Late Amazonian boulder breakdown and denudation rate

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BACKGROUND

To infer late Amazonian hydrologic conditions from alluvial fans, fan formative processes need to be determined. But, how much of the diagnostic morphology of the formative processes is preserved after long-inactivity? Do weathering and erosion remove and modify morphology? In other words: to what extent can we still infer fan formative processes from surface morphology on long-inactive fans?

INTRODUCTION

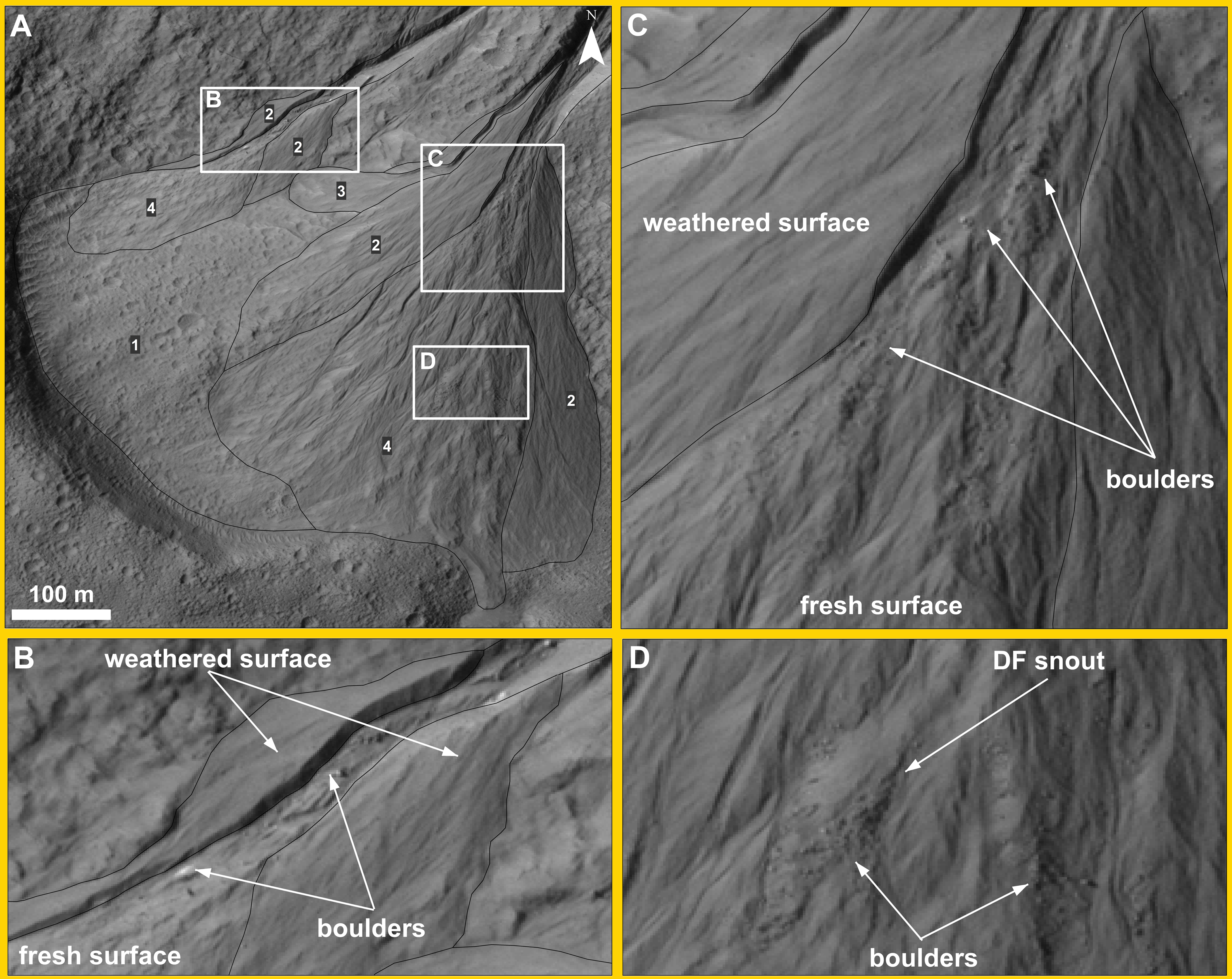
- Fans oft have lobes of different age; older lobes have mostly long been inactive and have been subject to weathering and erosion, breaking down surface particles and decreasing surface relief (denudation) (Fig. 1, 3).
- This can be used to infer weathering and denudation rates on Mars.

