HYDRATED UNITS IN THE MARTIAN NORTH POLAR REGION. B. H. N. Horgan[1], J. F. Bell III[1], E. Z. Noe Dobrea[2], E. A. Cloutis[3], D. T. Bailey[3], M. A. Craig[3], L. Stewart[3]. [1]Cornell University Dept. of Astronomy (briony@astro.cornell.edu); [2]JPL/Caltech; [3]University of Winnipeg.

Background: The north polar region of Mars is situated at the lowest elevation of a basin that encompasses much of the northern hemisphere, making it an ideal place for the potential deposition of outflow channel fluids and sediments [1]. Results from the Mars Express OMEGA near-IR imaging spectrometer investigation have indicated the presence of extended deposits of hydrated calcium sulfates in the Olympia Planitia (OP) region, which have been identified as gypsum ($CaSO_4$•$2H_2O$) [2]. Gypsum formation generally requires a source of sulfur and H_2O interacting with Ca-bearing minerals [3]. Langevin *et al.* [2] suggested that the water necessary to form gypsum was most likely present in or near OP, possibly related to outflows from the ice cap during a warm climate excursion. Fishbaugh *et al.* [4] reported that the gypsum deposit is nearly exclusively associated with the dark dunes, and a lack of apparent correlations between the presence of gypsum and the physical or thermal characteristics of the dune field in THEMIS data implies that the gypsum is well mixed with the dune material. Based on Mars Odyssey Neutron Spectrometer data, Feldman *et al.* [5] have proposed that the dunes are ice rich, and may be composed of a cemented niveo-aeolian layer overlain by a ~10 cm thick mobile layer.

Goals: We are examining hydration in the entire north polar region to establish a regional context for the OP sulfates and to test the proposed OMEGA global mineralogic history [6]. If the sulfates are limited to OP, then they are most likely intimately related to the dunes and may be much younger than sulfate deposits elsewhere; alternately, hydrated minerals elsewhere in the region may suggest otherwise.

To expand on the OMEGA results, we: 1) verify the sulfate detection locally in OP, 2) seek additional hydrated mineral signatures in the rest of the north polar region, 3) investigate the context of the hydration signature in the geology of the region, and 4) provide a new assessment of the sulfate content of the dunes, using independent spectral analysis methods and newly-available laboratory sulfate mineral spectra [7].

Methods: We used OMEGA team basic calibration tools [8] and developed our own tools for sorting candidate image cubes, removing bad spectels and the solar and atmospheric contributions, creating polar mosaics, and performing spectral parameterizations.

The OMEGA image cubes that we have used in this study have an average resolution of 4 km/pixel, lie between 75°N and 85°N, and are limited to L_S between 90° and 115°. We have chosen this time range in order to acquire data after summer solstice (to minimize the presence of surface frost) and to include coverage up to the latest publicly released date in the summer season.

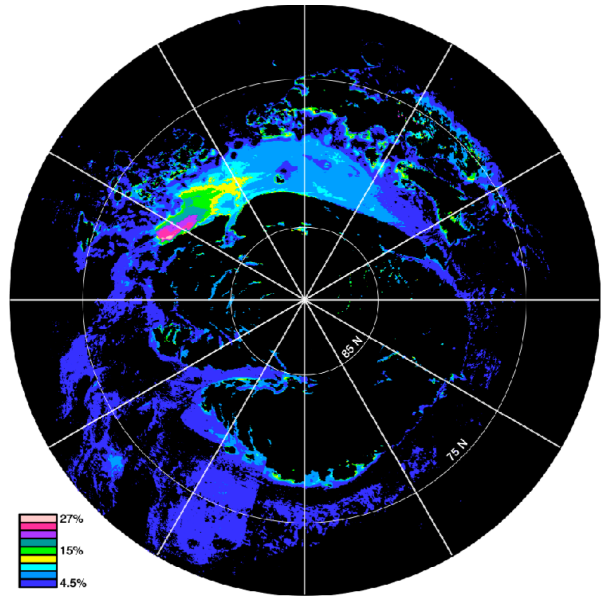

Figure 1: *Distribution of hydrated minerals, based on 1.94 μm band depth and the location of the band minimum near 1.94 μm, with band depth ranging from 4.5 to 27% below the continuum. Orthographic map at 1 km/pixel.*

To compensate for atmospheric absorption, we have employed an empirically-derived correction based on the ratio of OMEGA spectra of high and low elevation regions on Olympus Mons [8].

