SMECTITE DETECTIONS AT MURRAY RIDGE AND CAPE TRIBULATION, MARS, FROM ALONG-TRACK OVERSAMPLED CRISM OBSERVATIONS. V. Fox[1], R. Arvidson[1], S. Murchie[2] and S. Squyres[3], [1]Washington University in Saint Louis, Mo, 63130, foxv@levee.wustl.edu, [2]Applied Physics Laboratory, Laurel, MD, 20723, USA, [3]Department of Astronomy, Cornell University, Ithaca, NY 14853, USA

Introduction: Aluminous, ferric and magnesian smectites were identified along the rim of Endeavour crater in three major outcrops using CRISM hyperspectral data from enhanced spatial resolution along-track oversampled (ATO) observations. Single Scattering Albedos (SSA) from 0.4-2.5µm were retrieved using a first-principles radiative transfer model and processed to the standard 18 m/pixel resolution to increase the signal to noise ratio and improve detections of faint absorptions. An Al-OH combination band at 2.21µm identifies montmorillonite at two locations on the western edge of Murray Ridge. This detection is likely associated with the alteration of the Shoemaker formation impact breccias. A mix of saponite and nontronite, identified using metal-OH combination absorptions at 2.28-2.31 and 2.39µm, together with montmorillonite, is apparent on the floor of a cross-cutting valley on Cape Tribulation, which may be an exposure of ancient bedrock predating the Endeavour impact event. These outcrops will be visited by the Opportunity rover during the next two years to decipher the stratigraphic, structural, and aqueous histories of these smectite-bearing deposits.

Data and Methods: Four recent ATO observations (ATO0002AAD, ATO0002B95C, ATO0002DDF9 and ATO0002EC36) cover the southwestern rim of Endeavour Crater where Opportunity is currently located. We modeled the SSA of the surface from first principles using the radiative transfer modeling package DISORT, which accounts for dust and ice aerosols as well as gas absorptions by CO_2, CO, and water vapor [2]. The Hapke surface scattering function [3] was used to model how light is scattered from the surface. SSA is independent of the observational geometry and can be recast using the full Hapke function into other reflectance measures, enabling direct comparison to laboratory observations.

SSA spectra for the Endeavour rim segments of each CRISM scene were manually inspected for absorption features characteristic of phyllosilicates between 2.1 and 2.5 µm. Both systematic and random spectral noise is minimized at these wavelengths because CRISM onboard calibration lamp has high intensity at these wavelengths, the detector sensitivity is high, and noise from thermal background is relatively low. Individual pixels with features above the noise threshold and with appropriate band widths were averaged to obtain a mean spectrum for each mapped region of interest. Spectra were filtered to reduce noise from the detector operating at higher temperatures than originally planned. Regions of interest were localized using HiRISE observations of the rim to confirm geologic and morphologic context of the detections.

Al-smectites at Murray Ridge: A bright outcrop at the northern tip of Murray Ridge exhibits an Al-OH vibrational absorption feature at ~2.21 µm (green region in Figure 1) characteristic of montmorillonite. Opportunity carried out a cursory investigation of the outcrop, called Moreton Island, and determined that the montmorillionite spectral signature corresponds to a light-toned, matrix-rich facies of the Shoemaker formation impact breccia. Texturally, Moreton Island has more matrix than most breccias observed at Cape York. Compositional analysis indicate that Fe and Mn have been fractionated with respect to the Cape York breccias, and that Moreton Island has slight enrichments of Al and Si with respect to unaltered Martian basalts [5]. This implies that Moreton Island materials have been subjected to minor aqueous alteration [5].

The 2.21 µm absorption feature was also detected in a west-facing linear cliff face (blue region in Figure 1) about 600 meters south of Moreton Island. The outcrop is hypothesized to be a Shoemaker breccia member similar to Moreton Island, and provides a large exposure with ~30 m of vertical stratigraphic extent and ~250 m of along-strike bedding for Opportunity to explore and characterize.

Fe-Mg Smectites at Cape Tribulation: Another 3000 meters south along Cape Tribulation from Moreton Island is a valley that cross-cuts the rim ridge (red region in Figure 2). Metal-OH absorptions indicate the presence of three smectites - montmorillonite, saponite and nontronite - in the exposed bedrock on the valley floor. The mix of Fe and Mg species, with absorption bands broadly around 2.28-2.31 µm and 2.39 µm, were previously reported in [6]. There is also a shallow but detectable band around 2.21 µm, again indicating the presence of montmorillonite. Alteration studies of terrestrial analogues show that the absorption depths place an upper limit on the amount of smectite present in the outcrop as about 5% [7]. Consistent results from CRISM observations ATO00019E9C, ATO0002DDF9 and FRT000CE1D indicate that the body of the outcrop is limited to the valley floor, a heavily fractured bedrock unit in the HiRISE images.

Conclusions: Opportunity-based investigations will be necessary to determine formation process of the smectite assemblages identified along Murray Ridge and in the valley cutting across Cape Tribulation.

Extended investigations planned for the coming months along Murray Ridge will determine if the montmorillonite-bearing outcrop 600 m south of Moreton Island is a Shoemaker breccia similar to Moreton Island (Figure 3, top). Questions to be addressed include whether or not the montmorillonite is limited to a particular stratigraphic layer or facies within the outcrop, is a veneer or coating on the surface, and if the related outcrop is more widespread than determined from orbit. Surface exploration will also allow for detection and characterization of small-scale textural and morphologic features not visible from orbit, such as veins or bedding.