AIMS

- Infer late Amazonian boulder breakdown (weathering) and denudation rate.
- Investigate the preservation potential of diagnostic morphology over time.

METHODS

- Measurement of boulder size on different fan lobes (Fig. 1, 2).
- Estimation of relief on different fan lobes.
- Lobe ages from crater counts and climatic constraints (e.g. Schon et al., 2009; Head et al., 2003).
- Boulder breakdown and denudation rate estimation: dividing difference in boulder size and relief by age difference.



LOBE AGE

- Lobe 1: ~1.25 Ma: crater counts (Schon et al., 2009)
- Lobe 4: > 0.4 Ma: Fan activity dependent upon liquid water; snowmelt only possible in the last ice-age (2.1 - 0.4 Ma; Head et al., 2003) (e.g. Dickson & Head, 2009).
- Lobe 2, 3: < 1.25 Ma & > 0.4 Ma. Lobe 2 and 3 postdate lobe 1 and are thus younger than 1.25 Ma, and they predate lobe 4 and are thus older than 0.4 Ma.
- As a best guess estimate, we assume an age of 1.25 Ma for lobe 2 and an age of 0.4 Ma for lobe 4, yielding an age difference of 0.85 Myr.

BOULDER SIZE

- Lobe 4: Max 4.9 m (Fig. 2). Based on catchment boulder survey 4.9 m is exceptionally large --> we assume 3.5 (2nd largest boulder) as maximum boulder size.
- Lobe 1-3: No visible boulders --> boulders < 2 * pixel size = 0.5 m.

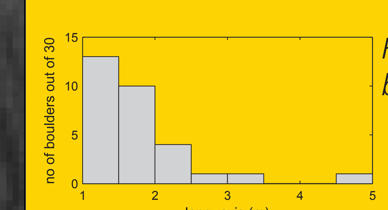


Fig 2) Size of 30 largest boulders on lobe 4.

