Soil Sedimentology, Textures and Dynamics at Gusev Crater from Spirit's Microscopic Imager. Nathalie A. Cabrol[1], Edmond A. Grin,[1] Kenneth Herkenhoff[2], Lutz Richter[3] and the Athena Science Team, [1]NASA Ames Research Center. Space Science Division, MS 245-3, Moffett Field, CA 94035-1000. ncabrol@mail.arc.nasa.gov; [2]U. S. Geological Survey, Flagstaff, AZ; [3]DLR Institut für Raumsimulation, Koln, Germany.

Introduction: We analyzed the undisturbed soils imaged by Spirit's Microscopic Imager (MI) from landing to Sol 1035. They provide a complementary vision to previous sedimentological analysis at Gusev [1-5]. Characteristics, such as grain-size distribution, proxies for shape, textures, sorting, and morphologies were examined. They are particularly important as indicators of soil dynamics and provide clues to understand whether particles have been mobilized recently or have remained in place over extended periods of time. In turn, this information can be used to better model past and present erosional and depositional activity, in particular as related to aeolian processes (e.g., dust deposition, erosion, saltation) [7] or aqueous processes (e.g., cementation of particles in areas) [8].

Method and Constraints: The analyzed MI images include structured soils (e.g., ripples, dunes) as defined by [6] and unstructured soils [2, 9]. Overall, 17 MI images were examined, from which we developed a statistical database of 1,884 particles. The analyzed Sols are: 039, 045, 073, and 074 along the traverse from the landing site to Bonneville. Sol 073 is the only disturbed soil examined (Serpent scuff) as a comparison with the top of the dune, undisturbed (074); Sol 110, near Missoula crater; Sols 460, 499, and 612 in the Columbia Hills; Sols 812, 822, 913, 937, 1008, 134, and 1035 in the winter haven area. The method used to analyze those particles is the same as that detailed in [1-3]. While the pixel scale of the MI is ~ 30 µm, 3 to 4 pixels are necessary to identify a single grain. Therefore, we did not measure particles less than 100 µm in size (e.g., very fine sands, silt).

A significant fraction of the grain-size population at Gusev is made of fine to medium sand, making the count of every single one of them a tedious and time consuming effort. Therefore, representative areas are selected on the MI images in order to evaluate the overall population of an image. As a proof of concept, we run a test to assess the confidence level that can be gained from results obtained from representative areas. We used the Sol 039 MI image to evaluate the potential discrepancies between statistical results from (a) a count obtained from the entire MI image; (b) a count on a fraction of that image, which is then (c) normalized to the entire surface area of the MI. Results are shown in Figure 1.

When the three histograms are compared, all sedimentological classes are represented in each of them, thereby showing that a careful selection of a representative area avoids missing critical information.

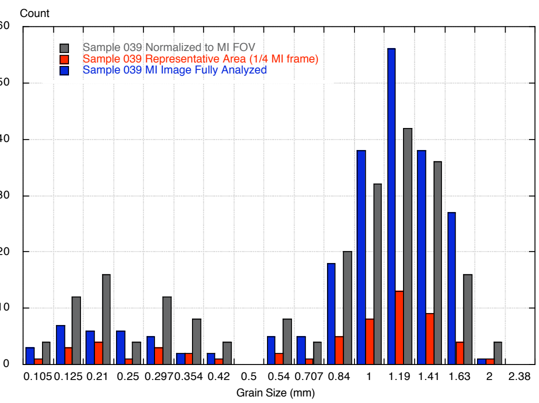

Figure 1: Sol 039 grain-size distribution from: Red - representative area (25% of the entire frame); Grey – results from the representative area normalized to the entire MI Field-of-View (FOV); Blue – count of all measurable particles in the entire frame.

Overall, this method proves to be efficient in assessing the shape of a distribution, therefore identifying the main populations. The identification of such populations is key to evaluating the type of processes involved in their emplacement. Assessing the relative abundance of each of those populations from a representative area is, however, less precise as shown by the comparison of the grey and blue histograms. The normalization of the results from the representative area to the entire frame seems to artificially increase the number of small particles and decrease the number of large particles. Since this test has been performed on the image of a ripple only, it may be that those results are dependent on the nature of the sample. Similar tests are currently being performed on images of soils composed of finer fractions to assess the dependability of the results versus the nature of the sample. Meanwhile, here, as a conservative approach for the grain-size distribution obtained from representative areas we do not discuss the absolute abundance of each population but rather the meaning of their peaks and overall shapes.

Grain-Size Distribution: With a few exceptions (granules and pebbles) and regardless of the locales where the soils were observed, sand dominates at Gusev. Most of the distributions are multimodal, with only one exception on Sol 612 (Figure 2). The presence of multimodes and poor sorting suggest the contribution of several agents to the formation of soils (e.g., wind, impact, volcanism).

