WHAT DO YOU CALL A MARTIAN THAT (STILL) LIKES STREAM DEPOSITS? A BIG ALLUVIAL FAN. M. C. Palucis[1*], A.M. Morgan[2], J.V. Strauss[1], F. Rivera-Hernandez[1], J.A. Marshall[3], E. Menio[3], and Rebecca Miller[1]; [1] Department of Earth Sciences, Dartmouth College; [2]Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution; [3]Department of Geosciences, University of Arkansas; *marisa.c.palucis@dartmouth.edu

Motivation: Hesperian- to Amazonian-aged depositional features, such as alluvial fans, record one of the last widespread episodes of fluvial activity on Mars' surface. Understanding how climatic conditions are recorded in the form and sediments of these features may provide key insights into habitability and climate change on Mars; however, conceptual models for alluvial fan formation come mainly from work on arid terrestrial fans, such as those in the American Southwest, which have largely experienced Pleistocene to Holocene drying [3]. Thus, there is an important knowledge gap regarding fan-forming processes and associated water runoff when a cold and icy climate begins to warm.

Here initial results are presented from a field-based terrestrial analog study involving characterization of the sedimentology and geomorphology of a periglacial alluvial fan in the Richardson Mountains, Northwest Territories, Canada. We (1) qualitatively described the range of sedimentary processes occurring on the periglacial alluvial fan and compared them to prior observations [4], (2) measured flow discharges and runoff rates that occurred during a summer storm event, and (3) estimated fluvial sediment fluxes for runoff rates comparable to those suggested for Mars [5].

Field Site: We conducted a field examination of the ~4 km long, ~2 km wide Black Mountain fan, located on the eastern slope of the Richardson Mountains near the town of Aklavik (Fig. 1). Continuous permafrost extends to depths of ~100 meters in places [4,6]. Runoff is sourced from both rainfall and snowmelt; the catchment area is a nivation-modified hollow with steep headwalls that serve as snow repositories [4]. The mean annual temperature for Aklavik is ~8.8 °C, with a minimum of -29 °C in January and a maximum of 14 °C in July. Data from nearby weather stations show that the mean annual temperature is increasing, and winters are warming faster than summers, with winter increases of up to 4 °C [7]. The fan has shallow, ephemeral distributary channels, and stream flow is confined to the summer months [4,6]. Permafrost and periglacial features, including polygonal cracks and frost mounds, were observed to be pervasive on the fans in this region in the 1960s and 1980s [4,6]. The source material to the fan consists of Cretaceous shale, siltstone, and sandstone [4].

The Black Mountain fan is an ideal analog for martian alluvial fans, with a similar average slope and area scaling with its catchment [9]. This suggests that erosional processes occurring in the catchment may be comparable to those that occurred on martian crater rims. Perhaps most importantly, it is an active snowmelt-fed fan, with minimal input from rainfall, as has been inferred for most martian fans [8-10]. The Black Mountain fan is predominately composed of fine-grained material, which has also been inferred for martian alluvial fans [8].

Data Collection: The following data were collected during an initial field campaign in August 2019:

Sedimentary processes. Twelve stratigraphic sections were measured down fan along the walls of an incised channel. Based on sedimentological observations, the channel wall sediments were interpreted as debris flow or fluvial deposits. Fluvial deposits consist of clast-supported conglomerate with clast imbrication, sub-rounded to rounded clasts, ripple trough cross-stratification, and normal grading. Debris flow deposits consist of poorly sorted matrix- to clast-supported conglomerate with angular to sub-angular clasts, a lack of stratification and imbrication, and if fully exposed, contain lateral levees and depositional lobes. Fluvial deposits within active channels are expressed as bedforms (dunes, ripples, alternate bars, and steps/pool), which we mapped (along with the degree of armoring and bar form dimensions and wavelength), using data collected by terrestrial lidar and UAV surveying (~2 cm/pixel).

Active sediment transport. We observed a snow/rain event on August 17th 2019, where ~14 mm of rain and snow accumulated over several hours. Directly post-dating the storm, we documented active channel geometry (i.e., bankfull channel width, W, and depth, H), surface flow velocity (U), critical versus subcritical flow, and median grain size (D_{50}) at 20 locations down-fan (Fig. 2). Grain size was determined using Wolman pebble counts, where 100 randomly chosen grains were measured along their intermediate axis (within several meters of where we measured W and H). Local channel bed slopes (S) were estimated from a DEM generated from UAV-imagery and structure-from-motion techniques.

Initial Findings:

Sedimentary processes. We observed active bedload transport on the upper- to mid-fan, as well as several small debris flows that had initiated from ice-filled gullies in the catchment. This suggests both processes are actively occurring under the current changing climate. Periglacial processes, which were documented to be pervasive on the fan in the past [4,6], were muted and mainly observed on the upper, steeper portions of the fan. Within well-exposed stratigraphic sections in the main incised channel on the upper fan, we observed that clasts generally are sub-angular to sub-rounded, poorly sorted, non-imbricated, and occasionally had reserve grading, suggestive of debris flow (or mass flow) origin. On the lower fan, the deposits consist of alternating layers (~5 cm thick) of silt and clay, where the silt often occurred in lenses. The lower fan deposits are often overlain by ~0.5 to 0.75 m of soil/tundra. We infer these deposits to be predominately fluvial in origin.

