Interpretation of Wind Direction from Eolian Features: Herschel Crater, Mars

Benjamin D. Stanley[1], Christopher T. Adcock[2], Richard A. Marston[2]

[1] Department of Geology, Oberlin College, Oberlin, OH 44074. [2] Department of Geology, Oklahoma State University, Stillwater, OK 74078

INTRODUCTION

Problem Statement

Ground truth measurements of surface and near-surface wind direction have been acquired by the Viking and Pathfinder landers only for small areas of the surface of Mars so little is still known about the surface wind regimes on Mars.

Significance

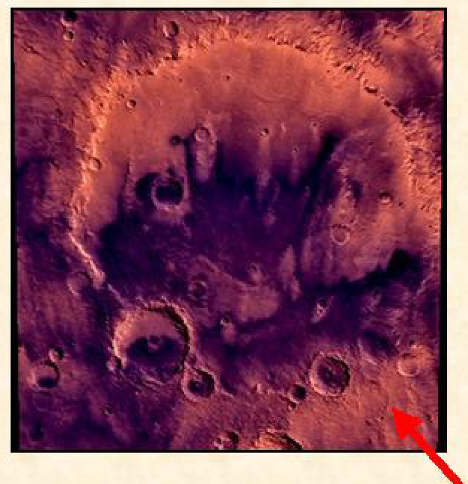
The surface mapping of wind directions on Mars will allow us to consider the relationship to existing global circulation models as well as contributing to the existing body of knowledge on Martian wind regimes. In the future, these data could be used by NASA to determine the best site for landing unmanned rovers and manned craft.

Purpose

The purpose of our project is to observe eolian landforms… sand dunes, yardangs and wind streaks… in Herschel Crater on Mars to develop a better understanding of the surface and near-surface wind conditions in the area.

Objectives

1. To identify eolian landforms in the study area.
2. To determine the dominant wind direction in Herschel Crater on Mars where eolian landforms can be identified.



