CHARACTERIZING ANOMALOUS WIND ERODED TERRAIN ON MARS: THE OLYMPUS MACULAE.

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Introduction: The Olympus Maculae are a series of semicircular, generally low albedo features spanning approximately 1,400 km^2 within the aureole terrains of Olympus Mons, less than 200 km from the western flank of the volcano's escarpment (*Figure 1.*). These maculae exhibit elevated thermal inertia, little to no topographic relief, non-definitive spectral characteristics, and minimal surface dust in an otherwise dusty region. While their exact origin remains unclear, landforms surrounding the maculae record complex geologic processes.

This research sought to map the diverse aeolian geology that exists within the maculae region, including yardangs and layered materials with cross strata, to characterize the current and paleoenvironment and understand possible reasons for the maculae's existence. Since the Olympus Maculae have little surface dust compared to the surrounding region, they act as windows into the enigmatic Medusae Fossae Formation (MFF), prevalent in this region and superposed on the ridged aureole terrains. By understanding the Olympus Maculae and their formation, we provide insight into the MFF, a topic that has been debated for several decades [e.g., 1-3].

Landforms: To understand the maculae region as a whole, we looked at both the aeolian and non-aeolian landforms at a variety of scales using high resolution imagery and digital terrain models (DTMs) from the Context Camera (CTX) and High Resolution Imaging Science Experiment (HiRISE)

Yardangs. After the emplacement of the MFF, likely a pyroclastic ignimbrite [4, 5], prevailing winds preferentially eroded less resistant materials into "U-shaped" troughs surrounding elevated remnants of more resistant material. These wind eroded landforms, called yardangs, are observed throughout the entire maculae region, both interior and exterior to the maculae, and are 100s of meters long (*Figure 2a.*). Nearly 3000 yardangs were mapped and their orientations recorded to determine paleowind directions (*Figure 1)*. We found that the paleowinds responsible for these features had little directional variation with the most dominant winds blowing towards the northeast.

Cross Stratification. Within the low-dust maculae, meter-scale crossbedding is commonly seen in the MFF materials. These intersecting sets of concentric layers (*Figure 2b*), most evident within the troughs of yardangs, suggests that the crossbedding may record past aeolian transport. To test this hypothesis, we used the automaton ripple model of Rubin and Carder [6] to simulate wind, sediment, and erosional conditions that would generate crossbedding consistent with our observations. We found that the cross stratification most

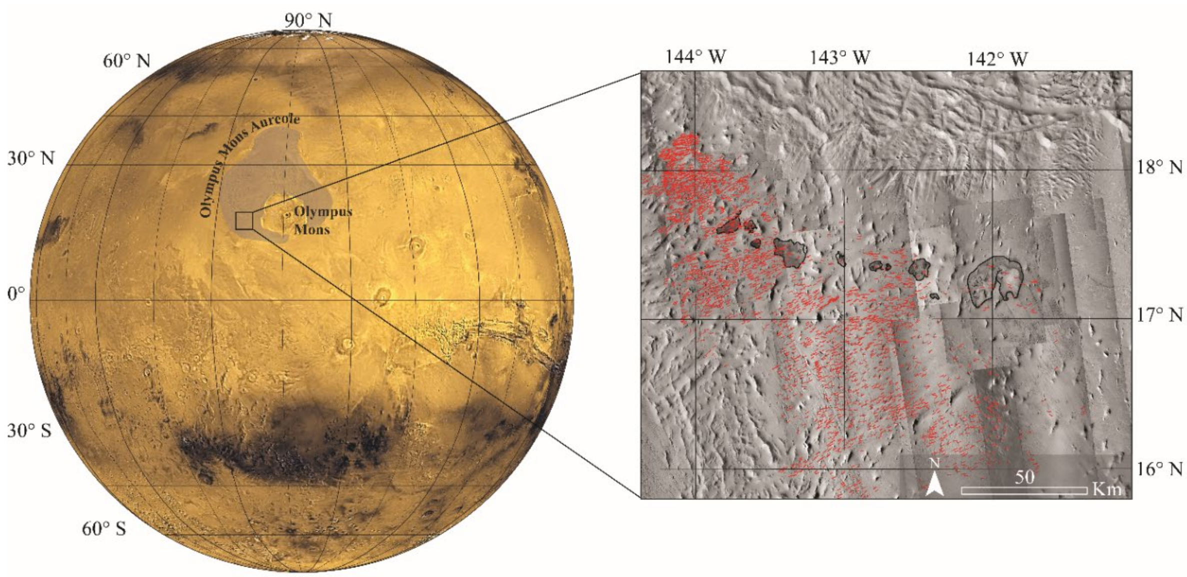

Figure 1: (Left). *Study site with respect to major geological features on Mars; Viking color basemap, (Right) CTX mosaic showing the 10 individual Olympus Maculae outlined in black and yardang paleo wind vectors indicated in red.*

closely resembles either climbing barchan dunes or festoon cross-lamination, where material is deposited into pre-existing troughs [7,8].

