RAPID GROWTH OF MARS-ANALOG GULLIES IN A BURIED ICE SUBSTRATE: GULLIES AS A DISEQUILIBRIUM LANDFORM IN GARWOOD VALLEY, ANTARCTICA . Joseph S. Levy[1], Andrew G. Fountain[1], Thomas H. Nylen[1], James W. Head[2], James L. Dickson[2] [1]Portland State University Department of Geology, Portland, OR, 97201. jlevy@pdx.edu, [2]Brown Univ. Dept. of Geological Sciences, Providence, RI 02912.

Introduction. The McMurdo Dry Valleys of Antarctica are a key location for documenting the physical processes driving Mars-analog gully formation under cold, polar desert environmental conditions [1-2]. Mars-like attributes of Antarctic gullies include ephemeral and sporadic flow associated with peak insolation, top-down melting of surface snow and shallow ground ice, and bounding of gully hydrological processes by underlying ice-cemented permafrost [1,3]. Like martian gullies [1, 4-6], Dry Valleys gullies are thought to form from primarily though fluvial/alluvial processes.

Gullies and Buried Ice on Mars. Recent HiRISE observations have raised the intriguing possibility that many martian gullies formed directly in the latitude dependent mantle (LDM)—a geologically recent, surface deposit on Mars composed primarily of ice admixed with internal and surficial (lag) sediments [7-8]. Key observations supporting this hypothesis are the erosion of gully channels into LDM-surfaced slopes and the preservation of remnant gully fans (not associated with a visible channel) at low latitudes in locations where the LDM has become dissected (depleted in ice) [8,13]. These results suggest that buried, debris-bearing ice, rather than regolith or bedrock, may be the primary substrate in which many gullies form on Mars.

Gullies and Buried Ice in Antarctica. Buried or debris-covered glacial ice is common in the McMurdo Dry Valleys, Antarctica [9]. However, much of this massive ground ice is present at high elevations in the Upland Stable Zone (e.g., Beacon Valley), where ground ice melting does not occur [2]. Garwood Valley, a low-elevation and coastal member of the McMurdo Dry Valleys (78ºS, 164ºE) provides a unique terrestrial analog for studying the rates and mechanisms of gully formation in massive, debris-bearing, buried ice deposits (Figs. 1-2).

In Garwood Valley, a reentrant lobe of the West Antarctic Ice Sheet/Ross Ice Shelf was stranded at the close of the last glacial maximum (LGM), ~6-12 ky before present [10]. The LGM ice lobe fills the middle and lower portions of the valley and is surfaced by a silt-sand drift that is capped by a cobble and boulder desert pavement. The buried ice is currently out of equilibrium with the colder LGM temperatures that characterized its emplacement, resulting in the formation of numerous thermokarst ponds. The valley is drained by the glacier-fed (essentially first-order) Garwood River. Bank erosion by the river has revealed a 10-15 m tall "ice cliff" composed of glacier ice interbedded with sediment-rich river ice lenses, and capped by sandy drift and ice-cemented fluvio-deltaic sediments.

Gullies, consisting of a recessed alcove, sinuous channels, and a sedimentary fan or apron [11] have formed in this unusual sediment-capped ice deposit. Field observations of Garwood gullies during 2009 and 2010 indicate that the gullies support sediment transport through fluvial sedimentation and erosion, wet debris flows, and dry granular flows, depending on sediment availability (spatially variable) and water availability (seasonally variable).

Direct insolation on the steep ice surface results in melt generation and runoff over the ice surface during the austral summer. Alcoves form in the ice during this insolation-driven melting, resulting in undercutting of the overlying sediments. Periodic collapse of the mantling sediments results in the introduction of sediment into the gully, which is transported downslope through sinuous channels to sand-dominated fans. Like many martian gully fans [12], these Garwood gully fans show evidence of fluvial reworking.

Garwood Valley gullies represent an extreme case of rapid landscape change in response to a strong disequilibrium between ground ice and surface temperature/humidity conditions. During peak summer, several cm (up to 10 cm) of ablation (backwasting) can occur per day in the gully alcoves as measured by a sonic ranger. Repeat LiDAR scans conducted in January, 2011 will provide a year-to-year measure of gully alcove erosion and fan aggradation volumes, permitting the calculation of Mars-analog gully alcove and fan growth rates. Rapid ice removal, coupled with a limited sediment supply, may result in the eventual destruction of the Garwood buried ice gullies, leaving only modified, channel-less, remnant sediment fans as evidence of past activity. On shorter (seasonal) timescales, the cessation of overland flow during winter, coupled with erosive katabatic winds, was found to result in the geomorphic muting of gullies to the extent that they resembled ungullied slopes prior to flow reactivation during late summer (Fig. 2).

Conclusions. Garwood Valley, Antarctica, is a type locality for studying cold desert gully development in a buried ice substrate. Gully alcove development can occur rapidly—on annual, or even seasonal timescales—when ice, rather than sediment or bedrock, is the primary eroded material. Ice melting and sublimation are the major drivers of alcove growth for gullies forming in buried ice substrates, rather than fluvial or debris-flow erosion of sediment. Removal and transport of overlying and/or englacial sediment results in the formation of well-preserved, fluvially modified fans.

