# A new generation of CRISM data products

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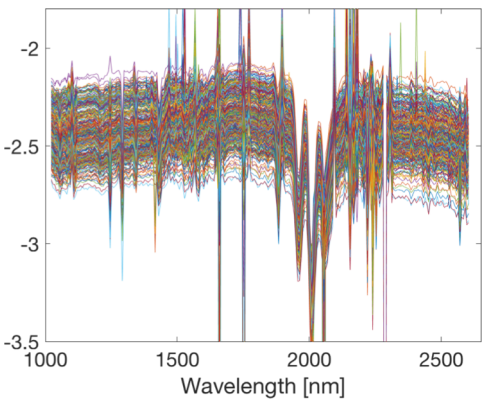
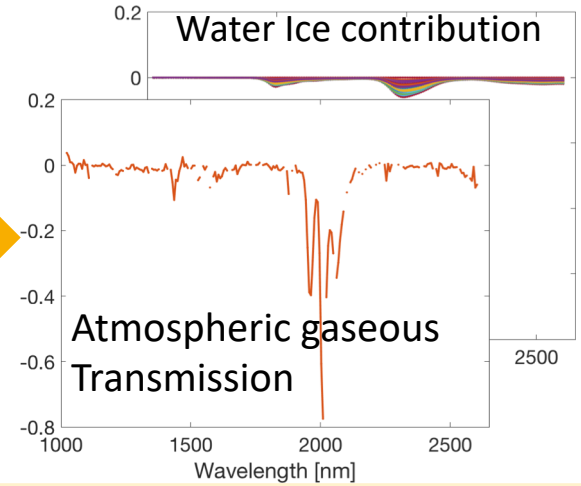
# Improved CRISM data products

- New CRISM targeted (high resolution) images
  - Provide cleaner spectra over the areas within and surrounding the landing site
  - use all the available images, including the ones at elevated noise
  - Methods scalable to processing whole dataset
- New CRISM mineral maps
  - Provide high confidence, pixel-based mineral maps for targets within and around landing site ellipses
  - Overcome limitations of maps based on CRISM parameters (e.g. Viviano-Beck et al. 2014)
  - Avoid need for expert system of rules for detection (e.g. Tetracorder)
  - Avoid detections based on ratioing
- Concentrate on NE Syrtis and Jezero Crater, (very) preliminary analysis for Columbia Hills

# Joint atmospheric compensation and denoising of CRISM (1.0-2.6μm)

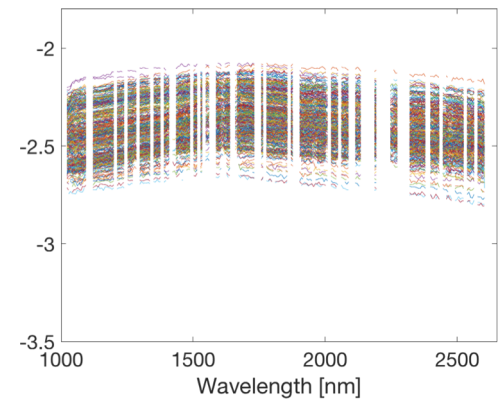
Log of I/F, in one column




+

Surface contribution




## Simultaneously model surface and transmission spectrum with an iterative unmixing-based method

- Beer-Lambert law
- linear mixing model with variable background [Itoh and Parente, 2017 IGARSS] in the logarithmic domain
- Spectral database (CRISM spectral library, CRISM Type spectral library, USGS splib, and RELAB)
- Atmospheric transmission spectra in ADR (Ancillary Data Record).
- Robust formulation of unmixing to take various kinds of noise into consideration
- Detection of spurious noise based on residual
- Absorption efficiency of water ice particles

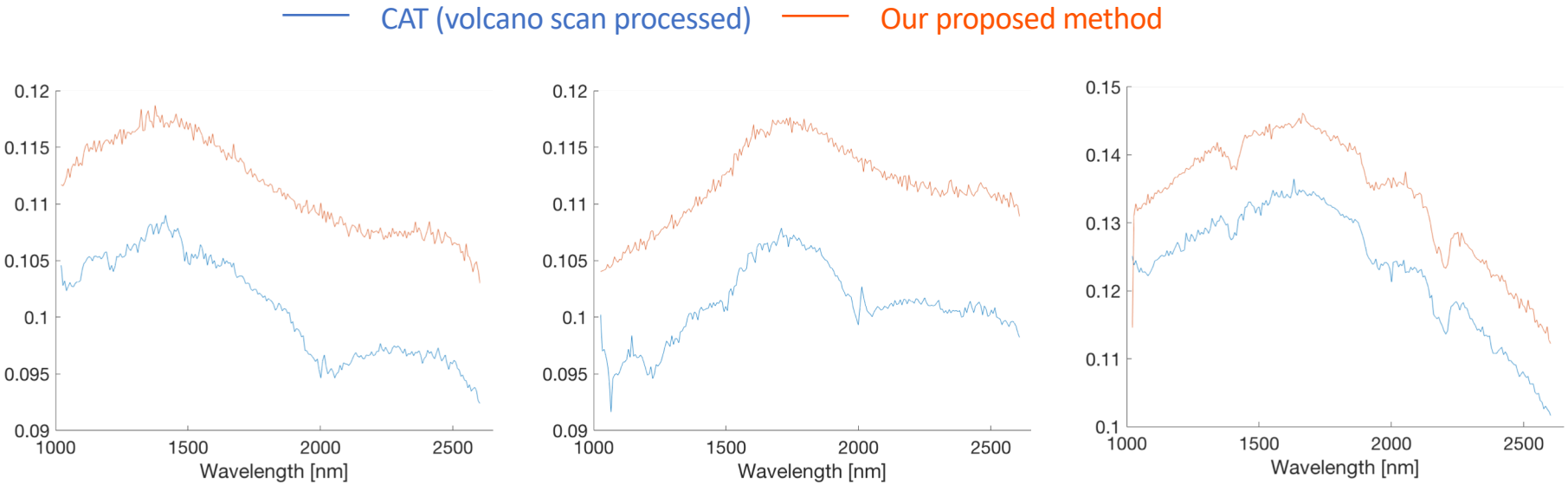
# Joint Atmospheric Compensation and Denoising

- Remove static atmospheric residual and calibration errors
- Remove water ice aerosol, if present
- Remove different kinds of spurious noise
- Work on pixel-by-pixel basis (no-spatial smoothing)
- Work on high IR detector temperature images
- Output will almost look like ratioed spectra

# Validation

- Visual check by expert assessment
  - Internal
  - Several other groups involved
- Comparison with CAT processed I/F (w/ or w/o filtering) and TER I/F spectra
- Examining with spatial neighbors for spatial consistency
- Examining the spectra at the same location in different images

# Comparison with Volcano Scan method



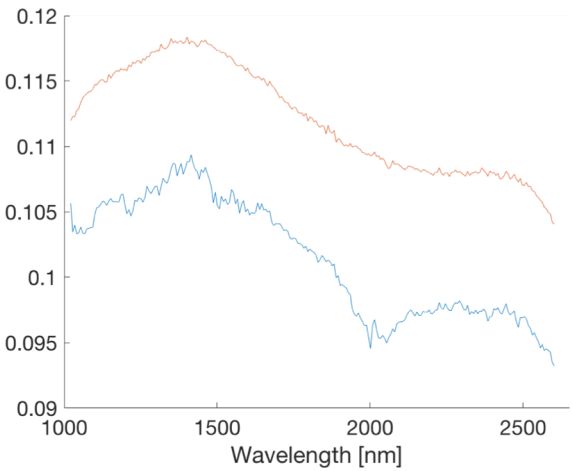

FRT0000ABCB (IR detector temperature 116K)

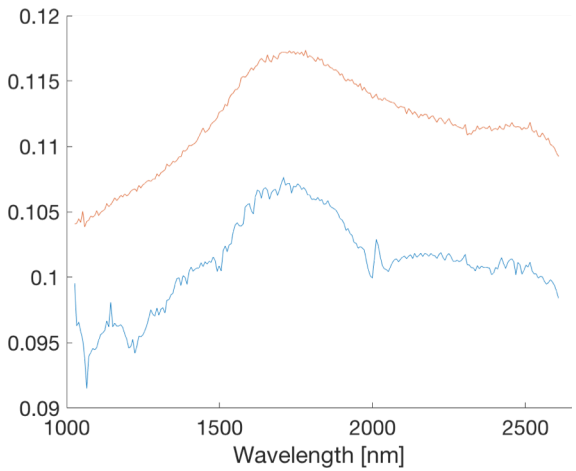
Our method shows more Gaussian noise because no spatial filtering is applied unlike TRR3 I/F.

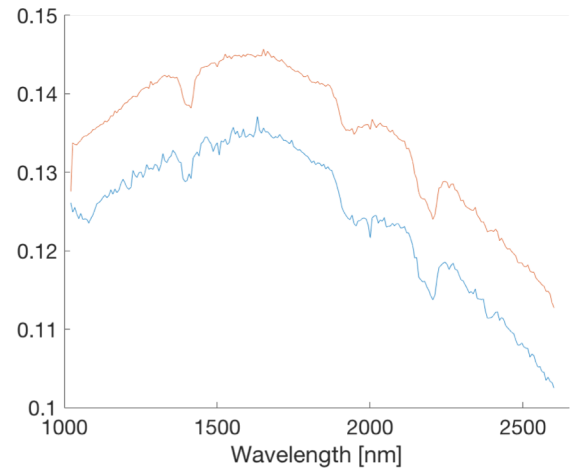
# Comparison with Volcano Scan method

Since the static errors are removed, averaging directly improve the signal quality.

CAT (volcano scan processed) Our proposed method



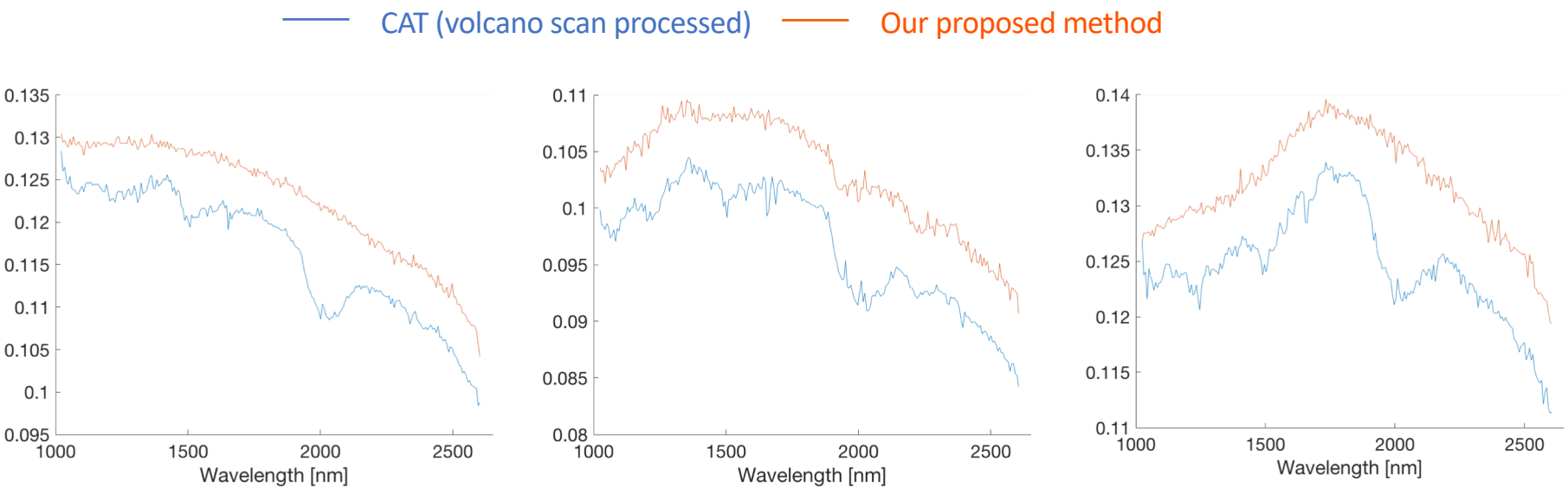




3x3 average

FRT0000ABCB (IR detector temperature 116K)

# Comparison with Volcano Scan method



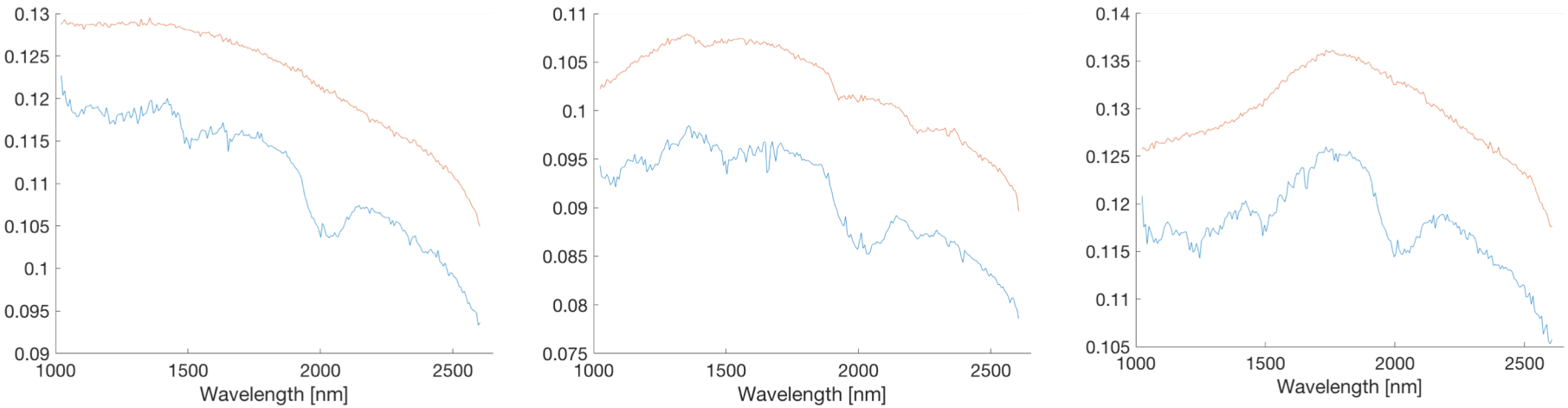

FRT0000B573 (IR detector temperature 121K)

Our method shows more Gaussian noise because no spatial filtering is applied unlike TRR3 I/F.

# Comparison with Volcano Scan method

Since the static errors are removed, averaging directly improve the signal quality.

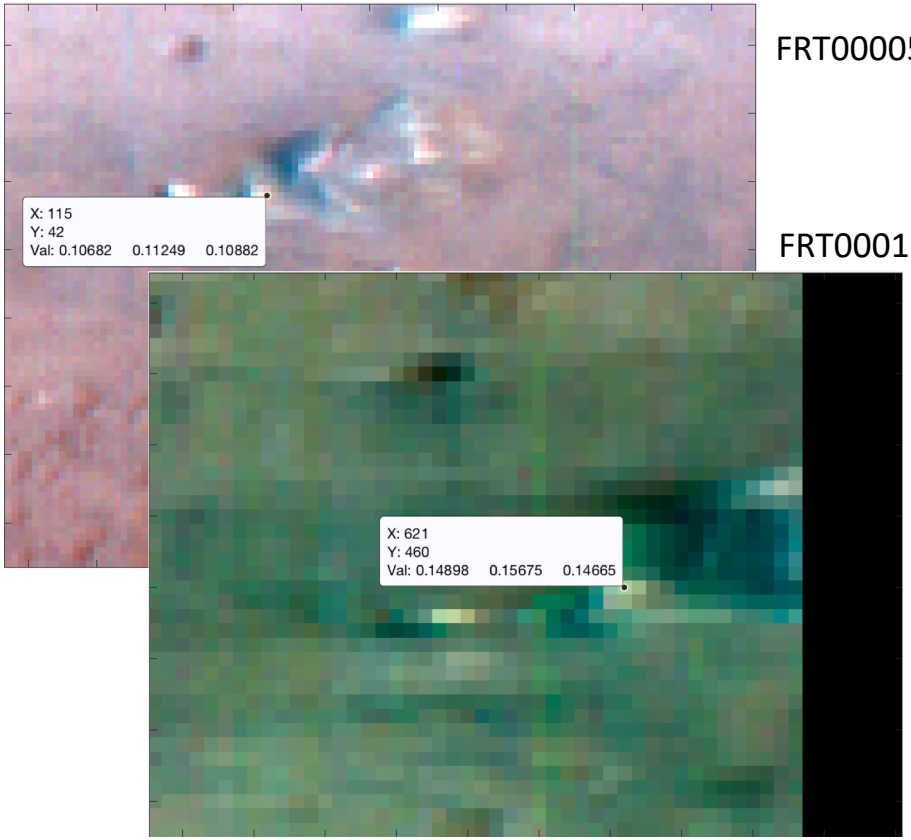
CAT (volcano scan processed) Our proposed method




3x3 average

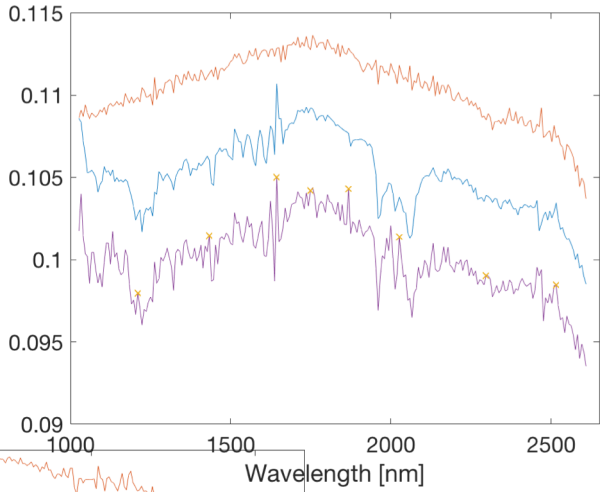
FRT0000B573 (IR detector temperature 121K)

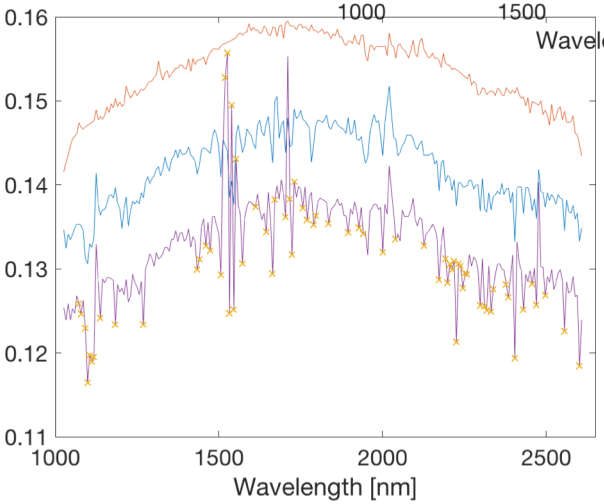
# Inter image comparison (Jezero crater)




FRT00005C5E (111.4K)

FRT0001EAE0 (131K)



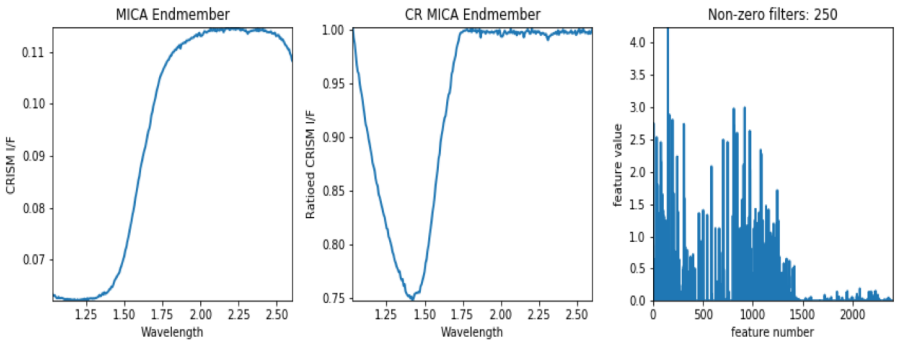

Our proposed method

CAT (volcano scan processed)

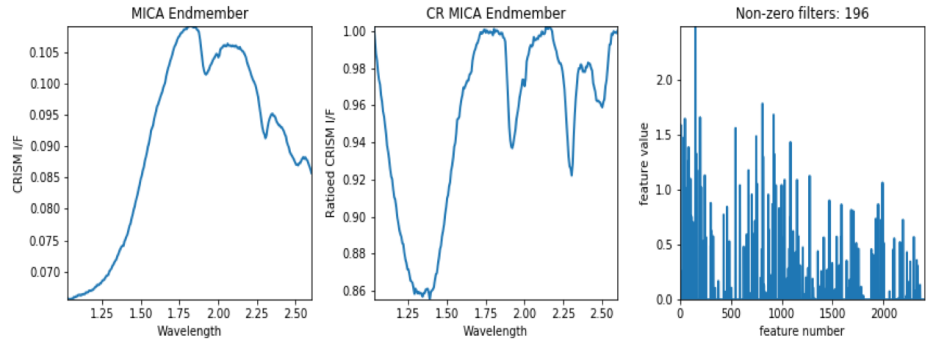
# Mineral mapping

- Use deep learning (GAN) to build a feature vector for each spectrum and for prototype spectra of different mineral classes
- Compute similarity score between feature vectors of CRISM and prototype spectra
- Two maps:
  - **Detection Maps:** pixels with very high similarity (>0.9) to prototype.
  - **Best Guess Maps:** pixels with high similarity (>0.707) but there might be some confusion between similar endmembers
- Can map any know spectrum
- Detected spectra are pixel spectra. Extent of a detected class can be as small as one pixel

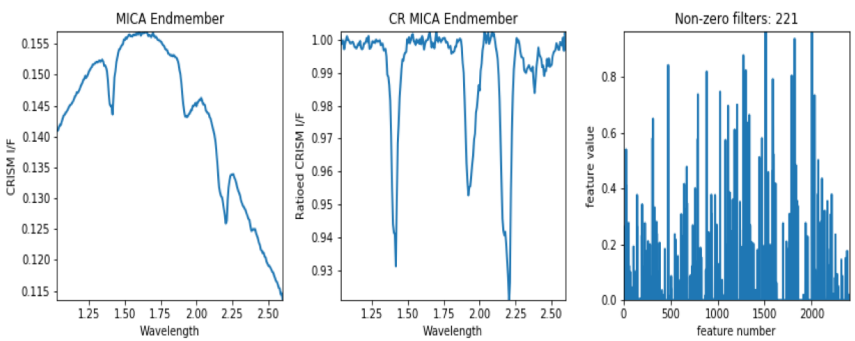
# GAN feature vectors



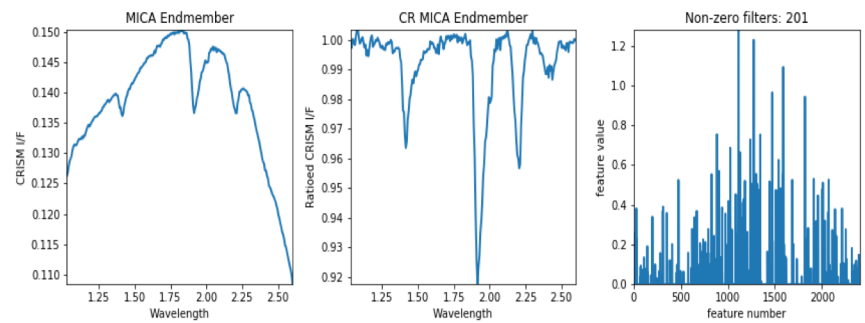

**Olivine**




**Mg-Carbonate**




**Kaolinite**




**Al-Smectite**

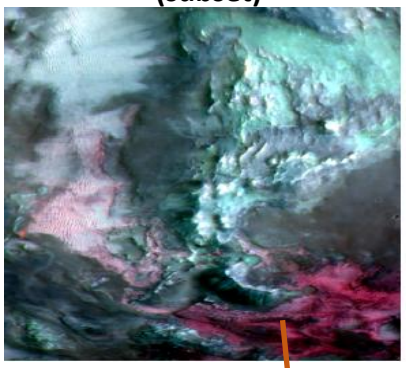
***Even Minerals with similar spectral shapes have very different feature vectors.***

