REINTERPRETING THE IMPACT CRATERS OF THE NORTH POLAR LAYERED DEPOSITS, MARS.

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Introduction: The North Polar Layered Deposits (NPLD) on Mars records the recent climate history of the planet. The NPLD preserves a sequence of stratigraphic layers and dating these layers would yield insights into recent Martian climate change. However, age estimates for the surface of the NPLD range widely. Herkenhoff and Plaut [1] assigned an age of less than 120kyr based on the lack of any visible craters in Viking images. Tanaka [2] derived an age of 8.7kyr based on two superposed craters. Banks et al. [3] searched CTX and HiRISE data and recorded a population of ~100 craters on an area that they determined had recently accumulated. Using the crater production function of Hartmann [4], they inferred that the current craters were an equilibrium population, with crater lifetime proportional to crater size, and that all of the current craters likely accumulated within the last 10-20kyr.

Not only is the age of the whole deposit not well constrained, there are also open questions about the current mass balance of the NPLD. Models suggest that the NPLD should currently be accumulating at the expense of mid-latitude ground ice [5]. However, the sizes of ice grains on the NPLD surface in late summer suggest that old ice is currently being exposed, so there is net annual ablation in progress [6]. This situation cannot have persisted long, as those same data show that the old ice surface has not accumulated any significant amount of dust. Examining the cratering record will put further constraints on how quickly the NPLD could be accumulating or ablating in the recent past, as well as the minimum age of the deposit.

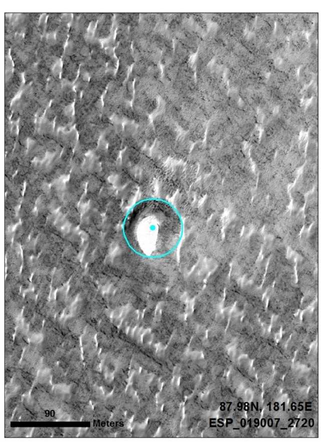

Figure 1. HiRISE image of small NPLD crater originally identified a CTX image [3]. The rim (D ~70m) is outlined in light blue, and ice is present at the bottom of the crater. Image: NASA/JPL/ University of Arizona.

Here, we revisit the NPLD crater population, described in [3], with an important new piece of information. Recently, Daubar et al. [7] measured the production of small craters on Mars directly, and this new production function yields different conclusions for north polar history. We have also acquired more HiRISE images of these craters since the Banks et al. [3] study. Several craters were originally measured with CTX data alone and now these diameter measurements can be refined.

Methodology: Crater diameters were measured using the ArcMap Crater Helper Tools, available from the United States Geological Survey. Where craters were in close proximity to each other (~1 crater diameter separation), they were identified as clusters and the effective diameter was calculated according to the formula $(\Sigma D^3)^{(1/3)}$ [3,7]. Where multiple HiRISE images existed for a site, the diameters were measured in each and averaged.

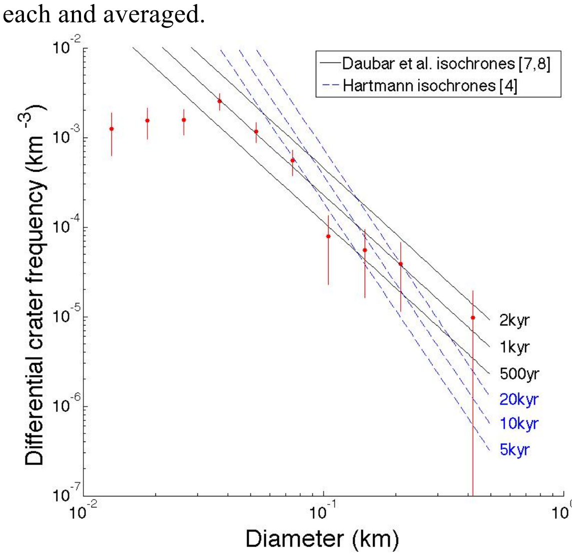

Figure 2. Differential size-frequency distribution of NPLD crater population is plotted in red. The Daubar et al. [7,8] isochrones for 0.5, 1 and 2 kyr are shown in solid black while the Hartmann [4] isochrones for 5, 10 and 20 kyr are shown in dashed blue.

We took crater counts above a diameter of 31m to be statistically complete, as it is the diameter bin before the roll-over of the data on the differential plot. There are 56 craters fitting this criterion (e.g. Figure 1), twelve of which have had their diameter measurements refined through newly acquired HiRISE data after the publication of [3]. For craters previously imaged by HiRISE, the new diameters were on average

2±5m smaller than [3] (at most a 10% difference due to differing determinations of degraded or irregular crater rims). For craters that had only been measured in CTX images reported in [3], the diameters were revised by at most 20m (~4 CTX pixels).

