VARIATIONS IN THE MORPHOLOGY AND MINERALOGY OF MARS' OLYMPIA UNDAE SAND SEA. K. L. Yanez[1,2], J. L. Bishop[2], and L. K. Fenton[2]. [1]California State University, Northridge (18111 Nordhoff St, Northridge, CA 91330, katya.yanez.212@my.csun.edu), [2]SETI Institute (339 N. Bernardo Ave Suite 200, Mountain View, CA 94043).

Abstract: The mineralogy and morphology of the dunes and light-toned interdune regions of the Olympia Undae Sand Sea near the north pole of Mars are actively changing due to interactions with frost and wind. Gypsum and basaltic sand dominate the undae. However, wind and microscale aqueous processes appear to be altering the existing material and changing its composition. Through analysis of CRISM images, we documented changes in the spectral signature from east to west and from dune to interdune material. The gypsum-like features of the spectral signature become weaker towards the west with some features disappearing altogether. The signature is also weaker in the interdune region, which could indicate the presence of additional bright minerals including anhydrite or chlorides. HiRISE analyses revealed changes in the morphology of the interdune light-toned patches such that the easternmost area contains mostly Transverse Aeolian Ridges (TARs), whereas towards the west polygonal cracking is observed. Further, our analysis of interdunes over time demonstrates that these are actively changing from one martian year to the next. Continuing studies of the interdune material are key to understanding how this active environment is altering the undae sediment.

Introduction: The Olympia Undae Sand Sea is of great scientific interest as the largest gypsum ($CaSO_4 \cdot 2H_2O$) deposit on Mars. This evaporite mineral forms in pH-neutral water under relatively low temperatures and high humidity conditions [1]. Therefore, understanding the nature of gypsum at Olympia Undae can provide clues to the aqueous history of Mars.

Gypsum was discovered at Olympia Undae in 2005 using OMEGA spectral images with the highest concentration of gypsum in the east [2]. The gypsum signature decreases towards the west coinciding with wind direction [3]. The Olympia Undae dune sediment is much darker than expected for gypsum alone, so it must also contain mafic material. The mafic sand was likely eroded by katabatic winds [4] from the basal unit of Mars' North Pole [5]. The source of gypsum is less understood, and the study of its origin goes beyond the scope of this paper. Light-toned patches appear throughout Olympia Undae in many of the interdune areas that also include gypsum-like spectral signatures, although weaker than the dunes. Our study is focused on changes across the dunes and light-toned interdune patches across the sand sea.

Methods: We subdivided the large geographical area of Olympia Undae into regions 1(east) to 4 (west) to characterize changes from east to west. We collected spectral data from 138 Map-projected Targeted Reduced Data Record (MTRDR) CRISM images and 656 HiRISE images. From these, we selected images that best meet our scientific goals. We calculated the solar longitude (L_s) of each image to determine the martian season and prioritized CRISM images taken during the martian summer (90° <L_s<180°) since they contain the least amount of frost that could obscure the spectral signatures. In addition, we emphasized sites where CRISM and HiRISE images overlap for joint evaluation of the morphology and mineralogy. Also, all candidate images contained light-toned interdune patches since they represent a major focus of this study.

For each of our 4 study areas, we selected 8 CRISM images and used ENVI's ROI tool to collect data from the light-toned patches and the dark-toned dunes. We surveyed the spectral features from all images and created spectral averages for each study area. We plotted these average spectra and documented changes in the spectral features across Olympia Undae (**Fig. 1**). Gypsum's spectral signature contains a triplet near 1.4-1.5 µm, two strong bands near 1.75 and 1.95 µm, a doublet near 2.2 µm, and another band at 2.4-2.5 µm [1]. From these spectral data, we calculated the band depth of the ~1.95 µm hydration band and observed band depths of 28.3% for Area 1, 16.6% for Area 2, 13.7% for Area 3, and 13.2% for Area 4.

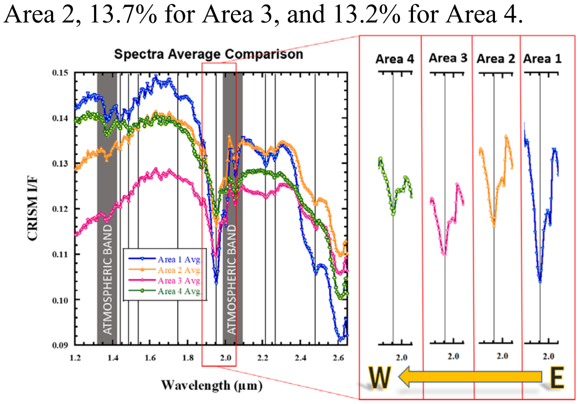

Figure 1. *Average spectra for areas 1-4 with expanded views of the ~1.95 µm due to gypsum.*

We selected one representative HiRISE image per area and annotated the interdune morphology using different colors to differentiate between areas of TARs, small ripples, featureless smooth surfaces, and polygonal cracking (**Fig. 2**). We also examined HiRISE images of the same location acquired during winter and summer to document changes in morphology from one season to the next and from one martian year to the next to evaluate the annual changes.

