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Field analog studies of the distribution of windblown sediments at Amboy Crater, California, with application to Mars

Rebekah L. Kienenberger *, Ronald Greeley [1]

School of Earth and Space Exploration, Arizona State University, PO Box 871404, Tempe, AZ 85287-1404, USA

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ABSTRACT

Many shallow craters in the Spirit Mars Exploration Rover site contain asymmetric distributions of windblown sediments, which could indicate the predominant local wind direction at the time of their deposition or redistribution. Terrestrial analog field work at the Amboy lava field, Mojave Desert, California, included real-time wind measurements and assessments of active sediment deposition in four small (<100 m) craters. Preliminary results indicate that reverse flow or stagnant wind flow likely occurs in craters with depth-to-diameter (d/D) ratios of ≥ 0.05. Measurements taken within a crater of d/D of ~ 0.02 do not indicate reverse flow; therefore, reverse flow is expected to cease within a d/D ranging from 0.02 to 0.05, resulting in wind movement directly over the crater floor in the downwind direction. Craters with asymmetric eolian deposits near the Mars Spirit landing site have d/D from 0.034 to 0.076, suggesting that reverse flow occurs in these craters. Thus, the position of windblown sediments in the small craters on the northwest part of the floor would indicate prevailing winds from the northwest to the southeast at the time of deposition or redistribution.

1. Introduction

The Mars Exploration Rover, Spirit, landed in Gusev Crater in January 2004 (Squyres et al., 2004). Shallow craters <200 m in diameter, termed "hollows" (Golombek et al., 2006), are common and are thought to be mostly eroded secondary impact craters (Grant et al., 2006; McEwen et al., 2005). Many of the craters contain asymmetric distributions of windblown (eolian) sediments (Fig. 1), which could indicate the predominant local wind direction during deposition or redistribution. For example, raised-rim craters with deep floors exhibit reverse flow across the floor in wind tunnel experiments for comparisons with Mars (Greeley et al., 1974a, b). In this model, particles are blown into the crater and then swept by reverse flow across the floor and deposited on the upwind side in an area of stagnant wind. However, the shallow craters near the Spirit landing site have low rims and shallow floors and might not experience reverse flow due to a different flow separation and reattachment for shallow craters. In these cases, windblown sediments might be deposited on the downwind part of the crater floor. Therefore, there are two possibilities for interpreting the local wind direction from the position of the deposits, depending on the morphometry of the crater: deposition on the upwind part of the floor or deposition on the downwind part of the floor. Resolving which case is valid for the small craters in Gusev is critical for interpreting the prevailing winds at the time of eolian deposition or redistribution.

In this paper, we present the results of terrestrial analog field work at Amboy lava field in the Mojave Desert, California (Fig. 2). This site has been used as an analog for many applications to Mars, including the interaction of eolian and volcanic processes (Greeley and Iversen, 1978). The lava field consists of $\sim 70\ \mathrm{km}^2$ of vesicular pahoehoe basalt with an estimated age of 6000 years (Parker, 1963). A dark wind streak in the lee of a large cinder cone represents an area of the lava flow swept free of loose eolian material (Greeley and Iversen, 1986) and extends ~ 4 km to the southeast, indicating prevailing winds from the northwest. Alluvial deposits located upwind of the lava field provide the primary source for sand particles, which are transported across the lava and provide a contrast to the basalt flow. Small endogenic craters ~ 20–110 m in diameter (Fig. 2b) provide good analogs for secondary impact craters on Mars because they have similar morphometric properties (depths and diameters) and are partly mantled by eolian material, similar to the "hollows" on the lava plains of Gusev Crater.

2. Data collection

Morphometric data for craters at the Amboy site were collected in the field and from aerial photographs. Those shown in

* Corresponding author.
E-mail addresses: Rebekah.Kienenberger@asu.edu (R.L. Kienenberger), Greeley@asu.edu (R. Greeley).
[1] Tel.: +1 480 965 7029

