TERRACED CUTBANKS AND LONGITUDINAL BARS IN GULLY CHANNELS ON MARS: EVIDENCE FOR MULTIPLE EPISODES OF FLUVIAL TRANSPORT.

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Introduction: First identified by Malin and Edgett [1], gullies are among the youngest and most enigmatic geomorphic features on Mars. Originally hypothesized to be the result of confined aquifer breakouts, they have subsequently been interpreted to be the result of dry mass flows (e.g.,[2,3]), water-lubricated debris flows (e.g., [4]), brine seepages (e.g., [5]), or top-down melting of surficial ice and snow deposits (e.g., [6,7,8]). Surveys undertaken by Heldmann and Mellon [9], Balme et al. [10], and Dickson et al. [11], have shown persuasively that the global distribution of gullies is preferential. The greatest concentrations of gullies are observed in the mid-latitudes (~30-50°) of both hemispheres where gullies exhibit a poleward orientation preference (>80% in the southern hemisphere survey of Dickson et al. [11]) and are found at a variety of elevations (-5177 to 3089 m). Finally, gullies are found exclusively on steep slopes, typically 20-30° [11,12]. The Mars Orbiter Camera with a typical resolution of 1.5-m/pixel [13,14] allowed for the definition of gully alcove source regions, channel transport areas, and depositional aprons, but did not allow detailed geomorphic studies of these components. The High Resolution Imaging Science Experiment (HiRISE) [15] now enables detailed sedimentary geomorphic investigation (e.g., [16,17]); we use these new data to analyze in-channel sedimentary features, which can provide evidence regarding the style of transport in gully systems.

HiRISE Observations: Drawing on the survey results outlined above, we focus on the 30° to 45°S latitude band where gullies are abundant. Approximately 175 HiRISE observations of gullies in the survey area are contained in the first two PDS releases examined.

Channel Morphology: The channel portion of a gully system is a region of transport in which sediment from the alcove source region passes through prior to deposition in the gully fan. As such, sedimentary structures in the channels (Fig. 1) can provide information on the prevailing style of transport and markers of significant events that are not recorded in the (eroded) alcoves and may not be visible in the fans. The presence of terraced cutbanks (terraces) and longitudinal bars (Fig. 1) suggest multiple distinct episodes of fluvial transport in these channels. The low preservation potential of these high-slope, steep-sided, non-lithified features suggest that they are very latest Amazonian in age. Consideration of these structures in comparison to terrestrial analogs for proposed gully formation mechanisms suggests a discrimination between the proposed hypotheses.

Interpretation: The presence of in-channel longitudinal bars is most consistent with sediment deposition as a result of helical, secondary, flows in a fluvial channel environment [18,19]. In this manner, gully channels may be most analogous terrestrially to ephemeral braided stream channels. Terraced cutbanks and inner channels indicate that flow volumes and energy have varied between multiple episodes of activity. The presence of these well-preserved features implies multiple episodes of recent (latest Amazonian) activity, suggesting that gullies are not catastrophic landforms that formed in single events, such as one-time debris-flows or subsurface outburts. Rather, these observations favor a fluvial scenario in which small amounts of surficial meltwater are derived from snow and ice accumulation. This is further supported by the insolation geometries of gully systems and modeling by Williams et al. [20] which shows that Martian snowpacks can reach melting temperatures under a variety of conditions (e.g., freshly uncovered snowpacks under current conditions, snowpacks at higher obliquities, and windblown snow proposed by Head et al. [8] to seasonally concentrate in gully channels) and produce small amounts of meltwater.

