GEOPHYSICAL MARS ANALOG STUDIES OF MULTIPHASE WATER IN THE GREAT KOBUK SAND DUNES, NORTHWESTERN ALASKA. C. L. Dinwiddie[1] (cdinwiddie@swri.org), R. N. McGinnis[1], D. E. Stillman[2], K. L. Bjella[3], and R. E. Grimm[2]. [1]Geosciences and Engineering Division, Southwest Research Institute®, 6220 Culebra Road, San Antonio, Texas 78238, [2]Space Science and Engineering Division, Southwest Research Institute®, 1050 Walnut Street, Suite 300, Boulder, Colorado 80302, [3]Cold Regions Research and Engineering Laboratory, U. S. Army Corps of Engineers, Ft. Wainwright, Alaska 99703.

Introduction: Martian æolian systems belong to two broad categories: (i) the sprawling high-latitude north polar erg, thought to be rich in and immobilized by seasonal and perennial volatiles [1]; and (ii) isolated low- to high-latitude dune fields generally confined to topographic traps. High-latitude Martian dunes may have reduced mobility due to seasonal, surficial volatile cycles of H_2O and CO_2 ice/frost and the putative presence of deeper interior reservoirs of permafrost. Although this hypothesis is generally consistent with multiple unsuccessful searches for signs of high-latitude dune activity based on spacecraft imagery [2,3], recent studies of high-resolution imagery have begun to produce robust evidence for modern æolian activity, including bedform modification [4–8].

Sparse Martian data drive æolian scientists to use the theory and lessons from terrestrial dunes to interpret and predict the evolution of Martian dune morphologies. Terrestrial dunes studied as Mars analogs are often warm-climate dunes, even though slowly migrating cold-climate dunes containing frozen volatiles and subjected to longlived snow cover may be significantly more analogous. There is little detailed knowledge of such terrestrial systems, however, due to their remote locales and demanding logistical requirements.

The migration rates of the Great Kobuk Sand Dunes (GKSD), Kobuk Valley National Park, Alaska (**Fig. 1**), were estimated by [9] to range from 0.5 to 1.5 m/yr. The subarctic GKSD are ideal for polar Mars analog studies because they migrate more slowly than low-latitude terrestrial dunes, are terrain-bound like Martian intercrater dunes, are decoupled from atmospheric forcings by snowcover for ⅔ of each year, and are surrounded by ice wedge polygon terrain and thus possibly permafrost-rich at depth. Factors influencing dune stability at the GKSD (e.g., bimodal wind regime, moisture content, niveo-æolian deposits, and permafrost) have been alluded to in the literature [10,11], but have not been meaningfully qualified or quantified.

Objectives and Methodology: To lay a foundation for understanding controlling factors on cold-climate sand mobility and transport, we conducted broadband ground-penetrating radar (25–1000 MHz) and capacitively coupled resistivity geophysical surveys and interpreted these data given ground truth obtained from 9 hand-augered boreholes. We consider controlling factors that could contribute to mechanical arrest of dune movement, including the seasonally frozen active layer, niveo-æolian sedimentation of windblown snow and sand, and deeper volatile reservoirs. Fieldwork took place near maximum freeze conditions in late winter from 15 March to 1 April 2010 [12,13].

Figure 1. Context map for Kobuk Valley (KOVA) National Park. Image credit: Alaska Information Services.

Setting: Pleistocene glaciation in the Brooks Range produced glacial drift, which was reworked by meltwater streams that deposited sand and silt along Kobuk Valley concurrent with the last glacial advance {~24 ka [10]}; æolian transport processes and sedimentation produced loess and cold-climate dune fields. The GKSD occupy 62 km^2 at latitude 67°N and are characterized by transverse, barchanoid, longitudinal, star, and coppice dunes, and sand sheets [10,11]. These moderately well-sorted sands have 167 µm mean grain size, 43% porosity, and 2.69 ± 0.05 g/cc particle density [14]. Ephemeral niveo-æolian deposits develop throughout each long subarctic winter [10].

Multilevel air temperature measurements [12] show a generally isothermal surface layer, with a strongly stable surface layer observed on some nights [14]. Neither condition is conducive to strong boundary layer convection, although some mechanically-driven turbulence (due to vertical wind shear) is possible, given increased scatter in measured wind velocities [14]. Prevailing wind direction in March was generally within the range from NNE to SE [14]. Wind speeds were generally less than 10 m/s, and the strongest nearly always were from the NNE/NE. Erosion flux measurements from atmospherically exposed dune crests suggest a saltation threshold of ~9 m/s [14].

