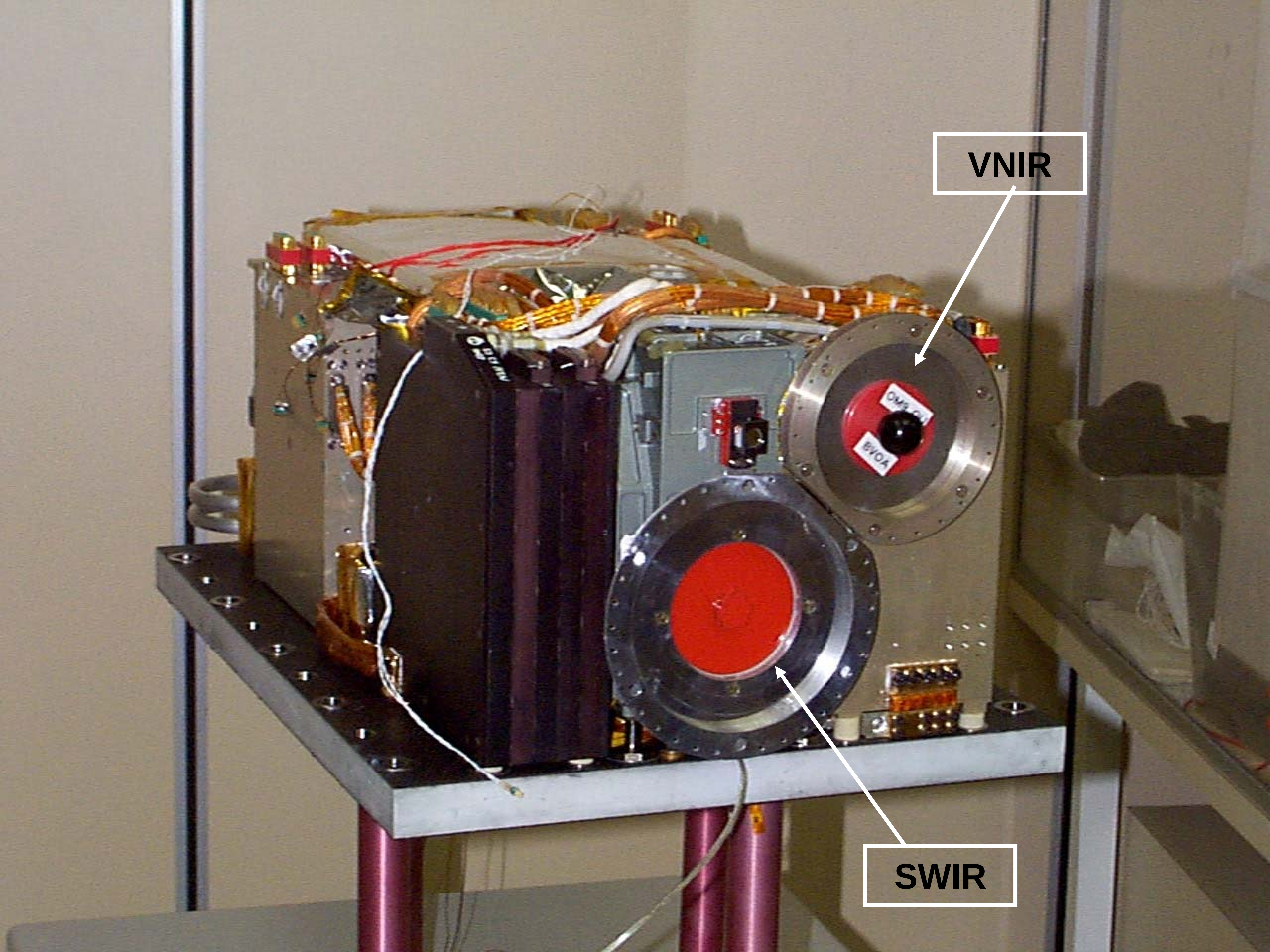
Species potentially identified range from surface minerals to frosts, to atmospheric aerosols and clouds.

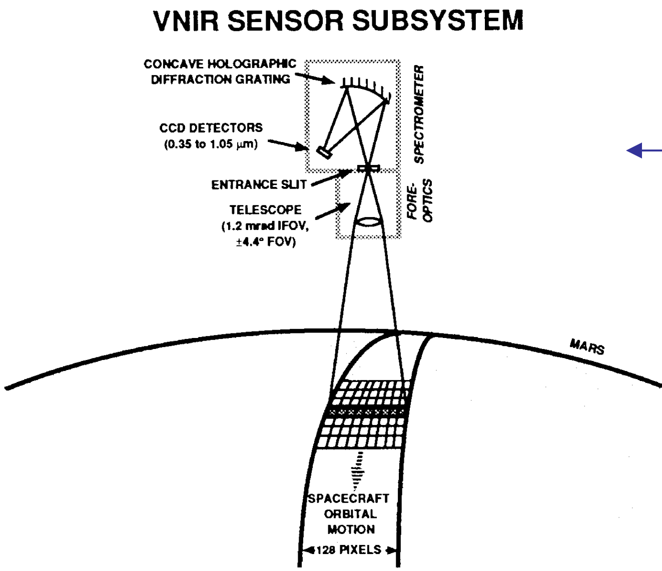
OMEGA : science introduction

1. How to build a spectral image

2. How to identify species

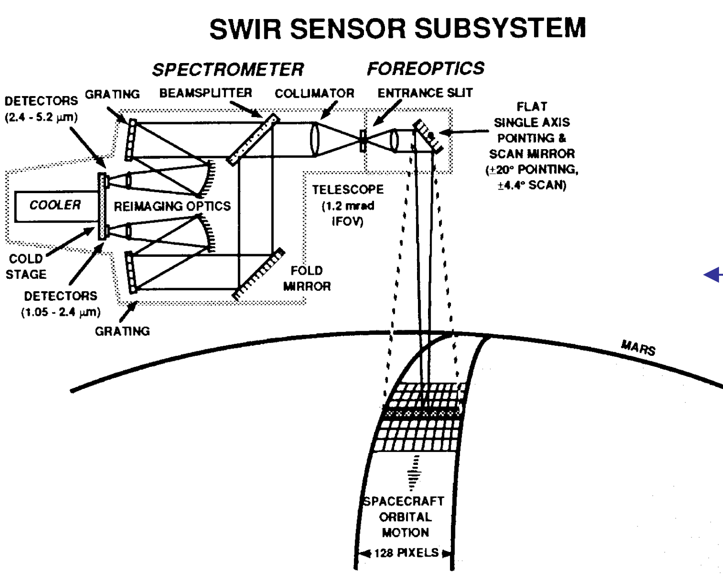
OMEGA : how to build a spectral image


VNIR
SWIR



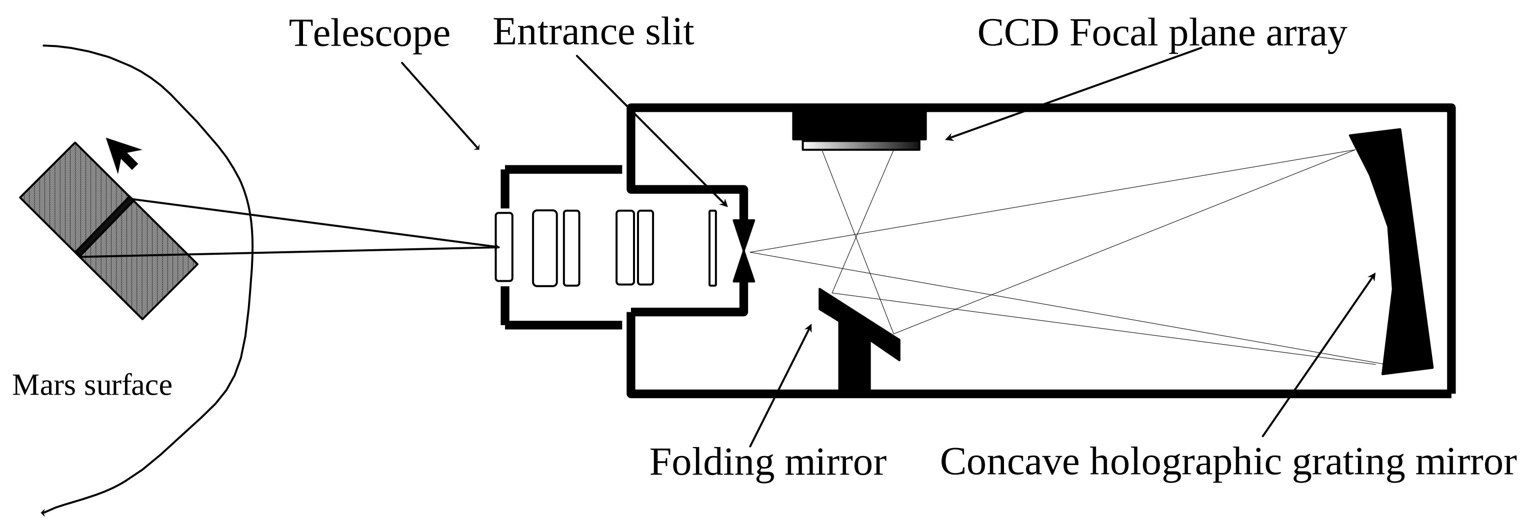
“Visible” channel

pushbroom mode



near IR channel

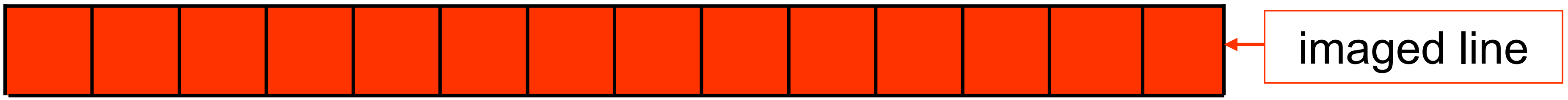
whiskbroom mode



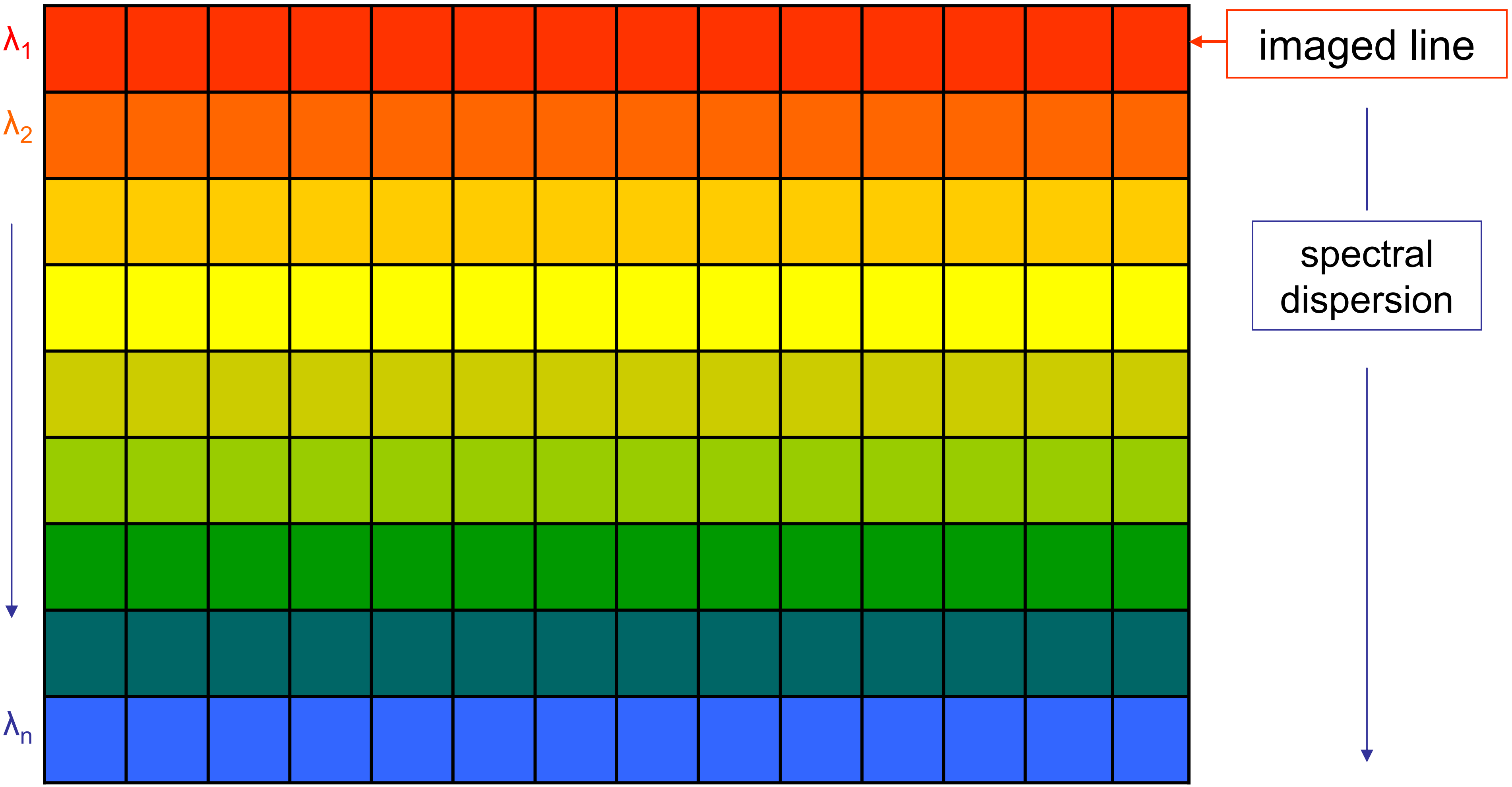
OMEGA "visible" channel

One line of 128 pixels at the surface of Mars is imaged at once, and spectrally dispersed along the other dimension of the matrix.