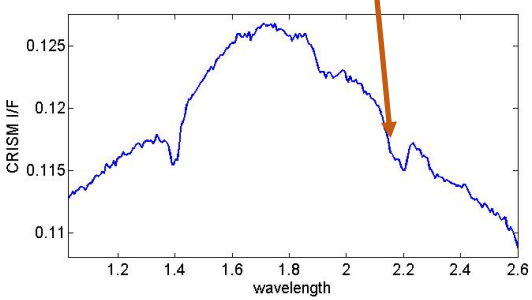
# Validation

- Visual check by expert assessment
  - Internal
  - Several other groups involved
- Comparison with parameter maps
- Comparison with other methods (focus group at AGU, LPSC)

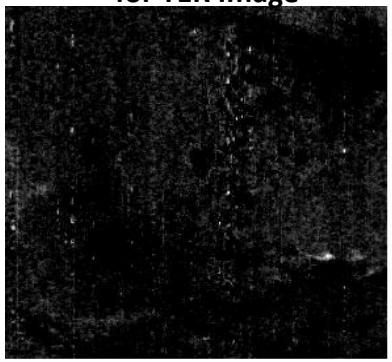
# Comparison with Parameter maps

**RGB Composite Of 97E2 (subset)**





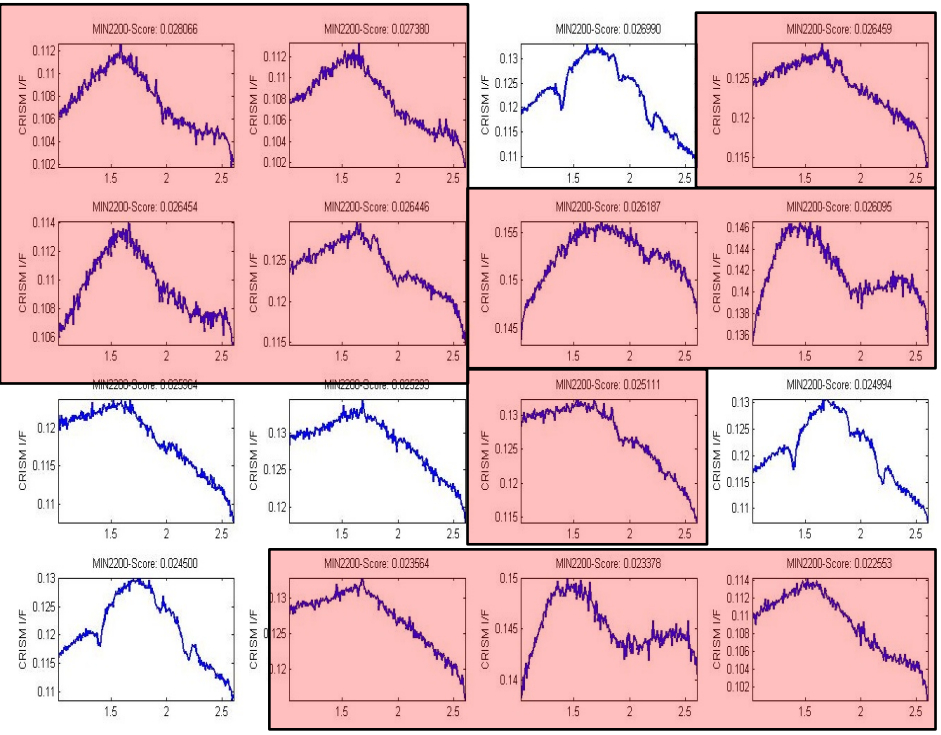

**MIN 2200 Parameter Map for TER Image**



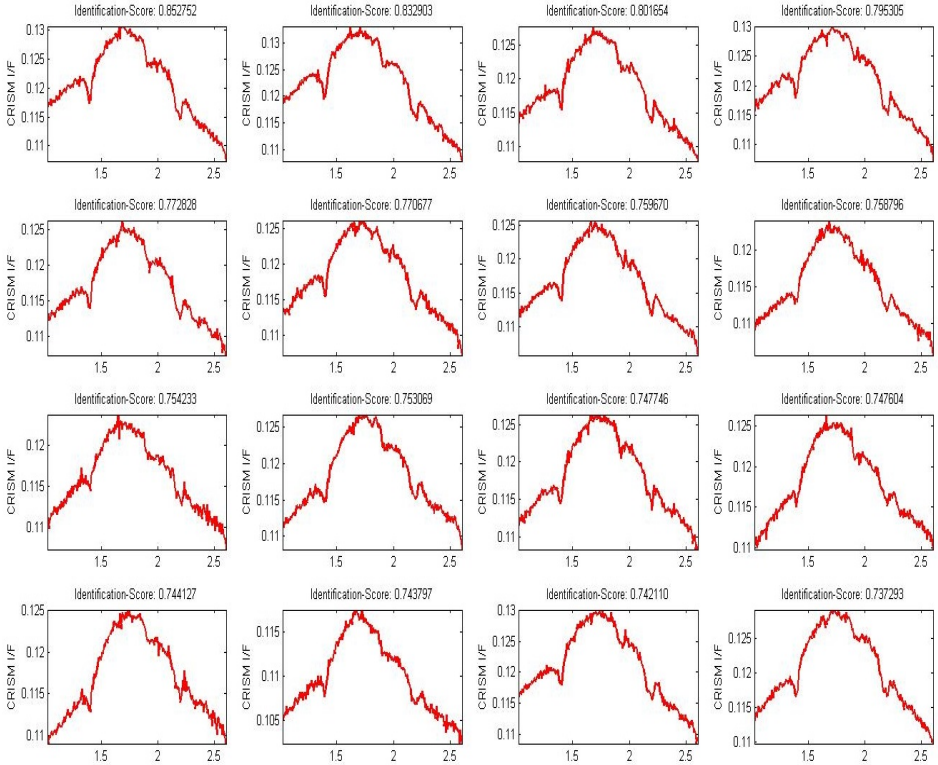
**Identification Map using the GAN Pipeline**

# Comparison with Parameter maps

**Spectra with highest MIN 2200 (TER)**




**Spectra with highest similarity (our method)**



# Spectra used for detection

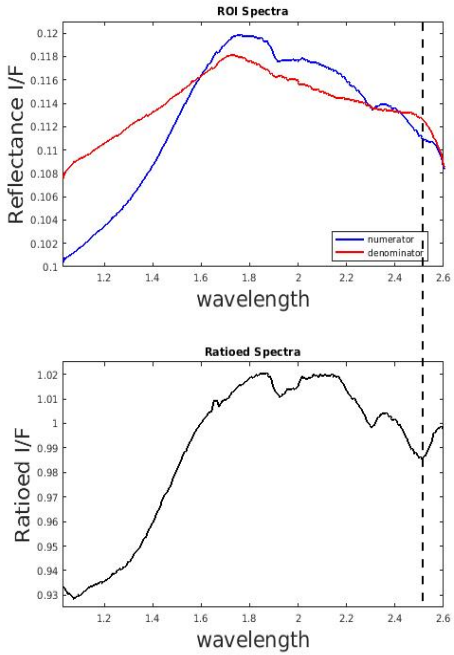
- We limited validation to MICA library spectra (numerators, not ratios)
  - We ignore detections where mineral bands are only evident after ratios
- Many others (USGS, RELAB) processed but not validated

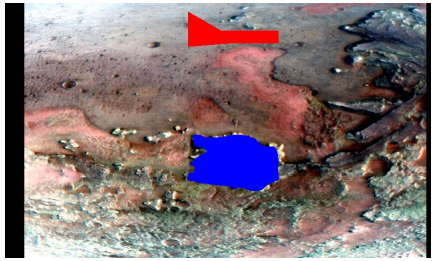
| | | | | | |
|---|---|---|---|---|---|
| Mg-Olivine | Fe-Olivine | Mg-Carbonate | Low-Ca Pyroxene | Monohydrated Sulfate | Alunite |
| Jarosite | Gypsum | Kaolinite | Al-Smectite | Fe/Mg-Smectite | Prehnite |
| Hydrated-Silica | Poly-hydrated Sulfate | Illite | Talc | Serpentine | Epidote |
| Analcime | Hydroxylated Fe-Sulfate | High-Ca Pyroxene | Bassanite | Margarite | Hematite |
| Ca/Fe-Carbonate | Chloride | $H_20$ Ice | $CO_2$ Ice | | |

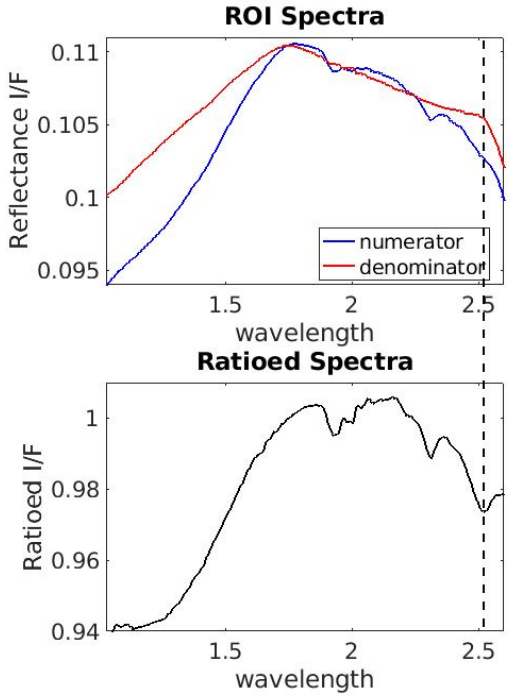
Key: In Use, Not Suitable, Future Use

# Denominator induced bands

- In some cases the ratio seems to induce shapes that are either not present/very weak in the numerator spectra.



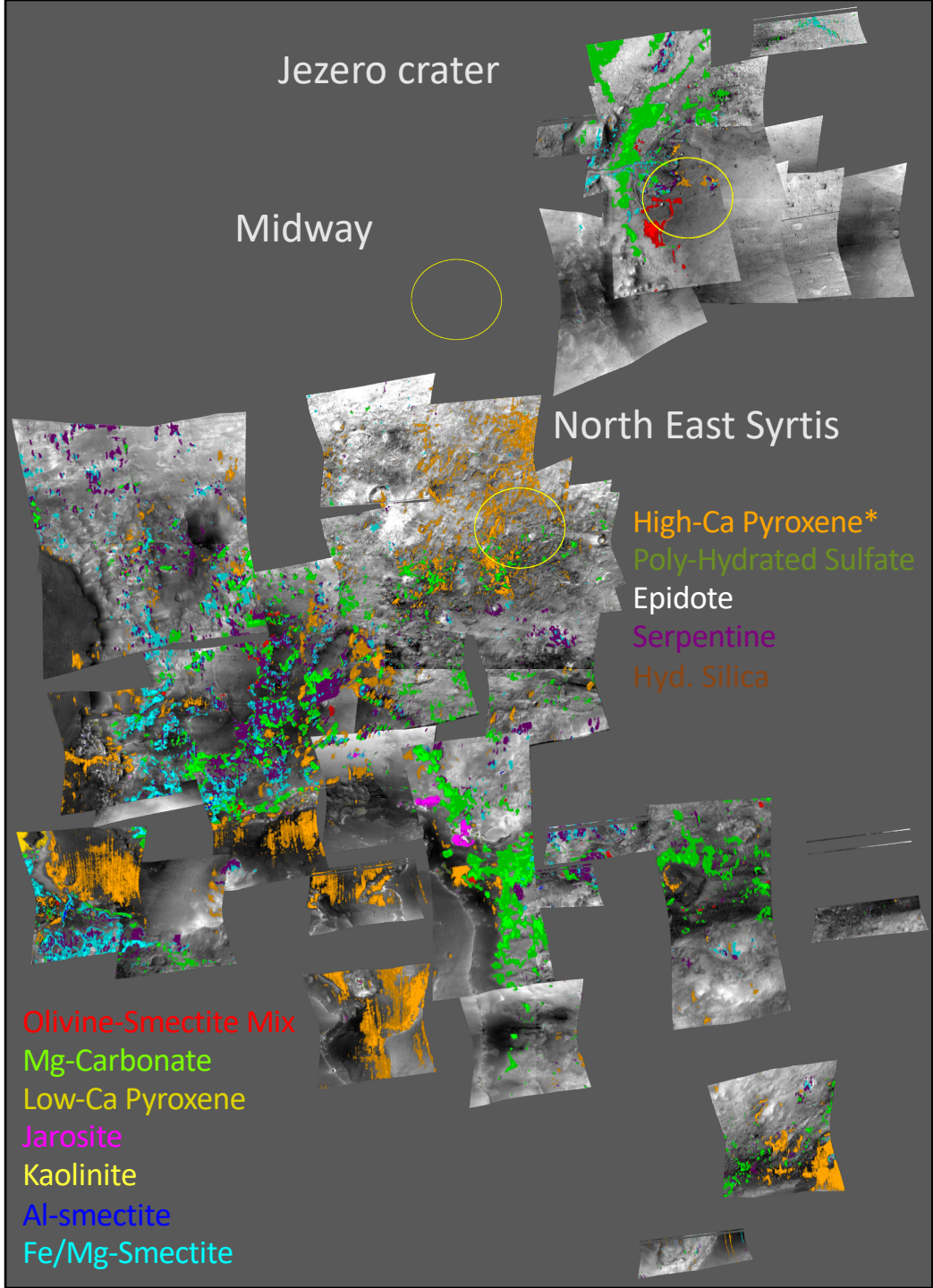





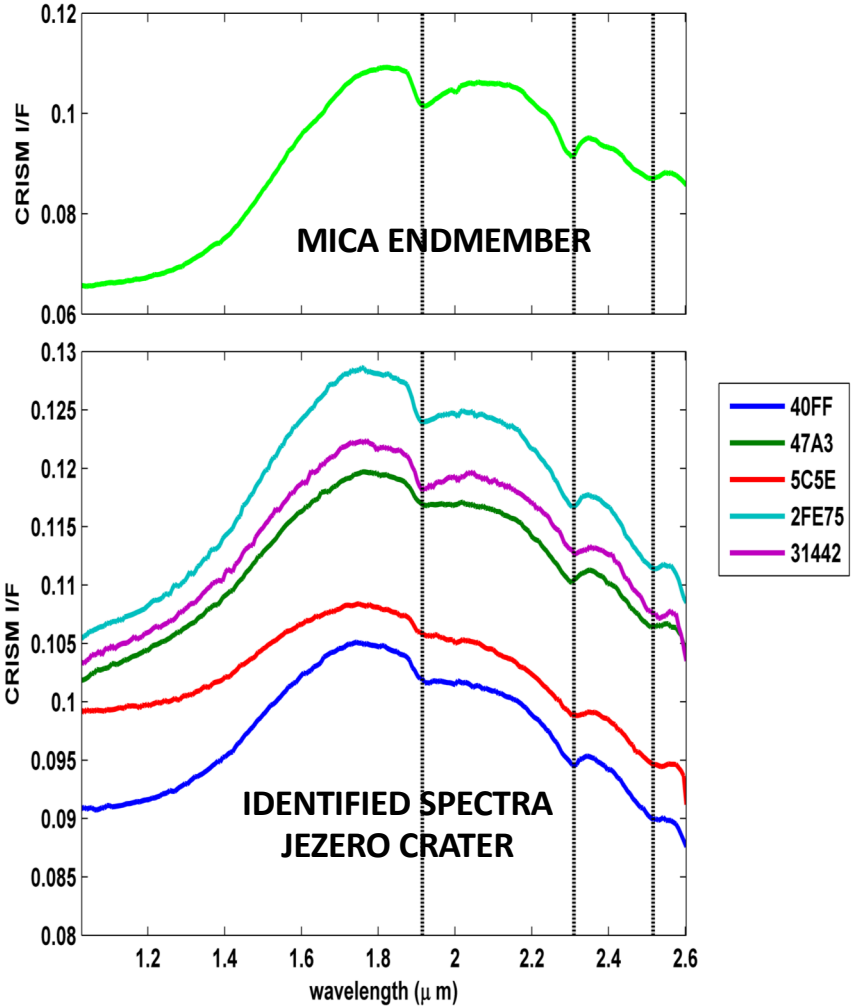
# Detection and best guess maps

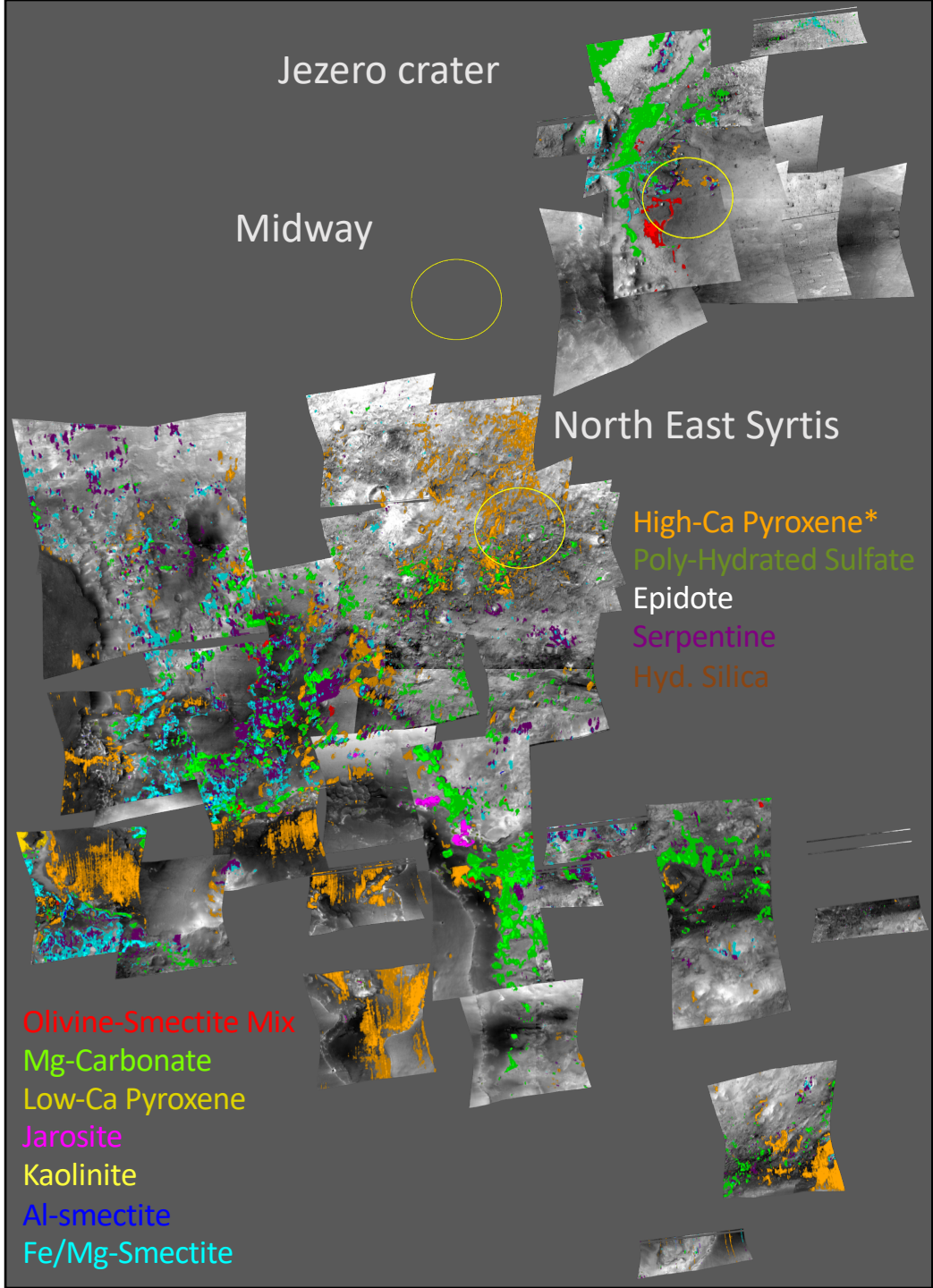
# NE Syrtis and Jezero crater

# Detections

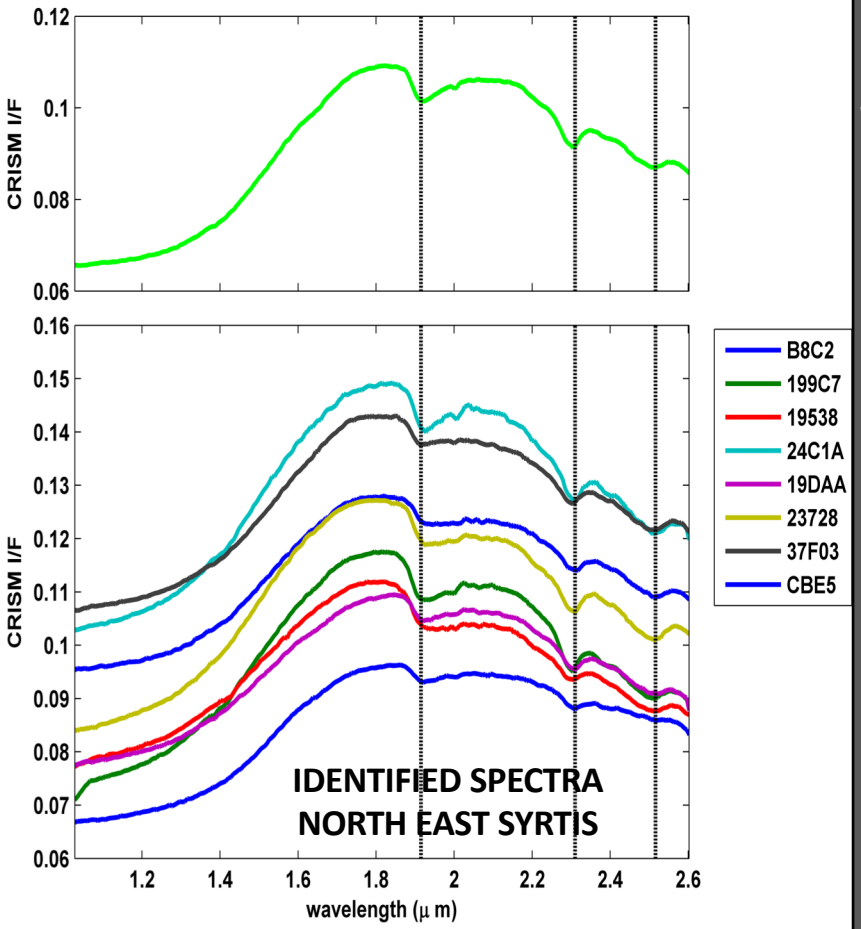

Jezero crater
Midway
North East Syrtis
High-Ca Pyroxene*
Poly-Hydrated Sulfate
Epidote
Serpentine
Hyd. Silica
Olivine-Smectite Mix
Mg-Carbonate
Low-Ca Pyroxene
Jarosite
Kaolinite
Al-smectite
Fe/Mg-Smectite

