Characterizing the Aqueous Geochemical History at Tyrrhena Terra, Mars

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AGU FALL MEETING
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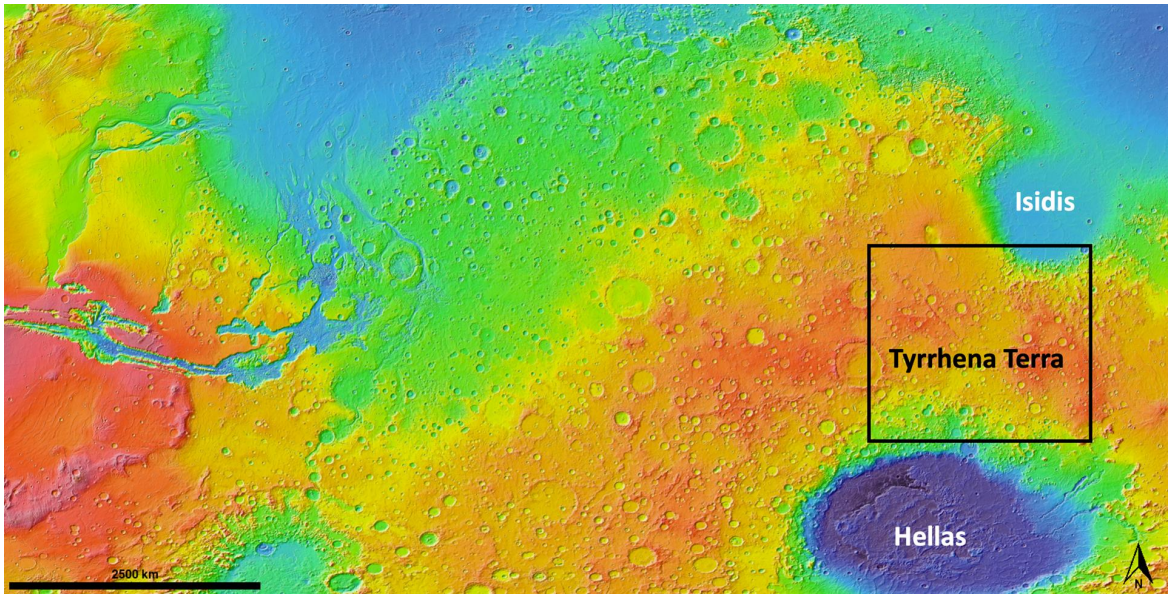
PLAIN LANGUAGE SUMMARY

We are performing coordinated analyses at central Tyrrhena Terra, Mars using multiple spectroscopic and imaging systems to characterize high temperature alteration featuring chlorite, silica, and zeolite versus low temperature alteration featuring smectites and hydrated sulfates. We are using orbital spectra with high coverage of the surface to identify sites of interest for detailed study with high resolution CRISM spectroscopy and HiRISE imagery. These close-up surface views are revealing mineral assemblages characteristic of distinct aqueous alteration environments. We are using these together with new geologic maps to piece together the geologic history of the region.

TYRRHENA TERRA REGION

Tyrrhena Terra is an intriguing region of Mars extending from the southern part of Isidis Basin at the Libya Montes southward to Hellas Basin. Noachian and Hesperian basement rocks are covered by Syrtis lavas, especially in the northwestern part of Tyrrhena Terra and the surface is carved by craters and fluvial features. The central region is marked by the craters Jarry-Desloges, Owen, Krupac, and Briault, and contains abundant Fe/Mg-rich phyllosilicates and olivine-bearing outcrops in Noachian-Hesperian terrains [1-5]. We are investigating the mineralogy and geology of this region through a coordinated study using TES, THEMIS, CRISM multispectral strips, CTX and HRSC imagery, and HRSC digital elevation models at a regional scale, as well as CRISM targeted images and HiRISE views of the surface at a local scale.

The Tyrrhena Terra region is shown here on a MOLA map of Mars for our group project at this site [3,4].



A geomorphological map of our project region (black box above) demonstrates that craters and fluvial features are abundant, and that much of the exposed surfaces are Noachian or Hesperian [6]. The units mapped are defined as:

