A PRELIMINARY ASSESSMENT OF SUB-MM SPHERULES AT ROCKNEST, GALE CRATER, MARS.

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Introduction: Impact spherules derive from target and impactor materials that were melted or vaporized by impact, transported, and then deposited back on the target body's surface. The presence of impact spherules on Mars has been suggested but never confirmed. Sub-mm sized spherules of likely glassy luster imaged within surface materials of the Rocknest area of Gale crater by the Mars Science Laboratory Mars Hand Lens Imager (MAHLI) camera, may be impact spherules.

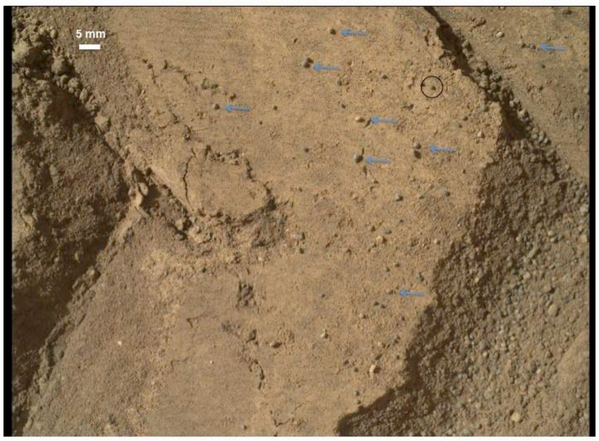

Figure 1. MAHLI sol 58 image of a scuff made by the rover wheel into Rocknest sand shadow (eolian deposit). Arrows indicate potential spherules; black circle indicates the grain shown in Figure 2. Image 0058MH0024001000E1.

Data Collection: As part of the first scoop, sample processing system cleaning and sample sieve and delivery to onboard analysis instruments, several MAHLI images were acquired at an eolian deposit near the location informally known as "Rocknest". MAHLI was used to document and assess scuffing and scooping activities, and to provide data for science analysis of the geologic materials at the site.

Starting on sol 58, MAHLI acquired dozens of images of the eolian sediment, including scuffed and scooped surfaces. Most images were acquired at offset distances of 25 cm (100 μm/pxl), 10 cm (~50 μm/pxl) and 5 cm (~30 μm/pxl).

Observations: Sub-mm spherulitic clasts are present in nearly all disturbed soils imaged by MAHLI in the Rocknest drift area. These grains are commonly dark or light grey, and a glassy luster is evident in a few grains, but both color and luster are often partially or totally obscured by mantling dust. The grains that are most easily identified are likely those that were disrupted and displaced by rover activities, so that any dust coating fell away. The average distribution of spherules that can be reliably identified comprise 1-2% of the 0.15-1.0 mm diameter fraction, but again, most grains are dust-coated, and this coating can make shape determination difficult. Thus, this estimate is a minimum value.

Figure 2. Close-up of circled grain in Figure 1. The pixel pattern at this resolution helps determine sphericity. The uniformity of the pixel pattern with respect to light reflectivity helps identify glassy surface texture. On adjacent grains in this image, even when spheroidal, there is no uniform expression of the pixel response to the light source, indicating a non-uniformly reflective surface.

Potential sources: Two hypotheses have been suggested for spherule origin: volcanic clasts (either glassy droplets or accretionary lapilli); or distal impact ejecta in the form of quenched melt droplets.

Impact spherules. Because melt tends to assume a spherical shape in flight, the most diagnostic characteristic of impact spherules is their shape, though they also occur as highly elongated dumbbells and teardrops [e.g., 1]. Impact spherules on Earth tend to occur in layers or lenses that are thicker than the surrounding layers. They often have a coarser grain size than nearby beds and are regionally persistent, thus forming excellent marker beds. In terms of composition, impact spherules tend to be composed primarily of melt from the target rock; they are lower in water content than volcaniclastics, contain Fe in 2+ form, and can be anomalously high in platinum group elements [2].

Volcaniclastics. Fire fountaining can produce glass fragments of similar size and shape to impact spherules. Pele's tears, for example, are smooth-surfaced glassy lapilli, which form in some basaltic fountains. They vary in size from ~0.5 to ~5 mm in size. Many are spherical, but they also occur as spheroids, teardrop shapes, and dumbell shapes. All of these are indicative of their fluid nature when erupted and the ability of surface tension to round or almost round them prior to quenching. Occasionally they are connected to a strand of basaltic glass. Pele's tears usually do not extend more than 1-2 km from their source [3]. Extraterrestrial examples of grains of similar origin include lunar glass beads [e.g., 4].

Another type of spheroidal volcanic particle is accretionary lapilli. Caused by hydromagmatic eruptions, these are agglomerations of ash [5, 6], and thus their internal structures are not consistent from grain to grain. Also called armored lapilli, when due to agglomeration onto a core [e.g., 7], these grains can form in impacts as well (impact accretionary lapilli), and when they do, they resemble those in volcanic eruptions. Hydromagmatic eruptions are typically more energetic than fountaining eruptions so accretionary lapilli are often found farther from the vent than Pele's tears.

Discriminating between hypotheses: There are many potential lines of evidence that ideally could be used to discriminate between the impact and volcanic origins. However, in a field site such as Gale crater, we have only the remote tools on the rover to determine grain characteristics that might discriminate between hypotheses of formation, methods of identification. Textural criteria outlined by Simonson and Glass [3] can in most cases be addressed with a hand lens. We thus apply these criteria to data acquired by the MAHLI camera. MAHLI is a 2-megapixel color camera with an auto-focusable macro lens mounted on the turret at the end of Curiosity's robotic arm [8]. In practice, MAHLI can acquire images at < 20 µm/pxl [9], essentially the hand lens scale, making these images ideal for the methodology of [1].

The criteria of [3, 10] to identify impact spherules include: (1) sphericity; (2) sand size (larger particles would splat on impact, whereas smaller particles tend to occur as fragments); (3) distribution of particles, over a broad region; and (4) particles commonly have off-center voids or filled voids [10]. Of these criteria, the first three can be assessed using MAHLI images.

Discussion: The sphericity and glassy luster of observed spherules are consistent with an impact origin. The small sample area does not allow for definitive conclusions regarding extent of spherule distribution.

Without the ability to examine the interiors of spherules (to determine whether cores are off-center or are filled voids), surface texture becomes a crucial characteristic. Accretionary lapilli tend to display an ashy texture [11]. Again, dust can obscure the surface texture, but those spherules that are relatively dust-free do not have an ashy texture. Finally, the lack of an unambiguous proximal vent or other source for pyroclastics adds weight to the interpretation of an impact, rather than a volcanic origin. Based on the current evidence, we interpret these sub-mm spherules to be impact-derived.

Next steps: In discriminating between these two possible origins, it is important to sample a larger area for the presence and nature of spherulitic grains, to determine extent. Additionally, we will expand our search for potential impact spherules to include other splashforms (e.g. dumbbell or teardrop shapes), to gain a clearer understanding of the distribution of these grains. The obscuring of shape by mantling dust is especially problematic in determining if other splashform shapes exist within the appropriate size range; we will thus focus our efforts on images that may capture disturbed or displaced grains (e.g., those documenting scooping, scuffing or sieving activities). One possibility is to assess grain size distribution and sphericity on scooped material, to determine whether we can reliably identify highly spheroidal grains of this size frequency in the dust-covered mantling deposits.

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