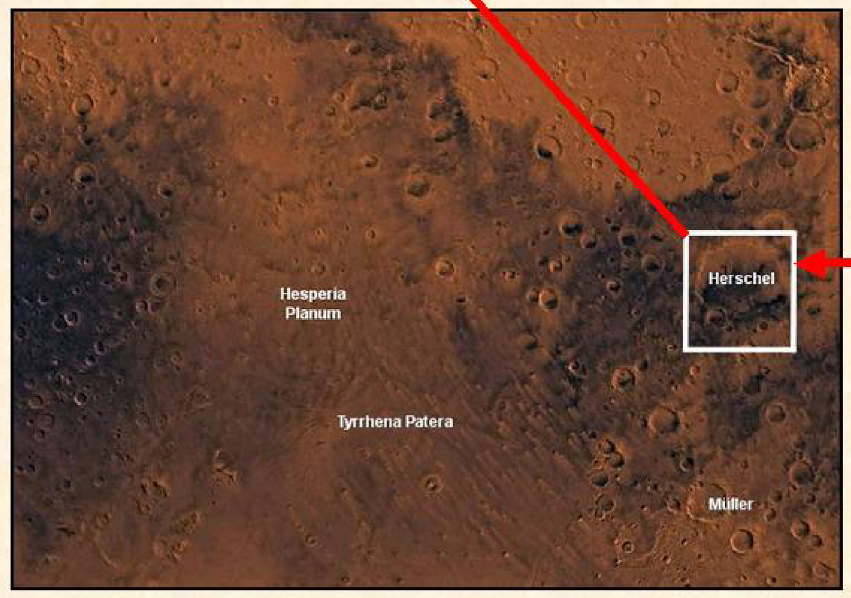
Study Area

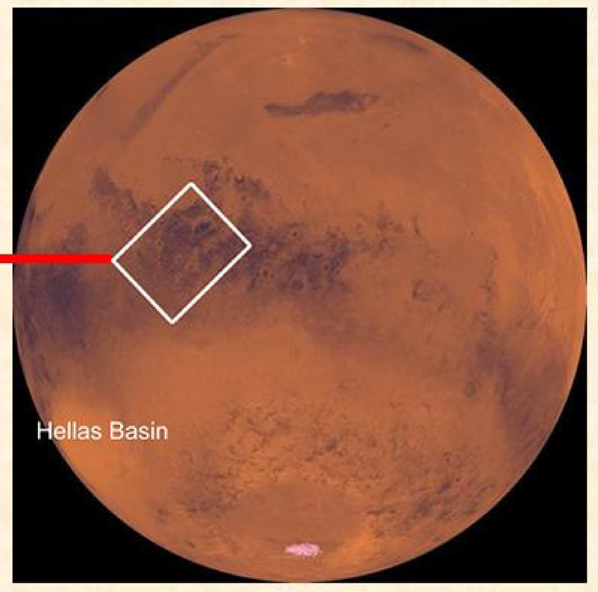
Herschel Crater (Fig. 1c) is a 300 km diameter crater in the southern highlands of Mars near Hellas Basin (Fig. 1a). The crater is approximately centered at 228° W long. and 15° S lat. in the area called Mare Tyrrhenum (Fig. 1b).

Fig. 1a (below right): Viking image PIA00196 showing Mars centered at 210 ° W long. and 30 ° S lat., modified slightly (NASA, 2003b)

Fig. 1b (below left): Viking image PIA00182 showing Mare Tyrrhenum, modified slightly (NASA, 2003b)

Fig. 1c (left): A NASA PDS Merged Color image of Herschel Crater (NASA, 2003a)





Previous Work

A number of previous authors have written on the subject of eolian features on Mars:

- Fenton's Ph. D. thesis (2003) has proved to be the most relevant and helpful to our research, as she investigated similar eolian features in Proctor crater, a 150 km crater also in the southern hemisphere.
- Thomas et al (1999) used Mars Global Surveyor (MGS) high-resolution pictures to take the first detailed look at the brighter variety of craters on Mars and concluded that the bright material is soft and possibly some form of sulphate.
- Edgett and Blumberg (1994) studied the relative lack of longitudinal and star dunes on Mars, concluded their occurrence on Mars indicates a unidirectional wind regime with rare pockets of topographically caused bi- or multidirectional wind regimes.

EOLIAN FEATURES

Overview

Eolian landforms exist on both Earth and Mars and have been studied extensively as indicators of wind direction on Earth. (Bagnold, 1941)
The three main types of eolian landforms are: sand dunes, yardangs and wind streaks.

Sand dunes are mounds of sand that are moved and created by the action of the wind. They usually have a steep slip face on the downwind side of the dune. There are several types of sand dunes including:

barchan dunes: normally form in areas with lower sand supply and unidirectional wind regimes (Fig. 2)

Fig. 2: A ground level image of barchan dunes on Earth

longitudinal dunes: which normally form in areas with medium sand supply and bidirectional or strong unidirectional wind regimes (Fig. 4)

star dunes: which normally form in areas with higher sand supply and multidirectional wind regimes (Fig. 6)

Yardangs are elongate ridges of solid material aligned parallel to the direction of prevailing wind with rounded windward faces that taper downwind (Fig. 3)

Fig. 3: A ground level image of yardangs on Earth

Fig. 4: A Landsat image of Erg Chech on Earth (Short and Blair, 1986)

Wind streaks are tear-shaped areas appearing on the downwind side of features with vertical extent. They can be light or dark depending on the subsurface color. They are the result of erosion and deposition (Fig. 5)

Fig. 5: A satellite image of wind streaks in the Aorounga region of Chad (Pengelly, 2003)

Fig. 6: An aerial photo of star dunes in the Namib Desert on Earth (Short and Blair, 1986)

METHODS

Procedures

1. Comparing terrestrial remote sensing of known eolian features such as sand dunes, yardangs, and wind streaks with the geomorphology of remotely sensed surface features on Mars will allow us to determine whether they are eolian in origin.
   - ~ We will visually interpret all of remote sensing images we have collected of the Martian surface looking for features that are similar to identified eolian features in terrestrial remote sensing images.
2. To determine wind direction we draw on previous studies to determine the wind direction from specific types of known eolian features in the area.
   - ~ Using the known eolian features in the area we will then determine the predominant wind direction an image and plot it on a larger map of Herschel crater to create a map of wind directions.

