RECONSTRUCTING BASALTIC SEDIMENT TRANSPORT ON MARS USING TERRESTRIAL ANALOGS.

E. R. Rogers[1], M. C. Palucis[1], A. M. Morgan[2], R. A. Craddock[3], E. Benyshek[4], D. F. Richards IV[5], [1]Dartmouth College Earth Sciences Department, (emma.rogers.gr@dartmouth.edu), [2]Planetary Science Institute, [3]Center for Earth and Planetary Sciences, National Air and Space Museum, Smithsonian Institution, [4]School of Ocean and Earth Science and Technology, University of Hawaiʻi at Mānoa, [5]Department of Geology, University of Georgia

Introduction: Weathering of basaltic sediment as a function of the transport mechanism and distance is poorly understood. For example, NASA's *Curiosity* rover imaged rounded basaltic pebbles in Gale crater during its traverse in 2013 [1-2]. These pebbles were within a clast-supported, well-sorted conglomerate rock unit that extended at least 9 km and was tens of meters thick [1]. However, the implications these deposits have for martian sedimentary processes in not clear, because existing models of fluvial sediment abrasion generally do not account for basaltic lithology [3] that is common on Mars but rare on Earth. Providing a better understanding of basaltic transport relations might allow us to determine the provenance of Gale crater pebbles and how transport conditions may have evolved over time.

We can infer the history of sedimentary rocks through measurements of grain size characteristics (e.g., form & roundness) [4-6]. Form refers to sphericity/circularity [7] and reflects variations in the grain's proportions due to the relative lengths of its *a* (short), *b* (intermediate), and *c* (long) axes. In general, sphericity increases as a function of transport distance. Roundness refers to the degree of sharpness of the corners and edges of a grain, qualitatively classified on a scale from "very angular" to "well rounded" [7]. This can be measured with either the Wadell Method [8] (Eq. 1) or the Modified Wentworth method [9] (Eq. 2). Roundness can often reflect transport process. Combined, these properties provide a key window into past sedimentary environments.

Objectives: Our goal is to determine how basaltic particles breakdown during sustained fluvial transport to better understand the provenance of sedimentary deposits on Mars. To address this question, we have the following objectives: 1) to characterize the size, shape, and sorting of basaltic sediment in temperate and cool climatic conditions, based on field measurements at terrestrial analog sites; 2) to use laboratory analyses to develop quantitative relationships between grain shape and transport distance; 3) to use field and laboratory data to constrain the transport history of observed gravels on Mars.

Methods: Our technical approach involves a three-task process of field work, lab work & remote sensing, and quantitative analysis.

Field Work: We have identified field sites in two basaltic-dominated environments in contrasting climatic regimes: (1) an alluvial fan along the base of the Hilina Pali escarpment in Hawaiʻi (temperate environment; Fig 2); (2) a channel system and associated gravel bar outwash plain downstream of the Þórisjökull glacier in Iceland (cold environment).

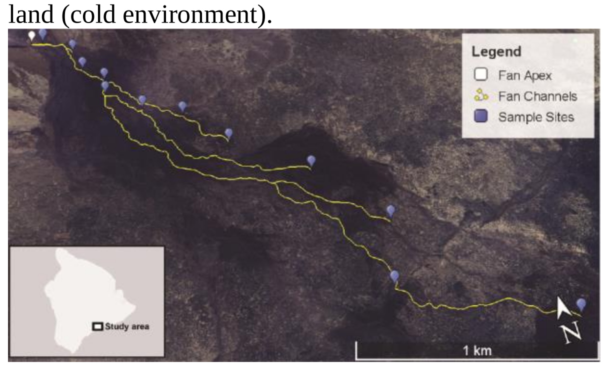

Fig 1. The Hilina Pali alluvial fan in Hawaiʻi with labeled channels and sample sites.

At each sample site, we randomly sample ~100 grains using the Wolman method [10]. For each grain, we measure its *a*, *b*, and *c* axes, as well as take photographs of each grain against a white background for analysis of rounding later. We analyze the degree of rounding (*P*) with both the Wadell [8] (Eq. 1) and the Modified Wentworth [9] (Eq. 2) methods in MATLAB [11] (Fig 3) and categorized grains using the Powers scale [7], with a randomly selected subset checked by hand.

