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 Levy[1], Andrew Fountain[2], James Head[3], James Dickson[3] [1]University of Texas Institute for Geophysics, Austin, TX 78758. [2]Portland State Univ. Departmentof Geology, Portland, OR, 97210. [3]Brown Univ. Department of Geological Sciences, Providence, RI 02906. joe.levy@utexas.edu

1. Martian Gullies: Wet or Dry?

Recent HiRISE observations have raised the intriguing possibility that many martian gullies formed directly in the latitude dependent mantle (LDM), an ice-rich mantling unit found ubiquitously at high (>~40°) latitudes on Mars [1-3]. Key observations supporting this hypothesis are:

- Erosion of gully channels into LDM-surfaced slopes [1].
- Gully erosion of pre-existing polygonally patterned ground [4].
- 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) [2].

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.

Concurrent with these observations, analyses of ten southern hemisphere gully sites showing evidence of seasonal change suggests that "dry" (CO_2-dominated or volatile-free) geomorphic processes are at work in some modern gully environments [5]. 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.

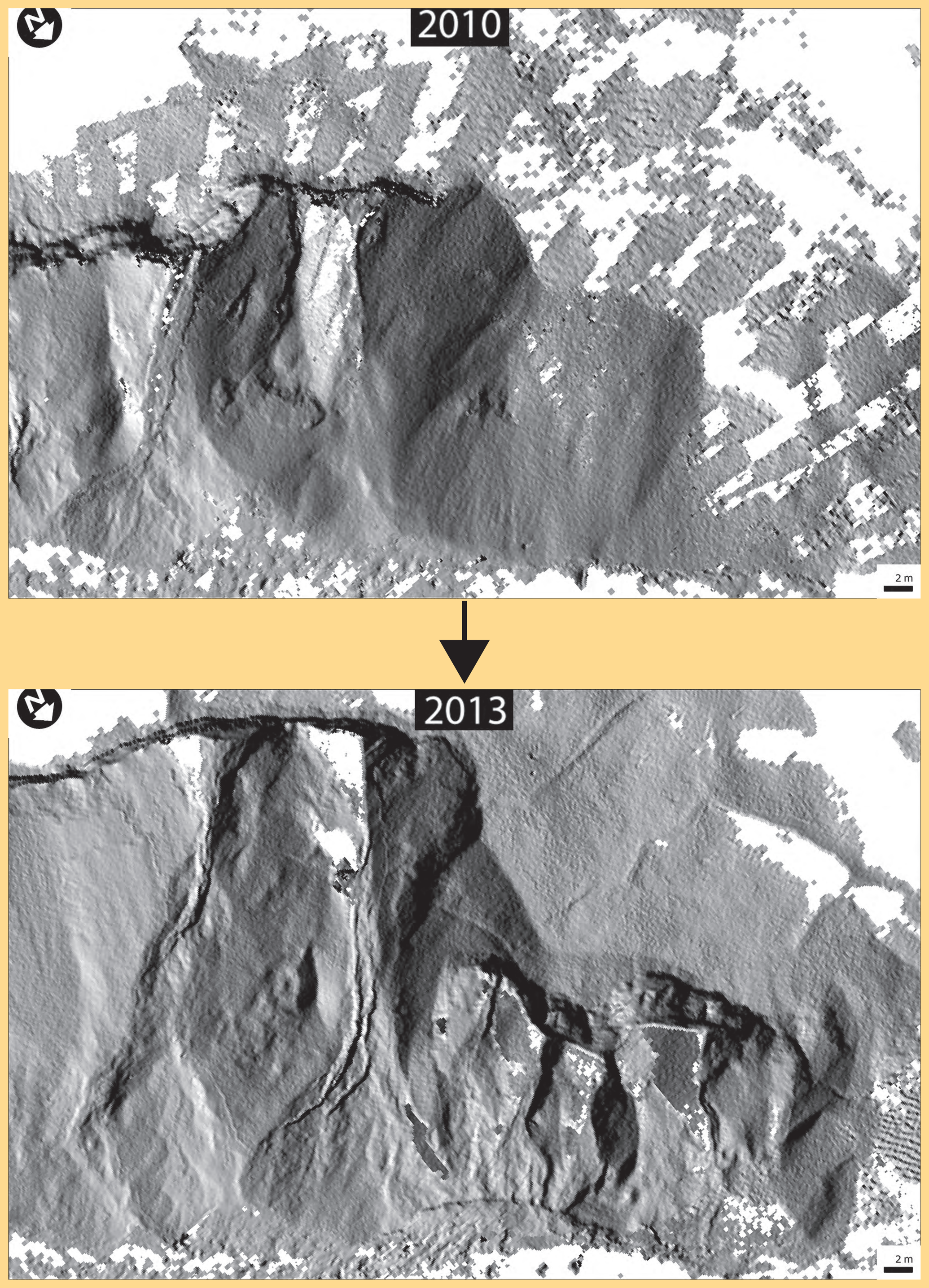
2. Antarctic Observations

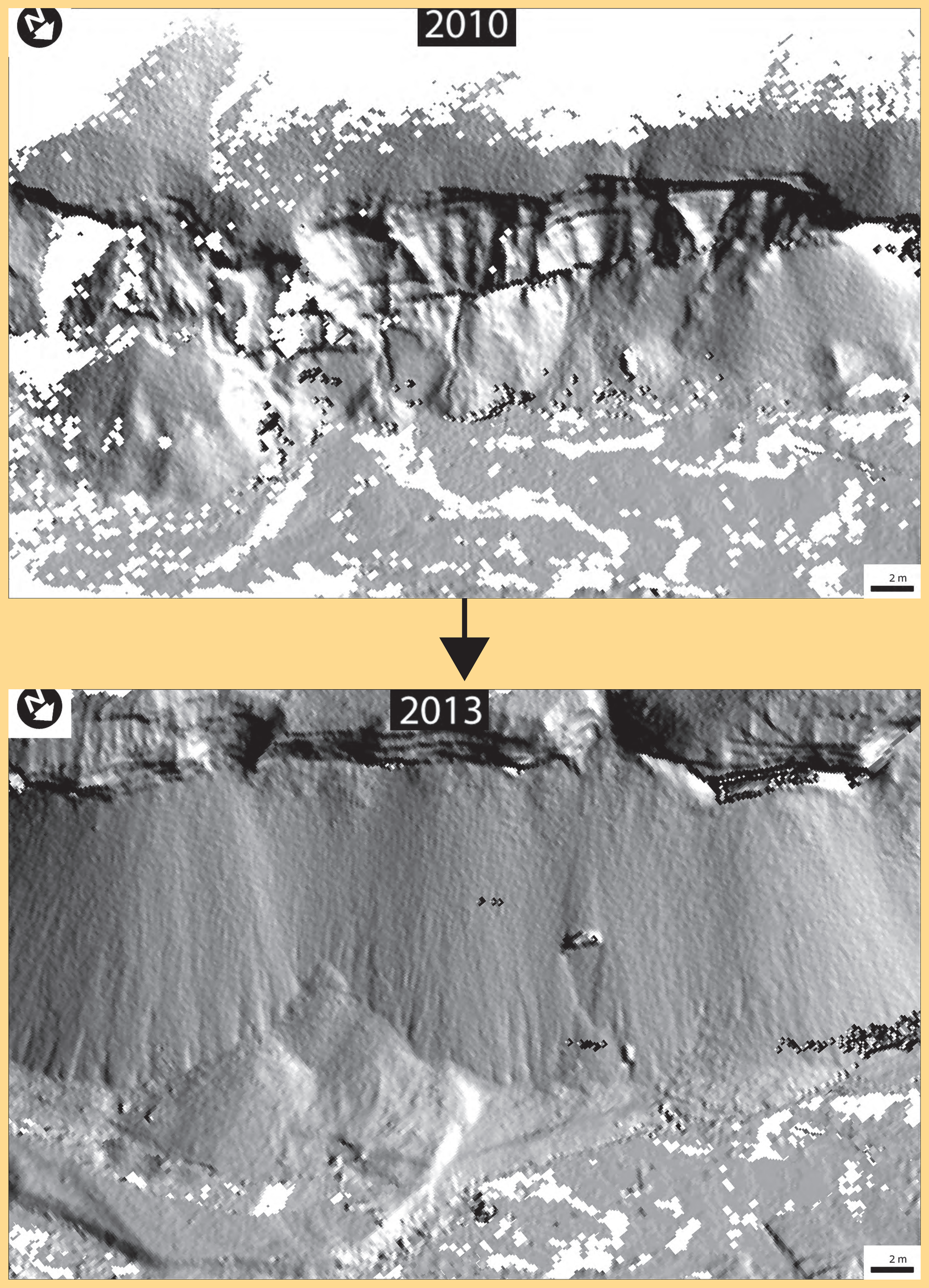
In order to understand the roles of wet and dry mass wasting processes in an LDM-analog buried ice substrate, we have conducted multiyear observations of gullies and buried ice in Garwood Valley, Antarctica, one of the southern, coastal McMurdo Dry Valleys (78°S, 164°E).

