Erodibility of Microbial Mats and the Implications for Preservation of Microbially Induced Sedimentary Structures (MISS). K. R. Fisher[1,2], R. C. Ewing[2], and M. Sweeney[3], [1]NASA Johnson Space Center 2101 E NASA Pkwy, Houston TX 77058 (Kenton.r.fisher@nasa.gov), [2]Texas A&M University, College Station, TX 77843, [3]Univ. of South Dakota, Vermillion, SD 57069.

Introduction: Microbial induced sedimentary structures (MISS) are frequently discussed as potential astrobiological markers on Mars and other planetary bodies [1,2,3]. The presence of fossilized microbial mat structures from the Archaean demonstrates the ability of microbial mats to remain preserved for billions of years [3,4,5]. To be preserved microbial mats must survive erosion to be buried in their depositional environment [5]. Erosion of mats is typically due to water, but mats also exist in aeolian environments where wind is a dominant agent of erosion. The susceptibility of microbial mats to erosion due to aeolian and subaqueous sediment transport has important implications for understanding the distribution and preservation of potential biological materials on the surface of Mars, Titan, and the early Earth.

Here we measure the erodibility of microbial mats by water and wind using field experiments on hypersaline tidal flats at Padre Island, Texas. The sandy sedimentary environment of Padre Island is a promising astrobiological analogue for Mars and Titan.

Methods: The Padre Island study site features a variety of microbial mats and crusts within tidal flats and interdune areas. These areas experience a mix of aeolian and subaqueous erosion as they fluctuate between subaerial and flooded states. To determine the effect of water and wind shear on the mats, two erosion detection instruments were deployed during relevant field states (dry and flooded). We classified 5 different mats and crusts at Padre Island for this work. These included wave rippled mats, boundary mats, degraded mats, grey crusts, and salt crusts.

Figure 1: PI-SWERL on 'boundary mat' during erosion test.

Aeolian Erosion: Field measurements of aeolian erosion thresholds were performed with the Portable In Situ Wind Erosion Lab (PI-SWERL) [6]. The PI-SWERL housing is a cylinder 39 cm in internal diameter and utilizes an annular blade to generate a shear stress on the surface [6]. A suite of optical gate sensors are used to count entrained particles larger than 90 um [7]. When the number of grains counted by the sensors increases steadily above the level of noise in the sensor it is determined that erosion has initiated. The annular blade rpm can then be converted to a threshold friction velocity (u*) [6,7]. Tests began with the fan blade at 0 rpm and increased steadily to 6000 rpm over 5 minutes. Measurements were performed on a collection of different microbial mat and crust structures. Dune sand was also tested in the field, dried, and tested again in the lab to understand influence of humidity on the cohesion of sand and its threshold to movement.

Figure 2: Three different CSM erosion tests on same surface. In the tests where the surface failed a clear puncture in the mat can be seen. This test was performed in ~3 cm of water.

Subaqueous Erosion: Subaqueous erosion thresholds were measured utilizing a cohesive strength meter (CSM). The CSM was developed to measure critical erosion thresholds for intertidal flats and other subaqueous and fluvial surfaces [8,9]. The CSM is composed of a small cylindrical head (diameter ~5.2 cm) with an integrated infrared diode and receiver and a water jet mounted perpendicular to the surface [8,9]. Pulses of water are fired from the jet at increasing pressures to increase erosional force at the surface. The initiation of erosion is determined when the transmission of the sensor beam decreases steadily without recovery, signaling failure of the surface and consistent transport of grains. The water jet pressure can then be converted to a threshold friction velocity (u*) [8,9].

Results: Erosion tests were replicated for each surface, when possible, to allow for comparisons of aeolian and subaqueous thresholds. The most expansive microbial mat structure at Padre Island, the wave rippled mats, did not erode in either test series. The other microbial mat structures experienced erosion in one or both aeolian and subaqueous scenarios.

Aeolian Erosion: PI-SWERL measurements were performed for 6 surfaces in the field: 5 different crust and mat surfaces plus 1 test on dune sand. An additional test was performed in the lab using a dried sample of the dune sand to quantify the effect of high humidity in the field on the dune sand test. The boundary microbial mats (u*t = 88.9 cm/s), degraded microbial mats (92.4 cm/s), and the salt crust (102.2 cm/s) all eroded during the PI-SWERL testing. Entrainment was not detected for the grey microbial crust and wave rippled microbial mats.

