Constraining Environmental Conditions for Dune-Alcove Formation in the Northern Mid-Latitude Region of Mars. J. M. Widmer[1] and S. Diniega[2], [1]University of Maryland (jwidmer@terpmail.umd.edu), [2]Jet Propulsion Laboratory, California Institute of Technology.

Introduction: Dune-alcoves are triangular shaped erosional features formed through mass-wasting on the brinks of sand dunes; downslope there may be a depositional apron (see Figure 1). These geologic features have been found in dune fields throughout the North Polar Region (NPR) [1] and Northern Mid-Latitude Region (MLR), defined as 30°-65° N [2]. Similarities in shape, size, and the appearance of new dune-alcoves during the autumn/ winter season suggest the same formation mechanism is present among NPR and MLR dune-alcoves [2]. The formation mechanism is not yet known but has been hypothesized as an interaction of early snowfall with early seasonal frost on dunes [3]. Recently, an anti-correlation of dune fields with alcoves and large amounts of shallow subsurface H_2O ice was proposed, potentially placing an environmental constraint on where alcoves can form [4].

Thus far, the locations of dune fields with alcoves appear to be randomly scattered throughout the NPR and MLR. To better understand the mechanism(s) driving alcove formation, we will compare specific environmental conditions that may be related to an alcove formation mechanism, within MLR dune fields with and without alcoves.

Environmental Conditions: Previous studies have suggested connections between alcove formation and environmental conditions such as seasonal frost [1-4], brink degradation [1], elevation [2], and subsurface H_2O ice [4], but no correlations have been conclusively identified yet. Additionally, sand dune morphologies reflect the environmental conditions in which the dunes were formed [5]. Together, these conditions are used for a preliminary comparison of MLR dune fields.

Latitude and longitude coordinates mark the locations of dune fields being tested but can also be used with recent studies of seasonal frost to better understand if and when frost is present in a given dune field location [6]. Brink degradation state is categorized as either sharp (i.e. appearing fresh/ recently active) or rounded (i.e. degraded), with brink appearance used as a proxy for how active a given dune may be under current atmospheric conditions [7]. Minimum elevation values are calculated using map sampling of the lowest elevation value encountered in the 128ppd MOLA elevation map under a dune field polygon in JMARS [8]. The presence of H_2O ice within the topmost meter of ground under a dune field is given as the max number

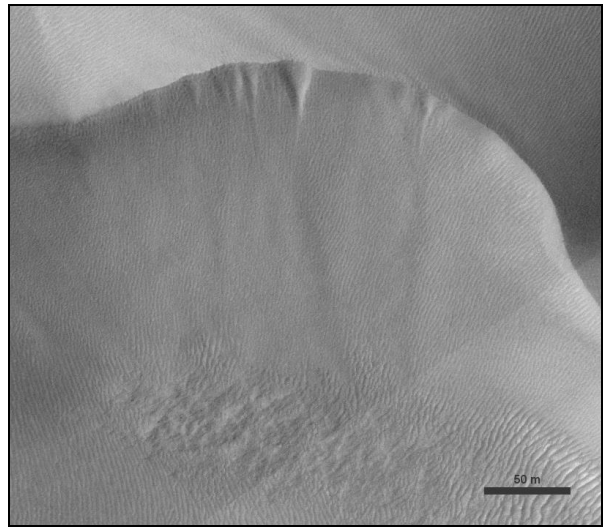

Figure 1: *HiRISE image PSP_007640_ 2440 shows several alcoves of varying sizes that have formed on the brink of a sand dune in field NML043 (63.76° N, 292.12° E). Downslope extends toward the bottom of the image, where interdune ground is visible.*

of counts from neutron spectrometer (NS) epithermal observations [9]. For this parameter, a lower count value is interpreted to mean a higher amount of subsurface H_2O ice is present within the uppermost meter of the ground [10]. Dune types present in each field are categorized based on the Mars Global Digital Dune Database (MGD3) naming scheme [11].

