INVESTIGATING THE ORIGIN OF GYPSUM IN OLYMPIA UNDAE: CHARACTERIZING THE MINERALOGY OF THE BASAL UNIT. E. Das[1], J. F. Mustard[1] and J. D. Tarnas[1,2], [1]Department of Earth, Environmental and Planetary Sciences, Brown University, Providence RI 02912 (eashan_das@brown.edu), [2]Jet Propulsion Laboratory, California Institute of Technology

Introduction: The Olympia Undae Sand Sea, near the North Polar ice cap, contains the largest known deposit of gypsum discovered on Mars [1]. The formation of gypsum requires liquid water, hinting that it formed in the North Polar region under circumstances vastly different from today's Martian environment. The presence of gypsum in the late Amazonian age dunes, likely sourced from materials of the late Hesperian-early/mid-Amazonian ages [2], are consistent with wetter periods during these ages. Since the discovery of gypsum in the north polar dunes, various hypotheses have been suggested for its source. One hypothesis suggested formation from in-situ aqueous alteration of sulfide and high-Ca bearing pyroxene present in the dunes and/or precipitation of evaporitic gypsum crystals within pore spaces [3]. The water needed for gypsum formation is suggested to be sourced from nearby channels resulting from melting of the NPLD. Another leading hypothesis suggests that gypsum formed in the early-middle Amazonian-aged Basal Unit underlying the North Polar Layered Deposits (NPLD) and has been eroded from this unit [4]. Previous studies to search for spectral signatures of sulfates in exposures of the Basal Unit using CRISM (Compact Reconnaissance Imaging Spectrometer for Mars) and OMEGA (Observatoire pour la Minéralogie, l'Eau, les Glaces et l'Activité) data have been largely inconclusive [5]. We hypothesize the spectra of sulfate-bearing rocks and soils are dominated by water ice and dust, which occlude spectral signatures diagnostic of poly-hydrated sulfates.

Recently, new quantitative methods based on factor analysis (Dynamic Aperture Factor Analysis Target Transformation (DAFA/TT) and Guided Endmember Extraction (GEEn)) have been developed with the ability to detect target mineral signatures in complex mixed environments that obscure mineral signatures [6,7,8]. For example, DAFA/TT has been used to detect the spectral signatures of small and/or spectrally weak exposures of hydrous mineral deposits on Mars with CRISM data [9]. Here we show that sulfate minerals are present in the basal unit via application of the Guided Endmember Extraction method to a set of CRISM observations in the north polar region of Mars where the basal unit is exposed

Methods: The Guided Endmember Extraction method consists of two steps: 1) Endmember extraction: The algorithm identifies the number of independently varying spectral components represented in the eigenvectors derived from the Hysime algorithm [10] and determines the independent components of the mixed system. 2) Dot Product Mapping: The dot products of the image cube with individual eigenvectors, specifically those containing interesting spectral features, are obtained to highlight regions within the image cube where the target mineral may have a strong spectral signal. The 3rd eigenvector along with its associated dot product map of a subset of CRISM image (HRL00003084) over Olympia Undae are shown in Figure 1. The 3rd eigenvector was chosen as it contained prominent spectral features similar to the target mineral gypsum.

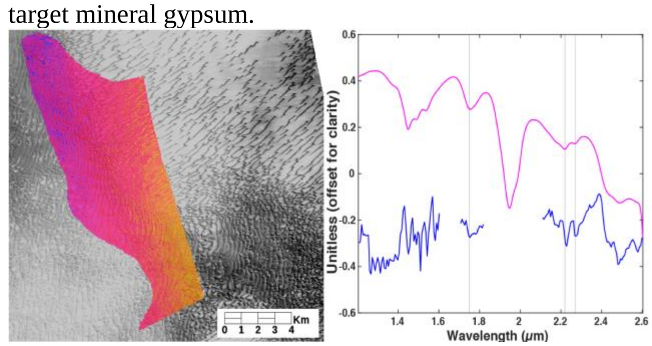

Figure 1: The 3rd eigenvector determined for a subset of CRISM image HRL00003084 along with associated dot product maps overlaid on CTX observation P01_001457_2603. Higher values appear in blue/magenta and lower values in orange/yellow.

Workflow and Implementation: A set of 5 CRISM targeted-TRDR (FRT0000287f, FRT0000c58f, HRL00002f91, FRT000024506, HRL0000b99f) were selected in an area of the Mars North Polar region where the Basal Unit is exposed during Martian spring-summer (L_s = 90º-180º) between Mars years 28-30. These criteria were chosen to obtain the best possible data with the least noise and frost cover. The data were atmospherically corrected using the CRISM analysis tool (CAT) atmospheric correction pipeline. Subsets of the atmospherically corrected images were then generated focusing on exposures of the Basal Unit and their spectral signatures. CRISM parameters [9] were then calculated on these subset regions. Relevant parameter maps highlighting poly-hydrated sulfates (SINDEX2, D2300, BD2100_2) were used to define regions of interest (ROIs) in ENVI based on morphological correlation and higher values in the sulfate spectral parameters. We then applied the GEEn routine on image subsets of the ROIs. The Resultant Dot Product Maps were then used to highlight regions within the image with a high degree of correlation with the extracted endmember spectra and are used to isolate pixels within the image indicative of sulfates.