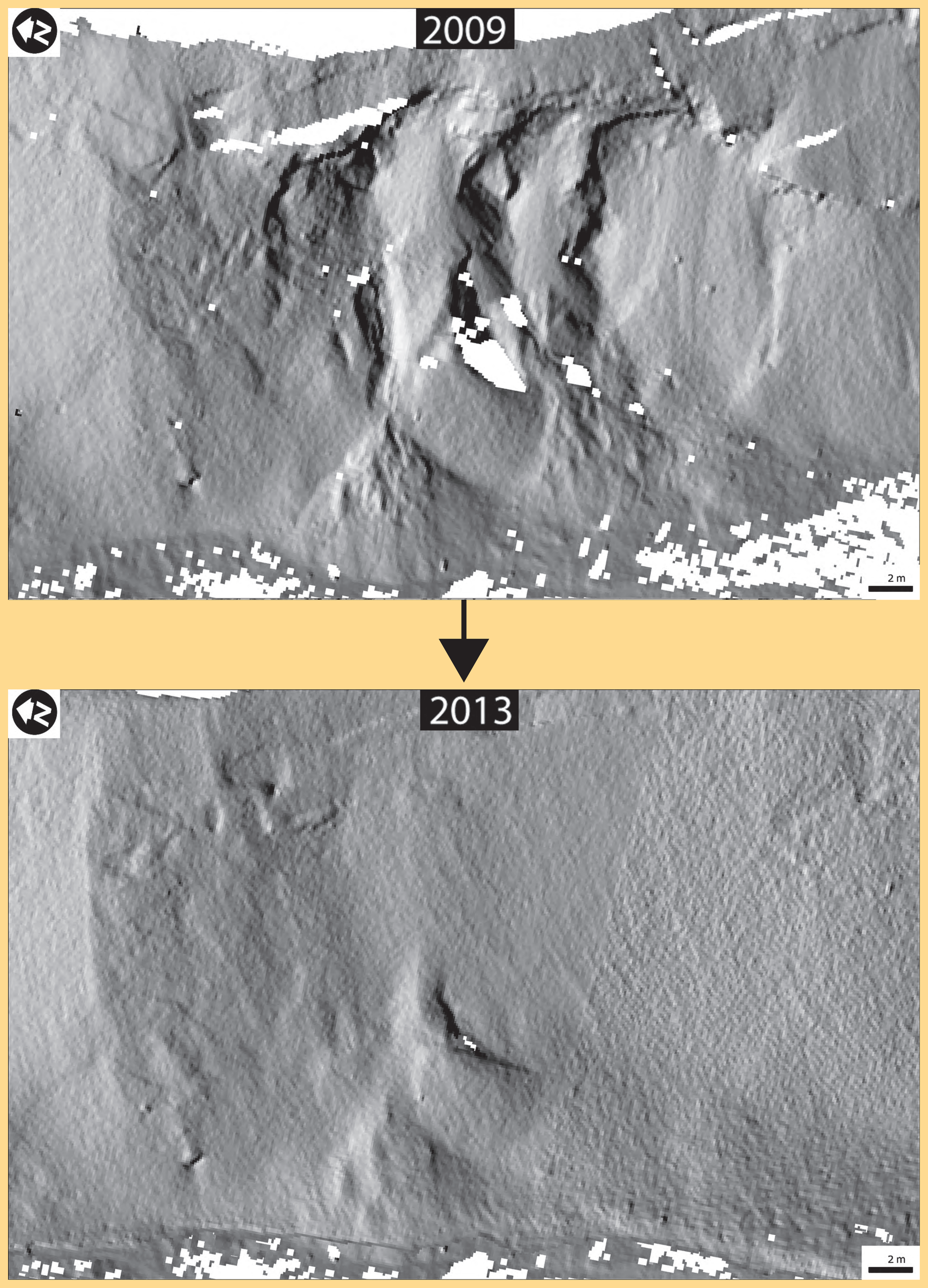
Gullies, consisting of a recessed alcove, sinuous channels, and a sedimentary fan or apron [6] have formed and evolved during the 2009-2013 observation period in association with the sediment-capped buried ice deposits in the valley [7]. Significant new observations from Garwood valley time lapse imaging and repeat LiDAR imaging include:

- Erosion of complete, ~10 m long gullies (alcove, channel, fan) by a combination of fluvial erosion and slope failure in ~24 hours.
- Resurfacing of gully channels and fans by digitate and incrementally growing flows of dry sediments.
- Complete working of the landscape over multiyear timescales as dry sediments are deposited or removed.
- Annual incision and deposition rates for gully channels in excess of 1 m/yr, despite <3 months of seasonal discharge (See Section 3).
- Broadscale fan darkening similar to that ob-served at RSL sites by [8] (See Section 7).

P.S.-If I'm at the poster, you can see these full-res! Otherwise, please download them on your smartphone or tablet!

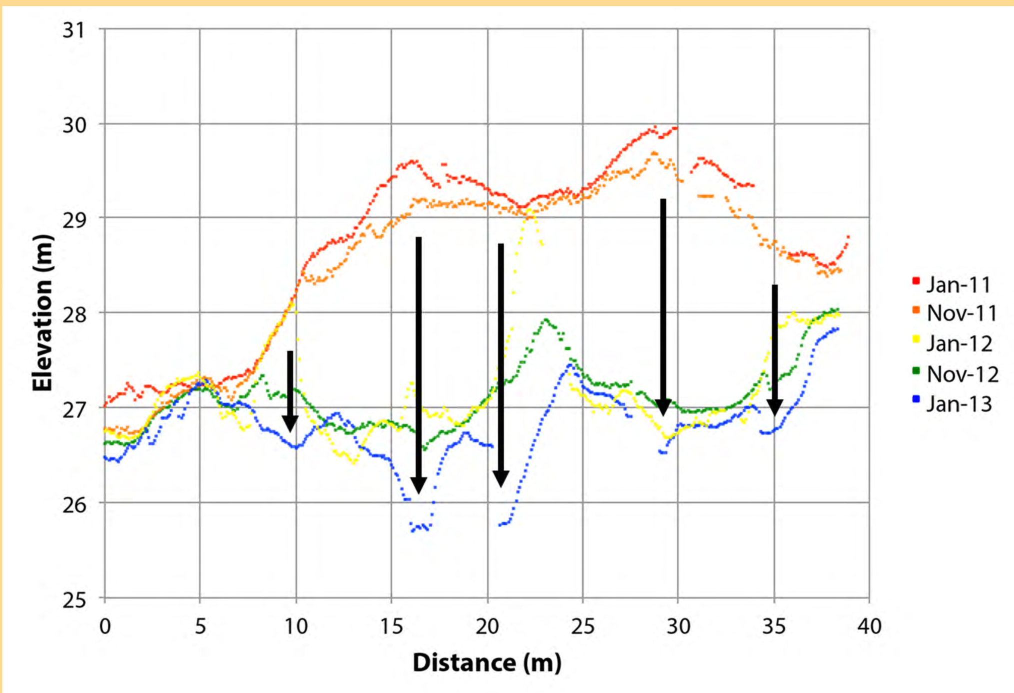






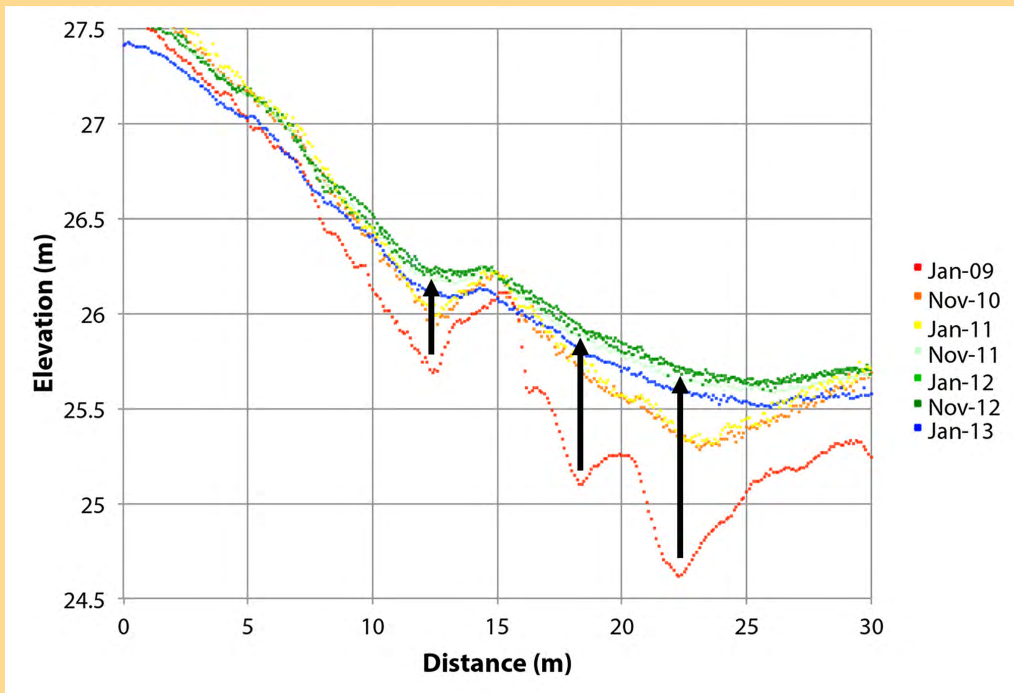
3. Rapid Fluvial Erosion

A permafrost calving event during austral winter 2011 resulted in the fresh exposure of buried ice in this field of view. Summer insolation warmed the dark sediment above the ice, resulting in rapid melting and erosion of a broad channel in '11-'12, and incision of a set of deep (~1 m) channels in '12-'13. Cross-channel profiles shown below.



4. Overprinting

Oversteepening of gully slopes resulted in the sloughing of dry sediment over gully channels. With time, this dry mass wasting infills channels, leaving behind ice-cored talus cones. Daily summer observations show that the behavior is more like "repainting" than "rebuilding" of the gullies. No channels formed via dry mass wasting. Cross-channel profile shown below.