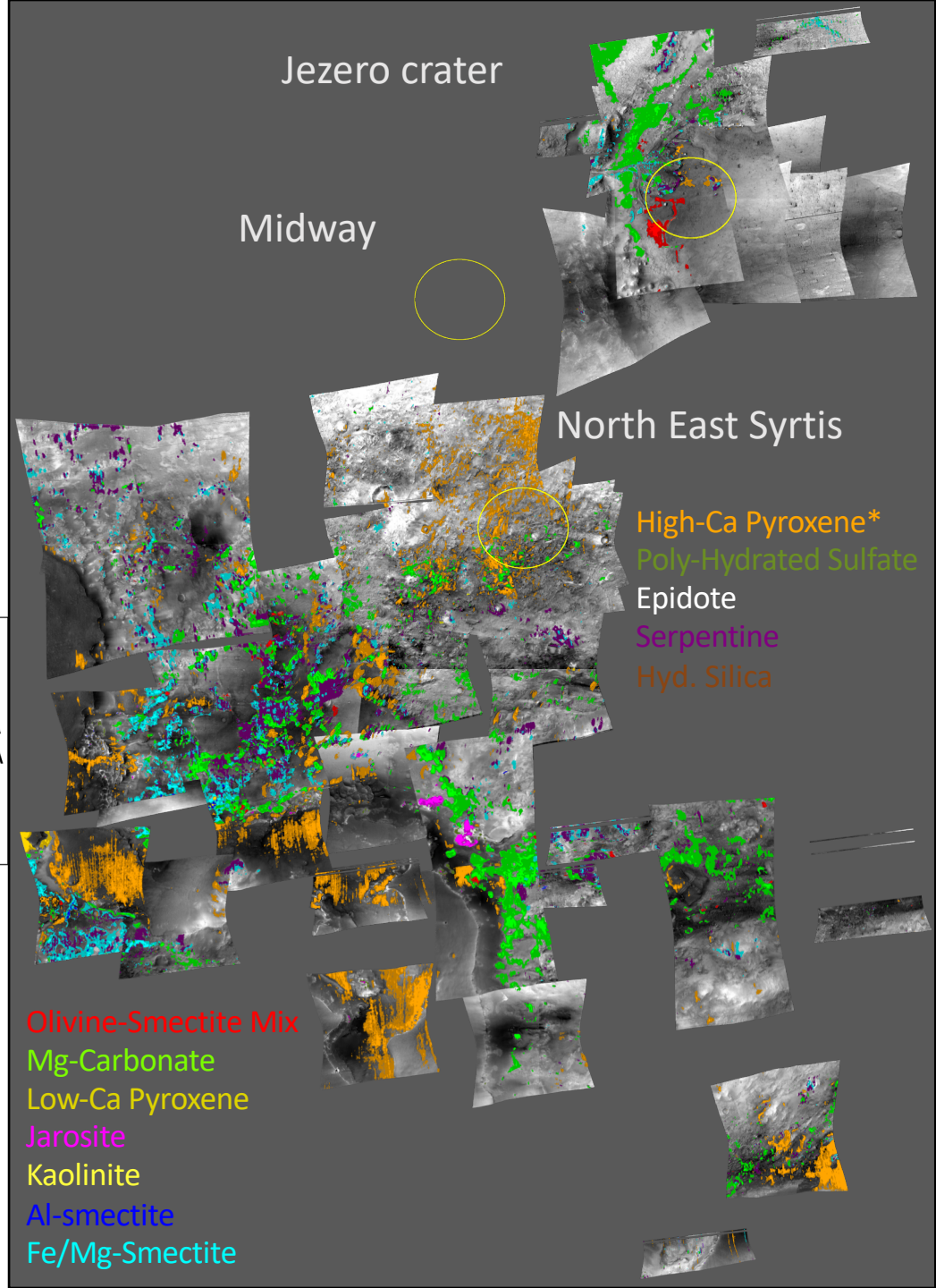
# Mg-Carbonate



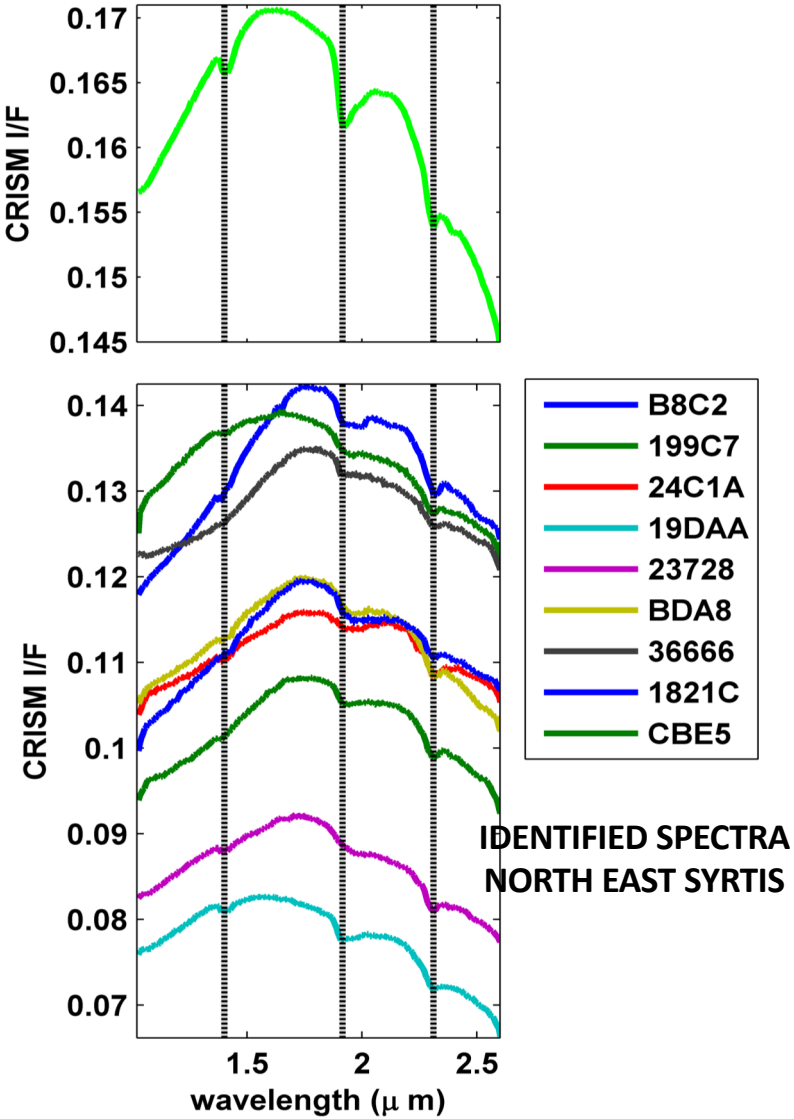



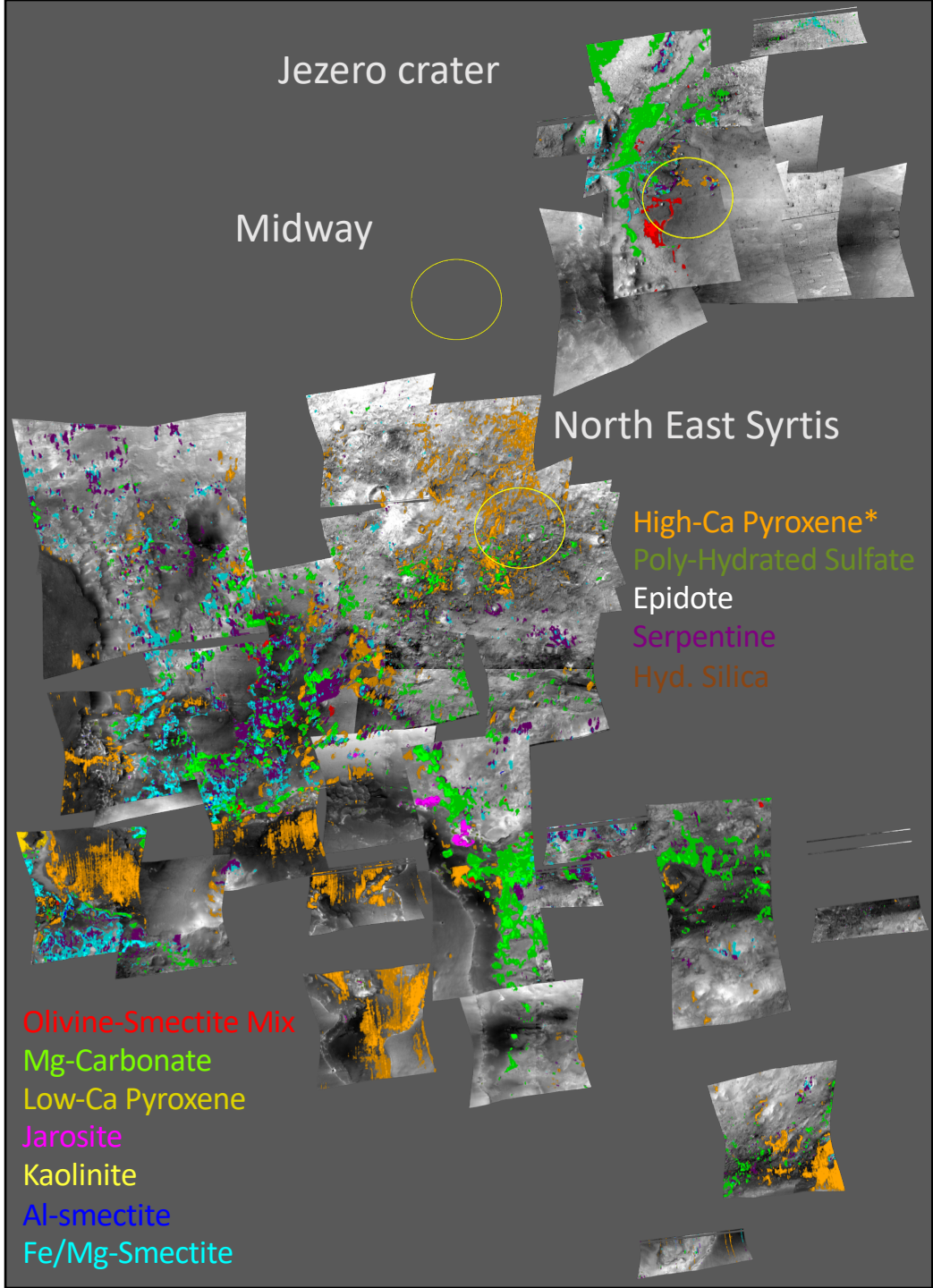
# Mg-Carbonate



# Fe/Mg-smectite



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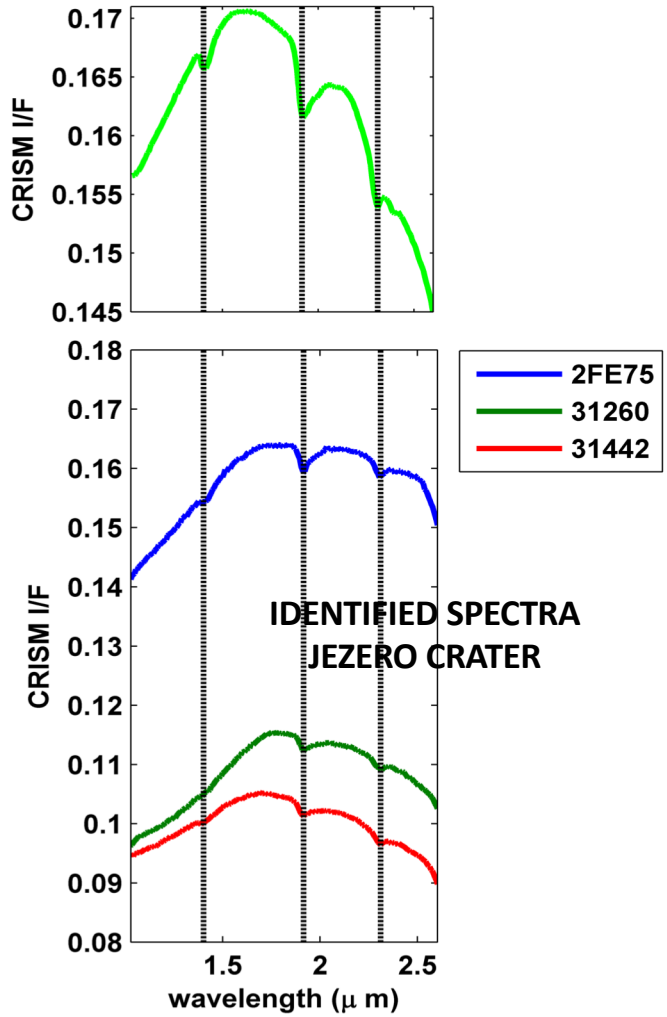
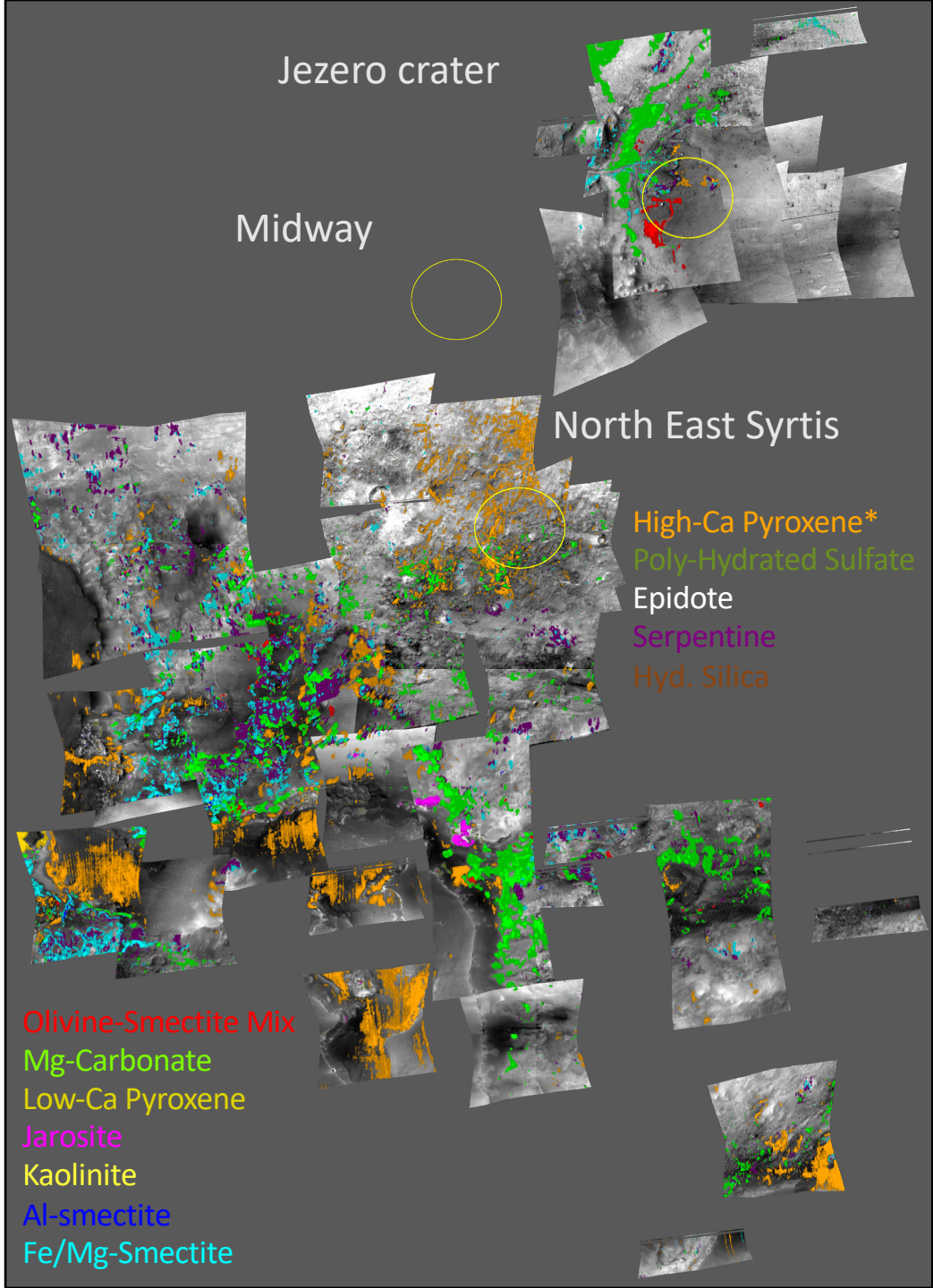
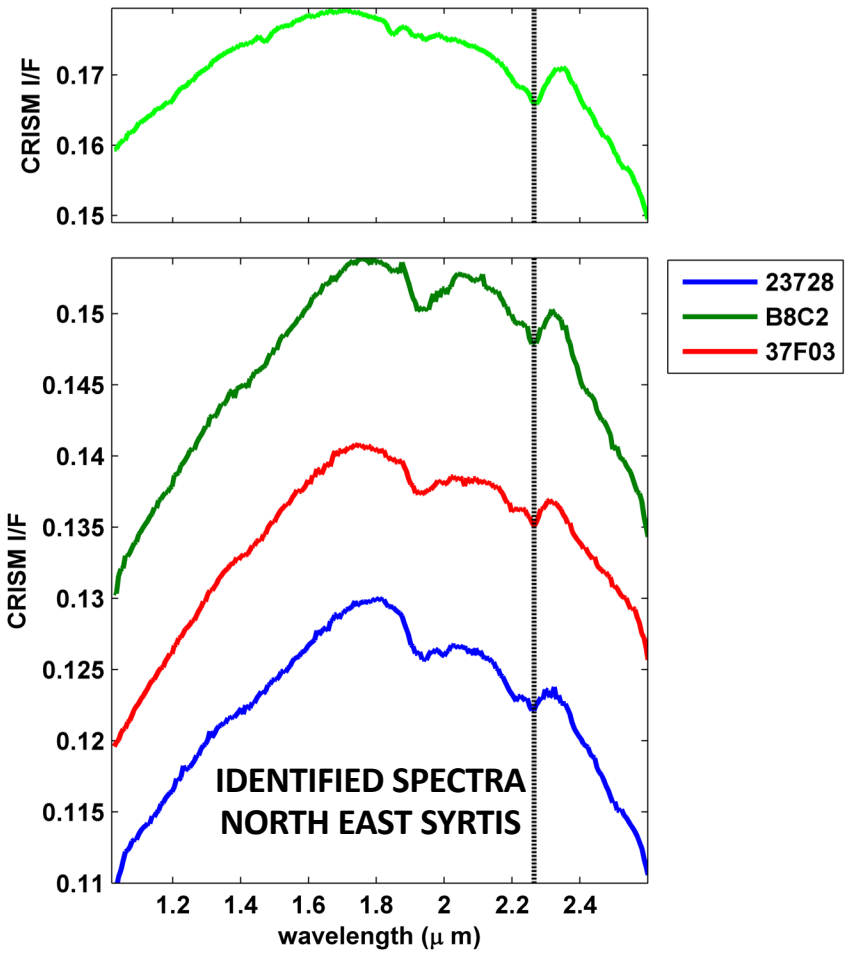
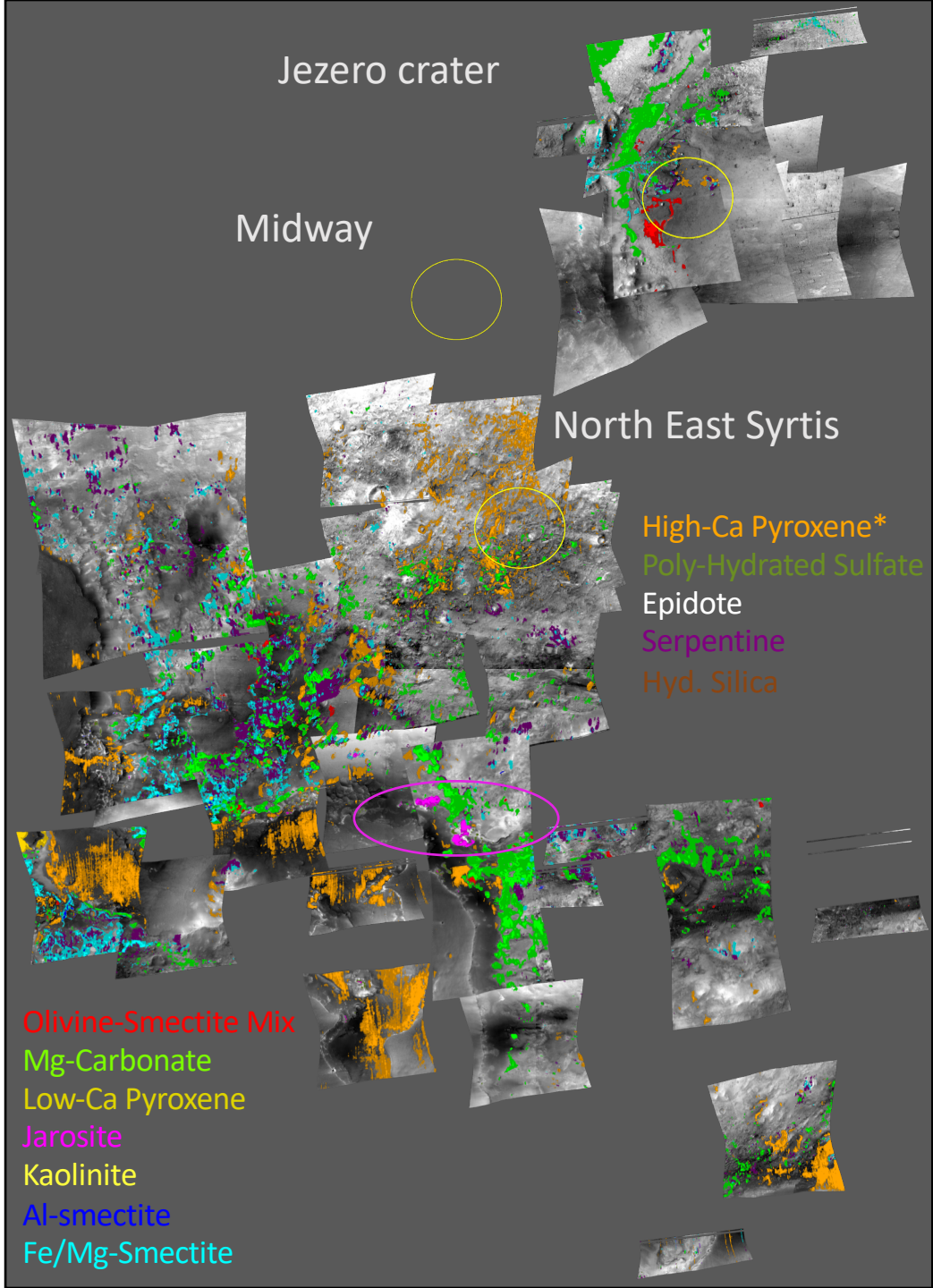


# Jarosite


CRISM I/F
0.17
0.16
0.15
CRISM I/F
0.15
0.145
0.14
0.135
0.13
0.125
0.12
0.115
0.11
1.2
1.4
1.6
1.8
2
2.2
2.4
wavelength (μ m)
23728
B8C2
37F03
IDENTIFIED SPECTRA
NORTH EAST SYRTIS


