RADAR REFLECTIVITY ANALYSIS OF BOULDER HALOS ON MARS: IS SUBSURFACE ICE THE CULPRIT? B. S. Tober[1], J. W. Holt[1], C. Grima[1], and J. S. Levy[2]. [1]Institute for Geophysics, Jackson School of Geosciences, University of Texas at Austin, (tober@utexas.edu), [2]Department of Geology, Colgate University

Introduction: Boulder halos are enigmatic features composed of boulder clasts distributed in circular or concentric patterns on a relatively smooth topographic surrounding. These features have been documented extensively across the middle to high latitudes of Mars, with greatest abundance in the northern hemisphere between ~0-180° E [1-3](Fig. 1).

A study focused on the distribution and characteristics of these features at high latitudes on Mars proposes that boulder halos form by the excavation of boulders from substrate beneath an ice-rich, non-boulder generating layer [1](Fig. 2). The presence of these features suggests that the lifetime of boulder ejecta outlives the removal of crater topography, as boulder clasts may float at the surface during crater infill by ice-rich soils [4].

Numerous studies have demonstrated the capacity for radar sounders to provide information on Mars' subsurface composition and structure [eg., 5-9]. Reflectivity maps of Mars have been produced at 3-5 MHz with Mars Advanced Radar for Subsurface and Ionospheric Sounding (MARSIS), onboard ESA's Mars Express, and at 20 MHz with Shallow Radar (SHARAD), onboard NASA's Mars Reconnaissance Orbiter (MRO); indicating global surface echo power [10,11].

In alignment with the current formation hypothesis of boulder halos, a lower dielectric constant and thus, reflectivity, may be expected for boulder halo sites when compared to areas where boulder halos have not been identified. This might validate the presence of an ice-rich layer necessary for their formation. Northern hemisphere surface reflectivity is slightly greater in areas where boulder halos have not been identified than those where they have (-16.9 dB vs. -20.2 dB). However, this trend is reversed in the southern hemisphere, with greater reflectivity in areas with more boulder halo sites than areas without boulder halos (-23.7 dB vs. -26.3 dB)[1].

Hemispheric variations in reflectivity may be the result of surface processes affecting the preservation of boulder halos, or changes in the spatial extent of an ice-rich layer, once necessary for their formation. Surface echo amplitudes represent the summation of electric fields reflected and scattered by dielectric contrasts within the radar footprint, down to near-surface depths. Thus, the surface return holds information on both surface roughness and near-surface composition and structure [11,12].

Objectives: As global averages of SHARAD reflectivity do not align with expected trends supporting the current formation hypothesis for boulder halos, this study will apply a method developed to discriminate between the deterministic and non-deterministic structure of the surface and near-surface from the surface echo. This method aims to assess subsurface composition and structure independent of surface roughness using the statistical behavior of the surface return amplitudes [11,12].

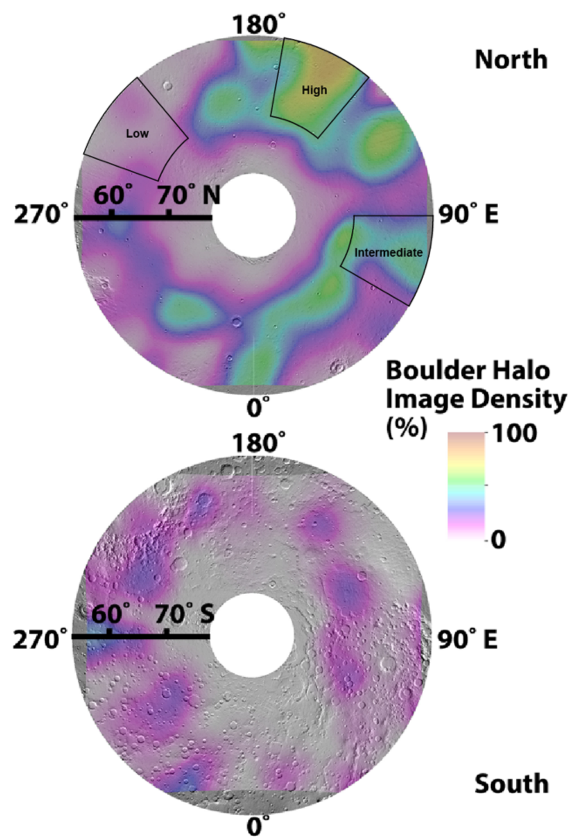

Figure 1. *Adapted from [1], Fig. 3. Spatial distribution of HiRISE images with boulder halos present. Boulder halo image density represents the percentage of images with boulder halos present, as a fraction of the total number of images in a moving 500 km square window. Northern hemisphere study areas shown, consisting of high, intermediate, and low boulder halo image density. Basemap is MOLA shaded relief.*

