THE MINERALOGY OF LITHIC SEDIMENTS WITHIN THE SOUTH POLAR LAYERED DEPOSITS OF MARS.

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Introduction: Polar Layered Deposits (PLD) on Mars are a massive ice-rich plateaus formed under the influence of climate cycles that drive the transport of volatiles and dust [1]. The South Polar Layered Deposits (SPLD), nearly the size of Alaska [2], form the Planum Australe plateau and are estimated to be 100 Myr old [3]. PLDs were identified as high priority targets by the 2013-2023 Planetary Science Decadal Survey to sample ice cores and reconstruct the history of recent climatic and geologic processes on Mars. The SPLD being older than its northern counterpart provides an opportunity to probe pre-modern but geologically recent records.

Characterizing the sediments in the SPLD is essential to interpret nature of the deposits and associated climate signals, however, the bulk composition of its non-ice components remains unconstrained. Radar studies suggest bulk dust content of SPLD to be ~15% [4-5], but primary minerals may also be present [6]. Here, in this study we use the high resolution orbital spectral data from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) to constrain the composition of lithic sediments present in the SPLD.

Method: The ENVI CRISM analysis toolkit is used to analyze CRISM MTRDR hyperspectral image cubes which are corrected for atmospheric, photometric, and instrumental effects. The 18-40 m/pixel data is examined at visible/near-infrared wavelengths (VNIR; 0.35-2.65 μm) to detect the mineralogy of Fe-bearing primary minerals within the sediments of the SPLD. Fe-bearing minerals cause a broad absorption at 1 μm and often also near 2 μm [7-9]. The position and shape of the absorption bands is used to identify minerals like olivine, pyroxenes, and glass. Olivine has 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. Absorption bands for glass are resolvable at abundances greater than 50-70% and spectra associated with a featureless strong blue and concave up slope is interpreted as weathering of the glass surface [10].

RGB composite maps are generated using spectral summary parameters BD530 (red), BDI1000VIS (green), HCPINDEX (blue), which measure the ferric absorption band at 0.53 μm and ferrous absorption bands at 1 and 2 μm, respectively [11]. RGB maps highlight spectral variation resulting from iron absorptions and aid in identifying regions of interest (ROI) for spectral analysis. The corrected I/F spectra of the ROI has unwanted effects from dust, ice, and atmospheric residuals which prevents the detection of lithic in the scene. To clearly see the spectral contribution from lithics, these effects are suppressed by dividing the I/F spectra by a reference spectrum which is an average of pixels with high values of BD530 (ferric dust) and low values for BDI1000VIS and HCPINDEX (mafics). Further, the continuum of each spectra is suppressed by dividing the ratio spectrum by a modeled continuum [12].

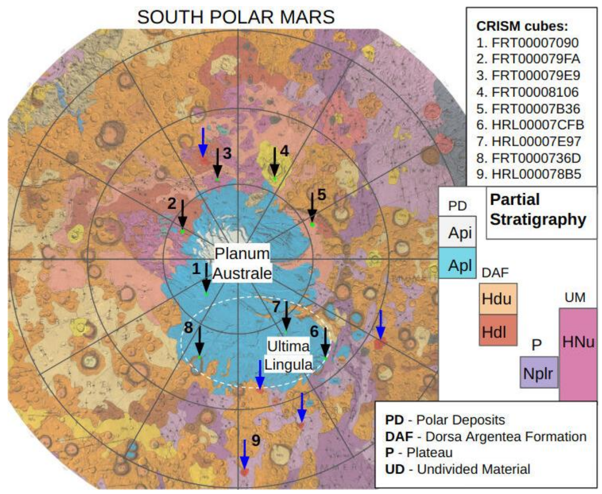
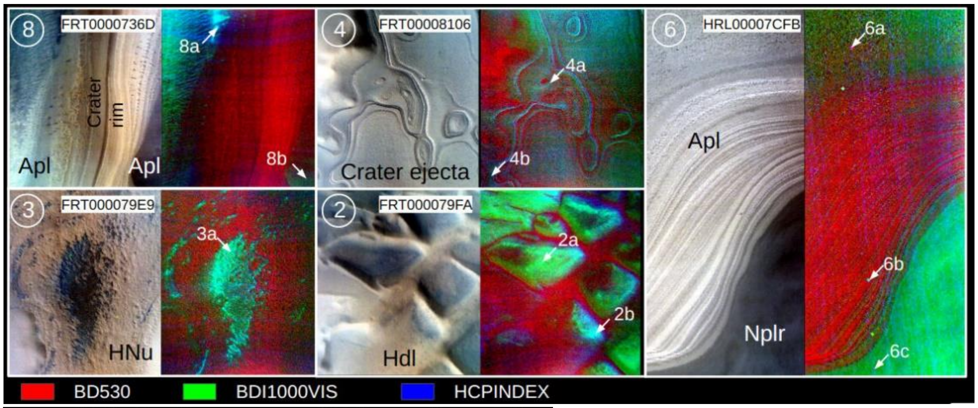


Figure 1: *Locations of CRISM images in this study (black arrows); blue arrows point at volcanic features around SPLD.*

South Polar Plateau Units [13]: (Fig 1) The uppermost high albedo deposits, Amazonian polar ice (Api), is the residual polar cap surmounting the Amazonian layered deposit (Apl) whose accumulation time is estimated to span up to 15 Myr [14]. Underlying Apl is middle Hesperian age Dorsa Argentea Formation (DAF) which is divided into smooth upper (Hdu) and degraded lower (Hdl) units, and forms polar plains. Mostly lying underneath DAF is a Hesperian-Noachian undivided material (HNu) which is comprised of degraded plateau rocks. Nplr is Noachian plateau ridged unit formed by volcanism or folding/faulting of preexisting structures.

