

# LINKING COMPOSITIONAL AND DURABILITY VARIATIONS OF VOLCANICLASTIC SANDS TO EOLIAN DUNES. M.J. Zawaski<sup>1</sup>, E. M. Lund<sup>1,2</sup>, R. C. Ewing<sup>1</sup>, and J. Radebaugh<sup>3</sup>.

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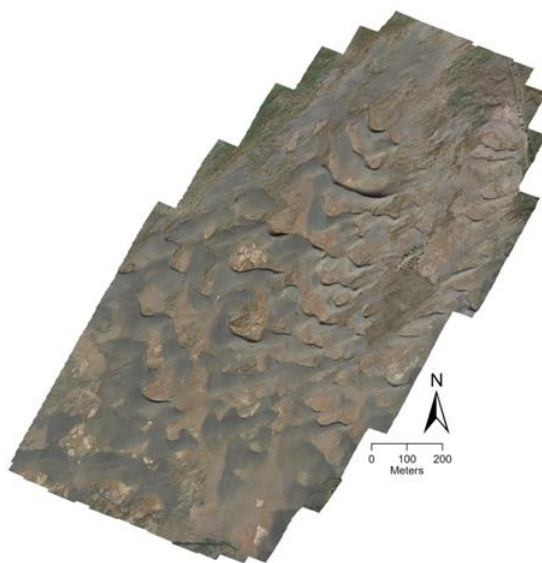
**Introduction:** Eolian landforms are widespread across the solar system [1-4]. These landforms occur on bodies with diverse lithologies, atmospheres, and gravities [5-7]. The presence of these landforms on these worlds affords an opportunity to uncover past and present environmental conditions about them. A grand challenge is understanding how planetary boundary conditions affect the formation of eolian landforms and their deposits. Terrestrial analogue studies play a key role in understanding how boundary conditions shape planetary eolian landscapes and ancient sedimentary deposits. Volcaniclastic eolian systems on Earth have received relatively little attention, despite recognition that terrestrial mafic eolian systems are strong martian analogues [8]. In this study we examine variations in the composition of sands across a dune field that possess a gradient from mafic to quartzofelspathic dominated dunes. We target surface deposits, including ripples, on the stoss slope, grainflows on the lee slope, and dune stratification from trenching.

The Black Rock Desert Dunes (Utah) (**Fig. 1**) is surrounded by the Wasatch Range, which is composed mostly of Precambrian and early Paleozoic clastic and carbonate rocks [9]. The Wasatch is part of the Basin and Range tectonic province. Within this basin, quartz-rich silty Pleistocene-aged paleolake Lake Bonneville

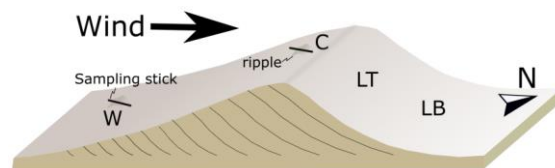
deposits cover the basin floor [10, 11]. Also in the basin is the Black Rock Desert volcanic field where volcanism began about 6 Ma and has been most active since 2.5 Ma. The dunes are positioned downwind of one of these volcanoes, Pahvant Butte, which is the remnant of a Pleistocene volcano that erupted in the ancient Lake Bonneville.

This tuff cone is composed of vesicular, glassy basalt with olivine and plagioclase phenocrysts. Volcaniclastic sediments from Pahvant are detectable in eolian bedforms throughout the area. The quartz and carbonate sands have three likely source areas: the nearby Sevier River channel, from Lake Bonneville deposits, or from surrounding Wasatch Range alluvium. The dune field has a mix of light and dark minerals (e.g., quartz, feldspar, carbonates, and glassy mafic fragments), clearly visible in aerial imagery. The dunes are mainly unvegetated barchan and barchanoid.

**Methods:** We collected aerial imagery using a DJI Mavic 2 Pro and DroneDeploy, then processed the imagery in Agisoft to create a digital terrain model and orthomosaic. Along a 10-dune prevailing wind transect, we collected up to three different sediment sample types from each of four locations per dune (**Fig. 2**). Sample types include: (i) loose surface samples consisting of only the top 1-2 mm of sediment close to the dune crest, (ii) double-sided tape affixed to wooden sticks (tongue depressors) to collect the surface layer of grains including across individual ripples at W and C, (iii) bulk samples taken of the



**Fig. 1.** Orthomosaic of the Black Rock Desert Dunes, Utah.



**Fig. 2.** Sampling locations: W = Windward. C = Crest, LT = Lee Top, and LB = Lee Bottom. Ripples, perpendicular to the prevailing wind direction were sampled for variations in composition at W and C.

upper ~10 cm. We analyzed the loose surface samples and the bulk samples for grain size distribution using a Retsch Technology CAMSIZER®. Depressor samples were analyzed for elemental composition and abundance using a Bruker M4 Tornado Plus  $\mu$ XRF at Texas A&M.

