Hydrated minerals on Endeavour Crater's rim, interior, and surrounding plains: New insights from CRISM data. E. Z. Noe Dobrea[1], J.J. Wray[2], F.J. Calef III[3], T.J. Parker[3], and S.L. Murchie[4], [1]Planetary Science Institute, Tucson, AZ (eldar@psi.edu) [2]School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, GA; [3]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA; [4]Johns Hopkins University Applied Physics Laboratory, Laurel, MD.

Introduction: The Mars Exploration Rover (MER) Opportunity reached the Cape York rim segment of Endeavour crater on August 9, 2011. Endeavour is a middle to late Noachian- aged, 20-km crater that has been largely infilled and buried by sulfate-bearing sedimentary deposits that unconformably mantle Meridiani Planum [1]. Its rim rises almost 100 meters above the surrounding plains, and contains clay-bearing materials that form part of the early Noachian highlands crust [2]. In preparation for the arrival of Opportunity at these clay-bearing terrains, we re-analyzed the CRISM data with the intent of further constraining the mineralogy and hydration state of these minerals and to establish targets of interest to sample with Opportunity. Our analysis of the data reveals that the spatial distribution and spectral character of both the sulfates and the phyllosilicates in the area is more diverse than has been reported to date.

Methods: Atmospheric correction of CRISM data was performed using the currently available version of the volcano-scan technique [e.g., 3] as well as an alternate atmospheric-correction technique [4]. This latter technique takes advantage of the sequence of high angle observations obtained by CRISM as the spacecraft approaches and then recedes from the target, which allows us to recover the shape of the atmospheric opacity spectrum for the region of interest at the time of the observation with no a-priori assumptions about the column abundances of water or ice relative to that of CO_2. This technique is particularly useful in overcoming the systematic noise generated in the 2 µm region by the currently available volcano-scan technique.

Results: Figure 1 maps the strength of the 1.9-µm absorption due to molecular water in hydrated minerals. We find that despite the presence of phyllosilicates known to exist in outcrops on the rim, the optical surface of the rim of Endeavour Crater contains, for the most part, the most anhydrous terrain in the scene (Fig. 1b). Analysis of the EPF-corrected spectra from terrains exhibiting the lowest values of the BD1900R parameter show that these terrains do not exhibit a 1.9 µm feature, nor any narrow absorptions in the 1–2.6 µm range for that matter. The spectra do show a broad 2 µm band that is probably due to crystal field transitions in pyroxene, suggesting that the rim may contain unaltered mafic mineralogy. This is also true of the spectra of the dunes present inside the crater.

Sulfates: Our analysis identifies the same sulfates as Wray *et al.* (2009) when averaging large swaths of the plains material adjacent to the rim. However, more focused analyses using only 9 to 25 pixel averages find that some of the terrains adjacent to the rim also present a broad, shallow band centered around 2.21 µm, which is consistent with either Ca-sulfates or hydrated silica. The 1.9 µm band has a minimum at 1.93 µm, which is consistent with that of gypsum, given the uncertainty in the data. Shortward of 2 µm, the relative reflectance of the CRISM spectrum drops rapidly, which results in a loss of spectral contrast.

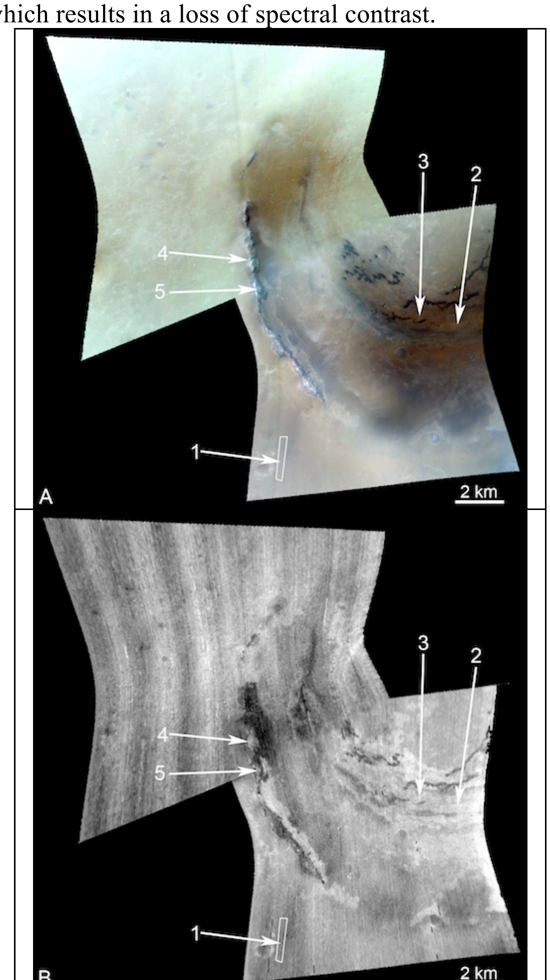

Figure 1. (a) RGB composite of CRISM FRT00008541 and FRT0000CE1D showing approximate locations of spectra shown in Figure 2. Image centered at approximately 5.30ºW, 2.34ºS. (b) BD1900R hydration parameter map of the same area showing spatial variation in relative hydration. North is up in all images.