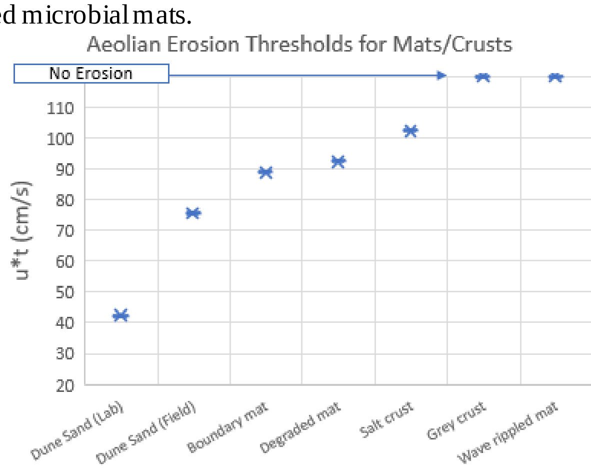

Figure 3: Erosion thresholds measured for various surfaces using PI-SWERL.

Subaqueous erosion: CSM erosion tests were performed on 4 different crust and mat surfaces. To facilitate accurate CSM results and mimic real erosion conditions the CSM tests were performed when the study area was flooded from recent rains. Dune sand was not tested as the CSM does not function properly on unconsolidated surfaces. The results of the CSM tests were similar to PI-SWERL with the degraded microbial mats (u*t = 8.46 cm/s) and boundary microbial mats (8.45 cm/s) experiencing erosion while the wave rippled microbial mats did not erode. The grey microbial crust (8.04 cm/s) did fail in the CSM test while it had previously withstood the PI-SWERL test. The salt crust was not tested as it was not present due to the flooding.

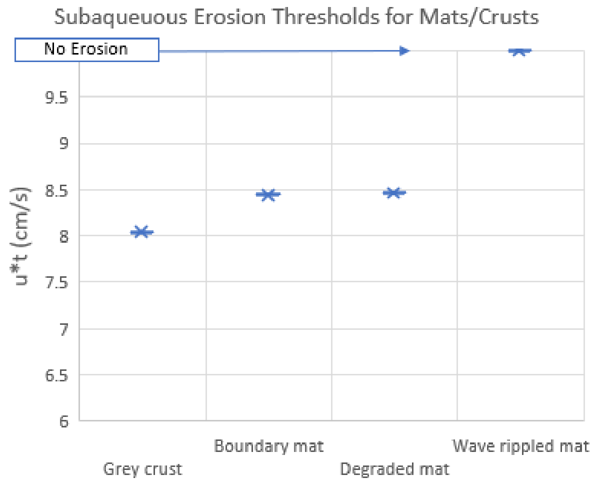

Figure 4: Erosion thresholds measured for various surfaces using the CSM.

Discussion:

The results of the PI-SWERL and CSM testing shows that the erodibility of microbial mat structures can vary significantly. Thick, well-developed structures like the wave rippled mats at Padre Island are resistant to erosion by winds and floods while the weaker mat structures are susceptible. The resistance to erosion increases the preservability of these types of structures. ERA5 reanalysis wind data from 2010-2019 for the study site shows that the u* thresholds for the boundary mats and degraded mats can be exceeded by winds at Padre Island.

The variability in erosion potential between the different microbial mat structures may affect the search for these astrobiological markers. The specific planetary boundary conditions must be considered in determining the erodibility of mats and crusts on other surfaces and their likelihood to enter the rock record.

Acknowledgments: This work was supported in part by NASA's Solar System Workings Program through grant number 80NSSC17K0763 to R. Ewing.

References:

[1] Des Marais, D. et al. (2008) *Astrobio., 8, 715-730*. [2] Westall, F. et al. (2013) *Astrobio., 13, 887-897*. [3] Noffke, N. (2010) *Geobio. Mic. Mats., Springer, 1-194*. [4] Schopf, J..W. (2006). *Phil. Trans. Of the Roy. Soc.: Bio. Sci., 361, 869-885*. [5] Noffke, N. et al. (2002). *Palaios, 17, 533-544*. [6] Etyemezian, V. et al. (2007) *Atmo. Enviro., 41,3789-3796*. [7] Sweeney, M. et al. (2013) *JGR:ES, 118, 1460-1471*. [8] Paterson, D. (1989) *Limnol. Oceanogr., 34, 223-234*. [9] Tolhurst, T.J. et al. (1999) *Est., Cstl.., & Shelf Sci. 49, 281-294*.