Wadell Method: Where *r* is the radius of the corner circle (Fig 2b, green circles), *R* is the radius of the maxium inscribed circle (Fig 2b, red circles), and *N* is the number of corners.

$$\frac{N}{\sum\left(\frac{R}{r}\right)} = P \qquad (1)$$

Modified Wentworth Method: Where *d* is the diameter of the smallest corner circle (Fig 2b, smallest green circle), and *D* is the diameter of the maxium inscribed circle (Fig 2b, red circles).

$$\frac{d}{D} = P \qquad (2)$$

Results: Preliminary results indicate that roundness increases down fan (Fig 4). Results differ between the two methods; grains classified as angular by the Modified Wentworth method are classified as sub-rounded by the Wadell method. Both methods show that the grains round only slightly over ~4 km. The Wadell results appear more similar to our qualitative assessments, but the Modified Wentworth allows comparison to historical grain rounding studies done by hand using this method. The fan becomes more poorly sorted downfan, and the median grain size decreases at a rate of 6 mm/km. The decrease in sorting, opposite to the expected trend [13], may be attributed to sampling off the main fluvial channel, a combination of fluvial and mass flow processes occurring on this fan, or possibly a difference in how basalt abrades over distance.

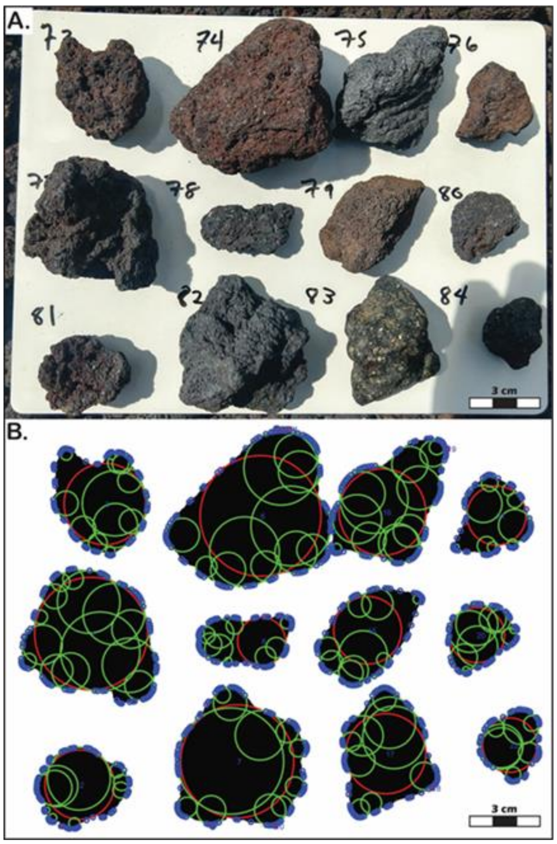

Fig 2: Sample output from the modified MATLAB model [11] used to calculate roundness. (A) Input is an image of samples 58 m downslope of the fan apex. (B) Red circles are maximum inscribed circles (R, D), green circles are fitted to the corners (r, d), blue circles mark the corners based on measure convexity.

Significance and Future Work: We plan to conduct similar field work in Iceland, where we expect frost weathering to have a significant role on grain size and shape distributions. Specifically, we would expect the grains in Iceland to be more angular than those in Hawaiʻi and become smaller more quickly. Quantifying this relationship can lead to crucial interpretation of data from Mars rovers with respect to the climatic environment the fluvial systems were deposited in.

Current martian imagery of samples are all in 2D (i.e., we generally can only measure 2 of the 3 axes from rover data). This makes our development of transport relationships and photo-based grain size and shape analysis useful for understanding how basalt abrasion works in 3D [e.g., *11*].

Future work also includes experiments on a racetrack flume [3] and rotating drum. This project will be one of the first experimental datasets to address the relationship between grain shape and transport distance for mass flows and sheet flows, along with their importance in interpreting climatic regimes. The relationships we derive for grain rounding will be scaled for Mars and applicable to grain size data collected from multiple Mars rovers.

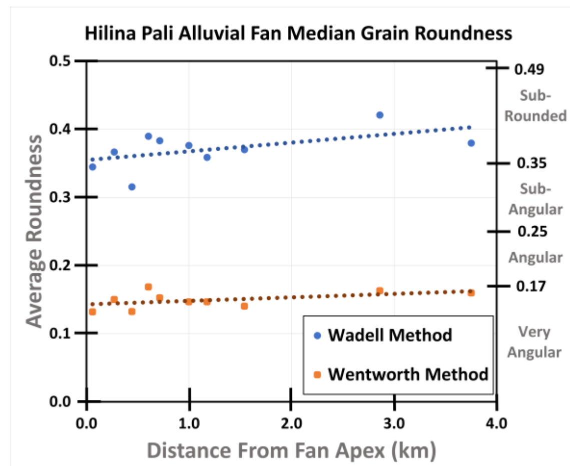

Fig 3. Median roundness change over distance at seven different field sites in Hawaii using the MATLAB roundness code. We would expect data from non-mafic alluvial fans to round more quickly over the same distance [12,13].

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