NHm: Noachian-Hesperian massif material

NHf: Noachian-Hesperian fluted and dissected terrain

NHicp: Noachian-Hesperian inter-crater plains

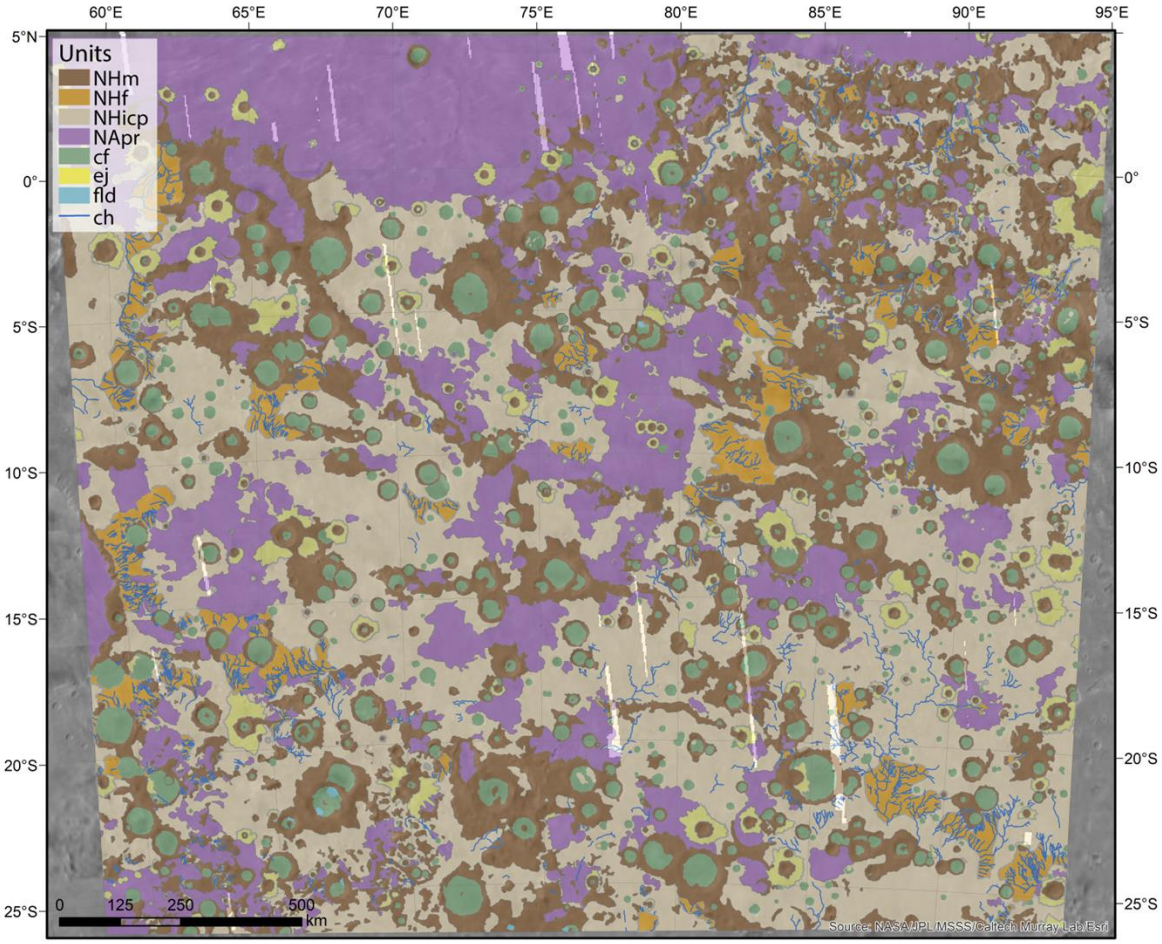
NApr: Noachian-Amazonian ridged plains

cf: crater floor

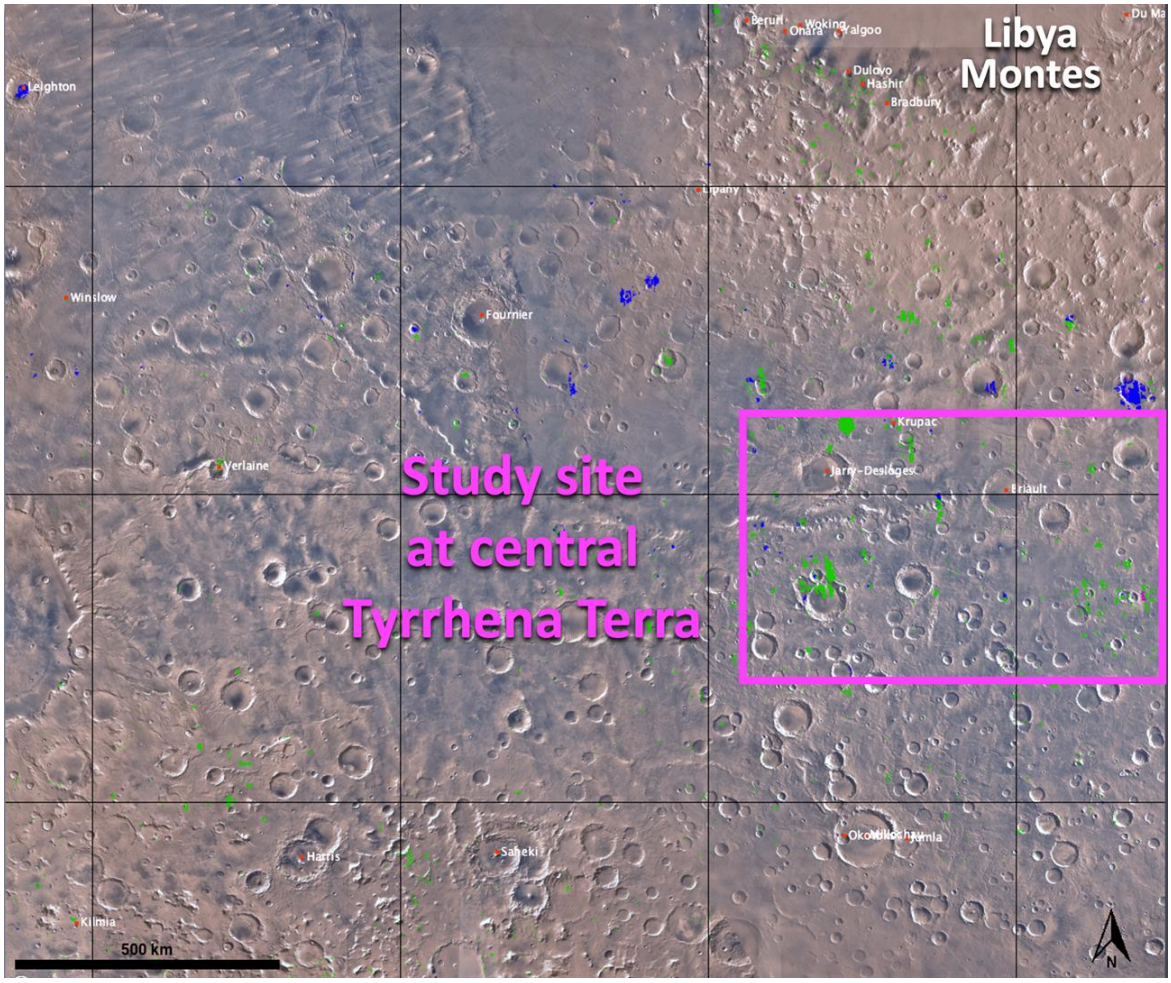
ej: ejecta

fld: fan-shaped and lobate deposit

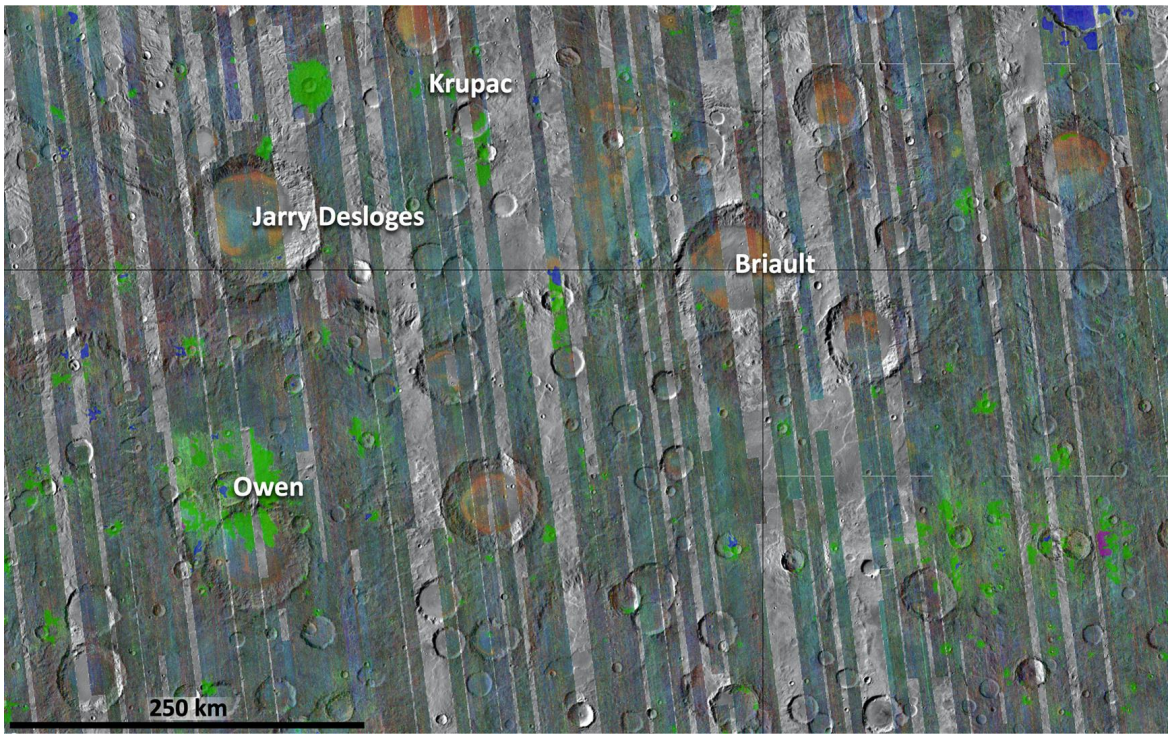
ch: channel



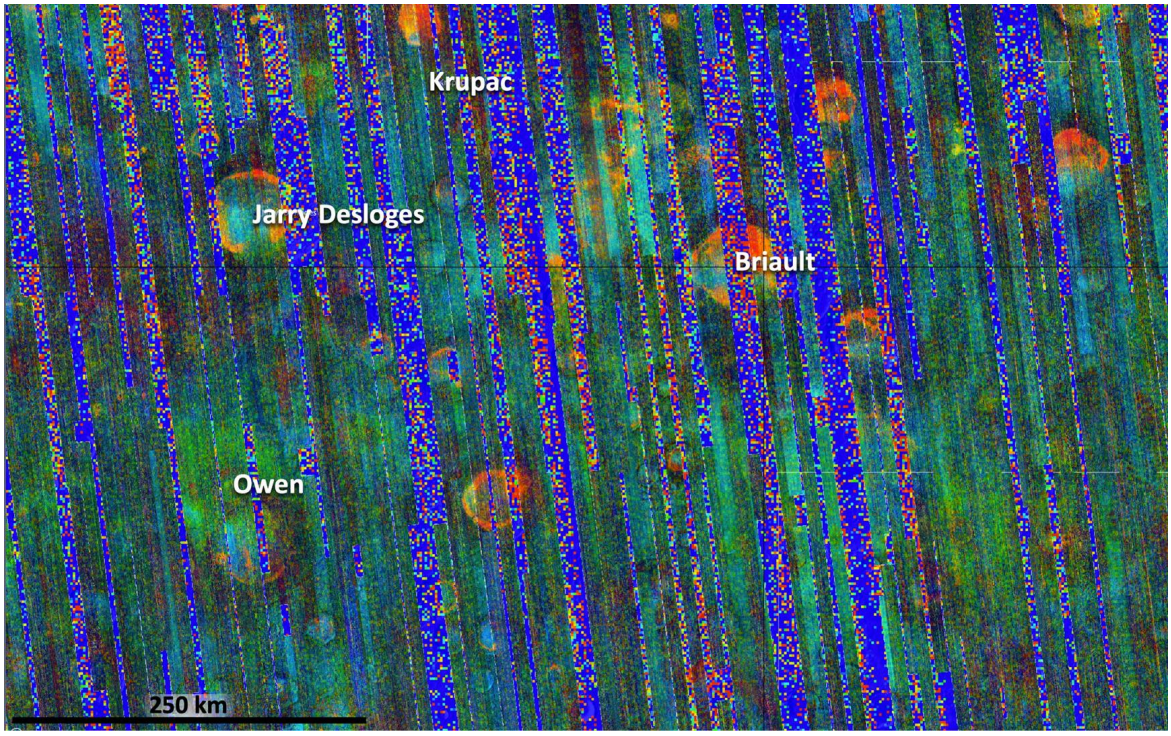
This view of our project region (black box above) includes Fe/Mg-phyllosilicate detections in green and chlorite detections in blue from CRISM analyses [2] over a Viking color mosaic. Central Tyrrhena Terra features abundant mafic signatures from olivine and pyroxene, and aqueous components including