5. Channel Removal

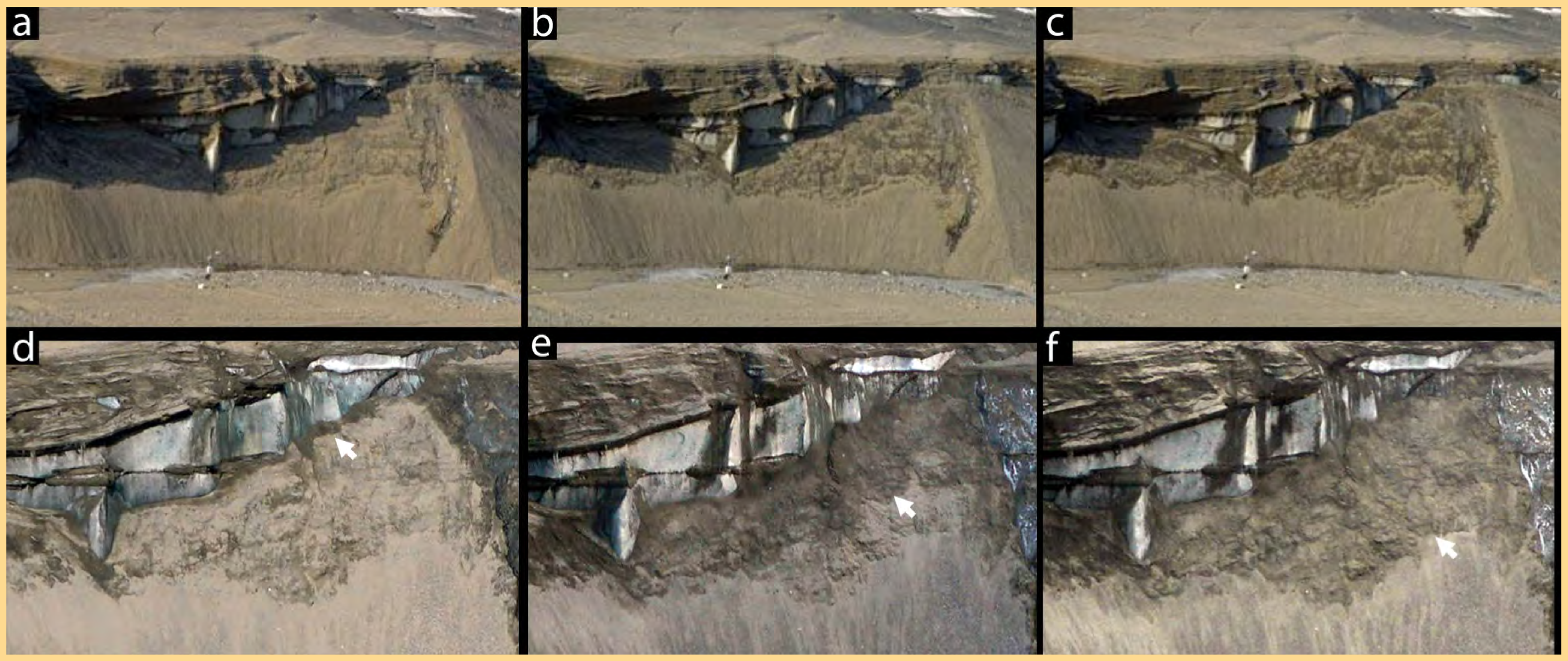
As buried ice is covered by a thick (several cm) sediment lag, seasonal melting is reduced, which results in overprinting and removal of the gully channel. WIthout an exposed ice meltwater source, gully erosion ceases and slopes become smoothed by dry mass wasting. Gully fans can be preserved even in the absence of channels or alcoves.

6. 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, degrade, and resurface gullies**.

Key Conclusions:

- Gully alcove and channel development can occur rapidly—on annual, seasonal, or even daily 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 by draping fan deposits, resulting in signficnatly reworking and "removal" of fluvial landforms via burial or "repainting" with high albedo dry sediments.
- Dry mass-wasting can produce digitiate flows with similar morphology to wet flows.
- Garwood analog gullies show that both "wet" and "dry" geomorphic agents can affect gullies in a single microclimatic zone.



7. RSL Analog?

Fan darkening similar to that observed on RSL fans by [8] is observed in the ice-cored talus cones that front the Garwood Valley ice cliff. Images (right) 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 under morning insolation. 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. Both are insolation-driven melt processes that require the presence of near-surface ground ice. a-c is a pore ice phenomenon. d-f is a consequence of massive ice melt.

8. References

[1] Head, J.W. et al. (2003) Nat., 426, 797-802. [2] Dickson, J.L. & Head, J.W. (2009) Icar., 204, 63-86. [3] Schon, S. & Head, J. (2011) Icar, 213, 428-432. [4] Levy, J.S. et al. (2009) Icar., 201, 113-126. [5] Dundas, C. et al. (2010) GRL, 37, doi:10.1029/2009GL041351. [6] Malin, M. & Edgett, K. [2000] Sci., 288, 2330-2335. [7] Levy, J.S. et al. (2013) GSAB, 125, 1484-1502. [8] McEwen, A. et al. (2013) Nat. Geo., DOI: 10.1038/NGEO2014.

9. Acknowledgements

This work was supported by the NSF Office of Polar Programs Antarctic Earth Sciences division via award PLR-1343835 to JSL.