imagery in pushbroom mode



spectral imagery in pushbroom mode



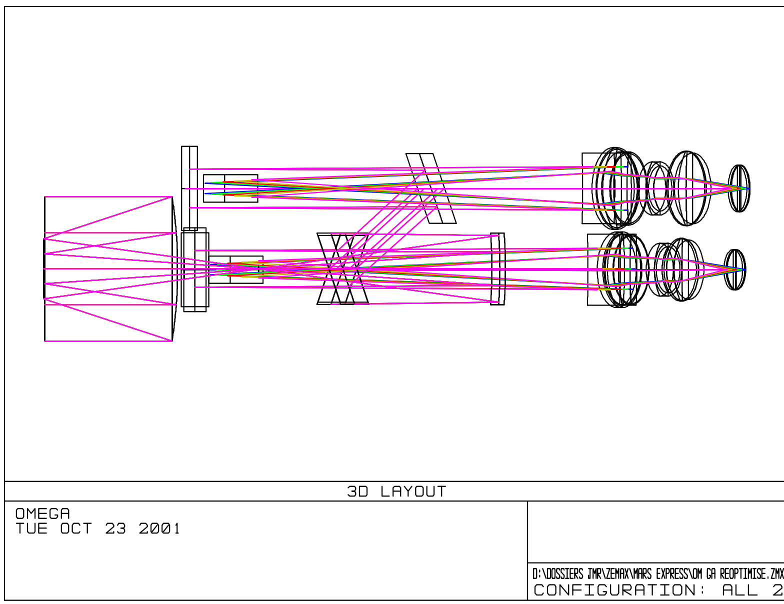
NIR channel:

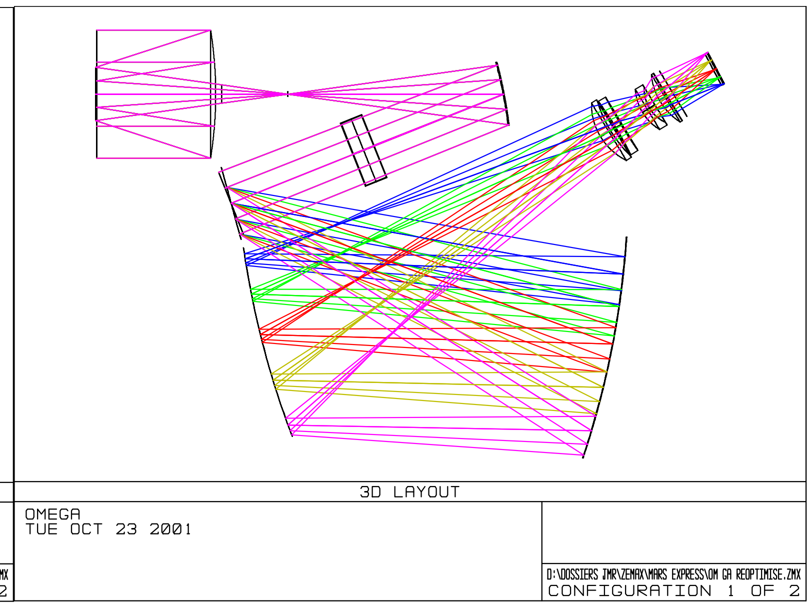
1 telescope with a scanner

2 spectrometers

2 linear arrays of 128 elements ("spectels“), each cooled by a crycooler

SWIR-C	0.93 to 2.6 µm	sampling: ~ 13 nm
SWIR-L	2.5 to 5.1 µm	sampling: ~ 20 nm





OMEGA: whiskbroom mode

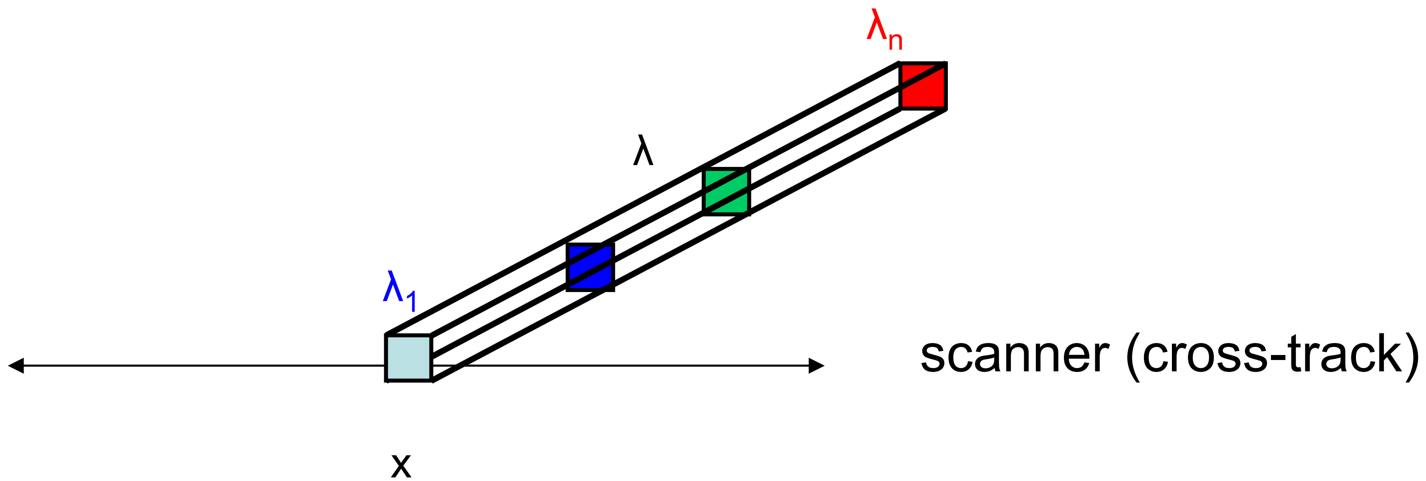


image building

OMEGA: whiskbroom mode

along the track

(spacecraft drift)

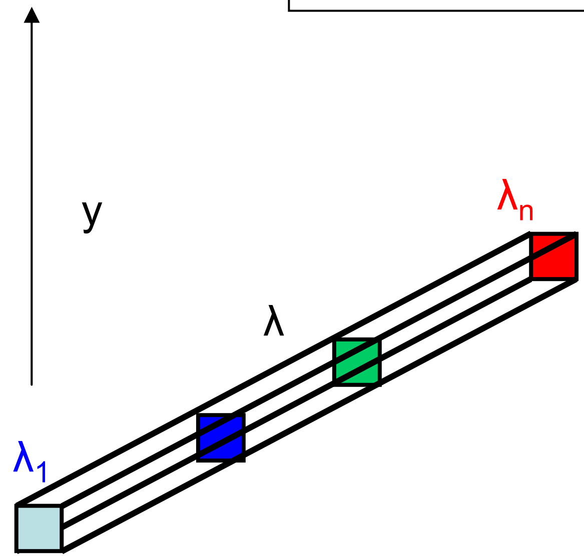
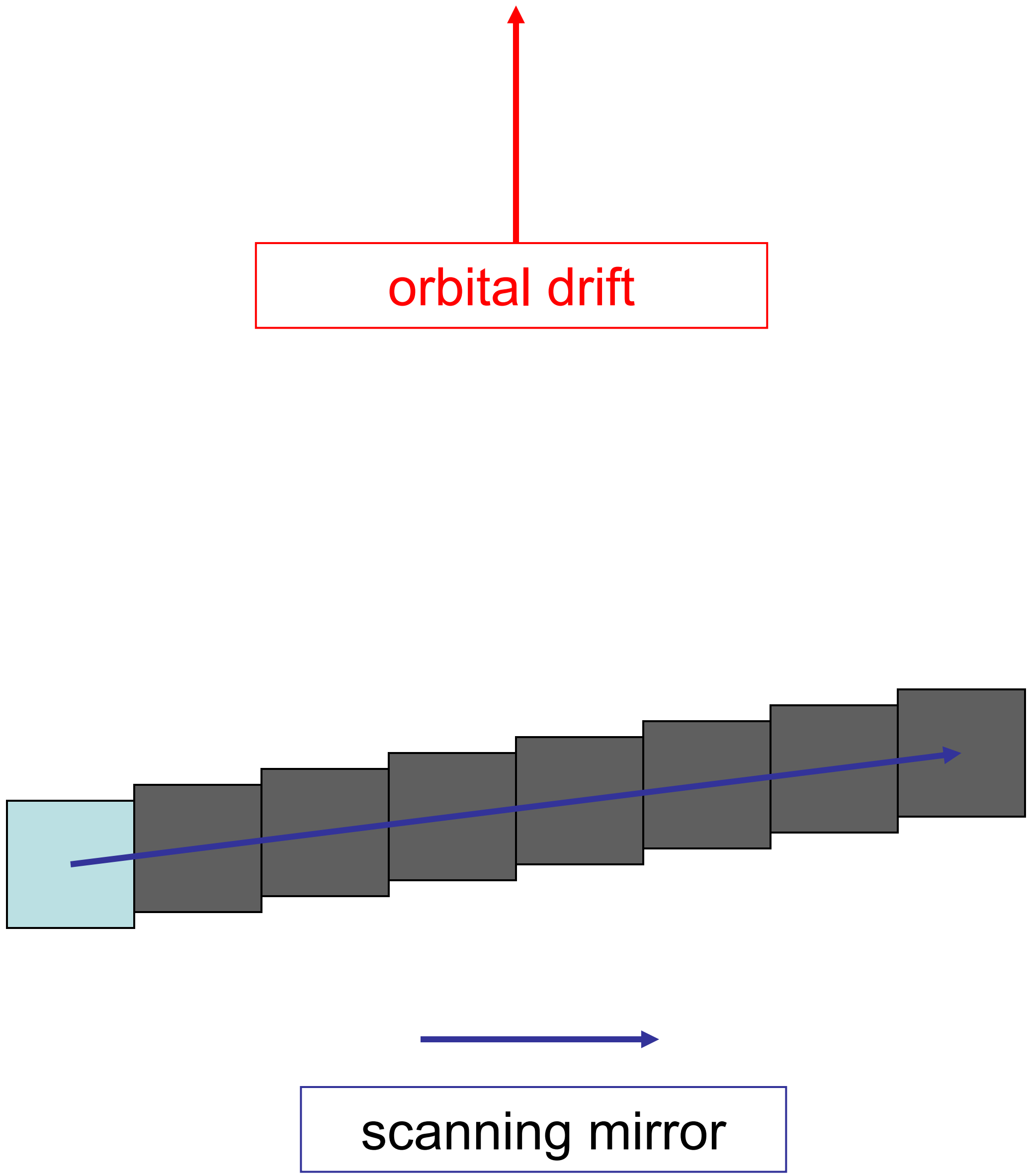
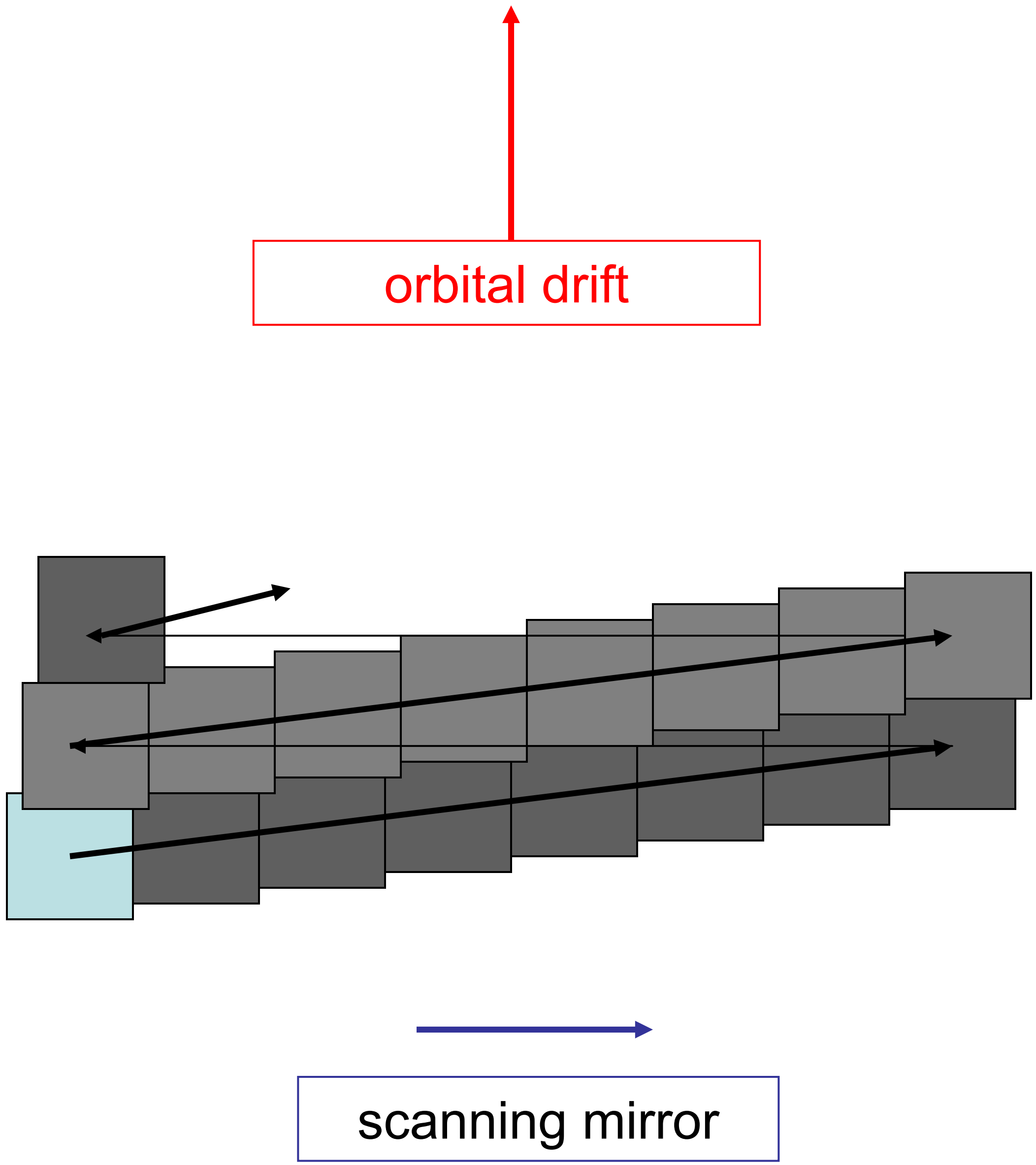


