

MARTIAN GULLIES AND GROUNDWATER: A SERIES OF UNFORTUNATE EXCEPTIONS. A.H. Treiman, Lunar and Planetary Institute, 3600 Bay Area Boulevard, Houston TX 77058 <treiman@lpi.usra.edu>.

In most hypotheses, Martian gullies are initiated or promoted by liquid water as it leaves the ground. In this model, groundwater must be available near gully sites, and the bedrock must include impermeable layers (aquicludes) that do not tilt away from gully sites. Lamentably, nearly all gully sites fail these prerequisites and the requirement for groundwater is questionable.

Introduction: Gullies are commonly inferred to represent debris flows, lubricated and carried by liquid water that flowed from underground [1-8]. The inference of groundwater, based principally on the apparent initiation of gullies at specific bedrock layers [1-6], has not been considered for consistency with local geology. Here, I examine gully occurrences for: presence of impermeable layers (aquicludes) in the subsurface, that the layers not tilt away from the gully-bearing walls, and that liquid water could have been available at or above the gully elevations.

What are Gullies? Gully landforms occur on walls of chasms, pits, impact craters, peaks within craters and basins, knobs, and mesas [1-3,9]; the most com-

Fig. 1. Gullies on crater wall, R15-02707, Noachis; north at top, crater floor to bottom. **A:** alcoves; **C:** channels; **D:** deposit fans. Above gullies is unlayered rubble.

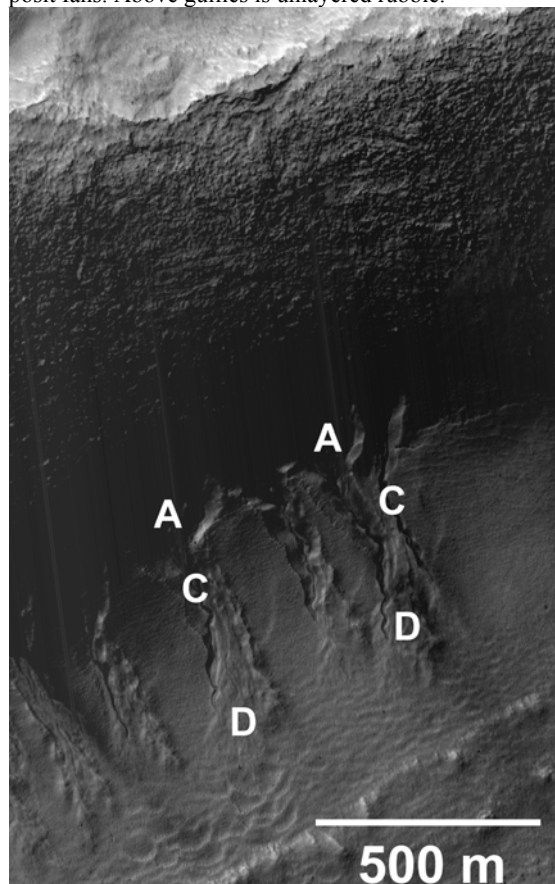
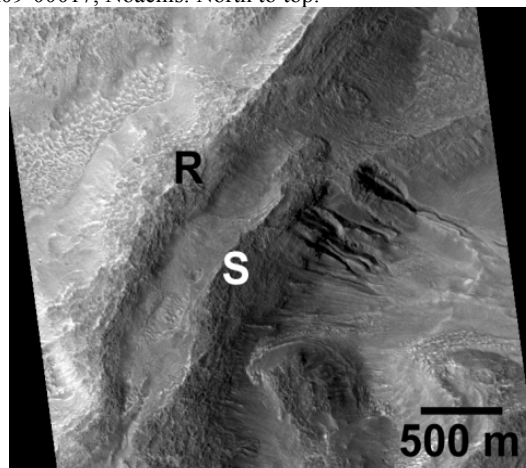


Fig. 2. Slump block (S) with gullies below crater rim (R). R09-00017, Noachis. North to top.



mon setting is the wall of an impact crater [3]. A typical gully includes an alcove, a channel, and a deposit (Fig. 1). Alcoves are theatre-shaped depressions, which commonly coalesce to yield bare slopes above gullies. Alcove bottoms narrow into channels, straight or sinuous. Channels debouch into fan- or cone-shaped mounds. Data here are narrow-angle MOC images [10], without radiometric or precise spatial calibration.

Impermeable Layers. For groundwater to accumulate and flow out of slopes, the subsurface must contain permeable and impermeable layers ([1-6], Fig. 3 of [4], Fig. 11 of [5]): “Implicit in this model is that regions without impermeable layers would lack gullies” [4].

Walls of impact craters, sadly, will not expose impermeable layers; had such layers been present, they would have been shattered as the craters formed [11-13] (Fig. 1, M11-00530, M15-01616, E11-04375). Rock in central peaks and peak rings would be similarly disrupted ([12], Fig. 9a of [9], M15-00539, R13-02591, E05-01556) and perhaps welded to massive rock ([14], Fig. 3, Fig. 8a of [9], M0703089); neither will include both permeable and impermeable layers.

Layer Tilt. For groundwater to assist in gully formation, subsurface layering must allow water to flow towards the gully-bearing slope – i.e., impermeable horizons must not tilt away from gully-bearing slopes.

