DETECTION OF BASSANITE IN THE NORTH POLAR DUNES OF MARS AND IMPLICATIONS FOR AQUEOUS ACTIVITY. M. Parente[1], J. L. Bishop[2], A. M. Saranathan[1,3], A. Szynkiewicz[4], and L. Fenton[2], [1]University of Massachusetts (Amherst, MA; mparente@ecs.umass.edu), [2]SETI Institute (Mountain View, CA), [3]NASA Goddard Space Center (Greenbelt, MD), [4]University of Tennessee, Knoxville.

Summary: The North Polar dunes of the Olympia Undae Sand Sea have intrigued researchers since the discovery of gypsum ($CaSO_4 \bullet 2H_2O$) in OMEGA spectra [1]. Subsequent studies of this region proposed formation of evaporitic gypsum in pore spaces of the dune sand following melting of the polar layered deposits [2] or release of gypsum-bearing particles through wind-related ice ablation [3]. Recent advances in image processing [4] and hyperspectral mapping [5] are facilitating improved characterization of the materials present in the North Polar dunes. Our analyses reveal the presence of bassanite ($CaSO_4 \bullet 0.5H_2O$) in addition to gypsum on the dunes. Gypsum is widespread and most prevalent in many of the dunes across this region, but bassanite is extensive in the eastern part of the Olympia Undae Sand Sea where bright patches at interdunes are also present (Fig. 1). This exciting discovery is consistent with a dynamic aqueous environment at the North Polar dunes of Mars.

Gypsum at the Olympia Undae Sand Sea: Both the OMEGA and CRISM hyperspectral imagers provide near-infrared data that enabled detection and mapping of gypsum on the dunes [1-3,6]. The best spectral bands for remote detection of gypsum include a triplet at 1.45, 1.49, and 1.54 µm, bands near 1.75 and 1.94 µm, a doublet at 2.22 and 2.26 µm, and another broad band at 2.4-2.5 µm [7]. The mapping of gypsum concentration using OMEGA data used a band centered near 1.93 µm [1-3,6] that could include gypsum and other hydrated minerals. At the time of those studies it was widely assumed that gypsum was the only sulfate present.

Methods: Employing the Fandango algorithm for simultaneous atmospheric correction and denoising of CRISM images in the 1.0-2.6 µm spectral range, we removed most of the residual atmospheric bands and spurious noise, enabling a clearer view of the surface [4]. For our study CRISM images FRT0000285F, FRT000C2FC, HRS0000302A, and HRS0000CA17 were processed using this technique. Additionally, we applied a new mapping algorithm that employs Generative Adversarial Networks (GANs) to learn the diagnostic spectral features needed for discriminating among spectral types using hyperspectral components in the feature extraction [5]. This technique extends the CRISM mineral parameters developed using a spectral band, ratio, or slope [8] and is highly effective in identifying promising locations in the images that contain specific compositional units through the use of machine learning algorithms.

Results: We investigated spectra from Fandango-processed CRISM images in regions dominated by both gypsum and bassanite spectral signatures in the dunes of Olympia Undae. We documented the presence of gypsum in CRISM images in the west and bassanite in the east. We examined the lighter toned (tan-colored) interdunes in the gypsum-rich regions (Fig. 1) and observed spectra consistent with mixtures of gypsum and bassanite (Fig. 2). A related study is characterizing the morphology of the Olympia Undae dunes [9] and notes a correlation of polygonal fractioning with the bright-toned (white) patches of the interdunes in the eastern part of this area, where we identify primarily bassanite rather than gypsum on the dunes.

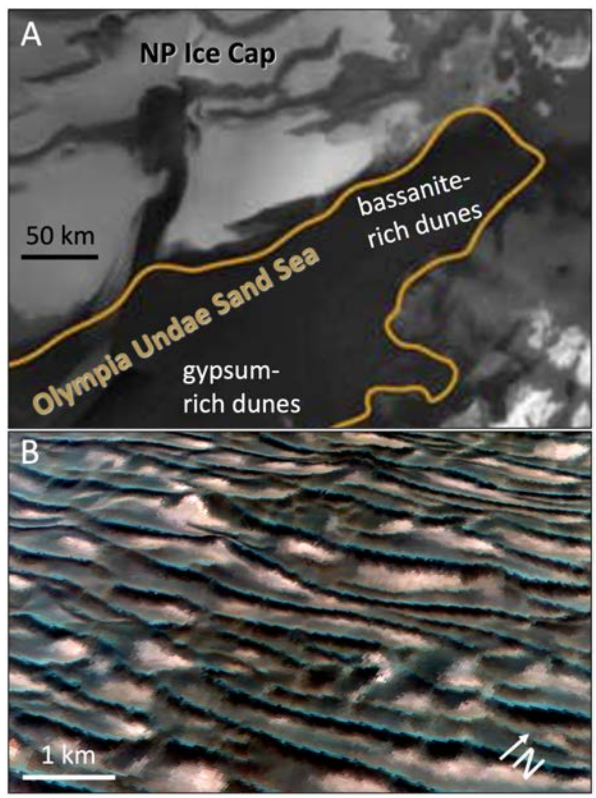

Figure 1. A) *View of the Olympia Undae sand sea (after [2]) indicating locations of gypsum-rich and bassanite-rich dunes. B) Gypsum-rich dunes in CRISM image FRT000285F, where strong gypsum spectral signatures are observed across most of the dunes (dark areas) and spectra consistent with gypsum-bassanite mixtures are observed in the tan-colored regions of some interdunes.*

