Insights from Ferrous Mineralogy into the Transport of Martian North Polar Materials. B. H. N. Horgan[1] and J. F. Bell III[1], [1] Cornell University Dept. of Astronomy, Ithaca, NY, 14853 (briony@astro.cornell.edu).

Motivation: The north polar region of Mars contains two areally extensive, dark aeolian deposits: (1) the north polar sand seas that encircle the polar cap, and (2) the north polar veneers that drape over the polar cap itself [1,2]. Both deposits are sourced from within the north polar layered deposits (PLD) [2], have been previously identified as containing ferrous [3,4] and hydrated minerals [5], and exhibit spectral features consistent with gypsum, a hydrated calcium sulfate [6]. However, it remains unclear whether or not the deposits have exchanged material in the past, and whether any portion of either deposit is active today. In this study, we are investigating the distribution of ferrous minerals in the north polar region using near-infrared spectral data from the Mars Express OMEGA imaging spectrometer.

Spectral differences between and within the deposits may reflect: (1) compositional variations among the sources of the deposits, (2) the degree of modern activity of the deposits, or (3) changes in mineralogy due to breakdown of softer minerals during aeolian transport over long distances. By quantatively cataloging these spectral differences, we have been able to help identify sources of aeolian material, transport pathways, and the most active regions of modern aeolian activity.

Methods: Ferrous (Fe^{2+}-bearing) minerals, such as olivine and pyroxene, are most readily identified by the presence of wide absorption bands around 1 μm, and, for most pyroxenes, 2 μm. Observations of changes in the position, depth, and shape of these absorption bands may be used to track changes in composition.

Near 1 μm, orthoproxene (OPX) (a calcium-free or low-calcium pyroxene (LCP)), clinopyroxene (CPX), (usually a high-calcium pyroxene (HCP)), and olivine all exhibit strong Fe^{2+} crystal field transition absorptions, and the locations of these absorptions have been well categorized for both the individual minerals and mixtures [*e.g.,* 7]. Although the overlapping nature of these bands makes extracting abundances challenging at best, because these bands are all caused by the same transition, it is plausible that we can identify the most abundant mineral by the location of the minimum of the 1 μm band. In particular, we have identified a minimum near 1.12 μm in N. polar low albedo terrains. This absorption is characteristic of spectral type A CPX, which differs from the more common spectral type B CPX by the presence of 2 bands near 1 μm and no band near 2 μm, and exhibits a very high Ca content

(Wo>40%) [7].

Near 2 μm, discerning the presence of OPX or CPX bands is complicated by the presence of bound water and sulfate absorptions due to the presence of gypsum. To solve this problem, we have used laboratory spectra of gypsum and basalt sand mixtures, at a range of abundances [6], to model and remove the gypsum component. The gypsum components of the lab spec-
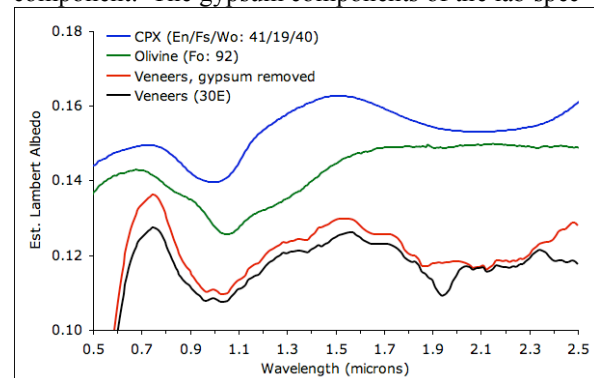

Figure 1: Veneers on plains near 30°E, before and after gypsum removal, compared to HCP and olivine. Olivine is the dominant mineral near 1 μm, and a CPX band is present near 2 μm.
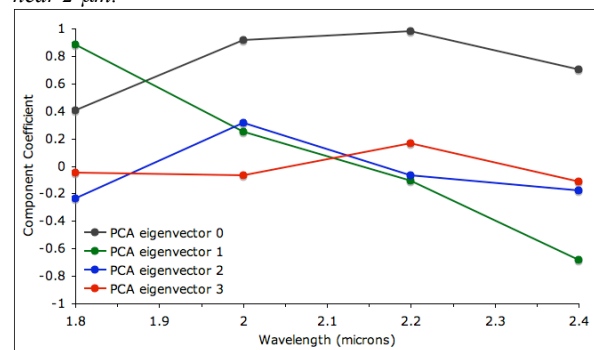

Figure 2: Eigenvectors produced by applying PCA to calculated band depths at the wavelengths shown.
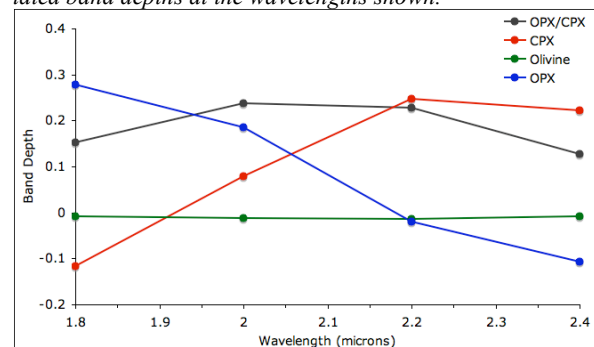

Figure 3: Band depth trends for OPX, CPX and olivine, calculated relative to 1.6 μm (CRISM spectral library).

tra are scaled to match the 1.9 μm band depth of each OMEGA spectrum and then divided out. Because we are using gypsum spectra at similar abundances to those observed by OMEGA, this method has proved effective, reducing all 1.9 and 2.4 μm band depths to values below the detection limit (*e.g.* Fig. 1).