a variety of phyllosilicates and other hydrated materials. For this study, we are focusing on a part of central Tyrrhena Terra where phyllosilicates are more abundant.



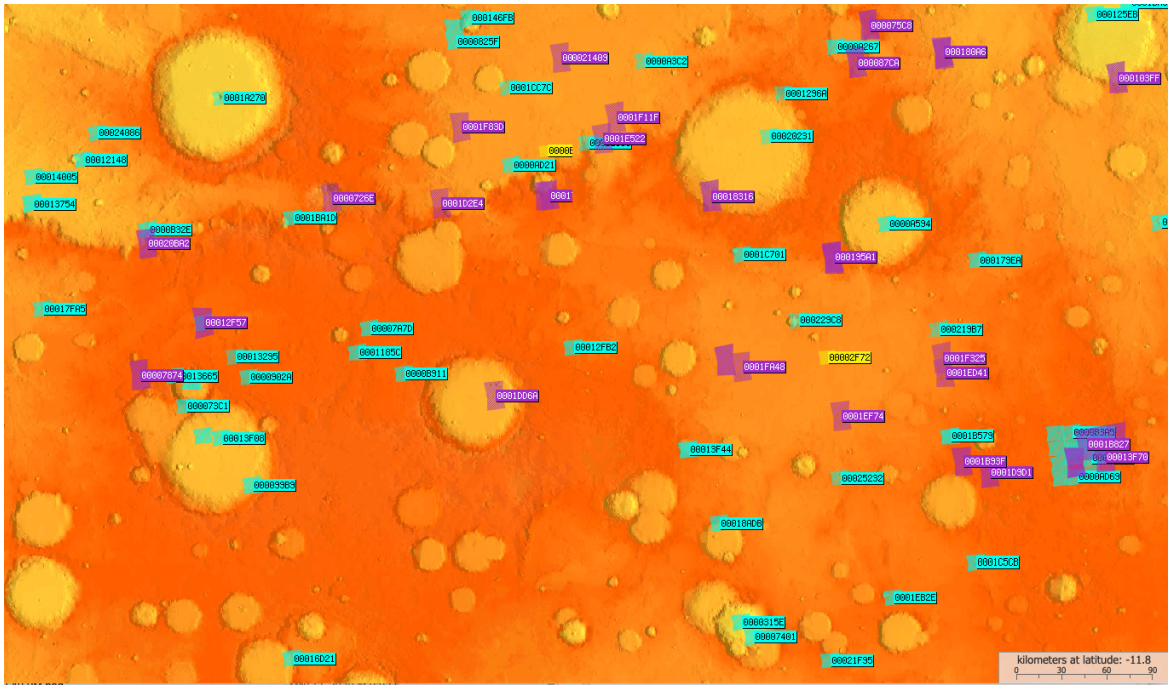
Our study site (pink box above) illustrates mineral detections from CRISM [2] including olivine (red/orange), pyroxene (cyan), Fe/Mg-phyllosilicate (green), chlorite (blue), and zeolite (pink).



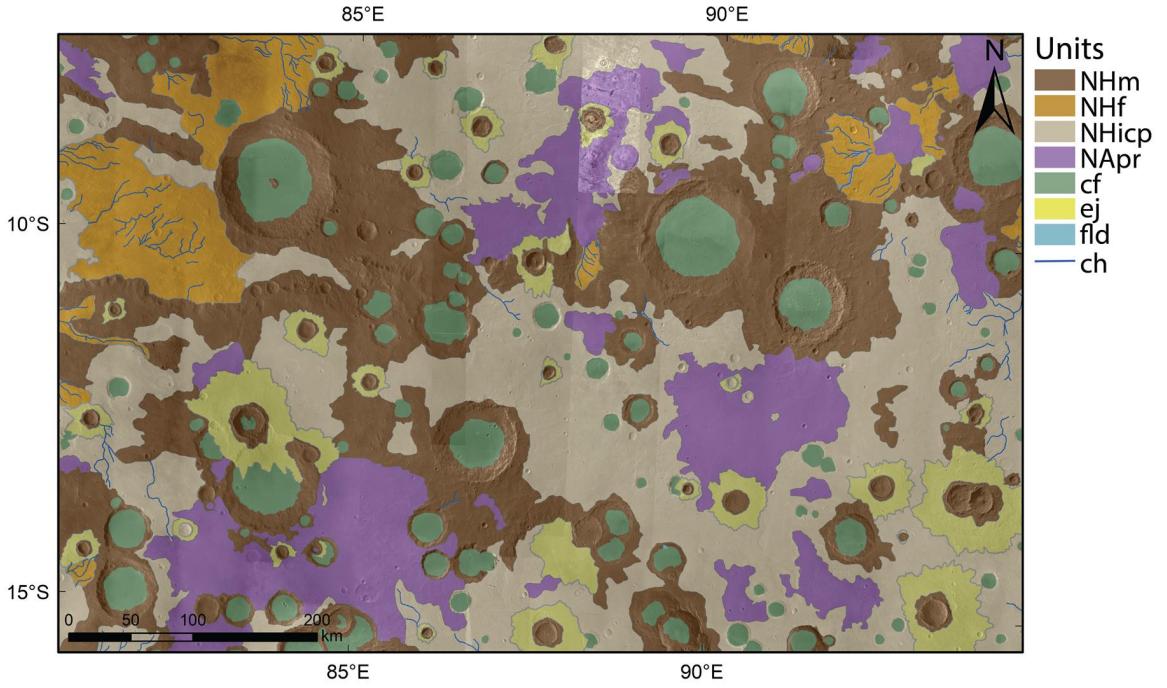
Another view of our study site (pink box above) compares the detections from CRISM above [2] over a TES map of Fo50 olivine (red) [5]. Red olivine detections from both datasets are consistent where overlapping data are available and typically occur inside the large craters.



