Earth-like aqueous debris-flow activity on Mars at high orbital obliquity in the last Ma

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Introduction

Gullies and liquid water

- Liquid water is currently extremely rare on Mars, but was more abundant during periods of high obliquity in the last few millions of years, testified by the widespread occurence of midlatitude gullies.
- Key questions that remain unanswered are how much water could potentially melt during high-obliquity periods? And how frequent was the aqueous activity within the gullies?

Objectives

- We aim to determine how much water melted during high-obliquity periods and how frequently this happened.

Methodology

- We quantify debris-flow size, frequency and associated liquid water contents on Mars, in the very young Istok crater in Aonia Terra.

Study site: Istok crater

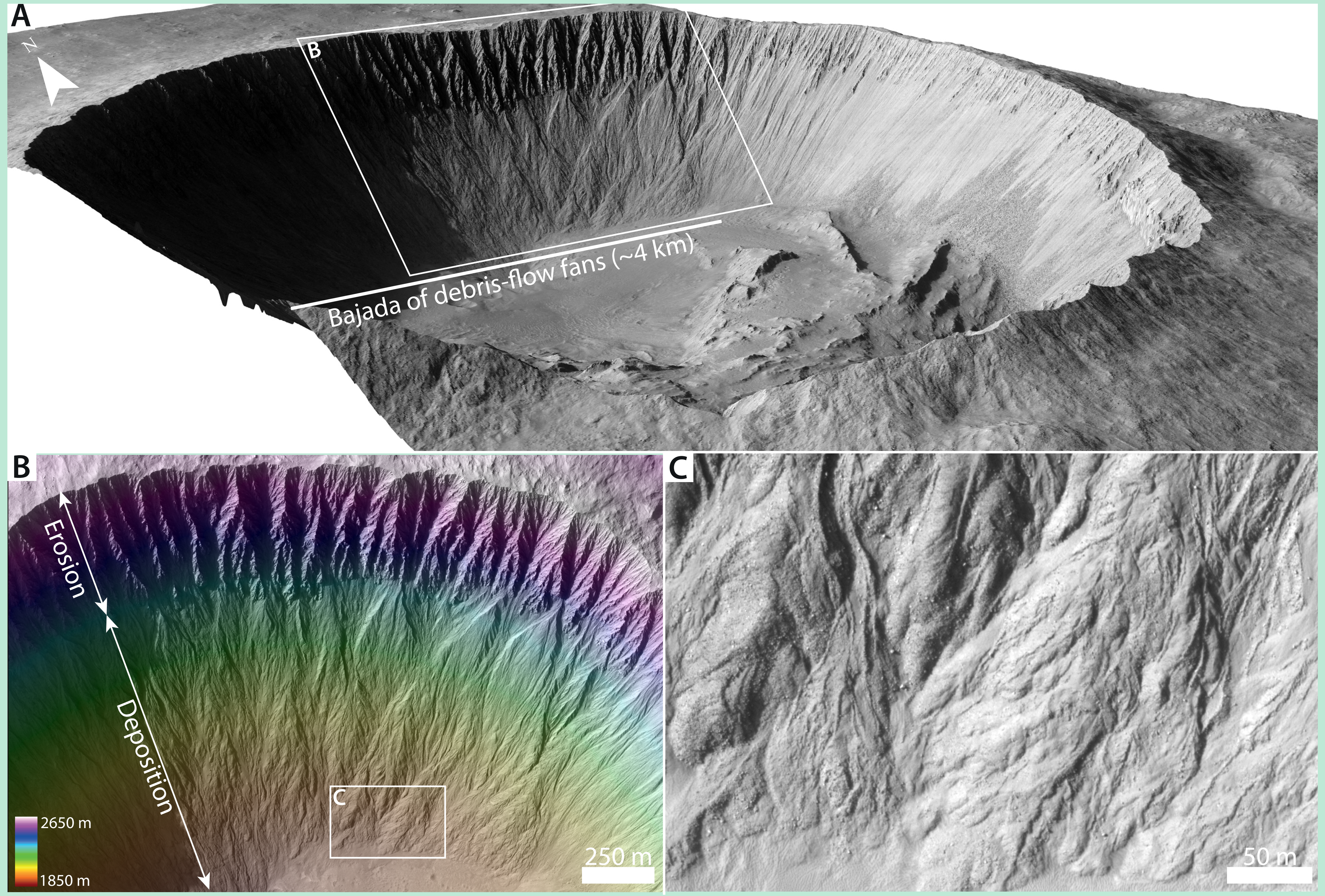

Fig. 1) Istok crater. (A) Bajada of remarkably pristine debris-flow fans on the pole-facing slope (45.11^{0}S; 247.2^{0}E). (B) Eroding alcoves supply sediments to the downslope bajada of fans. (C) The fans are composed of debris-flow deposits, as testified by the widespread occurrence of paired levees, distinct depositional lobes and embedded boulders.

Debris-flow volumes and return period

- Modal debris flow volume is 605 m^3, the 95th percent largest flow has a volume of 3307 m^3 (Fig. 2; Table 1).
- Debris flow return periods roughly range between 1 to 200 yr in the entire crater and per catchment, depending on the chosen obliquity threshold somewhere between 30 - 35^0 (Fig. 2).

