MARTIAN ALLUVIAL FANS: UNDERSTANDING THE CRATER CONNECTION

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ABSTRACT

Our global survey of alluvial fans has found 28 locations that contain more than 50 large alluvial fans. Twenty-seven of these locations are impact craters. All alluvial fans originate from the rim of the crater and deposit their apron into the basin. The locations of alluvial fans are regionally groups and focused in three main locations, all in the southern hemisphere. The correlation between alluvial fans and impact craters on Mars indicates that some part of the impact process may help set conditions favourable to fan formation.

1. INTRODUCTION

The results of a global survey (Figure 1a) for Martian alluvial fans shows an important relationship, that alluvial fans on Mars are found almost exclusively to originate from the inside rims of impact craters.

Our survey has found ~50 fans on the Martian surface, primarily through a global search of THEMIS data. While our survey is global, and not limited to impact craters, only one fan has been discovered so far that does not originate on an interior crater wall. This single fan is located in Capris Chasm (Figure 1c).

Here we report on work devoted to understanding why impact craters are the preferred site locales for alliuvial fans on Mars. Crater walls are steep and they are heavily faulted, but the same is true for other Mars locales, so that explanation requires a very careful evaluation. Nor is it obvious why craters should be favorable, topographically, for the tapping of groundwater near their rims, given that rims are raised above the mean ground surface. The source of groundwater associated with these fans is not readily evident; if it is water originating from precipitation then one is challenged by the fact that fans are strictly localized, as discussed below.

And so, one is compelled to search for genetic links with cratering. Plausible explanations we are exploring include radial and subsurface faulting [1] that may lead to effective mobilization of groundwater, or impact-induced hydrologic cycles proximal to a recently formed crater, or impact-triggered mobilization of ground ice towards a freshly formed crater (see abstract by Plesko *et al.* in this volume), or the possibility that isostatic rebound after crater formation provides the uplift associated with the formation of many terrestrial alluvial fans.

2. GLOBAL SURVEY RESULTS

We conducted our global survey using THEMIS IR images at ~100 m/pixel resolution. 27 craters have been found that contain fans, and to date we have identified ~50 alluvial fans in these craters, with some craters contain multiple fans originating from different directions (Figure 1b, 1d). Thus, 98% of the alluvial fans detected in this survey are located within impact craters. While we have searched globally, all fans identified are located in the southern hemisphere.

One interesting finding of our survey is the confirmation, after a global survey down to 20 km diameter crater sizes, of the initial finding [2] that a majority of fans are located in three distinct regions, with the two exceptions shown in Figure 1b and 1d.

The craters that contain alluvial fans range in diameter from 27 km to 157 km; the craters that contain the most fans are between 80 km and 90 km in diameter. The search for fans in smaller sized craters may be limited by our ability to resolve thin depositional layers at small scale, so a lower crater limit has not been established. For example, Williams et. al have reported on fan-like structures in Mojave Crater, a 60 km diameter crater where the structures are too small to be resolved in THEMIS 100m/pixel imagery [3].

Fan orientation (location on the rim where the fan originates) has a broad spread, as shown in Figure 2, and does not show a preferential orientation overall. We are studying the statistics of fan distribution within craters that contain multiple fans, to understand whether there is a preferential alcove spacing.

3. CRATER CONNECTION

The striking connection between alluvial fans and impact craters indicates that some aspect of the cratering process is responsible for helping set initial conditions that can be exploited to form alluvial fans on Mars.

The simplest hypothesis to be tested is that craters of a certain dimension simply define the most advantageous topographic profile for fan formation, and thus are the most common site. This effort involves a first-order comparison of topographic profiles wherever fans are located on Mars, both inside of craters and elsewhere, e.g. on valley walls. We are in the process of examining topographic profiles as a function of crater diameter, for any indication of whether alluvial fan preference for craters of a given diameter may simply be correlated with the typical profiles inside of craters of that diameter.

This explanation is already challenged by observations, in THEMIS images, of multiple apparently similar craters that have formed in very similar geologic units, in close proximity. Only one will have a fan or fans, while the proximal nearly identical craters have none. So topography alone may not be able to offer an explanation.

Another aspect being examined is sediment production. In order to form alluvial fans, there must be a source of clastic sediments in the alcove. The bedrock geology of the crater rim is an integral aspect of this sediment production function. While many aspects of cratering are scale similar, the differential scaling of melt production is well known to lead to large craters being more melt rich, owing to the greater energy required per unit volume for excavation. The same is likely to be true regarding clast size production, with larger craters resulting in the production of finer clasts.

Another aspect of the cratering process involves the formation of large-scale radial faults that may be advantageous for alluvial fan production, given that in terrestrial settings, alluvial fan alcoves tend to initiate along pre-existing faults or joints. Separate from issues of hydrology, we are examining alcove distribution within the craters that contain multiple fans (FIGURE) to see whether this correlates with the expected distribution of radial structures resulting from impact fracture.

