SOUTHERN CIRCUMPOLAR CRATER ICE DEPOSITS ON MARS. O. W. Westbrook,[1] M. T. Zuber,[1] and S. Byrne[2], [1]Dept. of Earth, Atmospheric, and Planetary Science, Massachusetts Institute of Technology, 77 Massachusetts Ave., Cambridge, MA 02139 (owestbro@mit.edu, zuber@mit.edu), [2]Lunar and Planetary Lab, University of Arizona, Tuscon, AZ 85721 (shane@lpl.arizona.edu).

Introduction: Layered deposits at the poles of Mars are thought to preserve a record of past climatic conditions in up to 3 km of water ice and dust. Just beyond the extent of the south polar layered deposits (SPLD), dozens of impact craters in the heavily-cratered southern highlands contain mounds of fill material. Many of these crater-filling deposits (CFDs) appear to be outliers of the main SPLD, and some have previously been mapped as such [1,2]. Prior workers have scrutinized these deposits for possible glacial flow and fracture features [3] and described them in general morphological and geographical terms [4,5]. We extend this work by cataloging all CFDs found near the south pole and quantifying the physical parameters of both the deposits and their host craters. Using MOLA topography data, MOC imagery, THEMIS infrared data, and SHARAD radar sounding data, we investigate the distribution, structure, and origin of the deposits. We also consider the relative importance of solar and eolian mass-balance processes in shaping the distribution and morphologies of these deposits. The isolation of these deposits from the main SPLD points to the polar crater microenvironment as key to the persistence of these deposits. We explore the possibility that crater sand dunes may have provided a substrate for ice accumulation.

Deposit Identification, Morphology, and Measurements: CFD identification was performed on the basis of MOLA topography, MOC imagery, and THEMIS infrared data. Using mapping from a previous study [3] as a starting point, we examined prominent raised features on crater floors poleward of 60° S for typical CFD features, including a rounded or flat top and a distinct bounding slope steepest at the margins. On the basis of these characteristics, along with the tendency of CFDs to be asymmetric or offset from the crater center, we identified 76 likely CFDs and noted several more marginal cases (Fig.1).

In order to catalog the physical properties of these CFDs and constrain future modeling efforts, we developed techniques for the automated measurement of fill deposits and their host craters from MOLA digital elevation models of the south polar region. We made measurements of 74 CFDs and their host craters, recording the latitude and longitude of the crater center, crater diameter, depth, and rim elevation, as well as the latitude, longitude, and elevation of the CFD peak.

Most deposits were found in craters with a diameter of at least 20 km situated within roughly 500 km of the outer limits of the SPLD, between 65° S and 80° S. As past studies have noted [3,4], deposits closer to the main SPLD tend to be more circular and less asymmetric and to fill a greater percentage of the crater. Features consistent with ice flow [5] also become less apparent with distance from the SPLD. The distribution of CFDs shows a strong longitudinal bias that follows the extent of both the SPLD and the oldest Noachian-era cratered highland terrain.

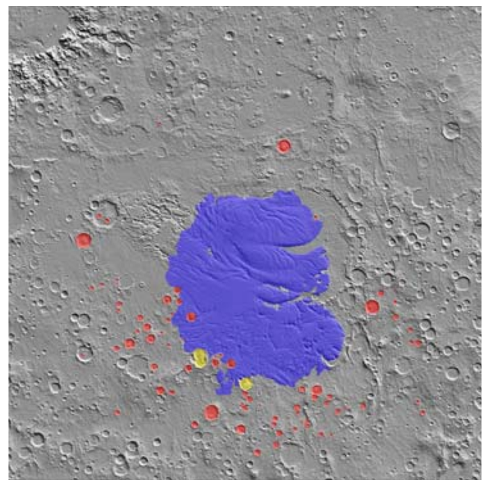

Figure 1: MOLA shaded relief map centered on the south pole. Craters containing deposits measured in this work are shaded red. Craters shaded yellow hold deposits that presented measurement dificulties due to asymmetries of the host craters. The approximate extent of the SPLD [1] is shown in blue.

Crater Insolation: The circumpolar placement of these CFDs near the south pole and the trend of increasing crater fill at higher latitudes indicate that solar insolation strongly affects overall deposit distribution. In addition, the large north/south offsets of many deposits within their host craters suggest that solar heating and shadowing influence the stability zone and morphology of a given deposit. For roughly a dozen prominent CFDs, we calculated the average annual solar insolation received both with and without the effects of shadowing taken into account (Fig. 2).