Preliminary Test Location: A subset of mid-latitude dune fields chosen for preliminary study included three fields with alcoves and three fields without alcoves from a region north of Chryse Planitia and west of Acidalia Planitia. This region contains a higher amount of dune fields with alcoves than any other portion of the MLR [4] so we can control for broad regional environmental conditions and focus on field-specific conditions. Figure 2 shows this region and the six chosen dune fields.

Results and Discussion: Preliminary results for the environmental condition tests are recorded in Table 1. Thus far, the tested conditions are not noticeably different between dune fields with and without alcoves. For the six fields tested, the variation in the NS data is not consistent with the anticorrelation of alcove locations and subsurface H_2O ice proposed in [4]. This inconsistency may be due to the use of a higher resolu-

tion NS map used for this study [9] or that a range of NS epithermal counts (i.e. variety of subsurface H_2O ice thicknesses) can be present without effecting alcove formation.

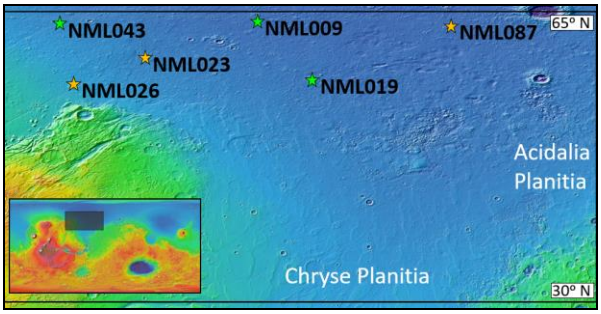

Figure 2: *Six MLR dune fields were chosen for preliminary study of environmental conditions conducive to alcove formation. Stars indicate the locations of dune fields with alcoves (green) and without (yellow).*

Interpretation of the preliminary results suggests that the tested conditions are not individually responsible for the presence or lack of alcoves in the six dune fields tested. This would indicate that the environmental condition(s) associated with an alcove formation mechanism fall into one of two categories.

1) A single environmental condition is associated with alcove formation but has not yet been considered in this study.
2) A combination of environmental conditions are associated with alcove formation and may include one or more of the conditions identified in Table 1.

Future Work: Future work will include the addition of more alcove and non-alcove dune fields from the MLR. Additional inquiries into environmental conditions conducive to alcove formation may include the presence of CO_2 snowfall over or near dune fields and the timing seasonal CO_2 frost is present on dune fields (when possible).

Dune-Alcoves and Martian Science: If the alcove formation mechanisms are determined, then the presence of alcoves can serve as proxy indicators of local-scale environmental conditions on the martian surface, in the present-day climate. Since alcove formation seems to be driven by specific frost conditions, dune-alcoves provide ideal targets for understanding cross-cutting relationships among atmospheric and surface processes. Thus, the investigation of environmental conditions surrounding alcove formation ties into high priority science goals such as Goal III A3.1-3 of the MEPAG goals document [12] which is focused on identifying and understanding the formation of geologic features active in the present-day martian environment. Alcoves provide a record of the interaction between the surface and atmosphere which directly contributes to the focus of Goal III A4.2, the characterization of these interactions by erosional processes. Lastly, the hypothesized interaction between snowfall and seasonal frost (i.e. volatiles) and sand dunes (i.e. surface) links alcove formation with Goal II A4.1-2, which involves understanding aspects of the martian climate through characterizing the exchange of volatiles between the surface and atmospheric reservoirs as well as the processes by which this occurs.

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Dune Field ID	Alcoves (Y or N)	Lat (N)	Lon (E)	Dune Type	Brink (Sharp/ Round)	Min Elev (m)	Max Counts from NS Data
NML009	Y	64.542	315.913	Bd	Sharp	-5913	4.68
NML019	Y	56.699	322.629	B, Bd, S	Sharp	-6085	7.03
NML043	Y	63.755	292.120	B, Bd, S, D	Both	-5770	3.90
NML023	N	59.330	302.537	B, Bd, S, T, D	Sharp	-5969	5.58
NML026	N	55.907	293.921	Bd, S, D	Both	-4859	5.76
NML087	N	63.175	339.364	B, Bd, T, D	Round	-5572	3.85

Table 1: *Preliminary results comparing environmental conditions between dune fields with and without alcoves.*