USING OVERLAPPING MOC IMAGES TO SEARCH FOR DUNE MOVEMENT AND TO MEASURE DUNE HEIGHTS.

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Introduction: The first observations of dunes on Mars were made during the Mariner 9 mission, which revealed dunes within craters in the southern highlands [1-4]. Dunes associated with the north polar laminated terrain were speculated from Mariner 9 images and confirmed by Viking Orbiter images, and more dunes were observed across the planet in the higher resolution Viking images [5, 6].

The Mars Orbiter Camera (MOC) on MGS has now provided thousands of high-resolution (~5 m/pixel) Narrow Angle images that show the ubiquitous presence of dunes on Mars [7,8] (*e.g.* Fig. 1). These new images give the opportunity to investigate whether Mars dunes have moved recently [8-10]. Zimbelman [10] compared an early MOC image to a high-resolution Viking image of the Acheron Fossae region and concluded that dunes thee moved less than 8 m during the ~21 Earth years spanned by the two images.

As part of the MGS Guest Investigator Program, four areas containing dunes imaged earlier in the mission were scheduled for re-targeting. The target areas were dunes within Proctor and Rabe craters, Chasma Boreale, and an unnamed crater at ~4N, 5.7W. Re-imaging of the areas took place ~2 Earth years after acquisition of each original image. This study used the overlapping images to search for dune movement and took advantage of stereo imaging over Proctor and Rabe craters to measure dune heights. Also, a newly released THEMIS image shows a possible cinder cone within Proctor as the source of some of the crater fill material and possibly some of the dune material.

Image Processing: The ISIS software produced by the USGS was used to radiometrically correct and geometrically project the PDS format MOC images. Because the spacecraft position information is not sufficient to match the overlapping images at the scale of a few meters, further processing of the images was necessary to take a detailed look at whether any dune movement occurred. The MOC images were separated into smaller subsets where distinct dunes and features such as boulders could be used as tie-points. Subsets with adequate tie-points were matched together with more accuracy than was possible using ISIS alone.

Search for Dune Movement: Unfortunately, several factors prevented ideal comparison of all four image pairs. The overlapping portion of the unnamed crater images did not contain dunes. Also, we were not

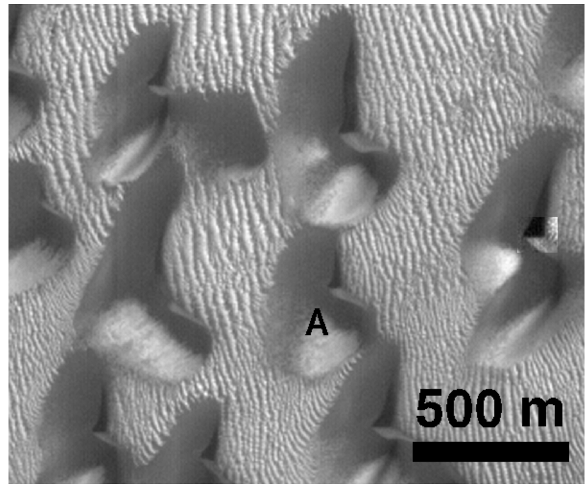

Fig. 1. Portion of MOC image E0301039 showing barchan dunes in the Proctor dune field. Dune 'A' is 30 m tall. North is to the top. (*NASA/JPL/MSSS*)

able to project the initial image of the dunes in Chasma Boreale, and after consulting with the USGS, we left analysis of that area to a later study. Image editing software was therefore used to trace dune brinks and outlines in the overlapping images of Proctor and Rabe craters. The traces were then compared to test for movement between the two images. Because the later images were acquired during the Extended mission, it was necessary to consider parallax caused by the off-nadir viewing of those images.

No movement of dune brinks was detected in the overlapping images of Proctor and Rabe craters where sufficient tie points existed for good image registration. It was determined that a dune must move at least 2-3 times the pixel width in order for the movement to be detected. The images used in this study were projected to 4.5 m/pixel, so dune movement of ~10-15 m would be necessary for detection. Therefore, either the dunes are not active or brink movement was less than 5-7 m per Earth year.

