LATE-WINTER PHASE STATE OF WATER IN THE GREAT KOBUK SAND DUNES, ALASKA, AND TESTABLE HYPOTHESES FOR A PERCHING MECHANISM. C. L. Dinwiddie[1] (cdinwiddie@swri.org), R. N. McGinnis[1], D. E. Stillman[2], R. E. Grimm[2] and K. L. Bjella[3]. [1]Department of Earth, Material, and Planetary Sciences, Southwest Research Institute®, 6220 Culebra Road, San Antonio, Texas 78238, [2]Department of Space Studies, 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: Sparse data compel planetary æolian scientists to use lessons from terrestrial dunes to interpret and predict the evolution of Martian polar dune morphologies. Slowly migrating cold-climate dunes containing frozen volatiles and subjected to longlived snowcover have many advantages over warm-climate analogs. The migration rates of the Great Kobuk Sand Dunes (GKSD, **Fig. 1**), Kobuk Valley National Park, Alaska, were estimated by [2] 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 may be permafrost-rich. The mean annual air temperature at the dunes is −5°C. 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 [3,4], but were not meaningfully qualified or quantified until our fieldwork and modeling began in 2010 [5–8].

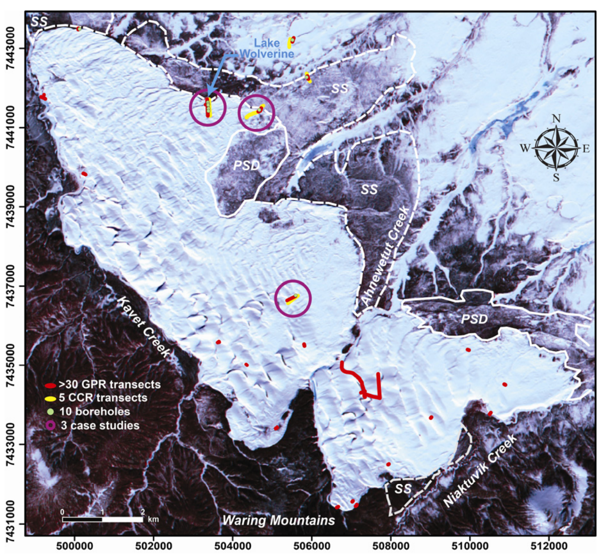

Figure 1. *GKSD context image with data collection locales. Aufeis and valley network fens illustrate late-winter groundwater discharge. Precipitation ridges form at field margins where winds lose velocity at the boreal forest edge, causing sand to drop. Sand sheets (SS) & partially stabilized dunes (PSD) are noted as defined by [1]. UTM coordinates, Zone 4, NAD 83 datum. ASTER image (courtesy of NASA LP-DAAC, USGS and Japan's METI) acquired 20 March 2010.*

Objectives and Methodology: NASA funded us to test geophysical methods applicable to Mars in relevant geophysical Mars-analog environments. Expanding outward from this high-level objective, our work lays a foundation for understanding controlling factors on cold-climate sand mobility and transport. To meet these objectives, we conducted broadband ground-penetrating radar (GPR, 25–1000 MHz), capacitively coupled resistivity (CCR), and real-time kinematic DGPS surveys and also hand-augered 10 boreholes. Fieldwork took place from 15 March to 1 April 2010 [5,6], under near-maximum freeze conditions.

Setting: Pleistocene glaciation in the Brooks Range produced glacial drift, which was reworked by meltwater streams that deposited sand and silt along Kobuk Valley [8—Fig. 1] concurrent with the last glacial advance {~24 ka [3]}; 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 [3,4]. Dunes climb the Waring Mountains to the south, and an elevated sand sheet on the northwest margin of the system [8]. Dune-forming wind directions are in the range from NNE to SE [7]. Ephemeral niveo-æolian deposits develop throughout each long subarctic winter [3]. In this environment, large dune crests may be exposed, but barchanoid arms, stoss slopes, and lee catchments are generally snowcovered, such that fetch-limited sand transport occurs much of the year [8].

Results: The high-contrast frozen active layer was well-imaged with CCR, having resistivities from 5,000–500,000 ohm-m (**Fig. 2**).

Sand Sheet and Precipitation Ridge: Liquid water infills a borehole within the sandsheet adjacent a precipitation ridge on the northeast margin of the dune field. Geophysical signatures of liquid water are within the underlying sand sheet below thin dune sands (**Fig. 2**). At this locale, the active layer is interpreted as underlain by continuous groundwater, and the presence of permafrost is doubtful. Our data are consistent with aufeis observed in **Fig. 1** and reports of springs that drain water in the dunes to surrounding creeks.

