ARE MARTIAN DUNES MIGRATING? A PLANET-WIDE SEARCH FOR DUNE MOVEMENT. K.K. Williams, Center for Earth and Planetary Studies, Smithsonian Institution, MRC 315, Washington, DC 20013-7012; williamskk@si.edu.

Introduction: The question of whether dunes on Mars are migrating in the current wind regime is one that continues to go unanswered. The discovery of moving dunes *or* the lack of movement both have implications for understanding the current martian wind regime and how it may have changed since the dunes were originally formed. The vast majority of dunes do not possess impact crater scars, suggesting that dunes are relatively young or have enough activity to erase evidence of craters.

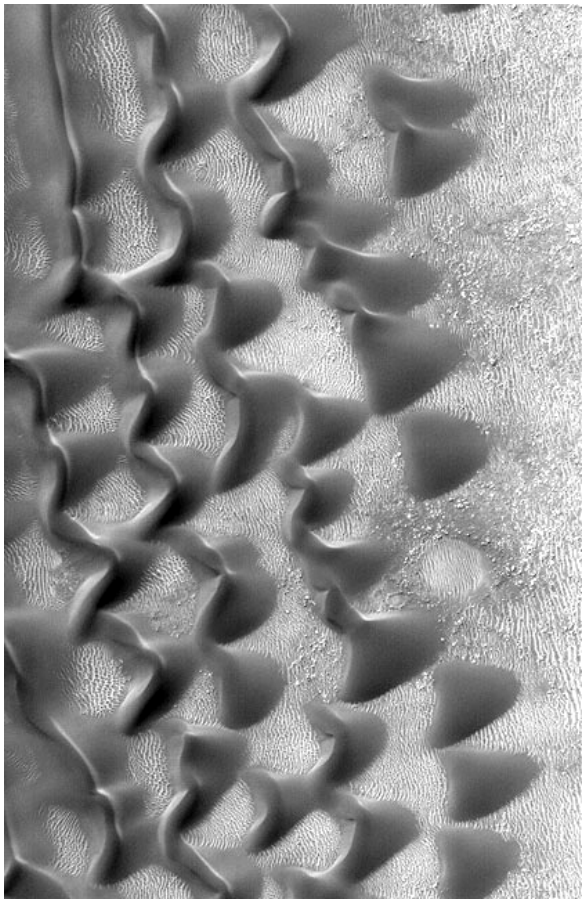

Fig. 1. Dark dunes on the eastern edge of large dune field in Proctor crater. Smaller, lighter features between dunes are ripples. This area is discussed in [12]. Image is 3 km across. [*Credit*: MGS MOC release No. MOC2-274, 21 Jan. 2001]

The history of studying martian dunes goes back to the Mariner missions. The first dunes seen on Mars were intra-crater dunes in the southern highlands observed in Mariner 9 images [1-4]. Mariner 9 images also led to the speculation of dunes associated with the north polar laminated terrain, and Viking Orbiter images confirmed the existence of those dunes. The higher resolution of the Viking Orbiter images also led to the discovery of other dunes elsewhere on Mars [5,6]. A further improvement in resolution has been provided by the Mars Orbiter Camera (MOC) onboard Mars Global Surveyor.

Since it began transmitting images from Mars, MOC has returned thousands of high-resolution (1.5-12 m/pixel) Narrow Angle images of dunes across the planet [7,8]. Dune appearance varies drastically depending on various conditions that affect dune formation and modification [e.g., Fig. 1], and the wide range of morphologies can be seen at http://www.msss.com/mars_images/moc/themes/DUNES.html. MOC images have led to MGS-era investigations of whether martian dunes have moved recently [8-12].

An early MOC image was compare to a high-resolution Viking Orbiter image of the Acheron Fossae region [10], but no evidence for movement was observed. Based on image resolutions, Zimbelman concluded that any dune movement there was less than 8 m in the ~21 Earth years between the two images.

We previously reported on a focused study of four areas that were targeted as part of the MGS Guest Investigator Program [11]. Images from that study showed frost and avalanche changes on the dunes, but no migration was detected.

Malin Space Science Systems, Inc. has also been searching for dune changes, and many changes related to frosting/defrosting and avalanching sand are discussed at the website given above. Figure 2 shows one example of dune activity revealed by MOC.

Beyond these changes, the question of whether the dunes are currently migrating remains. Almost all previous and current studies have concluded that any amount of dune brink migration must be below the image resolution, but Fenton [12] has shown what may be evidence for movement of sand by saltation.

Following the studies mentioned above, the work presented here has involved a planet-wide search for dune migration using MOC images. THEMIS visible images were also considered, but their coarser resolution would require a greater amount of movement so those images were used as context for MOC images. Viking images were also considered, but their resolutions prevented their use, even given the longer time since the Viking mission.

Fig. 2. Sand avalanches on a dune in Kaiser crater. Avalanches and crisp dune brink suggests active sand. Image is 3 km across, illumination from the left. [*Credit*: MGS MOC release No. MOC2-410, 3 July. 2003]

Procedure: The method for searching for dune migration was applied to each Mars Chart (MC) because MOC images are arranged by MC on the Malin Space Science Systems, Inc. website (www.msss.com). In each area, MOC images covering dunes were identified by selecting full images of samples listed on the DUNES website on the previous page, areas of dunes discussed in the literature [e.g., 5,6,8,10], or dunes identified by surveying the region. For each image that contained dunes, other MOC data release maps were queried to determine whether an overlapping image existed. This was repeated for new MOC image releases.

For overlapping images that contained dunes, the ISIS software from the USGS was used to radiometrically correct and geometrically project the PDS format MOC images. For many images, no movement was evident, but that determination could not always be made from the ISIS-processed images. In those cases, further processing of the images was necessary to take a detailed look at whether any dune movement occurred, because spacecraft position data are not sufficient to match overlapping images at the scale of a few meters. Features such as boulders were used as tie-points to match the images more closely and to allow a closer search for movement.

When considering images from the Extended missions, the viewing angle of the image also had to be taken into account. During the nominal mission, images were acquired in a nadir-pointing configuration, but later images were acquired off-nadir. Whereas this geometry enables stereo measurements [e.g. 11], the resulting parallax complicates the search for meter-scale movements.

Discussion and Conclusions: Although MOC images continue to be released, this study has taken an in-depth look at images released through Fall 2005 covering dunes all over the planet. As other studies have found, many martian dunes are active – they have crisp brinks, lack impact crater scars, and exhibit avalanches of sand. In fact, many instances of this activity in the form of sand avalanches and dark streaks have been observed by repeat imaging by MOC during the MGS mission. Dunes in Proctor crater may also show evidence of sand movement by saltation [12].

This study has not, however, found convincing evidence for dune migration in the current wind regime. One possibility is that wind velocity and/or atmospheric density has changed sufficiently such that sands can be moved around slightly but not enough to result in dune migration. An alternative possibility is that some dunes are migrating, but at a rate below what could be detected during the MGS mission thus far.

With the arrival of MRO at Mars this year, high-interest targets will be submitted for imaging by the HiRISE instrument. The improved resolution of HiRISE might identify small amounts of dune migration that has so far gone undetected.

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