UTILIZING A GLOBAL DATABASE TO EXPLORE MORPHOLOGIC TRENDS OF MARTIAN ALLUVIAL FANS.

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Introduction: Alluvial fans are fan-shaped accumulations of sediment that form at the base of mountain fronts as a channel debouches onto an adjacent, lower-lying terrain. The channel loses competence and capacity due to a combination of the reduction in slope and the lateral expansion of flow, depositing the sediment into a semi-conical form. Alluvial fans are found in all environments with topographic relief where there is high sediment production within the catchment [1]. Alluvial fans on Mars are enigmatic; their large size, intricate stratigraphic layering, and partially infilled embedded craters suggest that they were deposited over tens to hundreds of thousands of years [2-4], but many appear to have been active as recently as the early Amazonian [2, 5] during a time that was generally thought to less favorable for fluvial activity.

As a depositional feature in close proximity with its sediment source, alluvial fans have the potential to preserve a record of environmental change during the transport and deposition of sediment [e.g., 6-8]. The martian fans therefore contain clues into a critical time in the evolution of the climate history where it transitioned from a potentially wet and warm early state to the cold and dry world we observe today.

Methods: Previous workers have compiled inventories of martian fans [9-12], but these have been limited by the availability of high-resolution data, and only searched for fans within impact craters. We expand on this earlier work by conducting a systematic global survey of fan-shaped landforms using the Google Earth CTX mosaic layer. Due to the limited coverage of the CTX layer in Google Earth (~45% between +-60°N, relative to the total coverage of >90%), we marked all visible fans as well as all locations where it looked as though there might potentially be a fan based on terrain relief, the qualitatively assessed state of crater degradation, and proximity of other fluvial features, such as valley mouth, in the THEMIS daytime IR.

Data were loaded into ArcGIS and fan and catchment morphologic properties (e.g. area, slope, concavity) were measured using projected CTX visual images and HRSC- and MOLA- derived topographic data. Using the Robbins crater database [13] we obtained properties of host craters, including crater diameter, depth, and degradation state. We also documented surface features, including ridges and channels.

Observations:

Global Distribution. While alluvial fans are more widespread than previously reported, they are not distributed globally on Mars (**Fig. 1**). Fans are concentrated in the southern hemisphere, which may be related to the higher number of large craters which provide high-relief surfaces required for fan formation. Typically, fans are found within craters with depths (rim to floor elevation) of >2 km. We did not identify any fans south of ~50°S, but it is not clear if this restriction is due to some control on fan formation processes or if fans are simply not preserved at higher latitudes due to polar processes. The region south of ~45° is covered by a km-thick mantle [14], which could obstruct the identification of alluvial fans.

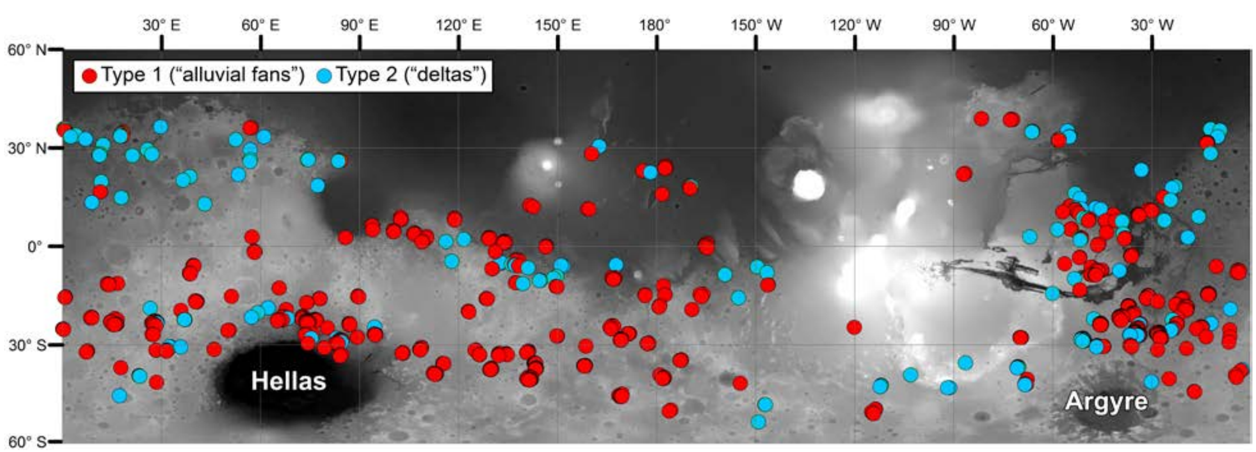

Figure 1. Global distribution of martian fan landforms. Type 1 features (red dots), commonly referred to as "alluvial fans," are the focus of this work. Type 2 features (blue dots) are commonly referred to as "deltas," though subaqueous deposition has generally not been demonstrated.

Our criteria in discerning fans likely excludes a number of features that formed as fans but have subsequently been eroded. Large alluvial fans in crater interiors that have been heavily eroded to the point of being more of a piedmont surface would not be identifiable as fans in topographic data. All of the latter features were excluded from this survey, as it was not possible to discern whether they were fans or simply degraded crater interiors. On the other end of the size range, many small fans may have been degraded or may simply have aeolian surface mantles and be too small to be visible in the MOLA or HRSC topographic data.

