CHARACTERIZATION OF CLASTS IN THE GLEN TORRIDON REGION OBSEERVED BY THE MSL CURIOSITY ROVER. S. Y. Khan[1] and K. M. Stack[2], R.A. Yingst[3], [1]Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge MA 02139 (syked@mit.edu), [2]Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena CA 91104 (kathryn.m.stack@jpl.nasa.gov), [3]Planetary Science Institute, 1700 E. Fort Lowell, Suite 106, Tucson, AZ 85719

Introduction: The Mars Science Laboratory (MSL) Curiosity rover explored the Glen Torridon (GT) region of Gale crater during sols ~2300-2600. Along its traverse, Curiosity encountered a striking abundance of granule- to cobble- sized clasts between 2-70 mm in diameter, scattered on and around a series of linear ridges interpreted as periodic bedrock ridges (PBRs) [1].

Since clast morphology and distribution can be used as indicators of erosional history and bedrock geology [2], this study seeks to characterize the observed GT clasts by shape, size and dispersion parameters in order to determine the processes of clast formation and modification, as well as their relationship to local PBRs.

Data and Methods: We use images from the Mars Descent Imager (MARDI) and Mastcam clast survey campaign between sols 2302 to 2593 to assess clast properties. MARDI is a fixed-focus camera intended primarily for navigational use during Curiosity's descent through the Martian atmosphere. As such, MARDI image quality decreases with spatial scale, but post-landing calibration has enabled the instrument to capture 1.5 mm resolution images of the surface directly below the rover [3]. MARDI images of the terrain were routinely captured at the conclusion of drives throughout GT, providing an archive of clast images for the area. While MARDI images are not of sufficient resolution for quantitative measurements, they were used to catalog qualitative physical properties (e.g. texture, angularity, erosional markers), the presence of in-place bedrock, and clast dispersion for classification into clast types.

The systematic clast survey observation, detailed in [4], is comprised of images taken from the left and right mounted Mastcams (M-34 and M-100 respectively). The images were captured at a mast orientation intended to decrease working distance while also minimizing obstructions by rover hardware. The field of view is 0.71 m for M-34 and 0.24 m for M-100, resulting in a pixel scale of 0.62 mm/pixel and 0.21 mm/pixel for M-34 and M-100 respectively [4]. In addition, clast survey images were acquired in the afternoon in order to regularize surface illumination and enhance textural features [4]. The high resolution and overall uniformity of the clast survey data set makes these images ideal for directly measuring clast size and morphology, including major axis (length of the longest clast axis), angularity

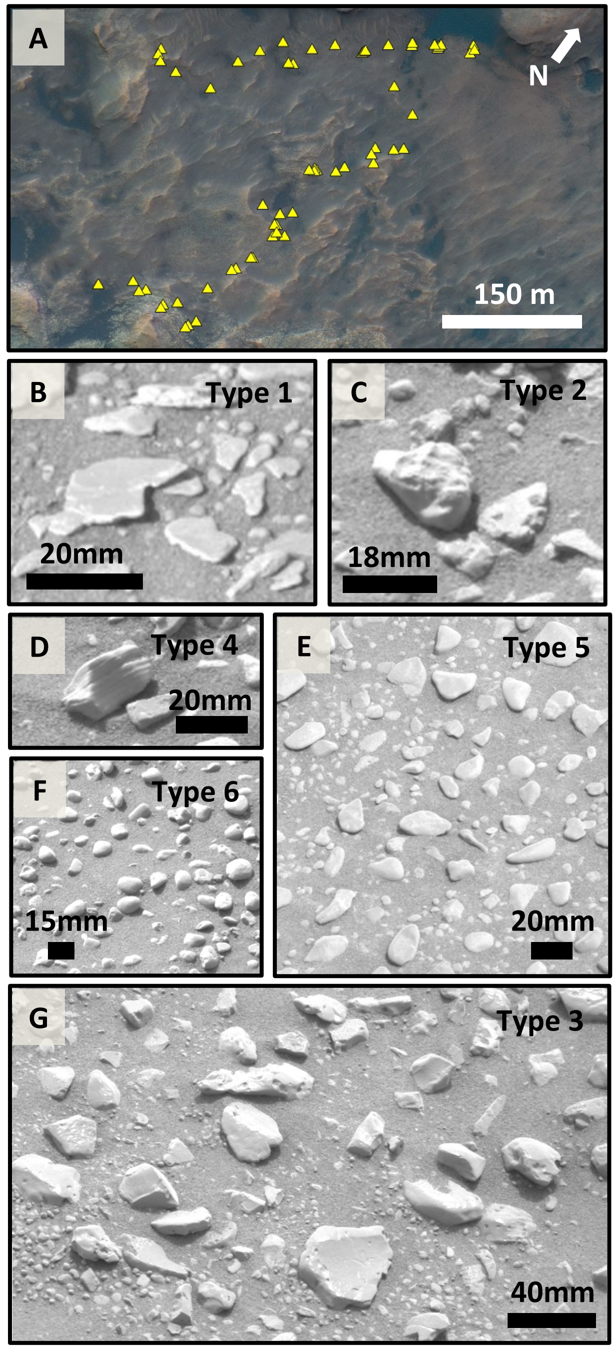

Figure 1. (A) Map of GT region depicts MARDI and Mastcam clast survey imaging locations. PBRs trend to the northeast. (B) Type 1 clast, M-100 image, sol 2420 (C) Type 2 clast, M-100 image, sol 2563 (D) Type 4 clast, M-100 image, sol 2476 (E) Type 5 clast, M-100 image, sol 2316 (F) Type 6 clast, M-100 image, sol 2466 (G) Type 3 clast, M-100 image, sol 2306.

