AEOLIAN ABRASION AND THE PRESERVATION OF ROCK COATINGS AT THE MARS PATHFINDER LANDING SITE. M. D. Kraft and R. Greeley, Department of Geology, Arizona State University, Tempe, AZ, 85287-1404; mdkraft@asu.edu.

Introduction. Among the discoveries from the Mars Pathfinder mission were ventifacts and possible rock coatings. Ventifacts are pitted, fluted, and grooved rocks that provide the first direct evidence for mesoscale aeolian abrasion on Mars [1,2]. Ventifacts indicate a past prevalent wind direction different from the current aeolian regime near the landing site[1,2]. Rock coatings are indicated from morphologic and albedo variations on rocks as seen in Imager for Mars Pathfinder (IMP) and rover images [2,3]. Coatings on rocks are also suggested as an explanation of the scattering parameters derived from photometric analysis of surface materials at the Pathfinder site [4].

Aeolian abrasion and rock coating formation are competing processes and it is unusual to find the products of both present at the Pathfinder site. To address this problem, we conducted abrasion experiments to determine how easily rock coatings abrade in comparison to rock. We found the rock coatings are generally more easily abraded than rock; however, rocks coated with amorphous silica resist abrasion more than basalt. We use these results, coupled with interpretations of site geology, to constrain the aeolian history of the Pathfinder site. We suggest that the soil layer at the Pathfinder site has been deflated and that the aeolian abrasion has been minimal in recent times, during which rock coating formation has been the dominant of the two geologic processes.

Observed rock coatings. Coatings seen at the Pathfinder site could consist of several types. Here we suggest three: varnish-like coatings, salt-cemented coatings, and amorphous silica coatings. Varnish-like coatings would consist of dust-size particles cemented by Fe- or other metal-oxides. These would be similar to terrestrial rock varnish, which is largely composed of clay minerals [5] cemented by Mn- and Fe-oxides [6]. Salt-cemented coatings could be sulfate minerals or aggregated fines cemented by sulfates. This type of coating would be similar to calcrete or gypcrete coated rocks found in terrestrial deserts [7,8]. Finally, amorphous silica could coat rocks at the Pathfinder site. Silica coatings have been reported from many areas on Earth, such as desert regions on the island of Hawaii [9,10].

Possible crusts adhere to rocks at the Pathfinder site [2,3]. In one example, a crust appears to have spalled from a rock [2]. And it has been suggested that hard, bright soil deposits might instead be crusted rocks [3]. We suggest that crusts coat some additional rocks at the Pathfinder site. Crusts can be seen in IMP images as albedo and textural variations on rocks. Although variable, crusts are typically lighter than the other portions of the rock and often have a smoother appearance. They occur mostly on the lowermost portions of rocks with some variability in the height at which they occur on rocks. Crusts occur on ventifacts, and are themselves pitted and fluted. Pits are often wider on crusted portions of rocks than on the rock itself and flutes are broader and limited in comparison to the rocks. Because they have been abraded in a style similar to the ventifacts, crust were formed prior to ventifact formation. We suggest that crusts on rocks could be salt-cemented coatings.

Other coatings have been suggested for the Pathfinder site based on photometric evidence [4]. The scattering parameters calculated for dust-free rocks at the site are not consistent with scattering from pure rock materials. In addition, the rocks, unlike other surface materials, have an appreciable forward-scattering component to their photometric functions [4]. Forward-scattering of light from rock surfaces can be seen qualitatively in IMP images taken at higher phase angles as glints from rock faces. Because there are a large number of reflective rock surfaces seen in such images, coatings of this variety may be pervasive at the Pathfinder site. These patinas might be varnish-like coatings [4] or amorphous silica coatings.

Abrasion experiments. We performed experiments to determine the susceptibility to abrasion, S_a, of the various rock coatings we suggest for the Pathfinder site. As surrogates to each type of suggested Martian rock coating we used naturally occurring rock coatings as targets: rock varnish for varnish-like coatings, calcrete for salt-cemented coatings, and amorphous silica rock coatings. We also abraded basalt and andesite to compare rock S_a to rock coating S_a. As agents of abrasion we employed quartz sand, which abrades similarly to basalt; basaltic ash; and dust aggregates, which were dust particles cemented by gypsum and simulate comminuted crust materials.

