HOW TO BUILD A GULLY IN A DAY AND ERASE IT IN A YEAR: OBSERVATIONS OF SMALL SCALE FLUVIAL EROSION AND DEPOSITION IN ANTARCTIC BURIED ICE LANDSCAPES AS ANALOGS FOR MARTIAN GULLIES AND RSL. Joseph S. Levy[1], Andrew G. Fountain[2], James W. Head[3], James L. Dickson[3] [1]University of Texas Institute for Geophysics, Austin, TX 78758. [2]Portland State University Department of Geology, Portland, OR, 9720, [3]Brown Univ. Department of Geological Sciences, Providence, RI 02906. joe.levy@utexas.edu

Introduction. The McMurdo Dry Valleys of Antarctica are a key location for documenting the physical processes associated with 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, Dry Valleys gullies are thought to form through sediment transport by fluvial/alluvial processes, punctuated by debris-flows [1, 4-6].

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 [7-8, 14]. 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]. 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. Recent observations of fresh impacts into mid-latitude LDM deposits have shown the presence of high purity ice beneath <1 to a few meters of regolith, at latitudes polewards of 39° [9].

Concurrent with these observations, analyses of ten southern hemisphere gully sites showing evidence of seasonal change suggest that "dry" (CO_2-dominated or volatile-free) geomorphic processes are at work in some modern gully environments [10]. These sites show modification of gully channels and fans that occur during the winter season on Mars, during which water ice melt or water-based brine flow is not expected to be an active geomorphic process.

Multi-Year Observations of Gullies and Buried Ice in Antarctica. Garwood Valley, one of the southern, coastal 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. Gullies, consisting of a recessed alcove, sinuous channels, and a sedimentary fan or apron [11] have formed and evolved during the 2009-2013 observation period in association with the sediment-capped massive ice deposits in the valley [12]. Significant new observations from Garwood valley time lapse imaging and repeat LiDAR imaging include: 1) erosion of complete, ~10 m long gullies (alcove, channel, fan) by a combination of fluvial erosion and slope failure (http://goo.gl/OVvC5t); 2) resurfacing of gully channels and fans by digitate and incrementally growing flows of dry sediments (http://goo.gl/9hcU0P); 3) complete working of the landscape over multi-year timescales as dry sediments are deposited or removed (Fig. 1); 4) annual incision and deposition rates for gully channels in excess of 1 m/yr, despite <3 months of seasonal discharge (Fig. 2); and 5) broadscale fan darkening similar to that observed at RSL sites by [13] (Fig. 3).

Discussion. Garwood Valley, Antarctica, is a type locality for studying cold desert gully development in a buried ice substrate where ground-ice melt drives gully growth. It is also an ideal laboratory for studying dry mass-wasting processes that modify and degrade gullies. Gully alcove and channel development can occur rapidly—on annual, or even seasonal timescales—when ice, rather than sediment or bedrock, is the primary eroded material. Dry mass-wasting can modify gullies by transporting sediment through gully channels, or draping fan deposits, resulting in signficnatly reworking and "removal" of fluvial landforms. Dry processes can produce digitiate flows with similar morphology to wet flys. Garwood analog gullies show that both "wet" and "dry" geomorphic agents can affect gullies in a single microclimatic zone.

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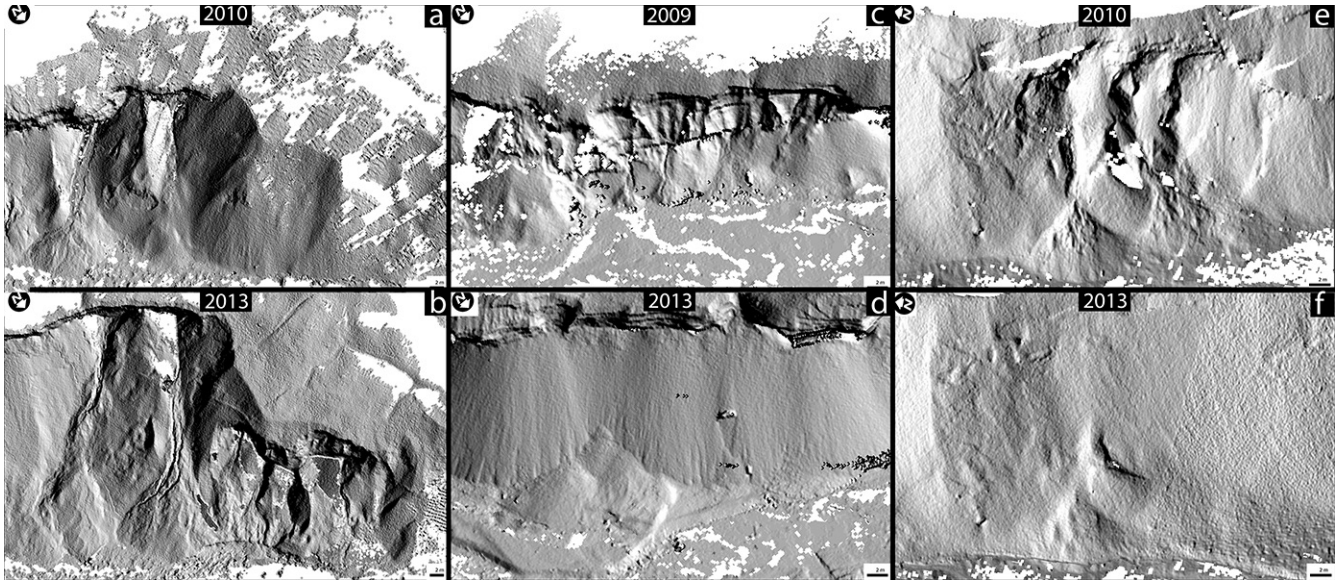