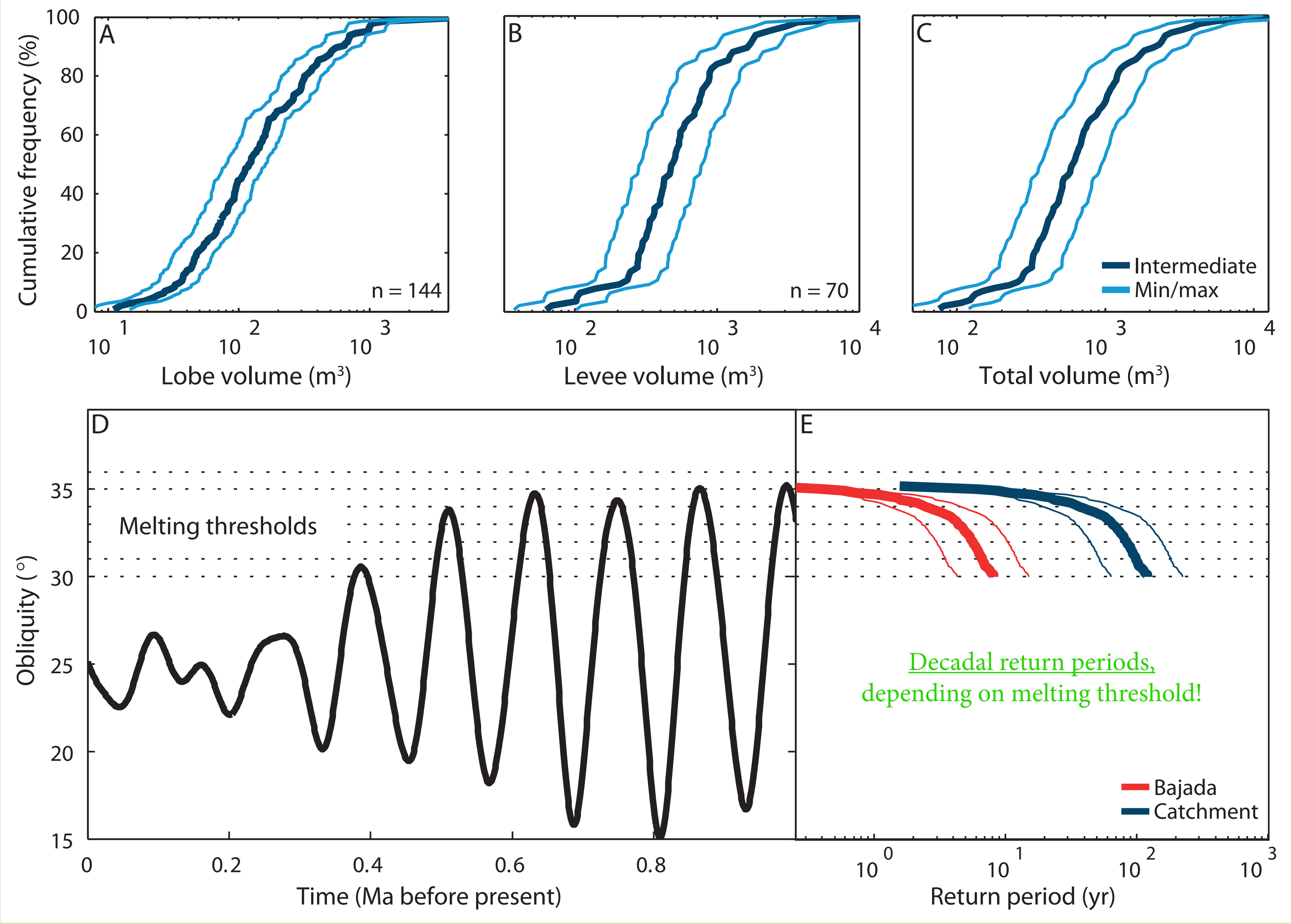

Fig. 2) Debris-flow return periods and size in Istok crater. (A) Cumulative frequency distribution of lobe volume. (B) Cumulative frequency distribution of levee volume. (C) Cumulative frequency distribution of total debris-flow volume (lobe and levee volume combined). (D) Obliquity in the last Ma on Mars, and potential thresholds for melting on mid-latitude pole-facing crater walls. (E) Debris-flow return periods on the bajada and per catchment. The intermediate estimate (thick line) is calculated from the intermediate-estimate debris-flow size and best-estimate catchment size. The minimum and maximum estimates are calculated from the largest debris-flow size and smallest catchment volume and the smallest debris-flow size and maximum catchment volume, respectively.

Earth-like debris-flow frequency

- Debris flows occurred at Earth-like frequencies during high-obliquity periods in Istok crater during the last million years on Mars (Fig. 3).