SPLD Mineralogy: Nine CRISM images from around the south polar plateau poleward of 70°S except one were chosen for the study and covers the Ultima Lingula region which is suggested to have the most consistent climate record [14]. The spectral cubes studied were acquired during the summer in southern hemisphere (L_S 290 - 330°), hence, the cubes were mostly ice free. The layered deposits (Apl) appear to be dominated by ferric dust (absorption at 0.53 μm) and is represented by red in the RGB composite (cube 6 Fig 2). However, upon ratioing, absorption bands at 1 and 2



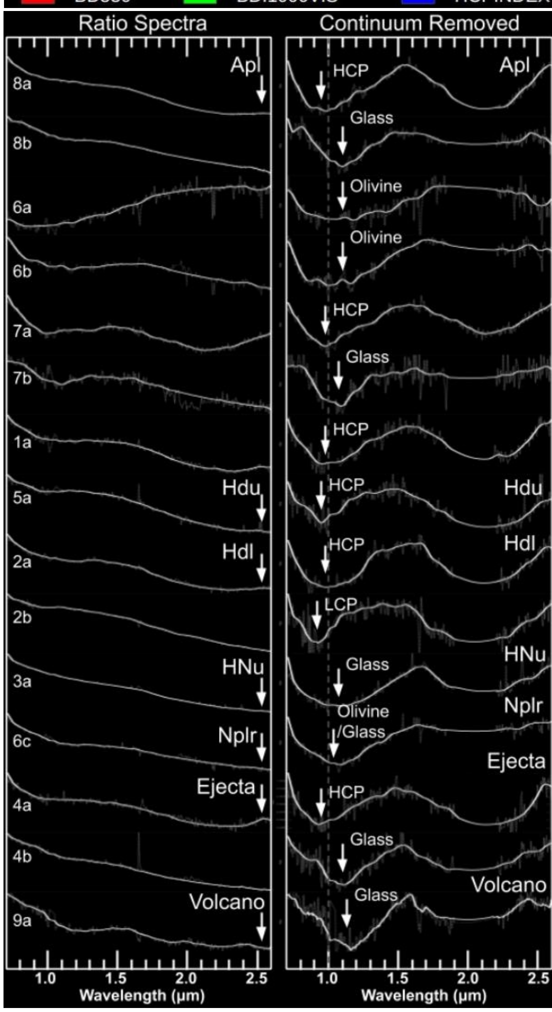


Figure 2: *(Top)True color image and RGB composite of spectral cubes from SPLD. (Bottom) Ratio and Continuum Removed spectra from SPLD.*

µm suggest presence of a diverse suite of mafic minerals including olivine, pyroxene, and glass within the Ultima Lingula region of the SPLD (spectra 6a-b,7a-b, 8a-b). Broad 1 µm absorption with high band area ratio (band area at 1 µm/ band area at 2 µm) values for spectra 6a-b suggests olivine. HCP signatures have also been detected in the sediments eroding from Apl up to ~84°S (spectrum 1a).

Mafic sediments dominate the green/blue on the RGB map. Spectra 5a, 2a-b from Hesperian-aged DAF shows signatures of both high-Ca pyroxene (HCP) and low-Ca pyroxene (LCP). HNu appears glass-rich (spectra 3a) whereas Nplr shows only a broad 1 µm absorption, therefore, a high band area ratio suggesting presence of olivine (spectra 6c). Overall, the band center for mafic signatures at 1 µm ranges 0.9 µm to a little beyond 1.1 µm and band center at 2 µm lie between 2 – 2.3 µm.

The color contrast between layered deposits (Apl in red) and floor unit Nplr (in green) as shown in RGB composite for cube 6 suggests active erosion of the layered unit at the periphery by katabatic wind which frees coarser sediments causing them to roll on to the underlying unit, this process prevents uninterrupted supply of airfall dust from settling on the floor which is reflected in the color map.

Discussion: The south polar layered deposits appear dusty but contain mafic sediments entrained in its layers. Therefore, apart from airfall martian dust, lithic sediments were simultaneously deposited likely due to impacts or volcanism (see locations marked with blue arrows in Fig 1). Spectrally, volcanic material (9a; interpreted as glass) and ejecta layers (4a-b; interpreted as HCP & glass respectively) appear similar to the mafics (6a-b,7a-b,8a-b) observed over the SPLD (Apl). Detection of in place mafic units within the SPLD would mean that the sediments are dateable and the age of the deposits can be constrained by radiometric age-dating. Detection of distinct LCP in the lower unit (Hdl) of the DAF forming polar plains may provide an insight into the evolution of volcanic material in the south polar region.

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