Jezero crater
Midway
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High-Ca Pyroxene*
Poly-Hydrated Sulfate
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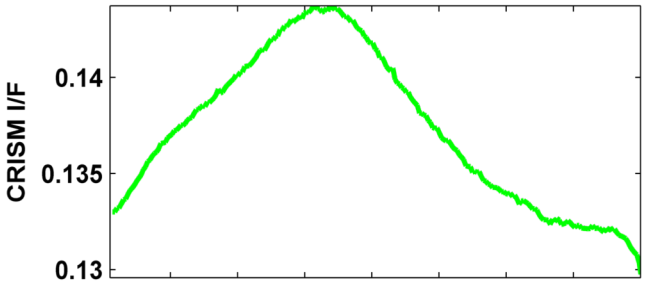
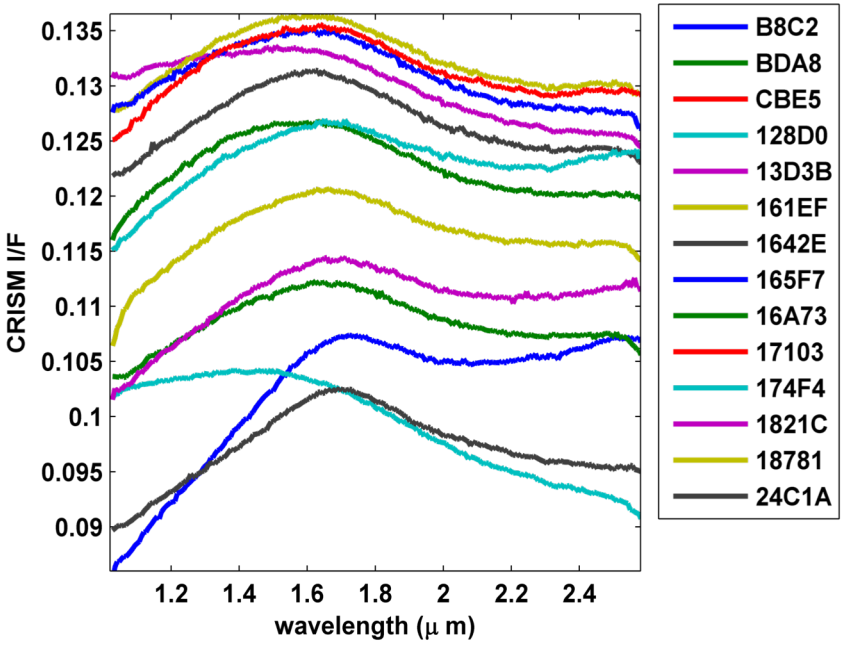
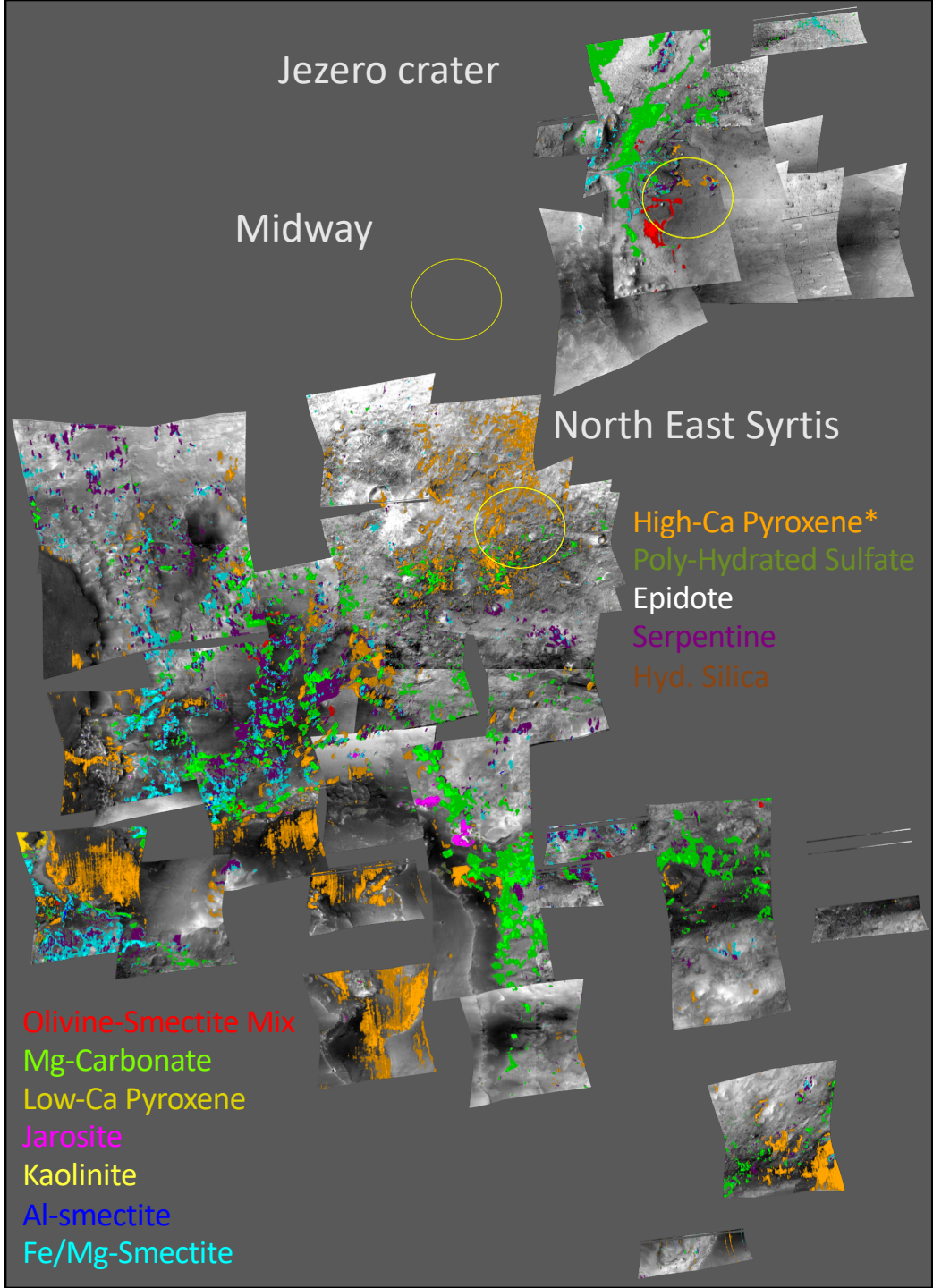
Serpentine
Hyd. Silica
Olivine-Smectite Mix
Mg-Carbonate
Low-Ca Pyroxene
Jarosite
Kaolinite
Al-smectite
Fe/Mg-Smectite