Lake Wolverine and Precipitation Ridge: Liquid water infills boreholes at shallow depths, consistent with the strong resistivity contrasts that were observed (**Fig. 2**). The depth to liquid water ranges from 1.5 m below interdunes to 4.0 m below dune crests, and generally mirrors topography. At this locale, the active layer is interpreted to be underlain by continuous groundwater connected to Lake Wolverine.

Centrally Located Barchanoid Dune: Liquid water infills a borehole beneath the interdune. A hydrologic GPR reflector that cross-cuts bedding closely mirrors topography [8]. CCR data, for the first time, show a less dramatic decrease in resistivity at the depth of this hydrologic reflector (**Fig. 2**). At this locale, the active layer is interpreted to be underlain by a relatively thin perched water zone; its thickness cannot be resolved with CCR data. 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). For perched water to be present, it must be underlain by a low-permeability unit—such as that provided by relatively young permafrost that may persist in dynamic equilibrium with the slowly migrating topography of this slow-moving dune system. Alternatively, the relatively continuous, low permeability perching unit may be calcrete [9], which is said to form below the seasonally active layer throughout the dune field [10].

Discussion: We identify the macroscopic phase state of water in the system according to resistivity zones in **Fig. 2** having the following *average values*:

- Frozen active layer: 50,000–90,000 ohm-m
- Regional groundwater: 1,400–1,900 ohm-m
- Zone below perched water: 15,000 ohm-m

We picked the 5,000 ohm-m contour (**Fig. 2**) as representitive of where the frozen active layer begins to transition to unfrozen, but liquid water and ice mixtures are still possible below the hydrologic reflector. Our soil auger had a maximum depth of 4.3 m, and we did not find direct evidence for permafrost or calcrete within the active dune system using the auger.

Conclusions: Based upon hydrologic principles and material properties for sand, we conclude liquid water in the thicker portions of the dune field must be perched above a relatively continuous, low permeability unit. We have not determined whether this unit is permafrost or calcrete. We infer the perched water must flow down to a regional aquifer located below the interdunes, at approximately the 70 m amsl elevation of Ahnewetut Creek [8—Fig. 2]. On Earth, the deflationary base is often determined by the water table because water acts as a stabilizing agent. It is not surprising, then, that low resistivities are observed below the active layer in the interdunes—and for the centrally located barchanoid dune (**Fig. 1**), this depth is consistent with the elevation of nearby Ahnewetut Creek.

While we did not find direct evidence for permafrost or calcrete within the active dune system, our GPR data [e.g., 8—Fig. 2] suggest several locations that could be probed with an auger to confirm or invalidate their presence, and thereby test the hypotheses.

GPR and CCR are both highly effective at mapping the subsurface hydrocryosphere; one or both instruments should be included regularly in rover payloads.

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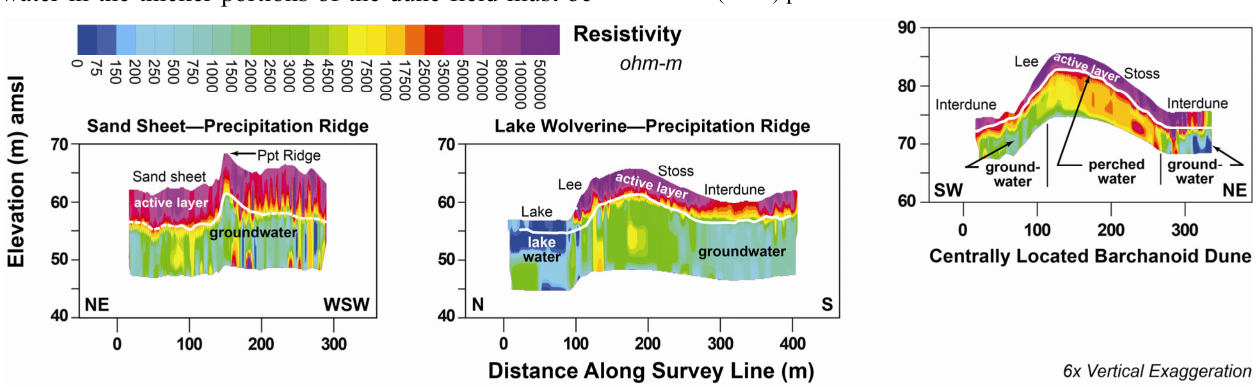

Figure 2. *Resistivity data from (i) transition between sand sheet and precipitation ridge, (ii) transition between Lake Wolverine and precipitation ridge, and (iii) a centrally located barchanoid dune. Hydrologic GPR reflector position traced in white.*