

CHARACTERISTICS OF PEBBLE AND COBBLE-SIZED CLASTS ALONG THE CURIOSITY ROVER

TRAVERSE FROM SOL 0 TO 90. R. A. Yingst¹, W. Goetz², V.E. Hamilton³, V. Hipkin⁴, L.C. Kah⁵, M. Madson⁶, H. Newsom⁷, R.M.E. Williams¹, J.C. Bridges⁸, J. Martinez Frias⁹, P.L. King¹⁰, and the MSL Science Team, ¹Planetary Science Institute (1700 E. Fort Lowell, Suite 106, Tucson, AZ 85719; yingst@psi.edu), ²Max-Planck-Institut für Sonnensystemforschung, Katlenburg-Lindau, Germany; ³Southwest Research Institute, Boulder, CO; ⁴Canadian Space Agency; ⁵Univ. of Tennessee, Knoxville, TN 37996; ⁶Niels Bohr Institute, University of Copenhagen, Denmark; ⁷Institute for Meteoritics, Univ. New Mexico, Albuquerque, NM; ⁸University of Leicester, UK; ⁹Centro de Astrobiología (CSIC-INTA); ¹⁰Res. Schl. Earth Sci., Aust. Nat. Univ., Canberra, Australia.

Introduction: The transport, sorting and abrasive processes that modify the loose surface particles comprising a sedimentary population are best recorded in the morphologic characteristics of those particles [1-3]. Here we report an initial assessment of morphologic characteristics (size, shape, roundness, texture) of surface particles in Gale crater imaged along the path of the Curiosity rover from sols 0 to 90. Our eventual goal is to use these data to help constrain the boundaries of potential transport mechanisms that were important throughout the geologic history of the crater interior.

Geologic Setting: The Gale crater floor is dominated by a ~5 km high mound of stratified rock (informally known as Mt. Sharp) that is assumed to be fill material deposited as sediment. The MSL landing ellipse is located to the northwest of the mound. Within the ellipse is an alluvial fan (Peace Vallis Fan) that transported alluvium from the crater rim, across the landing ellipse, and toward a topographic low at the base of Mt. Sharp [4]. Sediment from the walls of fluvial canyons that debouch onto the crater floor, fragments shed from the upper and lower mound strata, and grains from modern eolian dunes also likely contribute to the inventory of sedimentary materials. Pebble- to cobble-sized clasts along Curiosity's traverse thus most likely include these geologic materials.

Data Collection: To better investigate the characteristics of loose particles in the pebble to cobble size range (2-256 mm [5]; also referred to as clasts or float) we utilized a series of "clast survey" images. The clast survey is an observation consisting of two images taken with the left (M34) and right (M100) Mastcam cameras [6] at a 3 m working distance, and 45° elevation, 120° azimuth in the rover frame (towards the starboard side). From sols 0 to 90, clast survey observations were taken on eight sols. All standard Mastcam clast survey images were rectified to simplify comparisons of clast morphology and size distribution of clasts along the rover traverse. Further characterization of clasts in selected survey images utilized stereo meshes generated by the Operations Product Generation Subsystem (OPGS) Team, JPL. Clasts were also analyzed in images other than those acquired by the clast survey campaign. An alternate, semi-automated approach us-

ing ImageJ, a public domain image processing and analysis program [7], was also tested.

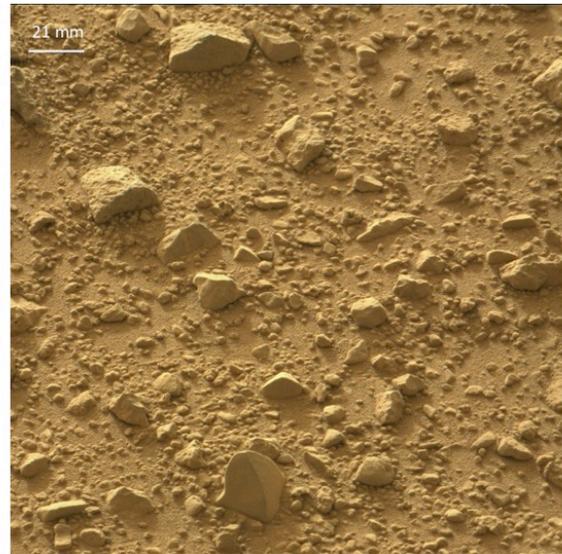


Figure 1. Clast survey image, taken on sol 49 from the M100 Mastcam camera (~0.21 mm/pxl).