Azimuthal orientation. For the alluvial fans that do lie within craters, we compiled the location of the fan apex along the interior crater rim (**Fig. 2**). We excluded non-crater fans from the orientation analyses since many are in Ganges Chasma, which is an E-W oriented canyon, and would bias the results. We find that there is a prominent N-S trend, a strong indicator of control by solar insolation (**Fig. 2**).

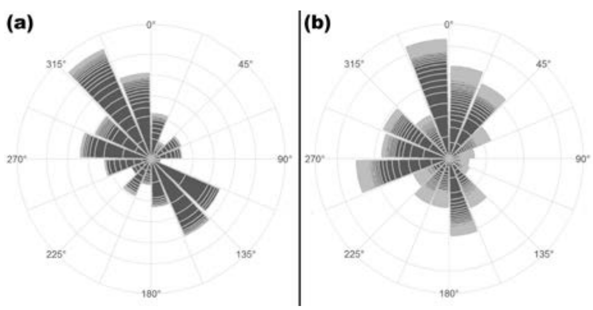

Figure 2. Orientations of alluvial fans along interior crater rims in the (**a**) Northern hemisphere and (**b**) Southern hemisphere.

Morphometric Properties. Martian fans follow similar trends to terrestrial fans, but are generally larger relative to their source catchments (**Fig. 3**).

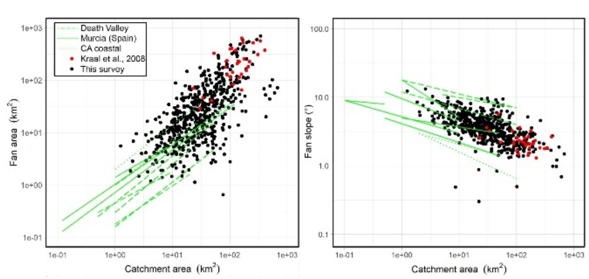

Figure 3. Morphometric properties of martian fans. Left: Area of the catchment versus the fan area. Right: Catchment area versus fan slope. Data from this study (black dots) relative to Earth (green), with additional Mars data (red dots) from [10].

Age of the Alluvial Fans. The timing for martian fan formation has significant implications for Mars' climatic history. In an initial survey of martian fans by [9], they inferred that the alluvial fans were contemporaneous with valley network formation [15], during a period of enhanced fluvial activity across Mars [15-16]. They also hypothesized that the highly eroded craters from the early to mid Noachian were unable to provide the relief needed for fan formation due to degradation [17]. More recent studies of fans and deltas suggest, however, that they were deposited some time closer to the Hesperian-Amazonian transition [2, 5, 18] an era long considered to be unfavorable to fluvial activity due to a thick global cryosphere. Assuming that all fans formed concurrently (which has not been confirmed), 39 craters larger than 1 km diameter (from [13]) superpose the fans, suggesting an age of 2.5 Ga, or early Amazonian. We reach similar results by comparing the fan locations with geologic units in the most recent global geologic map of Mars [18]. The bulk of the fans are atop surfaces mapped as Amazonian-Hesperian in age.

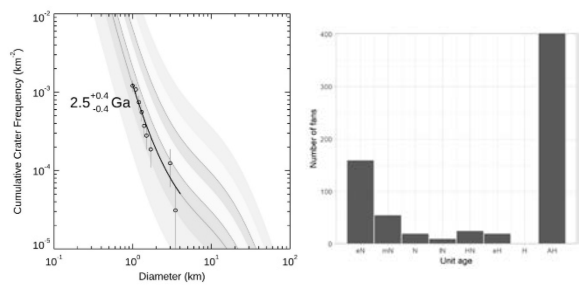

Figure 4. Left: Cumulative crater statistics for all alluvial fans on Mars, assuming contemporaneous deposition Right: Number of alluvial fans that lie of different age landforms, as mapped by [18]. The vast majority of fans superpose Amazonian and Hesperian aged landforms.

References: [1] Blair, T.C., J.G. McPherson, in Geomorphology of Desert Environments, Springer Netherlands, 2009, 413–467 [2] A.M. Morgan et al., *Icarus*, 229, 131–156, 2014 [3] M.C. Palucis et al., *JGR*, 119, 4, 705–728, 2014 [4] E.S. Kite et al., *GRL*, 44, 9, 3991–3999, 2017 [5] J. A. Grant, S.A. Wilson, *GRL*, 38, 8, 2011 [6] A.M. Harvey, in Desertification in the Third Millenium, 2004, 83–98 [7] E.W. Haug et al., *Geomorphology*, 121, 3–4, 184–196, 2010. [8] B.C. Salcher et al., *Geomorphology*, 115, 215–227, 2010 [9] J.M. Moore, A. D. Howard, *JGR*, 110, 2005 [10] E.R. Kraal et al., *Icarus*, 194, 1, 101–110, 2008 [11] S. A. Wilson et al., 43rd *LPSC*, 2012 [12] S. A. Wilson et al., 44th LPSC, 2013, #2710 [13] SJ. Robbins, B.M. Hynek, *JGR*, 117, 2012 [14] M.A. Kreslavsky, J.W. Head, *JGR*, 105, 26695–26711, 2000. [15] A.D. Howard et al., *JGR*, 110, E12, 2005 [16] R. P. Irwin et al., *JGR*, 110, E12, 2005 [17] R.A. Craddock et al., *JGR*, 102, 13321–13340, 1997 [18] J.A. Grant et al., *GRL*, 41, 1142–1149, 2014 [18] K.L. Tanaka et al., USGS, SIM 3292, 2014.