image building

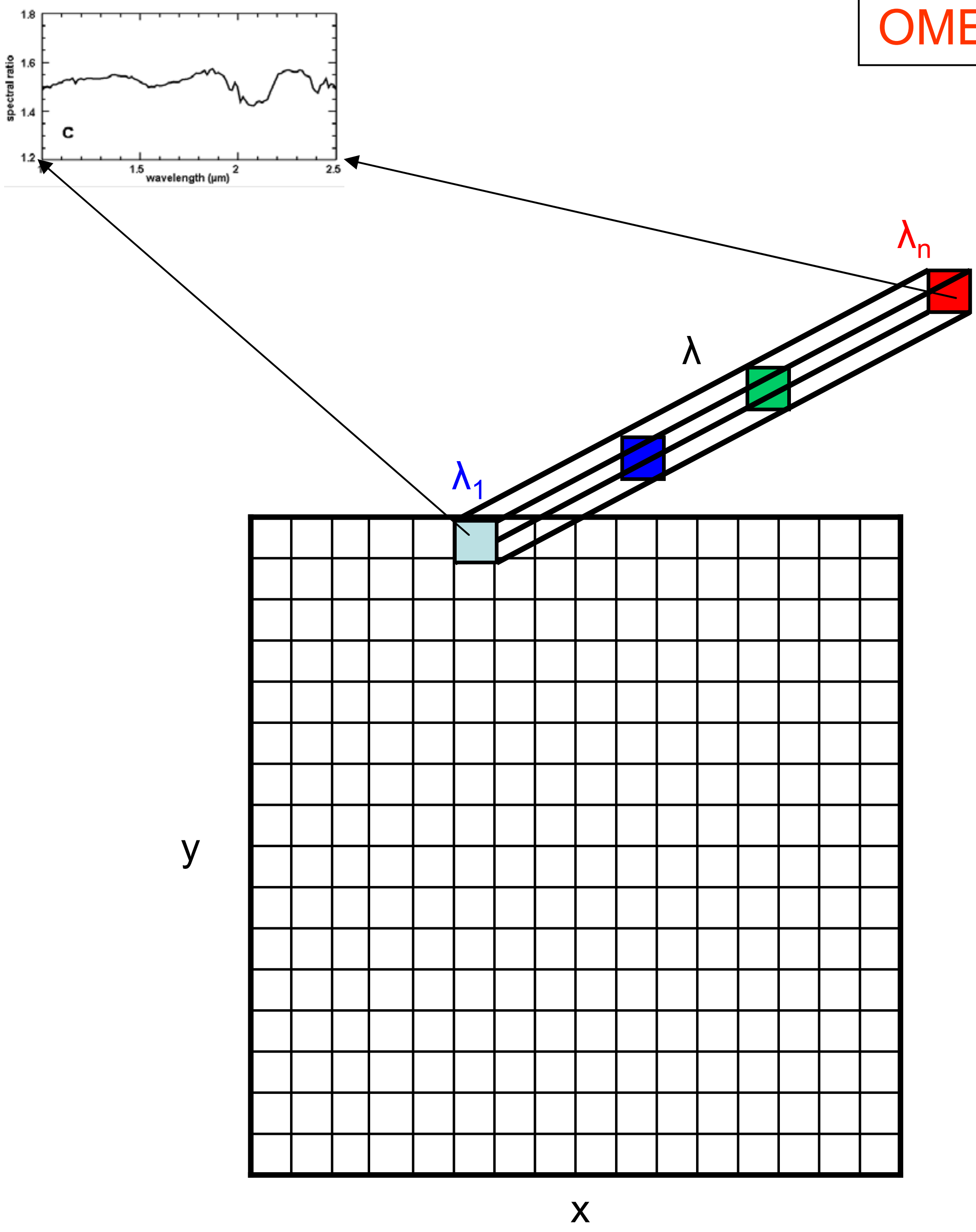
OMEGA: whiskbroom mode



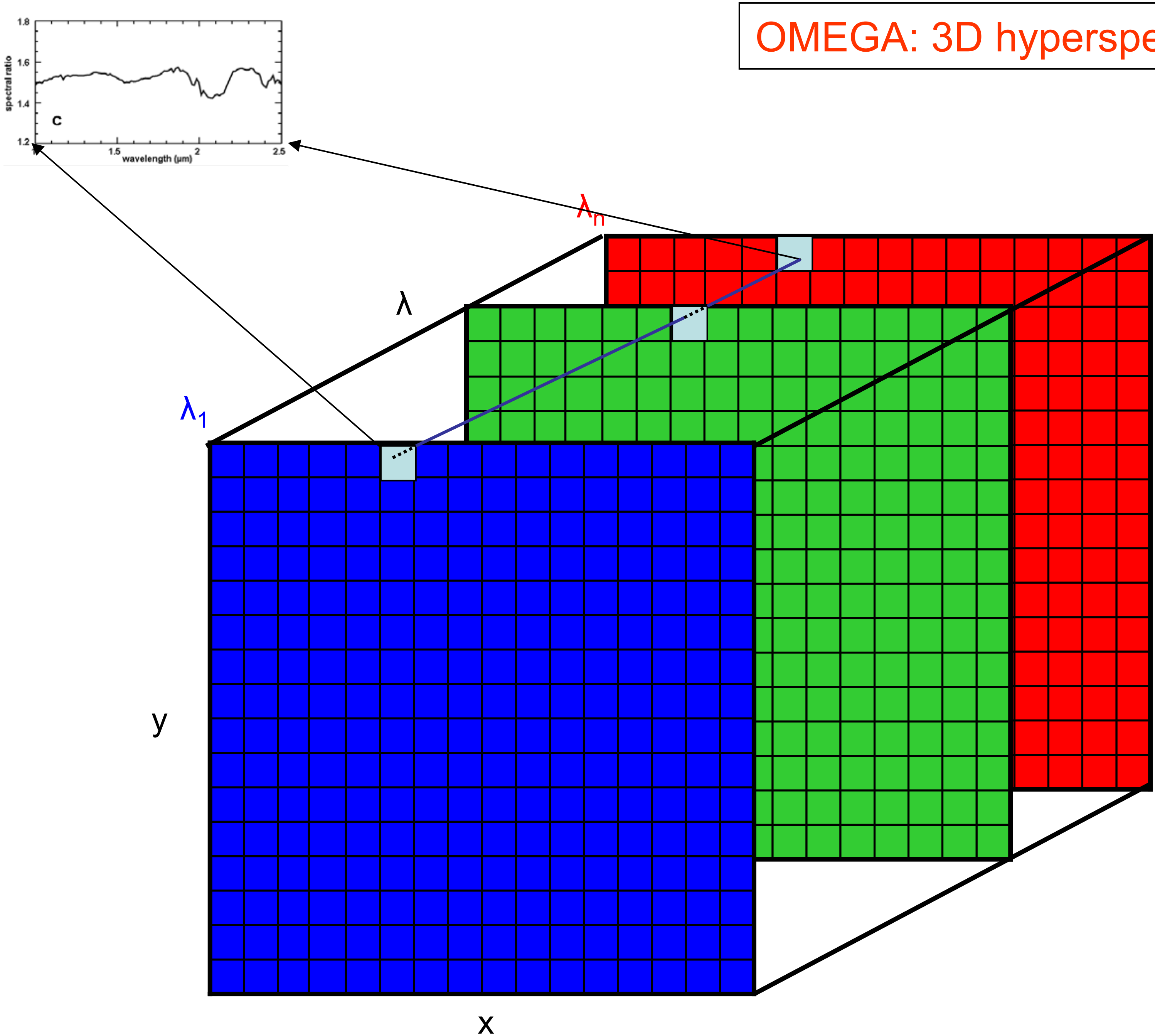
OMEGA: whiskbroom mode



OMEGA: whiskbroom mode

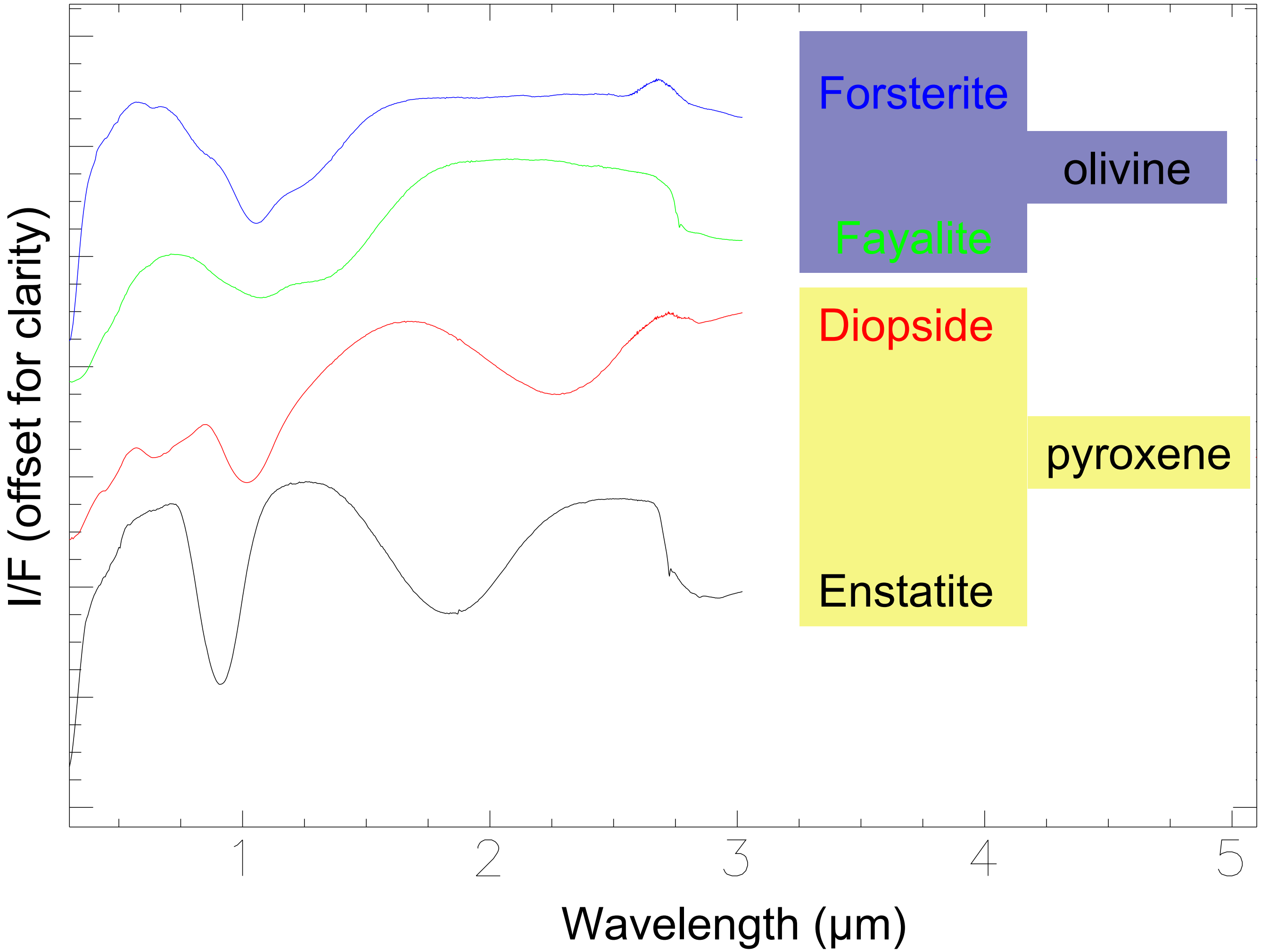


OMEGA: 3D hyperspectral images

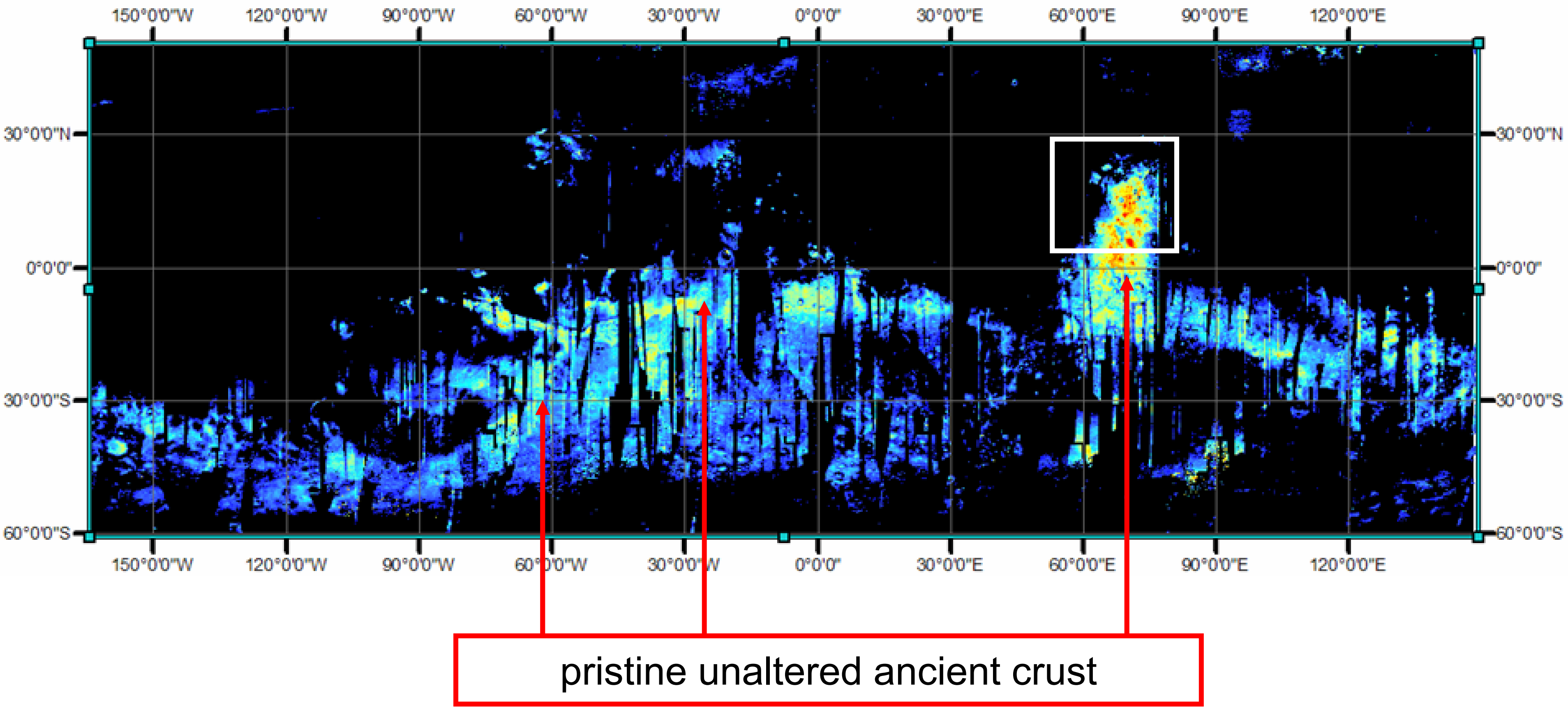


