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► To cite this version:

Alexander B. Bryk, William E. Dietrich, Christopher Fedo, Gwénaél Caravaca, Joel M. Davis, et al.. IN SITU INVESTIGATION OF THE GEDIZ VALLIS RIDGE: A REMNANT LATE-STAGE DEBRIS FLOW DOMINATED FAN DEPOSIT IN GALE CRATER. 55th Lunar and Planetary Science Conference, Lunar and Planetary Institute, Mar 2024, The Woodlands (Texas), United States. pp.1770. hal-04442711

HAL Id: hal-04442711

<https://hal.science/hal-04442711>

Submitted on 6 Feb 2024

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IN SITU INVESTIGATION OF THE GEDIZ VALLIS RIDGE: A REMNANT LATE-STAGE DEBRIS FLOW DOMINATED FAN DEPOSIT IN GALE CRATER. A. B. Bryk¹, W. E. Dietrich¹, C. M. Fedo², G. Caravaca³, J. M. Davis⁴, M. P. Lamb⁵, J. A. Grant⁶, R. C. Wiens⁷, O. Gasnault³, J. P. Grotzinger⁵, A. R. Vasavada⁸, K. Stack-Morgan⁸, R. E. Arvidson⁹, S. Le Mouélic¹⁰, V. K. Fox¹¹, K. A. Bennett¹², S. Gupta⁴, R. M. E. Williams¹³, R. Y. Sheppard¹³, K. W. Lewis¹⁴, D. M. Rubin¹⁵, W. Rapin³, A. A. Fraeman⁸, S. Banham⁴, M. N. Hughes⁹, M. Turner¹⁴, S. A. Wilson⁶, and E. S. Kite¹⁶. ¹University of California, Berkeley, CA (bryk@berkeley.edu). ²University of Tennessee, Knoxville, TN., ³Institut de Recherche en Planétologie et Géodynamique, Toulouse, France. ⁴Imperial College, London, UK. ⁵Division of Geological & Planetary Sciences, Caltech, Pasadena, CA. ⁶Smithsonian National Air and Space Museum, Washington, DC. ⁷Purdue University, West Lafayette, IN. ⁸Jet Propulsion Laboratory, Caltech, Pasadena, CA. ⁹Washington University in St. Louis, St. Louis, MO. ¹⁰Université de Nantes, Nantes, France. ¹¹Carleton College, Northfield, MN. ¹²USGS Astrogeology Research Center, Flagstaff, AZ. ¹³Planetary Science Institute, Tucson, AZ. ¹⁴Johns Hopkins University, Baltimore, MD. ¹⁵University of California, Santa Cruz, CA, ¹⁶University of Chicago, Chicago, IL.

Introduction: Numerous studies using orbital HiRISE and CTX data show evidence for extensive fan formation across the Martian surface [1, 2]. Fan-shaped deposits record a combination of fluvial, debris flow, and deltaic processes, with many fans likely forming during the late Hesperian or Amazonian [1, 3]. Curiosity-based observations of the deeply eroded deposits of the Gediz Vallis ridge (GVR), near the base of Aeolis Mons (Mt. Sharp), provide our first cross-sectional observation of a Martian fan, revealing episodic deposition by debris flows and reworking by fluvial processes.

Facies analysis: The GVR was deposited on top of the pediment-mantling aeolian Stimson formation and is divided into 6 depositional units (Fig. 1). Directly overlying the Stimson is a discontinuous basal unit comprised of fine-grained (\leq gravel size) decimeter-scale bedding that parallels the top of the Stimson. The unit sheds meter-scale boulders, reaches a maximum observed thickness of 15m. It is unconformably overlapped by stratified boulder deposits (Fig. 2). These deposits are comprised of two distinct boulder-facies whose frequency and lateral extent differ: 1) light-toned typically matrix-supported coarse facies with scattered erosionally-resistant dark-toned boulders, and 2) a dark-toned typically clast-supported boulder facies with rare light-toned boulders scattered throughout. The 5 stratified boulder packages (Fig. 1) are defined by the relative abundance and form of the dark-toned boulder

facies, which commonly down-cuts into the light-toned boulder facies. We found no evidence for late diagenesis (e.g., veins) in either boulder-rich facies. In all cases, the dark-toned boulders are more erosionally resistant than the light-toned boulders (Fig 2). Grainsize analysis from ChemCam's Remote Micro Imager (RMI) data indicates similar median grainsizes (170-190 mm) in light- and dark toned facies with isolated 1-3m boulders of both kinds scattered throughout.