This region also contains a large number of targeted CRISM images for detailed study of the mineralogy. This image displays the locations of the available CRISM images.



Finally, this map illustrates the geomorphological features for the central Tyrrhena Terra study site overlain on an HRSC mosaic.

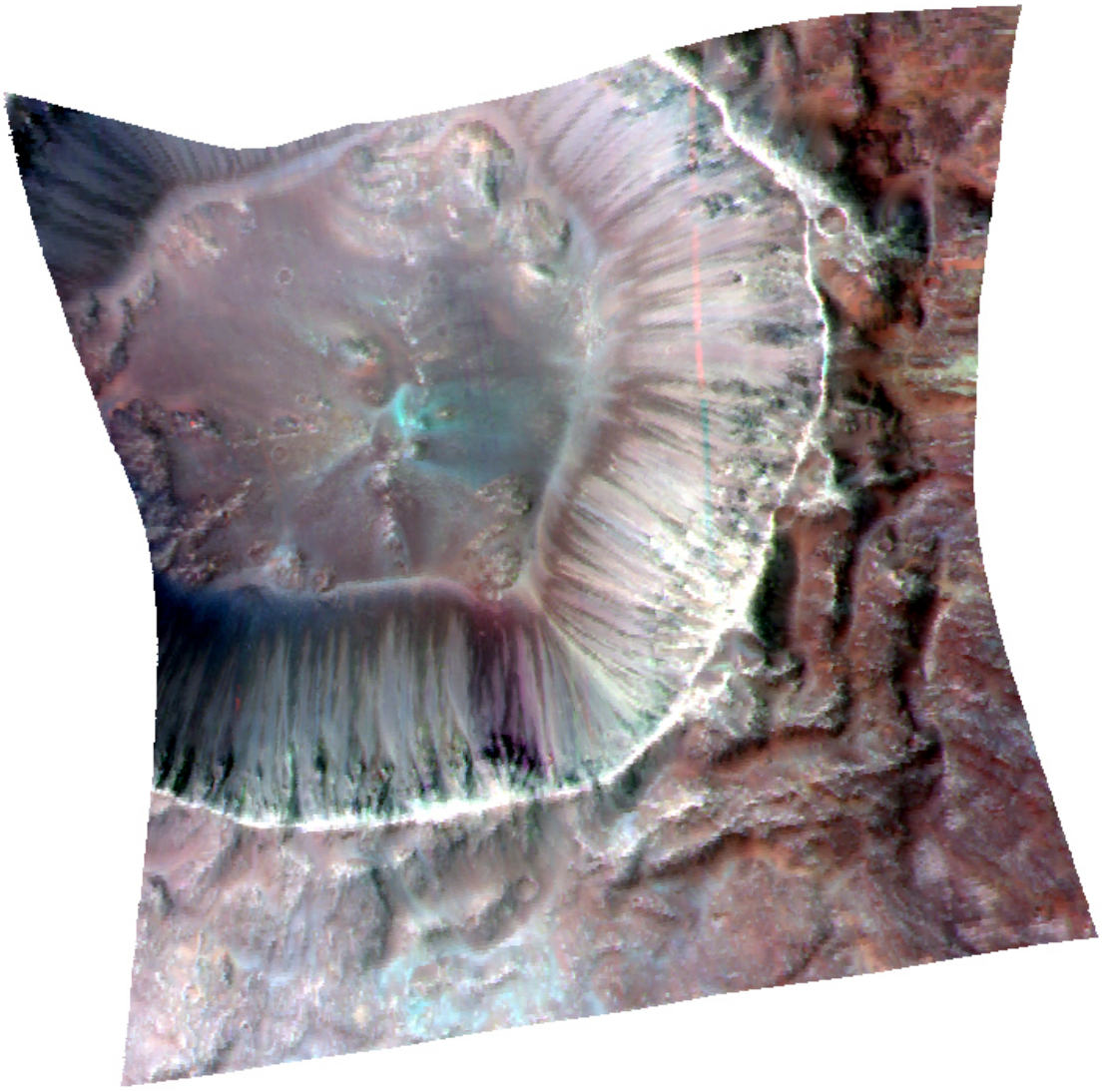

85°E
90°E
10°S
15°S
N
Units
NHm
NHf
NHicp
NApr
cf
ej
fld
ch
0
50
100
200
km
85°E
90°E

EVALUATING CRISM TARGETED IMAGES

MTRDR versions of CRISM images were used in this study to evaluate the mineralogy from targeted images. All available MTRDR images were downloaded from the PDS Geosciences Node (https://ode.rsl.wustl.edu/mars/indexproductsearch.aspx) and additional MTRDR images were prepared as outlined in [7]. We tested several mineral parameter options [8] in order to highlight mafic and aqueous components in the targeted CRISM images across central Tyrrhena Terra. The best options to illustrate the mineralogy of this region [9] with examples of each mineral parameter set are:

