GLACIERS, PERMAFROST, AND DRY MASS FLOWS, AND THEIR STRIPING, CORRUGATION, AND DEGRADATION ON MARS AND THROUGHOUT THE SOLAR SYSTEM. J.S. Kargel[1], H. Miyamoto[2], and R. Furfaro[3]. [1]Department of Hydrology and Water Resources, University of Arizona, Tucson, AZ, USA 85721 (kargel@hwr.arizona.edu). [2]University of Tokyo. Japan. [3]Department of Aerospace and Mechanical Engineering, University of Arizona, Tucson, AZ, USA 85721.

Introduction: Landform production due to landslides, avalanches, debris flows, and noninertial flows due to creep of ice, soils, and talus (and the degradation of these features) has been observed on Earth and inferred on Mars. We are exploring the characteristics and origins of flow lineations and corrugations, how they are produced, how they are etched by ablation, how they degrade over time, and what deposits or erosive structures they leave once the ice disappears. Common processes and also differences are evident in glacial/periglacial flows on Earth and Mars. As we seek ideal landform and environmental analogs on Earth for features on Mars, it is useful also to step back and consider possible regolith creep/flow processes, landslides, and other mass flows in Earth's dry regions, on asteroids, comets, icy satellites, and the Moon. Explored solid planetary objects represent 4 orders of magnitude variation in surface gravity; temperatures span an order of magnitude; and atmospheric and hydrologic effects range from pervasive to absent. Even on the smallest, atmosphereless objects, diurnal heating/cooling, impact/seismic shaking, and other processes, which also occur on Mars and Earth, are represented, according to image interpretation. Slope streaks and landslides are common even on low-g bodies. Ablation (sublimation and/or melting), eolian erosion, burial, tectonism, and other processes tend to obliterate or overprint these flows, but selective ablation can etch and accentuate internal structure diagnostic of flow. The degree of coherence (viscous coupling) and the relative rates and cumulative effects of these processes determine the geomorphic expressions of flows.

A multiplanetary comparison of mass movements and ice ablation landscapes on Mars compared with those on Earth, small asteroids, outer planet satellites, and comets shows that all of these objects exhibit dry mass movements, but only Earth and Mars clearly exhibit glaciers and rock glaciers according to geomorphological definitions. (Triton, Titan, and Enceladus also might have glacier-like flows and glacial landforms, but this remains highly conjectural.) We define four competing classes of processes that combine to produce many of the flow characteristics of a creep-produced landform: (1) coherent, viscously coupled flow and (2) incoherent mass diffusion; (3) flow-structure-controlled ablation, and (4) random or obliterative degradation.

Flow fields are revealed in glacial and periglacial flows by: (a) Topographic undulations related to bed topography and obstructions. (b) Formation of medial moraines of rock debris. (c) Formation of crevasse fields and other tensional tectonic forms due to shear and extension. (d) Buckling and folding due to compression or to unsteady flow from multiple sources. Partial sublimation and/or melting of these landforms cause etching and can enhance the visibility of flow-produced structure. A key common aspect is that disturbances propagate down-flow, and the more coherent the flow, the more complete is this propagation. Glaciers are among the most coherent surface flows of all mass movements, because they are completely laminar, have spatially distributed sources, and are well coupled by viscosity.

Most extant Martian and most terrestrial glaciers differ in accumulation source characteristics, prevalent temperature conditions (much colder on Mars), ablation dominated by either sublimation (Mars) versus melting (Earth), and some dynamical differences (such as common sliding over thawed beds on Earth, and presumably not on Mars). However, many dynamical behaviors and morphologies are very similar or identical. The flow structure within stagnating glaciers commonly is obliterated under the assault of randomized thermokarst and other degradational activity. Whether flow structures are visible at the surface thus depends on the relative vigor (process rates) of flow deformational activity, structure etching by degradational processes that are coherently linked to flow structure, and structure obliteration by diffusive mass transfers and incoherent degradation.

At the other extreme, pure diffusive in-situ disturbances (e.g., freeze-thaw, heating-cooling, wetting/drying, hydration/dehydration, bioturbation, and seismic shaking) produces colluvium, sorted stone circles, ice-wedge polygons, and other anisotropic structures, except that vertical sorting and minor lateral segregation of materials may occur. When these processes occur on slopes, downslope movement typically occurs, and this is normally betrayed by primary and ablational features. The possibility exists that very slow downslope transport due even to heating/cooling cycles or repeated impact shaking can produce features resembling rock glaciers if given enough time and if obliterative processes occur more slowly; candidates are identified on asteroid Itokawa in Hayabusa images.

There is a complete gradation between purely diffusive disturbances of clastic materials and fully viscously coupled flows. Similarly, there is a complete gradation between ablation processes that are random on the large scale, versus those that are coupled tightly to flow structures. It is the latter that provides some of the best evidence for viscously coupled glacial and periglacial flows of material. Dry mass movements and other clast-supported flows in some cases may exhibit some structures diagnostic of flow, but they do not undergo ablation etching (unless they are icy avalanches or ice-dominated debris flows). Icy terrains that have not undergone significant flow activity may nevertheless produce dramatic ablation terrains, but the ablation features will not produce textures suggestive of flow. Ablation terrains in low-gradient, non-flowing permafrost on Earth, Mars, and even comet Wild2 are remarkably similar to one another.

