Geomorphic and Flow Analysis for Gullies in Palikir Crater

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Introduction:
Gullies on sloped topography abound on the Martian surface. Gullies with distinct alcove, chute, and debris apron structures are cited as supporting evidence for the hypothesis of a historically wet Mars [1]. We present morphometric analysis of 17 gullies in Palikir Crater demonstrating consistency with fluvial origins. We assume certain sediment and flow characteristics in order to estimate average flow velocities and sediment transport capacities for these gullies using a suite of empirical formulae adapted to Martian conditions.

Study Location:
Palikir Crater, a ~15 km diameter impact crater in the Newton Crater Basin, is shown in Figure 1. Palikir Crater is a confirmed site for Recurring Slope Lineae (RSL). Figure 2 depicts the extensive gully system, which exposes a ridge of bedrock at the crater rim.

Methodology:
Analysis of gully topography was performed in ENVI GIS software using the HiRISE digital terrain model (DTM) synthesized from HiRISE stereo images PSP_005943_1380, ESP_011428_1380. Transect profiles were sampled at regularly-spaced intervals along the gully channels. Downstream reach lengths and representative meander wavelengths were also tabulated. Using these inputs, we automated analysis of channel geometry and produced estimates for transect cross-sectional areas, gully slope, concavity, sinuosity, and volume deposited. We calculated the excavated gully volume by numerically integrating the representative flow depth (RFD) to be the difference in elevation of the lowest terrace and the channel thalweg at a given transect. The RFD ranged from 1.0 to 2.7 meters with a mean of 1.9 meters. This assumes bankfull flow.

Results:
Longitudinal profiles for the 17 chosen gullies (A through Q) clearly indicate a concave-up shape, shown in Figure 4, which is consistent with a fluvial origin [10]. Gully slopes (shown in gradients) are typically steepest in the alcove region; calculated slopes averaged 9° for aprons, 16.4° for gully chutes and 20.0° for alcoves, though alcove slopes reached up to 30° in one gully.

Flow Characterization:
Table 1 summarizes velocities calculated in this study. All flows (except those calculated using the Ikeda method) were supercritical, a condition for applicability of the models. We calculated the representative flow depth (RFD) to be the difference in elevation of the lowest terrace and the channel thalweg at a given transect. The RFD ranged from 1.0 to 2.7 meters with a mean of 1.9 meters. This assumes bankfull flow.

Sediment Transport Estimation:
Using average adjusted Manning velocity for Martian conditions [9] and the calculate average flow depth based on channel geometry, we estimate slope- and bedload-dominated transport at 0.012 m³/s per unit width for non-cohesive, unconsolidated sediment. Table 2 summarizes the grain size distribution adopted for these calculations. We assume a specific gravity of 3.4 for Martian basalt and use viscosity of 1.6 x 10⁻⁶ and 3.74 m/s² for gravitational acceleration.

With an average gully volume of 2.6 x 10⁶ m³ (max 1.2 x 10⁷ m³), timescale of formation reaches up to 15 years (assuming a time step of 0.5 years).

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References: