LINKING HOME PLATE AND ALGONQUIN CLASS ROCKS THROUGH MICROTEXTURAL ANALYSIS: EVIDENCE FOR HYDROVOLCANISM IN THE INNER BASIN OF COLUMBIA HILLS, GUSEV CRATER.

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Background and Approach: Examining the history of a rock as the summed history of its constituent grains is a proven and powerful strategy that has been used on Earth to maximize the information that can be gleaned from limited samples. Grain size, sorting, roundness, and texture can be observed at the handlens scale, and may reveal clues to transport regime (e.g. fluvial, glacial, eolian) and transport distance. Diagenetic minerals may be of a form and textural context to allow identification, and to point to dominant diagenetic processes (e.g. evaporitic concentration, intermittent dissolution, early vs. late diagenetic emplacement). Handlens scale features of volcaniclastic particles may be diagnostic of primary vs recycled (by surface processes) grains and may provide information about eruptive patterns and processes. When the study site is truly remote, such as Mars, and when there are severe limitations on sample return or sample analysis with other methods, examination at the hand lens scale becomes critical both for extracting a maximum of information, and for best utilizing finite analytical capabilities.

Applying handlens scale imaging to martian surface materials through the Mars Exploration Rover Microscopic Imagers (MIs) has revolutionized our understanding of past and present surface processes (e.g. [1-4]). Here, we use Spirit MI images to conduct a microtextural analysis and comparison of rocks in disparate locations in Gusev Crater: Algonquin-class rocks and the materials of Home Plate. Our goal is to decipher whether there is a textural link between these disparate geochemical rock classes. We demonstrate such a link, and explore the implications for the formation and evolution of Home Plate and the outcrops associated with Algonquin-class rocks.

Data Collection: The Microscopic Imager is a fixed-focus camera able to acquire images at a spatial resolution of 31µm/pixel over 400-700 nm. It uses ambient light only (sun or skylight) to illuminate targets through a 32 x 32 mm field of view [5]. This camera is designed to mimic the information a geologist would retrieve in the field with a handlens. Images examined in this study include those taken by the Spirit MI during its traverse over the west rim of Husband Hill over several tens of sols, and those taken of the Home Plate structure and its surroundings (initial reconaissance occurred between sols 750-800; continued observations of the region are currently ongoing).

We examined rocks from the Home Plate area and rocks classified as Algonquin-class (e.g 6, 7) in terms of characteristics commonly exhibited at this scale (enumerated in the next section, below). These two groups of rocks were chosen for comparison because of their apparent textural similarities at the handlens scale. Also, the Barnhill class of Home Plate follows trends in major elements (SiO_2, Al_2O_3, FeO*) defined by the Algonquin class that have been attributed to igneous fractionation [6]. Home Plate rocks are basaltic in composition, but are enriched in volatile elements such as Cl, Br, Zn, and Ge. The Algonquin-class is olivine-rich and ultramafic in composition with high concentrations of MgO and low Al_2O_3 and CaO. Algonquin-class rocks included in this study are Algonquin, Seminole, Comanche and Larry's Bench (Miami, though considered Algonquin-class, has no MI images associated with it). Home Plate rocks analyzed include Barnhill, Posey, Cool Papa Bell and nearby targets such as Riquelme and Clast 1.

Diagnostic Characteristics at the Handlens Scale: Studies of geologic materials at the microscale, whether on Earth or Mars, most often encompass the following characteristics: (1) crystal form and cleavage of individual crystal grains; (2) grain morphology and appearance, including shape, roundness and individual grain texture; (3) texture, including grain size and sorting, grain fabric, orientation and grain-to-grain contact; (4) sediment structure; and (5) color. Those appropriate to studies of Microscopic Imager (MI) images studied here include grain morphology and appearance, texture and sediment structure (diagnostic crystal form and cleavage are not evident in the images examined, and MI images are not in color).

Results: The microtexture and morphology of these rocks are comparable in several key aspects, described in detail below.

Grain morphology and appearance. The targets analyzed are all similar in that they display a clastic texture in a consolidated matrix. However, grain shape ranges from angular to well-rounded, and this grain morphology translates to rock texture. The rocks Algonquin and Seminole, in particular, display a hackly texture that may stem from the shape and texture of individual clastics (the alternate hypothesis is that this texture is a manifestation primarily of the texture of the groundmass of these rocks). This texture is shown in Figure 1.

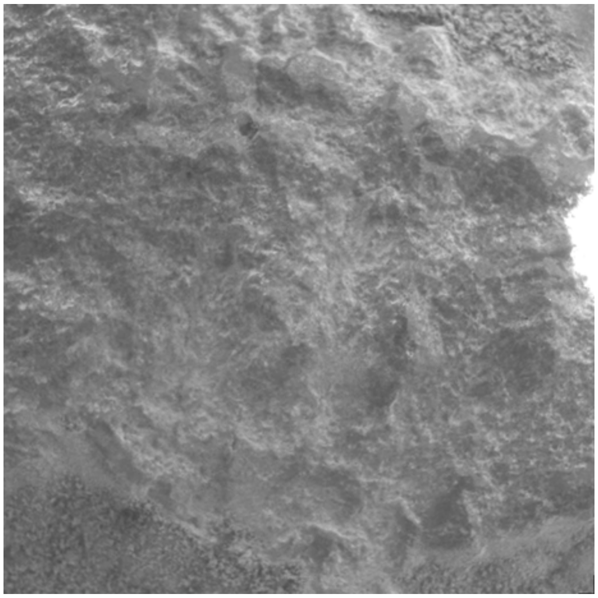

Figure 1. Target Seminole, taken on sol 675. Individual clasts are angular to sub-rounded. Hackly texture is evident; this may reflect the underlying angular grain morphology, or may be a feature of the groundmass. Image is 32 mm across.

In some targets (Posey, Cool Papa Bell target Crawfords), dark, very round grains are seen, evenly dispersed in the lighter matrix. The origin of these grains is unclear. Possible hypotheses include volcanic glass spherules, impact melt blebs, and eolian deposits.

Grain size. Grain size in these targets ranges from unresolvable (Larry's Bench) to grains several mm in diameter (Seminole and Algonquin). This size range is shown in Figure 2.

Texture. There are three distinctive textures among the targets studied: 1) hackly; 2) granular; and 3) massive, with the first two texture types displaying a prevalent cementing agent. The first type, including Algonquin, Seminole and Cool Papa Bell, is a poorly-sorted mixture of angular and more rounded grains within a clast-supported texture, indicating that these represent volcaniclastic deposits (Figure 1). Angular grain sizes range from 1-5 mm in diameter and are similar to what is found in some palagonitic tuffs on Earth [8]. The texture may be a reflection of the topography of the underlying groundmass, or of the embedded clasts, but is likely a result of both.

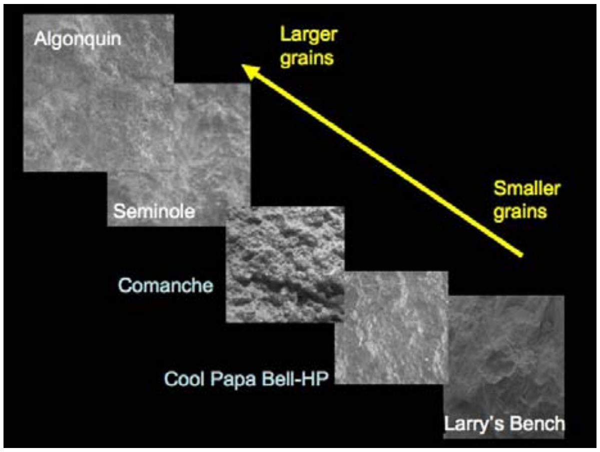

Figure 2. Sequence of grain sizes for rock targets in this study. The sequence ranges from unresolvable through the dark spherulitic grains in Cool Papa Bell (0.3 mm) to ~5 mm grains in Algonquin.

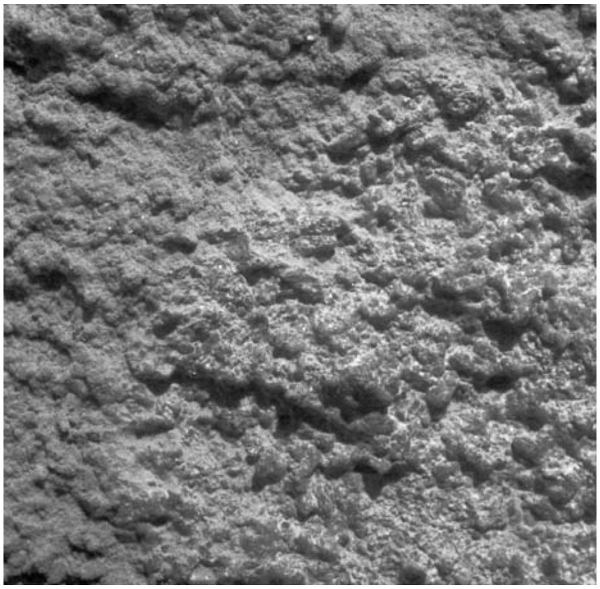

Figure 3. Mosaic of MI images of brushed target Comanche, taken on sol 700. Clasts are angular to sub-rounded, poorly-sorted and cemented together. The target texture is clast-supported. Mosaic is ~60 mm across.