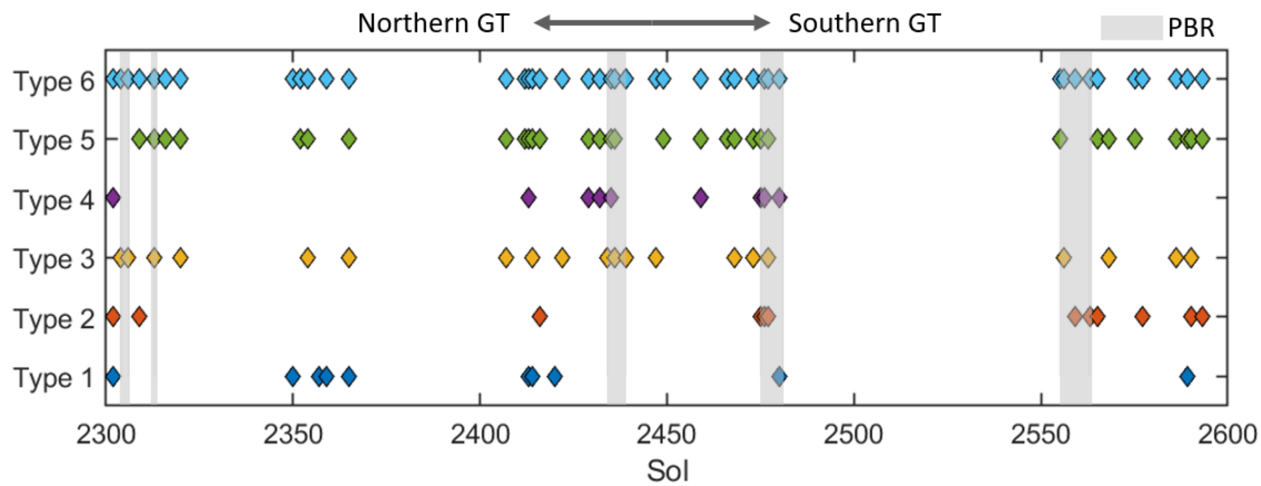

Figure 1: Distribution of clast types by sol. Curiosity drove within 20 m of PBRs between sols 2304-2306, 2313, 2434-2439, 2475-2481, and 2555-2563, as indicated in the plot. Gaps in plot at sols 2365-2407 and sols 2480-2555 represent periods in which neither Mastcam clast survey images nor MARDI images were taken.

(a measure of corner sharpness), sphericity (resemblance of the clast to a sphere), and solidity (the ratio of clast area to that of its convex hull).

Clast survey images selected for detailed quantitative analysis were sampled using the grid method. Morphological measurements were acquired by tracing selected clasts in ImageJ.

Results: Clast analysis using both MARDI and Mastcam clast survey images revealed 6 primary clast types. The types differ primarily in size, angularity and sphericity, but all possess similar lithologies. Types were designated if observed in three or more images.

Type 1. This type is comprised of sub-rounded, platy pebbles. Type 1 pebbles have low sphericity and appear commonly on or near bedrock

Type 2. These pebbles are distinctive for their angularity and rough surface texture. Type 2 clasts are moderately spherical.

Type 3. These clasts are sub-angular to sub-rounded with moderate sphericity and diameters greater than 25 mm. This type is often smooth textured, with facets, pits and flutes, though is occasionally observed with slightly rougher textures.

Type 4. The least abundant clast type, Type 4 pebbles are distinctly laminated, sub-rounded, and have diameters 20 mm or greater.

Type 5. These clasts are elongate, pyramidal, and sub-rounded with a diameter 25 mm or less. Type 5 pebbles are one of the most abundant clast types.

Type 6. The smallest clast type, with major axis length less than 15 mm. Type 6 pebbles are smooth textured, spherical and well-rounded. They are the most abundant clast type observed.

Fig. 2 shows the distribution of clast types along the GT traverse. Type 1 clasts appear almost exclusively in northern GT, whereas Type 2 clasts are most common in southern GT. By contrast, Type 5 and Type 6 pebbles occur frequently throughout the entire traverse. Notably, clast types 4 and 5 are more abundant near PBRs compared to the rest of the types identified.

Further analysis of clast properties and their relationship to PBRs reveals a consistent downward trend in major axis with distance from a PBR crest.

Discussion: Similarities in lithology across all clast types observed in this study along with the presence of bedrock in several of the images indicates that the clasts are sourced from local bedrock, meaning little to no transport occurred. Visual analysis of clast types in GT suggest clasts in this region experience in-place aeolian abrasion. The faceting, pitting and fluting prevalent in Type 3 pebbles (Fig. 1g) are recognized signs of aeolian abrasion [5]. Given that angularity decreases with increased erosion, it is likely that Type 1 and Type 2 clasts shed directly from the bedrock and transitioned to clast types 3-6. The abundance of clast types 5 and 6 throughout GT suggests that all pebbles ultimately erode into one of these varieties.

Additionally, the observed decrease in clast diameter with distance from PBR crests suggests heightened erosion in the troughs, consistent with an interpretation of the GT ridges as eroded bedforms.

References: [1] Montgomery D.R. et al. (2012) *JGR Planets,* 117(3) [2] Yingst R.A. et al. (2016) *Icarus, 280*, 72-92 [3] Malin M.C. et al. (2009) *LPS XL,* Abstract #1199 [4] Yingst R.A. et al. (2013) *JGR Planets, 118(11)*, 2361-2380 [5] Durant M. and Bourquin S. (2013) *CRG, 345(3)*