Measurement of Dune Heights: Because the second images over Proctor and Rabe were off-nadir, the stereo geometry allowed for geometric measurement of dune heights. In both cases, the first and second images were separated by ~20°. Common points such as dune brinks, boundaries, boulders, and outcrops were selected, and distances between points on each image were used together with the exact geometries to construct profiles across the dunes.

Figure 2 shows an example profile across two dunes and demonstrates the importance of the local topography. Although there are variations in heights among the dunes, the barchans in the northern part of the Proctor dune field have heights of 30-40 m. Dune heights increase (and morphologies change) moving southward into the dune field. The larger dunes are 50-100 m tall. In Rabe, smaller dunes are ~50 m and larger dunes are ~80 m tall.

There are likely larger dunes within Proctor and Rabe, but this analysis was limited to dunes within the areas of overlap where features such as boulders also existed. Fenton [11] used a MOLA track to measure other dune heights in Proctor at 50-200 m. The MOLA track ran sub-parallel to the crests of the larger dunes and could not resolve the smaller dunes, but this demonstrates how stereo measurements and MOLA measurements are complementary techniques for independently measuring dune heights on Mars.

Fig. 2. Sample profile over two dunes in Proctor.

Other Observations: In the images considered here, there is a paucity of dust devil tracks on the dunes within Proctor crater. This was also noted by Fenton [11], who concluded that the dark slope streaks are slope adjustments of sand. However, most of the dark slope streaks look very similar to other streaks that have been described as dust avalanches [12]. The dunes in Rabe crater have slope streaks, but they also have many dust devil tracks. The dust devil tracks reveal the presence of a thin layer of dust, but there is no obvious evidence that dust devil tracks survived from the first image to the second. This suggests that either the older dust devil tracks are entirely covered over by new dust within a martian year, or the dust in which they exist is put into suspension by moving sand at some point between the image times. If the dust is removed, there must have been more dust deposition and dust devil activity prior to acquisition of the second image. At the least, it appears there may be a process where dust accumulates, is marked by dust devil activity, and is later removed by active sand. Within this process there may be a way to have dust streaks on steep slopes of dunes while having other portions of the dunes be dust-free. The new THEMIS images should help answer some of the inconsistencies associated with dust coverage on dunes.

Fenton[11] concluded that the dune material and some floor material in Proctor is basaltic. Figure 3 shows THEMIS coverage of a volcanic edifice on the floor of Proctor that is likely the source of some crater fill material and possibly some dune material. Shadow length was used to measure the cone height at ~500 m.

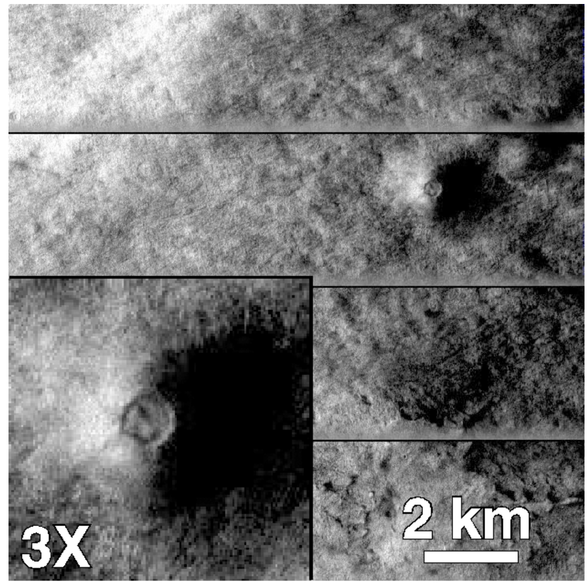

Fig. 3. THEMIS visible image V01510003 of a cinder cone on the floor of Proctor crater. Inset is a close-up of the cone. Illumination is from the left. North is to the top. (*NASA/JPL/ASU*)

Conclusions: Re-targeting of four areas led to a detailed study of overlapping images of dunes in Proctor and Rabe craters. No dune movement was observed, but the dune heights were measured. Smaller barchan dunes are 30-40 m tall, and larger dunes are up to 100 m tall. There may be yearly cycles of dust deposition, dust devil activity, sand activity removing the dust, then continued dust deposition. Finally, a possible cinder cone has been identified on the floor of Proctor crater. Its presence indicates that at least some of the crater fill material may be composed of volcanic material.

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