Distressingly, subsurface layering near small impact craters tilts away from the craters. During crater excavation, rock around the crater is forced up and outward, thus tilting its layers away from the crater [11,13,15]. If original impermeable layers had not been shattered in the crater-forming impact, or had been welded or cemented again, they would direct groundwater away from the crater walls.

Slump blocks in impact craters can have even steeper dips. After a crater forms, blocks of wall rock can slide into its cavity, rotating original layering away from the crater center [12,13,15]. Such back-tilted blocks can also bear gullies (Fig. 2, Fig. 8b of [9], E16-01781). Massifs in multi-ring basins can have steeply tilted layering and so be regrettably unsuitable as groundwater reservoirs, but still host gullies (Fig. 3).

Source of Groundwater. For groundwater to participate in forming a gully, it must be available at the elevation of the gully. Gullies atop isolated knobs and massifs are problematic, as (alas) most hypotheses lack provision for raising groundwater to those heights. Gullies occur on central peaks and peak rings (Fig. 3) of impact craters [9,16], and on other summits: massifs near impact basins (Argyre, M0-800012, E18-00791; Hellas, M04-02479, R04-01278), knobs at the highland-lowland boundary (Tempe, Fig. 4, E23-01461; Cydonia, R03-00855, R07-00422; Deuteronilus, R08-00250), and other knobs (Acidalia, E10-02693, E22-01210; Phlegra Montes, M09-06567, R05-02495). Gullies also occur on isolated mesas in Dao Vallis (R15-00527), Gorgonum Chaos (E18-01449), and the

Fig 3. Peak ring massif, Hale Crater, E1800163, NNW to top. Gullies in center. Aligned ridges above and below gullies imply near-vertical layering.

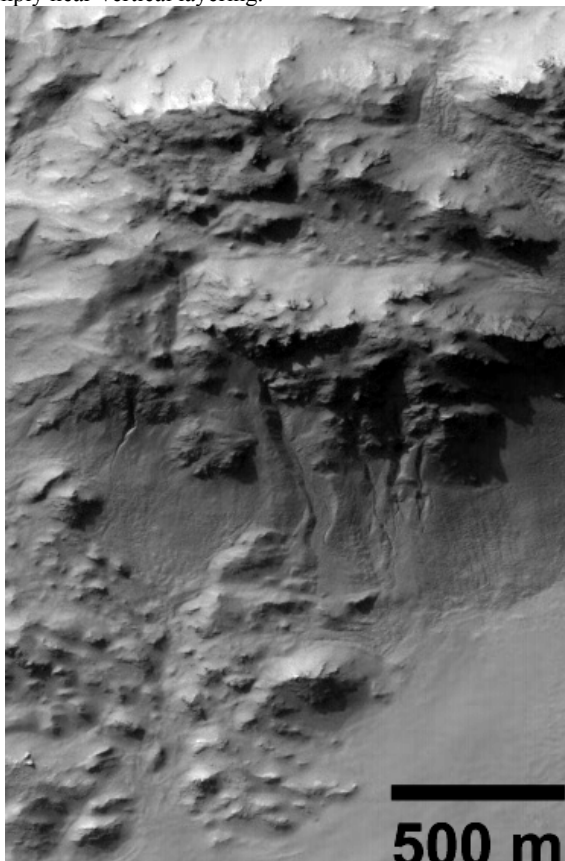
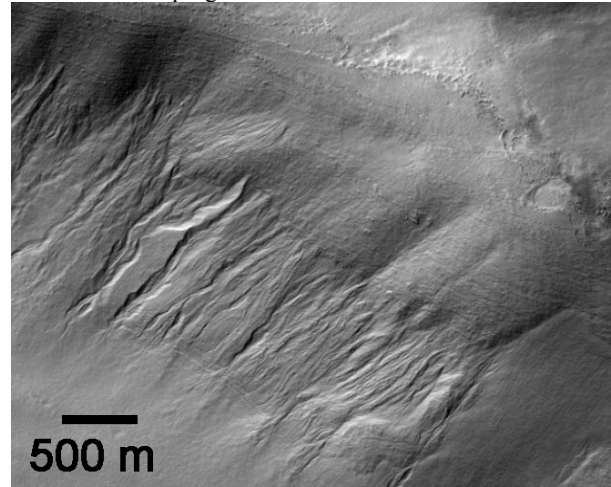


Fig 4. Isolated knob, N Tempe Terra, E05-02689. W to top, knob's crest at top right. Gullies on SE face of knob.



south polar pits (E0-400704).

Discussion: Most gully localities are geologically inconsistent with the involvement of groundwater. Impact crater walls lack impermeable layers that are not tilted away from gully sites. Only the groundwater brine hypothesis [7] allows production of impermeable layers above and below liquid water. Gullies on isolated knobs are difficult to reconcile with regional groundwater systems, but might be explained by local snowmelt [6,17]. Regional groundwater is consistent with gully formation only in areas of layered rocks cut by chasms or channels (e.g., Nirgal Vallis); even there, gullies on isolated mesas (Dao, Gorgonum, polar pits) suggest that other processes must be involved in gully formation.

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