# High Ca-Pyroxene

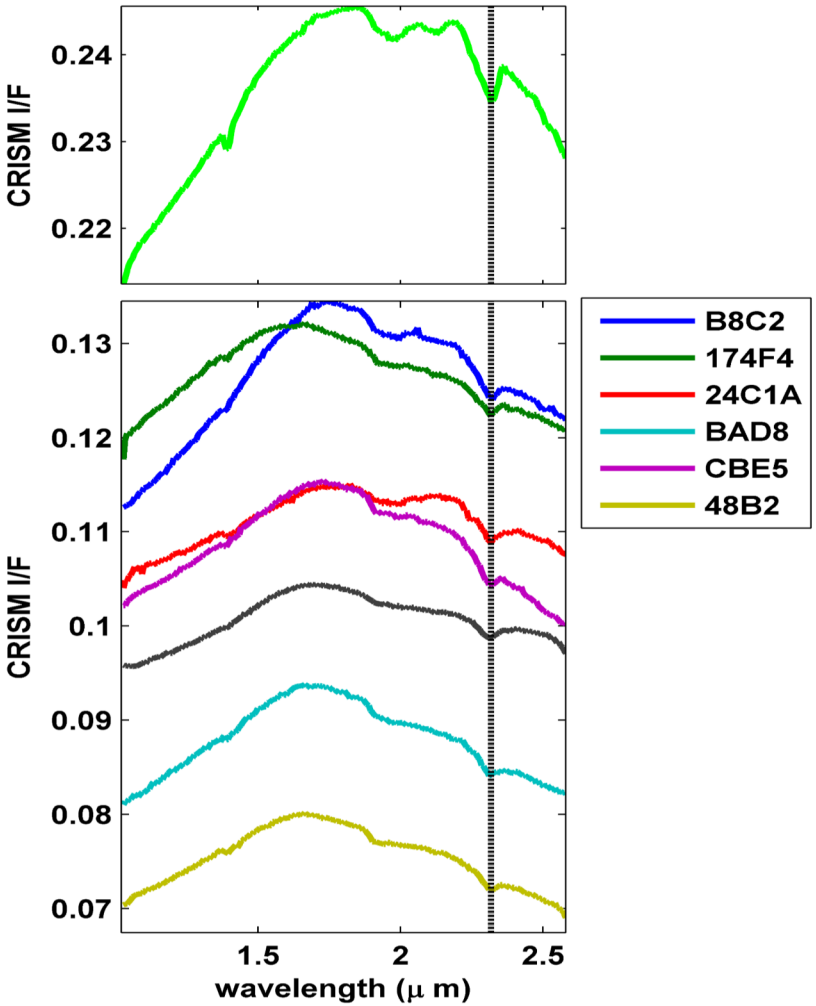


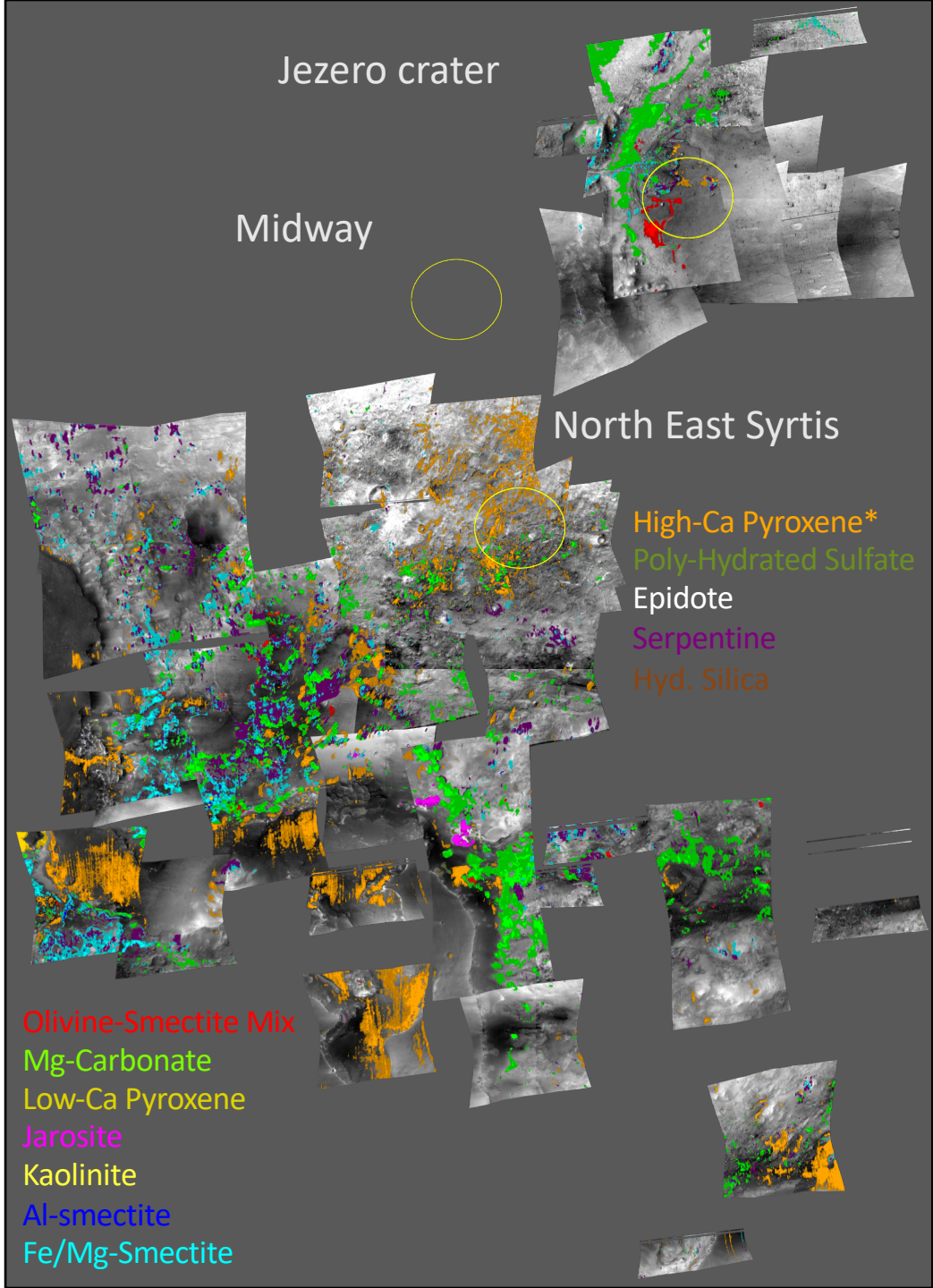

**IDENTIFIED SPECTRA**
**NORTH EAST SYRTIS**

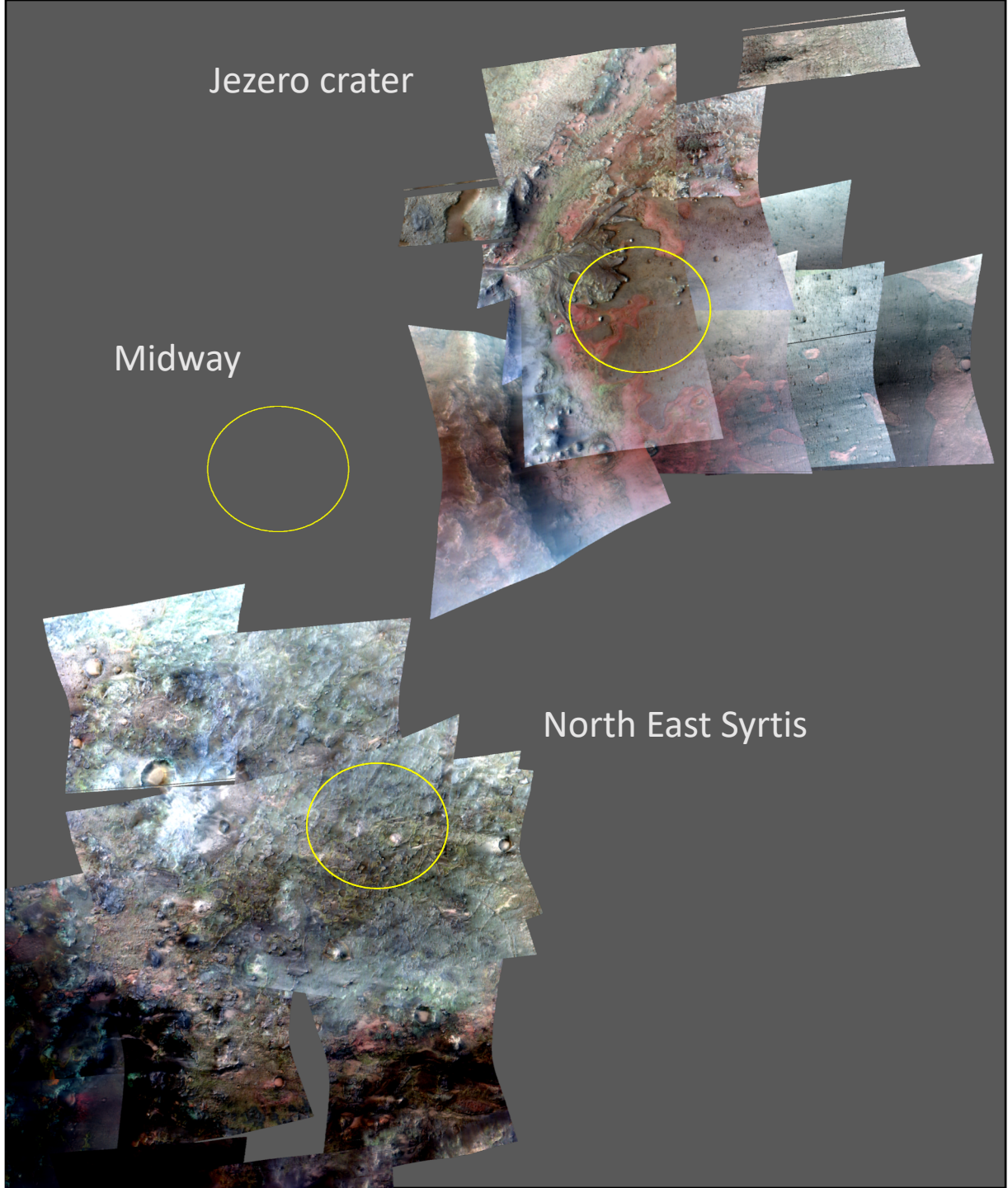


# Serpentine

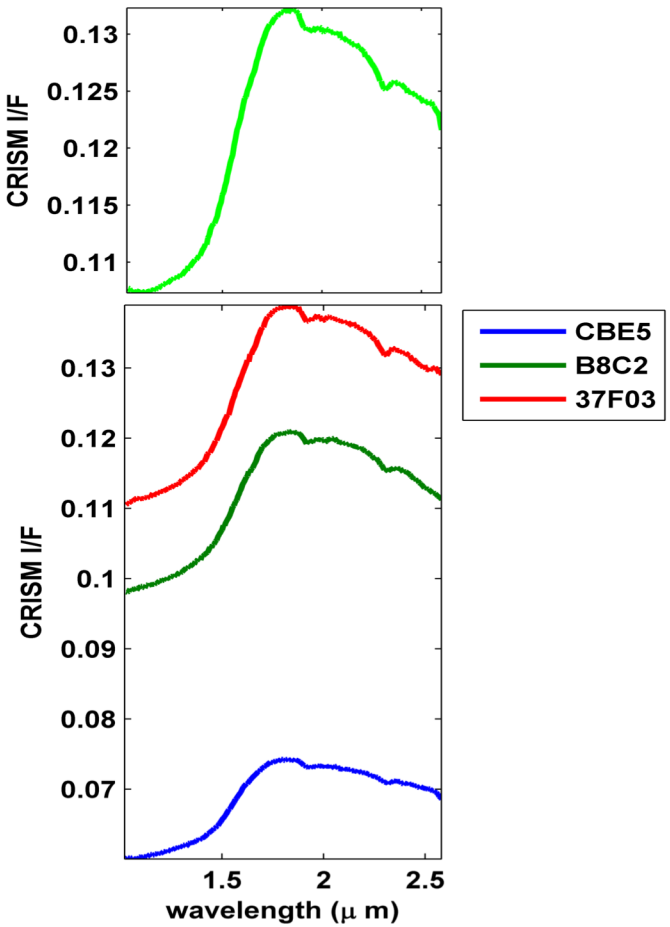



**IDENTIFIED SPECTRA**
**NORTH EAST SYRTIS**

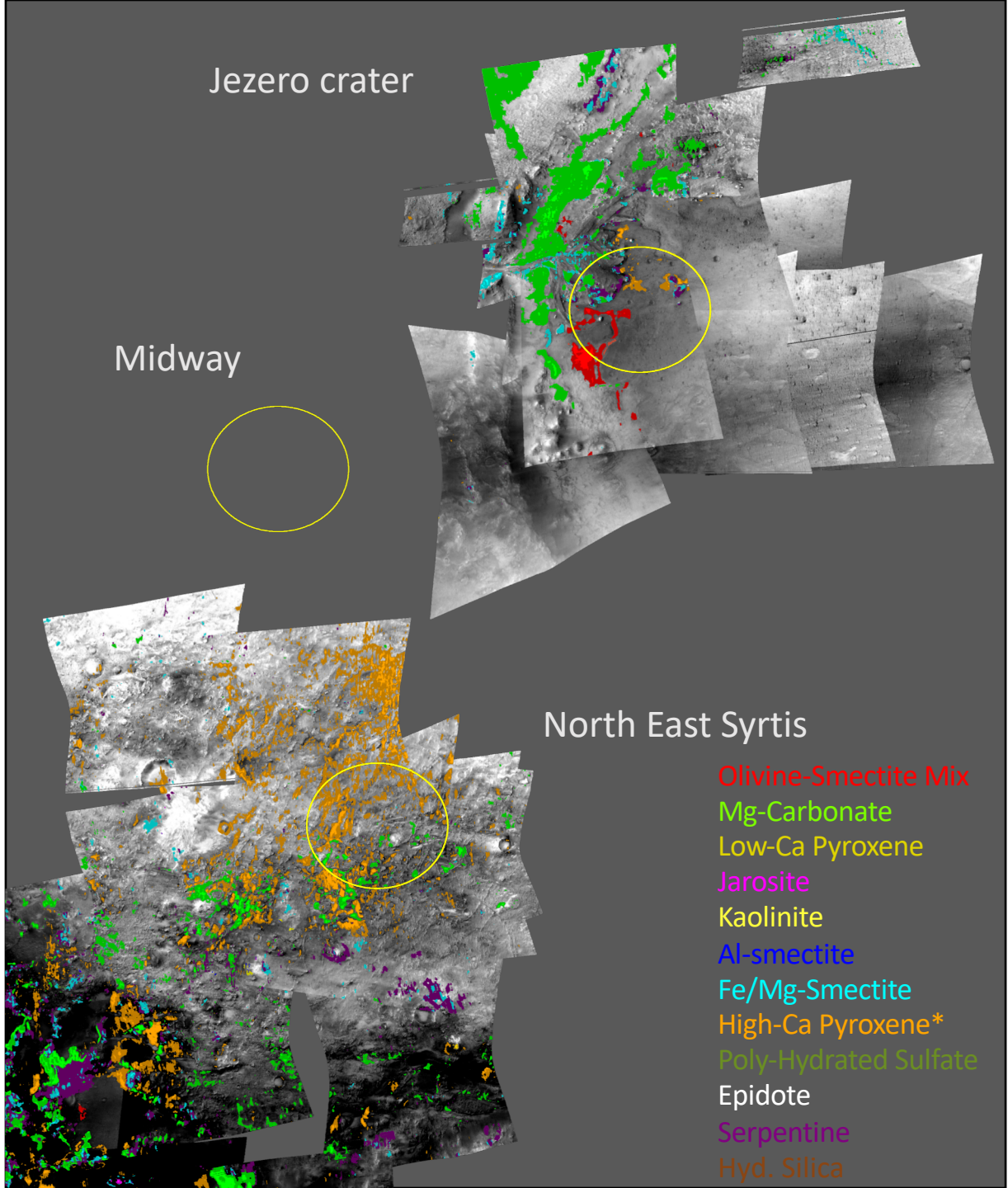



Jezero crater
Midway
North East Syrtis

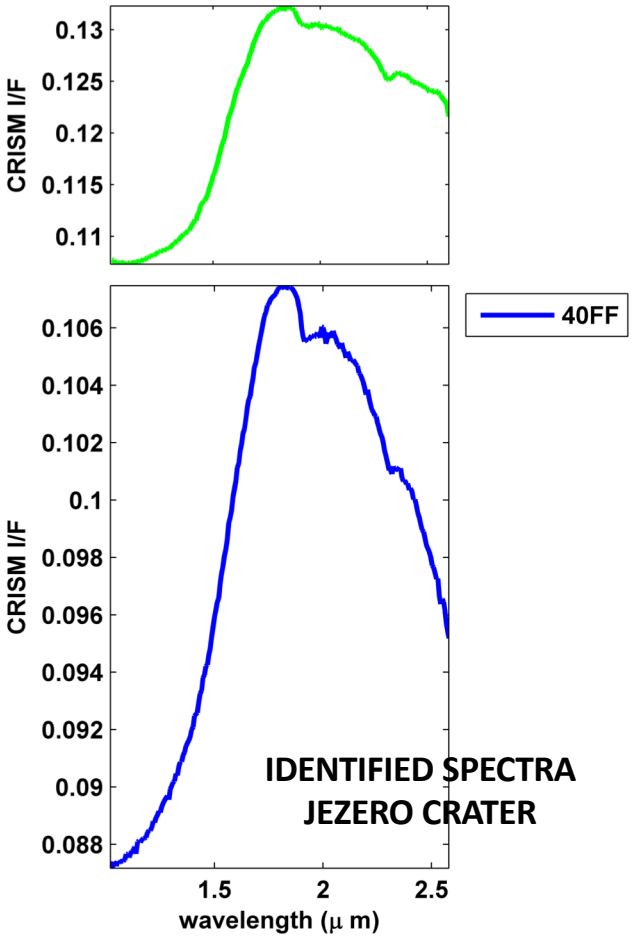
# Olivine/ smectite mixture

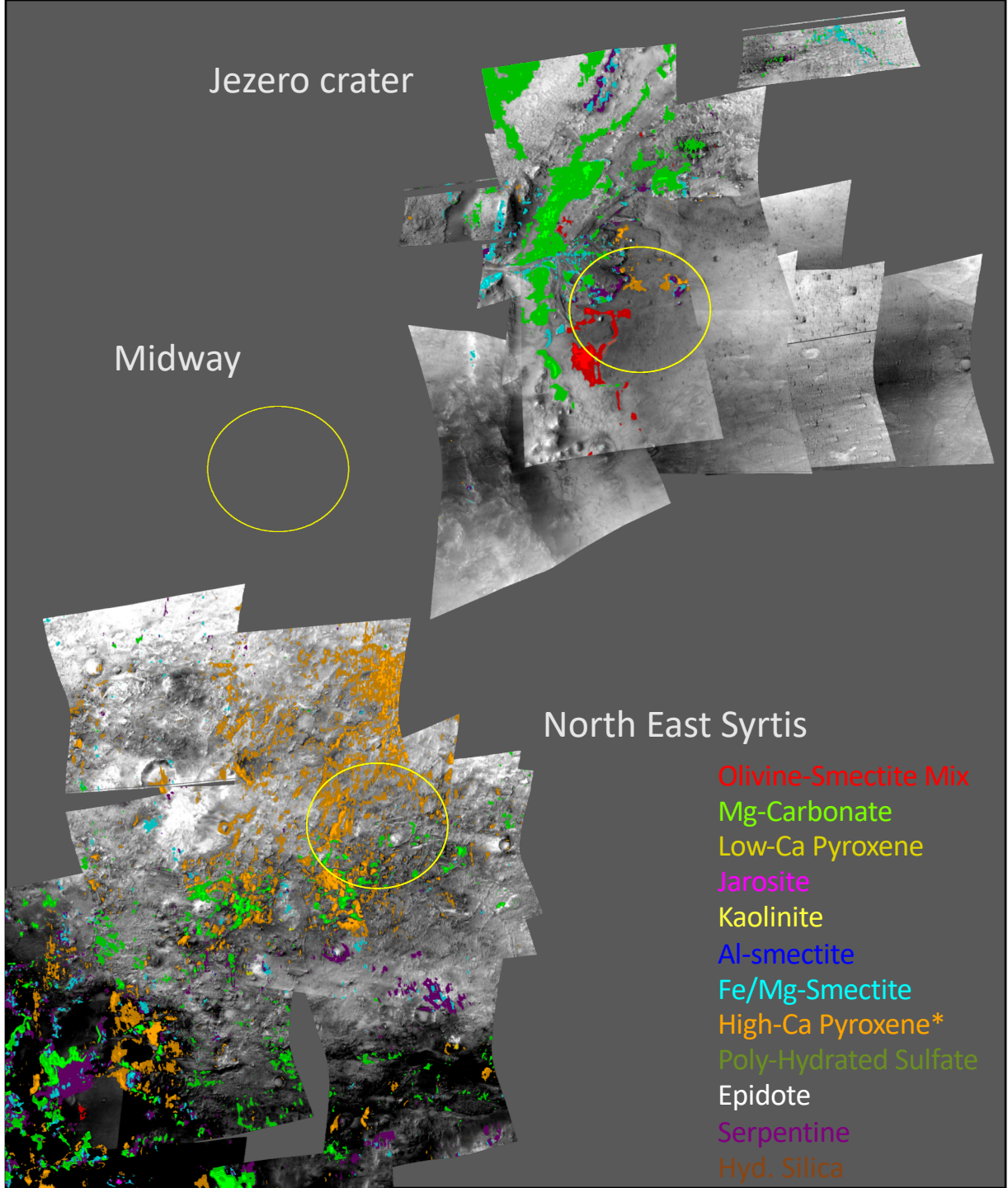



**IDENTIFIED SPECTRA NORTH EAST SYRTIS**

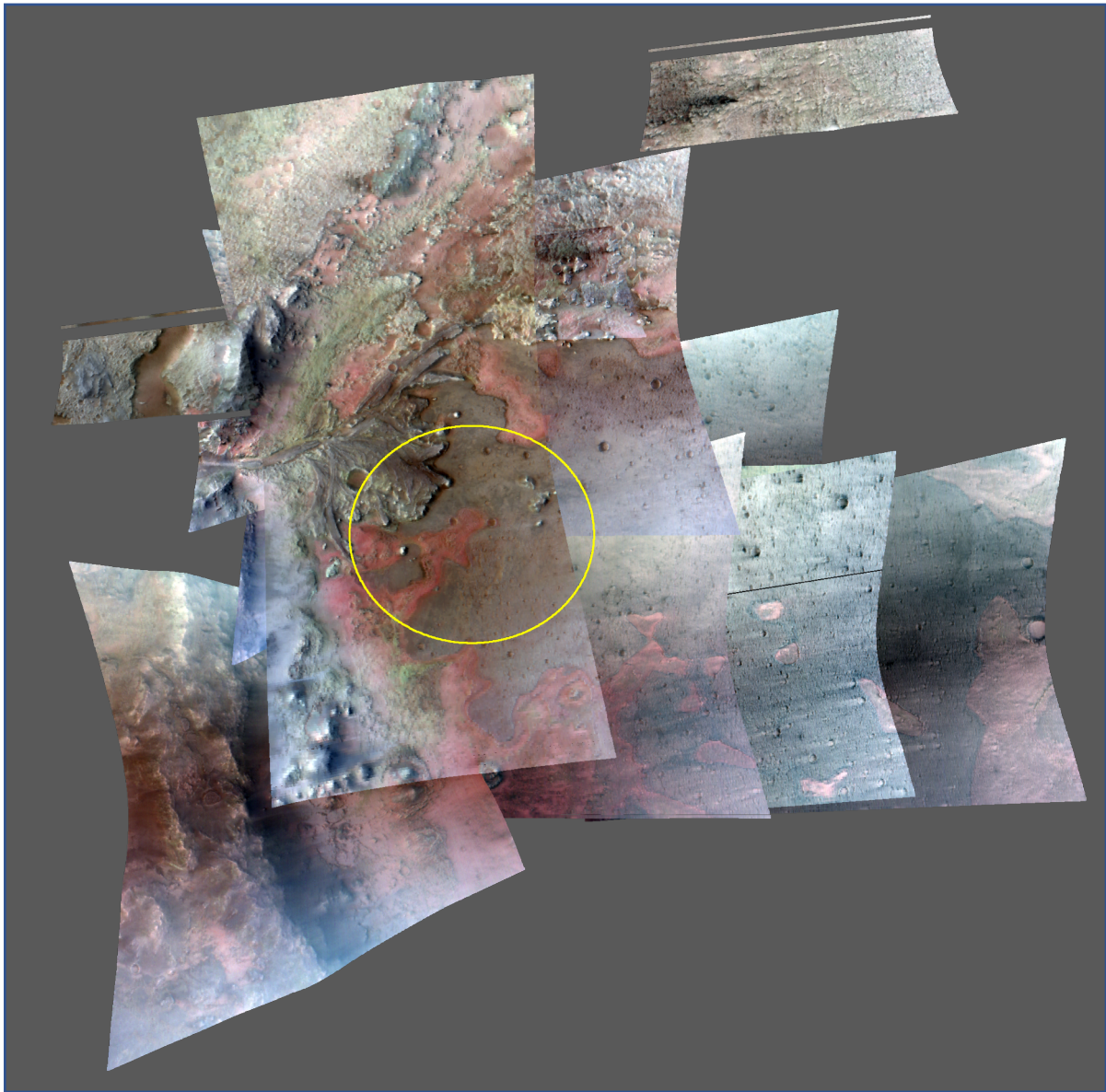


# Olivine/ smectite mixture

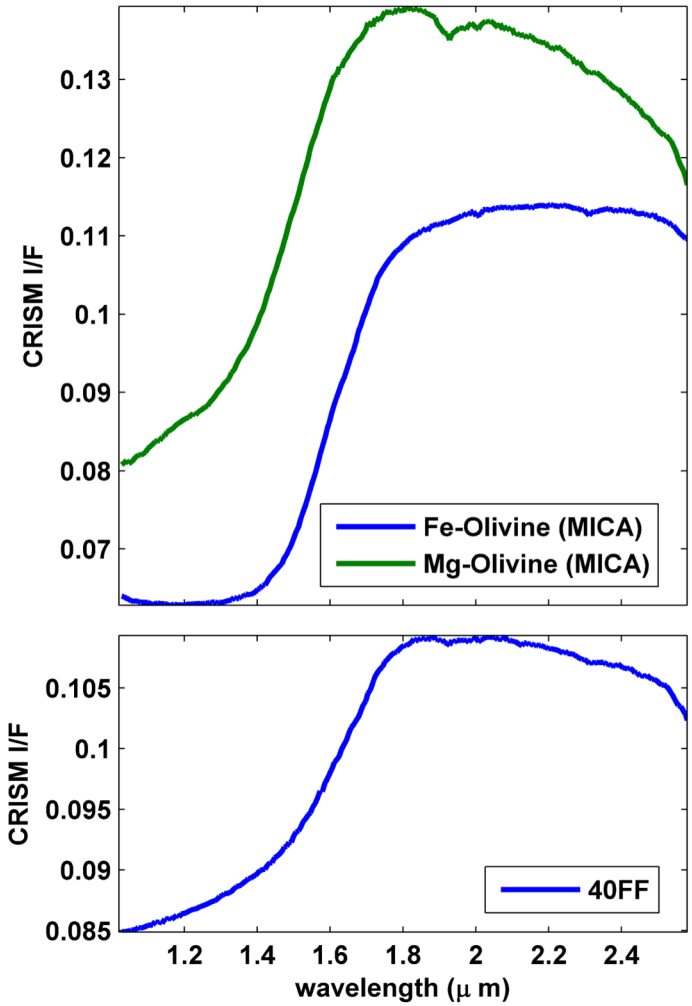