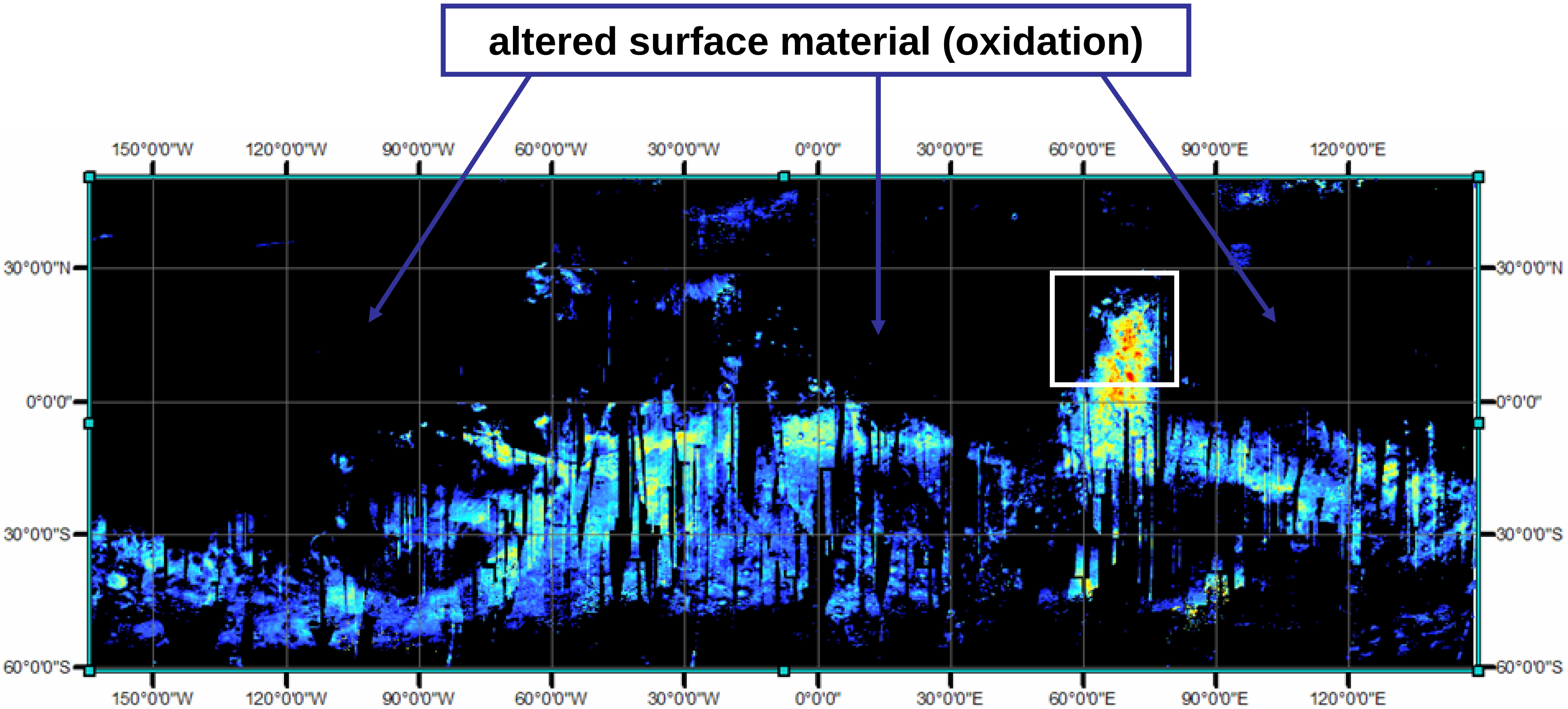
OMEGA : how to identify species

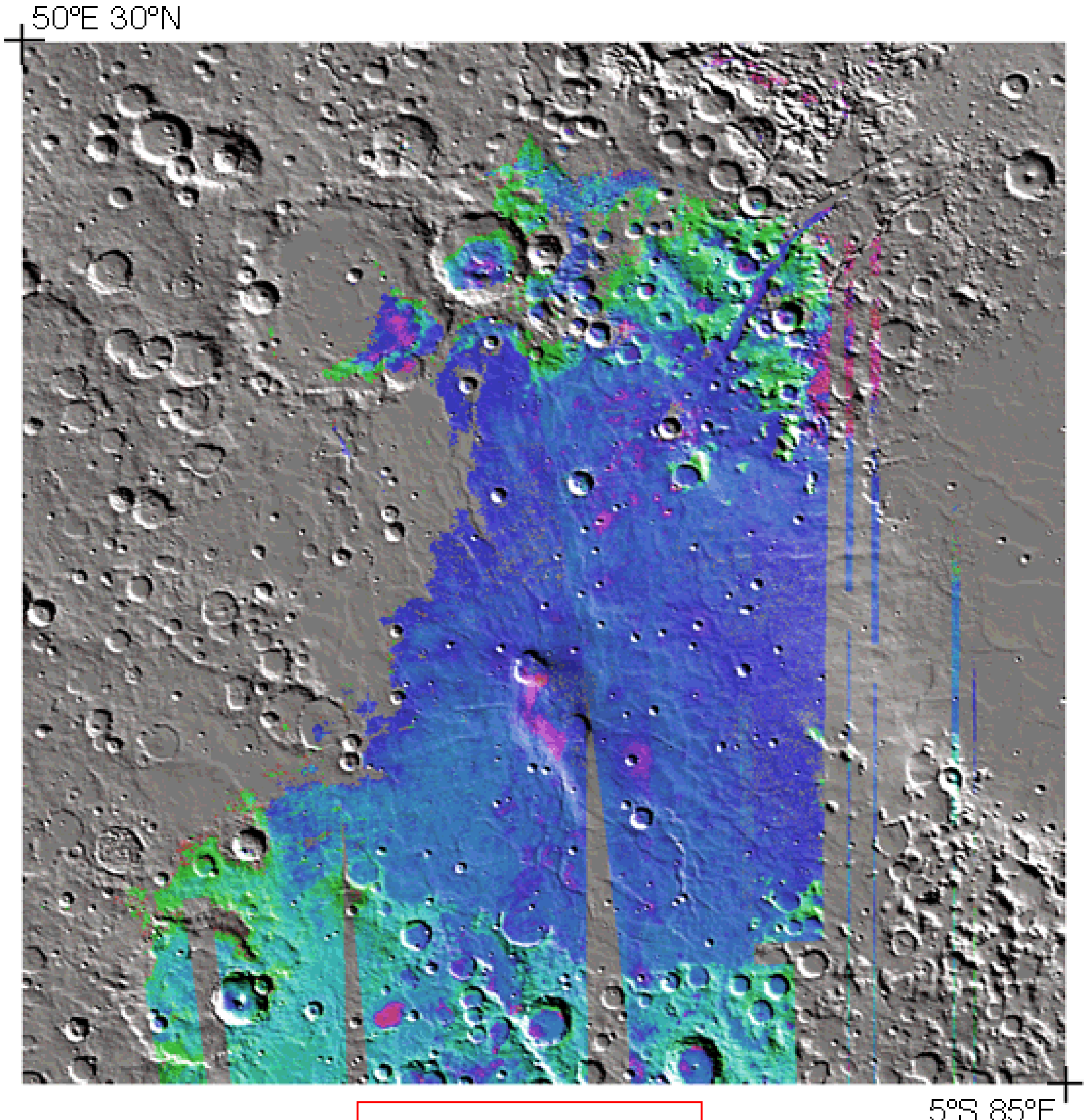
mafic silicates



Pyroxenes (HCP)




altered surface material (oxidation)
150°0'0"W
120°0'0"W
90°0'0"W
60°0'0"W
30°0'0"W
0°0'0"
30°0'0"E
60°0'0"E
90°0'0"E
120°0'0"E
30°0'0"N
0°0'0"
30°0'0"S
60°0'0"S

