VENTIFACTS ON MARS. N. T. Bridges[1], [1]Jet Propulsion Laboratory (MS 183-501, 4800 Oak Grove Dr., Pasadena, CA 91109; nathan.bridges@jpl.nasa.gov)

Introduction: Prior to the Pathfinder mission, rocks on the Martian surface appeared relatively unaffected by physical weathering processes. A major discovery of Pathfinder was the finding that numerous rocks exhibit features characteristic of ventifacts, rocks that have been abraded by windborne particles [1,2]. Initial studies have shown that 1) at least half the rocks at the landing site are abraded, 2) ventifacts are more abundant at the Pathfinder site than at the Viking sites, and 3) most of the rock erosion appears to have occurred in a climatic regime different from that of today [1].

Characteristics of Martian Ventifacts: Ventifacts on Earth can be divided into three categories: 1) Rocks with polished or etched surfaces, 2) rocks with wind cut faces or facets, and 3) rocks marked by indentations such as elongated pits, flutes, and grooves (commonly collectively referred to as flutes) [3,4]. Examples representing the first two classes are not definitively identified at the Pathfinder site. Forward scattering rock surfaces at the landing site [5] could be due to surfaces polished by aeolian abrasion, but other possibilities such as rock varnish coatings are also plausible. Some rocks appear faceted, but other origins such as fracturing during impact or flood transport may also produce these morphologies. The best evidence for ventifacts are the abundant rocks exhibiting flutes (Fig. 1). Initially identified in rover images, these have also been documented extensively in IMP (Imager for Mars Pathfinder) frames.

The orientation of the flutes at the Pathfinder site generally trend in a northwest direction, indicative of winds blowing from the southeast [1,6]. This is in marked contrast to wind tails seem at the site, crater wind streaks visible from orbit, and predictions of the General Circulation model, all of which indicate that the strongest winds blow from the northeast to the southwest (Fig. 2) [2,7]. The generally orthogonal ventifact wind direction does, however, agree with the trends of subtle, small-scale wind streaks trending from secondary craters near the landing site, the direction of dunes within Big Crater seen in MOC images, and possibly some small wind tails seen at the Pathfinder site.

Ventifacts appear to be relatively rare at the Viking landing sites [1,6]. Because using close-up Pathfinder rover images biases the results, IMP frames were compared to comparable resolution Viking images. Flutes are found on at least half the rocks. In contrast, save for a few elongated pits, rocks at the Viking sites are generally devoid of well developed flutes or other wind-carved features.

Origin of Ventifacts on Mars: The formation of ventifacts requires that winds be capable of entraining particles and that a source of particles be present. To produce flutes and other linear features, the winds must be ~ unidirectional. Terrestrial studies show that a number of particle types abrade rock surfaces, including dust and snow [8,9]. However, sand is by far the most efficient abrasive agent and on Earth is responsible for producing ventifact forms like those seen at the Pathfinder site. It therefore seems probable that the Pathfinder ventifacts were produced by the abrasion of sand carried in strong, generally unidirectional winds. Dust may also be responsible for some abrasion, but its ubiquitous presence on the Martian surface and the lack of ventifacts at the Viking sites indicates that it is not a major factor.

The orientation of ventifact features at the Pathfinder site and the evidence that they were dominantly formed by sand abrasion suggests that the ventifacts formed under a different climatic regime in the presence of abundant sand. Prodigious supplies of sand-size material were likely deposited by the Ares and Tiu Valles floods 1.8-3.5 Ga. Entrainment of this sand by winds blowing dominantly from the southeast then formed the ventifacts. Since this time, most of the remaining sand at the site and elsewhere on Mars has been segregated to depressions (craters, valleys, etc [10]). where it is shielded from further transport, effectively slowing down rock abrasion.

Implications: The presence of ventifacts on Mars has important implications for Martian geology and the planning of future missions The fact that many rocks on Mars have been significantly abraded, combined with observations of abundant dust and perhaps other alterations products on rocks [11], indicates that unaltered rock surfaces are relatively rare on Mars. The recording of ancient wind directions provides important information on ancient Martian climatic regimes that cannot be easily gleaned from an examination of orbital images. The study of ventifacts should be considered an important component of future lander and rover geomorphology investigations.