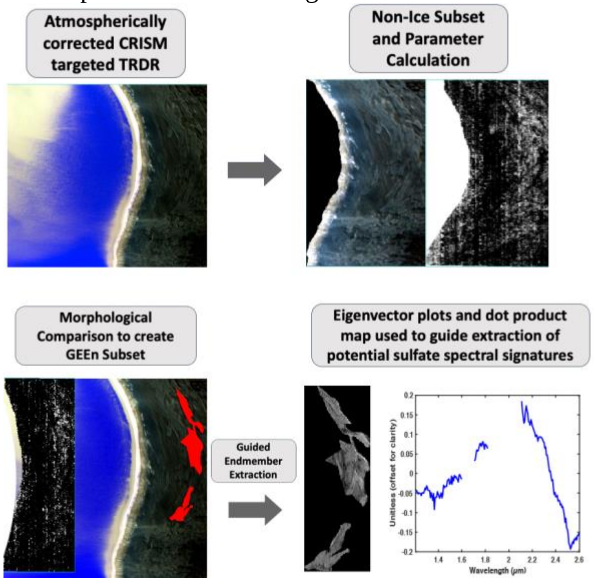

Figure 2: Schematic of Guided Endmember Extraction Workflow.

These pixels are used to draw detailed ROIs to obtain spectral ratios to isolate strong spectral signatures and remove atmospheric absorption effects and instrument noise. The mean spectrum of the detection ROI is divided by mean spectrum of a pixel cluster within the same detector column which is spectrally bland. Spectrally bland clusters are identified by regions with relatively low values of a relevant parameter (e.g. SINDEX2.)

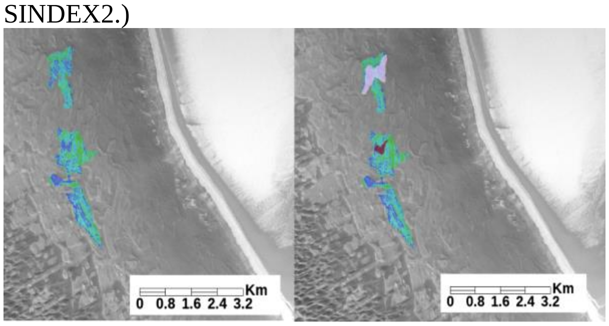

Figure 3:[Left] GEEn eigenvector 3 dot product map overlaid on CTX observation b02_010397_2638 (high values appear in blue/cyan low values appear in green) [Right] Numerator ROIs used for ratioing.

Methods Verification: To verify the ability of GEEn to detect target minerals, we applied the algorithm to various regions of Mars where sulfates have previously been identified (Valles Marineris, Olympia Undae, and Mawrth Valles). Using GEEn we have been able to reproduce published results of sulfate detections in these regions. An example from Capri Chasma in Valles Marineris is shown in Figure 4. Using our workflow, we are able to reproduce published spectra of kieserite, hexahydrite, and szmolnokite from CRISM data in Capri Chasma [10].

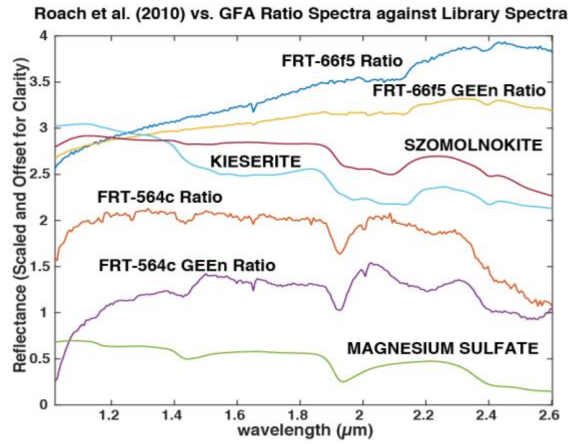

Figure 4:Methods Verification on Capri Chasma. Roach et al. ratios are presented above GEEn ratios with CRISM library spectra for reference.

Results: Using the workflow outlined we obtained ratio spectra with features indicative of sulfates consistently observed across all CRISM images used within our study area in the North Polar region. We observe a strong 2.3μm downturn along with features near 2.37-2.40μm and 2.52μm in each ratio spectra (fig. 5). On comparing our ratio spectra to sulfate library spectra and water ice-sulfate mixtures, we find strong evidence indicating the basal unit likely consists of a sulfate-water ice mixture. We are currently in the process of performing mixture modeling to constrain sulfate mixtures providing good fits to our ratio spectra.

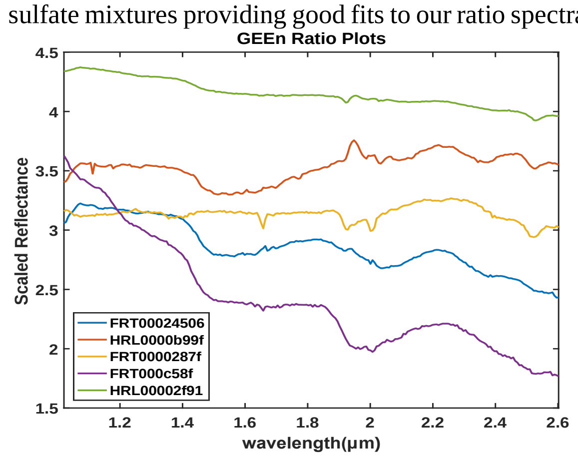

Figure 5: GEEn Ratio Results from all CRISM observations.

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