Results: We found liquid water infilling boreholes at shallow depths consistent with where a hydrologic radar reflector and a strong resistivity contrast were observed—resistivity being highest in the frozen active layer and lower below the hydrologic reflector/water table. The liquid water table ranges in depth from 1.5 m below interdunes to 4.0 m below dune crests, but generally mirrors topography (**Fig. 2**). Our soil auger had a maximum depth of 4.3 m, and we did not find direct evidence for permafrost within the active dune system using the auger. Based upon hydrologic principles and measured or assumed material properties for sand, we conclude this liquid water must be perched above a relatively continuous, low permeability unit within the dunes. We have not yet determined whether this unit is permafrost or calcrete [15] that is said to form below the seasonally active layer throughout the dunefield [16]. Common midpoint surveys yielded dielectric constants consistent with very low liquid water content throughout the volumetric bulk of the dune system (i.e., below the apparent perched water).

Conclusions: Just as migration of the GKSD is affected by snowcover for up to ⅔ of each year, Martian polar dunes are decoupled from boundary layer winds by frost mantling for up to ⅔ of each Martian year, significantly limiting the duration of sand transport. We obtained geophysical and borehole evidence that a shallow water table is present throughout the active portion of the GKSD, consistent with reports of springs draining the sand dunes to surrounding creeks [10,11]. Field data and remotely sensed imagery suggest the active portion of the GKSD may serve as a localized recharge zone, with volatiles emplaced in this reservoir through both meltwater and rainfall. Regardless of whether the liquid water within the GKSD is perched upon permafrost or calcretes, the thin water films surrounding sand grains in the near surface make moist sand cohesive and structurally stable. Partially saturated sand above the capillary fringe in the GKSD will limit sand available for transport, potentially similar to effects of putative ice-rich permafrost within Martian polar dunes. We hypothesize that longlived (though ephemeral) niveo-æolian deposits combined with a near-surface perched aqueous reservoir are primarily responsible for the low migration rate of the GKSD.

Ground penetrating radar and capacitively coupled resistivity are both highly effective at mapping the nature of the subsurface hydrocryosphere; one or both instruments should be regularly included in rover payloads.

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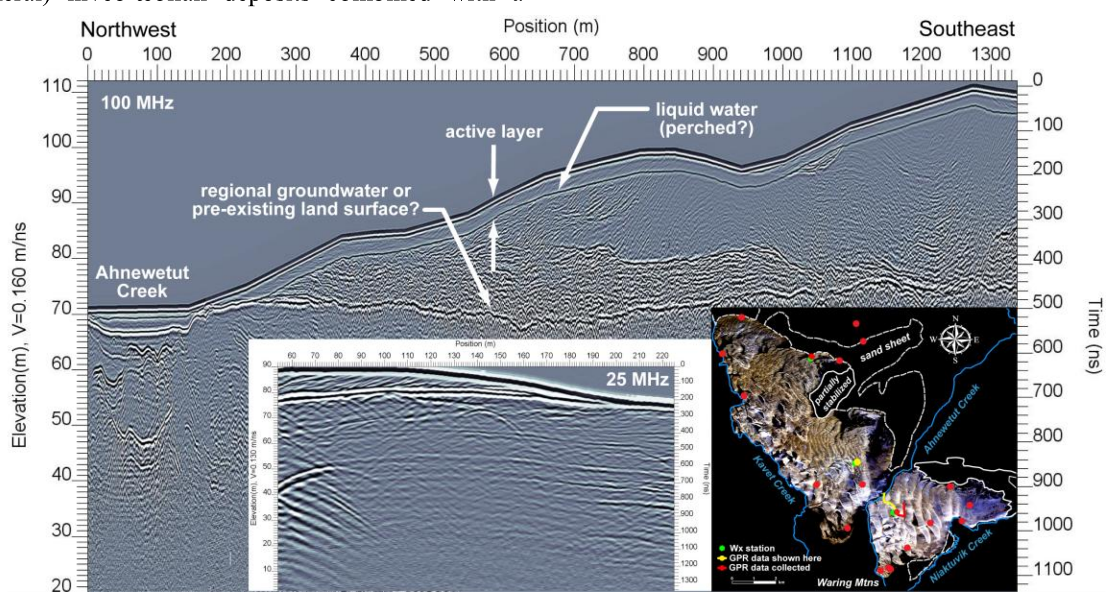

Figure 2. *Radargram from a curvilinear transect illustrates a continuous reflector that mirrors topography and crosscuts foreset beds in near surface; scattering at depth; and a continuous reflector near Ahnewetut Creek elevation of ~70 m amsl. Insets: Radargram illustrates foreset beds above ~75 m amsl; point heterogeneities within underlying subhorizontal stratification (weather station casts airwaves from left); and deep signal penetration. Data acquisition sites superimposed on ALOS AVNIR-2 contrast-enhanced imagery (courtesy M. Necsoiu and JAXA).*