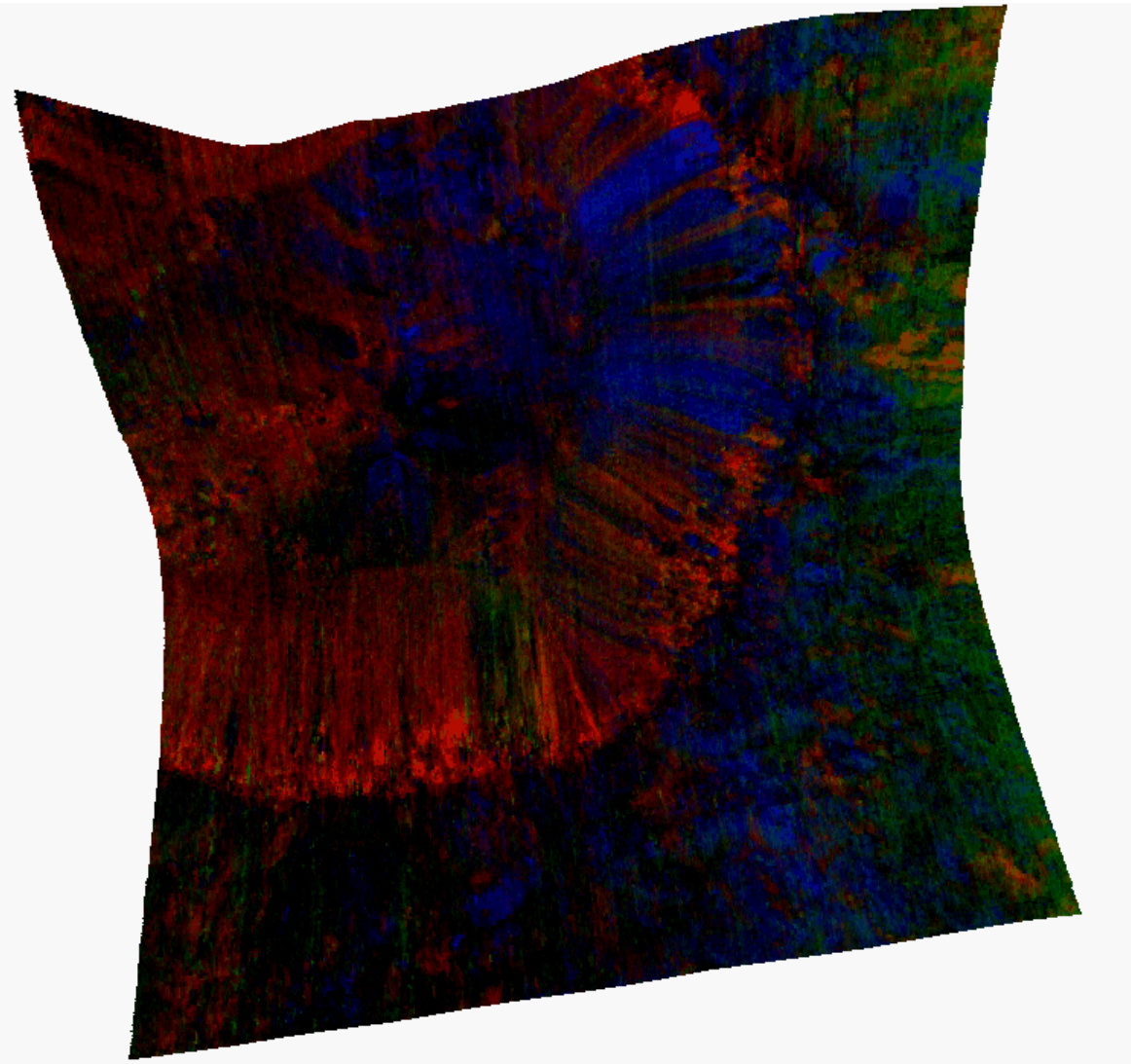
1) Enhanced infrared false color view

- R = 2.536 μm
- G = 1.336 μm
- B = 0.775 μm



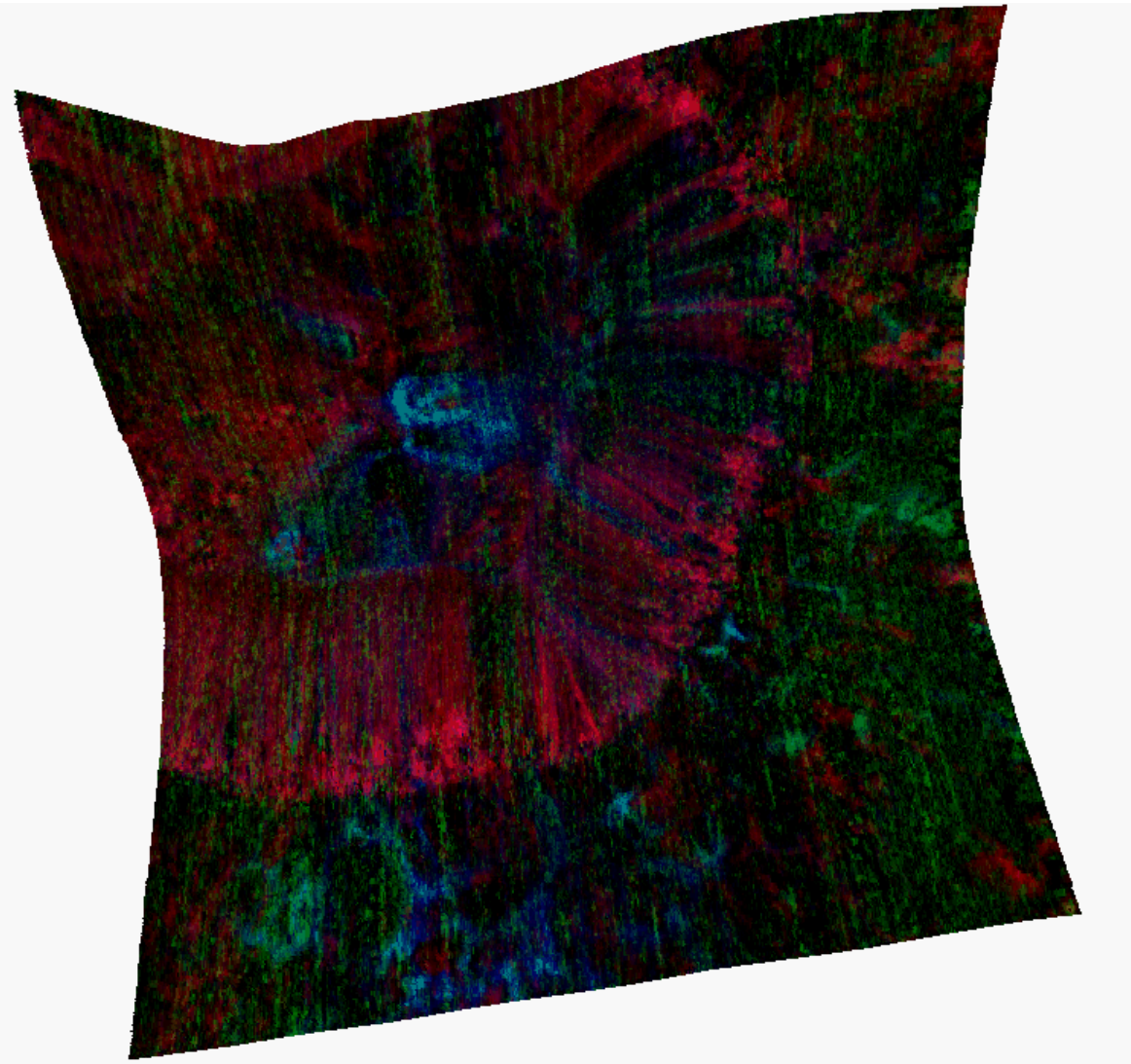
2) Mafic and Fe/Mg-phyllosilicate comparison

