DUNE-YARDANG INTERACTION IN BECQUEREL CRATER, MARS. A.C. Urso and M. Chojnacki.

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Introduction: Wind-driven bedform activity is occurring on Mars today. Examples of this activity in the form of dune and ripple migration have been observed at sites in the Arabia Terra-Meridiani region. High sediment fluxes from 1 to 20 m³ m⁻¹ yr⁻¹ have been recorded for intracrat dune fields located in Firsoff, Xainza, Endeavour, and other relatively topographically simple regional craters [1]. While reports of dune activity continue to grow, little is known about the interaction between dunes and the topography surrounding them.

Many dune fields on Mars are trapped in topographically low-lying areas where interior layered deposits (ILDs) are located. Observations of these sedimentary deposits in Ophir Chasma and Gale crater indicate similarities in the morphology and erodability of ILDs across Mars [2, 3]. However, the relationship between dune sediment flux and ILD erosion is not well understood. For example, a study of Gale crater abrasion textures formed on rocks using in situ data from the Curiosity rover found that orientations of were inconsistent with the morphology of dunes and their migration direction [4].

Layered deposits are frequently found within large impact craters in Arabia Terra. One example of this is the thinly bedded, high albedo deposit in Becquerel crater (Fig. 1). Stairs weathering patterns [5] and yardangs can be seen along the edges of the deposit. Dunes are located along both the north and south edges of the ILD and the plains to the west. Here we investigate how dune sediment fluxes in Becquerel crater are influenced by topography, which is in turn affected by aeolian abrasion and erosion.

Methods: Dune migration rates were measured in ArcMap using repeat images (25 cm/pix) from the High Resolution Imaging Science Experiment (HiRISE) [6]. Sediment fluxes were calculated based primarily on dune heights obtained from HiRISE Digital Terrain Models (DTMs) constructed from stereo pairs at 1 m post spacing [7]. Additionally, images were orthorectified to the DTM aiding change detection. Sediment fluxes were calculated as the product of height and displacement per year [8] and abrasion rates were estimated using the equations and assumptions described in Bridges et al. [9].

Results: Dune migration measurements were made at four sites around the Becquerel ILD representing locations of varying topographic influence (Fig. 1). Dunes are primarily barchans with slip faces oriented southward, implying southward migration.

Average migration rates, heights, and sediment fluxes for each of the four sites are shown in Table 1. The greatest migration rates are observed at Site #1 with corresponding sediment fluxes of up to 2.9 m³ m⁻¹ yr⁻¹ (all times are given in Earth years). The largest dunes are found at Site #2 and #3 reaching heights of up to 20 m and with moderate sediment fluxes of 1.6-1.7 m³ m⁻¹ yr⁻¹. Site #4 consists of significantly smaller dunes with sediment fluxes as low as 0.5 m³ m⁻¹ yr⁻¹.

<table>
<thead>
<tr>
<th>Dune Site</th>
<th>Rate (m yr⁻¹)</th>
<th>Height (m)</th>
<th>Sand Flux (m³ m⁻¹ yr⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.19</td>
<td>9.5</td>
<td>1.8</td>
</tr>
<tr>
<td>2</td>
<td>0.14</td>
<td>12.2</td>
<td>1.7</td>
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<tr>
<td>3</td>
<td>0.16</td>
<td>10.5</td>
<td>1.6</td>
</tr>
<tr>
<td>4</td>
<td>0.16</td>
<td>7.4</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Yardangs tend to be less abundant towards the east, closer to the deposit summit (>700 m in height). Little to no basaltic sediment is detected in CTX or HiRISE on the deposit at heights >300 m. The height of the deposit at the western sites ranges between 100-300 m with abundant yardang corridors (Fig. 2) reaching depths of up to 70 m. Basaltic sediment can be seen lining yardang corridors and moving southward based on observations of ripple migration (i.e., inset; Fig. 2). Average abrasion rates for all dune sites range from a minimum (horizontal surfaces) of 0.2 μm yr⁻¹ to a maximum (vertical surfaces) of 12 μm yr⁻¹ assuming both the saltating particle and target material are basaltic.

Figure 1. Sand dune site study locations within Becquerel crater shown on a CTX mosaic with HiRISE overlaid. East (D18_034419_2014, ESP_042173_2015) and West (B19_017211_2015, PSP_001546_2015). Note that sites #1-3 are sub-regions of a single HiRISE monitoring sequence. Upper Left: MOLA elevation (m) from A to A’.

Table 1. Average values for migrating dune sites.
Discussion: Migration rates appear to be greatly affected by the ILD in Becquerel crater. A comparison of dunes on the plains at Site #1, impeded by ILD topography, to Site #2, adjacent to the deposit, show a migration rate decrease of up to 25%. This is consistent with the low migration rates of dunes approaching the ILD at Site #4 in the east. The large dunes at Site #2 may be the result of sediment accumulation as dunes approaching the IDL, slow down and funnel into yardangs. Variations in sediment flux of individual dunes at Site #3 reflect the effects of topographic sheltering (Fig. 3). Sediment fluxes increase as dunes travel south, away from the deposit edge. An increase in flux is also seen from east to west as the height of the deposit decreases. The ILD decreases in height from east to west (Fig. 1) and appears more eroded on the western limb near Sites #1-3. The orientation of barchan dunes lining the deposit are consistent with the orientation of yardangs in the region. Becquerel crater is dated to the late Noachian period [10] placing the deposit formation in the Hesperian or Early Amazonian period [5]. The paucity of impact craters on the deposit indicates that the surface of the deposit is relatively young [2]. Additionally, the rim of Becquerel crater shows fewer signs of abrasion than the central deposit [11]. Minimal mass wasting can be seen along the edges of the deposit and little debris is found in yardang corridors. It is possible that some sediment is incorporated by migrating dunes. However, the lack of erosional debris and relatively young surface suggest the deposit is fairly friable. Assuming an abrasion rate of 12 µm yr⁻¹ and a yardang depth of 70 m, the calculated yardang formation time is 5.8 million years. These results are consistent with the erosion of an ILD in Ophir Chasma, which was estimated to have abrasion rates of 5-28 µm yr⁻¹ removing 500 m in 18-101 million years [2]. Poorly lithified sediment such as dust, clay and sulfate has been proposed as the primary composition of most ILDs in Arabia Terra [5]. The abrasion rates calculated above for basaltic sediment are therefore underestimated of basalt targeting a more friable material, thus erosion is likely more rapid. Also, rates will increase as dune activity heightens during high obliquity cycles and a thicker atmosphere [12]. Thus we chose to use the maximum abrasion rate calculated.

Figure 2. Deep yardang corridors located at Site #2 (ESP_042173_2015). Inset shows active ripples, which are detected to migrate southward.

Figure 3. Dune sediment fluxes at Site #3 (green circles in units of m³ m⁻² yr⁻¹). HiRISE (ESP_042173_2015) with DTM elevation overlaid.

Summary: The varying migration rates, morphologies, and sediment fluxes of different dune sites provide insight into interactions between dunes and topography. Migration rates and sediment fluxes decrease as dunes approach the ILD and begin to increase again downwind of the deposit. The effects of topographic sheltering also increase with the height of the deposit. Dunes in turn abrade more friable surfaces forming more pronounced erosional features, and affecting topography. The dune fields in Becquerel crater are example of sediment transport activity shaping Mars today.

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