DEFLATION HISTORY OF THE MARS PATHFINDER LANDING SITE.

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Introduction. Image data from the Mars Pathfinder landing site show a suite of geomorphic features that indicate the post-flood soils at the site have been deflated. The orientations of aeolian features—ventifact flutes versus wind tails and duneforms—indicate the dominant wind direction may have changed over time. Sedimentary deposits appear to have been deflated under both wind directions to an established base level. The site may have been blanketed by several centimeters of dust, which has been removed by saltating particles under the current wind regime.

Geomorphologic relationships. Numerous geomorphic features were observed at the Mars Pathfinder landing site, which have been attributed to aeolian processes. These include duneforms, wind tails, ripple patterns, possible lag deposits, and ventifacts [1,2]. Wind tails and duneforms are inferred to have formed in the current aeolian regime [1,3]. Wind tails, which taper away form in the lee side of rocks, are oriented toward the southwest, indicating winds blowing toward that direction. Duneforms also indicate winds blowing toward the southwest; Transverse duneforms are oriented orthogonal to the direction of wind tails, while horns of barchanoid features point toward the southwest. The wind direction inferred from these features matches very well with regional winds predicted by the Mars General Circulation Model [4,5], strengthening the suggestion that wind tails and duneforms were formed by the current wind regime. Conversely, ventifacts may have formed under a different wind regime. The orientations of ventifact flutes and grooves indicate formative winds blowing toward the west-northwest. It, therefore, appears that two distinct wind directions are indicated by preserved geomorphic features.

The soils at the Pathfinder site have been deflated. Deflation is indicated primarily by horizontal demarcations on large rocks in the Rock Garden [see 6], which is interpreted to be a former soil level [1]. The rocks are redder below this line [7], suggesting that detritus is adhered to the rock or that the rock has been stained by the previously existing soil. Several smaller rocks, especially rocks situated northeast of the lander, appear significantly brighter near the present soil surface. The bright strips at the base of these rocks is possibly an adhered crust, maybe composed of salts or salt-cemented fines. They may also represent the former existence of a thicker soil deposit.

Deflation is also suggested for the Pathfinder site by aeolian features. Wind tails are sculpted, a form more consistent with formation by deflation [1,8]. Wind tunnel experiments also suggest that wind tails are probably a result of erosion rather than primary deposition [9]. In addition, several soil areas may be lag deposits, indicating that smaller particles—dust and fine sand—have been winnowed away by wind.

Deflation history. The soil layer at the Pathfinder site has been deflated multiple times; there is direct evidence for at least two episodes of deflation or exhumation since emplacement of flood deposits. We suggest that the initial flood deposit [see 10, 11] produced the soil line apparent on rocks in the Rock Garden and was, therefore, 5-7 cm thicker than the current soil level. It is likely that ventifacts were produced by an abundant supply of crystalline sand or sand-size rock fragments furnished by floods, as suggested by [2,1]. There are flutes on large rocks, such as Flute Top, that lie below the inferred former soil level, suggesting that the soil was deflated before or during the time the ventifacts were formed. Because ventifacts more often form in areas where the soil is stable and firm [12], a likely scenario might be that the soil was deflated 5-7 cm leaving a partially armored surface of larger particles. This lag deposit would be stable under the formative wind, creating a deflationary base level. The armored surface would allow saltating particles to rebound from the surface higher into the wind profile, thus, giving them higher velocities and making them more efficient abraders.

Wind tails offer additional evidence of deflation; however, they must be remnants of a different deposit. In many instances, wind tails are seen to overlay what appears to be much coarser material (Fig. 1), which is interpreted to be the base-level lag deposit discussed above. Wind tails would have been out of equilibrium with the ventifact-forming winds inferred to blow toward the west-northwest and could not have been formed by such winds. Instead, wind tails appear to have formed under the current wind regime, in which winds are inferred to blow toward the southwest.

There must have been deposits of material lain between the time the ventifacts were formed and the time the wind tails formed. Such deposits could have been flood deposits, extensive dunes, or areal dust deposits. Flood deposits are not likely, as they would have disrupted the original deposits and provided new sand, which could be used to abrade rocks. There is no evidence to suggest that rocks are abraded under the current wind regime. Dunes are a possible source of wind tails, which could be material left behind rocks during dune migration [3]. The wind tails are very red in color and appear to be indurated, which may be more consistent with dust. In addition, the thickest wind tail is 3 cm thick [1], much thinner than the observed duneforms. Soil mechanics experiments show that drift material that makes up wind tails is compressible and fine-grained, consistent with aeolian dust [13]. If wind tails are comprised of dust, they are probably a residual of a once extensive dust deposit that was about 3 cm thick. And they reflect the strongest winds of the current aeolian regime.

A sequence of deflation to a coarse-grain base level followed by dust deposition and subsequent removal of the dust layer is consistent with a proposed drift-soil stratigraphy based on spectral investigation of the landing site [7]. This scenario agrees well with the results of soil mechanics experiments, which reveal that there is a firm, coarser-grain layer of cloddy materials overlain by fine-grain drift [13,14].

An areal deposit of dust could have been removed by dust devils, strong winds, or by saltating particles moving under lighter winds. Dust devils are not favored because of the strong directionality of wind tails. Winds strong enough to lift dust likely would have caused substantial reverse flow around rocks [see 15] allowing little protection in the lee of rocks and wind tails would not have formed. Therefore, we favor removal by saltating particles. However, the degree to which saltating particles swept the area must have been meager enough to cause little or no abrasion to rocks. There is no evidence for extensive abrasion by winds blowing toward the southwest. Possible rock coatings, suggested by photometric observations [16], show that rock surface have been stable for some time and that removal of material from rocks has not occurred at a scale greater than 10's of micrometers [17].

Discussion. The Pathfinder site has evidence of two distinct periods of deflation. One is the deflation of flood-deposited soil; the other is the deflation of an extensive dust deposit. Other periods of deflation may well have occurred during the time between the two periods noted, but evidence such as directional wind tails could have been eradicated by a change in wind regime. If wind tails are composed of dust, they represent a once larger areal layer of dust, which probably would have been deposited during a period of aeolian quiescence or, perhaps, in a rapid manner. Its later removal occurred under the current aeolian regime, which may be a relatively recent regime when considering changes in changes in the general circulation of the planet due to changes in obliquity [18]. This may support the hypothesis that dust is cyclically redistributed—deposited and removed, perhaps repeatedly—over time [19].

Dust was probably removed due to saltating particles. If so, the particles did no recognizable abrasion to rocks: particle movement was limited, saltating at low velocities, or otherwise insufficient to abrade rocks. The saltating particles may have been too weak to abrade rocks, perhaps aggregated dust particles. Or, if there are rock coatings present on rocks, they may be resilient [17] and serve to protect rocks from abrasion.

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Figure 1. Rover image (SO32094) showing bright, fine-grain wind tails overlaying a darker, coarse-grain substrate. This substrate is interpreted to be a deflationary base level established after the Ares-Tiu flooding events but prior to or concurrent with ventifact formation.