Transverse Aeolian Ridges (TARs). TARs are m-scale linear ridges and are found within the maculae region. The formation and migration of terrestrial TARs is controlled by winds perpendicular to the TAR crest. However, the process that forms TARs on Mars is poorly understood since Martian TARs have never been observed to move [9, 10]. Nevertheless, the TAR population in the Olympus Maculae region have unique orientations with respect to other landforms and may help with understanding the aeolian regime. Thus, we identified and mapped the orientations of a representative number of TAR crests using the random point method of [11]. We found that unlike the yardangs that formed via a regionally dominant wind direction, TARs appear be controlled by local topography with crests exhibiting radial orientations relative to larger-scale ridges of the underlying aureole terrain (*Figure 2c*).

Ripples. Dark patches of sand within the Olympus Maculae contain meter-scale ripples of various morphologies (*Figure 2d*). Dark sand ripples on Mars tend to indicate active movement, since otherwise they would become dust-covered and no longer appear dark [12]. However, inspection of repeat HiRISE images of ripple patches taken ~10 Earth years apart shows no observed ripple movement within the maculae. We hypothesize that the processes that may have indurated these ripples and inhibited dust deposition may also contribute to the formation of the maculae.

Lava Flows. Extensive Amazonian-aged lava flows originating from Olympus Mons extend to the eastern margin of the largest macula, with the dust-free macula superposed. We mapped the lobate flow to better understand how they may influence surface winds (Figure 2e). We are continuing to assess what influence the lava flows may have on the regional wind regime and will also use the flows to understand relative emplacement timing of the different landforms evident throughout the region.

Observed Changes: Mars experienced a global dust storm during the summer of 2018 (Mars year 34) that has provided a unique opportunity to study changes in dust deposition and removal in and around the maculae. Preliminary before and after analysis of HiRISE and CTX images reveals distinct changes in maculae brightness as well as border extent.

Conclusion: The Olympus Maculae and surrounding region has experienced multiple episodes of aeolian erosion and deposition, resulting in a diverse, complex, and changing landscape. The wide array of aeolian landforms and paleowind indicators is evidence

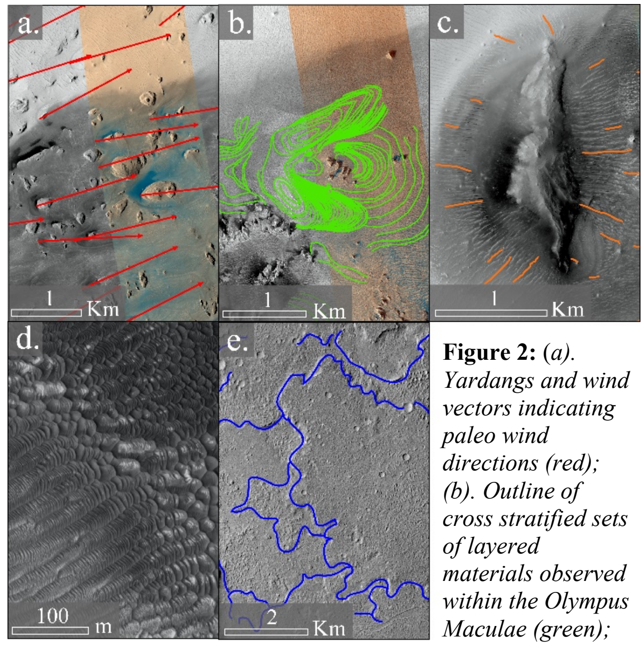

Figure 2: (*a*). *Yardangs and wind vectors indicating paleo wind directions (red); (b). Outline of cross stratified sets of layered materials observed within the Olympus Maculae (green); (c). Crests of TARs mapped radial to a ridge of aureole terrain embayed by MFF (orange); (d). Ripple morphologies observed in the Olympus Maculae; (e). Outlined margins of lava flows located NE of the maculae (blue).*

that the region offers unique insight into the material properties and dynamic evolution of the MFF and this poorly understood area of Mars. Future geomorphic and compositional research will seek to constrain the Olympus Maculae's formation and preservation, and to understand why these features remain dust-free.

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Acknowledgements: HiRISE images were provided by NASA/JPL/U. of Arizona. Support acknowledged from NASA grant 80NSSC17K0451 and the Internship/Research Participation Program at the JHU/APL, administered by the Oak Ridge Institute for Science and Education.