CRATER POPULATION AND RESURFACING AT THE MARTIAN NORTH POLE.

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Introduction: The Martian north polar residual cap (NRC) lies on top of the north polar layered deposits (NPLD). The NRC is about 1m thick and composed primarily of large-grained, dust-poor water ice [1]. The mass balance of the polar cap is uncertain. Long-term monitoring reveals small reversible changes in its extent on an interannual basis [2]. Images with a pixel scale of up to 0.25 m/pixel from the High Resolution Imaging Science Experiment (HiRISE) aboard the Mars Reconnaissance Orbiter (MRO), show brighter, or smaller-grained, (i.e. younger) ice superposing darker, or larger-grained, (i.e. older) ice. The lack of dust accumulation indicates that the material composing the NRC accumulated recently. On the other hand, the exposure of darker, larger-grained ice indicates a current state of net ablation. Small pits observed in HiRISE imagery resemble suncups and also suggest recent ablation.

The NPLD are believed to preserve a record of seasonal and climatic cycling of atmospheric water and dust and could reveal important information regarding Martian geologic and climatic history. The NRC is often considered new NPLD material. Thus, understanding the NRC's current behavior and mass-balance in relation to the current climate is an important step in reading the climatic record of the NPLD. One way to do this is to analyze the cratering record of the NRC. Previous studies concluded a NPLD resurfacing age of only ~20-100 Kyr. [3; 4]. However, due to the low resolution and sparse coverage of available imagery, these conclusions were based on 0 or 2 craters respectively. Now, Data from the Context Camera (CTX) aboard the MRO provide almost complete coverage of the NRC and NPLD with pixel scales of ~6 m/pixel.

To constrain the processes and rates of NRC resurfacing, we conducted a search for craters within the CTX dataset. Using the NRC crater population data, we will use landscape evolution modeling to investigate the recent (10-20 Kyr) mass-balance history of the NRC.

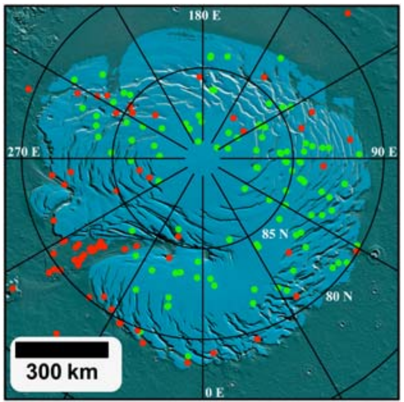
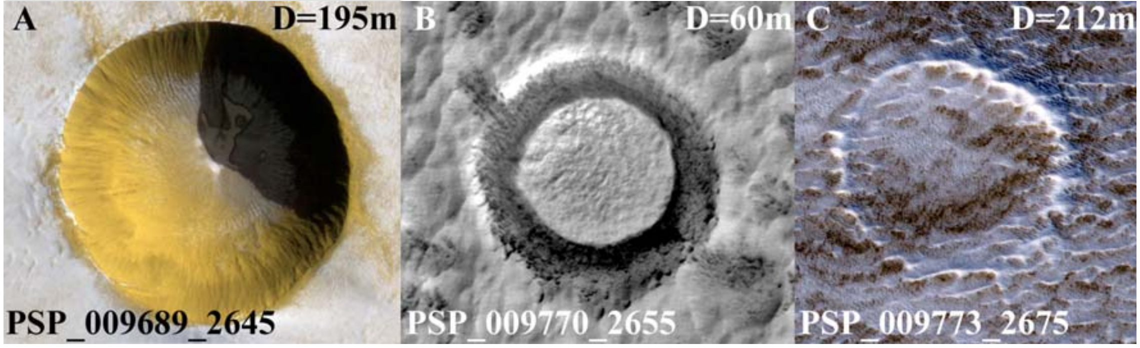


Figure 1: 183 craters (red and green dots) have been identified and measured on the combined NPLD and NRC with diameters ranging from ~10-420 m. Within the ROI (blue area), 103 craters (green dots) were identified with diameters ranging from ~10–352m.

Figure 2: HiRISE images show craters in various stages of degradation. A) A relatively fresh crater with little ice accumulation and rim erosion. B) partly infilled and the rim has been eroded by ablation and wind action. C) The crater is almost completely infilled and the rim is highly degraded.



Crater Observations: We have discovered and measured >100 craters on the NRC and NPLD combined (of which only 4 were previously known); 103 of these craters are located on the NRC (Figure 1). HiRISE images have been acquired to follow up on 52 of the craters (several in stereo). NRC and NPLD craters range in diameter from ~10-450m (~10–212m for craters on the NRC only). HiRISE observations reveal a morphological sequence of crater degradation states that provides a qualitative understanding of the processes involved in crater removal (Figure 2). Depth/diameter ratios calculated from shadow measurements for 20 craters range from 0.02 (mostly infilled) to 0.26 (fresh craters) with more than half of the craters having ratios below 0.12. Impact craters are the sites of preferential ice accumulation which gradually infills the crater cavity. Shadowing inside the crater promotes accumulation of fresh, small-grained ice which is brighter, stays cooler, and creates a positive feedback. Ablation and eolian erosion also contribute to crater removal by degrading crater rims where ablation pits (suncups) are commonly observed. In contrast to the residual ice cap, ice deposits within the craters stay bright (fine-grained) all year implying ongoing accumulation.

