CANT MICROBES LITHIFY DUNES? INVESTIGATING EXTRACELLULAR POLYMERIC SUBSTANCE DISTRIBUTION IN A MARS ANALOG DUNE FIELD. N. A. Jones¹, J. C. Bush², Y. Zhang³, B. E. McKeeby⁴, R. C. Ewing⁵, K. R. Fisher⁶, D. J. Jerolmack⁷, D. E. Koditschek⁸, S. Liu⁹, M. Nachon¹, F. Rivera-Hernandez¹, J. Ruck¹, T. F. Shipley¹, S. Thompson⁸, C. Wilson⁹, F. Qian³, C. S. Edwards¹, A. M. Rutledge¹. ¹Northern Arizona University, (natjones@nau.edu), ²University of Southern California, ³Texas A&M University, ⁴NASA Johnson Space Center, ⁵University of Pennsylvania, ⁶Georgia Institute of Technology, ⁷Temple University ⁸Oregon State University.

Introduction: The search for life on Mars has uncovered promising organic molecules, but no missions to date have found definitive evidence for life [1, 2]. A multifaceted approach of pairing physical evidence with geochemical measurements may bring scientists closer to finding life on Mars [3]. However, commonly used physical indicators (such as microfossil or stromatolite identification) have not proven useful on Mars [4, 5]. Geomorphic biosignatures formed by quantitative relationships between microbiology and sediment transport may provide more reliable ways to estimate the presence or absence of microbial life in a Martian landscape. For example, microbial organisms can increase soil cohesion and reduce erosion [6-12], which could be expressed in landscape-scale features such as aeolian dune morphology [13].

Extracellular polymeric substances (EPS)—sticky biopolymers excreted by common microbes—are ubiquitously found in soils on Earth [14, 15]. They appear in concentrations at the detection limit of spectroscopic instruments (<1.5 wt %) [16]. Regardless, laboratory experiments have shown that even a minimum of 0.016 wt % EPS in fine sand can significantly reduce erodibility and sediment transport in fluvial environments [6-8], which indicates that EPS has a cohesive strength an order of magnitude greater than clay [6]. They’ve also been observed to act as a nucleation site for carbonate minerals [17, 18], further contributing to sediment strength and potential preservation of sedimentary structures. This begs the question: could EPS have contributed to the cementation of the paleoforms identified in a variety of geographic locations on Mars [19, 20]?

Studies investigating the role of EPS in aeolian dune fields are limited [9-12]. Many previous EPS lab experiments have focused on fluvial sediment transport [6-8, 21], and there is still debate on whether EPS would have similar sediment stabilizing effects in an aeolian environment [16]. Furthermore, some field studies have sampled EPS distribution in arid environments [16, 17], but none have explicitly focused on Mars analog environments.

In this study we investigate the relationship between EPS abundance, spatial distribution along the dune field, erodibility, and sediment mineralogy in a gypsum aeolian dune field, White Sands National Park (WSNP), NM. We hypothesize that EPS concentration will positively correlate with distance downwind, which also correlates with a decrease in dune migration rate and grain size, and groundwater salinity, an increase in vegetation, a change in mineralogy [13, 22-23]. We expect EPS concentration to correspond with a change in erodibility, and an increase in ductile sediment response to penetrative and shear erodibility tests. While further investigation into grain size variations and mineralogy will be needed to confirm these trends, our results provide promising evidence that microbial biopolymers may create geomorphic biosignatures detectable from orbital or landed spacecraft, such as the barchan-to-parabolic transition observed at WSNP [13], and/or paleoform preservation on Mars [19, 20].

Research Site: White Sands National Park (WSNP), located in south-central NM (Figure 1), contains the world’s largest gypsum dune fields (~400 km²). The dunes migrate from southwest to northeast, forming three distinct morphologies: transverse, barchan, and parabolic [13]. Because of its high gypsum content, the WSNP dune field is often considered an analog for sulfate-rich bedforms on Mars such as the dunes of Olympia Undae, Mars [24, 25].

![Figure 1: Map of White Sands National Park (WSNP) dune field and sampling locations (yellow stars).](image)

Methods: We sampled a total of 48 sites for EPS along a downwind transect within three interdune regions (Figure 1). Two of the sampling locations (locations 1 and 3) were located in the barchan dune region, and one (location 2) was located farther downwind in the parabolic dune region. At each sampling location, we collected two sediment samples that EPS was extracted from: a surface sample (up to 3 cm deep) and a subsurface (up to 30 cm deep). EPS was extracted using methods developed by [26] and [27]. An additional sediment sample was collected up to 5 cm deep for grain size analysis, which was estimated by a particle size analyzer.
Surface sediment mineralogy and chemistry measurements were conducted in situ using a handheld X-ray fluorescence spectrometer (XRF), a handheld Visible and Near-Infrared (VNIR) spectrometer and a Laser Induced Breakdown Spectrometer (LIBS). These measurements were then compared to laboratory X-ray diffraction (XRD) measurements taken on a representative selection of sediment samples.

Sediment strength and erodibility measurements were also collected in situ using a robotic leg in development by the LASSIE (Legged Autonomous Surface Science In Analogue Environments) project team (please see the accompanying LPSC Abstract by Bush et al. for more details on the sediment strength tests by the robotic leg). Penetrative strength was measured up to 5 cm deep, and shear strength was measured across the sediment surface. Qualitative and numeric comparisons from the force-depth penetration results were used to classify sediment responses into brittle vs ductile categories.

**Results:** Preliminary results indicate increased EPS concentration in the downwind direction of dune migration (Figure 2). This increase corresponds to literature measurements of decreased dune migration rate, wind speed, sand flux, and grain size, and aquifer salinity, and an increase in vegetation, and perched aquifer depth [13, 22]. Our study’s grain size characteristics are consistent with the literature. Our mineralogy and chemistry analyses revealed that in the parabolic dune crust (location 2) there was an increase in non-sulfate-bearing carbonate minerals with VNIR absorption patterns similar to dolomite.

The soil strength and erodibility tests revealed that soil crusts in location 2 (the most downwind sampling location) show more ductile soil crust behavior, which correlates with increased EPS concentration. This implies that crusts with high EPS content are more flexible and will bend under increased vertical stress before failing, whereas more brittle crusts with less EPS are more likely to break under increased vertical stress. Other studies of crusts in aeolian dune field show a direct correlation between EPS and compressive strength of the crust [9], indicating that EPS may be driving the qualitative relationship we observe.

**Conclusions:** These results indicate that as EPS exceeds a certain concentration within fine sediments, the ductile behavior of the soil crust increases, which likely increases the durability and decreases the erodibility of these soils. Furthermore, we find that an increase in carbonate material with dolomite-like signatures also correlates with high concentrations of surface sediment EPS content. This correlation is consistent with literature observations of EPS and carbonate minerals [9, 17-18], indicating that EPS may facilitate crust mineralization, further reducing sediment erodibility. These findings suggest that EPS above certain concentration thresholds may influence the morphology and preservation of aeolian dunes with gypsum-rich sediments.

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