To map hydrated minerals, we first calculated the 1.94 μm band depth; however, our algorithm is also sensitive to water ice, which has a large band around 2 μm. To determine if a spectrum contains hydrated minerals as opposed to water ice, we require the band minimum wavelength to be at 1.941 or 1.955 μm.

Spectra are identified as primarily containing water ice with neglible hydrated minerals if they exhibit 1.94 μm band depths above 4.5% but have band minima between 1.955 and 2.053 μm. To account for band saturation at high ice content, spectra with band minima between 2.053 and 2.122 μm and band depths above 30% are also in this category. Fig. 1 shows a map of the 1.94 μm band depth above 70°N, where spectra with band depths below 4.5% or ice bands without hydration are blacked out. The noise level for the OMEGA data is approximately 2% [8].

Based on previous laboratory studies [*e.g.,* 9], spectra may be identified as hydrated and ice-rich since hydration bands are still apparent in ice-rich mineral mixtures. Within the hydrated terrains of the north polar region, we have identified a continuum of spectra

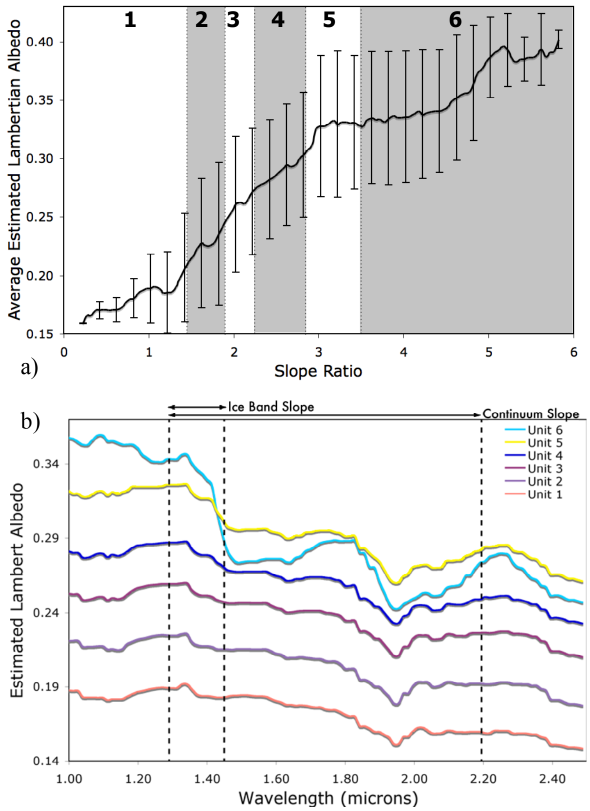

Figure 2: *(a) Average albedo of hydrated terrains vs. slope ratio parameter. Error bars given are 1 standard deviation. (b) Average spectra for units in (a). Dotted lines: locations of wavelengths used in slope ratio parameter.*

with increasingly deep ice bands. To distinguish spectra along this continuum, we have developed a parameter based on the spectral slope between 1.3 and 1.45 µm. This region lies on the short-wavelength side of the 1.5 µm H_2O ice band, so icy mixtures have a strong downward slope. By comparing this slope to the slope of the continuum, defined at 1.3 and 2.2 µm, we can parameterize the ice band depth of the spectrum. We have choosen to use this slope ratio parameter over a band depth parameter because a majority of the spectra have broad, shallow ice bands only apparent because of the local slope near 1.3 µm.