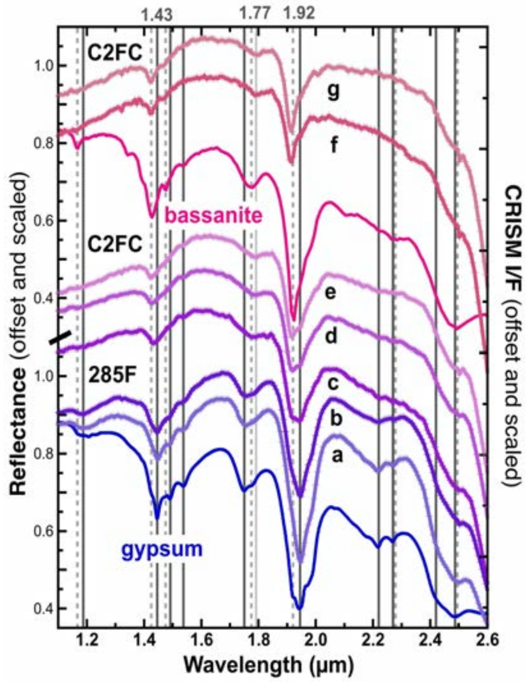

Figure 2. *Lab reflectance spectra of gypsum and bassanite compared with spectra from Fandango-processed CRISM images. Spectra from image FRT0000285F are characteristic of gypsum (a) and gypsum/bassanite mixtures (b), while spectra from image FRT0000C2FC are characteristic of bassanite/gypsum mixtures (c), bassanite (d-e), and additional bassanite mixtures (f-g). Gypsum features are marked by solid black lines, while features due to bassanite are marked with dashed grey lines. Important bassanite bands are provided at the top.*

Bassanite can be identified using features similar to those of gypsum, but shifted in many cases to include a triplet at 1.43, 1.48, and 1.54 µm, bands at 1.77-1.78 and 1.92-1.93 µm, and another broad band near 2.5 µm [7]. Specifically in our study we noted a shift in the bands near 1.45 to 1.43 µm, from 1.75 to 1.77 µm, and from 1.94 to 1.92 µm, together with a loss of the doublet at 2.22 and 2.26 µm (Fig. 2). This indicates a change from primarily gypsum in spectrum *a* (Fig. 2) towards some bassanite in spectrum *b*, more bassanite than gypsum in spectrum *c* and mostly bassanite in spectra *d* and *e*.

Spectra *f* and *g* in Fig. 2 were collected from the light-toned (white) patches in the interdune areas (Fig. 3) in eastern Olympia Undae (Fig. 1). These spectra are similar to those of bassanite, but the 1.77 µm band is shifted towards 1.79-1.80 µm and many of the other bassanite features are weaker. This is consistent with the presence of another hydrated component. These spectra do not line up perfectly with any minerals in our spectral library, but they do share some similarities with other phases that are under continued investigation. The

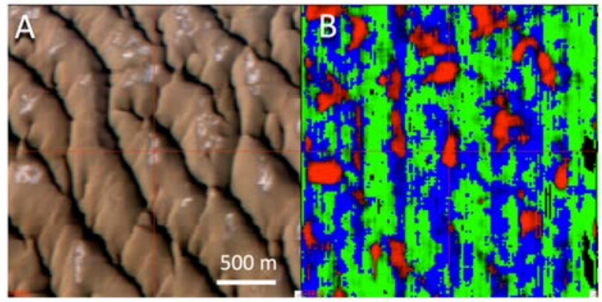

Figure 3. A) *Portion of CRISM image FRT0000C2FC showing bright albedo patches in some interdunes.* ***B)*** *CRISM view of A where three types of bassanite mixtures are mapped in green, red, and blue, and gypsum-rich regions are mapped in black. Example spectra for these regions are provided in Fig. 2, where green corresponds to spectrum c, blue to spectra d and e, and red to spectra f and g.*

bright tones in CRISM and HiRISE imagery of these interdune regions, together with their spectral signatures are consistent with a mixture of bassanite and another spectrally bright component.

Implications: Our study observed the presence of some bassanite mixed with gypsum in small lighter-colored patches of interdunes where gypsum dunes are most prevalent, and a similar transition to a mixture of bassanite and another component on the small white patches in the interdune areas in the bassanite-rich dune region. These observations are consistent with a transition from gypsum to bassanite with increasing alteration or from bassanite to gypsum with increasing hydration. Evaporation, sediment exchange, and significant water activity must have been active during the Amazonian to support this transition.

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