In the second rock type (including Comanche, shown in Figure 3, Posey, Riquelme and Barnhill among others), grain roundness and size are homogeneous. Targets are comprised of well-rounded, very well-sorted grains that appear similar to accretionary lapilli in texture. Though at 0.6-0.9 mm average diameter they are smaller than terrestrial accretionary lapilli, they are precisely within the size range predicted by some for such deposits on Mars [9]. A cementing agent is evident here as well, in varying concentrations (Comanche, shown in Figure 3, has less while Barnhill in Figure 5 appears to have more, for example). The overall texture in these targets ranges in roughness from the hackly texture to overlapping, angular-edged, semi-circular fracture texture, with fresher, cleaner facets and sub-circular pits and voids. This third and final texture is typified by the target Larry's Bench (Figure 4) and also includes Fuzzy Smith.

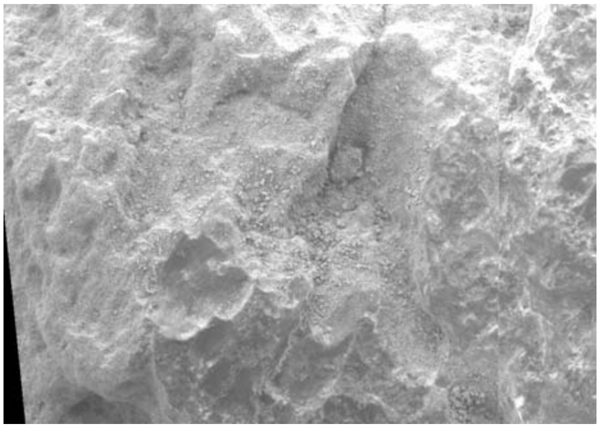

Figure 4. Mosaic of MI images of target Larry's Bench, taken on sol 660. Note the smooth facets seen within the semi-circular fractures. Image is ~30 mm across.

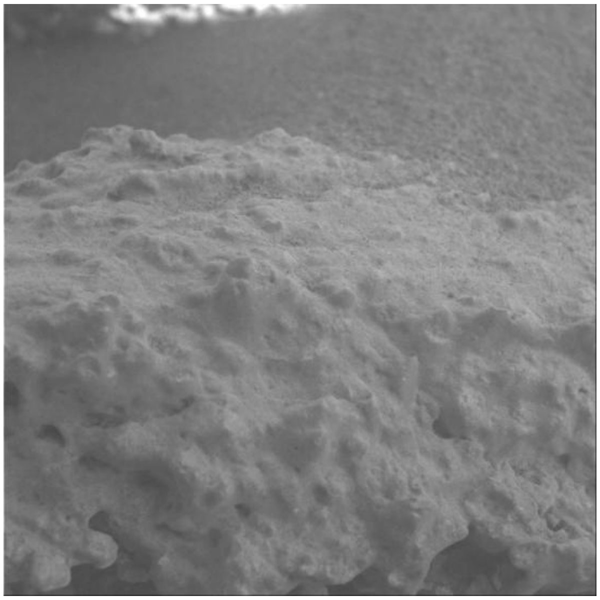

Figure 5. The target Fastball on the feature Barnhill. Stalks of less resistant material containing more resistant grains are evident in the lower left. Image is 32 mm across.

Sediment structure. Microscale sediment structures are seen in a few rocks in the form of small-scale layering. The feature Posey, for example, displays alternating clast-supported layers of more and less-resistant material, with layers averaging 5-10 grains (1-3 mm) in thickness. Layer rims show a rough granular texture that is a product of the morphology of the underlying grains. These poorly-sorted grains, ranging from angular to well-rounded, can be seen clearly through the lithifying agent. Because of the angle at which the MI imaged Posey, it is difficult to determine the grain size or sorting of the more recessed (less-resistant) layers.

By contrast, targets associated with the feature Barnhill (Figure 5) show little to no evidence of lamination in MI images, though coarse-to-fine-grained sequential layering is evident at the macroscale. At the microscale, the cementing agent dominates the texture, with stalks and grain-shaped voids showing evidence of more resistant grains embedded in a less-resistant matrix. The overall texture is clast-supported, but matrix volume between clasts is the highest of all targets in classes 1 and 3 described below.

In between the structures of these two targets is the rock Riquelme, taken on sol 1080. Well-rounded, well-sorted grains 0.6-0.9 mm in diameter are arranged in very subtle grain-scale-thick laminae, held together by a cementing agent that is not sufficient in volume to entirely fill the interstitial spaces.