Sediment transport. We estimate maximum precipitation rates of ~2 mm/hour (total rainfall/time), which are comparable to melt rates proposed for regions of Mars by [5]. We calculated discharge (Q) at each sample location using principles of continuity ($Q = WHU$), and runoff was calculated by taking discharge and dividing by the upslope contributing area. Runoff rates were ~0.01 to ~0.04 mm/hr, except near the fan apex, where they were ~0.1 to ~0.2 mm/hr (Figure 2). Grain size typically fined down fan, going from coarse pebbles at the apex, to fine to medium pebbles mid-fan, and coarse sand at the distal end. We estimated the Shields stress (τ^*) on the bed (a non-dimensional shear stress) assuming steady uniform flow, such that $\tau^* = \rho HS / (\rho_s - \rho) D_{50}$ where ρ is the water density and ρ_s is the sediment density. The critical Shields stress (τ^*_c) for initial sediment motion was estimated using the slope-dependent relation of [11]. At all sites where sediment motion was observed, we calculated $\tau^* / \tau^*_c > 1$, typically between 2 and 5 (Figure 2), which corresponds to sediment fluxes of 0.2 to 2 m^3/hr. This suggests that moderate flow events on the fan, similar to melt rates suggested for Mars, are capable of entraining and transporting appreciable amounts of sediment by fluvial processes.

Acknowledgments: This work was funded by a NASA SSW grant (#80NSSC19K0539) awarded to MCP, JVS, and FRH. We thank the G'wichin tribal council, the Aurora Institute, and the Yukon Geological Survey for logistical support and permission to perform this field work. We also thank Sonny McDonald for help with data collection in the field.

References: [1] Craddock and Howard (2002) *JGR*, *107(*E11*)*. [2] Wordsworth (2016) *Ann. Rev. of Earth and Planet. Sci.*, *44*, 381-408. [3] Bowman (2019) *Springer Nature BV*. [4] Catto (1993) *Geo. Annular: Phys. Geog*., 75(3). [5] Kite et al. (2013) *Icarus*, *223*(1). [6] Legget et al. (1966) *GSA Bull*., 77(1). [7] Arctic Climate Impact (2005) Cambridge University Press. [8] Morgan et al. (2014) *Icarus*, *229*. [9] Moore and Howard (2005) *JGR*, *110*(E4). [10] Palucis et al. (2014) *JGR*, *119*(4). [11] Lamb et al. (2008) *JGR*, *113*.

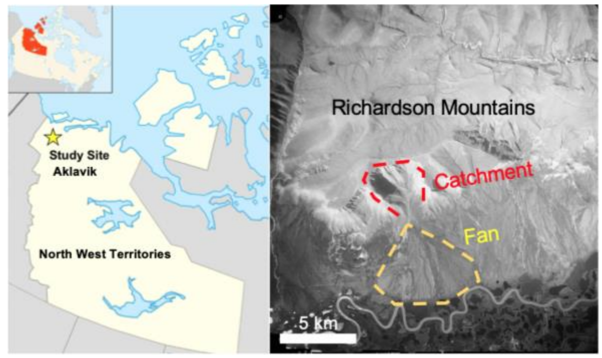

Figure 1. a. Study site is located near Aklavik, in the Northwest Territories of Canada. B. WorldView-3 image of the Black Mountain fan, showing the catchment (in red) and the fan (outlined in yellow).

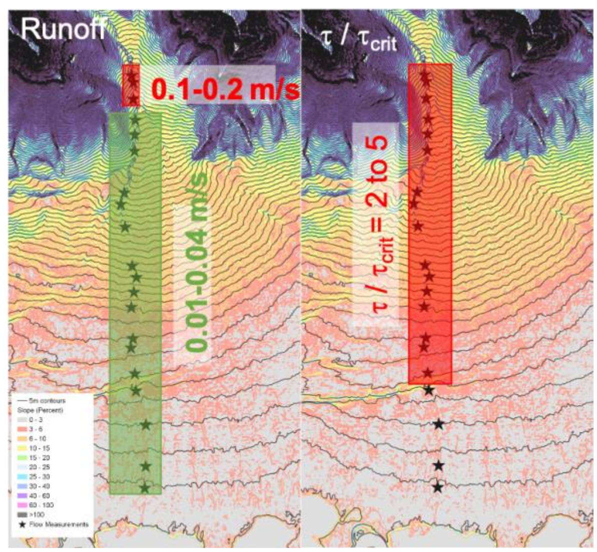

Figure 2. Slope map of the Black Mountain fan (with 5 m contours from ArcticDEM) showing (A) our estimated runoff rates along the fan and (B) sites where we both observed sediment transport and calculated $\tau^* / \tau^*_c > 1$ (red).