A field comparison of basalt vs. quartz sediment transport in the Grand Falls Dune Field, northeastern Arizona, USA

M.H. Redsteer[1], R. K.. Hayward[2]
[1,2] U.S Geological Survey, 2255 N. Gemini Dr. Flagstaff AZ 86001 [1]mhiza@usgs.gov, [2]rhayward@usgs.gov

Introduction: The Grand Falls dune field, located in semi-arid to arid northeastern Arizona, consists of source bordering dunes downwind of the Little Colorado River (LCR), near Grand Falls, on the northeastern margin of the San Francisco Volcanic Field. Individual dunes are primarily barchans, with a small number of zibars and coppice dunes on the leading edge of the dune field. Collectively the dunes form a mega-barchan complex of small and rapidly migrating dunes (Bogle et al. 2015). Dunes are typically from 500 m^2 to 4000 m^2 and 1 to 5 m high at the crest. Migration rates have been as high as 35 m/yr in recent years, and the dunefield itself has grown in areal extent by more than 70% since 1992 (Redsteer et al. 2011).

The dune deposits consist of fine-grained quartz sand abundant in Little Colorado River deposits and local sandstones, and medium to coarse-grained basalt sand derived from local ash deposits of the San Francisco volcanic field. Dunes become progressively higher in quartz sediment, smaller in size, and more closely spaced downwind (Figure 1.) The mixed source characteristics of sediment transported in the dune field offers an opportunity to conduct a field comparison of the transport characteristics of vesicular basaltic ash vs. well-rounded quartz sand (Figure 2).

Methods: Dune sediment was sampled from four dunes distributed across the dunefield, with samples taken from the crest, toe and limbs of the barchan dunes (Figures 1, 3 and 4). Additional quartz sediment was also sampled from the LCR riverbed for comparison. The density of quartz and basalt sediment samples were estimated by weighing samples and estimating their volume by the amount of water displaced in a graduated cylinder.

To examine the distribution, sorting and transport of basalt vs. quartz sediment across the entire dune field, additional sediment was collected from dunes along a transect, bisecting the dune field, and parallel to the predominant direction of the wind. In addition, passive-sampling Big Spring Number Eight (BSNE) sediment trap samplers [*Fryrear*, 1986] were deployed from the upwind to downwind sides of the dune field to examine sediment transport rates. Windblown sand was collected in three traps mounted on a vertical pole, with sand-trap orifices 0.25, 0.5, and 1.0 m above the ground.

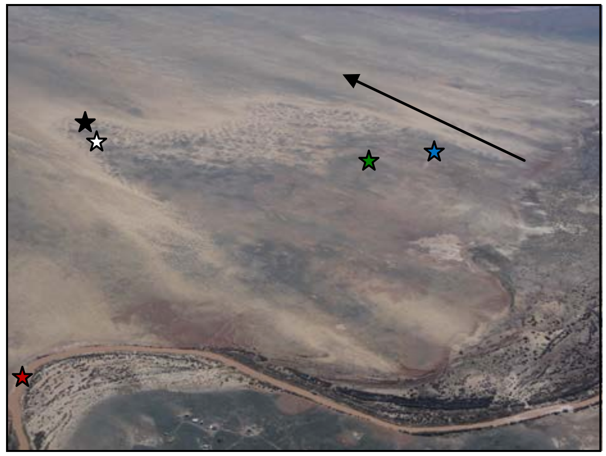

Figure 1. Oblique aerial view of the Grand Falls Dune Field looking east, showing overall dunefield organization with larger, more widely spaced dunes upwind (with higher amounts of basalt sediment) and smaller, more closely spaced dunes downwind (lighter in color, with higher amounts of quartz sand). Stars designate sample locations for data in PSA graphs, with colors corresponding to Figure 3. Arrow indicates predominant direction of wind.

Preliminary Results: There are significant differences in the particle size distributions of the basalt and quartz sediments, with a 300 µm median diameter of quartz river sediment and 1000 µm median diameter of basaltic ash in the dunefield (Figures 2 and 3). Some basaltic ash that is transported and trapped in BSNEs on the upwind side of the dunefield is very coarse (> 2mm, at 1 m height). There are also differences in sediment density, with the fine-grained quartz being somewhat less dense (2.4 g/cm^3) than the vesicular basalt (2.8 g/cm^3). We hypothesize that these differences have led to differentiation of sediment transport populations, so that the coarser, denser basalt grains are transported during the high wind events, whereas, the quartz sand is transported more frequently (with a lower velocity threshold).

Additional work is underway to examine the threshold velocity and transport rates for coarse-grained, vesicular basaltic ash in the Grand Falls dunefield.