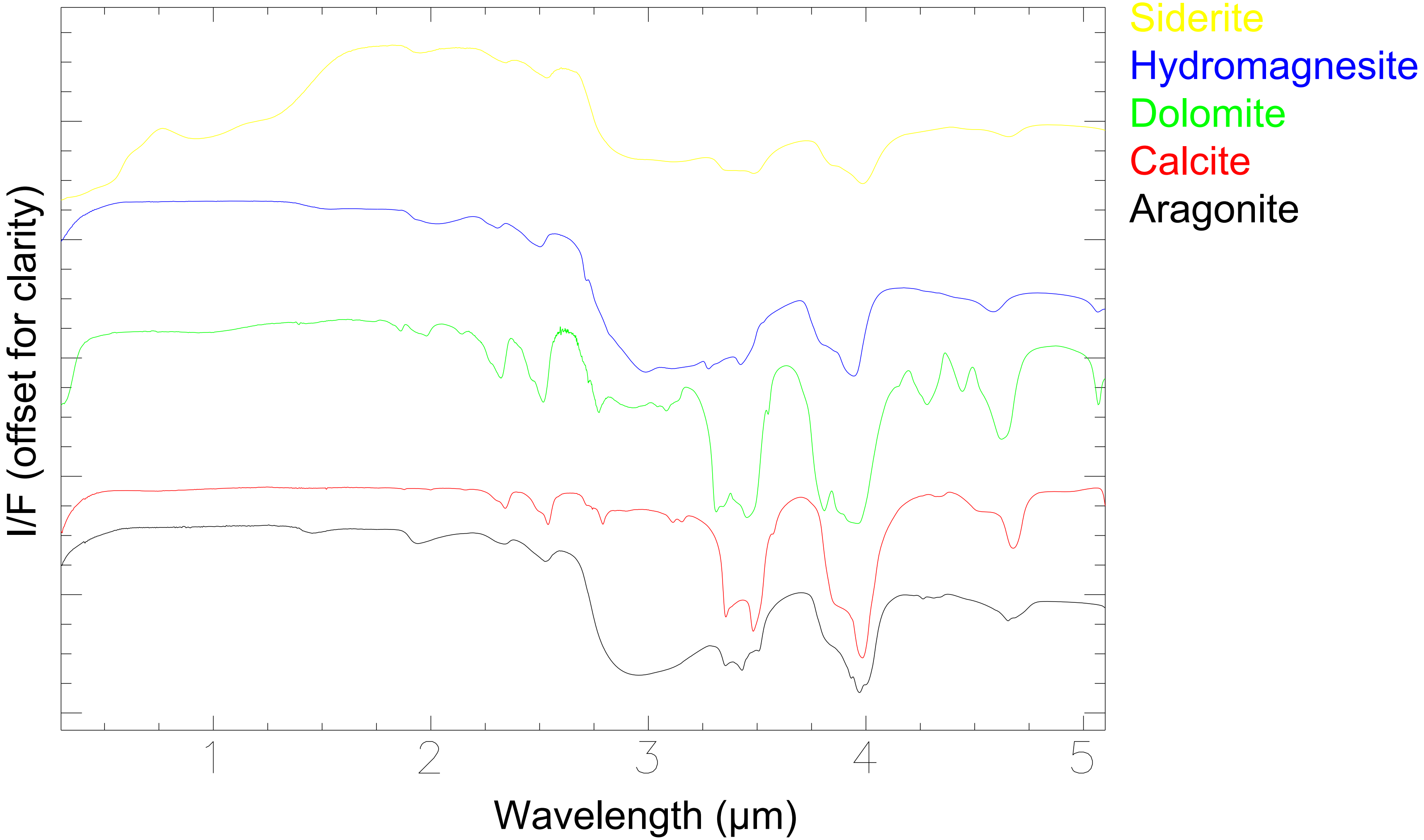


olivine: red
LCP: green
HCP: blue

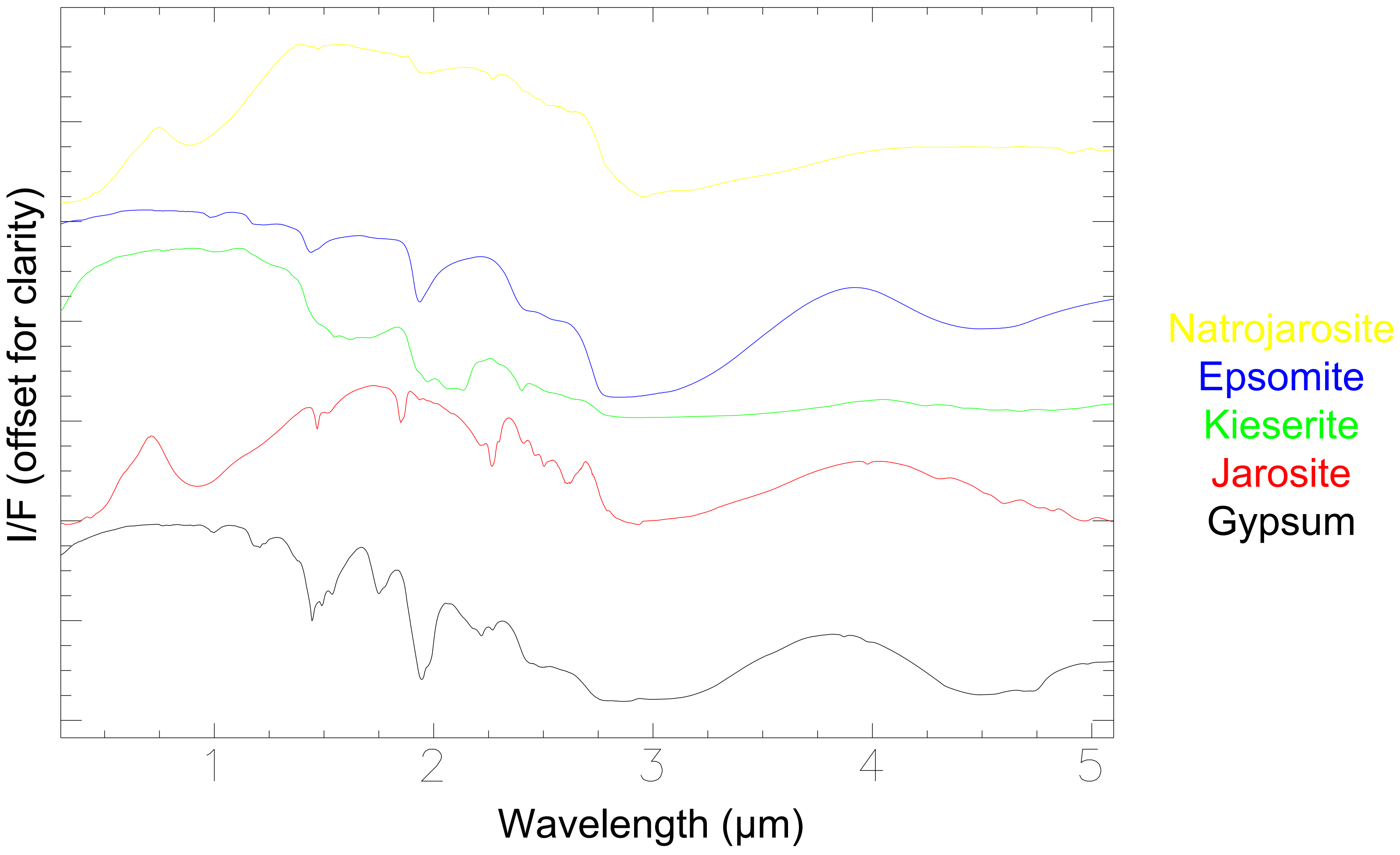
The ancient crust has still its pristine composition, with a mixture of LCP and HCP, while the lava outflows are enriched in HCP (partial melt). Olivine-rich spots are also identified.

