THE GEOGRAPHIC DISTRIBUTION OF BOULDER HALO CRATERS AT MID-TO-HIGH LATITUDES ON MARS. L. X. Rader[1], C. I. Fassett[1,5], J. S. Levy[2], I. R. King[3], P. M. Chaffey[1], C. M. Wagoner[1], A. E. Hanlon[1], J. L. Watters[2], M. A. Kreslavsky[4], J. W. Holt[2], M. D. Dyar[1]. [1]Dept. of Astronomy, Mount Holyoke College, South Hadley, MA 01075 rader22l@mtholyoke.edu, [2]University of Texas at Austin, Institute for Geophysics, Austin, TX 78758 [3]Department of Engineering, Harvey Mudd College, Claremont, CA 91711, [4]Earth & Planet. Sci., UC Santa Cruz, CA 95064, [5] NASA Marshall Space Flight Center, Huntsville, AL 35805.

Introduction and Background: Extensive evidence exists for ground ice at mid-to-high latitudes on Mars, including results from neutron spectroscopy [1-3], thermal properties [4-5], geomorphology [e.g., 6-9], and the *in situ* observations of Mars Phoenix [10]. This ground ice has been hypothesized to be emplaced diffusively and fill pores [11], or to have accumulated by ice and dust deposition that draped or mantled the terrain [7, 12]. These two processes are not mutually exclusive; both potentially have occurred on Mars [5].

One of the landforms found in areas where ground ice is common on Mars are boulder halo craters [e.g., 13-15] (**Figure 1**), which are topographically muted impact craters that are filled by ice-rich regolith. They are outlined by boulders that trace a circular outline of the original crater rim. Boulder halos generally have distinctly higher boulder densities than the surrounding background plains and have few boulders in their interiors.

The mechanism of boulder halo crater formation is somewhat uncertain. Our working model is that an impact event occurs with sufficient size to excavate to a depth greater than the boulder-poor, ice-rich soils. Excavated boulders are deposited around the crater's rim and in its proximal ejecta. Quite rapidly [14], the crater becomes infilled by icy soil. Rather than being buried, boulders in the halo remain at the surface, perhaps because they 'float' relative to finer-grained materials [14, 16]. Regardless of the details of this process, the lifetime of boulders at the surface is much greater than the timescale needed to remove most of the craters' topography. Physical weathering of rocks must be greatly outpaced by crater infilling (the opposite of what is typical, e.g., on the Moon [17]). The rapidity of this infilling is easiest to understand if icy mantling material is deposited and accumulates, rather than simply being added by pore filling of soils.

If this model is correct, boulder halos only form when they excavate rock-producing materials from beneath the upper surface. Thus, the distribution and size of craters that result in boulders halos may provide insight into the thickness of the ice-rich surface layer in different locations. Note that this thickness is necessarily that of the ice-rich layer at the time of impact, not at present. This study is an initial survey of boulder halo crater locations in the 50° to 80°N and 50° to 80°S latitude bands on Mars.

Methods: Data from the HiRISE instrument on the Mars Reconnaissance Orbiter (MRO) was used to map which images had boulder halo craters. More than 6000 images were selected in the latitude bands of interest, restricted to the summer season to avoid seasonal frost. The HiView image browser was used to manually classify each image based on whether they had features in each of five categories: (1) fresh craters with no boulders, (2) degraded craters with no boulders, (3) fresh