- R = D2300
- G = OLINDEX_3
- B = LCPINDEX_2



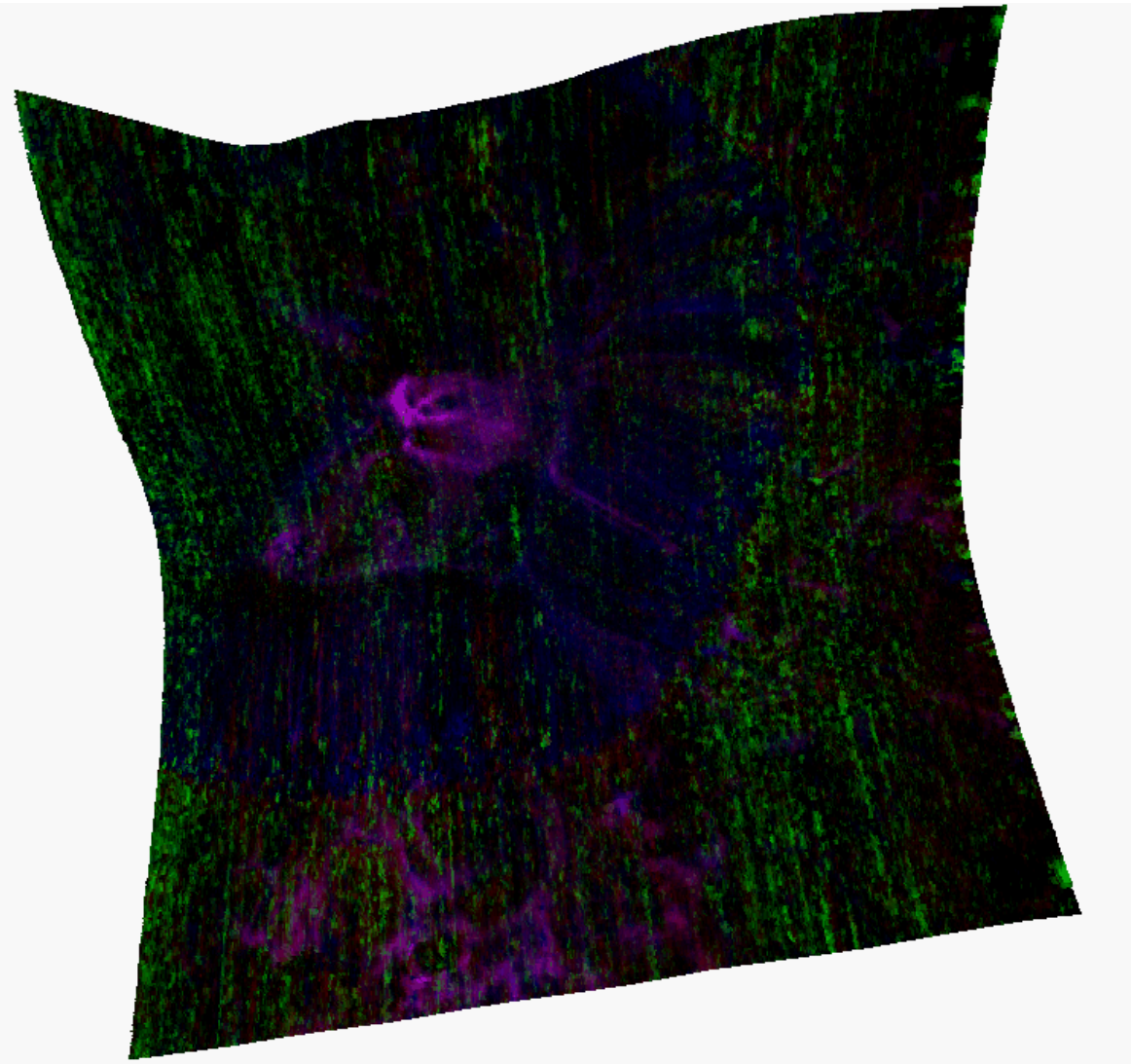
3) Fe/Mg-smectite vs chlorite

- R = D2300
- G = BD2500_2
- B = BD1900_2



4) Additional hydrated materials

- R = SINDEX_2
- G = BD2210_2
- B = BD1900_2



We processed these for all images across the study site and compared trends in the mineralogy. We used these results as a guide for collecting spectra of selected areas for detailed analyses.

Our study also includes analysis of 3D CRISM images over MOLA in order to gain a perspective view of the stratigraphy. Ongoing work is evaluating CRISM over HiRISE DTMs for detailed views of the morphologies of each compositional unit and stratigraphic relationships.

Here is an example of a short movie illustrating views of the 3D CRISM images for an enhanced infrared false color view from our study site.

[VIDEO] https://www.youtube.com/embed/7OwjQ8qWBXE?rel=0&fs=1&modestbranding=1&rel=0&showinfo=0

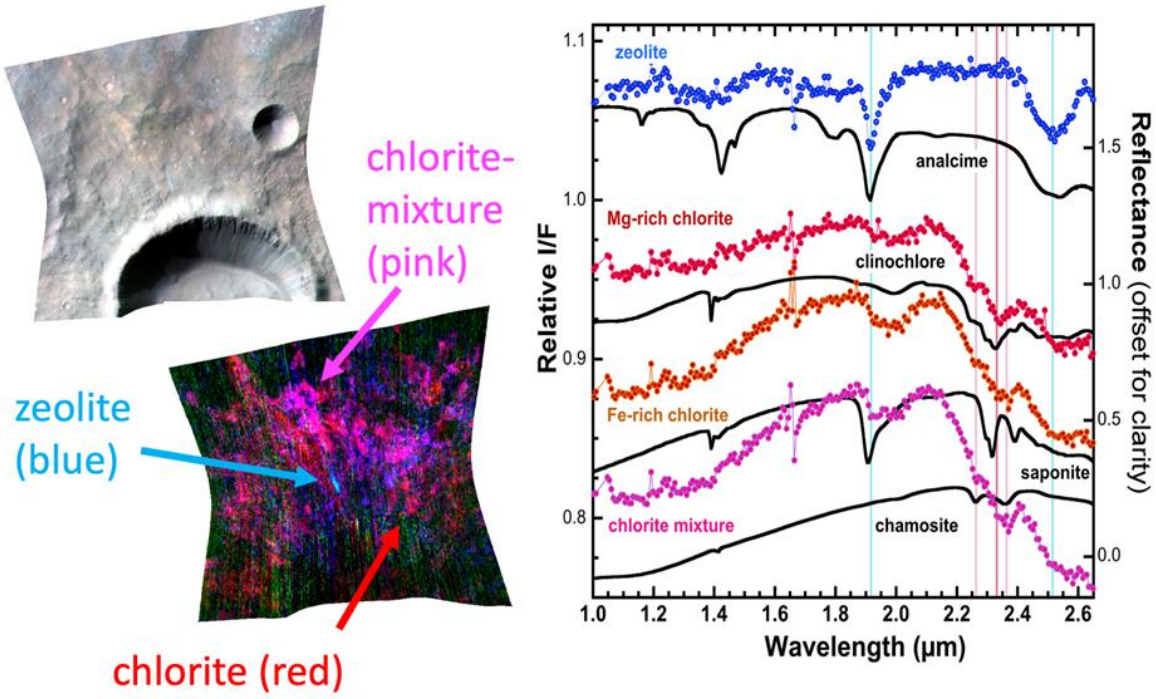
This short movie illustrates a similar view of the smectite-chlorite view from the same CRISM image.