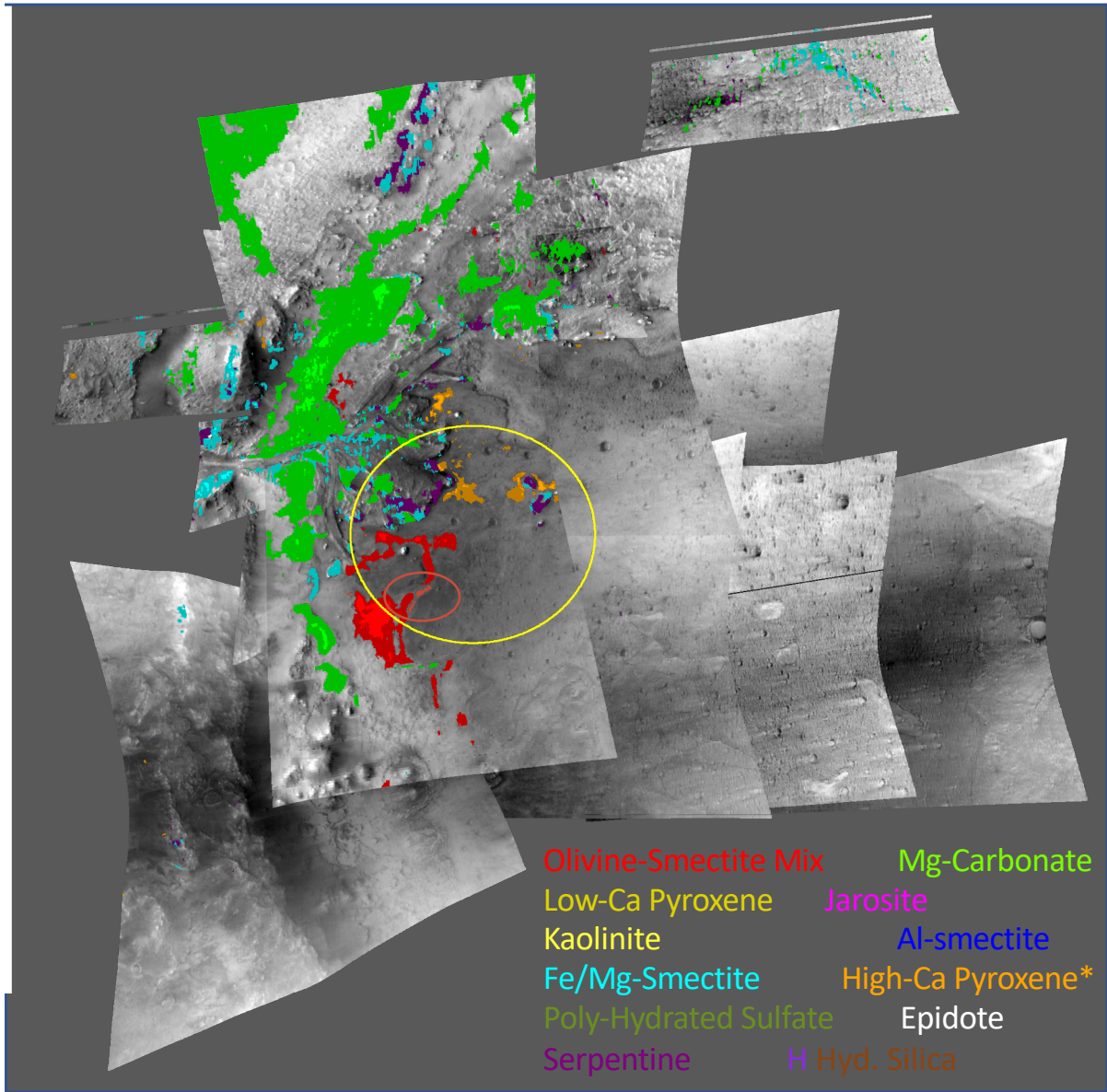



# Jezero Crater

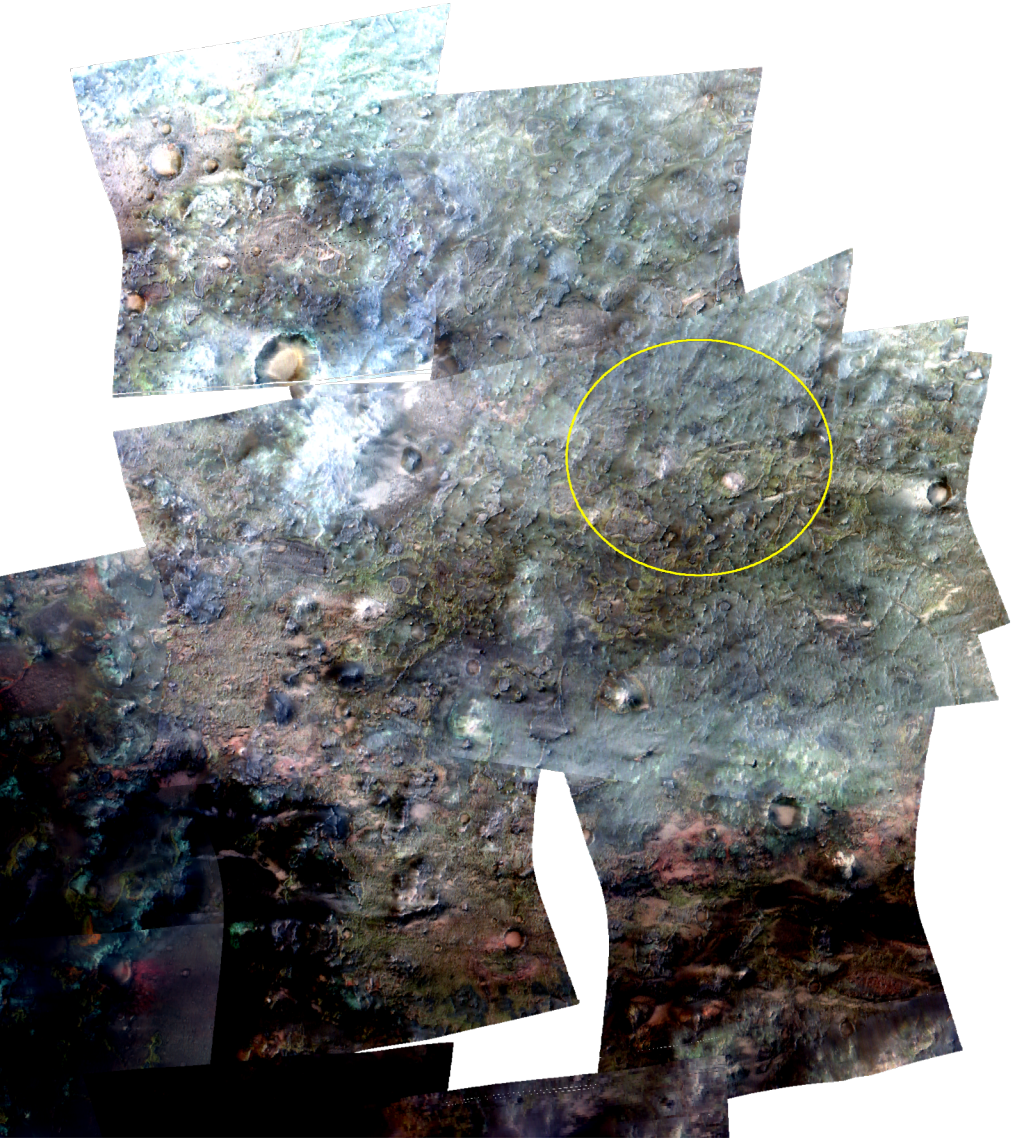


# Pure Olivine

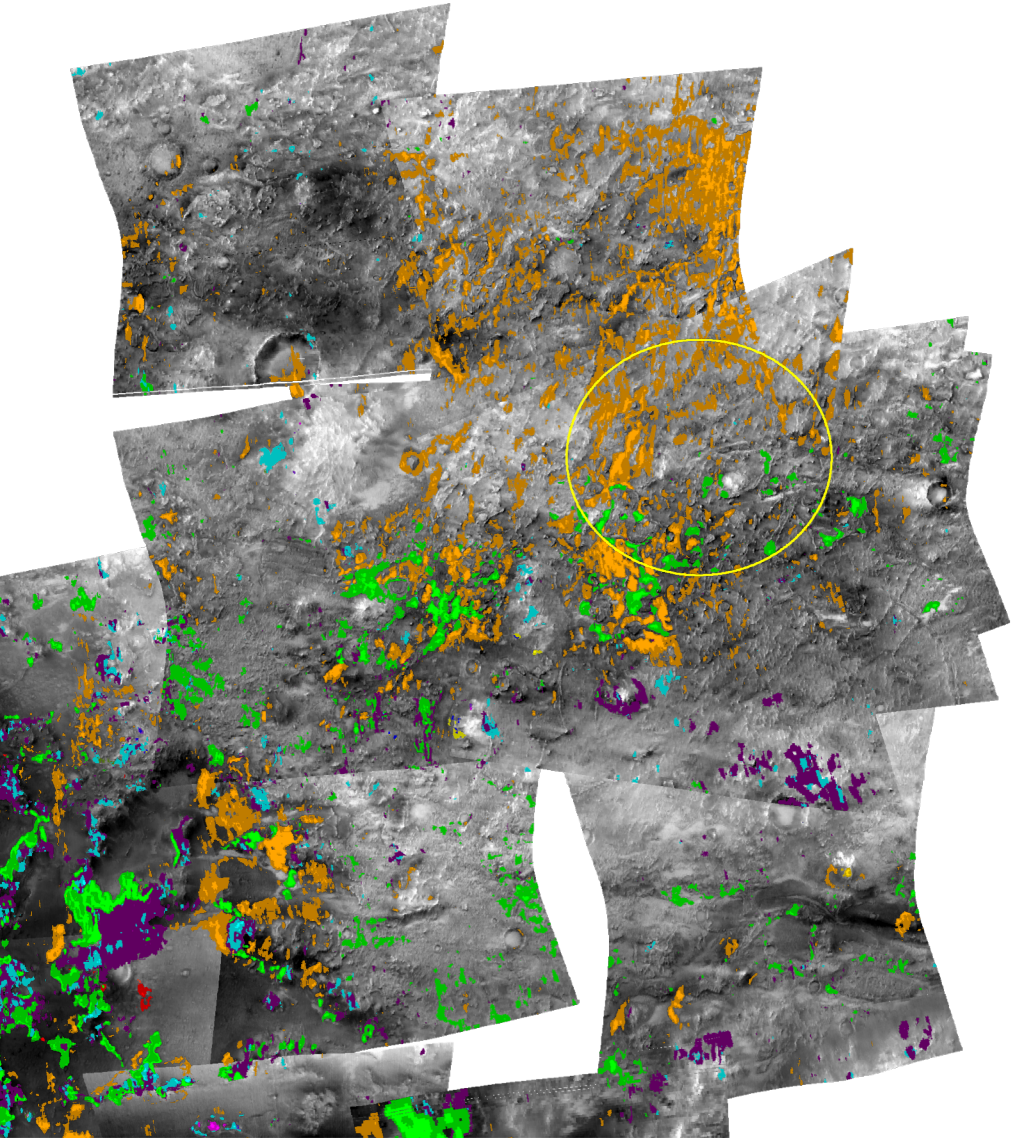


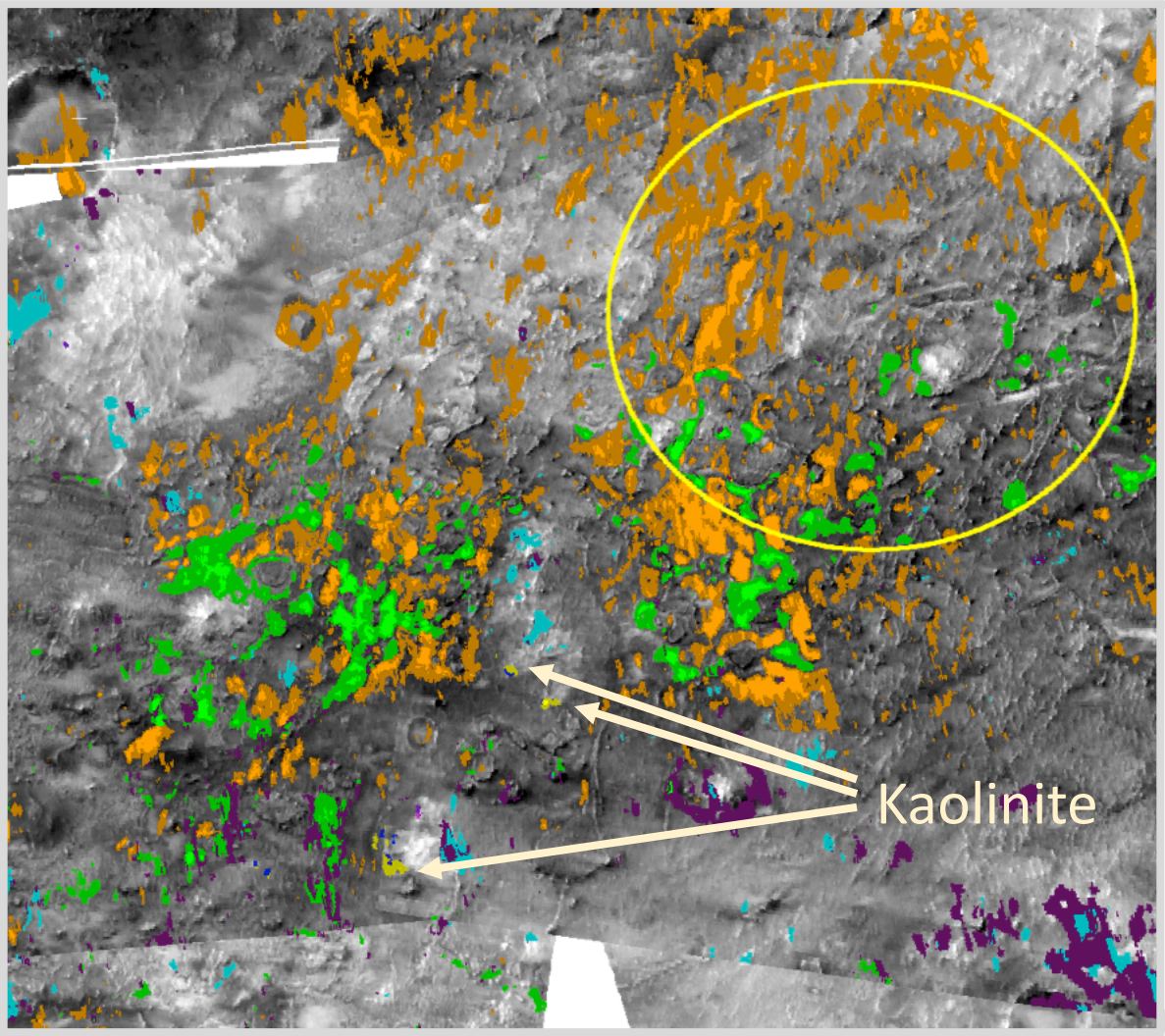
# North East Syrtis

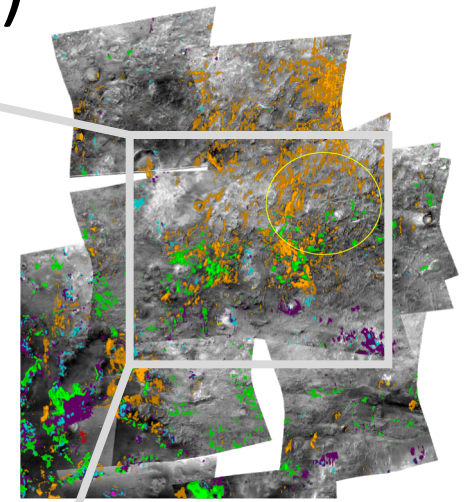


# North East Syrtis

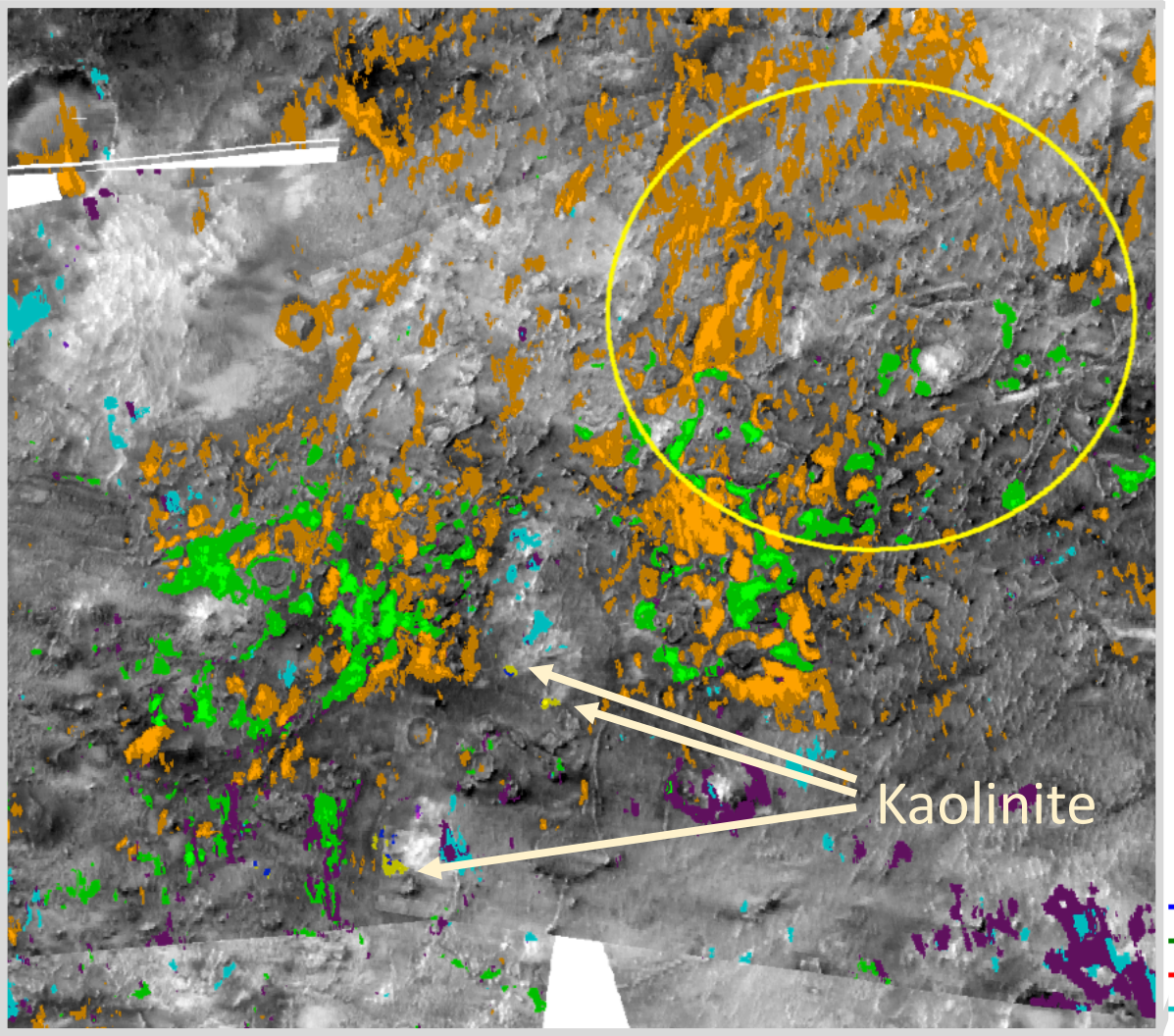


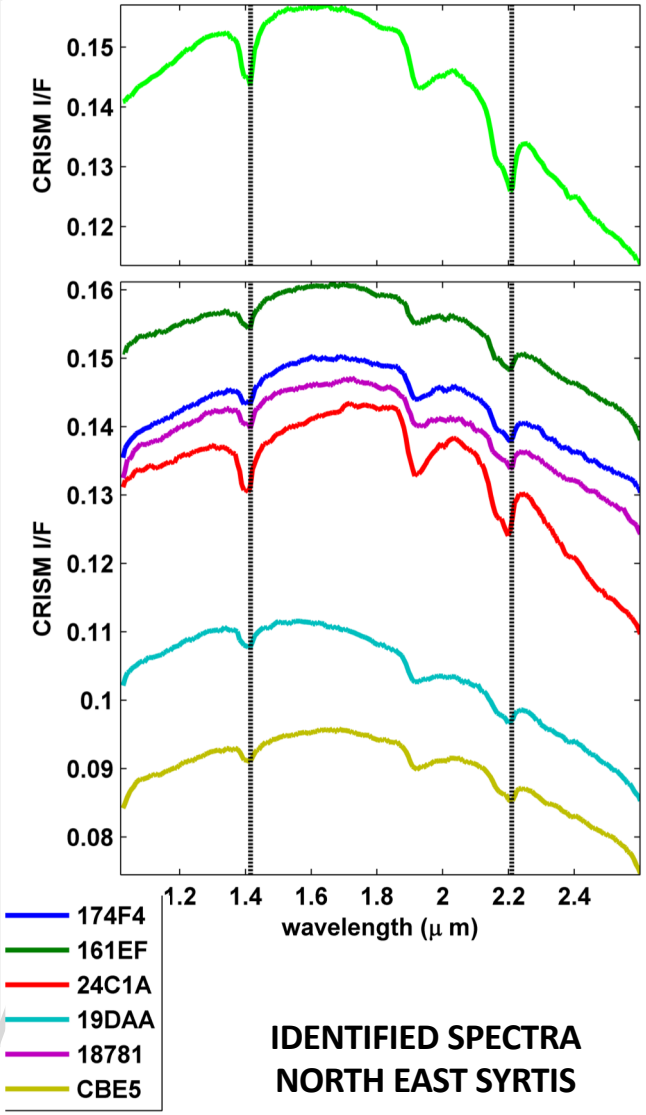
# North East Syrtis (kaolinite)



# North East Syrtis (kaolinite)



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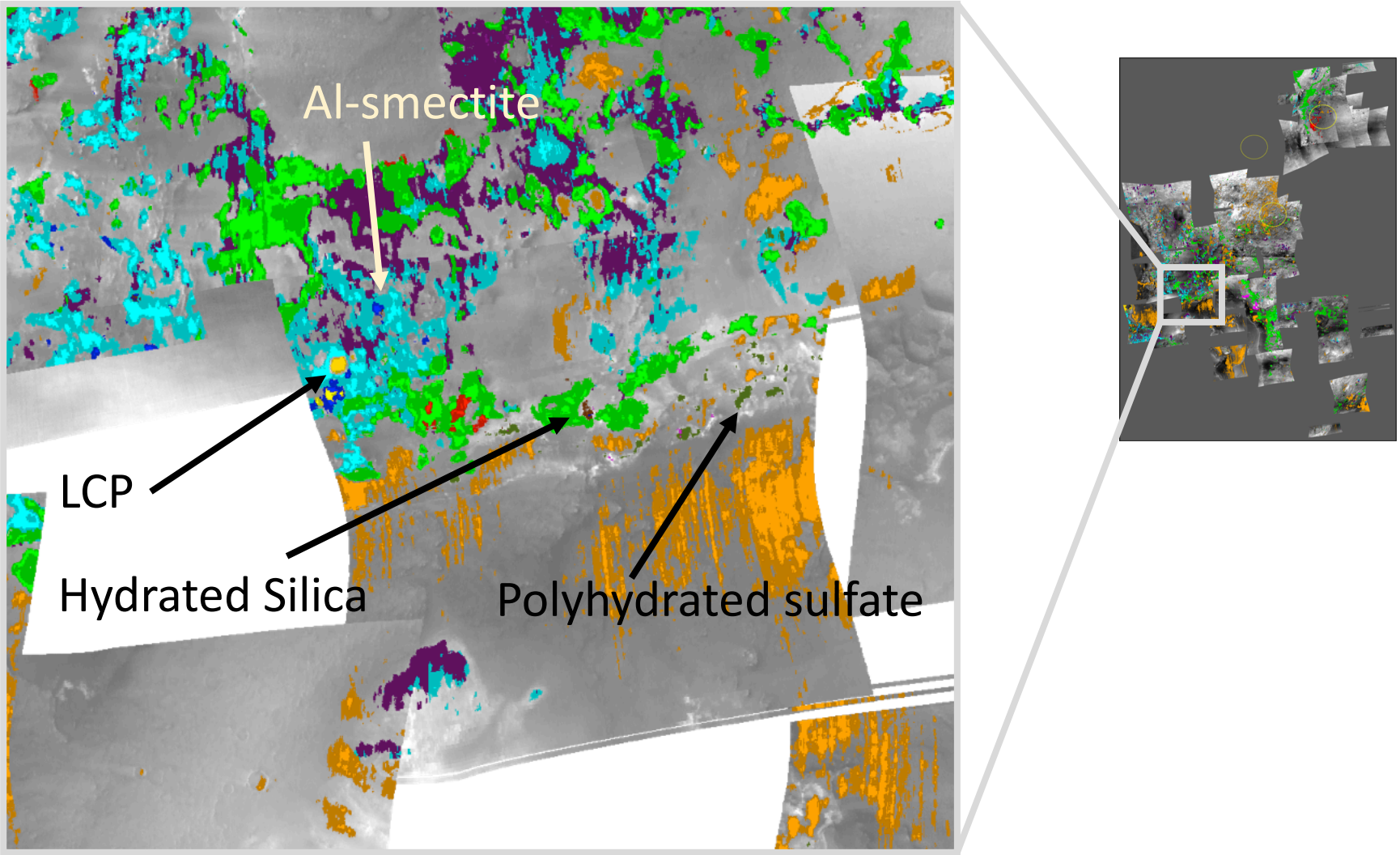
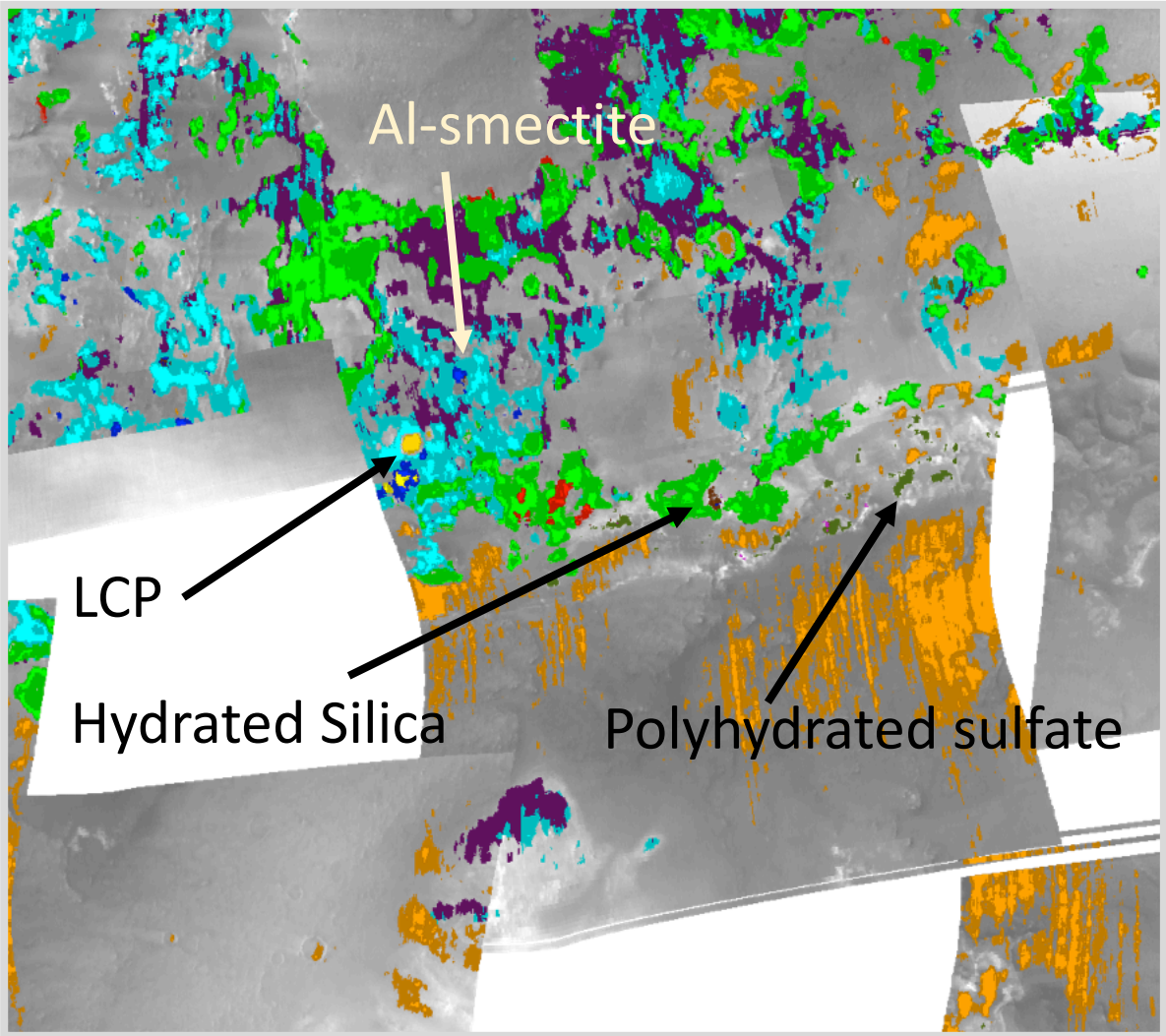
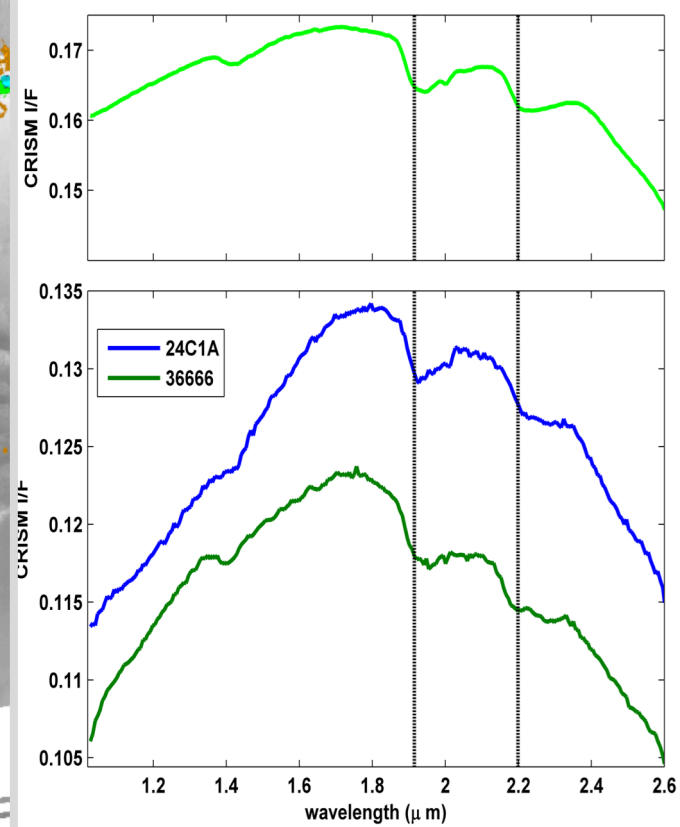


