MAPPING PHYLLOSILICATES AND AQUEOUS ALTERATION PRODUCTS AT TYRRHENA TERRA, MARS. F. H. Grant[1] and J. L. Bishop[2], [1]University of California, Los Angeles (Los Angeles, CA; fgrant@g.ucla.edu), [2]SETI Institute (Mountain View, CA).

Summary: Outcrops of phyllosilicates and small sites of less common aqueous alteration minerals were mapped at Tyrrhena Terra on Mars using CRISM parameters, and CRISM spectral data were collected to more closely analyze the mineralogy in this region. Fe- and Mg-rich smectite and chlorite group phyllosilicates are both detected at Tyrrhena Terra, including saponite, chamosite, and clinochlore. Zeolites and carbonates are among the rarer alteration minerals also observed at Tyrrhena Terra that further constrain the alteration history in this region. More chlorite than smectite is observed, indicating higher temperature alteration processes occurred at Tyrrhena Terra.

Introduction: Tyrrhena Terra is a region in the southern hemisphere of Mars, between the Isidis and Hellas impact basins and south of Libya Montes. The selected study site (Fig. 1) is of particular interest because it has a large concentration of phyllosilicate minerals exposed on the surface, among small outcrops of rarer aqueous alteration minerals [1]. Phyllosilicates are a crucial mineral group to study when striving to understand the aqueous alteration history of a region. Less common aqueous alteration minerals, including zeolite, carbonate, and hydrated sulfates, are also important to further constrain the alteration history of a region [2]. For this research project, we focused primarily on identifying the phyllosilicate minerals smectite and chlorite. Chlorites form at higher temperatures than smectites [3], thus observation of these two mineral groups yields information about the aqueous alteration history of the Tyrrhena Terra region. CRISM parameters were used to observe general trends in the surface mineralogy and spectral data were collected in order to identify the specific mineral types present within outcrops of interest.

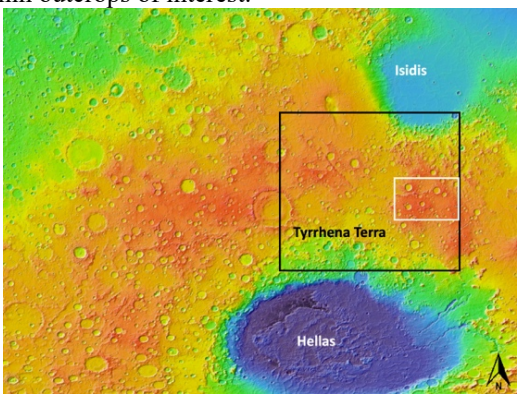

Fig. 1 Study site marked by white box within Tyrrhena Terra region of Mars.

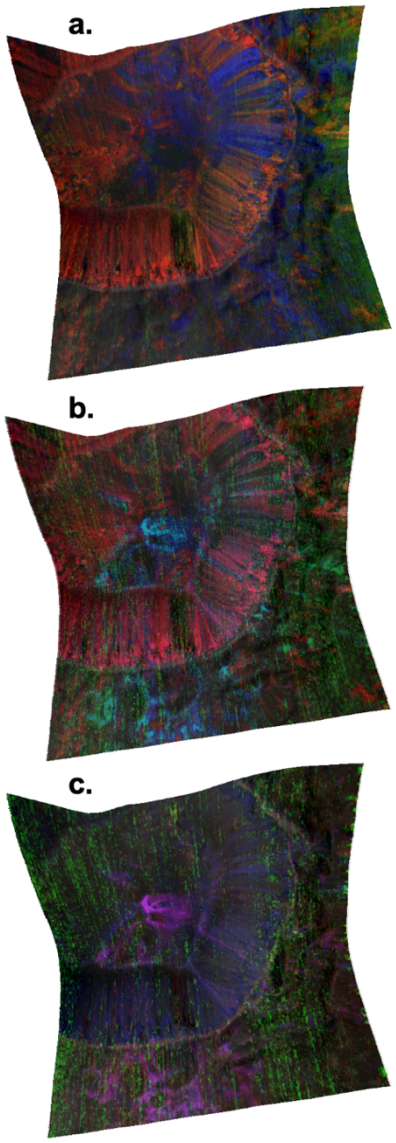

Fig. 2 Views of CRISM image FRT000148C1 highlighting mineralogy with different spectral parameters projected onto FAL (false color IR) using 25% transparency. a) Fe/Mg-phyllosilicates in red, mafics in green and blue, b) chlorites in red, smectites in purple, zeolites in blue, and c) Al-phyllosilicates in blue, other hydrated materials in purple.

CRISM Images and Parameters: We investigated ~55 CRISM images processed with the MTRDR calibration [4] at our study site (Fig. 1), using mineral parameters to document trends within this region. After testing combinations of the 60 total CRISM parameters [2], we selected combinations to differentiate phyllosil-

icates from mafic minerals, as well as smectites from chlorites and other aqueous phases. The parameter combination R: D2300, G: OLINDEX3, B: LCPINDEX2, shows phyllosilicates in red and mafic minerals from lava flows in green and blue (Fig. 2a). R: D2300, G: BD2500_2, B: BD1900_2 differentiates the phyllosilicate types: smectites appear in purple and chlorites appeared in red, while a mix of smectite and chlorite appeared pink (Fig. 2b). This parameter combination also identified rarer alteration minerals such as zeolites in blue or blue-green colors. In order to further identify occurrences of uncommon aqueous alteration minerals, the combination R: SINDEX2, G: BD2210_2, B: BD1900_2 was used, wherein additional hydrated minerals appeared in purple, while phyllosilicate minerals appeared in blue (Fig. 2c) [2].

