NEAR-SURFACE WIND SPEEDS INFERRED FROM MOVEMENT OF SAND GRAINS OBSERVED BY *SPIRIT* IN GUSEV CRATER, MARS.

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Overview: Wind is the dominant agent of surface modification on Mars in the current environment, as evidenced by active dust storms and abundant wind-related surface features observed from orbit and the ground. Quantifying aeolian processes requires knowledge of the near-surface wind regime, including wind speeds and surface shear stresses. Values for such parameters are determined from measurements of the wind velocity profile near the surface, but such direct measurements are lacking on Mars, other than those obtained from the "wind sock" experiment on the 1997 NASA *Mars Pathfinder* lander[1]. Consequently, derivation of information on near-surface winds is achieved indirectly through observations on Mars by the movement of active sands of known sizes, coupled with laboratory experiments of the winds needed to move such sands.

Observation: In 2007, the Mars Exploration Rover, *Spirit*, remained in one position from sol 1250 to sol 1291 on the east scarp of a polygonal-shaped feature named *Home Plate* in Gusev crater. Dust storm activity was high during this time and operational activities were restricted to conserve power. However, front Hazard Avoidance Camera (Hazcam) images **(Fig. 1)** taken on sol 1260 and sol 1265 show that a ripple crest had moved about 1.5 to 2 cm toward the southeast (azimuth 220^o), presumably under the influence of near-surface winds. The observed direction of movement is approximately consistent with wind directions based on previous analyses of aeolian features[2]**.** Although no Microscopic Imager (MI) frames were taken of the sands within the ripple, images were taken of sands within 0.5 m of the ripple. Of the 98 MI frames taken from sol 1250 to 1291, 18 frames contained useful information and the sands were found to average 218 μm in diameter, equivalent to fine sand **(Fig. 2)**.

Anaylsis: The fundamental parameter in aeolian processes is the *threshold friction wind speed,* u_{*t} [3,4], which defines the minimum wind conditions to set particles into motion and is a function of the wind velocity profile. Friction wind speed is related to surface shear stress by

$$\tau = u_{*t}^2 \rho = \mu \frac{\partial U}{\partial z}, \tag{1}$$

where τ is the shear stress responsible for movement, ρ is the atmospheric density, μ is the absolute viscosity (dependent on temperature) and $\partial U/\partial z$ is the velocity profile with respect to height for aerodynamically smooth surfaces. Extensive experiments under martian atmospheric conditions have defined these conditions [5], leading to the establishment of u_{*t} versus particle diameter "curves" for various atmospheric temperature and pressure conditions on Mars (**Fig. 3).** Assuming a temperature of 250 K and pressure of 6.5 to 9.5 mb at Gusev crater, the threshold friction wind velocity for 218-μm particles ranges from 1.7 to 2.5 m/s. Measurement of the wind speed, U, varies as a function of the wind friction speed, u_*, the aerodynamic surface roughness, z_0, and the elevation above the surface, z for naturally rough surfaces:

$$U = \frac{u_*}{\kappa} \cdot \ln\left(\frac{z}{z_0}\right) \tag{2}$$

u_{*t} is used in the place of u_* to determine the wind speed, U, when the particles were in motion. The aerodynamic roughness marks the boundary between turbulent flow above this height and laminar flow below. Changes in z_0 change the thickness of the laminar sublayer and influence how well particles can be lifted out of that region. Large nonerodible roughness elements remove energy from the airflow resulting in higher shear stresses (hence wind velocities) required for particle movement. In most cases z_0 is about 1/30 the height of the roughness elements. The aerodynamic roughness has not been determined at the *Home Plate* site in Gusev crater, but has been estimated to be 0.1 to 1.0 cm at the *Viking 2* landing site [5,6] and >3 cm at the *Mars Pathfinder* site[1]; because a qualitative assessment of the roughness suggests that the *Home Plate* site is smoother, we use z_0 << 1.0 cm. The elevation above the surface, z, was calculated from the expression

$$z = \frac{1}{2} NE \tag{3}$$

in which NE refers to the average diameter of nonerodible roughness elements (such as rocks) in the upwind direction from the site of interest, and a rough estimate from Navcam images is 3.5 cm. Based on these values, the near-surface winds speeds are estimated to have been at least 12 to 17 m/s within a few cm of the surface when the particles moved. In general, wind speeds increase with height above the surface, and these values would correspond to minimum speeds of 28 to 42 m/s at a height of several meters.