Data Acquisition

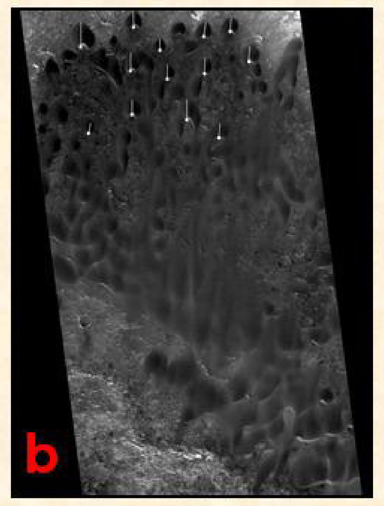
We are using images from the Malin Space Science Systems Mars Global Surveyor (MGS) Mars Orbiter Camera (MOC) Gallery and the NASA Planetary Photojournal. The Planetary Photojournal contains images from the MGS MOC and Mars Odyssey Thermal Emission Imaging System (THEMIS). These galleries are available to the public on the internet at http://www.msss.com/moc_gallery/ and http://photojournal.jpl.nasa.gov/target/Mars respectively.

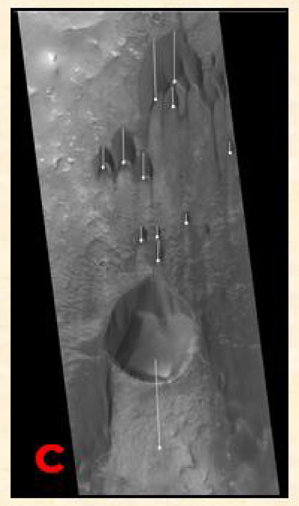
PRELIMINARY RESULTS

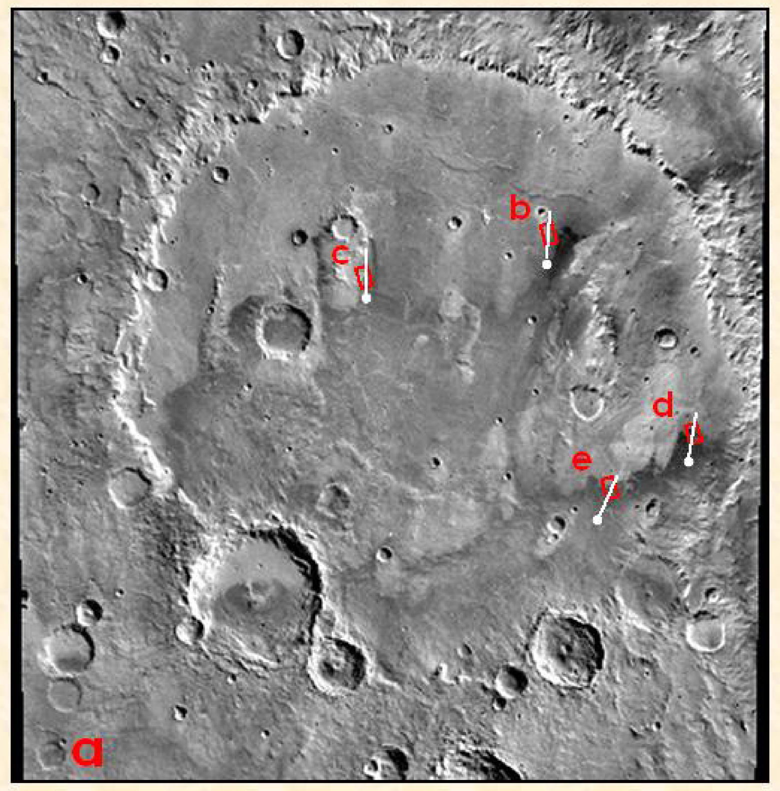
1. We have identified eolian landforms in over 70 Martian images, 25 of which are from the Herschel Crater region. Our Herschel dataset contains mainly dune forms with a few large, bright wind streaks.
2. We have analyzed eolian features in four images (Fig. 7b-e) and determined the predominant wind direction in them. In order to increase accuracy, multiple features were analyzed in each image and their directions averaged. We used the National Institute of Health's ImageJ program to determine the wind angle.