Observations and Interpretations: We utilized the methodology of [8] to estimate particle size, shape (sphericity, or how closely a particle profile resembles a sphere), roundness (a measure of corner sharpness), and texture (variation from a flat surface at scales smaller than the corners and angles of the particle). Clasts are organized into classes (below) representing many of the most commonly-occurring morphologic types observed both in the clast survey images and in other images acquired along traverse. Such measurements are best suited to grains within the pebble- to cobble-sized range. Experimentally, 2-dimensional grain analysis typically overestimates particle characteristics in smaller grain sizes (35-140µm/pxl), and results in erratic grain size frequencies [9].

Coronation/Mara/Bathurst-type. These particles are grey and fine-grained, with or without a tan/light patina or coating. Particles are ~5-30 mm long-axis, and angular to sub-angular, with flat or curved facets ending in sharp or rounded edges. Surface texture is often smooth, but fresher facets can be rough and knobby at

the sub-mm scale. Ventifacting is common. The smooth surface texture, flat facets and undulating breakage/wear pattern are common characteristics in basalt fragments. The Bathurst particle is basaltic [10] and contains subtle layering.

Wolverine-type. Particles in this class are dark, blue-green, coarse-grained and mottled, with areas of higher reflectance. Particles are ~5-20 mm long-axis, and range from angular to rounded. Some particles display a rough, platy surface texture that may indicate potential layers or foliation.

Pitted-type. These particles are gray, with a distinctive pitted surface mantled by a tan patina or coating of dust. Pits are circular or elongated concave-outward ellipsoids, averaging 0.5-1.5 mm long-axis. Particles tend to be ~20-40 mm long-axis, and are commonly angular to sub-angular, with some flat facets and rounded edges and corners. This class may represent weathered vesiculated basalt fragments.

Porphyritic-type. Though rare (or perhaps not always easy to resolve), these particles differ from any type seen elsewhere on Mars [e.g., 8, 11, 12]. Particles average 50-100 mm long axis, tend to be equidimensional in shape, and are commonly angular to very angular. Their defining characteristic is their porphyritic texture — light-toned, bladed or polygonal crystals 1-15 mm in length (inferred to be either pyroxene, plagioclase or rock fragments), embedded in a darker, fine-grained, grey matrix. The surface texture of the particles themselves is angular and hackly.

Link/Hottah-type. Particles in this class are associated with conglomerates, often littering the surface surrounding larger conglomerate fragments. Clasts range from 5-40 mm in diameter, range in color, are equidimensional or somewhat elongate, and tend to be subrounded to well-rounded [13]. Such fragments are a significant component of the clast population in some areas along traverse.

Douglas-type. These particles are smaller, lighter and tan, often with a light coating of dust. Rounded to subrounded in shape, most particles in this class are ~5-15 mm long-axis, with a very rough, knobby surface texture. These are very small fragments that are relatively rare, so they likely derive from a friable or easily-weathered parent rock.

Vuggy-type. Particles of this class are grey and are distinguished by large (1-5 mm) vuggy or large vesicular texture. These particles appear near the Rocknest area and along the traverse towards Shaler. It is not clear whether this texture is derived from primary vugs, or whether it represents a conglomerate in which the matrix was more solidly cemented than the clasts, allowing the clasts to be released during weathering.

Blanchet-type. Particles in this class are mottled in color, with or without patches of a tan patina or dust coating. The surface texture is very rough and distinctively characterized by bladed voids and pendants. Particles range from very angular to rounded, and shape tends to be equidimensional. The bladed voids and pendants are consistent with chemical weathering of soluble minerals within the matrix of these clasts.

Discussion: Although this study is in its initial stages, clast morphology appears more diverse than observed at any other Mars site [8, 11, 12]. This indicates that a complex interplay of varying lithologies, transport mechanisms, and environmental circumstances is responsible for the morphology observed. The clast population at Gale probably contains material due to impact processes, including meteorite fragments, ejecta from distant craters, and impactites consisting of shocked and impact melted Gale crater materials. Other potential transport mechanisms suggested by clast morphology include mass movement of material with or without fluvial assistance, and intermittent fluvially-driven flow. However, the overprinting of various factors on clast morphology will likely make definitive identification difficult.

Some clasts appear to have been broken or fractured in situ. Continued observations at different scales should consider how to determine whether salt or frost weathering processes are responsible for these fractures, of interest in the context of the Martian frequency and intensity of freeze-thaw cycles in the fissures, fractures and porous voids of rocks.

Over the course of the mission, we will examine the correlation between particle size/frequency distribution and ground temperature measurements that provide insight into the thermal inertia of the upper ~10-15 cm of the surface [e.g., 14]. Such comparisons will help to refine predictions of surface properties from orbital thermal inertia data.

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