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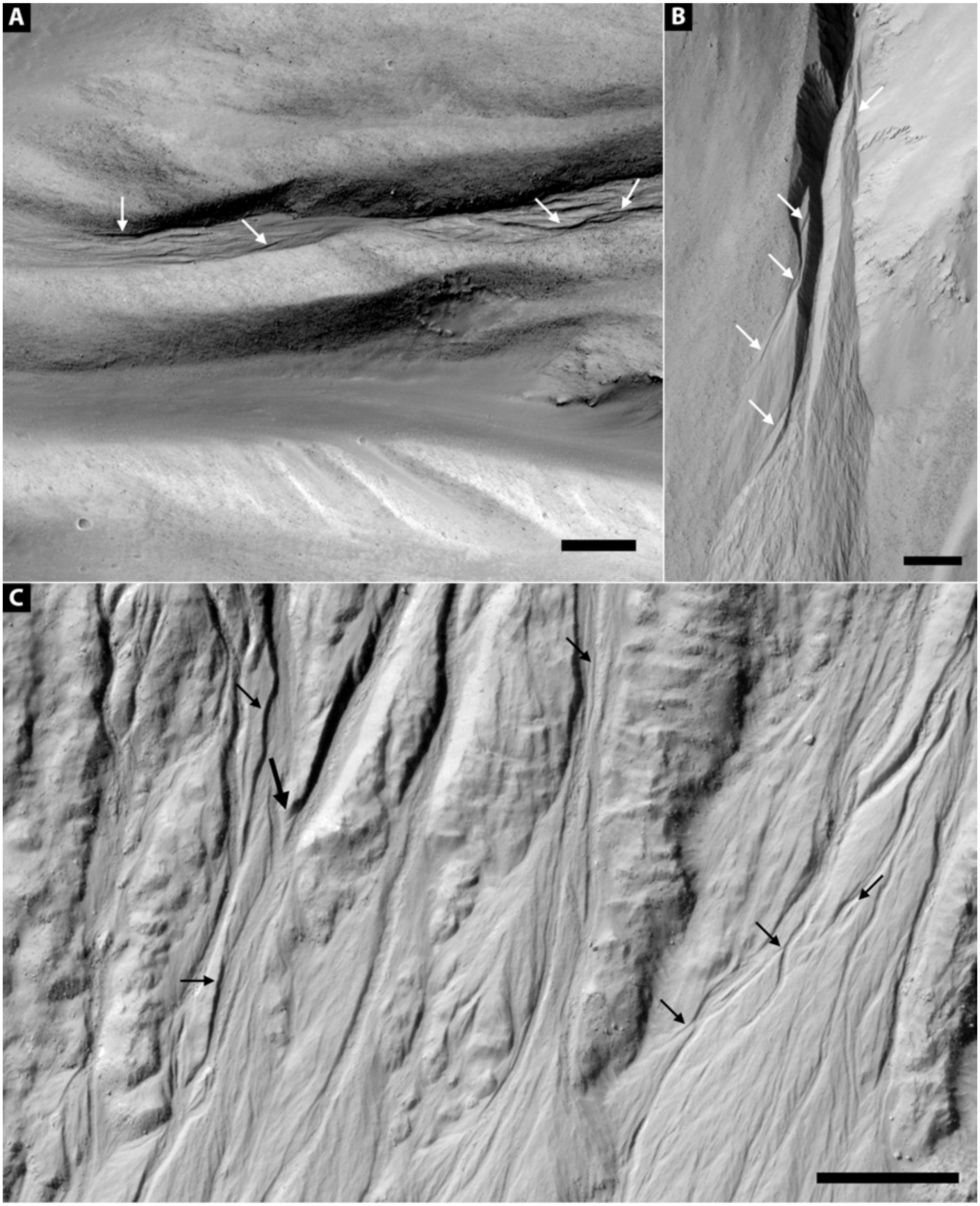

Figure 1: Examples of gully channel morphology. All scale bars are 50 m; arrows highlight illustrative features. **A**) Two adjacent channels (downslope to the left) with different morphologies, PSP_006593_1470. **B**) Gully channel with multiple terraces evidencing erosion of previously deposited sediment, PSP_002292_1490. **C**) Multiple anastomosing gully channels illustrate the complex pattern of flow recorded in the sedimentary structures; the larger arrow highlights an eroded longitudinal bar deposited in the lee of a spur, PSP_006869_1475.