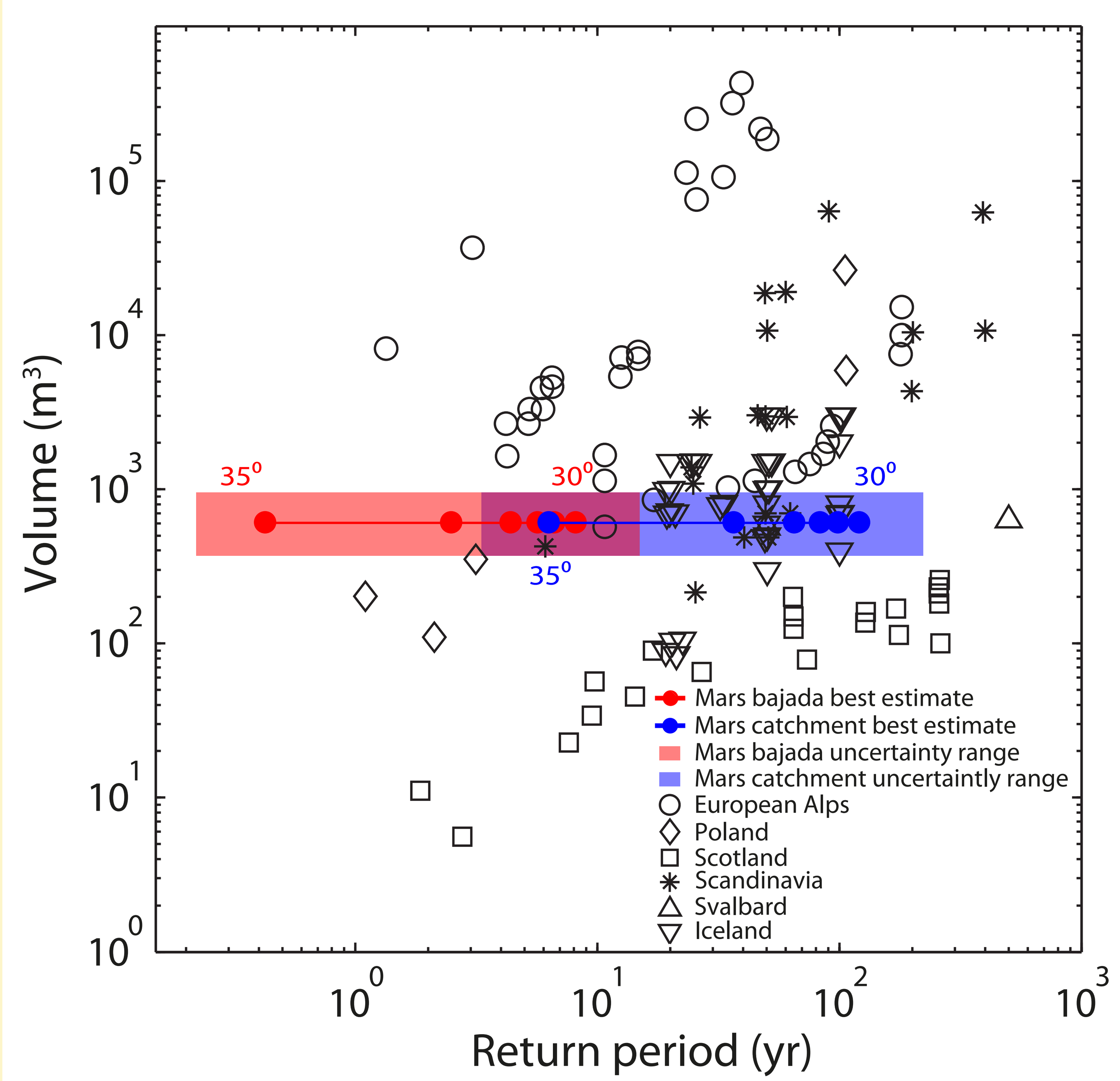

Fig. 3) Comparison between debris-flow volumes and return periods in Istok crater, Mars, and examples from Earth. The return periods on Mars are clearly within the range of return periods observed in temperate to polar regions on Earth regardless of the uncertainty in debris-flow volume, return periods per bajada or individual catchment and obliquity thresholds for melting between 30^0 and 35^0.

Amounts of liquid water

- Millimeters to centimeters of liquid water averaged over the catchments are required for the formation of the observed debris flows (Table 1).
- Actual snow/ice thickness must have been much larger due to the porosity of the snowpack, potential sublimation and evaporation losses and the fact that uniform melting over an entire alcove will generally not occur. On the other hand, snowdrift might have enhanced snow/ice accumulations.

		Water:sediment ratio 0.2		Water:sediment ratio 0.6	
Debris-flow size	Debris-flow volume (m^3)	Water volume (m^3)	Water in alcove (mm)	Water volume (m^3)	Water in alcove (mm)
Modal	605	121	3.0	363	9.0
95% largest	3307	661	16.4	1984	49.1

Table 1) Minimum amounts of liquid water required for the generation of debris flows. Error margins expressed as minimum and maximum values between brackets (see Fig. 2A-C for raw debris-flow volume data).

Conclusions

- Debris flows occurred at Earth-like frequencies in Istok crater during high-obliquity periods in the last million years on Mars.
- Debris-flow volumes are similar to the volumes of terrestrial debris flows.
- Millimeters to centimeters of liquid water averaged over the catchments were required to form the observed debris flows.
- This implies that centimeters to decimeters of snow needed to be present in the alcoves.
- This estimate is larger than the amount of annual precipation in the midlatitudes at high-obliquity that is currently predicted by climate models.

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