ORIENTATION OF AEOLIAN FLUTES AT THE MARS PATHFINDER LANDING SITE.

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Images of rock faces on the surface of Mars taken by the Sojourner rover front cameras and the Imager for Mars Pathfinder (IMP) show evidence for aeolian abrasion. About half of the rocks exhibit linear depressions analogous to flutes, grooves, and rilles (all of which are hereafter referred to simply as “flutes”), features that result from aeolian scour in the terrestrial environment (Fig. 1) [1-4]. Some rocks have up to dozens of flutes that record the direction of the winds that formed them. We have measured the orientations of these features and found that inferred wind directions are on average different than those predicted from wind tails at the site, wind streaks seen in orbiter images, and the Mars General Circulation Model.

Flutes were identified and classified using both IMP and Sojourner images. To measure orientation, stereo rover images were used to compute the positions of flute endpoints in the rover coordinate frame. Rover position was determined using Sojourner engineering data and analysis of rover traverse movies taken by IMP. Using this information, flute trend and plunge in the lander local level coordinate frame was computed. The greatest source of error was accurately determining rover position, especially where no supporting IMP images were available. Another potential error was improper measurement of flute endpoints. Errors of 10-20° were possible, although in most cases the accuracy was much better.

The trend and plunge of all measured flutes was plotted on a stereonet (Fig. 2). The distribution of points exhibit two characteristics that indicate the flutes formed by aeolian abrasion: 1) There is a general clustering between azimuths of ~230-300°, indicating a directionally-controlled process and, 2) Points cluster radially at plunges of ~10-20°, consistent with terrestrial field and laboratory evidence that most pitting and chopping of rock surfaces occurs at angles inclined to the wind [2,4,5,6]. Sojourner viewed fluted rocks of various sizes over an azimuth range of more than 180° (represented by the short lines extending outward from the stereonet edge). Therefore, the relatively few flutes with ~N-S trends as opposed to ~E-W is real and not an artifact of sampling. Also shown are the minimum (179°), maximum (251°), and average (217°) wind tail azimuths found at the site [7,8], the trend of wind streaks observed from orbital images (213°) [7,8], and the direction of strongest winds predicted by the general circulation model (209°) [7-9]. These three wind markers are tightly clustered, indicating winds blowing from the northeast to the southwest. In contrast, flute orientations indicate winds blowing from east to west.

Many of the rocks at the Pathfinder landing site were presumably deposited on the order of 2 billion years ago in the Ares/Tiu floods [10]. These rocks serve as paleowind indicators since that time. Therefore, the differences between flute orientations and other wind markers is strong evidence for changes in atmospheric circulation over the last two billion years or so. Two scenarios are considered: 1) The latest Martian storm that produced the wind tails at the Pathfinder site and the wind streaks in the region may have been unusual in that winds blew more from the northeast than is typical for this area or, 2) The east to west winds indicated by the flutes may have occurred over a short period(s) of time but been particularly strong. The small degree of scatter in flute orientations may reflect redistribution of some of the rocks by impact processes or fluvial events. Sand-size grains are the most likely cause of the erosion seen here, although dust or ice grains [3,11] may also be a contributing factor over a long time scale.