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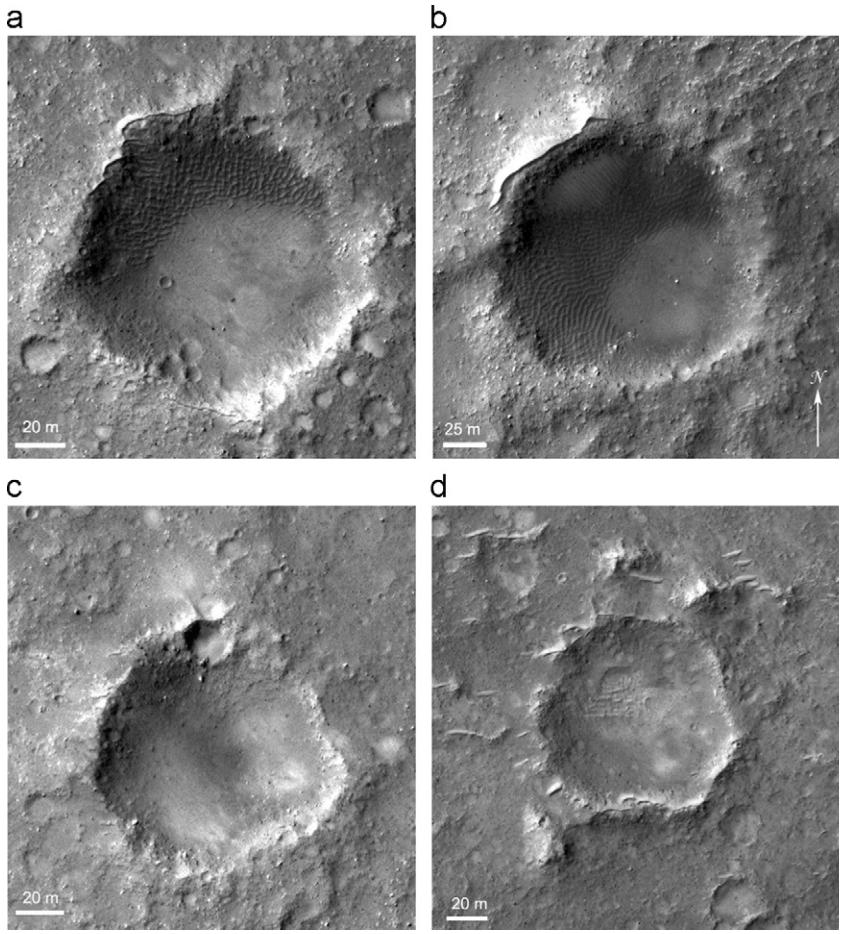

Fig. 1. Mars Reconnaissance Orbiter High Resolution Imaging Science Experiment (HiRISE) image (PSP_001513_1655) showing (a) Crater 1 and (b) Crater 3 with asymmetric windblown deposits and (c) Crater 32 and (d) Crater 38 with no asymmetric windblown deposits, all near the Spirit landing site in Gusev Crater, Mars.

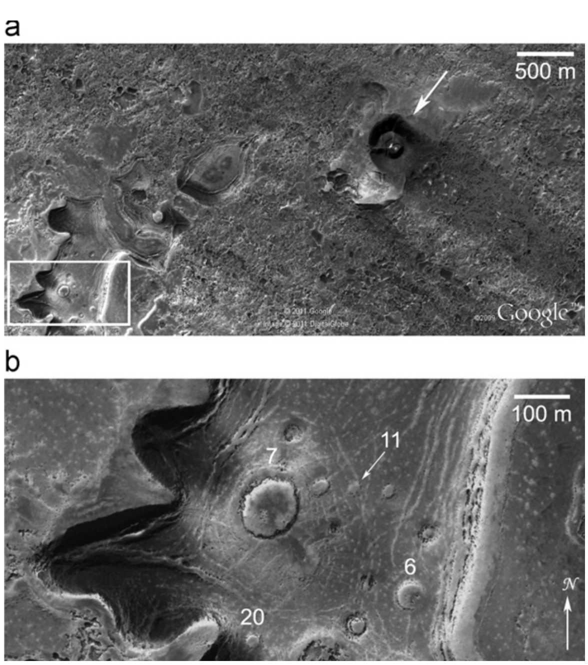

Fig. 2. (a) Google Earth image of part of Amboy lava field, Mojave Desert, California, with cinder cone (arrow) and wind streak and enlargement (b) with endogenic craters 6, 7, 11, and 20 on a lava pressure plateau; 20 craters were initially identified for study but this research focused on the four craters noted. Satellite image source: 34°32′07″N and 115°48′05″W. Google Earth. February 17, 2003. November 23, 2010.

Fig. 2b were the main focus of the study because they have similar morphometries to the craters in Gusev (Table 1). The rim-to-rim diameters of the craters were obtained following the method of De Hon (1981) by tracing the outline of the rim from an aerial photograph and overlaying perfect circles of different sizes to obtain a best-fit diameter. The rim-to-floor depths were collected in the field using a laser level placed on the crater rim and a measuring rod located in the deepest part of the crater floor. In addition, each crater was mapped in detail (Figs. 3–6) to illustrate prominent features such as active sand deposits, lag deposits, transitional zones (from sandy to lag surfaces), and desert pavement. Bushes and large rock piles (~0.5 m high), which could interfere with wind patterns in the crater, were also mapped.

Topographic profiles for Craters 6 and 7 (Figs. 3–4) were made with a laser level, measuring rod, and measuring tape. The profiles were extended past the crater rims to determine the slope of the surrounding terrain. An azimuth of 155° was chosen for the profile of Crater 7 because this value represents the observed wind direction during the site visit in February 2009. However, an azimuth of 130° was used for Crater 6 to correspond to the inferred predominant wind direction in the field area, as suggested by the wind streak in the lee of the cinder cone (Fig. 2a). Bushes and large rock piles were avoided to ensure that the topographic data were indicative of the crater floor.

Real-time wind patterns were determined for Crater 6 in October and December 2009 and for Crater 7 in April 2010 using metal rods and suspended weighted styrofoam balls (Fig. 7) placed in the ground at ~35 locations in and around each crater.