Evidence for recent wet-based crater glaciation in Tempe Terra, Mars?

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Evidence for basal melting of putative debris-covered glaciers in Mars' mid-latitudes is extremely rare.

- The glaciers are currently **frozen to their beds**, but has this always been the case?
- **Eskers** (Fig 1) emerging from two mid-latitude glaciers [1-2] indicate at least two **localized melting events** beneath existing glaciers **~110-150 Myr** ago (Fig 2).

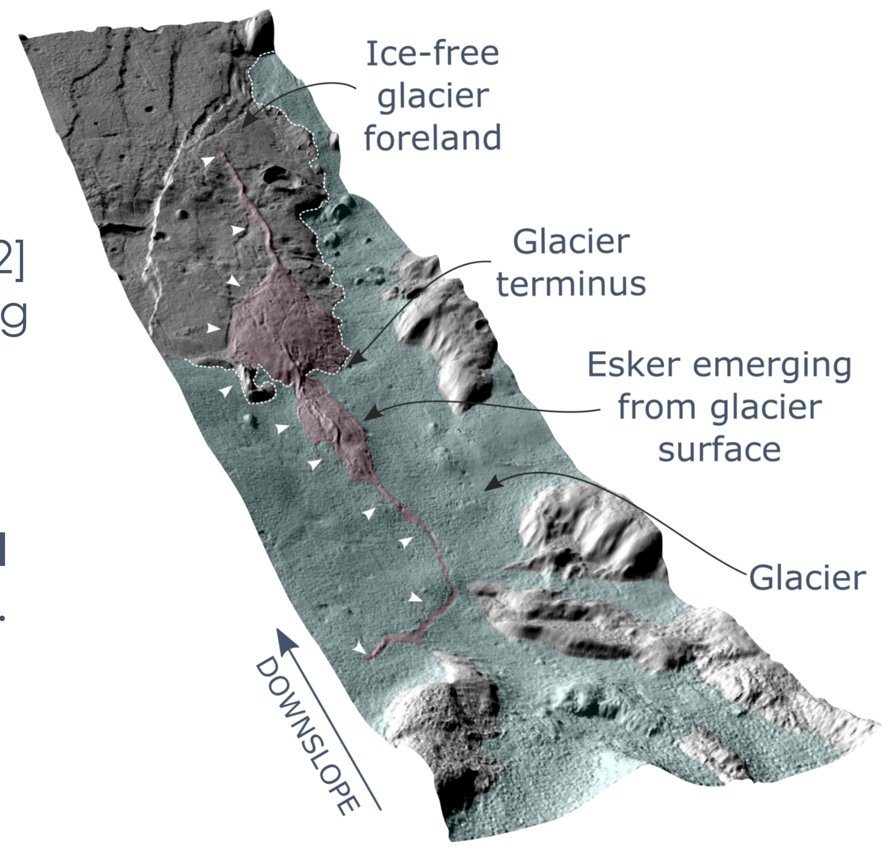


Fig 2: Esker (pink, 14 km long) emerging from a debris covered glacier (blue) in Tempe Terra [2]. Oblique shaded-relief map of HiRISE digital elevation model.

Eskers indicate past glacial melting.

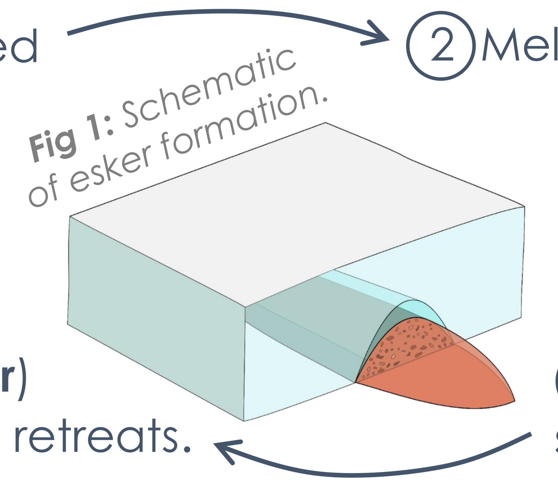


Fig 1: Schematic of esker formation.

Are glacier-linked sinuous ridges in Chukhung Crater eskers?

- Chukhung Crater (38.47°N, 72.42°W) is a 45 km-diameter, Hesperian-aged [3] central pit crater [4] in Tempe Terra.