4. CONCLUSION

We report on our global survey of alluvial fans on Mars, which extends the initial fan survey [2] globally to craters of much smaller diameter. In related work, the curious distribution of fan-containing craters seen in Figure 1a is being explored for its possible climate significance (e.g. Santiago et al., LPSC 2006). Here we are challenged to understand why craters are the preferred setting for fan formation, especially given that fans can exist inside of one crater and be absent from almost identical craters in the same THEMIS image. Examining the setting for fan formation may reveal not only evidence of past Martian hydrological activity, but may reveal how impact cratering events interacted with Martian subsurface geology in the Hesperian to produce appropriate conditions for fan formation.

5. REFERENCES

[1] Xia, K. and T.J. Ahrens, Impact induced damage beneath craters, GRL 28, 3525-3527, (2001) [2] Moore, J. M. and Howard, A. H. (2005) JGR, V 110, DOI: 10.1029/2004JE002352. [3] Williams, R. M. E., Edgett, M. C., and Malin, M. C., LPSC XXXV, abstract #1415.

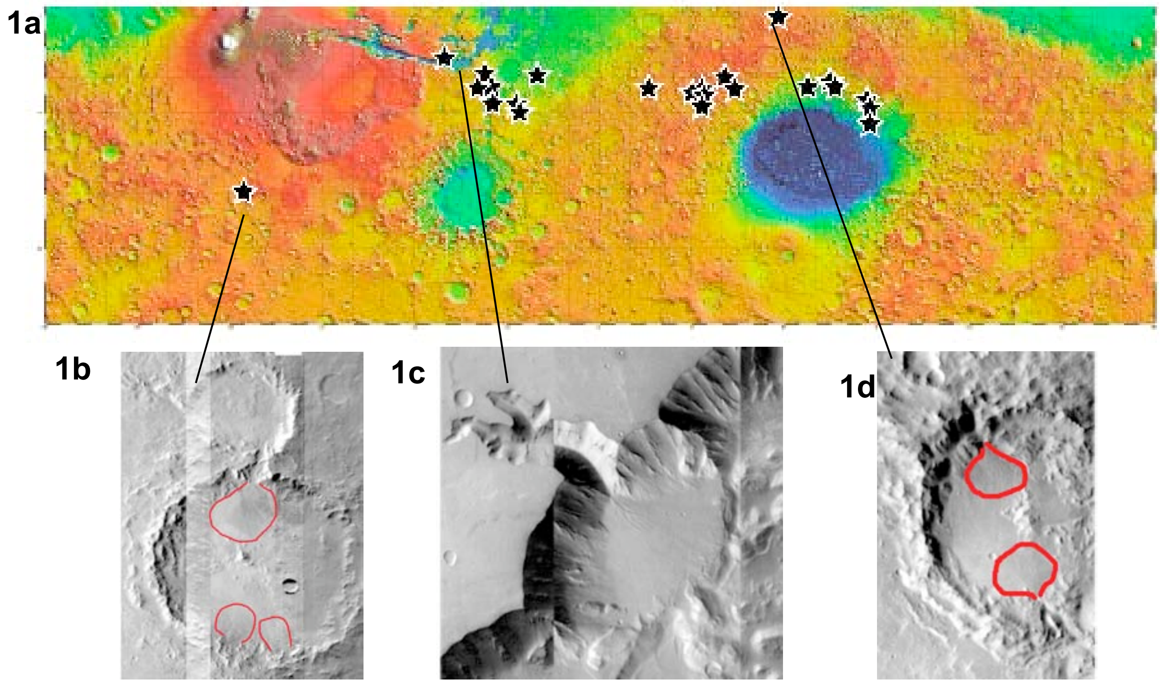

Fig. 1a shows the MOLA topography for 0S – 180S. Base image MOLA Science team. Fans are identified with a star symbol. 1b is Porter Crater, 50.7° S/113.71° W (100 km across) with fans outlined in red. The fan (13.6° S/51.7° W) in Capris Chasm (1c) is the only fan not originating from a crater rim. Fans have been found in small crater as well; 1d shows two fans in a 37 km diameter crater at 1.59° S/301.8° W.

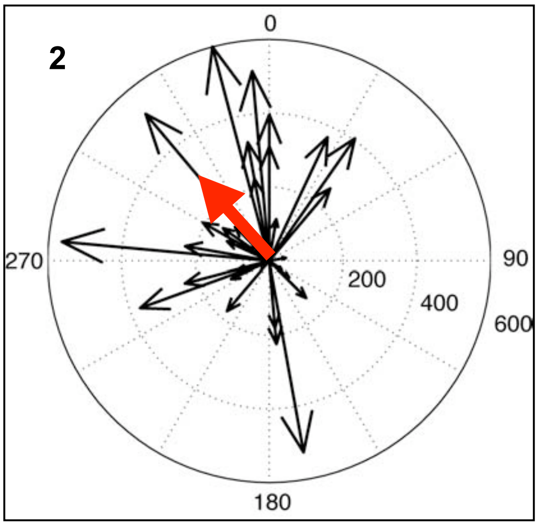

Fig. 2. Arrows point to the direction of emergence of the fan from the crater rim. Their length scales with area of the fan apron. North is up in all cases and area of fan is in km. The only fans included are those above MOLA topographic resolution (see [2]). Average fan is indicated in red. The average fan is 250 km^2 and originates from the northwest rim of the crater (300°), however there is a wide spread in the date. This is a preliminary plot and does not yet contain data for all of the fans identified, as data collection is still in process.