PROTALUS RAMPARTS AND TRANSVERSE RIDGE MORAINES ON MARS: INDICATORS OF SURFACE ICE DEPOSITIONAL PROCESSES.

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Introduction: Ridges resembling terrestrial protalus ramparts and transverse ridge moraines, which are ridges of debris that form through a variety of surface ice depositional processes, are associated with some gullies and alcoves on Mars. At least two types of ridges appear to exist on Mars including a rare non-sinuous variety with a broad profile (Figure 1), and a more common narrow and sinuous variety (Figure 2). The objective of this abstract is to illustrate that these ridges could be indicators of surface ice depositional processes and that a thorough understanding of the terrestrial forms is required to interpret them.

Protalus Ramparts: These are ridges of talus that gradually accumulates along the downslope margin of perennial snow and firn banks as talus slides, rolls, or bounces across them [1]. Protalus ramparts are oriented approximately transverse to slope, with the ends often following the perimeter of a snow or firn bank upslope. The better examples usually form below well-developed nivation hollows [2] at the bottom of steep, rocky slopes where the supply of talus is great.

Protalus ramparts may be able to form on Mars below sheets of ice derived from seepage associated with gully and alcove formation [3]. Talus derived from the walls of craters or valleys could accumulate along the lower perimeter of these sheets of ice. If the supply of talus is great enough and a sheet of ice persist long enough with a fairly stable lower perimeter, a protalus rampart could form.

Protalus ramparts can have a transitional relationship with terminal moraines associated with cirque glaciers and these two types of landforms may exist in the same environment [2]. If a firn bank thickens sufficiently in response to a change in its mass balance to deform viscously, a cirque glacier may gradually form and a protalus rampart previously associated with it may evolve into a terminal moraine. In transitional cases, identification of a ridge of talus as either a rampart or moraine can be problematic. Sheets of ice associated with gullies and alcoves on Mars could develop into features similar to terrestrial cirque glaciers if the ice thickens sufficiently to deform viscously [4].

Transverse Ridge Moraines: Terminal moraines are marginal ice-contact features oriented transverse to flow, and if the movement an ice sheet is lobate, it may follow the perimeter of the lobe (Figure 1).

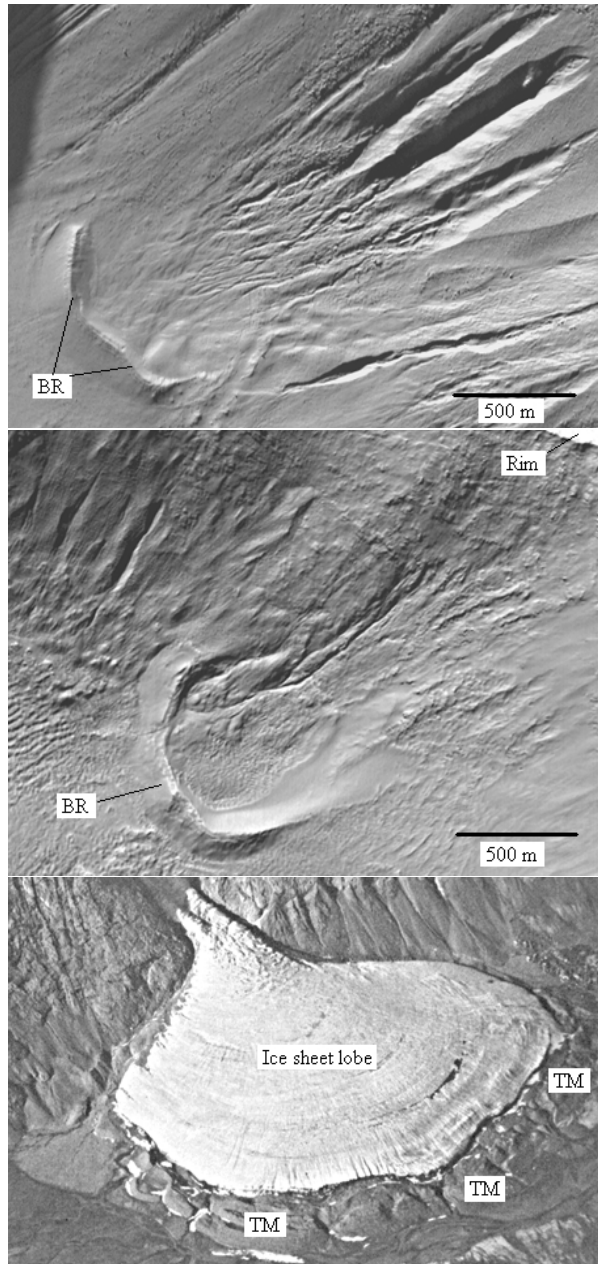

Figure 1: (Top and middle): Two broad ridge (BR) features formed below gullies and alcoves on crater walls. These curved features are consistent with formation in association with a lobate ice sheet and may be protalus ramparts or terminal moraines. Rims at top right. Lighting from top left. North at top. MOC image M2001718 and M1901783. (Bottom): Terrestrial lobate ice sheet with strongly curved terminal moraine (TM).

Terminal moraines form by the processes of dumping, squeezing, pushing, and glacitectonics [5]. In the case of dumping, englacial debris is transported to the surface of the ice along shear planes or flow lines and, through the processes of ablation and flow, accumulates into ridges or belts near a glacier front [5]. In the case of squeezing, water-saturated subglacial till moves under ice in response to the pressure exerted by the glacier and emerges along the ice front [5]. Pushing can generate push moraines, which are ridges that are formed by the bulldozing effect of advancing ice. Thrustblock moraines and composite ridges are formed by glacitectonic activity [6]. A combination of the above mechanisms may generate an individual transverse ridge during temporary halts of a glacier front and a series of these can form through history as a glacier advances and retreats.

In contrast to terminal moraines, interior moraines, which are interior ice-contact features, are created by subglacial processes and can take the form of transverse ridges as well [5]. Rogen moraines or ribbed moraines may form through the molding of saturated subglacial sediments by transverse differential stresses, or by deposition through ablation of debris-rich blocks of ice concentrated along thrust planes in zones of compressive flow [5]. Cross-valley moraines and washboard moraines or moraine ridges form within the marginal zone, commonly parallel to the ice front, possibly through pushing and squeezing phenomena [5].

References: [1] Ballantine, C.K. and Harris, C. (1994) The Periglaciation of Great Britian. Cambridge University Press. [2] Thorn, C. (1988) In: Advances in Periglacial Geomorphology. John Wiley & Sons Ltd. [3] Arfstrom, J.D. (2002) LPSC Abstract, 33, 1174. [4] Arfstrom, J.D. (2002) LPSC Abstract, 33, 1092. [5] Ritter, D.F. et al. (2002) Process Geomorphology. McGraw-Hill. [6] Benn B.I. and Evans J.A. (1988) Glaciers & Glaciation. Arnold Pub.

Figure 2: (Top) Two sets of narrow, sinuous ridges (NSR) at different topographic levels appear to be associated with an ice-rich material (IRM) that may be eroded by sublimation (EBS). MOC image M2001259. (Bottom) The well known C-Newton crater. The narrow, sinuous ridge may have formed at the margin of a sheet of ice that has sublimed away. The ridge runs up the slope (US), which supports interpretation as an ice sheet marginal feature rather than a shoreline feature. Smaller parallel ridges may be recessional ridges (RR). Lighting is from top left. North is at top.