MARS ANALOG: GRAND FALLS DUNE FIELD, ARIZONA R. K. Hayward[1], J. R. Zimbelman[2], L. K. Fenton[3], T. N. Titus[1], G. E. Cushing[1], [1]USGS, Astrogeology Science Center, 2255 N. Gemini Dr., Flagstaff, AZ 86001, rhayward@usgs.gov; [2]CEPS/NASM MRC 315, Smithsonian Institution, Washington, DC 20013-7012; [3]Carl Sagan Center/Ames Research Center, Moffett Field, CA.

Introduction: The history of the formation, growth and migration of dune fields on Mars can reveal much about Martian climatic history, but large features change so slowly on Mars [1, 2] that we may need hundreds to thousands of years of repeat imagery to calculate the flux rates needed to use dunes for climate reconstruction. The Grand Falls dune field, analogous in many ways to Martian dune fields, formed about 60 years ago and remains mobile today. It provides the opportunity to examine sediment mobility and meteorological data (historical records and *in situ* measurements) to determine how terrestrial dune field formation and mobility is affected by environmental/climatic conditions. We can use terrestrial-based relationships to help us interpret what the dune fields on Mars have to say about that planet's climate history. Here we introduce the Grand Falls dune field and examine it as a Mars analog. Analogous features include dune field size, topographic setting, sand composition, periodic source availability, and dune morphology.

Grand Falls, Arizona: *Overview.* The Grand Falls dune field is located ~ 70 km NE of Flagstaff, AZ, 2 km east of Grand Falls, and just north of the Little Colorado River (LCR). Vegetation is minimal. The dune field consists of barchans, smaller dunes/ripples, and bare interdunes with indurated surfaces, all features that commonly comingle on the Martian surface. Figure 1 highlights the visual similarity between rippled sand surfaces on Mars and the Grand Falls dune field.

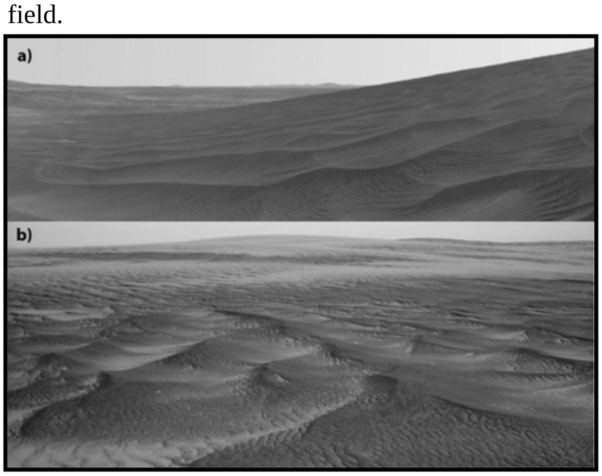

Figure 1. Which is Mars and which is Grand Falls, AZ? The top image, PIA03274, taken by Mars Exploration Rover *Spirit*, shows an example of a rippled sand deposit in Gusev crater on Mars. The bottom image shows a rippled surface in the Grand Falls dune field. Dark areas in 1.b are basalt grains, concentrated on ripple crests.

In 1935, aerial photos of the Grand Falls area showed no evidence of a dune field, but by 1954, a small dune field (~500 m by 750 m) had formed. Figure 2 documents the dune field's growth and rapid migration (averaging ~30 m/year), from 1954 to 2007.

Figure 2. Migration of Grand Falls dune field based on 1954 (red) aerial photo, 1997 (orange) and 2005 (gold) DOQQs and 2007 (yellow) NAPP. Between 1954 and 2007, the dune field moved ~1.6 km. Figure back-ground is 2007 NAPP.

Dune Field Size and Setting. The size of the dune field today (~1.5 km by 1 km) and its location within a topographic trap make it similar to small intracrater dune fields on Mars. The dunes at Grand Falls are in a relative topographic low, migrating toward topographic highs that will impede their progress. This setting is analogous to the setting of an estimated 1500 dune fields on Mars that occur within craters and valleys [e.g. 3, 4].

The composition and grain size of Grand Falls dunes contribute to its value as a Mars analog. Most of the dune sand on Mars is composed of basalt, but gypsum in dunes is also present [5]. At the Grand Falls dune field, composition is also bimodal. Dunes are composed of light-toned, fine-grained quartz sand and dark-toned medium- to coarse-grained basalt sand (Figure 3). The difference in composition results in contrasting albedo as shown in Figure 1.b. The basalt sand component may have originated as local ash and lapilli-fall from volcanic eruptions in the region. Flash floods from local tributaries may have washed additional ash and lapilli-fall deposits into the LCR, making more basalt available to the dune field. The source of the quartz sand, the major component of the dunes, is likely the LCR. Changes in the river flow and sediment load control the availability of quartz sand. A sudden influx from the LCR probably triggered dune formation in the first half of the 20th century. Aerial photographs show that the LCR had a well defined channel in 1935, but in 1954 the river channel was less well defined and loaded with sediment. This sudden availability of a local source of sand could be analogous to Mars, where a local source of unconsolidated sand may become available (e.g., through excavation by erosion or impact) and begin dune formation.