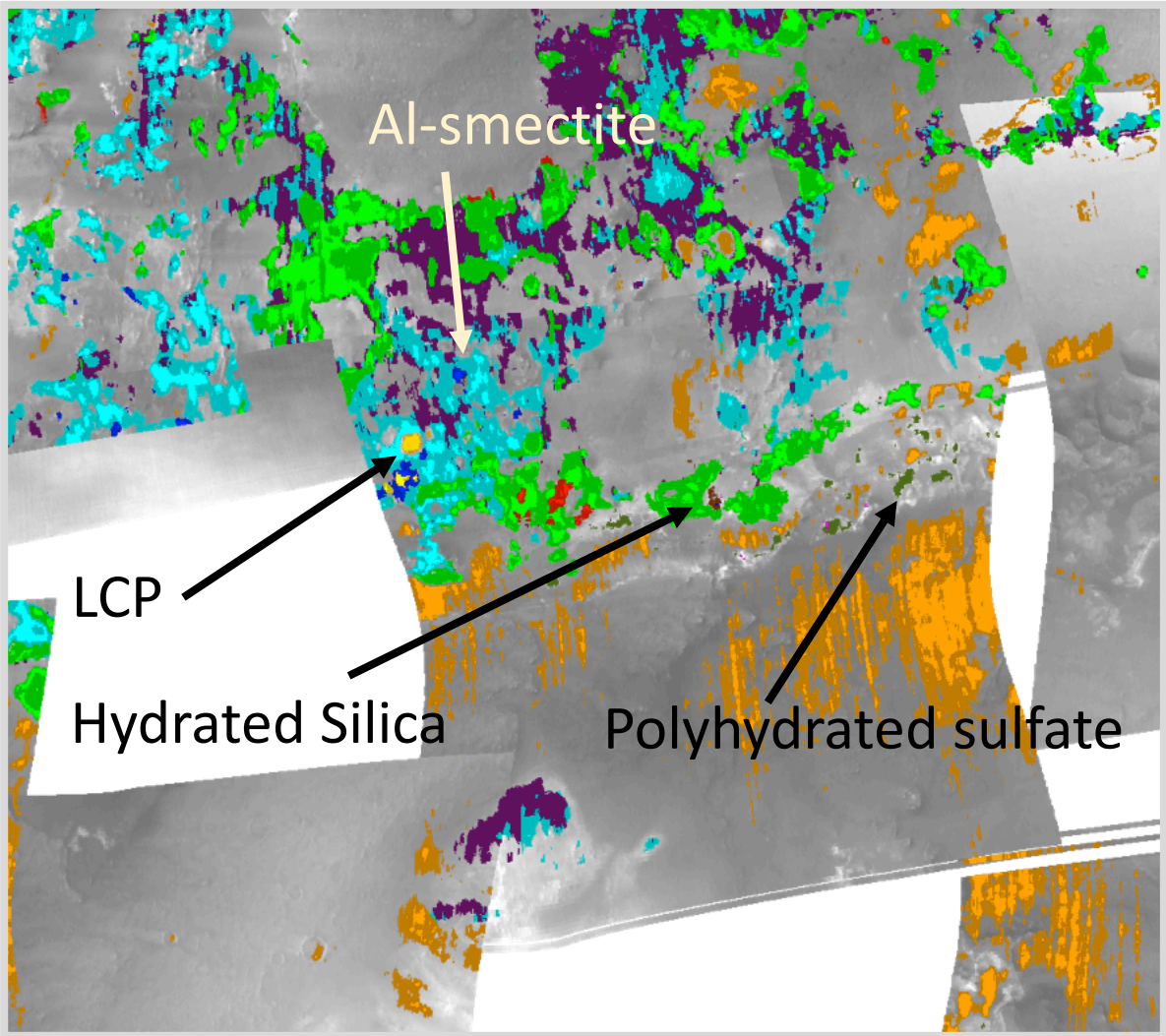
# Hydrated Silica

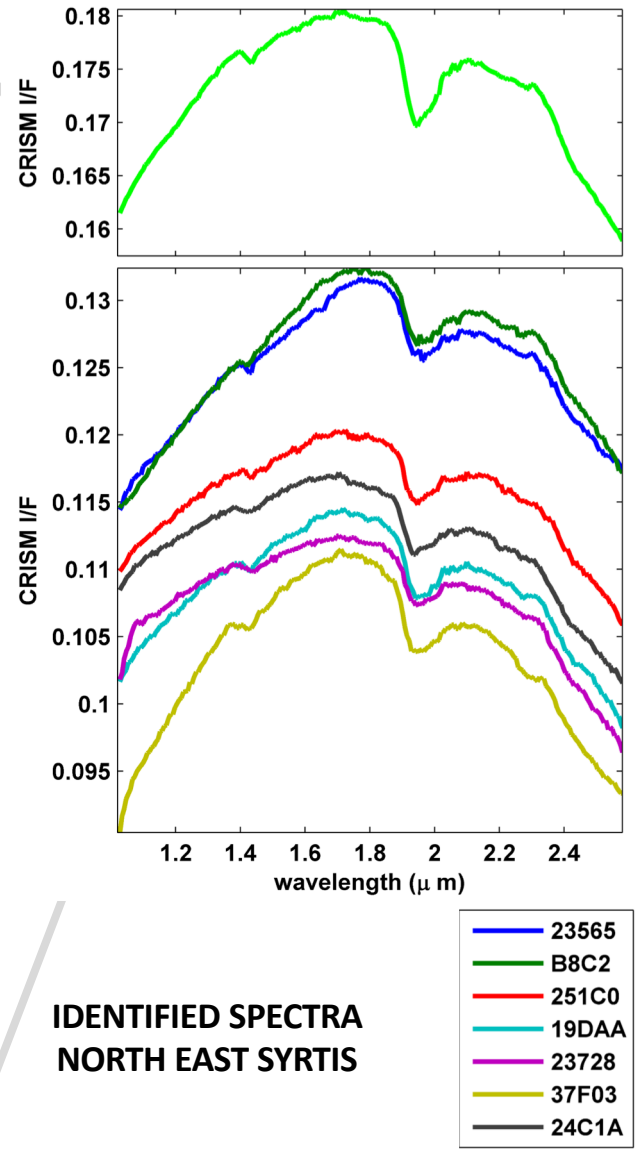



**IDENTIFIED SPECTRA**
**NORTH EAST SYRTIS**

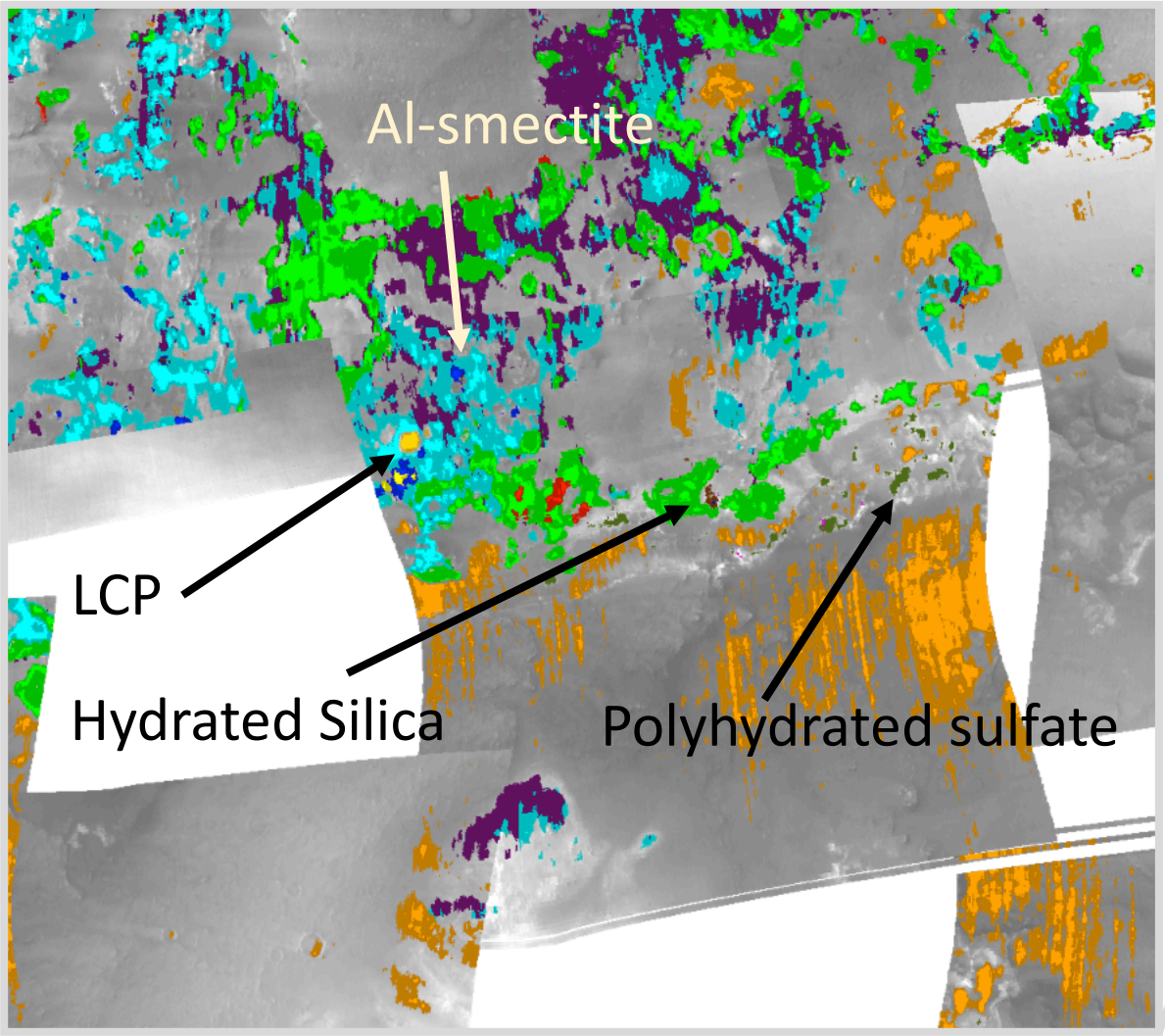
# Polyhydrated Sulfate

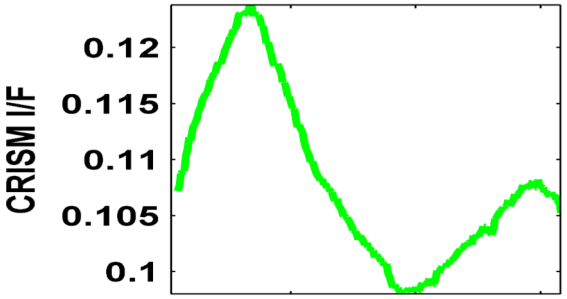


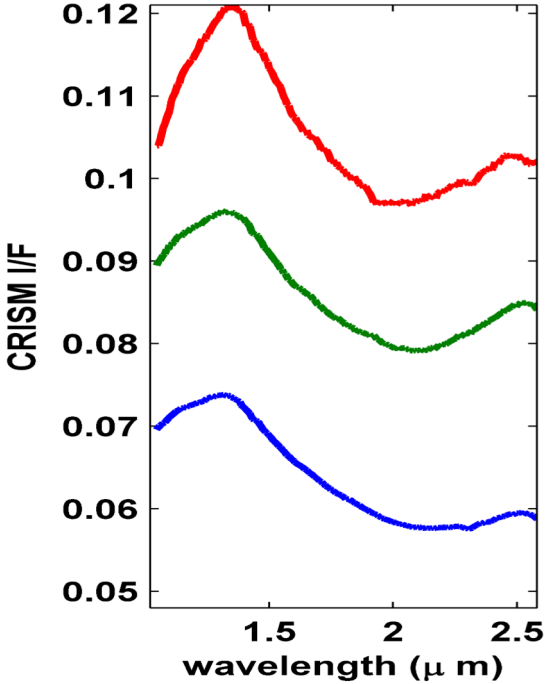




**IDENTIFIED SPECTRA NORTH EAST SYRTIS**

# Low-Ca Pyroxene



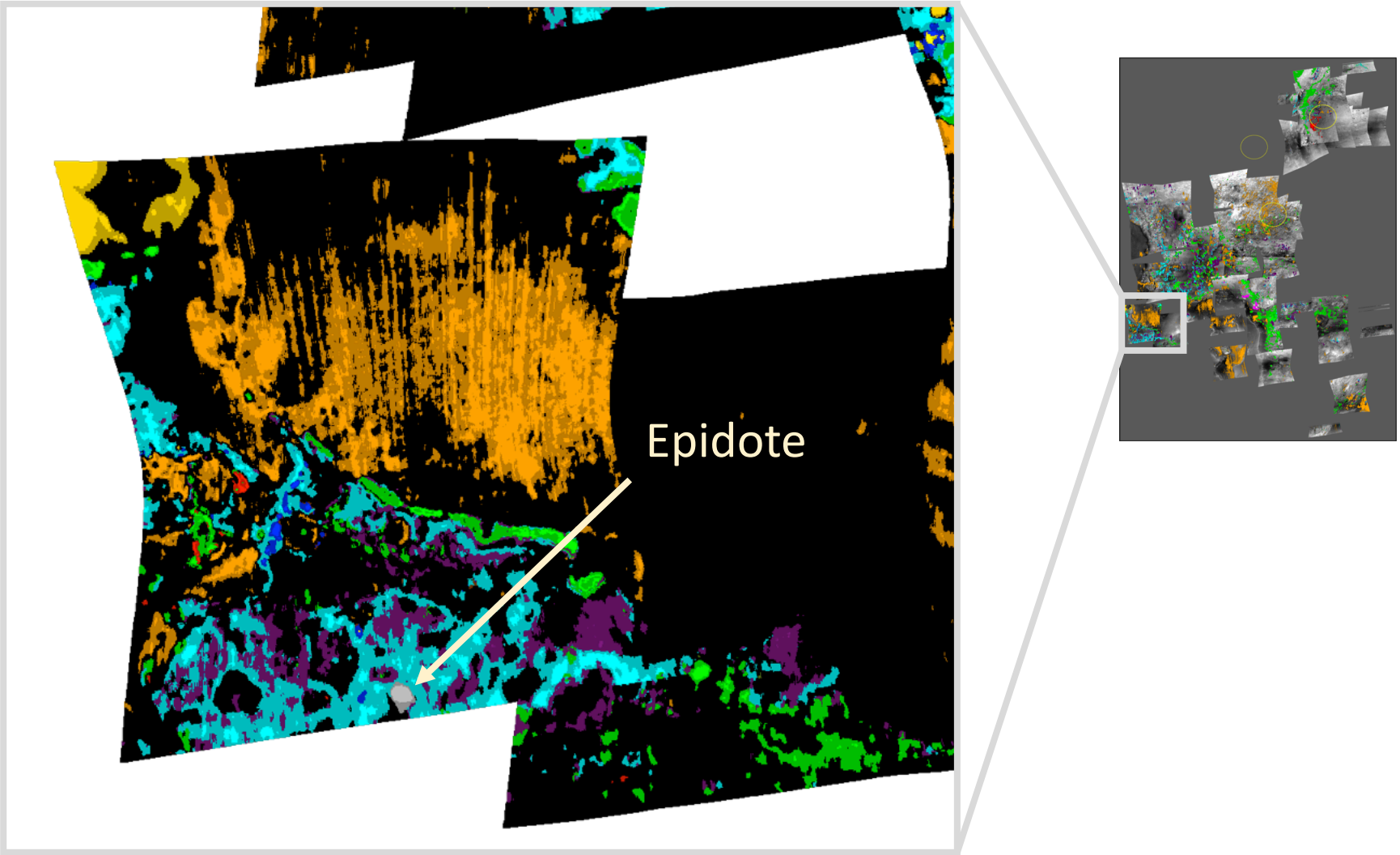



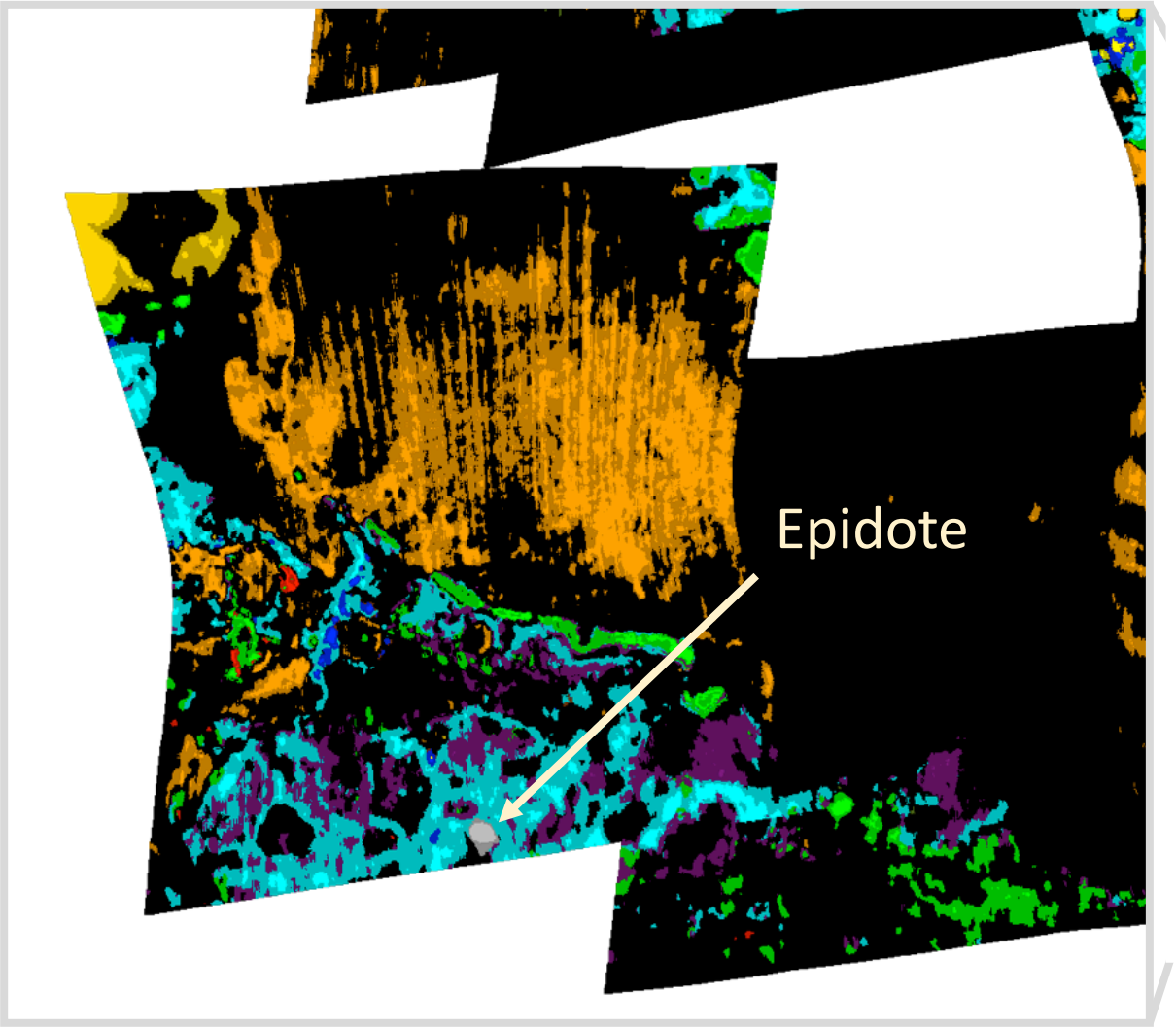

IDENTIFIED SPECTRA
NORTH EAST SYRTIS

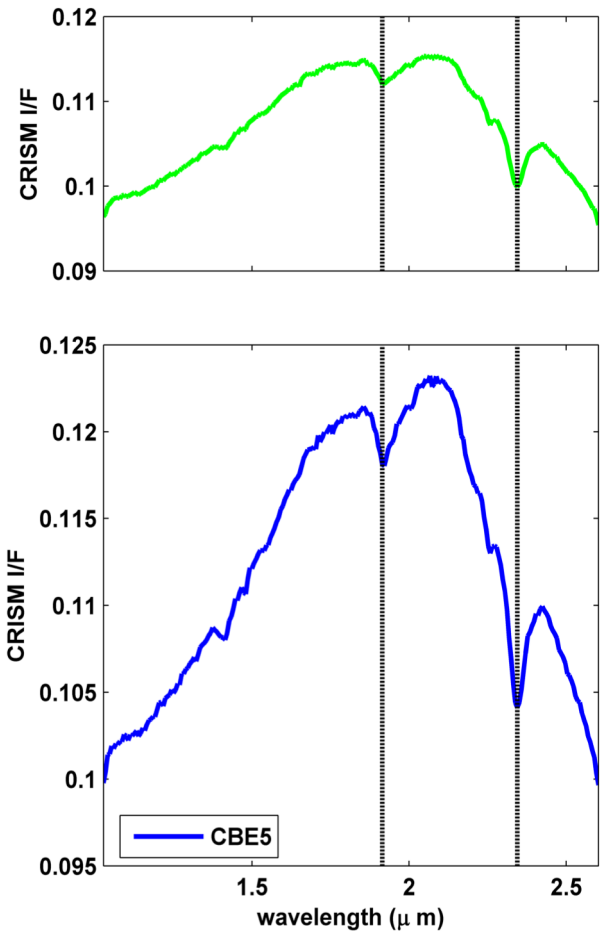
18DCA
CBE5
24C1A

# FRT000CBE5



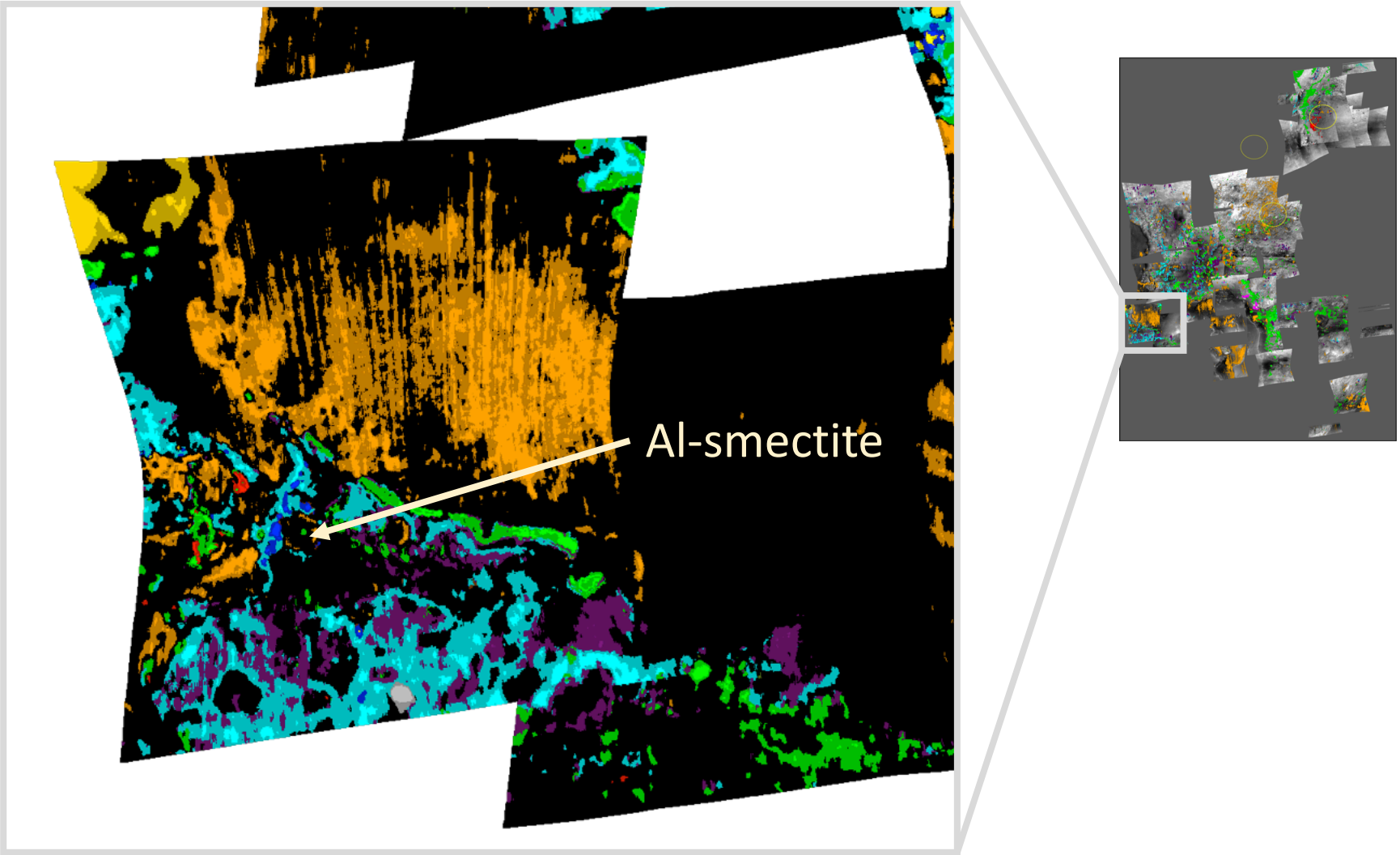
# Epidote (MICA)