References:

[1] Bridges, N.T., *J. Geophys. Res., 104*, 8595-8615, 1999. [2] Greeley, R., *J. Geophys. Res., 104*, 8573-8584, 1999. [3] R. Greeley and J.D. Iversen, *Wind as a Geological Process*, 333 pp., Cambridge Univ. Press, New York, 1985. [4] Laity, J.E.; in Abrahams, A.D. and A.J. Parsons (ed), *Geomorphology of Aeolian Environments*, Chapman & Hall, London, 506-535, 1994. [5] Johnson, J.R., *J. Geophys. Res., 104*, 8809-8830, 1999. [6] Bridges, N.T. et al., *Lun. Planet. Sci. Conf. XXX*, 1907, 1999 [7] Smith, P.H. et al., *Science, 278*, 1758-1765, 1997. [8] Whitney, M.I., *Geol. Soc. Am. Bull., 89*, 1-18, 1978. [9] Whitney, M.I. and R.V. Dietrich, *Geol. Soc. Am. Bull., 84*,

156`-2582, 1973. [10] Malin, M.C. et al., *Science, 279*, 1681-1685, 1998. [11] McSween, H.Y. et al., *J. Geophys. Res., 104*, 8679-8715, 1999.

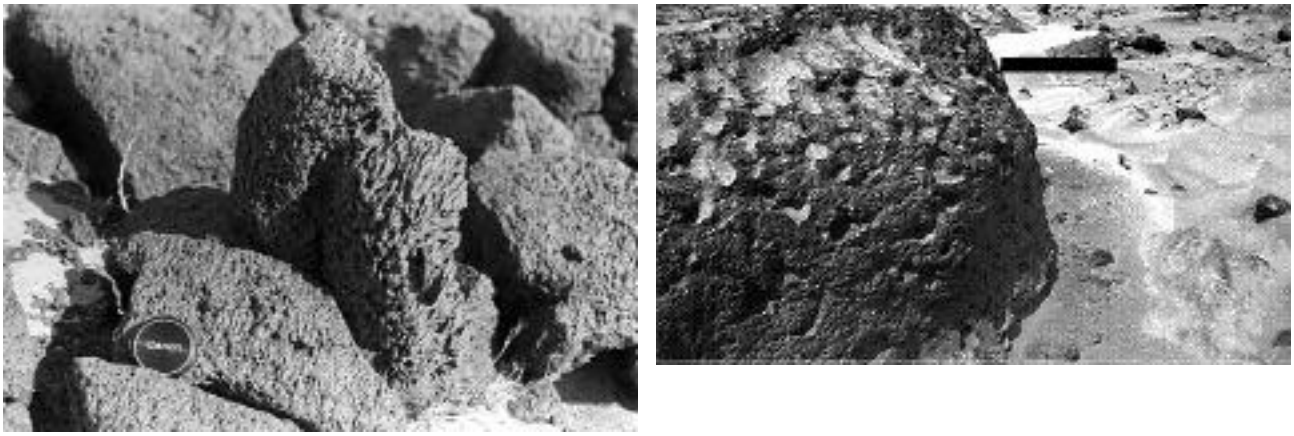

Figure 1: Pitted and fluted ventifacts on Earth and Mars. Left frame shows vesicular basalt from Amboy Lava Field, CA (photo by R. Greeley). The vesicles on the upper part of the rocks have been elongated by the action of aeolian abrasion, forming flutes. The right frame shows the rock Stimpy at the Mars Pathfinder landing site, as viewed by the rover's left front camera. The pits on the side of the rock become progressive elongated toward the top, indicating wind scour. The scale bar corresponds to a length of 10 cm at the back edge of the rock.

Figure 2: Visual evidence of two wind directions at the Pathfinder landing site. The rock Souffle, at right, and two other nearby rocks show flutes oriented to the west-northwest, consistent with winds blowing from the southeast. In contrast, the wind tails are oriented to the southwest, indicating winds blowing from the northeast (rover view here is along an azimuth of 245±1°).