Phyllosilicates: Our analysis of CRISM data from the rim, interior, and plains around Endeavour crater identifies terrains exhibiting absorptions at 1.93, 2.30, and approximately 2.4 µm (Fig. 2). In addition to these absorptions, we also note variations in the spectral slope between 1 and 2 µm, in the band-depth of the 1.9 mm feature, and in the depth, sharpness, and band centers of the 2.3 and 2.4 mm bands. In particular, the smectite spectra from the rim of Endeavour crater have a relatively shallow spectral slope in the 1–2 µm region, an easily discernable band at 1.93 µm, a sharp absorption at 2.30 and a shoulder at about 2.39–2.40 µm. In contrast, the smectite spectra from the crater's interior and the surrounding plains units exhibit a steeper slope in the 1–2 µm region, a shallower 1.9 µm band, a shallower and more rounded 2.3 µm band, and a displacement of the 2.4 µm shoulder to 2.43 µm.

Stratigraphy: We find that the sulfates are associated with two types of units in the area: 1) light- toned outcrops occurring around the rim and within Endeavour Crater, and 2) a darker, "etched" unit that appears laterally continuous to the light-toned unit.

Clays are found in three different types of geologic units: 1) the plains unit, 2) the rim, and 3) the interior

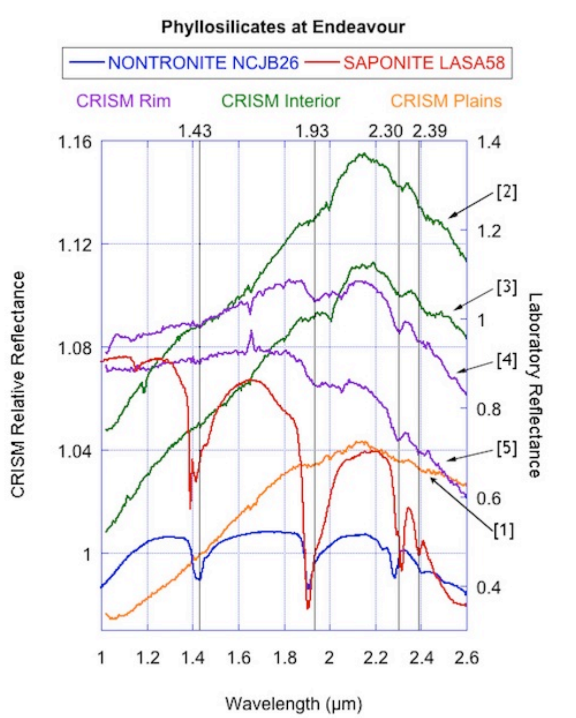

Figure 2. CRISM spectra of surface units exhibiting absorptions at 1.93, 2.3, and 2.4 µm. The spectral character of these absorptions varies with location, from the most well-defined on the rim (spectra 4 and 5), to the shallowest and most rounded in the crater interior (spectra 2 and 3).

of Endeavour Crater. The rim smectites are typically associated with polygonally-fractured surfaces and also with some talus material. On the other hand, the interior clays occur in association with dark mantling material that *overlies* lighter-toned sulfate-bearing material in the Endeavour crater interior and which is in turn overlain by darker barchanoid dunes. Since the material occurs in areas of positive relief with superposed small craters, it is consistent with an in-place layer and not a wind-blown transient deposit.

Discussion: The observations presented here are intriguing because they identify potential sources (the rim) and sinks (crater interior, plains) of phyllosilicates in the area. One of the more provocative results of this investigation is the evidence for Fe/Mg clays in the plains unit, either as part of the bedrock or of the dark mantling sands. This result supports the suggestion by [5] that nontronite is required to best fit the MiniTES data from the Meridiani plains outcrops, and is also consistent with Mössbauer Spectrometer data indicating an unknown ferric phase ("Fe3D3") in those same outcrops [6], [7]. Alternatively, these phyllosilicates could explain the high-silica phase proposed by [8] to occur in the Meridiani sands.

The identification of phyllosilicates in the interior of Endeavour is also important because these phyllosilicates form part of the dark mantling deposit that overlies the sulfates, and do not form part of the original bedrock into which the impact occurred. The unit in which these phyllosilicates occur appears to unconformably mantle the crater's interior mound, suggesting that it was deposited after the mound reached its present-day state. Therefore, we consider it to be reworked material, possibly derived from the crater rim.

Spectroscopically, the difference between the rim and interor phyllosilicate spectra are intriguing because they suggest that either these phyllosilicates experienced some type of alteration that affected their structure or that they are mixed with some other phase or phases. The structure of phyllosilicates can be affected by both by exposure to acids and by dehydration [9], [10].

References: [1] Arvidson et al., 2006; [2] Wray et al., 2009; [3] McGuire et al., 2009; [4] Noe Dobrea et al., 2011; [5] Glotch et al., 2006; [6] Klingelhöfer et al., 2004; [7] Morris et al., 2006; [8] Rogers and Aharonson, 2008; [9] Altheide et al., 2010; [10] Morris et al., 2011