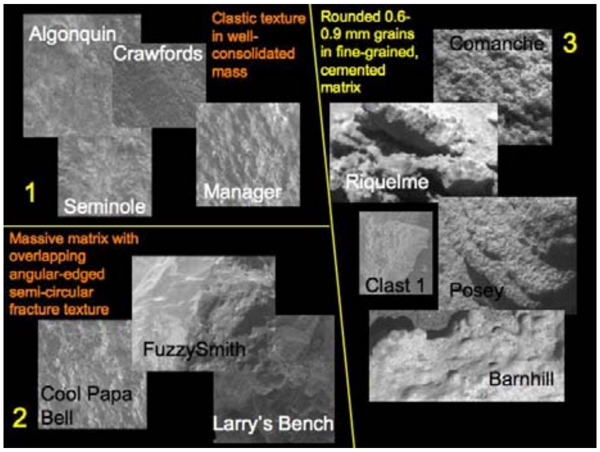

Figure 6. Classification of Algonquin and Home Plate rocks based exclusively on microtexture.

Interpretation and Discussion: Three classes can be assigned based on microscale analysis, drawing from the geochemically defined Algonquin and Home Plate classes: (1) clastic texture in a well-consolidated mass (with or without dark spherulitic grains); (2) massive groundmass with overlapping, angular-edged, semi-circular fracture patterns; and (3) rounded grains in a fine-grained, cemented matrix. Classes 1 and 3 appear to be volcaniclastic, and likely phreatomagmatic, in nature; the clast-supported texture and likely presence of accretionary lapilli, in particular, are diagnostic of such an origin. The microtexture and morphology of class 2 is less clear but is consistent with a volcanic origin, among other interpretations. Welded or cemented accretionary lapilli is the most obvious interpretation for Class 3 targets such as Posey, Barnhill and Riquelme. This welding or cementing agent may indicate a hyaloclastic origin, or subsequent diagenesis.

We have shown that there is a textural link between Algonquin-class and Home Plate-class rocks. The key characteristics of this link can be summarized as follows:

1. Grain morphology & appearance is characterized by either a mix of rounded/angular grains (Algonquin, Seminole, Cool Papa Bell) or more homogeneous, rounded grains (Posey, Barnhill). The most well-rounded grains are likely accretionary lapilli (e.g. 10, 11). The presence of putative accretionary lapilli would require that water was also present during eruption, sufficient enough for ash to nucleate.

2. Algonquin-class and Home Plate rocks are comprised of clastics with similar grain size and sorting. Grain size is most similar in Comanche and Home Plate rocks. Impact or volcanic activity could produce the range of grain sizes observed and would also be consistent with production of angular grains. However, it is more difficult to envision impact creating the well-rounded grain population. In addition, Barnhill shows voids that have been interpreted as vesicles [11]. While it is possible that these voids are the result of plucked grains, they show a range of sizes, with some notably smaller than the average grain size. Also, in the case of plucked grains, evidence from the original grain is often left behind in the form of residue from the cementing agent, rough edges along the void, irregular void shapes (especially showing the pattern of the interstitial material), or void edges that match grain topography. None of that is present here. Instead, the void profiles seem to be independent of grain shape or position.

3. In terms of grain fabric and grain-to-grain contact, clast-supported textures dominate in nearly all cases, arguing for a volcaniclastic origin for these materials. The presence of a cementing/welding agent is evident in several targets, but is most prevalent at Barnhill and Posey. This indicates either reworking of *in situ* deposits or cementation of grains shortly after deposition, possibly by palagonization or nano-phase Fe-oxide alteration.

4. Sediment structure is subtle where present at this scale. Structures take the form of laminae of 1-10 grains (up to 5 mm) in thickness, with most laminae at the low end of this range. Possible origins for these structures include impact airfall, eolian transport and volcaniclastic activity. However, a volcaniclastic origin for Algonquin-class rocks, and a phreatomagmatic origin for Home Plate rocks are the preferred hypotheses, as they best fit all the textural characteristics described as well as geochemical evidence for the volcanic origin of Home Plate [12, 13].

We conclude that the microtextural evidence of Algonquin-class and Home Plate rocks indicates similarities between these two geochemically disparate classes that may indicate a genetic relationship. Both classes are volcaniclastic and likely saw interaction with fluids during or subsequent to emplacement. It has been suggested that the volcanic textures in Home Plate rocks and their enrichment in halogen and volatile metal elements points towards volcanic interaction with external briny groundwater [10]. If there is a genetic relationship between these two classes, then the structure of Home Plate is part of a larger geologic unit of hydro-volcanic origin that encompasses the Inner Basin of the Columbia Hills.

Finally, these studies serve as a demonstration that rocks of similar geochemical composition may have very different textures. This is a crucial point that must be taken into account when attempting to interpret the genesis of rock classes.

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