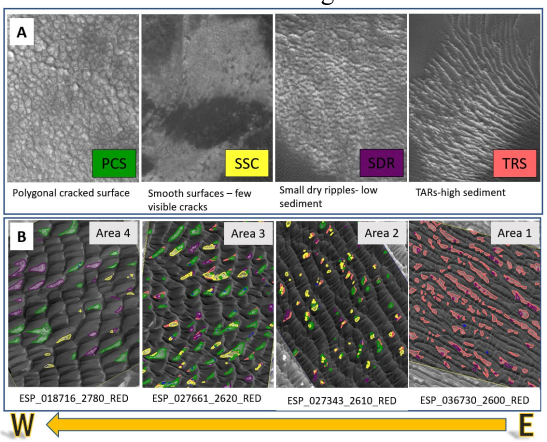

***Figure 2. A** – Annotation legend for interdune morphologies: heavy polygonal cracking (green), smooth areas with some low visibility polygonal features (yellow), small ripples with low sediment (purple), and TARs with high sediment (pink). **B**–Mapping of annotated images with TARs dominant in the easternmost Area 1.*

Results: *Minerology.* Our results corroborate that the gypsum signature becomes weaker from east to west and that the interdune patches contain a weaker signature than the dune crests. Spectra in all images of the undae include at least the strongest gypsum feature near 1.95 µm. Area 1 has the strongest 1.95 µm band depth and this becomes weaker towards the west (**Fig. 1**) This trend is observed for all gypsum bands and the 1.75 and 2.22 µm bands disappear altogether by area 4.

We examined the spectral signatures of the dunes and interdune regions and found a few features that may indicate the presence of additional hydrated sulfates or other phases that are affecting the shape of the bands near 1.45, 1.75, 1.95, and 2.4-2.5 µm. These are under continued investigation with SUBCONV processed CRISM images [6] and through comparison with lab mineral spectra.

Morphology. There is great diversity in the morphology of the interdune regions. We observed that patches with bright TARs are more common in the east and polygonally cracked surfaces are more prevalent towards the west and at the edges of the sand sea. These changes are likely due to wind processes and seasonal changes due to the freezing and thawing of the dunes in the winter and summer cycles. This is evidence that the Olympia Undae Sand Sea is a dynamic environment. Our annotated images illustrate a striking difference in the morphology of the interdunes across the sand sea. The heavy sediment TARs dominate the area where the gypsum signature is the strongest. Polygonal cracking is evident towards the west and at the perimeter of the undae.

HiRISE images of selected regions during summer and winter (**Fig. 3 A-B**) demonstrate that frost covers the dunes during the martian winter months to such an extent that many features are obscured. Changes in morphology and sand cover across the light-toned interdune regions are observed in as little time as one martian year (**Fig. 3 C-D**).

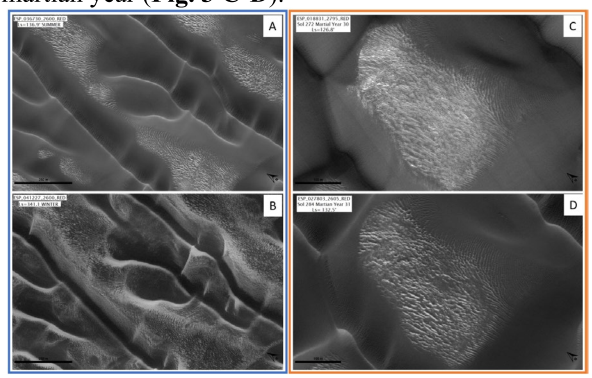

***Figure 3. A** – HiRISE image ESP_036730_2600_RED at mid-summer (L_s= 136.9°). **B** – HiRISE image ESP_041227_2600_RED during winter (L_s=341.1°). **C** – HiRISE image ESP_018831_2795_RED taken during summer (L_s=126.8°). **D** –HiRISE image ESP_027803_2605_RED taken during summer (L_s=132.5°) one martian year past image A.*

Conclusion: Olympia undae is a dynamic environment where wind and frost are actively changing the morphology and mineralogy of the sediments. We observed that the signature of gypsum decreases from east to west with some features disappearing in the westernmost sections. The interdune regions also contain weaker gypsum signatures and appear to include additional hydrated sulfates in the light-toned patches. Morphological changes in the interdune regions are also observed with mostly TARs to the east and polygonally cracked features to the west. The gypsum-rich composition of the undae implies that water must have played a major role in the geological history of this circumpolar region. Continuing studies of Olympia Undae could bring us closer to an understanding of Mars' paleoclimate and aqueous history.

References: [1] Bishop J.L. et al. (2014) *American Mineralogist, 99,* 2105–2115. [2] Langevin Y. et al. (2005) *Science, 307,* 1584-1586. [3] Fishbaugh K.E. et al. (2007) *JGR, 112,* E07002. [4] Ewing R.C. et al. (2010) *JGR, 115,* E08005. [5] Tanaka K. L. et al. (2008) *Icarus 196,* 318–358. [6] Gruendler M. R. D. et al. (2022) *GSA*, Abstract #207-1.