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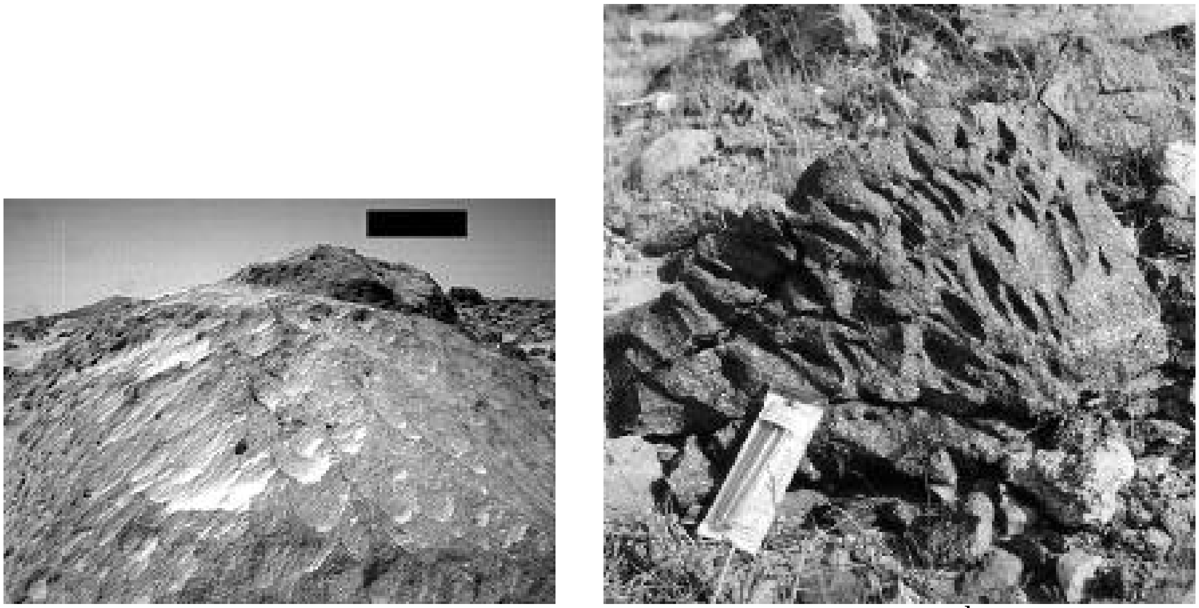

a b

Fig. 1: Comparison of fluted rocks seen on Mars at the Pathfinder landing site and on Earth. a) The rock “Moe” as seen by the Sojourner rover’s left front camera. The black bar corresponds to a length of 10 cm near the back edge of the rock. b) Fluted diorite at Garnet Hill, CA (photograph by R. Greeley)

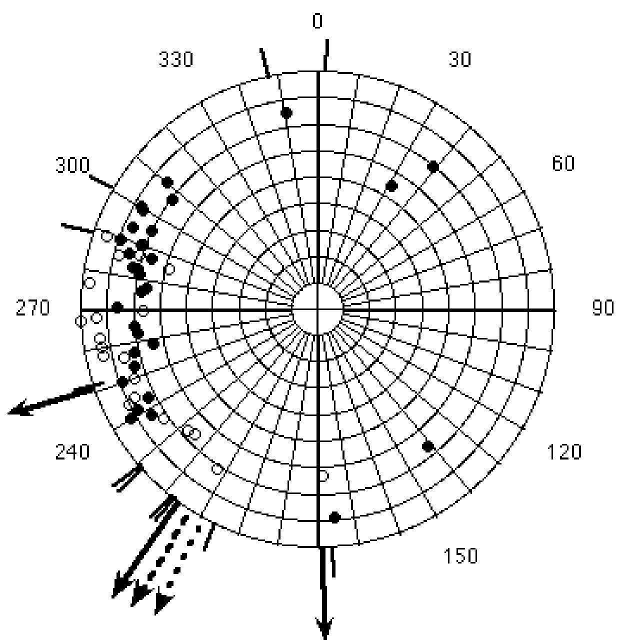

Fig. 2. Stereonet showing trends and plunges of fluted rocks at the Pathfinder landing site. Open circles are for flutes on the rock “Moe.” Solid circles represent flutes on all other rocks. Solid lines projecting outward from the edge of the stereonet show rover orientations when images used to derive flute orientations were taken. Solid arrows are minimum, average, and maximum values of local wind tail directions [7,8]. Arrow with large dashes represents the average trend of wind streaks as seen in orbital images [7,8]. Arrow with small dashes is the predominant wind direction predicted by the general circulation model [7-9].