Nili Fossae / Nili Patera

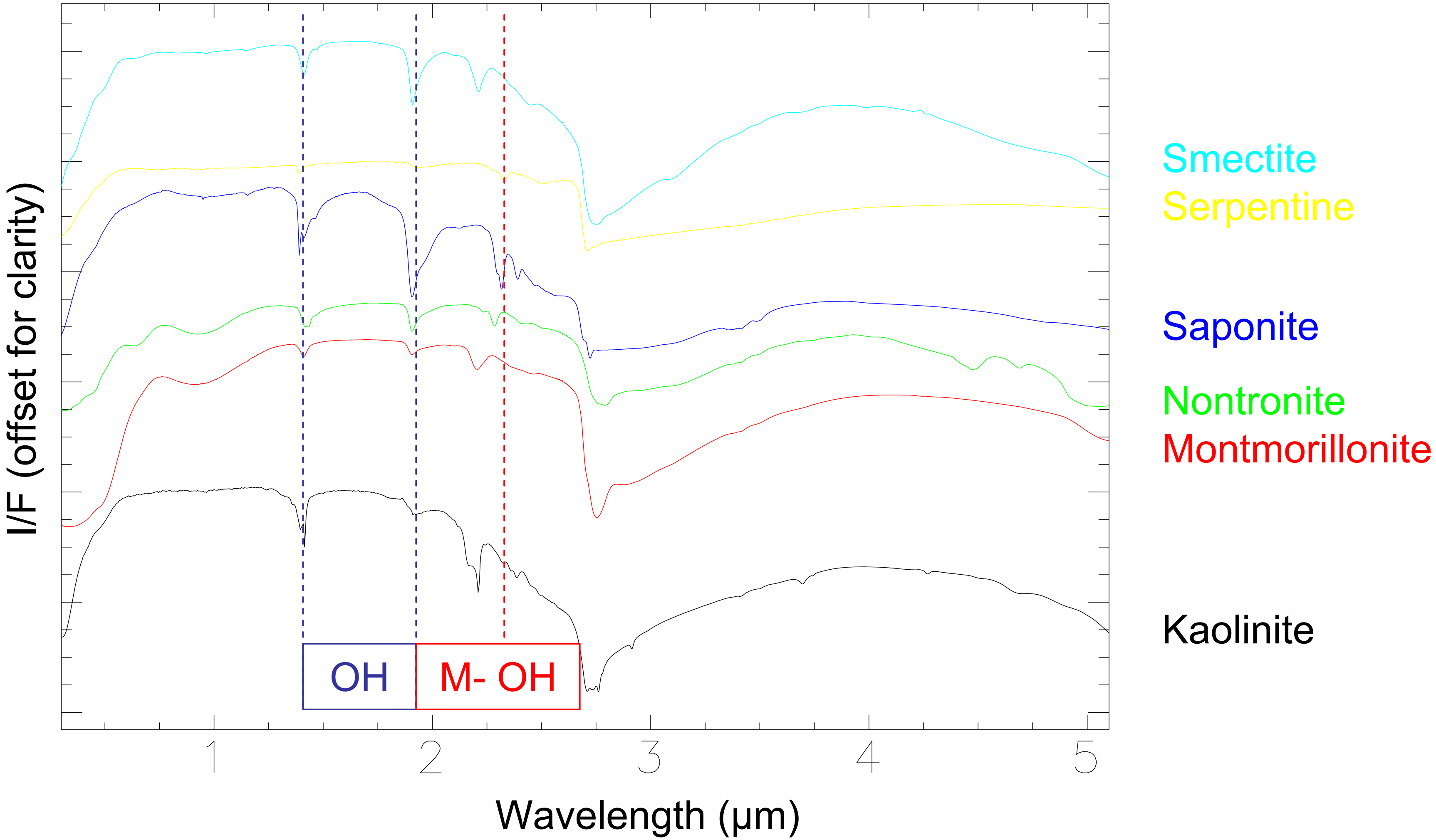
water alteration products: carbonates

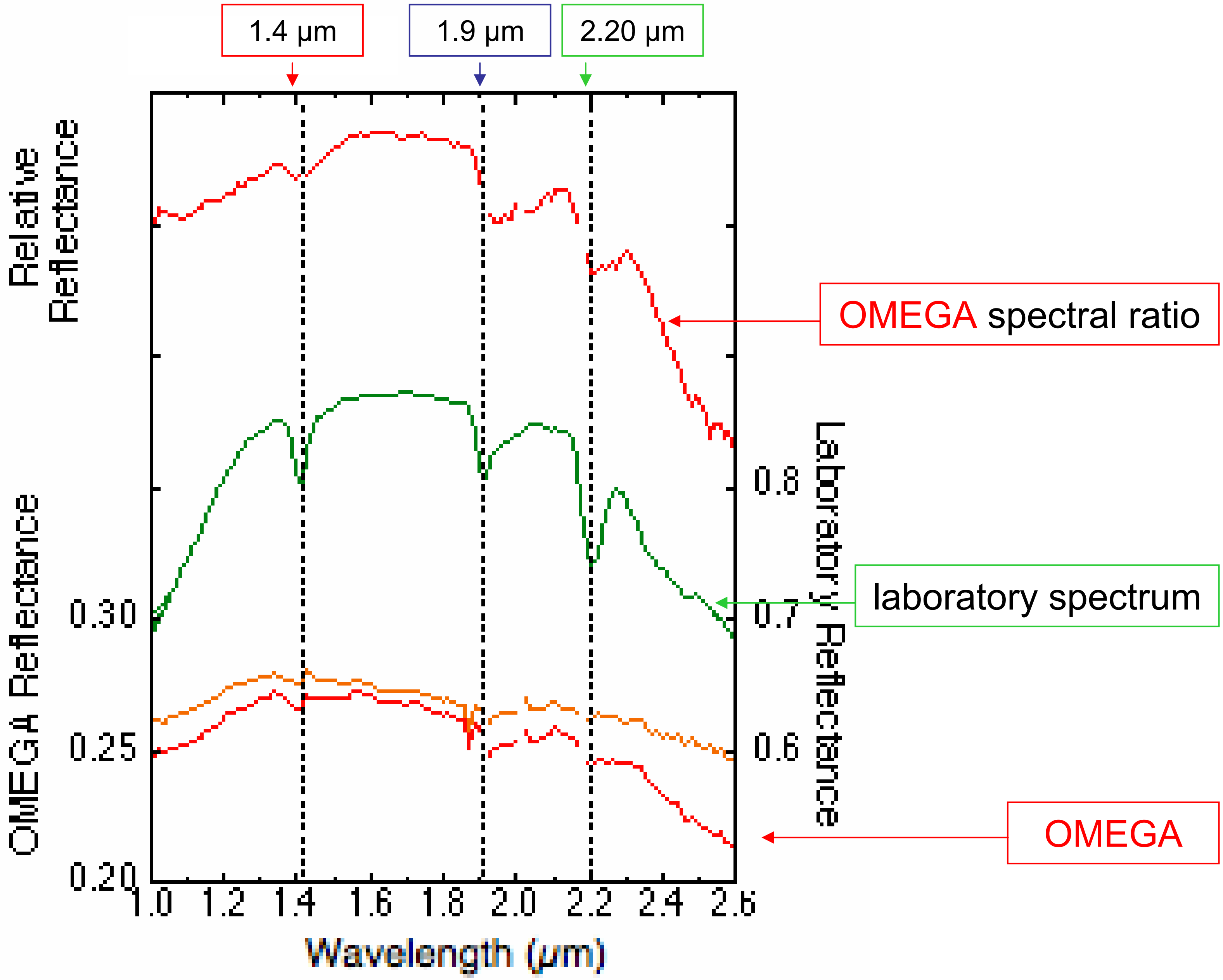


water alteration products: sulfates



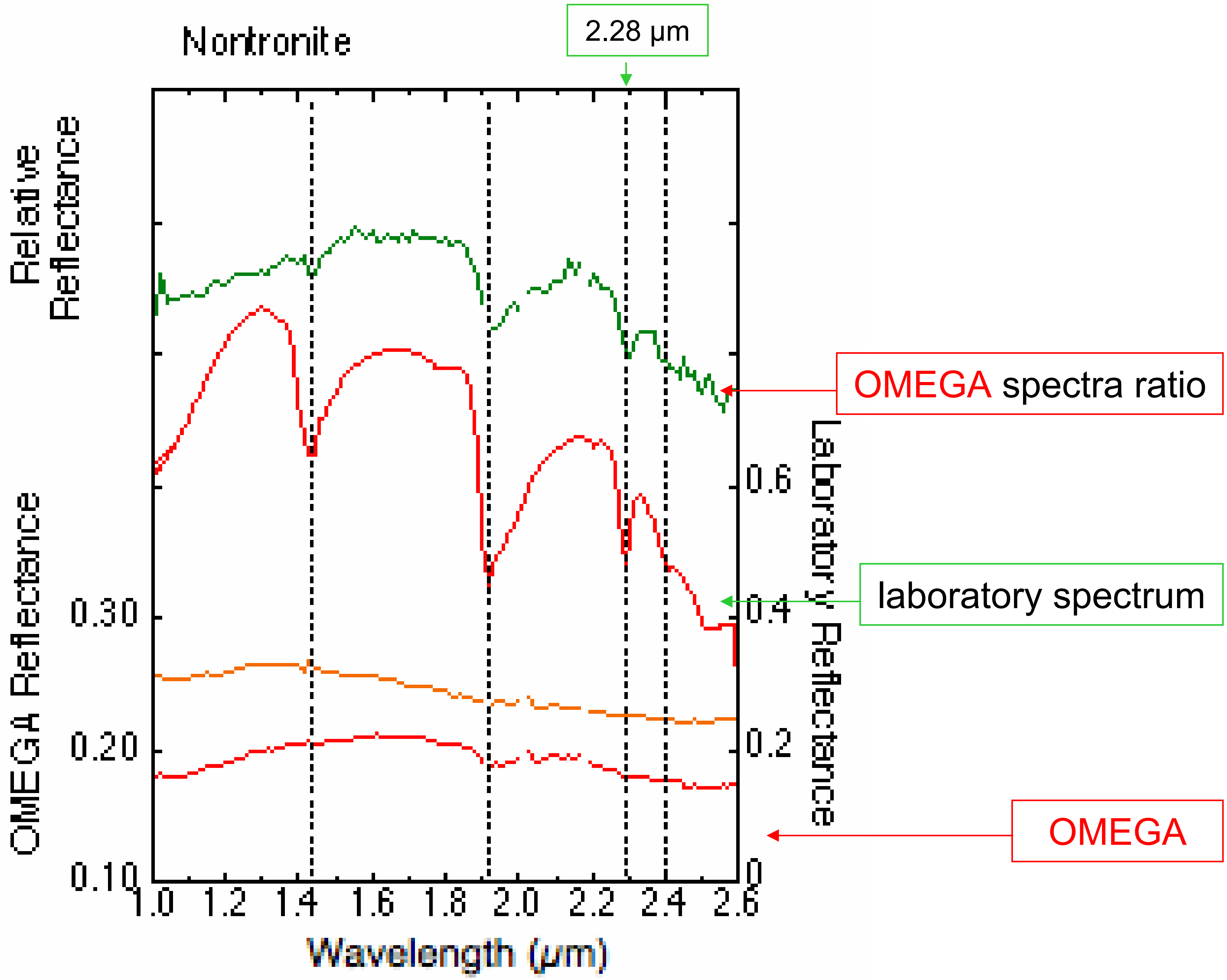
water alteration products: phyllosilicates





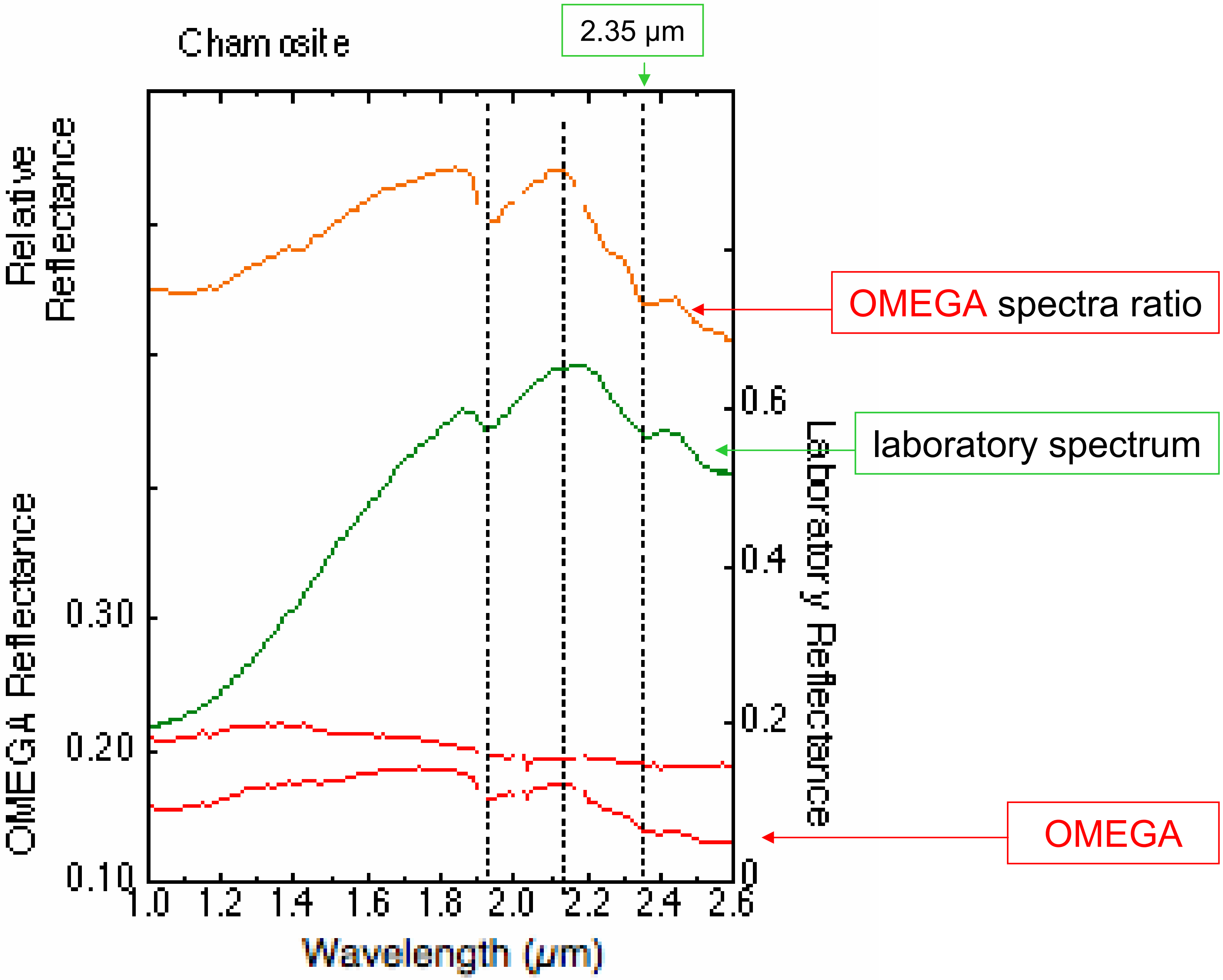
Al-rich phyllosilicate

Mawrth Vallis (20.60° W, 25.53° E)