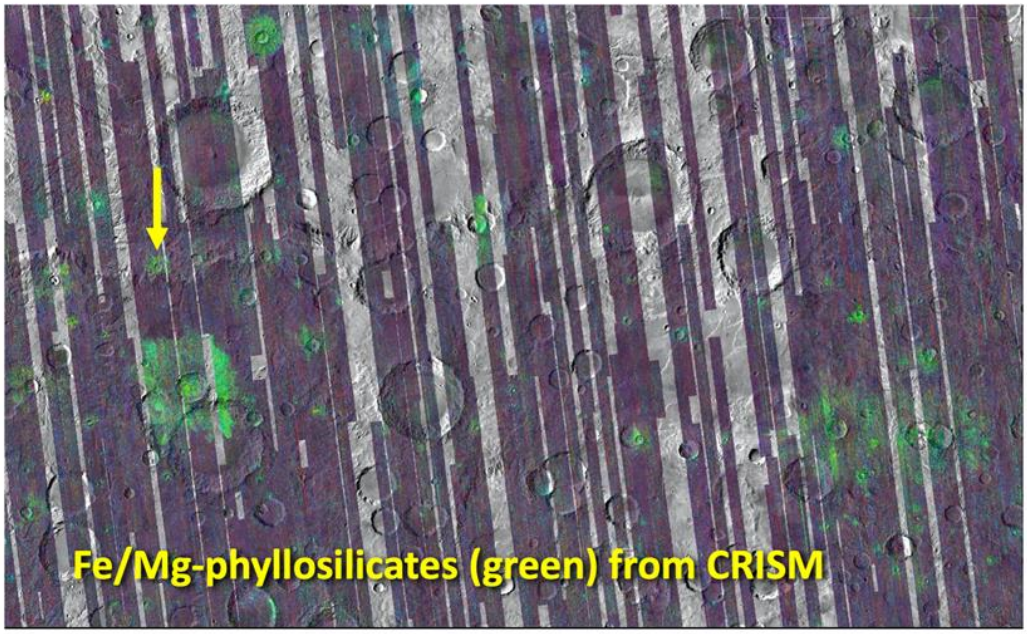
[VIDEO] https://www.youtube.com/embed/o6OqImtTGE4?rel=0&fs=1&modestbranding=1&rel=0&showinfo=0

SPECTRAL ANALYSES

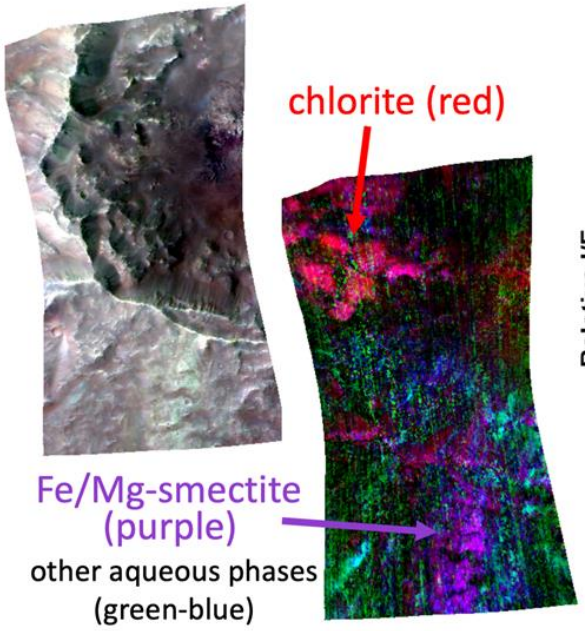
Analysis of targeted CRISM images indicates the presence of chlorite minerals with variable Mg and Fe contents, zeolite, Mg-smectite, and other hydrated materials.

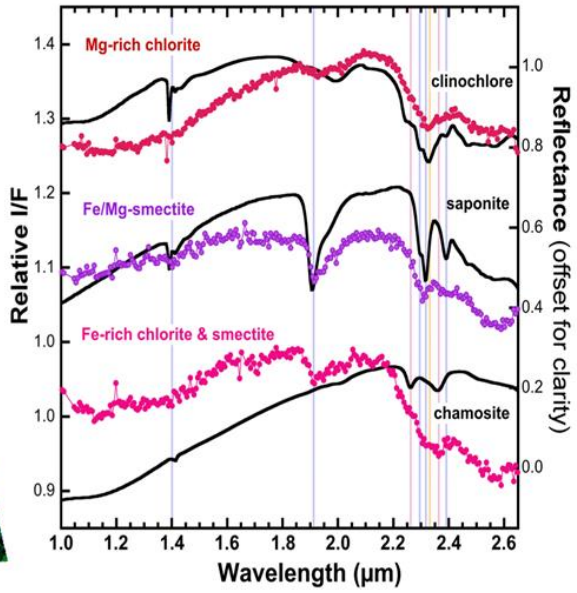
Chlorites are more common in the western part of this region. This image maps chlorite occurrences in red, chlorite mixtures in pink, and zeolite in blue. Example CRISM spectra of these units are shown in the plot with lab spectra of minerals for comparison.

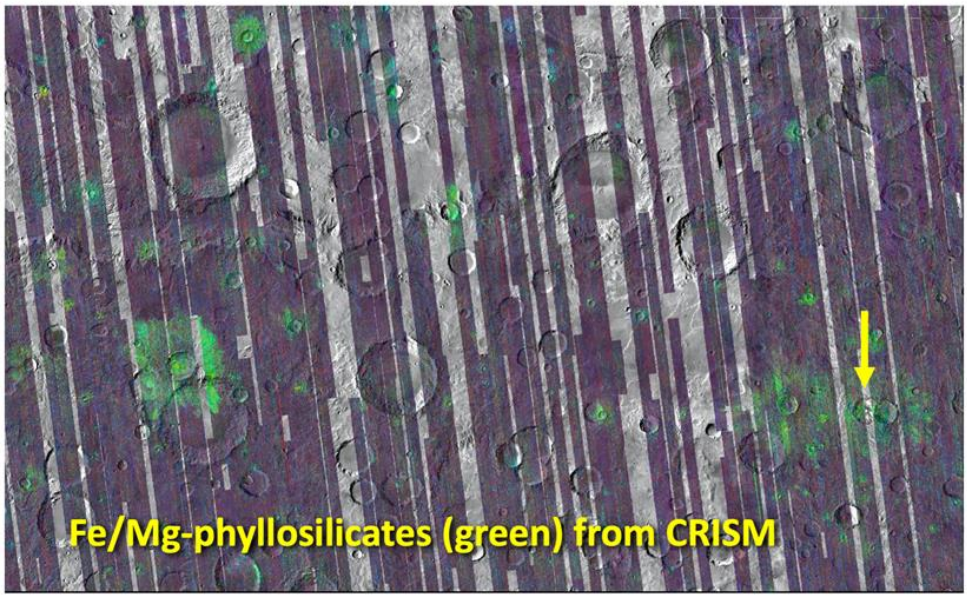




Fe/Mg-smectite and chlorite-saponite mixtures are more common in the eastern part of this region. Many of the smectite occurrences are consistent with the Mg-rich smectite saponite; however the mixed smectite-chlorite observations appear to contain the Fe-rich chlorite chamosite. A few spots are characteristic of the Mg-rich chlorite clinochlore. Example CRISM spectra of these units are shown in the plot with lab spectra of minerals for comparison.


chlorite (red)
Fe/Mg-smectite
(purple)
other aqueous phases
(green-blue)


Mg-rich chlorite
clinochlore
Fe/Mg-smectite
saponite
Fe-rich chlorite & smectite
chamosite
Relative I/F
Reflectance (offset for clarity)
Wavelength (μm)
1.4
1.3
1.2
1.1
1.0
1.0
0.9
1.0
0.8
0.6
0.4
0.2
0.0
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6


Fe/Mg-phyllosilicates (green) from CRISM

DISCUSSION AND MAIN POINTS

Many of the phyllosilicates in this region are located in crater ejecta and in central crater mounds, consistent with uplift of ancient materials, but some are present in dissected terrains. The phyllosilicate spectra across the central Tyrrhena Terra region are most consistent with chlorite, Fe/Mg-smectite, and mixed smectite-chlorite. A few hydrated silica and zeolite outcrops are also present. This mineralogy is consistent with higher temperature processes than the primarily Fe/Mg-smectite and carbonate spectra observed in the Libya Montes region to the north [3,4]. A few sites towards the east of our study site contain more Fe/Mg-smectite than chlorite and additional hydrated phases, which likely represent a different formation environment. Ongoing investigations of the targeted CRISM images at the eastern part of this area are characterizing the stratigraphy of these aqueous units and their association with higher temperature units towards the west and smectite-carbonate units towards the north.