Results: Figure 2 shows the differential size-frequency distribution of the impact craters in this study, plotted in red, against several isochrones based on the current production function given in [7] and recently revised in [8]. The size-frequency distribution of the impact craters on the NPLD is close to the 1kyr isochron from [7,8], while it crosses multiple isochrones from [4]. Error bars shown are standard counting statistics. There is also uncertainty associated with the production function determinations in [7,8] and [4]. Overall, ages determined are accurate within a factor of four using [7,8] and ten using [4] for this population.

Discussion: The closeness of the data to a model age using the updated isochroes from [8] of ~1kyr suggests two possible scenarios. First, a resurfacing event 1kyr ago could have reset the surface and all visible craters formed afterwards. Second, this may be an equilibrium population with both small and large craters having the same lifetime (~1kyr) on the surface (Figure 3). For shallower craters to persist as long as deeper ones, the accumulation rate of ice within smaller craters must be lower than within the large craters. Modeling accumulation rates of the NPLD surface in

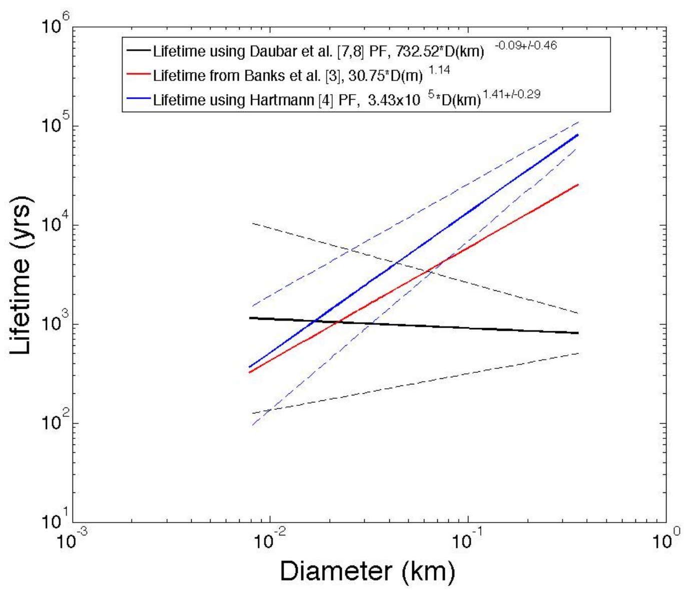

Figure 3. Lifetimes for NPLD impact craters calculated from the updated catalog using the [4] (blue) and [7,8] (black) production functions. The red line shows the lifetime function reported in [3]. The dashed lines represent the upper and lower limits of the lifetime function based on uncertainties propagated from crater counting.

craters of different sizes would distinguish between these two scenarios.

These conclusions stand in stark contrast to those of Banks et al. [3], which relied on the Hartmann [4] isochron system (Figure 2). They concluded that these craters were best explained as an equilibrium population where crater lifetime is roughly proportional to diameter (Figure 3). Therefore, infill rates are roughly the same for large and small craters. The Hartmann isochron system also indicates that the current crater population accumulated over the past 10-15 kyr, with small craters being erased more quickly by the uniform infill across crater sizes.

The choice of crater production function strongly affects the interpretation of the NPLD crater population. The Hartmann [4] system is based on extrapolation from lunar craters whose sizes differ from the NPLD population by at least an order of magnitude, while the Daubar et al. [7,8] population only overlaps with the smallest statistically significant size bin of the NPLD population. Uncertainties in the efficacy of atmospheric screening and how it changes with bolide size affect both crater production functions. The Hartmann system is an average over timescales orders of magnitude longer than those relevant to this population, while the Daubar et al. [7] system is a snapshot of crater production over timescales orders of magnitude shorter than those relevant to this population.

The varying preservation of the NPLD craters mean they are unlikely to all be secondary craters from a single impact and their young age rules out secondaries from several large, distant impacts. They are also spatially isolated (not in rays), and crater clusters are easily identifiable. This makes the production functions of Daubar et al. [7] more appropriate as it does not include distant secondaries, while the Hartmann [4] production function does. An additional feature of Daubar et al. [7] production function is that it is developed from currently observed small Martian impact craters, and so can be updated further using additional impact crater measurements [8]. Further updates could include additional craters in a comparable size rage to the NPLD population.

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