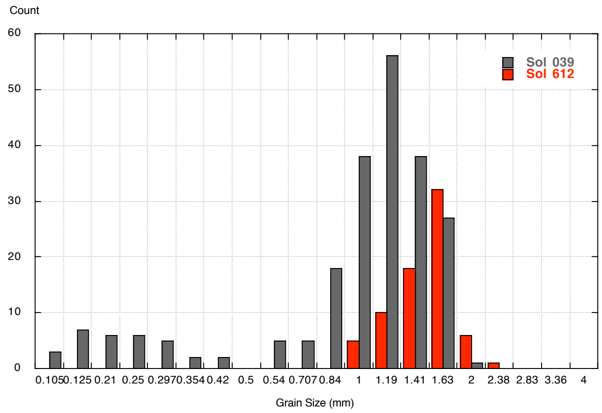

Figure 2: Examples of grain-size distribution in the Plains and in the Columbia Hills:

Shape: Grains axis ratio is consistent along the traverse, possibly indicating a dominant factor in the shaping of the grains over time (wind?). Sand particles are in general rounded to very rounded, as indicated by their position with respect to the 1:1 ratio (Length over Width) and 2:1 ratio (Figure 3). Spherical grains are not uncommon, which also points toward the role of wind in shaping them. Pebbles are irregularly shaped. No obvious evidence for significant water activity can be inferred from the particles' shapes, while their cementation in some cases indicates limited aqueous processes.

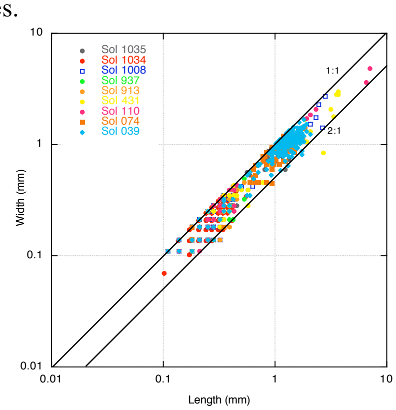

Figure 3: Examples of shape proxies for some of the MI images.

Dust, Cement and Other Agent of Grain Cohesiveness: Accumulation of dust (coating, filling) and cement can be used as indicators of a soil's dynamics. All samples located in the plains show dust coating and/or cementation to various degrees likely dependent on local conditions (e.g., wind exposure, amplitude of aqueous processes, soil chemistry). Dust deposits are made of either individual grains below resolution or aggregates. In some samples (e.g., 039; 045), grain-size and albedo suggest that cement could originate from the accumulation and cohesion of very tightly packed dust particles subsequently cemented together. Dust packing between larger particles varies between samples: For instance, while dust is filling spaces between sand grains on both Sols 039 and 045, it is packed against grains on 045 and more homogeneously distributed on 039. The MI of Sol 052 also shows a dusty sample with cemented material between particles. Grains commonly have what resembles a residue of cementing material on their edges. Still, isolated grains and broken-up material suggest the existence of mechanisms capable of dislodging the grains from the matrix. The top of Serpent (074) shows identical characteristics whereas the scuffed part of the ripple (073) is marked by very clean coarse sand-size particles. Overall, the presence of dust accumulation and cement on the five samples of the Plains suggest that those soils have been immobilized now for extended periods of time.

Near the Missoula crater, the MI of Sol 110 shows an unstructured soil mostly composed of very fine sand particles aggregated together in small clusters of ~350 µm and pebbles. Some of the pebbles are covered with a thin veneer of fine sand particles of similar size as those observed on the soil around the pebbles, by opposition to smaller grains that usually composed the dust. This potentially suggests a process (e.g., saltation) by which particles from the soil are transported on top of the pebbles rather than dust deposition.

The three unstructured soils and one ripple of the Columbia Hills contrast with the Plains samples in that all samples appear mostly clean of significant dust deposit in a region where Spirit encountered dust devils for the first time into the second year of the mission. Except for Sol 612 where fine granules dominate, all other samples (431, 460, 499), have very well-packed medium sand but no obvious evidence for cementation.

The 7 soils analyzed in the Spirit's latest winter haven (MIs 812, 822, 913, 937, 1008, 1034, 1034) are among the cleanest observed along the traverse and show no significant accumulation of dust. This region provides also the best example of grain cementation (MI 1035).

References: [1] Herkenhoff K., et al., 2004, *Science* 305, 824-825; [2] Cabrol, N. A. et al., 2006, *JGR* 111, E02S20; [3] Herkenhoff K., et al., 2006, *JGR* 111, E02S04; [4] Herkenhoff K., et al., 2006, *37^h LPSC* , # 1816; [5] Cabrol N. A., and E. A. Grin 2006, *Mars Water Workshop*, NASA Ames; [6] Greeley R., et al., 2006. *JGR* 111, E02S09; [7] Greeley R. et al., 2006. *EuroPlaNet Conference*, Berlin (Germany); [8] Landis G., et al., 2004, *35^th LPSC*, #1197; [9] Cabrol N. A., et al., 2005, *36^th LPSC*, #2328.