DATEABLE VOLCANIC AND IMPACT SEDIMENTS WITHIN THE NORTH POLAR LAYERED DEPOSITS ON MARS. P. Sinha[1], B. Horgan[1], and F. Seelos[2]. [1]Purdue University (sinha37@purdue.edu), [2]JHU/Applied Physics Laboratory.

Introduction: The ice-rich sedimentary deposits of the north polar plateau, Planum Boreum, record the recent climatic history of Mars [1]. The 2011 NRC Planetary Science Decadal Survey identifies the polar regions of Mars as high priority targets and recommends a lander mission to sample ice cores on the north polar layered deposits (NPLD). The aim of the mission will be to constrain the climatic and geologic processes on Mars in the recent past, much like how climatic records on Earth are studied using ice cores. The NPLD are hypothesized to have formed from long term deposition of ice and airfall dust during the late Amazonian [2]; however, the non-ice composition is poorly constrained. Linking the geologic record at the north pole to the climatic history will require quantitative age dating of datable lithic materials such as impact ejecta and volcanic ash within the NPLD. Ice cores on Earth are dated via K-Ar radiometric dating of trapped atmospheric gases or volcanic ash/impact layers [3]. In this study, we use high resolution orbital spectra from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) to test whether or not the NPLD contain the materials for quantitative geochronology. These mineralogical detections also provide constraints on the geologic processes that contributed to the formation of the NPLD.

Methods: CRISM TRR3 Full Resolution Targeted (FRT) and Half Resolution Long (HRL) images were analysed using the ENVI CRISM Analysis Toolkit (CAT). These 18-40 m/pixel hyperspectral VNIR (0.35-2.65 μm) images are processed to correct for photometric and atmospheric effects before analyzing for spectral signatures to detect Fe-bearing minerals which causes a broad absorption near 1 μm and often also near 2 μm [4,5,6]. Mafic minerals like olivine have a broad absorption centered between 1.05-1.07 μm, pyroxene exhibits bands centered near 0.9-1.05 μm and 2.1-2.4 μm, while Fe-bearing glass has relatively broader, shallow and symmetric bands centered between 1.08-1.16 μm and a weaker absorption band around 2.0 μm. The absorption bands for glass are resolvable only when glass is present in high abundances (>~70%) but can be detected as a distortion on other mineral bands at moderate abundances (>~50%). In addition, most previous glass detections in the region are associated with a spectrally featureless strong blue and concave up slope which is interpreted as weathering of the glass surface [7]. Spectral summary parameters are used to generate RGB maps showing spectral variations which aid in identifying regions of interest (ROIs) for spectral analysis [8]. The I/F spectra from ROIs contain unwanted contribution from surface dust, atmosphere and water ice that prevent the identification of lithics in the scene. To suppress these effects we calculate a reference spectrum from an average of pixels from the same detector column in the scene displaying a high value for spectral parameter BD530 (ferric dust), lower values for parameters BDI1000VIS and HCPINDEX2 (mafic minerals) and with a water ice band depth at 1.5 μm similar to the selected ROI. This process is effective in revealing the mineralogy of the lithic materials. To clearly see the broad Fe-absorption bands near 1 μm and 2 μm, the continuum of each spectrum is then suppressed by dividing the ratio spectrum by a modeled continuum shape [4,7,9].

Results: Five CRISM images from Chasma Boreale, Olympia Cavi, and on top of Planum Boreum (Fig.1) has been analysed to assess the lithic composition within the NPLD which comprises of three mapped geologic units. The Planum Boreum 1 (ABb_1) unit is an ice-rich meter-scale layers that makes up the majority of the NPLD. This unit has been proposed to be composed of ice and airfall dust accumulated during periods of low obliquity [10,11,12]. Spectrally, this unit does appear to be dominated by ice and ferric dust, but upon ratioing, also often exhibit broad absorptions centered between 0.95-1.05 μm and 2.05-2.3 μm which are consistent with varying mixtures of glass and HCP. Additional diversity may be present in some locations. For example, within the NPLD at Olympia Cavi, one region exhibits strong 1 μm bands consistent with olivine. ABb_1 is heterogeneously overlain by the Planum Boreum 2 (ABb_2) unit, which is a dark and lithified sediment layer that also mantles the floor of Chasma Boreale and Olympia Cavi. This unit has been proposed to be a sublimation lag [13,14], but could also be consistent with a regional airfall deposit that postdated the erosion of Chasma Boreale. ABb_2 exhibits a strong blue and concave up slope with no clear Fe-bands consistent with weathered glass. Both ABb1 and ABb2 are overlain by the Planum Boreum 3 (ABb_3) unit, which is a thin ice-rich unit proposed to represent recent and ongoing ice accumulation [10,11]. ABb_3 is spectrally dominated by ice, and does not appear to contain a significant non-ice component. The cavi unit (ABb_c) is a thick dark unit near the base of the plateau interepreted as an ancient induated sand sea. ABb_c more frequently exhibits weathered glass and glass signatures, although often mixed with HCP. Sand dunes are observed within Chasma Boreale and Olympia Cavi that appear to source the sandy material from the scarp due to erosion by katabatic winds. The spectra from these dunes exhibit deeper rounded absorption around 1.1 μm consistent with a glass-rich composition, most likely primarily sourced from the Cavi unit.

