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The Upper Gediz Vallis Ridge at Gale Crater: Sedimentary Rock Clasts Transported by a Late-Stage Debris Flow on Mars?

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The Mars Science Laboratory (MSL) Curiosity rover continues to ascend Aeolis Mons in Gale crater, Mars, with the goal of characterising formerly habitable palaeoenvironments. Since September 2022, Curiosity has been traversing Gediz Vallis, a ~9-km long canyon incising into sulfate-bearing, sedimentary rocks on the northern margins of Aeolis Mons. Along the Gediz Vallis floor is the upper Gediz Vallis Ridge (uGVR), a quasi-sinuuous, ~1.5 km long, ~80-100 m wide, ~5-30 m high, ridge. Upslope, uGVR is clearly set within an erosional channel, which disappears downslope. Near the Gediz Vallis outlet, uGVR transitions into the broader, lower GVR, recently interpreted by Bryk et al. (2023, AGU Fall Meeting) as a degraded alluvial fan. Since entering Gediz Vallis, Curiosity has undertaken an extensive long-distance imaging campaign of the eastern uGVR flank, acquiring multiple Mastcam and ChemCam Long Distance Remote Micro Imager (LD-RMI) mosaics. Additionally, in August 2023, Curiosity approached the ridge margins and conducted an in-situ investigation ("Region B"). A major objective of Curiosity's uGVR campaign is to determine the primary depositional conditions and palaeoenvironment of the ridge, which may record evidence for late-stage surface water flow in Gale.

Thus far, most uGVR exposures observed are formed of loosely consolidated, very poorly sorted, decimeter to meter-scale blocks. Most blocks are dark in tone and some are partially embedded within a finer-grained, matrix-like material. The blocks themselves are reworked, lithified, sedimentary rocks and many display a diversity of internal planar and/or cross-stratification, although others appear more massive. Where visible, bedding within the blocks is typically mm to cm in thickness. We used the Pro3D software package to measure mean diameter size of 70 blocks at Region B from stereo Mastcam images: 0.15 ± 0.11 m; although we note that the largest block (~

7 m diameter) occurs elsewhere. We also note that many blocks are fractured into multiple pieces, potentially due to post-depositional weathering processes. There is no obvious source bedrock from within the ridge that the blocks could be eroding from, consistent with the blocks being transported clasts, rather than erosional lag originating from in-situ bedrock. Generally, the clasts are very angular to sub-rounded, suggesting relatively limited transport and a local source bedrock.

The large clast size (cobble, boulder) and very poor sorting is consistent with deposition by debris flows: gravity-driven flows in which clasts are supported by a cohesive muddy matrix. The confinement of the uGVR to a channel argues against a completely unconfined flow, such as a drier landslide, forming the deposit. Post-depositional erosion has likely winnowed much of the finer grained fraction of the deposit. The sedimentary structures within the clasts (e.g., asymptotic cross-stratification) are similar to those in the Stimson formation, an aeolian sandstone, pointing to a potential upslope extension of Stimson, consistent with recent long-distance observations, though multiple sources are also possible. If our interpretation is correct, this would demonstrate that uGVR is providing access to lithologies transported from higher up Aeolis Mons.