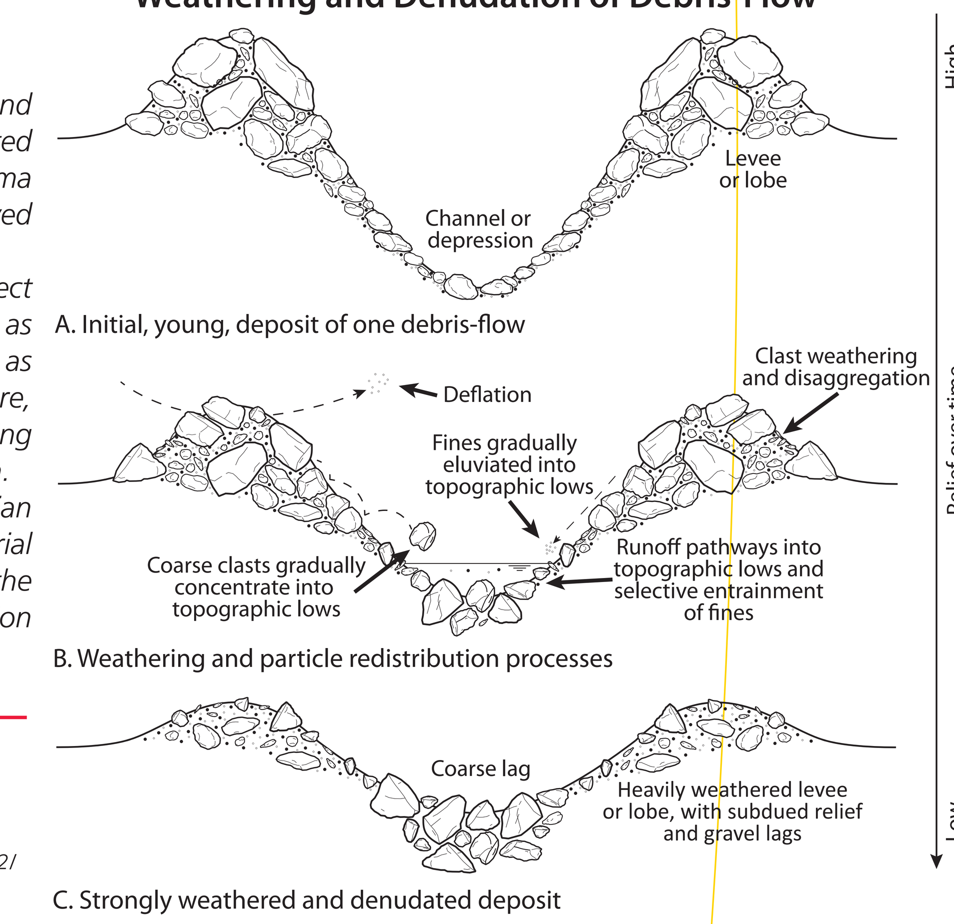
RELIEF

- Initial relief on debris-flow fans in the Mars-like climate of Antarctica is at least 1.5 m.
- Decrease in relief from lobe 4 to lobe 2 is at least 50%.

Fig 1) Fan on a crater wall in eastern Promethei Terra (35° S, 131° E), with four distinct lobes. (A) Lobe 1 is the oldest lobe and retains a dense population of secondary craters. (D) The youngest lobe (4) shows many relief and clear morphological features, such as debris-flow lobes and snouts. Additionally numerous boulders, up to 4.9 m in size are visible on its surface. (B, C) Lobe 2 and 3 show less relief than lobe 4, and no boulders are visible. This indicates that weathering and erosion had a severe effect on the fan surface between the formation time of lobe 2 and 4. HiRISE PSP_002293_1450 is shown in this image due to a more favorable sun altitude, boulder measurements are performed on ESP_012459_1450 due to the higher spatial resolution (0.25 m versus 0.50 m).

THE CONCEPT OF FAN SURFACE DENUDATION

Fig 3) The effect of weathering and erosion on a debris-flow dominated fan surface in the hyperarid Atacama desert in northern Chile, as observed by the presenting author.
Note that on Mars the relative effect of runoff is probably smaller, as precipitation occurs dominantly as snowfall in the last 5 Myr. Therefore, redistribution of fine weathering products is most likely by deflation. However, time of inactivity on Martian fans is much larger than on terrestrial fans, thereby compensating for the lower weathering and fluvial erosion rates on Mars.



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DISCUSSION

- The late Amazonian denudation rate exceeds previous estimates from crater degration (Golombek et al., 2006) by orders of magnitudes, and approximates Noachian values. This implies that local rates can be much higher over short time periods, even on recent timescales (< 1 Myr). We hypothesize the following causes:

1. Weathering and denudation are site specific;
2. Denudation rates inferred from crater rims are naturally lower than rates inferred from fan surfaces, because denudation rate is generally gradient-driven;
3. Denudation rates are highest shortly after abandonment, because they are gradient-driven;
4. The long timespan of the estimates of Golombek et al. (2006) means that these estimates of net denudation comprise cycles of relatively high and low weathering, and thus indirectly erosion and denudation. Denudation rates estimated over long time periods thus include more periods with relatively low weathering rates, decreasing the net denudation rate.

- Weathering rates are spasmodic over time due to variation in liquid water on Martian slopes, as weathering rates are limited by moisture availability in arid environments. In the last 5 Myr, liquid water on Martian boulders could have been present during periods of high obliquity and eccentricity when water ice was deposited on the rocks, criteria that are fullfilled during several short periods in the last glacial period (Head et al., 2011).
- The high, late Amazonian, surface denudation rate has significant implications for process interpretation of Martian landforms, as small-scale morphology indicative of the formative processes is likely to be removed within ~1 Myr.

CONCLUSIONS

- Late Amazonian boulder breakdown rate = 3.5 m/Myr, surface denudation rate = 0.89 m /Myr. These values exceed larger scale late Amazonian denudation rate estimates by orders of magnitude.
- Small-scale morphology indicative of formative processes is mostly removed within ~1 Myr. This is caused by location dependency, high initial smoothing rates following morphological activity, and variations in obliquity and eccentricity causing periods favorable for the presence of (metastable) liquid water with consequent enhanced weathering rates.

Publication The content of this poster has recently been published in Geophysical Research Letters (GRL): De Haas et al. (2013) Local late Amazonian boulder breakdown and denudation rate on Mars.
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