Fig. 1. Erosion of gully channels and deposition of gully fans and removal of those channels and fans by dry mass wasting of sand and gravel. Data are hillshade models from ground based LiDAR data collected in the year shown in each panel. Data gridded to 0.1 m/pixel. a&b) Erosion of fans and alcoves. c&d) Removal of alcoves and channels (digitate debris lobes are visible). e&f) Removal of alcoves, channels, and fans by dry mass wasting.

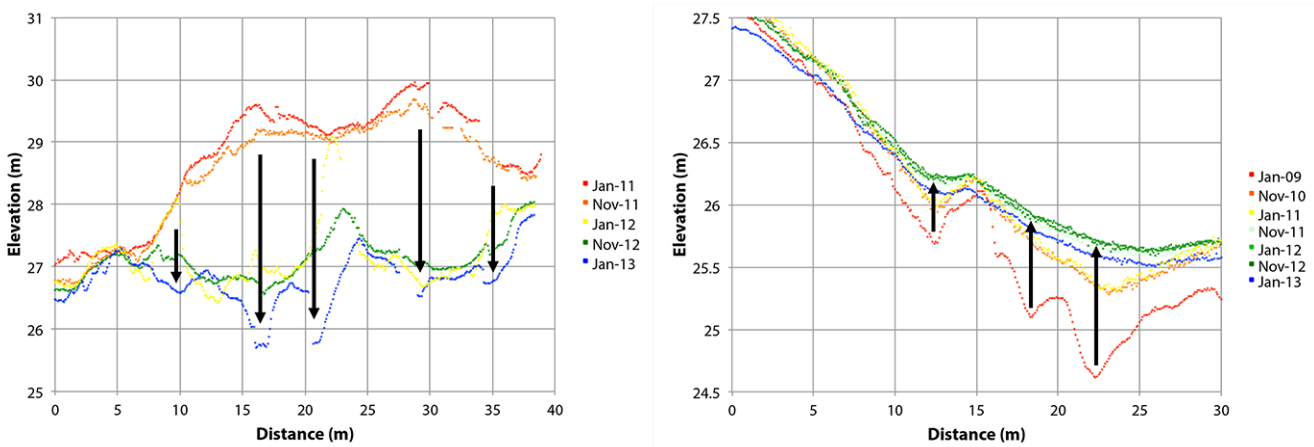

Fig. 2. Topographic profiles showing channel erosion (left) and infill (right) through time. Profiles are collected along gullied slopes, orthogonal to the flow direction.

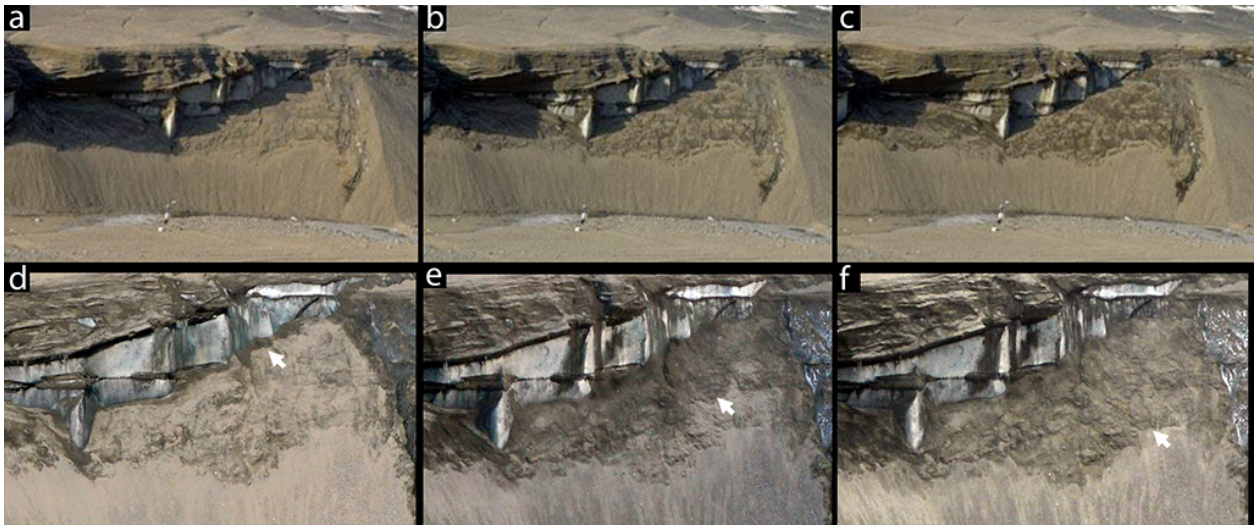

Fig. 3. Fan darkening similar to that observed on RSL fans by [13]. Images are 5 minutes apart with a 1 hour hiatus between a-c and d-f. a-c shows uniform darkening as sediment frozen the previous day thaws. d-f shows a wave of soil darkening (arrows) as melt from the buried ice infiltrates into the ice-cored talus cones and flows downslope.