CRISM Spectral Data: After observing the general mineralogy of the Tyrrhena Terra region using CRISM RGB parameters, we collected spectra of 5x5 and 10x10 pixel regions from mineral outcrops of particular interest, focusing on smectite and chlorite minerals. Saponite, the Mg-rich endmember in the smectite group, was identified based on spectral bands at 1.41, 1.91, and 2.31 µm (Fig. 3). Both chlorite group endmembers were observed in our study region (Figs. 3-4). Chamosite, the Fe-rich chlorite endmember, is identified by bands at 2.26 and 2.36 µm, and clinochlore, the Mg-rich chlorite endmember, has bands at 2.25 and 2.36 µm [3]. Also observed were mixtures of smectite and chlorite minerals, with bands due to both mineral groups in a single spectrum (Fig. 3). Analysis of the spectral data for the rarer alteration minerals that were observed in the RGB parameter views is ongoing.

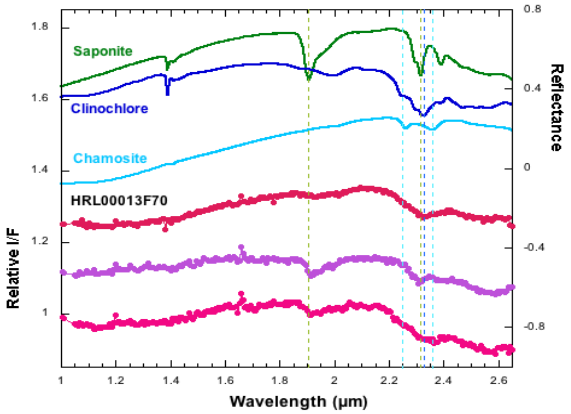

Fig. 3 Selected CRISM spectra illustrating spectral features consistent with saponite, clinochlore, chamosite, and mixed smectite-chlorite.

Mineralogy Implications: The phyllosilicate minerals observed at Tyrrhena Terra were evaluated with a focus on understanding the aqueous alteration history. Aqueous outcrops at Tyrrhena Terra contain more chlorite than smectite and the smectite observed here is primarily saponite, while Fe/Mg-smectite and carbonate are more prevalent in the Libya Montes region to the north [5-6]. The abundant chlorite and occasional zeolite at Tyrrhena Terra indicate hydrothermal alteration of the ancient basaltic bedrock occurred in this region. Chlorite forms under higher temperature conditions (low-grade metamorphism [1]) than those associated with smectite formation. Analysis to understand the nature of this higher temperature chlorite-forming alteration event is ongoing, however it is likely that this occurred after the initial alteration of the ancient basaltic bedrock to smectite ~4 Ga [5] and before the olivine-rich lava covered in this region ~3.7 Ga [6].

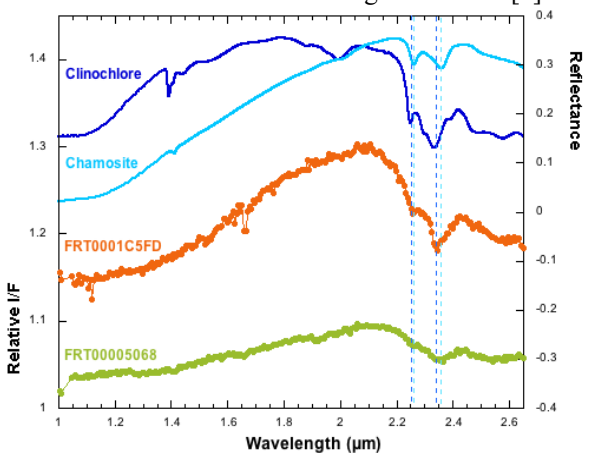

Fig. 4 Selected CRISM spectra highlighting differences between clinochlore and chamosite.

Future work on this research project will include analyzing more closely the occurrences of chamosite and clinochlore to understand trends with regards to Fe and Mg in the fluids. Additionally, zeolite and carbonate are found in a few small sites at Tyrrhena Terra. Further study of these rare alteration minerals in the CRISM spectral data will be crucial to constraining the alteration history in this region. We are considering potential contributions from hydrothermal groundwater [7] and volcanic events.

Acknowledgments: We thank T. Gregg and the LPI SUPPR program, as well as the SETI Institute REU program, and NASA MDAP for supporting this project. Many CRISM MTRDR images were obtained from the PDS Geosciences Node. We are grateful to F. Seelos for contributing the additional images.

References: [1] Loizeau D. et al. (2012) *Icarus*, *219*, 476-497. [2] Viviano C. E. et al. (2014) *JGR*, *119*, 1403-1431. [3] Bishop J. L. et al. (2008) *Clay Minerals*, *43*, 35-54. [4] Seelos F. P. et al. (2016) 47th *LPSC*, #1783. [5] Bishop J. L. et al. (2013) *JGR*, *118*, 487-513. [6] Tirsch D. et al. (2018) *Icarus*, *314*, 12-34. [7] Ojha L. et al. (2020) *Sci. Adv.*, *6 (49)*, eabb1669.