Figure 2 shows the average albedo of hydrated terrains as a function of our slope ratio parameter. Because ice is the most abundant high albedo material in this region, albedo is most likely correlated with ice content. As the slope ratio parameter appears to have correlations with albedo, ice band depth, and with distance from the ice cap (see Fig. 3), we contend that our slope ratio parameter is correlated with ice content.

To map the ice content of the hydrated terrains, we have identified 6 spectral types, chosen to highlight correlations with geologic features, and to correlate with inflection points in the albedo-slope parameter curve. Representative spectra from each of these types

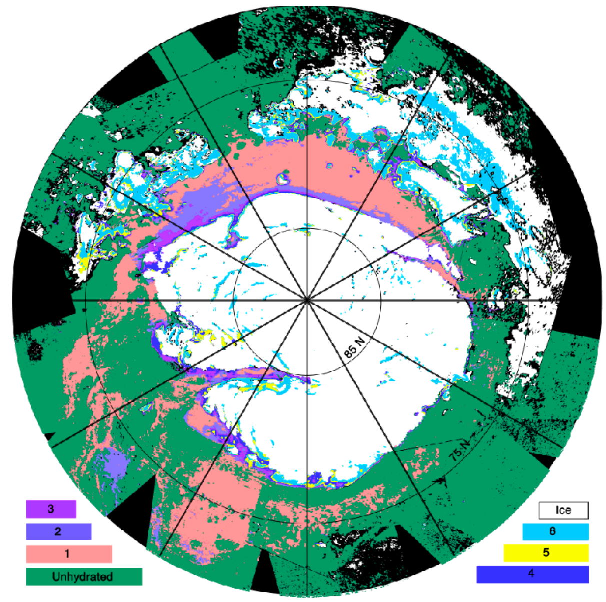

Figure 3: *Distribution of unhydrated terrain (green), water ice (white), and hydrated units identified in Fig. 1.*

are shown in Figure 2b. Figure 3 shows a map of the distribution of each spectral type.

Results: Hydrated terrains include many of the deeper chasma and reentrants in Planum Boreum, as well as all previously mapped dune fields and sand sheets [10]. In particular, Chasma Boreale exhibits remarkable hydration signatures on scarps and on actively eroding headwalls [11]. Preliminary investigations using the THEMIS 18 m summer mosaic (N. Gorelick/ASU) have indicated that the the hydrated terrains within Planum Boreum may be part of the same geologic unit or set of units.

The presence of hydrated minerals throughout the north polar region suggests that the high concentrations of gypsum observed in Olympia Undae may be sourced from a much older deposit than the dunes themselves, and that at some point in the past, liquid water may have played a role in the evolution of the region. Possible depositional and modification processes for the hydrated units include deposition in standing water, catastrophic outflows from lower latitudes, or aeolian sedimentation, and modification of existing materials via circulating groundwater or volcanic gases.

References: [1] Zuber *et al*. (1998) *Science*, *282*, 2053. [2] Langevin *et al.* (2005) *Science*, *307*, 1584. [3] Deer *et al.* (1992) *The Rock-Forming Minerals*, Pearson, 612. [4] Fishbaugh *et al.* (2007) *JGR*, doi: 10.1029/2006JE002862. [5] Feldman *et al.* (2007) *Icarus*, doi: 10.1016/j.icarus.2007.08.044. [6] Bibring *et al.* (2006) *Science*, *312*, 400. [7] Cloutis *et al.* (2006) *Icarus*, *184*, 121. [8] Poulet *et al.* (2007) *JGR*, doi: 10.1029/2006JE002840. [9] Clark (1981) *JGR*, *86*, 3074. [10] Tanaka *et al.* (2003) *JGR,* doi: 10.1029/2006JE002840. [11] Warner and Farmer (2007) *Icarus*, doi: 10.1016/j.icarus.2007.08.043.