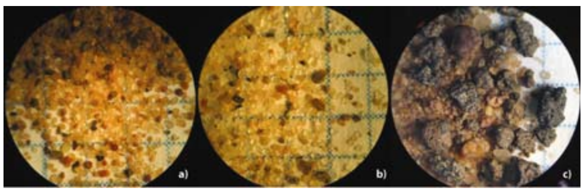

Figure 3. Microphotographs (1 mm grid) of samples taken from a) barchan slip face, b) adjacent LCR bed, and c) ripple crest in Grand Falls dune field. Grains are bimodal in composition and size. The river bed sample is similar to the slipface sample, but is not consistent with the coarse basalt found on the ripple crest.

Dune Morphology. The Grand Falls dune field consists of ~65 barchans/modified barchans that range from ~20 m to ~70 m in width. The tallest are an estimated 5 m to 8 m in height. Interspersed among the barchans are smaller dunes/ripples, and bare interdune areas with indurated surfaces. Figures 4 and 5 show examples of the similarity of dune morphology at the Grand Falls dune field and on Mars. Figure 4 shows classic barchan dunes and modified barchans with tails. Figure 5 shows barchans that have been modified to have one kinked limb [6].

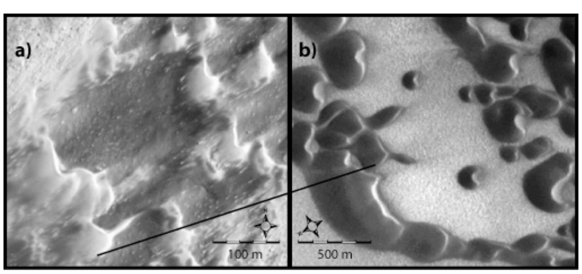

Figure 4. Comparison of dunes at Grand Falls (a) and on Mars (b). Martian dunes shown are ~ 5 times larger than terrestrial dunes shown. Note similarity in morphology, relative spacing, shape of modified barchans with tails (connected by line), and relative size of tails. Figure (a) NW tip of Grand Falls dune field, centered at 35.438° N, 111.167° W (2007 NAPP digital image, 1 m res). Figure (b) is centered at 83.57° N, 119.94° E, (CTX image P01_ 1593_ 2635_XI_83 N241W, 6m/pixel res).

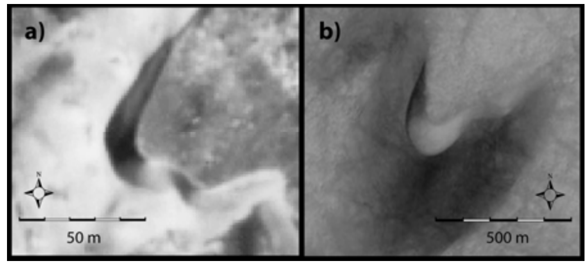

Figure 5. Comparison of dunes at Grand Falls (a) and on Mars (b). Dunes have a similar morphology, a modified barchan shape with a kinked limb. Here, as in Figure 4, the Martian dune shown is ~ 5 times larger than the terrestrial dune shown. Figure (a) Eastern portion of Grand Falls dune field, centered at 35.427° N, 111.163° W (2007 NAPP digital image, 1 m res). Figure (b) is cropped from MOC NA image R1401899, (image is centered at 41.38° S, 334.81° E, 3.5 m/pixel res).

Summary: Many of the aeolian questions on Mars are difficult to address, given the time required to detect change in Martian dunes. An active analog dune field on Earth, where environmental changes can be documented since the inception of the dune field and linked to dune migration rates, will help us understand environmental changes on Mars. Dune field size, topographic setting, sand composition, periodic source availability, and dune morphology are among the features that qualify the Grand Falls dune field as a Mars analog. Its value is enhanced because the dune field's history can be documented since it first appeared about 60 years ago.

References: [1] Bourke, M.C., Edgett, K.S., Cantor, B. A. (2008) *Geomorph. 94*, 247-255, doi:10. 1016/j.geomorph. 2007.05.012. [2] Zimbelman, J. R. et al. (2009) *Icarus*, doi: 10.1016/j.icarus.2009.03.033 [3] Hayward, R. K., et al. (2007), *JGR, 112,* E11007, doi:10.1029/2007JE002943 [4] Fenton, L. K. and Hayward, R. K., *Geomorph.* (2009), doi: 10.1016/j.geomorph.2009.11.006. [5] Langevin, Y., F. Poulet, J.-P. Bibring, and B. Gondet (2005) *Science, 307,* 1584-1586. [6] Bourke, M. C. (2009), *Icarus*, doi:10.1016/ j.icarus.2009.08.023.