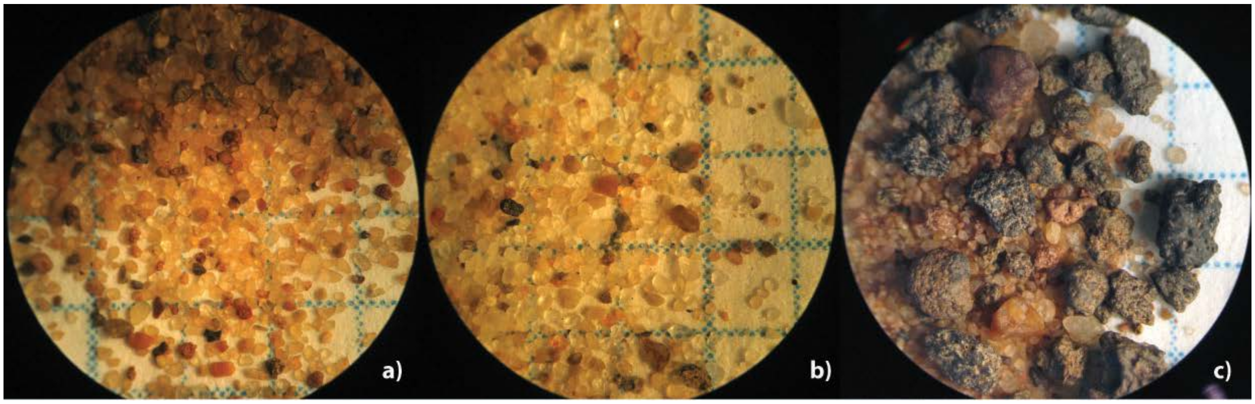

Figure 2. Microphotographs of samples from the Grand Falls dunefield study area: a) barchan slip face b) LCR alluvial deposit c) interdune ripple crest. Grid behind photos is 1.3 mm. (Photo courtesy of Jim Zimbleman.)

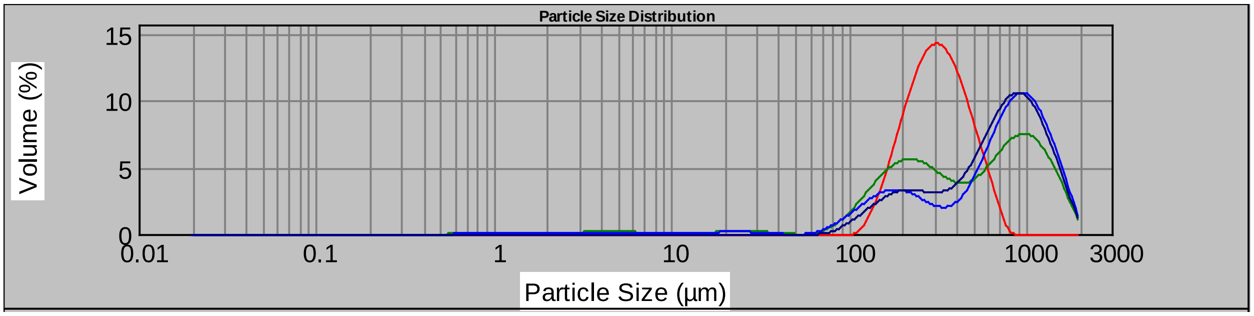

Figure 3. Particle size analysis for predominantly quartz river sediment (red) and for three dune samples of mixed quartz and basalt sand (dune crest of dune on downwind side of field (black) and from two basaltic dunes on upwind side of dune field (green and blue). Sample locations shown as stars on oblique photo of dune field, with same color designations.)

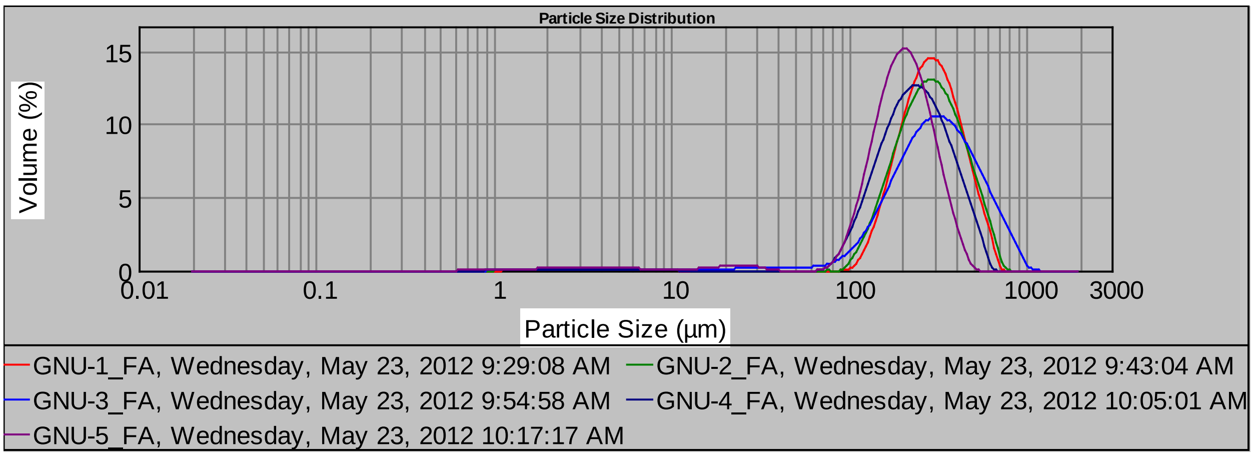

Figure 4. Particle size analysis for dune on western, downwind side of dunefield (location approximated with white star on photo). Dune sediment is prediminantly quartz with 10% basalt sand (visually estimated). Red designates sediment from dune crest, green- dune toe, purple- west limb of barchan, light blue and dark blue are from mid-way points between crest, toe, and limbs.

References

Bogle, R., Redsteer, MH. And Vogel, J. 2015, Field measurements and analysis of climatic factors affecting dune mobility in the Grand Falls area of the Navajo Nation of the Colorado Plateau, southwestern United States; Journal of Geomorphology, vol. 228, p. 41-51.

Redsteer, M.Hiza, Bogle, R.C. and Vogel J.M., 2011, Monitoring and Analysis of Sand Dune Movement and Growth on the Navajo Nation, Southwestern United States; U.S. Geological Survey Fact Sheet 2011-3085. http://pubs.usgs.gov/fs/2011/3085/