COMPOSITIONAL RELATIONSHIPS BETWEEN HIGH LATITUDE UNITS AND IMPLICATIONS FOR THE HISTORY OF THE NORTH POLAR REGION. B. Horgan1, J.F. Bell, III1, and E.A. Cloutis2, 1Arizona State University (briony.horgan@asu.edu), 2University of Winnipeg

Introduction: Planum Boreum, the north polar plateau, is composed of a series of sedimentary deposits. Several of the major questions surrounding these deposits regard their origin, modification history, and their interrelationships. Here we present new results on the composition of mafic units in the north polar region that address these questions. These units include the north polar sand sea, sourced from within Planum Boreum, the Cavi unit, an indurated ancient sand dune sea, and the north polar veneers, which drape Planum Boreum and appear to be sourced from the Planum Boreum 2 (PB2) unit [1,2]. Here we present results from spectral and morphologic studies, which together show that the history of these deposits involves volcanic, glacial, and sedimentary processes.

Methods: We have analyzed Mars Express OMEGA visible and near-infrared (0.3-2.5 µm) spectra from the first year of OMEGA observations above 45°N. In this study, we have focused on the 1 µm absorption band caused by iron. Together, the position and shape of this band are sensitive to both mineralogy and composition, making it an indicator of iron mineralogy [3]. Prior to analysis, all spectra were atmospherically corrected, ratioed with dust, continuum-removed, and mapped into a regional mosaic.

Figure 1: Representative OMEGA spectra from the north polar region showing diversity in iron mineralogy. Contributions from the atmosphere and dust, as well as instrumental and continuum effects have been removed.

Observed mineralogy: Based on the position and shape of the 1 µm band in OMEGA spectra, we observe three classes of spectra in the northern lowlands and the north polar region, represented in Figure 1. One class of spectra exhibit a shallow, broad absorption near 1.15 µm that is consistent with an enrichment in iron-bearing glass [4]. Based on laboratory mixing models, the lack of other ferrous mineral spectral signatures suggests that the ferrous component of these terrains is 80-90% glass. These same terrains also exhibit a strong blue concave slope, a spectral signature that is consistent with leached glass rinds, which form during acidic alteration of glass surfaces. The second class of spectra exhibit strong 1 and 2 µm bands with positions and shapes that are generally consistent with high-calcium pyroxene (HCP), and may be specifically consistent with an Fe-rich HCP. The third class of spectra exhibit band centers and shapes that could be interpreted as consistent with olivine; however, laboratory models demonstrate that these spectra are also consistent with a mixture of glass and HCP. Furthermore, as shown in Figure 2, these spectra only occur along transport pathways in the north polar sand sea where mixing between glass and HCP appears to be occurring, supporting a mixture interpretation.

Mineral distribution and origin hypotheses: Mineral distributions in the north polar region subset of our more extensive maps are presented in Figure 2. We have detected spectra consistent with iron-bearing glass in pixels totaling over one million sq. km north of 45°N on Mars, including throughout Acidalia and Utopia Planitia, in Siton Undae, and in many localized deposits adjacent to Planum Boreum. Based on analogy with the glass-rich sand seas of Iceland [5], we propose that these deposits formed during explosive volcanism, most likely caused by ice-magma interactions. For the main concentration of glass in Acidalia, this hypothesis is supported by the recent discovery of geomorphic features in Southern Acidalia and Chryse Planitia that may be consistent with sub-glacial volcanism and ice-lava interactions [6]. Glass from eruptions in this region may have been transported into the northern lowlands via airfall, aeolian redistribution, or floods. Based on comparison with spectral analogs in Hawaii [7], we interpret the leached glass rinds on these deposits as secondary weathering products, produced during moderately acidic, low water:rock ratio alteration, perhaps due to interactions with melt water from surface ice or snow.

HCP-bearing deposits in the north polar region include the region around the polar outliers and portions of the north polar sand sea. In the northern lowlands, spectra consistent with HCP are much less widely distributed, and appear to primarily occur in crater ejecta. This implies that the HCP is present in the subsurface,
consistent with previous CRISM investigations in Acidalia that interpreted pyroxene and olivine-bearing units exposed in crater walls as lava flows [8].

Implications for the history of Planum Boreum: Tracing apparent sediment transport pathways allows us to make predictions about the composition of source units within Planum Boreum. Apparent sources of the glass-rich sands in the north polar region appear to be highly correlated with exposures of the Cavi unit [1], while apparent sources of HCP-bearing sands appear to be correlated with the PB2 unit. This suggests that these two primary sandy units within Planum Boreum had different sources, underwent different alteration histories, and have not interacted. A plausible source for the glass-rich sands of the Cavi unit would be aeolian reworking of the widespread glass-rich deposits elsewhere in the northern lowlands; however, the origin of the HCP-bearing unit is less clear. The only HCP-bearing units in the northern lowlands observed so far are in the subsurface, below the glass-bearing terrains. Thus, the PB2 unit requires an origin that extracts HCP from the subsurface but does not result in substantial mixing with glass. One possibility is that a large impact into the northern plains may have liberated enough HCP-bearing sediment to create the PB2 unit, but this hypothesis requires further investigation.

Source of the Olympia Undae gypsum: One area of future research related to these results is the relationship between the HCP and glass-bearing units and the eastern Olympia Undae (EOU) gypsum deposit [9]. Despite high-resolution investigations, the source of the gypsum remains unclear, as no other unit in the region exhibits sulfate concentrations as high as EOU [10,11]. Thus, [11] proposed that the observed high concentrations are surficial and do not represent the volumetric concentrations, possibly due to capillary wicking of gypsum-rich brines from the interior of the dunes. Our morphological investigations support this hypothesis by demonstrating a strong correlation between the density of tensional surface cracks on sand dunes in HiRISE images and the strength of gypsum absorptions in OMEGA spectra, which we interpret as evidence that the dune surface is cemented by gypsum. Thus, this raises the possibility that either of the two Planum Boreum units discussed above could be the source for the gypsum: the PB2 unit, which contains gypsum, or the Cavi unit, which exhibits signs of aqueous alteration that would be expected to form gypsum and other sulfates. Further investigations of the ferrous spectral characteristics of eastern Olympia Undae may help to further develop this hypothesis.


Figure 2: Interpreted mineralogy of north polar deposits based on 1 μm band position and shape. Red: glass, blue: HCP, green: mixture.

Figure 3: Concavity of north polar spectra (-0.15 to 0.15), determined by A(0.7)/A(1.55) – A(1.55)/A(2.3), where A is albedo of the channel closest to the indicated wavelength. Concave spectra (concavity > zero: green/yellow/red) are interpreted to indicate leached glass rinds.