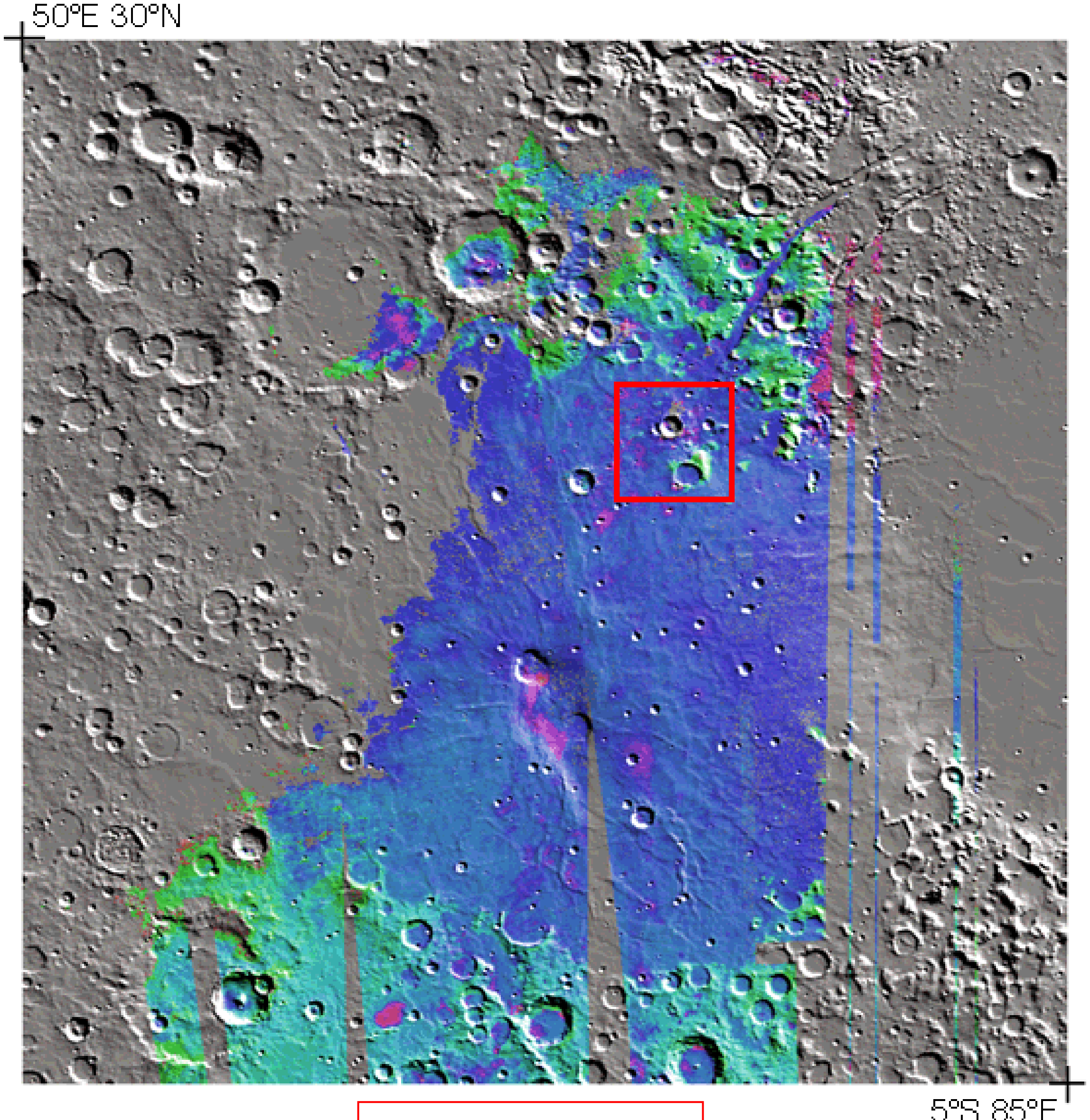
Fe-rich phyllosilicate

Nili Syrtis Mensa (73.32° E, 29.30° N)



Mg/Fe-rich phyllosilicate

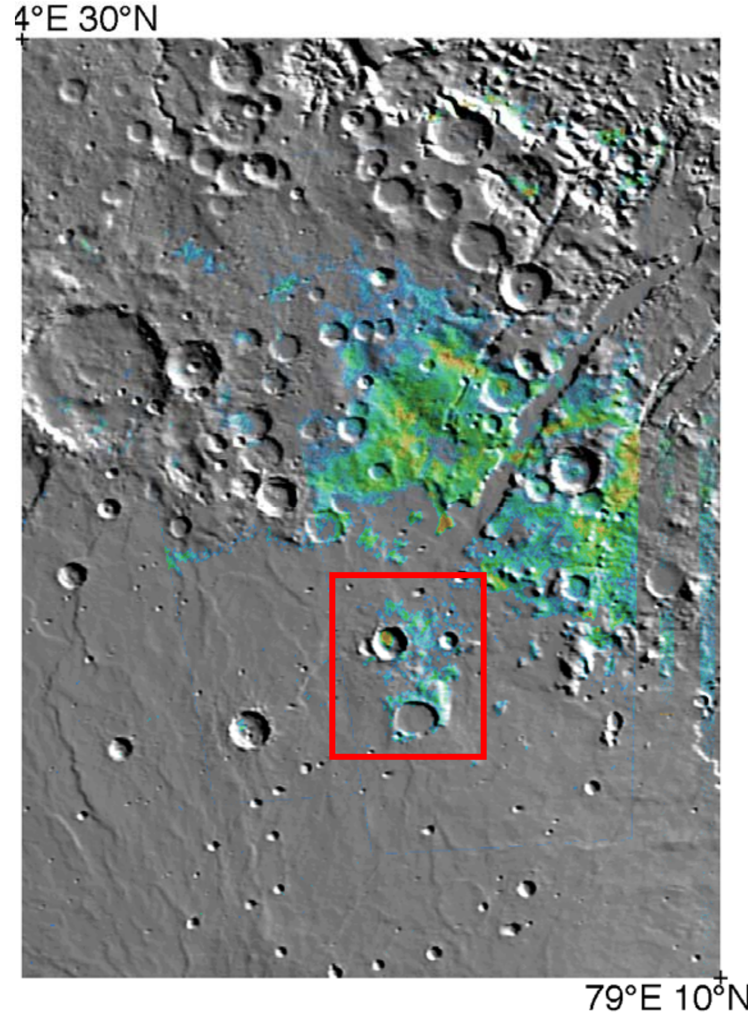
Syrtis Major (71.73° E, 17.09° N)