Our results indicate that shadowing plays a minimal role in deposit preservation, as the majority of the craters containing deposits are flat-floored and have low aspect ratios. Nearly all deposits lie beyond the protective shelter of the host crater rim and a majority are actually offset poleward of the crater's center, observations consistent with solar ablation of the northern, equator-facing slopes of icy deposits rather than shadowing. Such poleward offsets strongly suggest the presence of volatiles in the deposits, as volatile-free deposits would be less responsive to solar forcing. Current deposit morphologies may represent a balance between solar ablation of ice and the corresponding growth of an insulating dust lag as volatiles are lost.

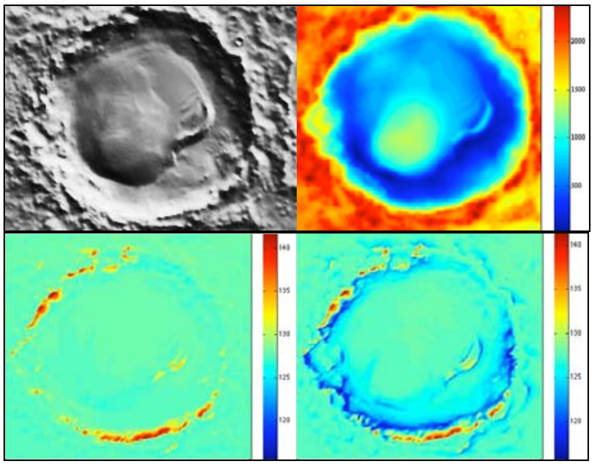

Figure 2: CFD in South Crater (77° S, 22° E, 107 km in diameter). Clockwise from top left: MOLA shaded relief, MOLA topography, average annual insolation without shadowing, and average annual insolation with shadowing. Topography scale is in m; insolation is in W/m^2. The insolation environment is similar inside and outside the crater, and shadowing offers little direct sheltering to the deposit.

Crater Winds: Our knowledge of Martian surface winds remains poorly constrained, but the polar regions, particularly the layered deposits, display signs of extensive eolian modification. Surface evidence, mesoscale modeling, and terrestrial comparisons suggest that winds strong enough to entrain sand and dust particles blow outward from the polar cap [6,7]. CFD peaks exhibit a marked tendency to be offset to the west of the crater center, a trend consistent with Coriolis deflection of these regional winds. The local wind regime may influence the morphology of a given deposit, however, and mesoscale modeling of the Martian atmosphere is only now advancing to the spatial scale of an impact crater [8,9].

Seasonal Frost and Sand Dunes: Observations of seasonal frost in the polar regions indicate that it preferentially forms first on sand dunes in the fall and winter and persists on some dunes until mid-summer [10]. Some authors have proposed that certain polar icy terrains could originate from water ice and dust left behind after the sublimation of the CO_2 component of this seasonal frost [11]. Year-long observations of icy dunes atop a CFD in Richardson Crater (72.4° S, 179.6° E) show that dune temperatures range from around the freezing point of CO_2 (~148 K) in the late winter to just under the freezing point of H_2O in mid-summer, when the dunes appear frost-free [12,13]. CRISM images of the dunes at the beginning of the southern spring identify this frost as a mixture of CO_2 and water ice, with water ice and sand visible through defrosting dark patches on the surface [14].

These observations suggest that CFDs may have formed from the gradual buildup of seasonal frost. By enhancing the deposition of seasonal frost and inhibiting the sublimation of that frost in the spring, sand dunes could provide a substrate for mounded water ice deposits to slowly accumulate over time. Mantling by continuing dust and sand deposition would help insulate existing layers from ablation. In turn, ice condensation within and on top of the dunes could immobilize sand grains and dust [9]. The ability of Martian craters to act as traps for windblown sand [15,16] would account for the persistence of these deposits beyond the current SPLD boundary. In addition, cold air pooling within impact craters [17] could potentially further enhance ice deposition and stability. If CFD formation and persistence is a result of the polar crater microenvironment, then CFDs may not be remnants of past climatic conditions in which the SPLD was significantly more extensive than it is today [e.g. 18,4,5].

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