MARTIAN DEBRIS-COVERED GLACIERS: SEEKING "SIGNS OF LIFE" IN A ~100 MY OLD DEEP-FREEZE. Joseph S. Levy[1], James Head[2], David Marchant[3] [1]Portland State Univ. Dept. of Geology, Portland, OR. [2]Brown Univ. Dept. of Geology. [3]Boston Univ. Dept. of Earth Sciences. jlevy@pdx.edu

Introduction. Debris-covered glaciers represent one of the largest reservoirs of non-polar ice on Mars [1-4]. Geomorphological observation have been used to suggest the presence of preserved glacial ice in Martian landforms including lobate debris aprons (LDA) [3, 5-8], lineated valley fill (LVF) [6, 9-11], and concentric crater fill (CCF) [2, 3, 12-14], identifying them as potential debris-covered glaciers—an interpretation verified by the radar detection of thick deposits of ice beneath surficial sediments [15, 16] in LDA and LVF (Figure 1). Con-currently, analyses of terrestrial glaciers (both debris-covered and non-debris-covered) have yielded multiple discoveries of englacial and subglacial microbial ecosystems, containing biomarkers including compromised DNA, intact DNA, viable but inactive cells, and presently-metabolizing active cells [17-19]. In the oldest debris-covered glacier ice, DNA and viable microbes have been preserved for upwards of 8 Ma at temperatures averaging c. -25˚C [18, 20, 21]. Taken together, the discoveries of ancient (~100 Ma) debris-covered glaciers on Mars, and of biomarkers and extant ecosystems in terrestrial glaciers, suggest that Martian debris-covered glaciers may represent a critical target in the search for Martian biosignatures.

Morphological Characteristics. The term, debris-covered glacier indicates a lobate mass of glacial ice (ice that once flowed) overlain by a lag of aeolian-derived and/or rock-fall sedimentary material that is partially generated by sublimation of debris out of the surface of the ablating ice mass [1, 6, 22, 23]. They can be distinguished from "rock glaciers," lobate features for which ice is predominantly present as an inter-sedimentary cement or as lenses, rather than as the dominant phase in the lobe [24]. Critical morphological characteristics typical of debris-covered glaciers include: The greater the number of criteria observed, the stronger the argument for glacier activity: (1) alcoves (indentations in valley and massif walls that form local snow and ice accumulation zones and sources of rock debris cover), (2) parallel arcuate ridges facing outward from these alcoves and extending down slope as lobe-like features (deformed flow ridges of debris), (3) progressive tightening and folding of parallel arcuate ridges where abutting adjacent lobes or topographic obstacles (constrained debris-covered glacial flow), (4) progressive opening and broadening of arcuate ridges where there are no topographic obstacles (unobstructed flow of debris-covered ice), (5) circular to elongate surface pits (differential sublimation of surface and near-surface ice), (6) individual LVF tributary valleys converging into larger LVF trunk valleys (local valley debris-covered glaciers merging into larger intermontaine glacial systems), (7) complex folds in LVF where tributaries join trunk systems (differential flow velocities causing folding), (8) integrated LVF flow systems extending for tens of kilometers (intermontaine glacial systems), and (9) rounded valley wall corners where flow converges downstream, and narrow arête-like plateau remnants between LVF valleys (both interpreted to be due to valley glacial streamlining) [1, 6, 8, 23, 25].

LVF, LDA, and CCF surface morphology indicates that massive, and debris-rich glacial ice has been present in the near-surface of these features, and has undergone up to tens of meters of sublimation to produce a thick sedimentary lag that may be several meters thick [8, 12] (in comparison, <1 m of till protects ancient ice in Beacon Valley, Antarctica) [26].

Ice Volume Estimates. How much ice is present in Martian debris-covered glaciers? LDA and LVF are regionally extensive landforms [1, 3] that have MOLA-measured thickness of up to several hundred meters [5, 6, 8, 22, 23]. Estimates of the depth of CCF deposits span ~600 m to ~1700 m, and commonly constitute ~75% of expected crater depth [2]. Taken together, CCF, LVF, and LDA deposits may an extremely large, widely-distributed astrobiological target.

Ages. When did Martian debris-covered glaciers form? Crater counts on the surfaces of LVF, LDA, and CCF commonly yield ages of ~100-500 Ma, but consistently younger than 1 Ga [2, 6, 8, 10, 22, 23]. Thus, unlike ancient crust or recent gullies, Martian debris-covered glaciers sample a unique period in martian history—the late Amazonian (figuratively, the beginning of Phanerozoic Mars).

Conclusions. Given the likely current presence of large quantities of non-polar ice in Martian debris-covered glaciers, the wide regional distribution of these landforms, the unique potential for preserving traces of life in glacial terrain, and the moderate age of these landforms, we propose that CCF, LVF, and LVF should be considered promising landing sites in the search for Martian biosignatures.

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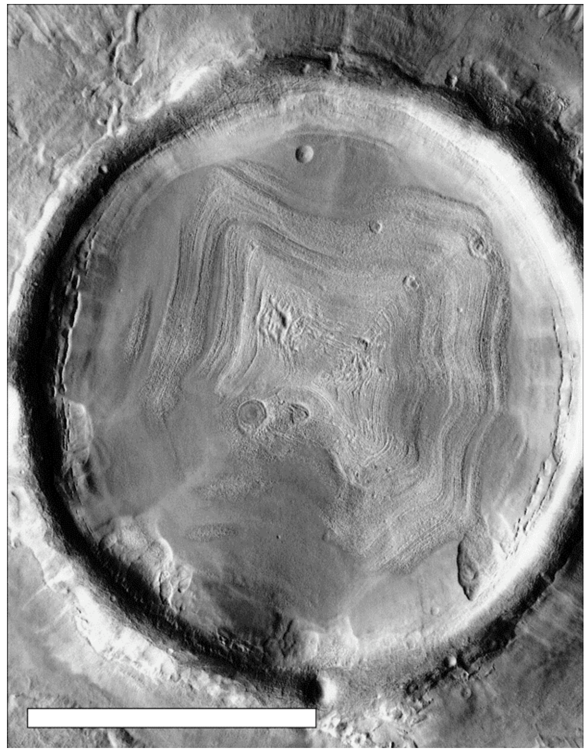

Figure 1. Debris-covered glacier landforms on Mars. Arrows indicate surface lineations suggesting downslope flow. (Counter-clockwise from lower left): Lobate debris apron (LDA) identified by [16] as debris-covered ice (P17_007782_2219); lineated valley fill (LVF) (P13_007782_2219); concentric crater fill (CCF) (P03_002175_2211). Scale bars are 5 km in all cases.