We shall show new HiRISE, Stardust, Hayabusa, and ASTER images and other observations of icy type flows and ablation features on Mars, Earth, asteroid Itokawa, comet Wild2, and elsewhere.

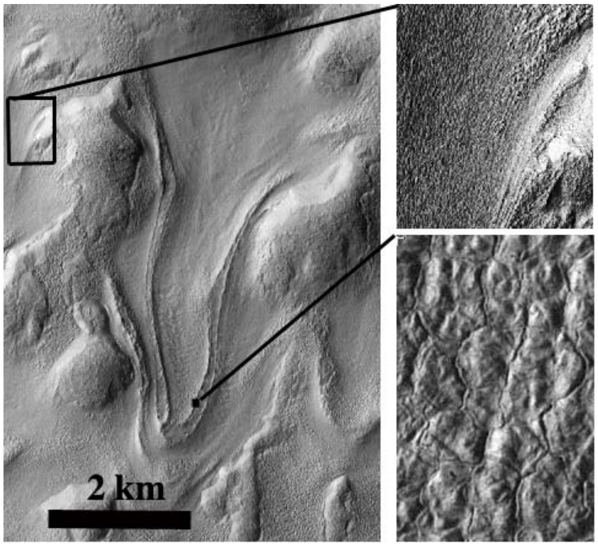

Fig. 1. HiRISE image of Martian flow easr of Hellas.

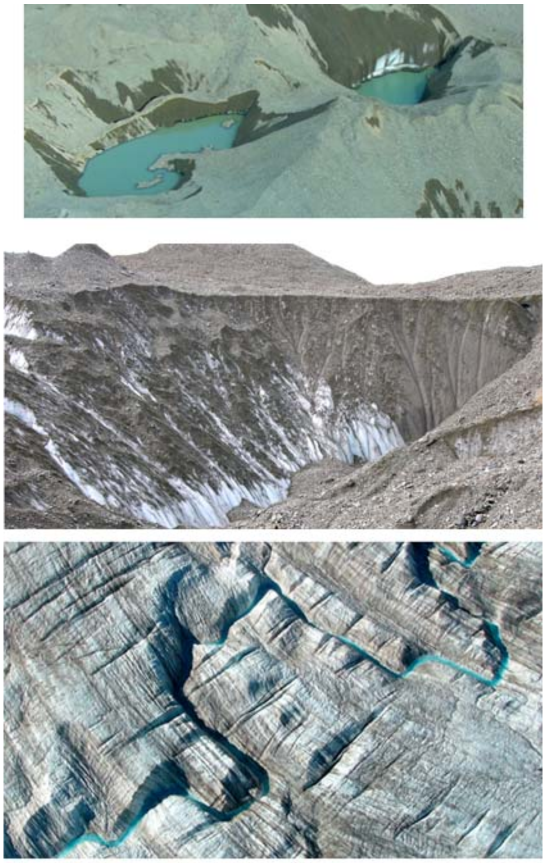

Figure 2. Kennicott Glacier, Alaska.. (Top). Totally stagnant, debris-covered ice undergoes ablation without structural control by the glacier. (Middle) Medial moraines of rock debris become elevated due to thermal insulation and reduced melting compared to debris-free parcels of ice. (Bottom) A stream, a couple meters across, winds across the Root Glacier. Its path is structurally controlled in two orthogonal directions by (1) the relief and foliation of ogives, and (2) crevasses.

Figure 3. Terrestrial glacier remnant in the Himalaya, where the moraine loop represents deposits from a former extension of the glacier now wasted into the higjh-elevation cirque. Photo by J. Kargel.

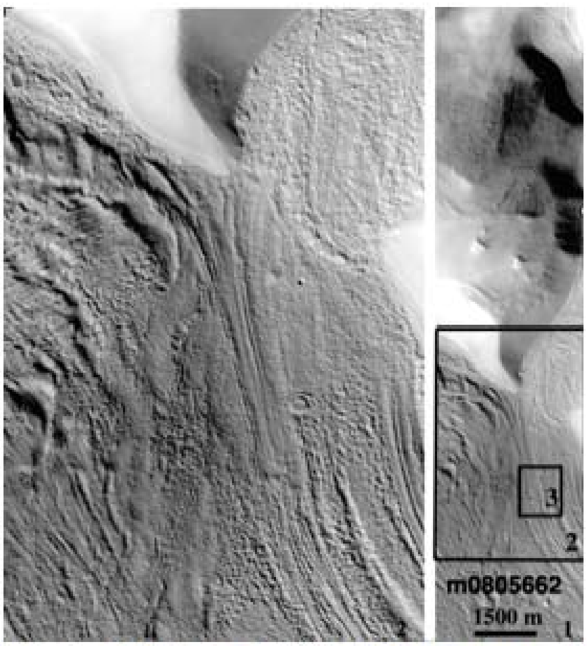

Figure 4. MOC image of ablation-etched flow structures in Coloe Fossae, Mars, including prominent medial moraines formed at the confluence of two debris-rich glacier-like flows

Figure 5. Medial moraines of Root/Kennicott glaciers (Alaska) have been etched by ablation to reveal laminar flow