Population Statistics: It can be seen from figure 3 that this population of craters, over the diameter range discussed above, does not follow an expected production function [5]. Our crater population is deficient in small craters relative to that expected i.e. the slope of the size-frequency curve is shallower than the production curve. The slope fit to our size-frequency distribution was -1.89 for the cumulative and -1.85 for the differential plot whereas a fit to the production function in this diameter range shows the isochron slopes to be -3.04 and -2.99 respectively (this slight mismatch is the result of incorporating atmospheric screening of projectiles). Such behavior can be explained in terms of an equilibrium population where craters are being removed on a timescale comparable to that over which they accumulate. In the case of the differential representation, the product of the crater production function (which is diameter dependent) and the crater lifetime (also diameter dependent) creates the size-frequency distribution of craters we see today. Taking the fits to the isochrons and size frequency distribution, we find that crater lifetime over the NRC is $30.75D^{1.14}$ years where D is the crater diameter in meters. Thus for example, a 100 m crater on this deposit is removed in just under 6 Kyr.

The 212 m diameter crater in Figure 2C shows what we consider the most degraded of the large craters (this crater is the 2^{nd} largest in our sample). Based on its morphology we could assume that this crater is so degraded that it is on the verge of being removed. Our above analysis shows that the time needed to remove a 212m crater such as this is 13.8 Kyr, and given its degraded state this is likely to be only slightly more than the age of the crater itself. The largest crater in our sample (352m, not shown) is partly infilled. Based on its diameter, the crater's estimated

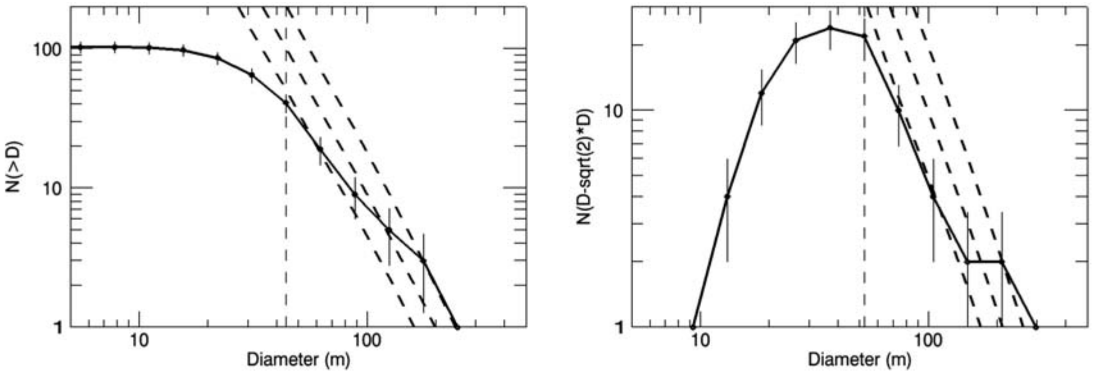


Figure 3. Cumulative (left) and differential (right) size-frequency distribution of craters in the ROI. Vertical dashed line shows diameter cutoff below which crater counts are thought to be incomplete. Inclined dashed lines represent (from left to right) the 5, 10, and 20 Kyr isochrons [5].

lifetime is expected to be 24.6 Kyr and so it likely formed more recently than this. Thus this population represents the past 10-20 Kyr or polar history.

Polar Cap Resurfacing: We can constrain the average accumulation rate within these craters; knowledge of initial crater depths enables us to derive an accumulation rate if we know the time needed to fill the crater. We use the expression for crater lifetime, $30.75D^{1.14}$, as a simplified approximation for crater infilling time (accumulation within craters is the main way in which they are degraded). An estimate of the initial depth comes from a 194m crater (figure 2A) within our sample. This crater is located in typical NPLD target material and is entirely fresh, with a sharp rim and no accumulated interior ice. The d/D ratio of this crater (calculated from shadow lengths and a HiRISE DTM) is 0.26. If initial depth is $\sim 0.26D$ for all craters in our ROI, then dividing this by the expression for infilling time gives an estimated accumulation rate of $8.5D^{-0.14}$ mm/year (i.e. accumulation is slightly faster in smaller craters). Over the crater diameter range considered in our statistical analysis, we estimate the average accumulation rate within NPLD craters to be ~4-5 mm/year. This is an order of magnitude faster than the rate thought to apply to the NPLD in general derived from stratigraphic studies.

This higher estimate is not wholly unexpected as NPLD craters appear to be preferential sites of accumulation today and this behavior could be expected to persist into the past. In addition, the accumulation rate we derived for the NRC craters is representative of the past 10-20 Kyr while the NPLD accumulation rates derived stratigraphically correspond to the upper ~500 m of material (or ~850 Kyr using their accumulation rates).

Conclusions. To infer past climatic conditions from the NPLD, we need to connect the current behavior of these deposits to the current climate. Resurfacing of the north polar cap is not directly tied to the crater removal rate as craters are preferred sites for new deposition. However, craters make ideal control features as they constrain rates of processes. The full range of crater morphologies observed in HiRISE images allows “space-for-time” substitution. Variations in the argument of perihelion will have affected polar climate over the lifetime of these craters. When perihelion occurs in the northern summer, as last happened 21.5 Kyr ago [6], icy material may be ablated from the NPLD. Simulations suggest that several meters of ice may have been removed [7] which would be sufficient to remove craters 10s of meters cross. About 10 Kyr ago deposition began again at the north pole fueled by south polar and mid-latitude ice loss. This accelerated deposition is what infilled the craters we have seen today.

We are beginning landscape evolution modeling of accumulation, ablation and eolian redistribution of ice to modify craters. By combining recent orbital solutions [6] with these processes, we can create landscape evolution models that are constrained by the size-frequency and degradation of the observed crater population and can quantifiably investigate the recent (10-20 Kyr) mass-balance history of the NRC.

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