To extract information about the presence of pyroxene bands from our now "gypsum-free" spectra, we have applied principal component analysis (PCA) to the band depths of the spectra at 1.8, 2.0, 2.2, and 2.4 μm, calculated relative to the value of the spectra at 1.6 μm (Fig. 2). The resulting eigenvectors are excellent matches for the band depth trends of LCP, HCP, olivine, and an intermediate pyroxene composition or mixture (Fig. 3) [7]. We can use the presence of these eigenvectors to confirm our observations at 1 μm.

Results: The variations in our observations of the spectrally dominant mineral at 1 μm in the north polar region have a strong correlation with the type and location of the sedimentary units (Fig. 4). The north polar veneers are consistently dominated by olivine, LCP is found in close proximity to previously identified sources in the PLD [8], and HCP is found in the Scandia unit [2] and in dunes sourced from Abalos and Olympia Undae [2,8]. Our results at 2 μm have confirmed these observations (Fig. 5), although the lack of signature at 2 μm from CPX-A has limited our ability to confirm it's presence outside of the 1 μm region.

Discussion: The proximity of LCP to previously identified PLD sources has 2 implications: (1) the sources may be LCP-bearing, and (2) the LCP may be being broken down before it can be transported any further away from the sources. We hypothesize that the LCP is broken down by saltation [9]. Based on lab studies, OPX loses spectral dominance when it falls below 20% abundance in simple mixtures [6]. By assuming that the abundance of OPX in the PLD is fairly constant and measuring the distance away from sources that OPX stays spectrally dominant, we can estimate that the units lose a few percent of their total pyroxene abundance to mechanical weathering per every ~10 km of saltation.

This hypothesis may allow us to gauge the "erosional maturity" of units within the PLD. In particular, our results indicate that the veneers are olivine-enriched relative to other deposits in the region. This may indicate that the veneers have undergone much longer periods of saltation than other PLD units, which may support the hypothesis that the veneers were originally sourced from an older sand sea [2,6].

Finally, HCP in the north polar region could be a significant, previously unidentified source of Ca for gypsum formation. The source of the sulfur still remains elusive [10].

References: [1] Rodriguez *et al.* (2007) *Mars*, *3*, 29. [2] Tanaka *et al.* (2008) *Icarus*, *198*, 318. [3] Bell *et al.* (1997) *LPSC XXVIII*, 87. [4] Poulet *et al.* (2008) *GRL*, doi: 10.1029/2008GL035450. [5] Langevin *et al.* (2005) *Science*, *307*, 1584. [6] Horgan *et al.* (2009) *JGR*, *113*, doi: 10.1029/2008JE003187. [7] Cloutis and Gaffey (1991) *EMP*, *53*, 11. [8] Tanaka and Hayward (2008) *PDW*, #7012. [9] Sullivan *et al.* (2008) *JGR*, *113*, E06S07. [10] Fishbaugh *et al.* (2007) *JGR*, *112*, E07002.
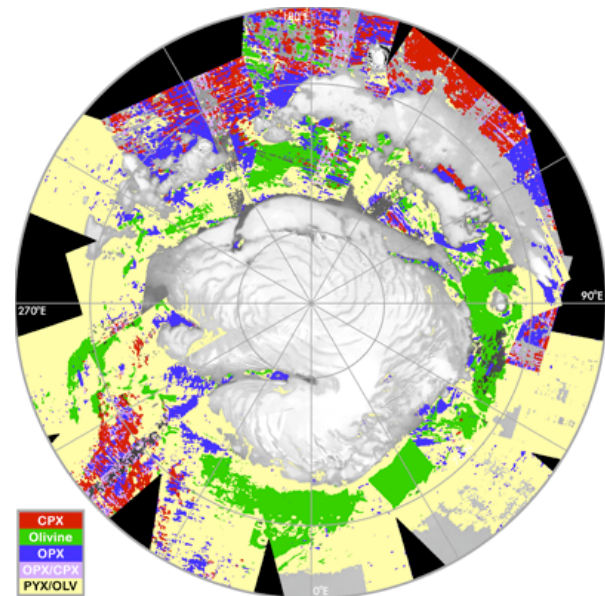

Figure 4: *Detected minerals near 1 μm, over OMEGA 1 μm albedo map. Terrains with 1.5 μm water ice band depths greater than 1% have not been included.*
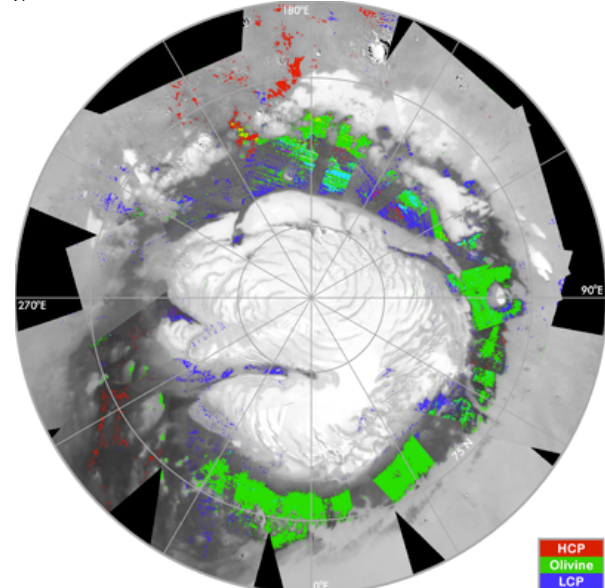

Figure 5: *Distribution of minerals that have been detected at 1 μm and confirmed at 2 μm.*