**Initial findings and hypotheses:** Across the dune field in a downwind direction: 1) Grain size decreases, mostly for the coarse-grained sand. By D9, all dune locations are medium-grained. 2) The abundance of elements associated with mafic grains (i.e., Al, Fe, Mg, Ti, Cr, P), zircon (as Zr), and carbonates (as Ca, S)) decreases, while the felsic portion (i.e., Si and K) increases (**Fig 3**). 3) When normalized to the averaged LB bulk samples and the average interdune sediments (Lake Bonneville deposits), we see the compositional and textural maturing of the surface sands. Variations in the major and trace elements show that between D4-6, the surface samples become more felsic than the dune cores (LB samples) and between D5-7, the dune field is depleted in carbonate grains relative to the surrounding sources (e.g., shell fragments). 4)  $\mu$ XRF scans of cross sections of the leeside dune shows distinct compositional variation in grainfall versus grainflow deposits explaining density differences in transport mechanisms. 5) The interdunes are actively eroding, apparently adding felsic material to the dunes.

We hypothesize that a compositional evolution may occur through a combination of three mechanisms. 1) Mechanical breakdown (e.g., chipping and abrasion) of mafic and carbonate grains is greater than felsic and zircon grains. Based on previous work, vesicular grains are more susceptible to mechanical weathering potentially explaining the mafic grain size decrease [12]. 2) Sequestering occurs as a lag in the LB for smaller and denser mafic and zircon grains. Our preliminary measurements show that the glassy, vesicular basalt grains' density, between 2.4 to 3 g/cc, for larger versus smaller grains respectively, supports the notion that the chipping process increases grain density while decreasing the size of vesicular grains. This may help explain why the mafic grains become enriched in the LB during grainflow events. 3) Adding

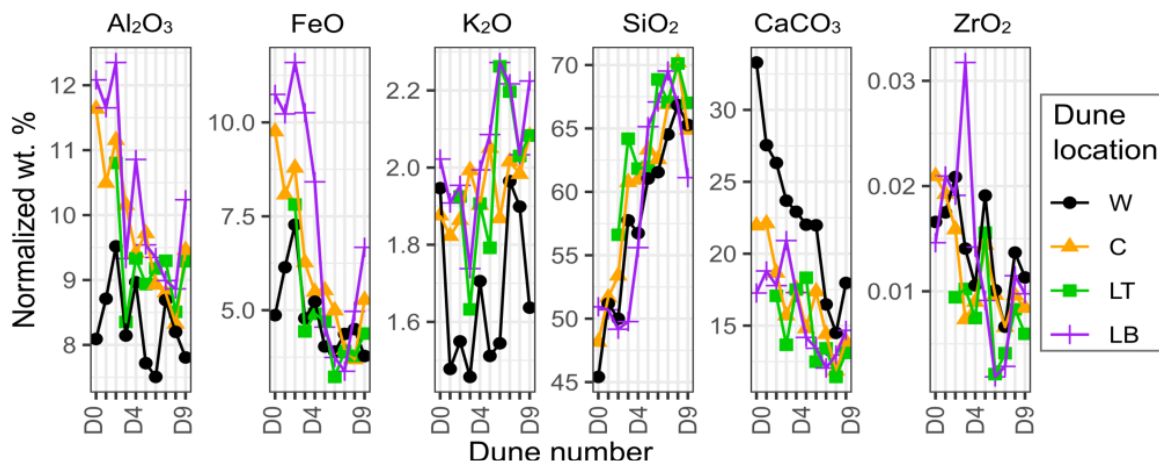
felsic interdune material occurs in the exposed interdunes. These three mechanisms act to make the dunes more felsic downwind.

The variation in mineral types points to the fractionation and abrasion of different minerals during eolian transport and segregation in dune processes (e.g., grainflows and grainfall). Remote sensing data suggests Mars is home to some felsic volcanism [13] and carbonate deposits [14]. While much less abundant than mafic rock, this Utah site may be an ideal analogue site if we find martian dunes that include all three lithologies. Overall, this site is an ideal, easily accessible mafic volcanoclastic dune field for planetary analog dune investigations.

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#### References:

- [1] Greeley R. et al. (1992) *JGR Planets*, 97, 13319-13345. [2] Cutts J.A. and Smith R.S.U. (1973) *JGR Planets*, 78, 4139-4154 [3] Lorenz R.D. et al. (2006) *Science*, 312, 724-727. [4] Telfer M.W. et al. (2018) *Science*, 360, 992-997. [5] Bridges N.T. et al. (2012) *Geology*, 40, 31-34. [6] Lapotre M.G.A. et al. (2017) *JGR Planets*, 122, 2489-2509. [7] Ewing R.C. et al. (2017) *JGR Planets*, 122, 2544-2573. [8] Edgett K.S. and Lancaster N. (1993) *Journal of Arid Environments*, 25, 271-297. [9] Johnsen et al., (2010) *UGA*, 39, 109-150. [10] Benson et al., (2011) *Quaternary International*, 235, 57-69. [11] Oviatt, (2015) *Quaternary Science Reviews*, 110, 166-171. [12] Cornwall et al. (2015) *Icarus*, 13-21 [13] Farrand W.H. et al. (2021) *Icarus* 357. [14] Zastrow A.M. et al. (2021) *GRL* 48.9.



**Fig 3.** Select elements showing the changes in composition in the downwind direction (D0-D9) for the four dune locations in Figure 1. Data from  $\mu$ XRF elemental scans of wooden sampling sticks.