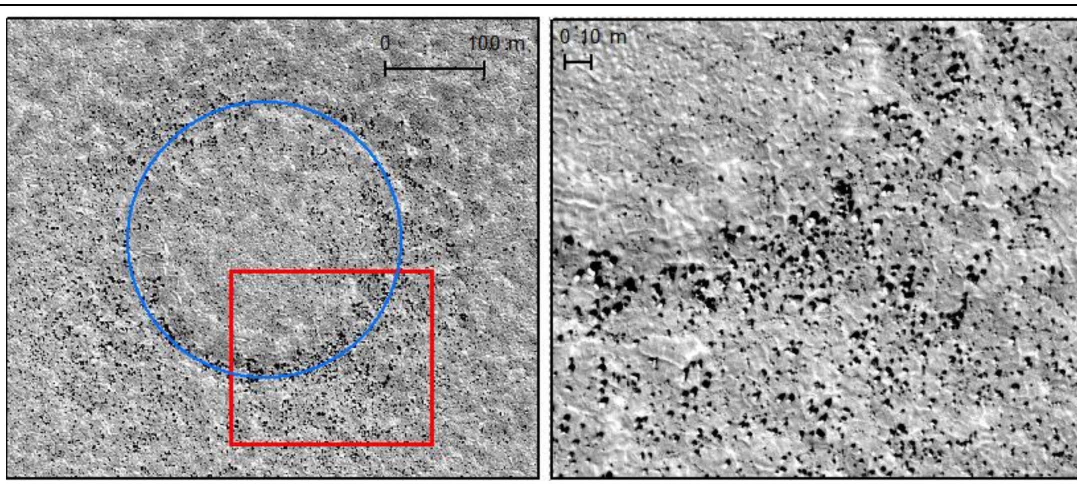

Figure 1. Boulder halo crater on northern plains of Mars with a best fit circle (blue) around the crater (left) and a close up view (red) showing the individual boulders (right). Portion of HiRISE image PSP_001505_2485.

craters with boulders, (4) boulder halo craters, and (5) degraded craters with boulders with more topography than a boulder halo craters. The resulting image classification was imported into ArcMap to assess the geographic distribution of craters in different classes.

Results: Derived frequencies of boulder halo craters in the images examined are shown in **Figure 2**. Two major findings are apparent from these results. First, the southern hemisphere has significantly fewer images with boulder halo craters than the northern hemisphere. Second, there are major regional variations in boulder halo densities in the northern high latitudes.

Interpretation: The dramatic difference between the boulder halo frequency of the northern and southern hemisphere is unexpected, but is unlikely to be a result of observational biases or the admittedly fewer summertime images in the southern hemisphere. Instead, it is likely symptomatic of significant differences in the geology and near-surface stratigraphy of the two hemispheres, despite both hemispheres having ice-rich soils at these latitudes. Earlier interpretations of the thermophysical and neutron observations [5, 18] also found major differences in the north and south as well, although these observations are only sensitive to the near-surface (e.g., depth to ice) so their relevance to boulder halo concentrations are unclear. Two possible explanations for the hemispheric differences are: (1) surface aggradation in the northern plains, allowing craters to infill more readily, enabling boulder halo formation, or (2) the more ancient southern hemisphere crust is deficient at depth in competent materials at depth, from which boulders can be excavated by impacts [e.g., 19].

Regional variations in the northern hemisphere may be due to variability in ice accumulation or stratigraphy. Qualitatively, there is an anticorrelation between the boulder halo frequency and the shallow ice-rich deposits in the north at longitudes around -120°E (e.g., Fig. 1 of [18]). High boulder halo concentrations are seen in Utopia Planitia and regions of Vastitas Borealis to its east, where recent work has documented an 80-170m thick ice rich unit [20].

Future work will examine in more detail the sizes of individual boulder halo craters and explore further boulder halo formation mechanisms.

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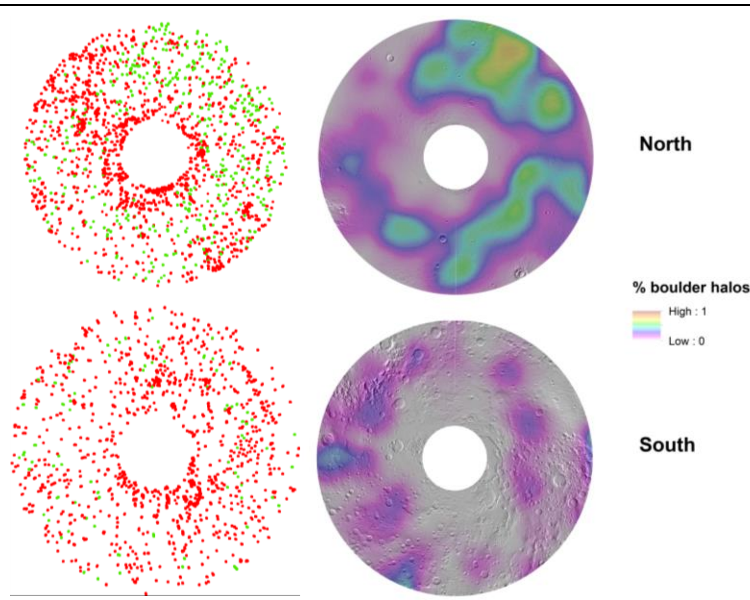

Figure 2. Yes (green)/no (red) classification (left) and percentage (right) of HiRISE images with boulder halos in the 50-80° latitude in the northern hemisphere (top) and the southern hemisphere (bottom). The percentage maps are calculated in a moving neighborhood of 500 km radius. Note that the percentage maps are not statistically debiased to account for the effect of targeting or to remove regions where boulder halo craters are unlikely for other reasons such as topography (e.g., crater Lyot).