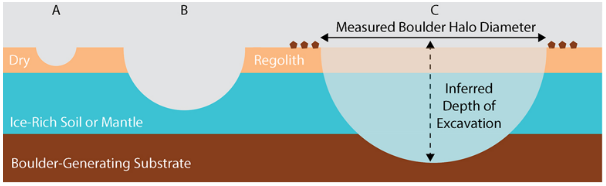

Figure 2. *From [1], Fig. 2. Illustration of boulder halo formation hypothesis. Impacts into dry regolith and ice-rich soil/mantle do not produce boulder halos (A and B, respectively), while impacts through the ice-rich soil/mantle eject material from boulder-generating substrate (C). Crater infill by ice-rich materials may take place subsequently, leaving behind boulder halos.*

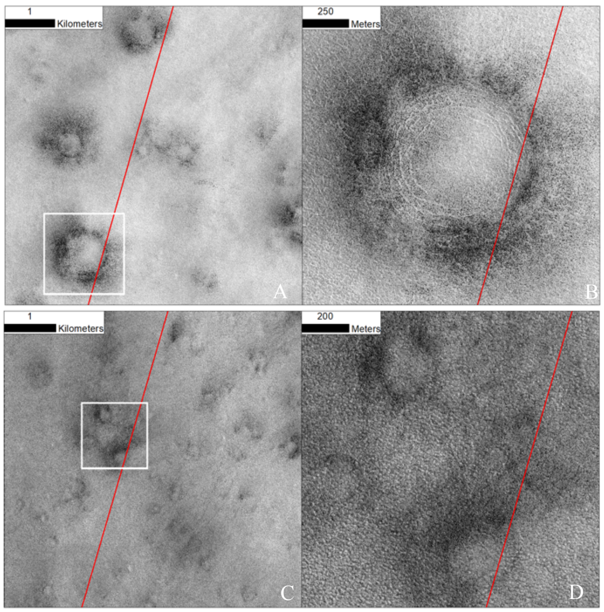

Figure 3. *SHARAD ground tracks in proximity to boulder halos in HiRISE northern plains imagery. (A,B) Portions of HiRISE image ESP_035151_2455. Red line indicates SHARAD ground track s_04391401 crossing a prominent boulder halo. Right panel (B) is a fuller extent of the left panel (A, white box), demonstrating boulder halo concentric landform characteristics. (C,D) Portions of HiRISE image ESP_035533_2455. Red line indicates SHARAD ground track s_00741402. Right panel (D) is a fuller extent of the left panel (C, white box).*

Methods: This study is primarily focused on Mars' northern hemisphere, due to the higher spatial distribution and regional variability of boulder halos. SHARAD tracks will be analyzed at local and regional scale in areas of varied boulder halo density.

Local-scale analysis aims to determine radar response to boulder halos by focusing on individual pulses of SHARAD tracks in areas where boulder halos are prominent, and will primarily be focused in the northern plains between Utopia Planitia and Vastitas Borealis from ~55-70°N and ~140-170°E due to the high density of boulder halos detected here. For this region, SHARAD tracks in proximity to imagery from MRO's High Resolution Imaging Science Experiment (HiRISE) indicating the presence of boulder halos will be analyzed trace-by-trace to determine radar responses (Fig. 3.).

Regional-scale analysis will apply radar statistical techniques similar to those developed for global reflectivity mapping with MARSIS and SHARAD, in an effort to determine variations in near-surface structure and composition between areas of varied boulder halo density [10,11]. The statistical behavior of surface echo power will be compared between this same region of high boulder halo density, along with the intermediate density region between ~55-70°N and ~60-90°E, and the low-density region between ~55-70°N and ~220-250°E (Fig. 1). A method for auto-detecting the surface from SHARAD tracks will be applied so that regional measurements can be made on surface echo power.

Discussion: While global reflectivity and dielectric properties alone may not fully explain the spatial distribution of boulder halos on Mars, statistical analysis of local-scale radar response and regional-scale surface echo power may provide further information related to near-surface structure. This will include the untangling of the coherent and incoherent power from the surface return. Implications of this analysis may better constrain near-surface structure between areas of varied boulder halo density, and thus help to explain the spatial distribution of these features, and potentially validate their formation hypothesis.

Future Work: Methods developed for this study on the reflectivity of northern hemisphere boulder halos may subsequently be applied to the southern hemisphere, which may provide information on the variability in boulder halo presence between the northern and southern hemisphere.

References: [1] Levy J. S. et al. (2017) *JGR,* Manuscript submitted. [2] Barata T. et al. (2012) *Planetary and Space Science, 72,* 62-69. [3] Rader L. X. et al. (2017) *LPS XLVIII,* Abstract #1294. [4] Orloff T. et al. (2011) *JGR, 116,* E11006. [5] Holt J. W. et al. (2008) *Science, 322,* 1235-1238. [6] Grima C. et al. (2009) *GRL, 36,* L03203. [7] Pearsons R. and Holt J. W. (2016) *JGR, 121*, 432-453. [8] Putzig N. E. et al. (2009) *Icarus, 204,* 443-457. [9] Bramson A. M. et al. (2015) *GRL, 42,* 6566–6574. [10] Mouginot J. (2010) *Icarus, 210,* 612-625. [11] Grima, C. et al. (2012) *Icarus, 220,* 84-99. [12] Grima, C. et al. (2014) *Planetary and Space Science, 103,* 191-204.