ADDITIONAL INFORMATION

Acknowledgments:

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References:

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[2] Viviano, C. E. & M. S. Phillips (2019), Hydrothermal alteration related to large impact basins, 9th International Conf. on Mars (Abstract #6359) Pasadena, CA.

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[9] Grant, F. H. & J. L. Bishop (2021), Mapping phyllosilicates and aqueous alteration products at Tyrrhena Terra, Mars, In 52nd Lunar Planet. Sci. Conf. (in preparation) The Woodlands, TX.

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ABSTRACT

Tyrrhena Terra is an intriguing region of Mars extending from the southern part of Isidis Basin at the Libya Montes southward to Hellas Basin. Noachian and Hesperian basement rocks are covered by Syrtis lavas, especially in the northwestern part of Tyrrhena Terra and the surface is carved by craters and fluvial features. The central region is marked by the craters Jarry-Desloges, Owen, and Briault, and contains abundant Fe/Mg-rich phyllosilicates and olivine-bearing outcrops in Noachian-Hesperian terrain [1,2]. Many of the phyllosilicates in this region are located in crater ejecta and in central crater mounds, consistent with uplift of ancient materials, but some are present in dissected terrains. We are investigating the mineralogy and geology of this region through a coordinated study using TES, THEMIS, CRISM multispectral strips, CTX and HRSC imagery, and HRSC digital elevation models at a regional scale, as well as CRISM targeted images and HiRISE views of the surface at a closer scale.

The phyllosilicate spectra across the central Tyrrhena Terra region (see attached figure) are most consistent with chlorite, Fe/Mg-smectite, and mixed smectite-chlorite. A few hydrated silica and zeolite outcrops are also present. This mineralogy is consistent with higher temperature processes than the primarily Fe/Mg-smectite and carbonate spectra observed in the Libya Montes region [3,4]. A few sites towards the east of our study site contain more Fe/Mg-smectite than chlorite and additional hydrated phases including sulfates, which likely represent a different formation environment. Ongoing investigations of the targeted CRISM images at the eastern part of this area are characterizing the stratigraphy of these aqueous units and their association with higher temperature units towards the west and smectite-carbonate units towards the north.

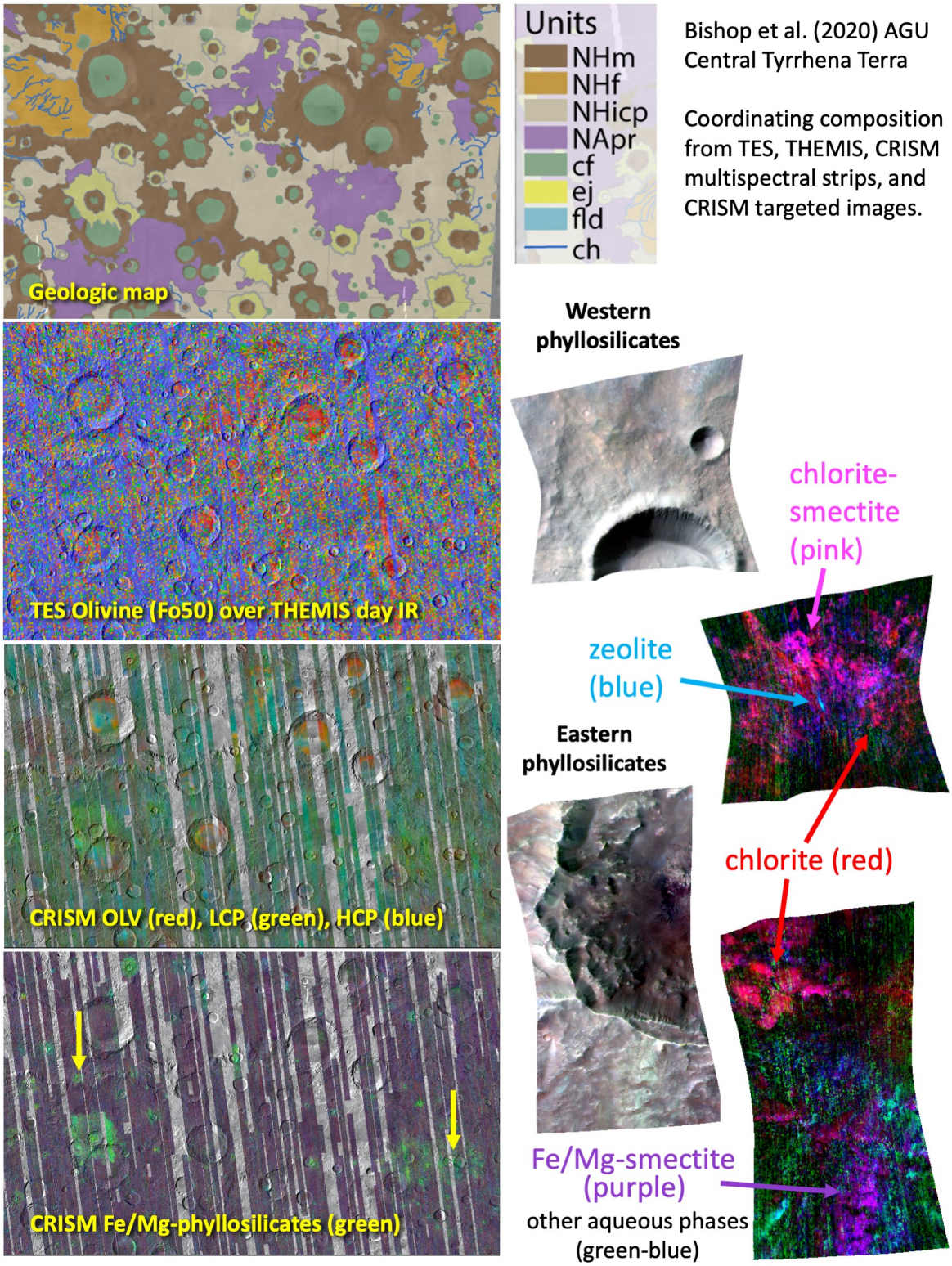
References:

[1] Loizeau D. et al. (2012) Characterization of hydrated silicate-bearing outcrops in Tyrrhena Terra, Mars... *Icarus*. 219**,** 476-497.

[2] Viviano C.E. & Phillips M.S. (2019) Hydrothermal alteration related to large impact basins. *9th Int'l Mars Conf.*, Abstract #6359.

[3] Bishop J.L. et al. (2013) Mineralogy and morphology of geologic units at Libya Montes, Mars... *JGR*. 118**,** 487–513.

[4] Tirsch D. et al. (2018) Geology of central Libya Montes, Mars... *Icarus*. 314, 12-34.



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