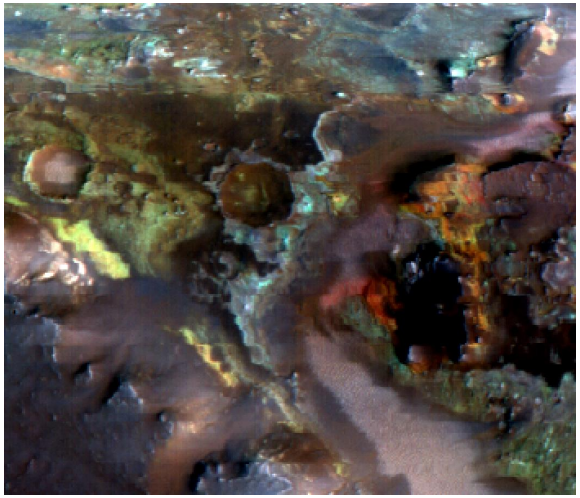


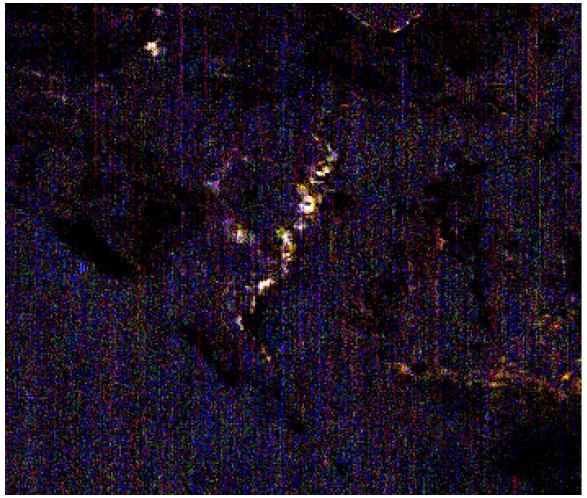

**IDENTIFIED SPECTRA NORTH EAST SYRTIS**

# Al-smectite



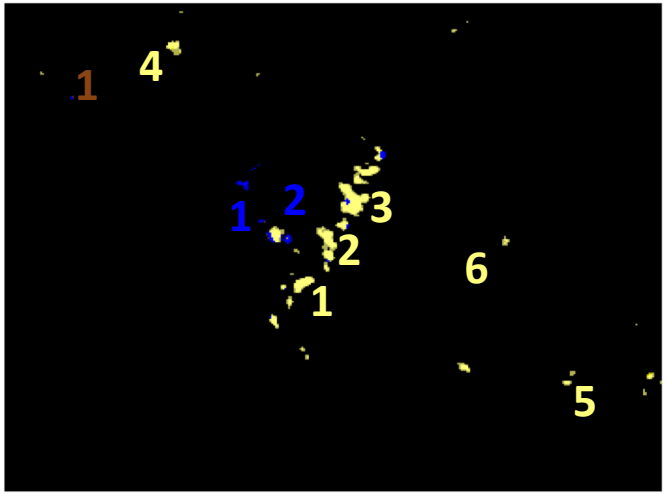


CBE5 RGB COMPOSITE



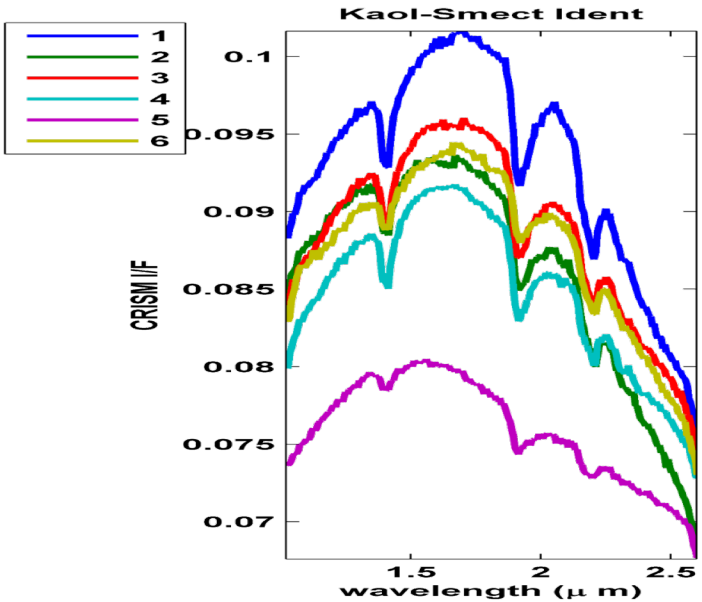
CBE5 SUMMARY PARAMETER MAP

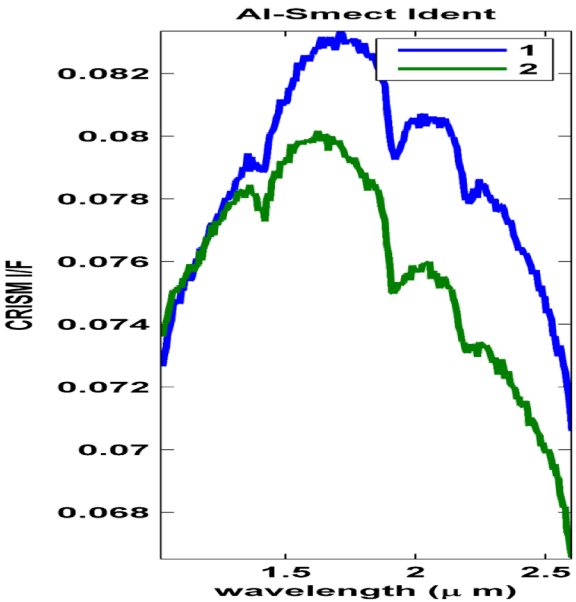
R: BD2190, G:MIN2200, B:BD2210_2

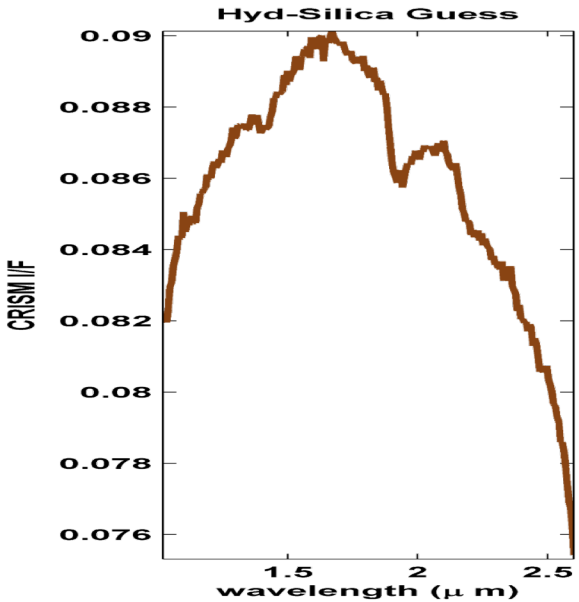



CBE5 DETECTION MAP

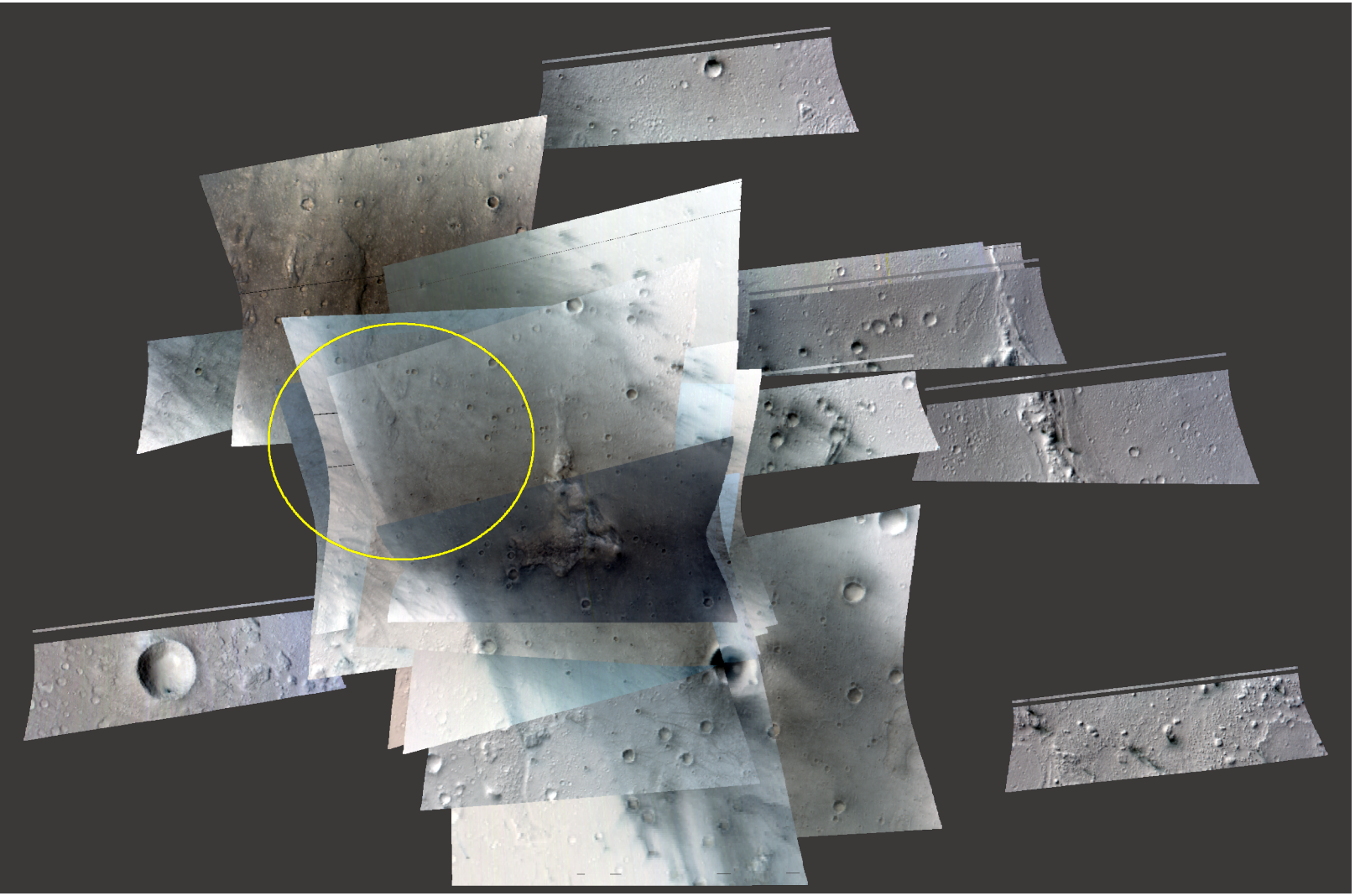
Kaol-Smect Mix: Yellow, Al-Smect: Blue



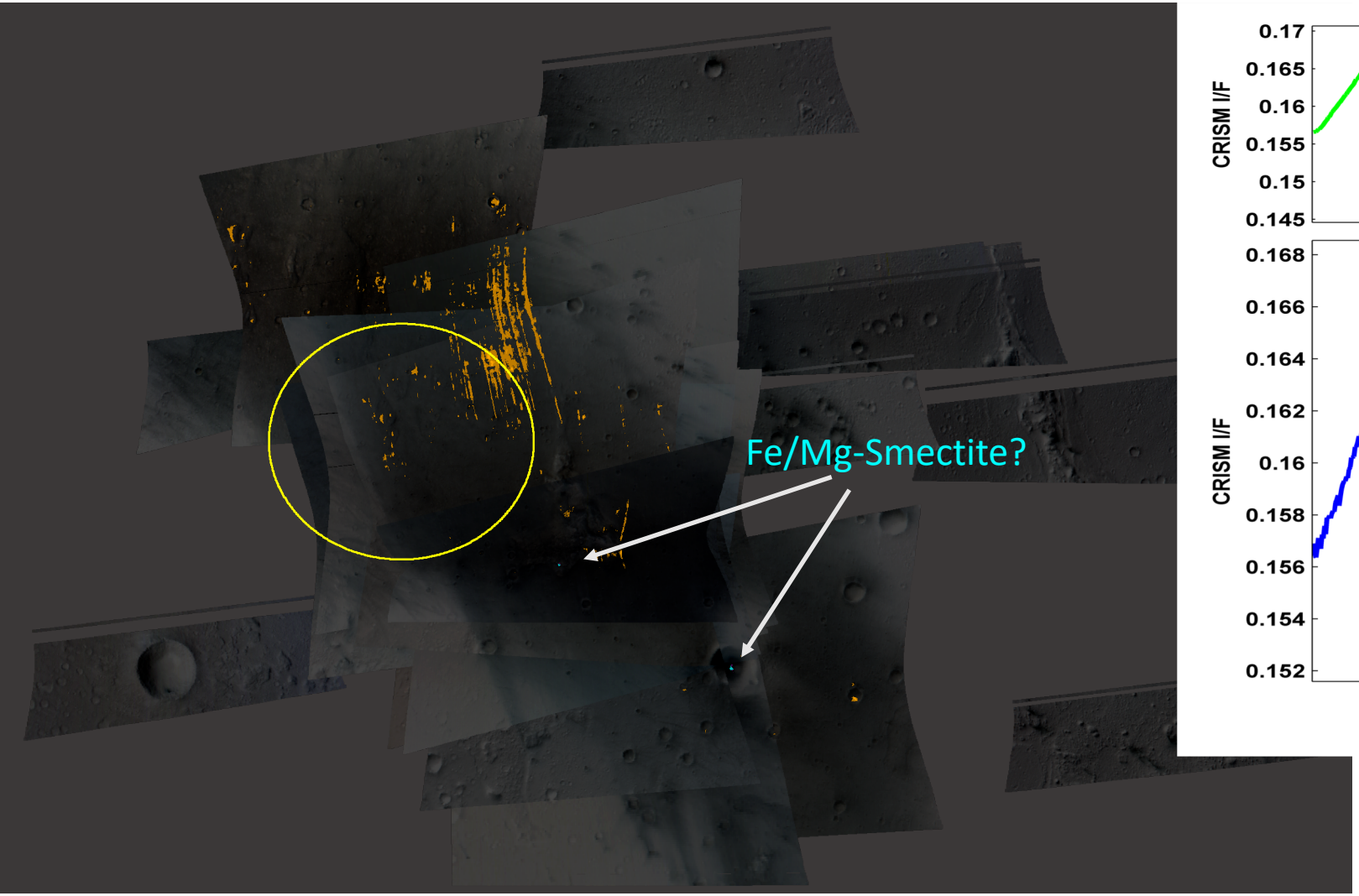



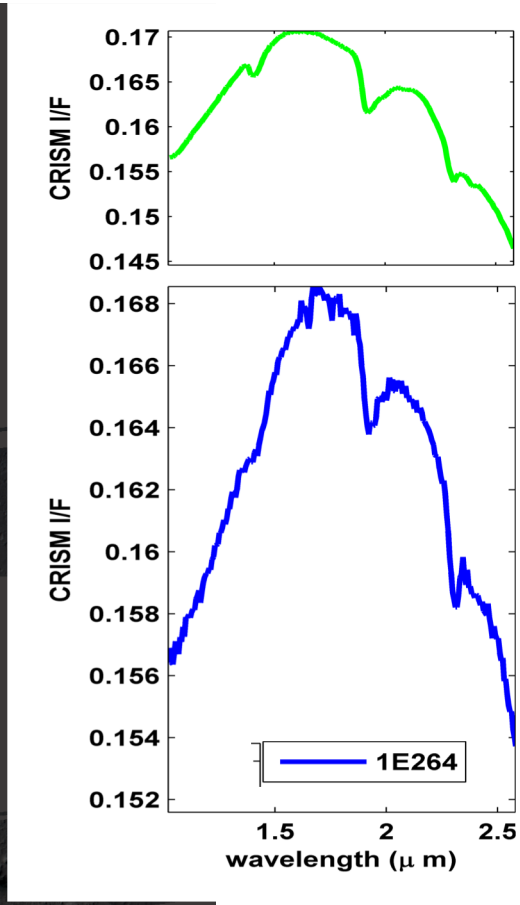



# Columbia Hills

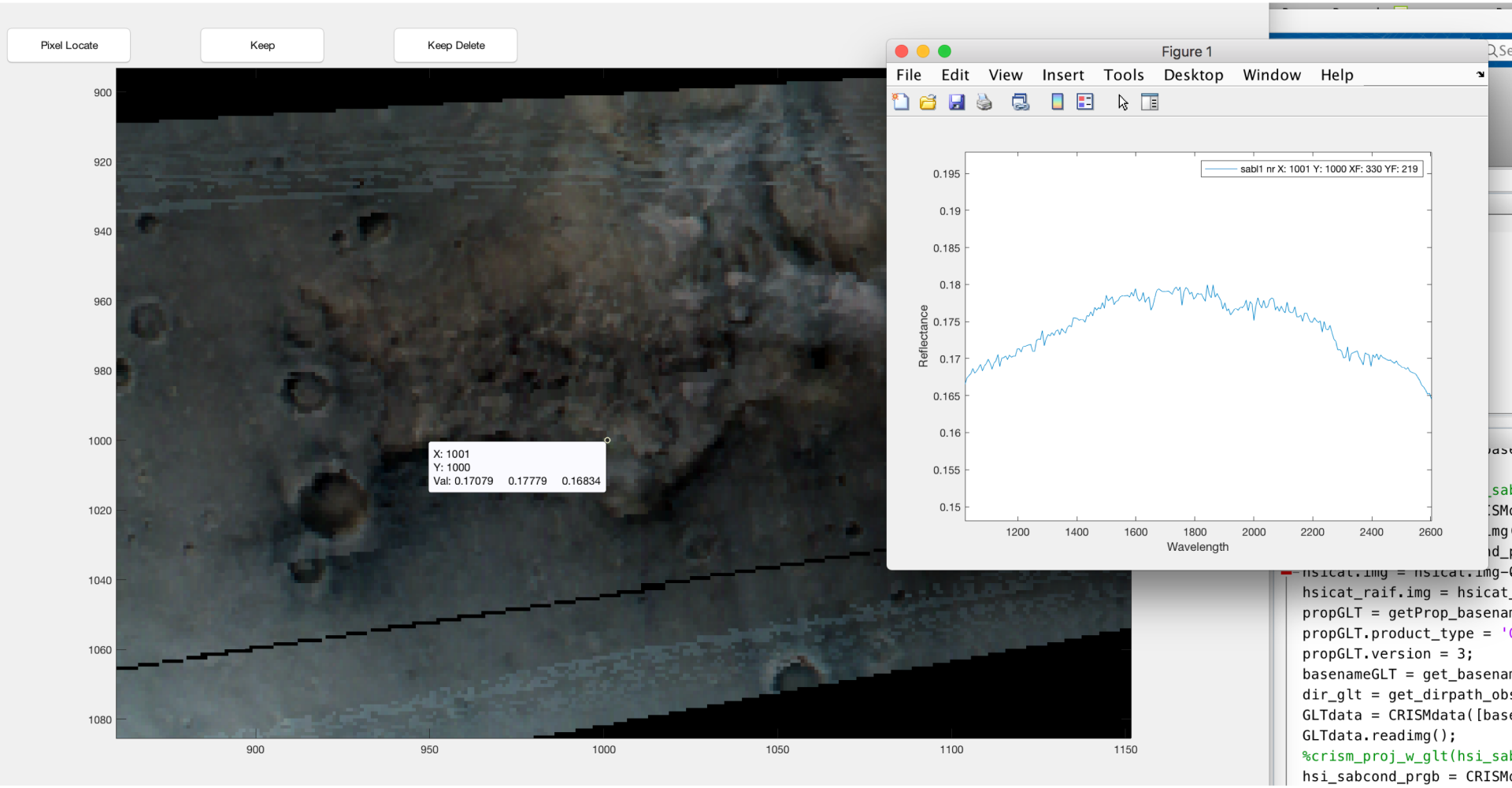


# Columbia Hills

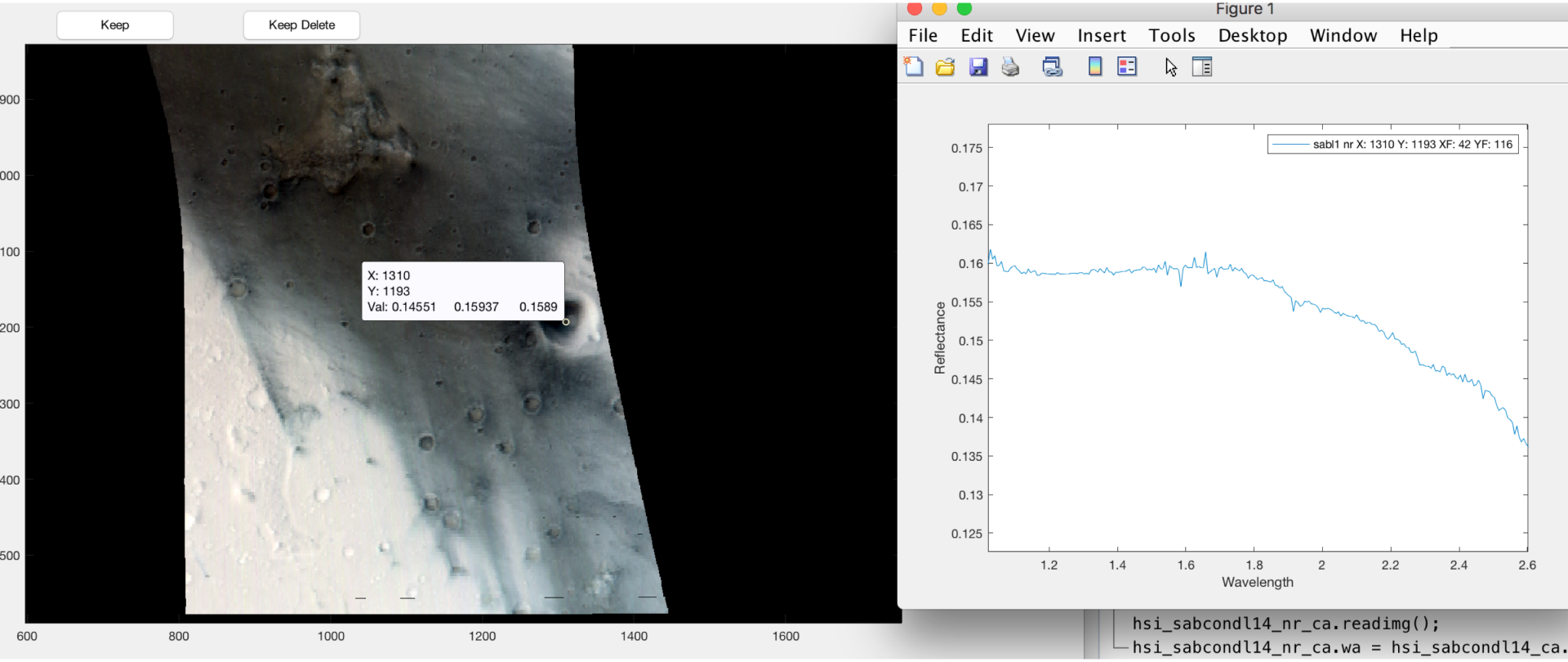
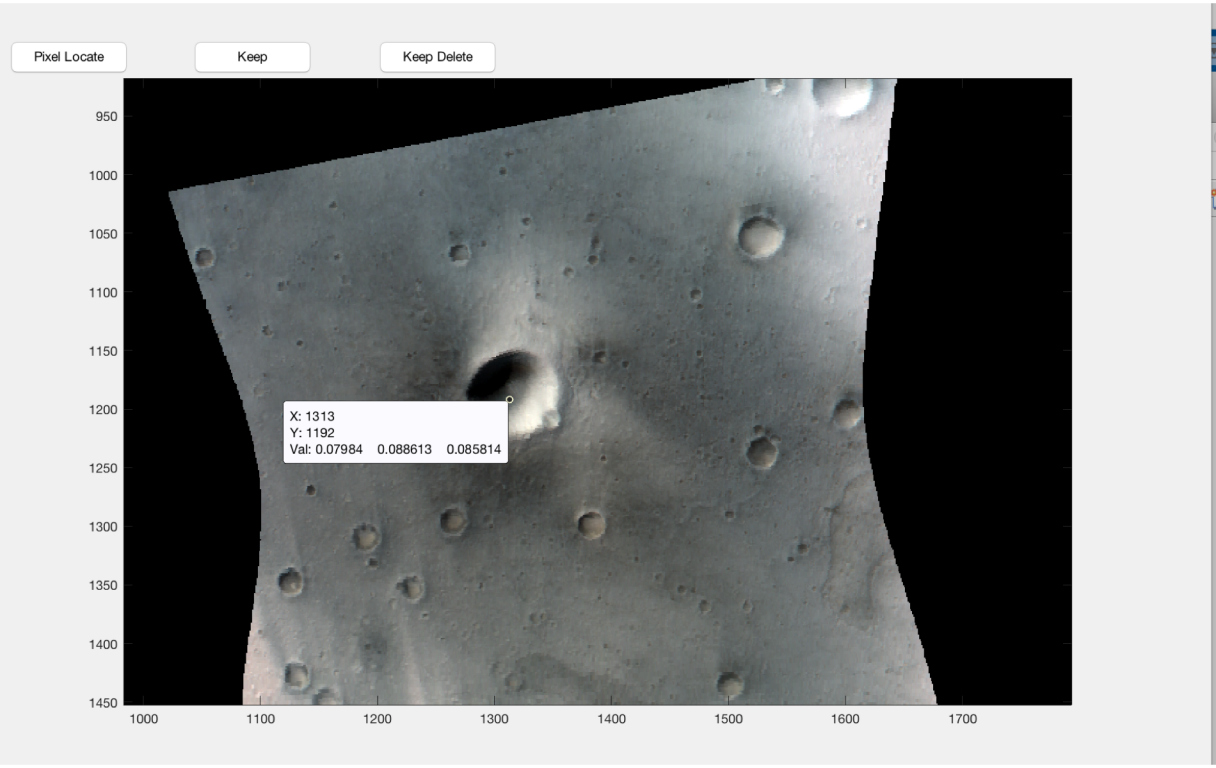
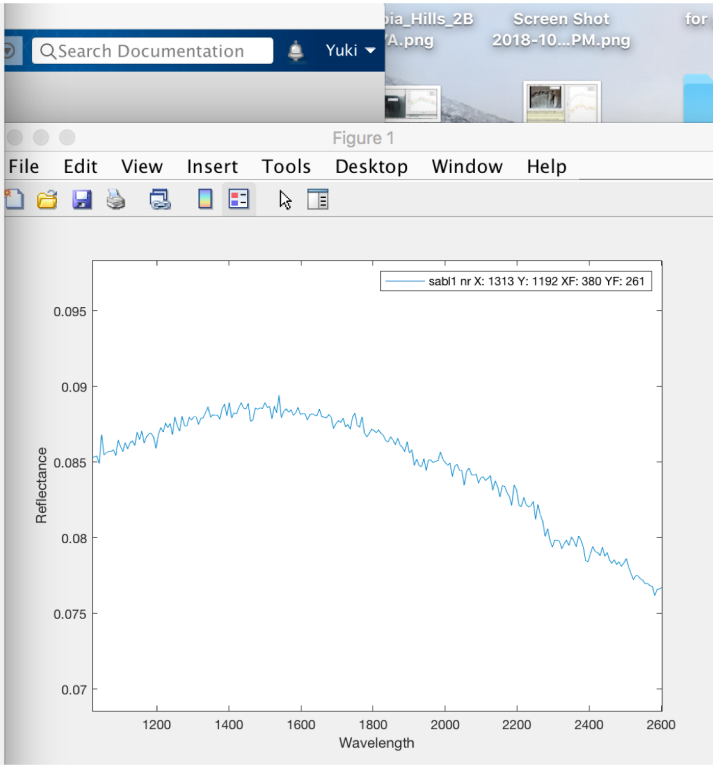


# Columbia Hills



# Columbia Hills



# Columbia Hills