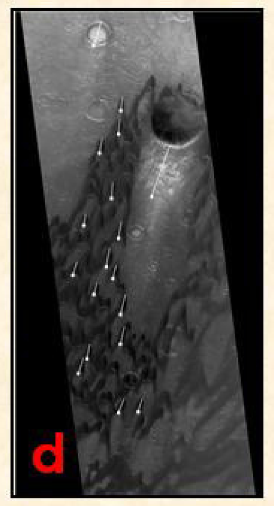
The results of our work indicate a predominant wind direction of south (180°) with possible wind deflection to the south-southwest (~200°) by the southeastern rim of Herschel Crater (Fig. 7a).

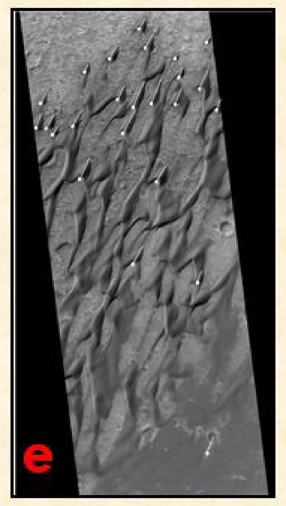
Fig. 7a: A NASA PDS MDIM1 image of Herschel Crater (NASA, 2003a).
Fig. 7b: MOC image E11-01859, wind direction 182°.
Fig. 7c: MOC image M08-6611, wind direction 179°.
Fig. 7d: MOC image E10-0272, wind direction 193°.
Fig. 7e: MOC image E02-0602, wind direction 206°.











FUTURE WORK

- Determine of the origin area of the two different kinds of sand in Herschel Crater.
- Investigate the dynamics of preferential sand deposition in a crater.
- Compilation of time lapse of dune movement in Herschel Crater to determine if the area is actively transporting sand.
- Determine the maximum and/or average wind intensity in Herschel crater.
- Expansion of the study area to Mare Tyrrhenum and eventually all of Mars.

REFERENCES

Bagnold, R.A., 1941. The Physics of Blown Sand and Desert Dunes. Methuen and Co. LTD., London, 265 pp.
Edgett, K.S. and Blumberg, D.G., 1994. Star and Linear Dunes on Mars. Icarus, 112(2): 448-64.
Fenton, L.K., 2003. Aeolian Processes on Mars: Atmospheric Modeling and GIS Analysis. Ph. D. Thesis, California Institute of Technology, Pasadena, California, 229 pp.
NASA, 2003a. PDS Map-A-Planet. http://pdsmaps.wr.usgs.gov/maps.html.
NASA, 2003b. Planetary Photojournal: Mars. http://photojournal.jpl.nasa.gov/target/Mars.
Pengelly, L., 2003. Space Photos of Earth. http://www.portaec.net/earth/table_of_contents.html.
Short, N.M. and Robert W. Blair, J. (Editors), 1986. Geomorphology from space: A global overview of regional landforms. NASA Scientific and Technical Information Branch, Washington, D. C., 717 pp.
Thomas, P.C. et al., 1999. Bright dunes on Mars. Nature, 397(6720): 592-4.

ACKNOWLEDGEMENTS

The authors acknowledge the use of several Mars Orbiter Camera images processed by Malin Space Science Systems that are available at http://www.msss.com/moc_gallery/." We would also like to thank the National Science Foundation's Research Experience for Undergraduates program and the Arkansas-Oklahoma Center for Space and Planetary Sciences for funding and providing the opportunity for this research.