References. [1] Head, J.W., et al. (2007) *10th ISAES,* Abstr. #151. [2] Marchant, D.M. & Head, J.W. (2007) *Icarus*, 192, 187-222. [3] Levy, J.S. et al. (2009) *Icarus, 201,* 113-126. [4] Dickson, J.L. et al. (2007) *Icarus, 188*, 315-323. [5] Lanza, N.L. et al. (2010). *Icarus*, 205, 1, 103-112. [6] Levy, J.S. et al. (2010) *EPSL*, *294,* 368-377. [7] Head, J.W. et al. (2003) *Nature*, 426, 797-802. [8] Dickson, J.L. & Head, J.W. (2009) *Icarus, 204,* 63-86. [9] Bockheim, J.G. et al (2007) *PPP*, 18, 3, 217–227. [10] Stuiver, M. et al. (1981) *Last Great Ice Sheets*, 319-346. [11] Malin, M.C. & Edgett, K.S. [2000] *Science*, 288, 2330-2335. [12] Schon. S.C. et al. (2009) *Geol, 37,* 207-210. [13] Head, J.W. et al. (2008) *PNAS*, 105*,* 13258-13263.

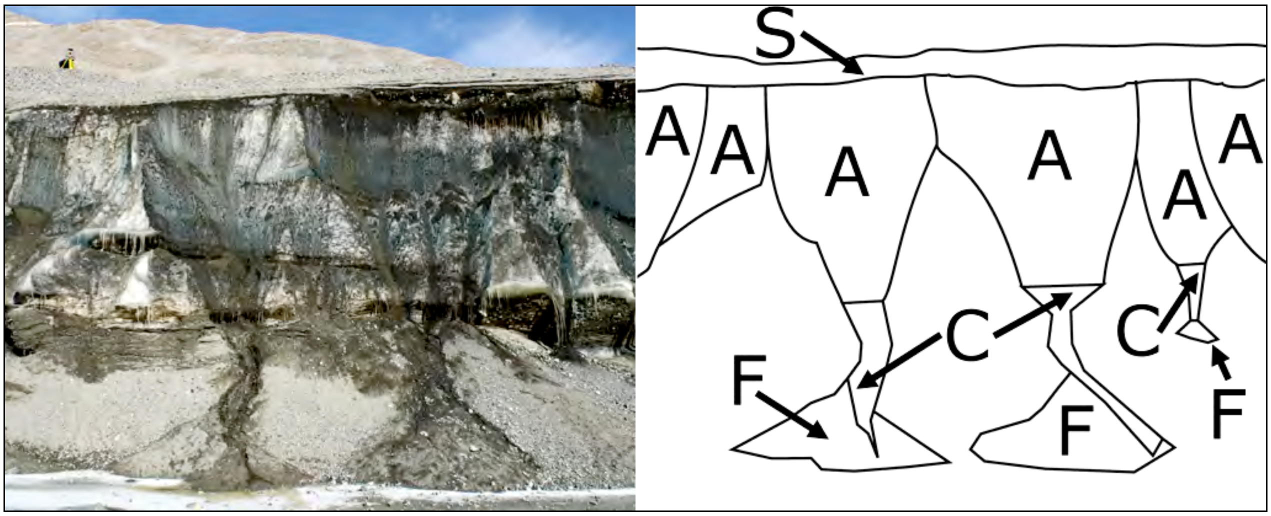

Fig. 1. Gullies forming in a buried ice substrate in Garwood Valley, McMurdo Dry Valleys, Antarctica. Note ~1.5 m tall surveying tripod to upper left for scale, located atop glacio-fluvial sediments (S). Gullies consist of a recessed alcove eroded from nearly pure, blue/white glacier ice (A), sinuous channels (C), and sedimentary fans (F).

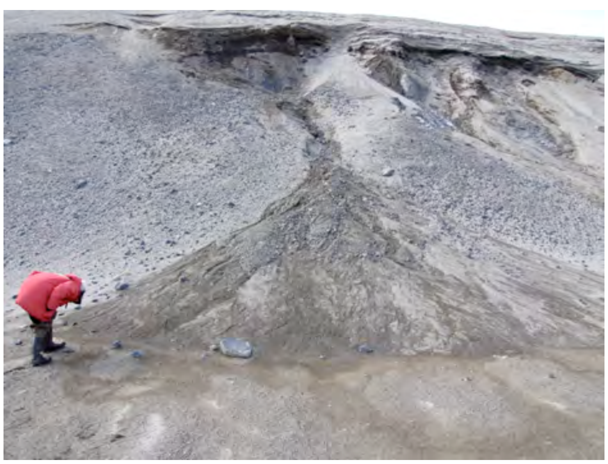

Fig. 2. (Left) Gullies forming as buried ice (blue, exposed in alcove) mobilizes overlying fluvio-deltaic sediments during January, 2010. Algal mats are abundant at the gully base. (Right) The same hillslope in December, 2010, prior to the onset of summertime melting. Bright pixels are locations of outcropping buried glacier ice.