Exploration by Opportunity will also be crucial for understanding the geologic context of the smectite assemblage observed on Cape Tribulation. The valley floor (Figure 3, bottom) may expose rocks older than the Shoemaker formation materials and similar to the Matijevic formation rocks observed at Matijevic Hill, Cape York, where nontronite and montmorillite were detected [4]. If this is the case, detailed characterization of the smectite-bearing outcrops will allow comparisons to the Matijevic formation materials and reconstruction of aqueous conditions for an early period in Martian history. The relatively large areal exposure of the valley as compared to exposures of the Matijevic formation on Matijevic Hill will allow detailed stratigraphic mapping and the search for textural features indicative of the original depositional environment. Combined with the mineralogic and compositional data this will allow a detailed reconstruction of early surface and/or subsurface Martian environmental conditions and implications for habitability and life.

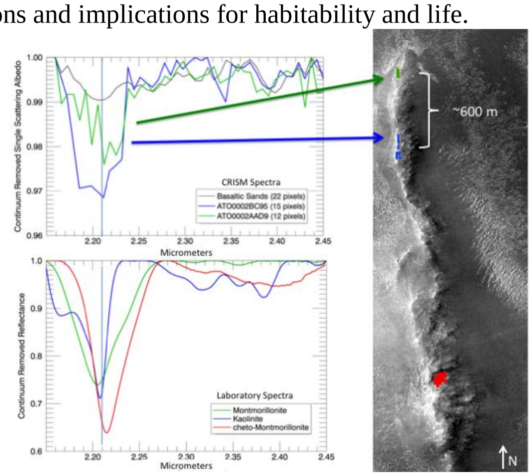

Figure 1. CRISM spectral retrievals (top) from the green and blue regions indicated in the HiRISE image, compared to laboratory spectra (bottom) of aluminous clay minerals. The CRISM basalt sand control spectra is taken from the dunes within Endeavour Crater.

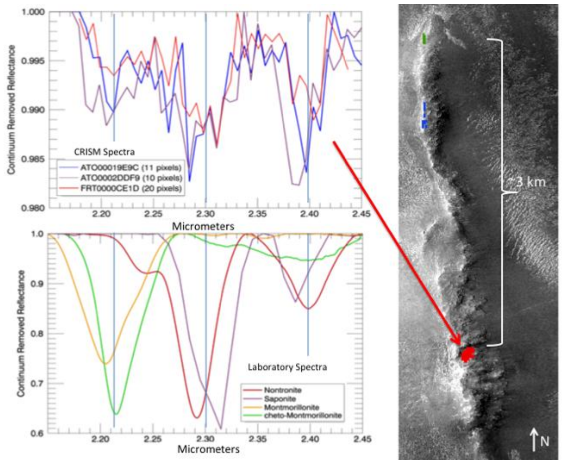

Figure 2. CRISM spectral retrievals (bottom) from the red region indicated in the HiRISE image indicate a mix of nontronite, saponite and montmorillonite. Smectite laboratory samples for comparison are above.

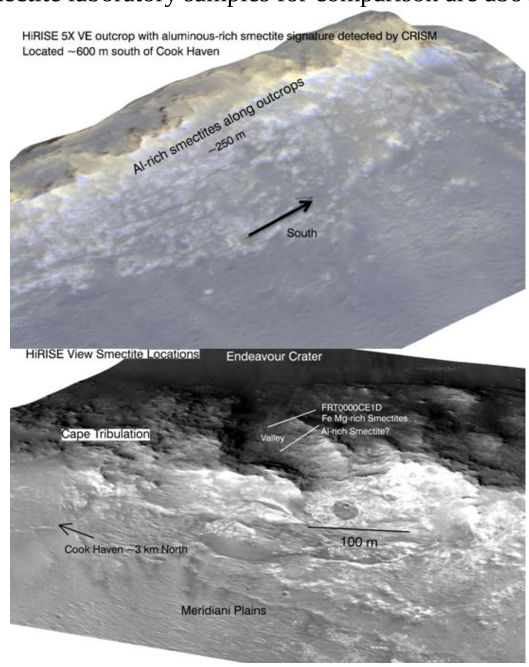

Figure 3. Regions along Endeavour's rim to be explored. Top: Al-smectite bearing linear cliff face, indicated in blue in Figures 1 and 2. Bottom: The valley that cross-cuts Cape Tribulation. Fe, Mg and Al smectites are associated with the fractures visible on the valley floor, in red in Figures 1 and 2.

References: [1] Murchie S., et al, (2007) *JGR*, doi:200710.1029/2006JE002682. [2] Stamnes K., et al. (1988) *Applied Optics, 27*, 12. [3] Hapke, B. (2012) *Cambridge University Press* [4] Arvidson, R., et al., (2014) *Science* 343 [5] Mittlefehldt, D., et al., (2014) *LPS XLV*, Abstract #1604 [6] Wray, J.J. et al. (2009) *GRL*, doi:10.1029/2009GL040734. [7] Ehlmann, B. (2010) *Moscow Solar System Symposium*, 1H-S3