The basal unit is lithified and may have formed through aeolian processes. The remaining boulder-rich strata in the ridge appear either unlithified or weakly lithified. The light-toned strata likely comprise hundreds of individual debris flow deposits. The less common dark toned boulder facies is consistent with fluvial processes, probably derived from surface runoff that concentrated dark stones from the light toned facies into channels and sheetflood deposits while destroying the weaker light toned clasts during transport.

Architecture and former extent: Discontinuous bedding within the boulder-rich GVR deposits (above the basal unit) ranges in thickness from 0.25 to 3 m thick and exhibits a mean slope of 7% oriented parallel to the ridge axis, much gentler than the slope of the basal contact (10-35%). Down-dip correlations also suggest possible retrogradational stacking in the Claw-Nose transition (Fig. 1). Upslope in Gediz Vallis, images obtained by the Curiosity rover showed numerous individual dark-toned boulders far from the inverted

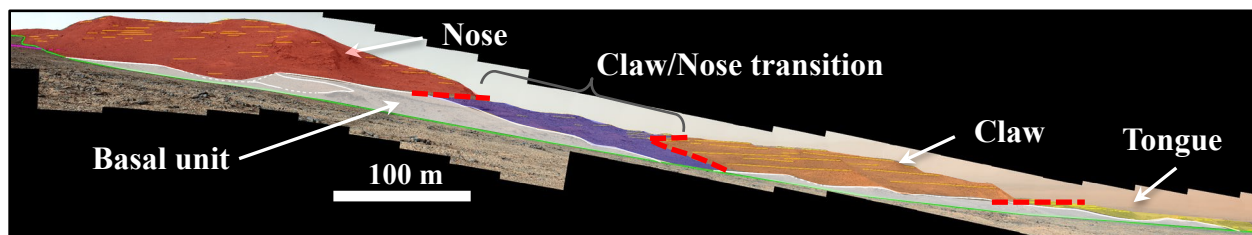


Fig. 1. Annotated Mastcam views of the Gediz Vallis ridge showing the 6 units (Basal unit, Tongue, Claw, Claw-Nose transition, Nose, and Transition to upper GVR) analyzed in this study. The green line indicates the base of the section above the Greenheugh pediment. Yellow lines denote approximate bedding planes and red dashed lines indicate approximate unit boundaries. Note the transition to the upper GVR (uGVR) package is not visible from this angle. Mastcam image credit: NASA/JPL-Caltech/MSSS.



Fig. 2. Merged Mastcam RGB color data and ChemCam RMI data of boulder-rich facies onlapping the Basal unit in the Claw-Nose trans. (Fig. 1). The figure shows the clear difference in outcrop expression between the resistant dark-toned boulders and the weaker light-toned boulders, which have been planed off flush with the hillside. Mastcam image credit: NASA/JPL-Caltech/MSSS. ChemCam image credit: CNES/LANL/IRAP/IAS