Discussion: Glass appears to be a major part of the lithic component of Planum Boreum, although HCP is also present throughout the bulk of the NPLD. Weathered glass and HCP signatures are present within the north polar sand sea, and in the broader northern plains which could be a source for sediments on NPLD. However, based on wind models for Planum Boreum, katabatic winds drive transport off of the cap, and are unlikely to transport materials up onto the cap [15]. Instead, the compositional similarity may be because the surrounding plains may be mantled by the same materials that were deposited via airfall onto the cap.

On Mars, dust is dominated by a globally homogenous mixture of sub-micron mineral particles and a large fraction of nanophase ferric oxides [16]. An important finding of this study is that while ferric dust sourced from airfall is a major component of the NPLD, it is not the only lithic component. Instead, pyroxene, glass, and likely some olivine are also present within the NPLD, suggesting that either impacts or volcanism contributed to sediment accumulation [17,18,19].

Proximal impact ejecta from regional impacts would be composed of a mix of local crystalline country rock and a small fraction of impact melt glasses, which decrease in grain size with distance from the impact, while distal impact ejecta from global impacts is composed of sand-sized spherules and larger tektites that are typically glassy but can contain crystalline minerals depending on the cooling history [20,21]. Volcanic tephras range from crystalline to glass-rich, where glass abundances are significantly enhanced by water/ice interactions during eruption [22]. Climate models suggest that volcanic ash from known edifices in the mid-latitudes is difficult to latitudinally transport; so the majority of material deposited at the poles would be quite fine grained [19]. Impact sources could be globally distributed, and could produce coarser deposits [17]. Distal impact deposits are composed of sand-sized spherules forming a layer mm to tens of cm in thickness, depending on the size and velocity of the impactor [17,23]. In either case, these sediments could provide both compositional markers for correlation of relative stratigraphies across the region, as well as potential sediments for quantitative geochronology via K-Ar dating. Thus, the NPLD on Mars could preserve not just a quantitative record of climate during the late Amazonian, but also a record of the impactor flux and/or volcanic eruption rate.

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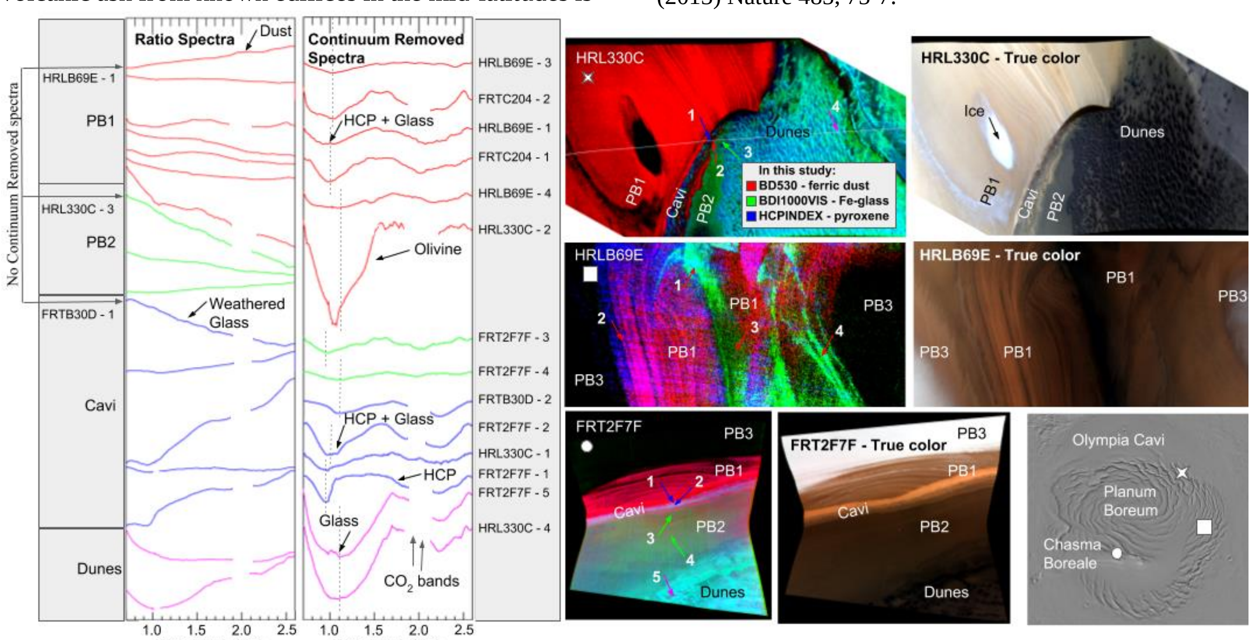

Figure 1: *Ratio spectra and continuum removed spectra from NPLD with interpreted mineralogy (on the left). RGB composite and true color image of CRISM cubes (on the right) from locations on Planum Boreum (bottom right) showing mineralogical diversity (FRTC204, FRTB30D – not shown in the image).*