The experiments were conducted using the Mars Rotating Erosion Device (MRED), which allows the separation of variables¾ impact angle, particle velocity, particle size, atmospheric pressure¾ that affect S_a [11]. Targets were weighed and then mounted in MRED at a specified impact angle under Martian atmospheric pressure (7 mbar). The targets were then subject to sandblasting by the chosen agent of abrasion

at a velocity of 15 m/s. The mass of sand striking each target was calculated from the MRED geometry and target size. After the experiment, targets were weighed and S_a was calculated as the mass lost by a target divided by the mass of particles that had struck it.

Results. Rock coatings are generally more easily abraded than rock; however, amorphous silica coatings resist abrasion more than rock (Fig. 1). The S_a of basalt is in general agreement with previous results [11]. The values of S_a are similar for basalt and andesite.

Target S_a versus impact angle was used as a basis of comparison. Basalt has a minimum S_a at 30°, with increasing S_a toward shallower and steeper impacts [11]. Andesite also has a minimum S_a at 30°. Rock varnish is similar with an S_a minimum between 30° and 60° and a somewhat shallower curve. Calcrete has a different trend of S_a versus impact angle with impacts of ~30° causing maximum abrasion. No trend was obtained for silica coatings.

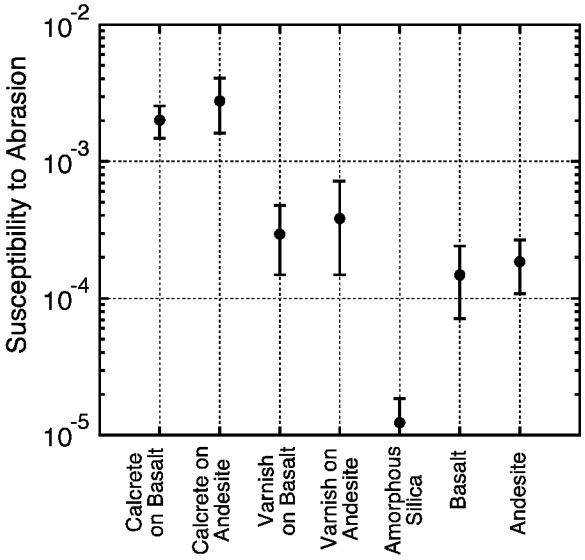

Figure 1. Comparison of S_a for rocks and rock coatings abraded by quartz sand at a 30° impact angle at 15 m/s.

Discussion. It appears that crusts on rocks predate ventifact formation at the Pathfinder site, because the crusts are themselves pitted and fluted. If crusts are salt-cemented coatings, the S_a of calcrete would approximate S_a of the crusts, which is more than an order of magnitude greater than the S_a of basalt. Crusts may have been preserved due to shielding from obstacles upwind of them or by protection from the soil during burial. Additionally, the position of crusts, which occur on the lower portions of rocks, may have aided in their protection; sand moving in saltation has a low velocity and, therefore, lower abrasive power nearer the surface.

We favor a scenario in which crusts were formed in a previously deeper soil, evidence of which includes horizontal demarcations on some rocks [2]. In this way, the crusts were protected from aeolian abrasion while buried. Subsequent deflation, which might have occurred at the time of ventifact formation, revealed the crusts which were then removed by sandblasting from all but the lowermost parts of rocks.

The varnish-like coatings or amorphous silica coatings are pervasive and appear to coat fluted rocks, which suggests that these coatings postdate the period of ventifact formation. Varnish-like coatings could be preserved if there has been a lack of abrasion since its formation. Aeolian abrasion may be lacking at the Pathfinder site because of a low frequency of saltation-strength winds, which might only occur during northern hemisphere winter. Abrasion could also be reduced because of a lack of agents of abrasion. The sand-size material available in the vicinity of the Pathfinder site might be inefficient as an abrader or sand-size particles might be locked into an indurated surface and be unavailable for sandblasting. Also, sand deposited by the Ares-Tiu flooding events might have been transported, forming the ventifacts, and the supply of abrasive particles has since been exhausted [1].

If the reflective coatings are amorphous silica, they could serve to protect rocks from further abrasion. The S_a of silica coatings is an order of magnitude smaller than the S_a of basalt, which implies a potentially significant reduction in the rate of abrasion.

An alternative to preservation of varnish-like or amorphous silica rock coatings is the possibility of active rock coatings genesis. If significant abrasion has occurred at the Pathfinder site in relatively recent time, coating formation could be outcompeting aeolian abrasion as a geomorphic process.

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