olivine: red

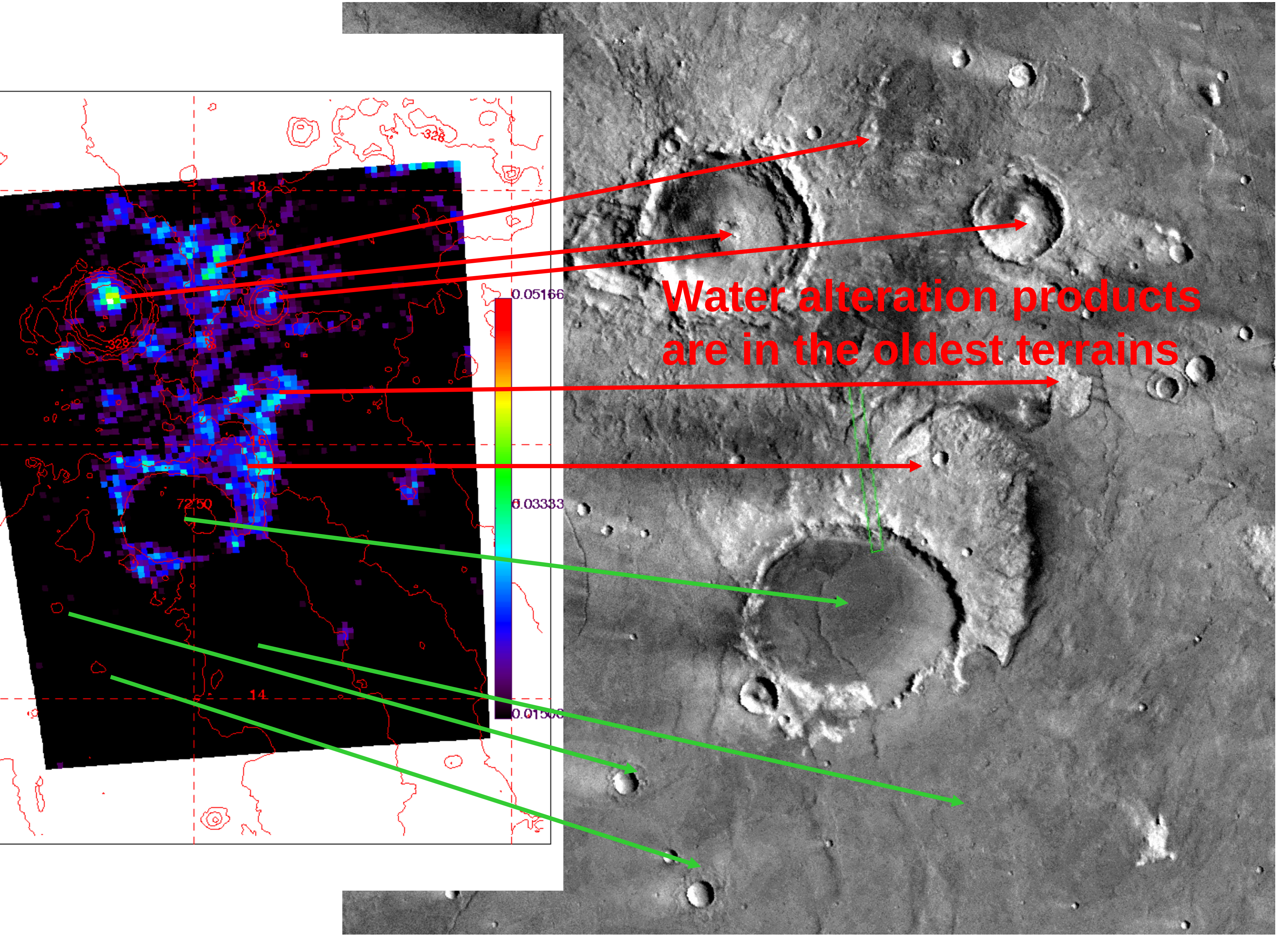
LCP: green

HCP: blue



1.9 μm hydration band intensity

Nili Fossae / Nili Patera



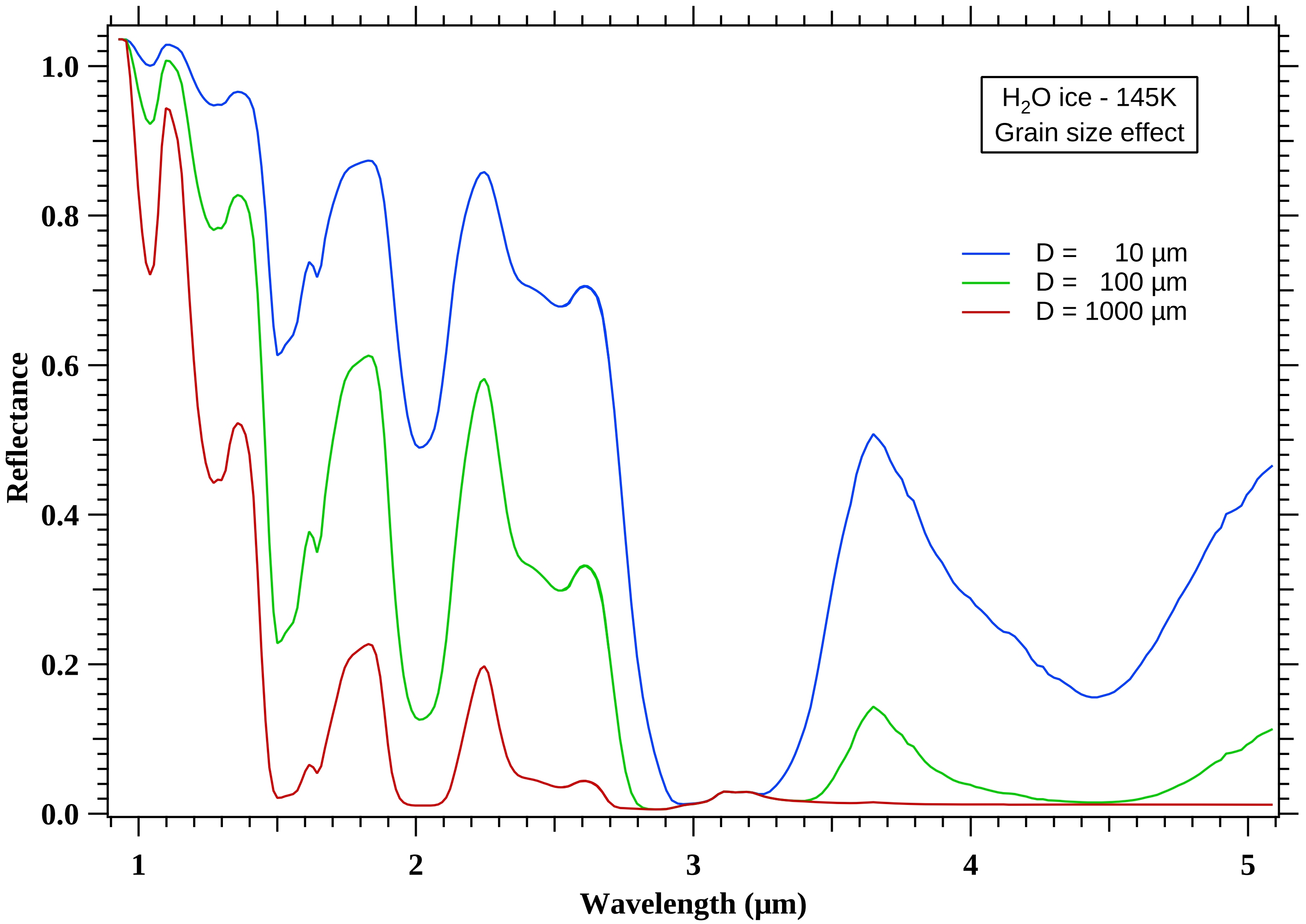
Water alteration products
are in the oldest terrains
0.05166
0.03333
18
16
14
328
72.50

H_2O and CO_2 frosts and ices

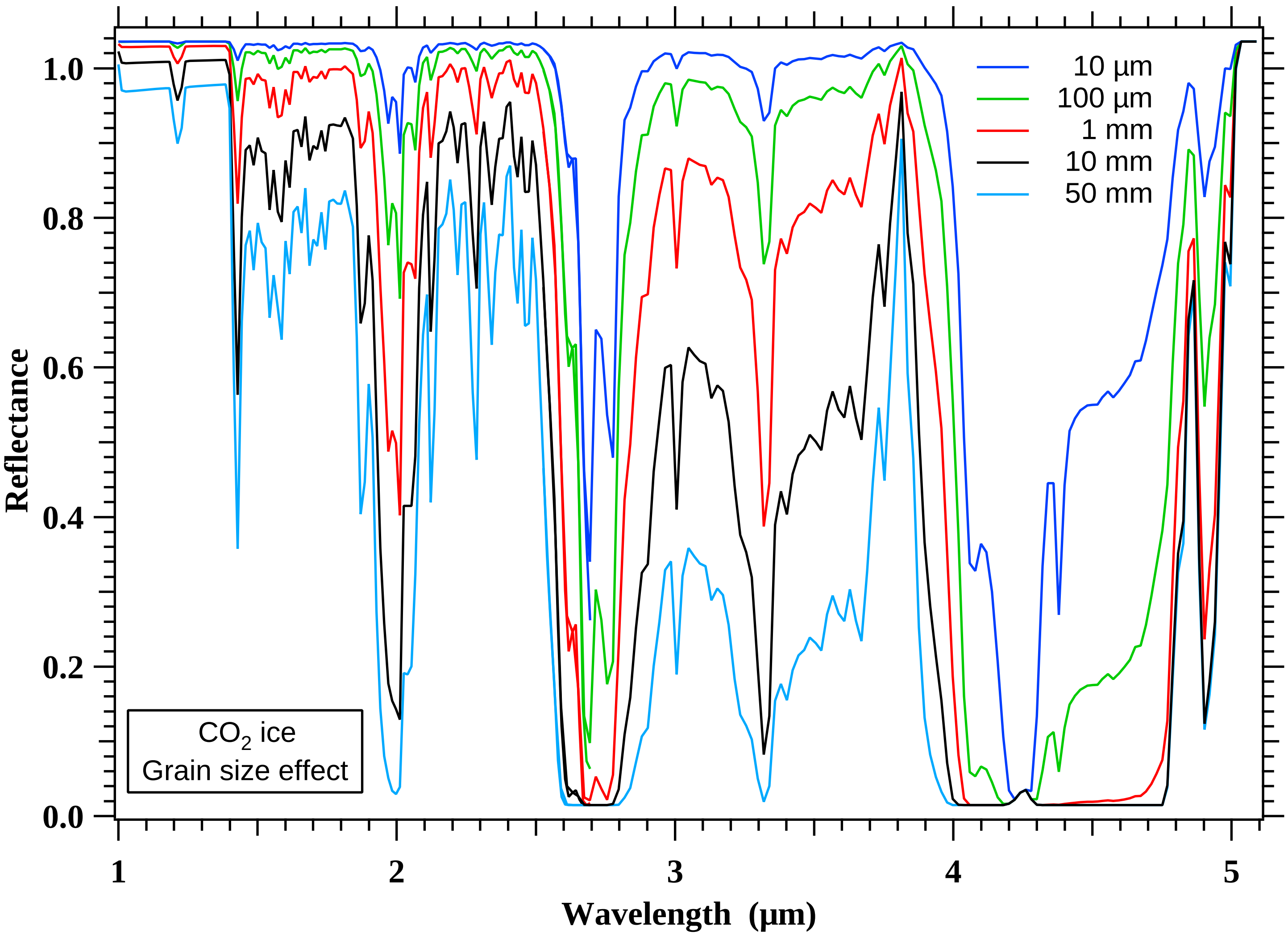
- **perennial and seasonal caps are critical players for the present and past climate of the planet**

- **perennial caps dominate the inventory of Martian H_2O today**

H_2O ice: effect of grain size



CO_2 ice: effect of grain size

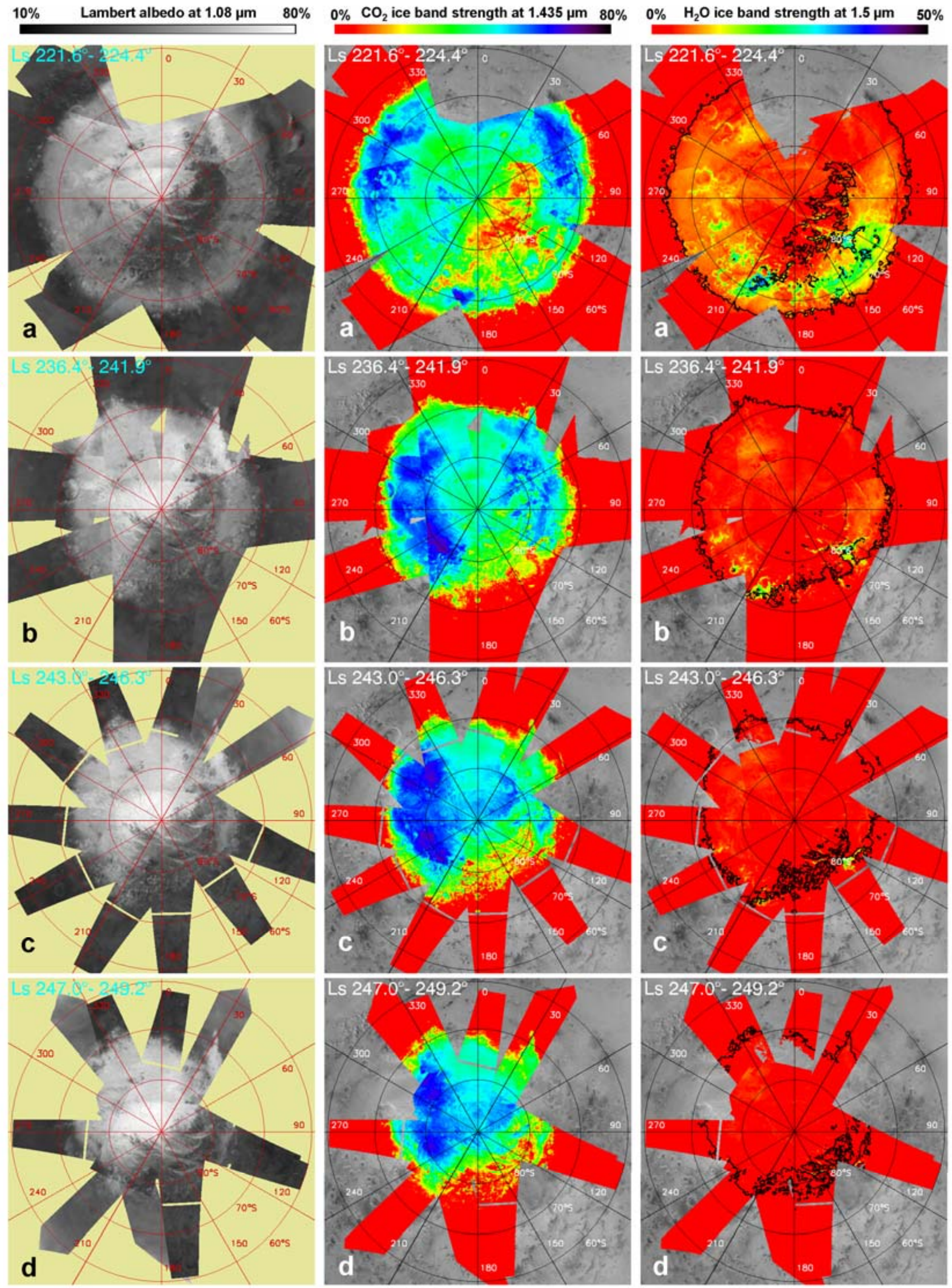


evolution of the southern seasonal cap during retreat from L_s 220° to L_s 250° (mid spring)

Left: albedo in the continuum

Center: CO_2 ice signature

Right: H_2O ice signature



OMEGA : summary

On each pixel, OMEGA has the potential to identify:

- atmospheric constituents: CO_2, CO, H_2O, O_2/O_3, clouds, aerosols
  - ⇒ short timescales evolution (days to months)
- surface frosts: CO_2, H_2O
  - ⇒ short timescales evolution (months to years)
- surface ices: CO_2, H_2O
  - ⇒ medium timescales evolution (10's to 10^4's years)
- surface minerals
  - ⇒ long timescales evolution (10^7's to 10^9's years)