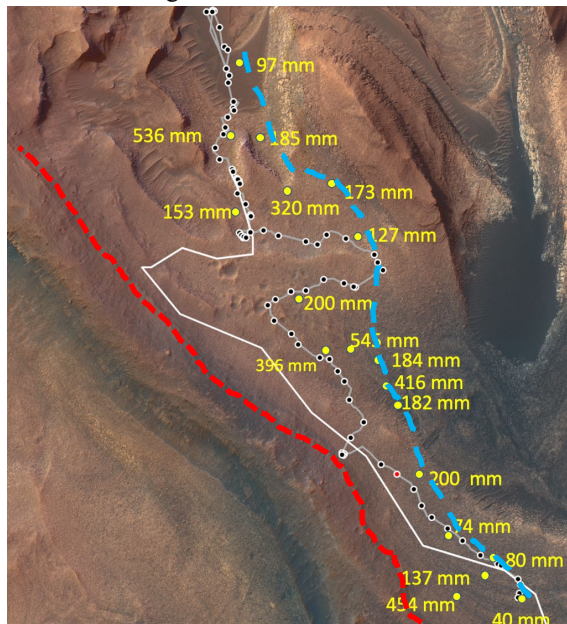


Fig. 3. HiRISE view of upper Gediz Vallis ridge (red dashed line) including foreign stones (yellow labels) and their maximum lateral extent away from the ridge (blue dashed line). HiRISE credit: [4]

upper Gediz Vallis ridge (yellow dots in Fig. 3). These likely indicate the former extent of the ridge within Gediz Vallis and demonstrate that the deposit once filled much of the valley floor and has subsequently been erosionally removed.

The gentle depositional slopes of the boulder-rich deposits in the GVR (Fig. 1), the retrogradational stacking, and the distal spread dark boulders in Gediz Vallis (Fig. 3) all suggest the fan was once significantly more extensive. These observations further indicate that the fan deposits back-stepped up the steep underlying pediment surface, and probably formed the core of fan that may have built as much as 10 km downslope. Linear projections of the average GVR bedding dip suggests the fan may have extended nearly across the entire MSL traverse (Fig. 4).

Discussion: The final fan size may have reached 100 km², matching that found elsewhere on Mars for

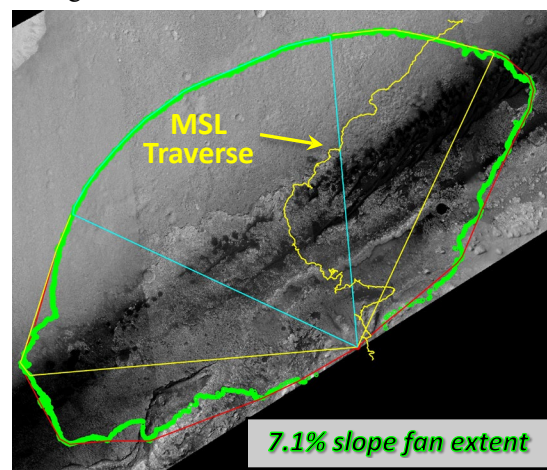


Fig. 4. Estimated aerial extent of the former Gediz Vallis fan. Fan extent reconstructions made using a 60°, 120°, and 170° opening angles, and a constant surface slope of 7.1% – representative of the mean bedding slope measured in the GVR. CTX credit: [5]

comparable catchments areas (127 km²). The modern GVR, however, likely comprises less than 1% of this former maximum fan extent. Most of the fan may have been composed of the light-toned sediment highly erodible by aeolian processes, leading to a near complete removal of the fan deposit at the cessation of fan construction. Stratigraphic differences in the five packages above the basal unit suggest significant changes in the magnitude and frequency of surface runoff and sediment supply likely reflecting variable climate conditions. This variability supports orbital-based proposals that Martian fans are characterized by mixtures of debris flow and fluvial deposits and that fan development was episodic, rather than a single pulse [6]. The GVR likely records one of the last significant hydrogeomorphic phases in Gale.

References: [1] Morgan et al. (2022) *Icarus*, 385, 115-137. [2] Anderson et al. (2023) *Icarus*, 394, 115-122. [3] Holo et al. (2021) *PSJ*, 2(5), 210. [4] McEwen et al. (2007) *JGR: Planets*, 112 (E5). [5] Malin et al. (2007) *JGR: Planets*, 112 (E5) [6] Williams et al. (2011) *Icarus*, 211(1), 222-237.