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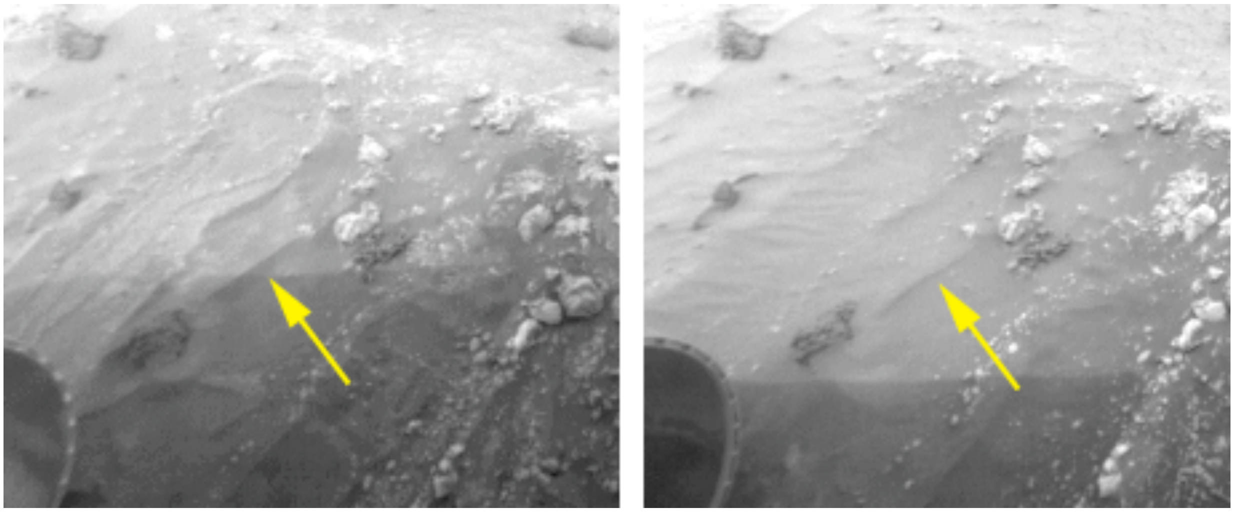

Figure 1. *Sol 1250 and 1291 front Hazard Avoidance Camera images show ripple crest displacements as large as 2 cm toward the southeast (azimuth 220°). Yellow arrows indicate the ripple crest used primarily for calculations. Rover heading was 50.261° at site 130 position 194.*

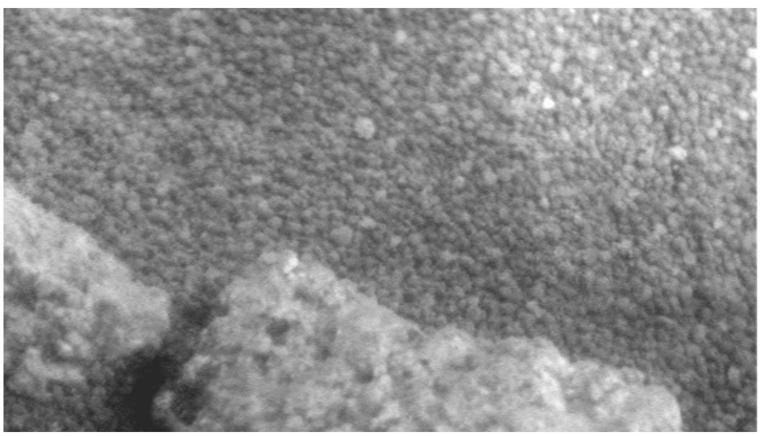

Figure 2. *Microscopic Imager Image of sands located roughly within 0.5 m of ripple. Sol 1291 (Site 130 Position 194).*

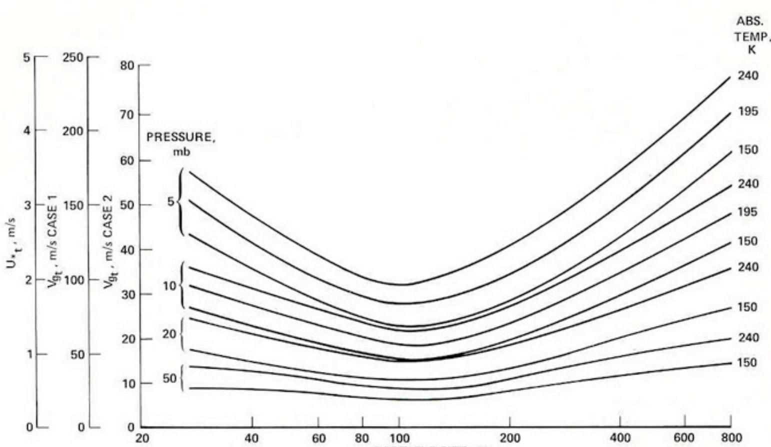

Figure 3. *Particle threshold curves as a function of particle size for surface pressures and temperatures. Case 1 scale is "free stream" velocity (above boundary layer) for winds blowing over a flat surface of erodible grains; Case 2 surface, contains cobbles and small boulders [5].*