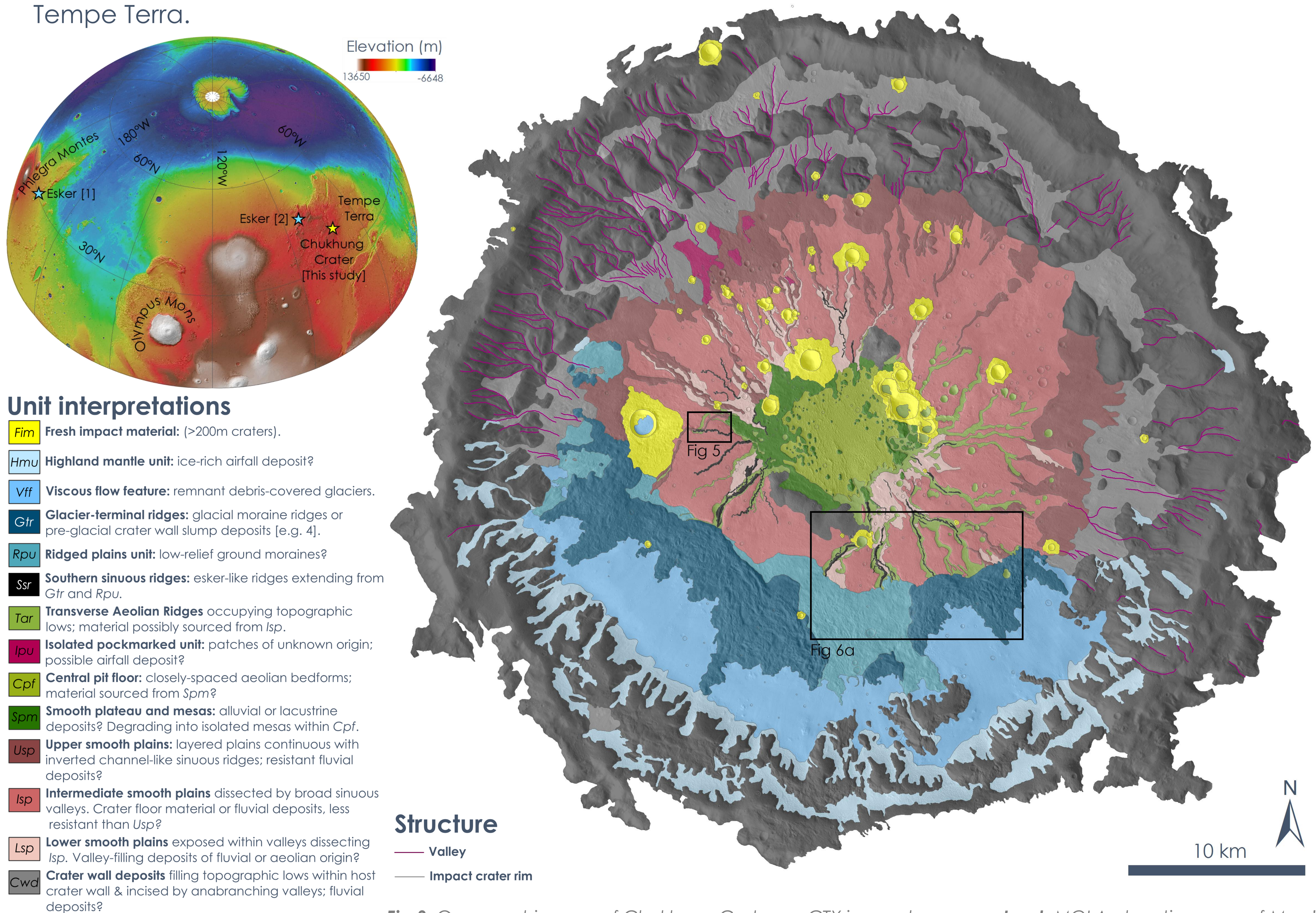
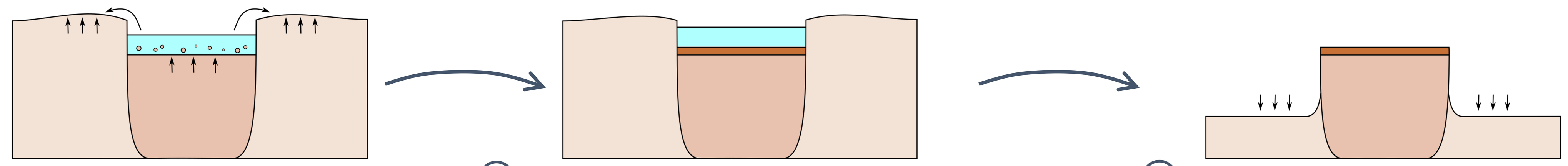


***Fig 3:** Geomorphic map of Chukhung Crater on CTX image basemap. **Inset:** MOLA elevation map of Mars' northern hemisphere showing the locations of Chukhung Crater & the two known glacier-linked eskers.*

Chukhung Crater hosts two populations of sinuous ridges.

- **Esker-like ridges** (*Ssr*, Fig 3) **emerge from moraine-like deposits** (*Gtr* & *Rpu*, Fig 3) bounding the termini of putative **debris-covered glaciers** (*Vff*, Fig 3) on the southern crater floor.
- **Inverted channel-like ridges** (within *Usp*, Fig 3) extend from fluvial valleys on the northern crater wall. They formed **prior to glaciation** of the crater. Their formation **does not require glacial meltwater** (Fig 4).

Fig 4: Schematic of inverted channel formation [e.g. 5]



The two sinuous ridge populations are morphologically distinct, supporting different origins.

- The esker-like ridges are **younger**, **more sinuous**, and have **sharper crests** than the inverted channel-like ridges (Fig 5).
- However, the ridges have **similar dimensions**, so differences in crest morphology could be due to **differences in degradation state** rather than formation mechanism.

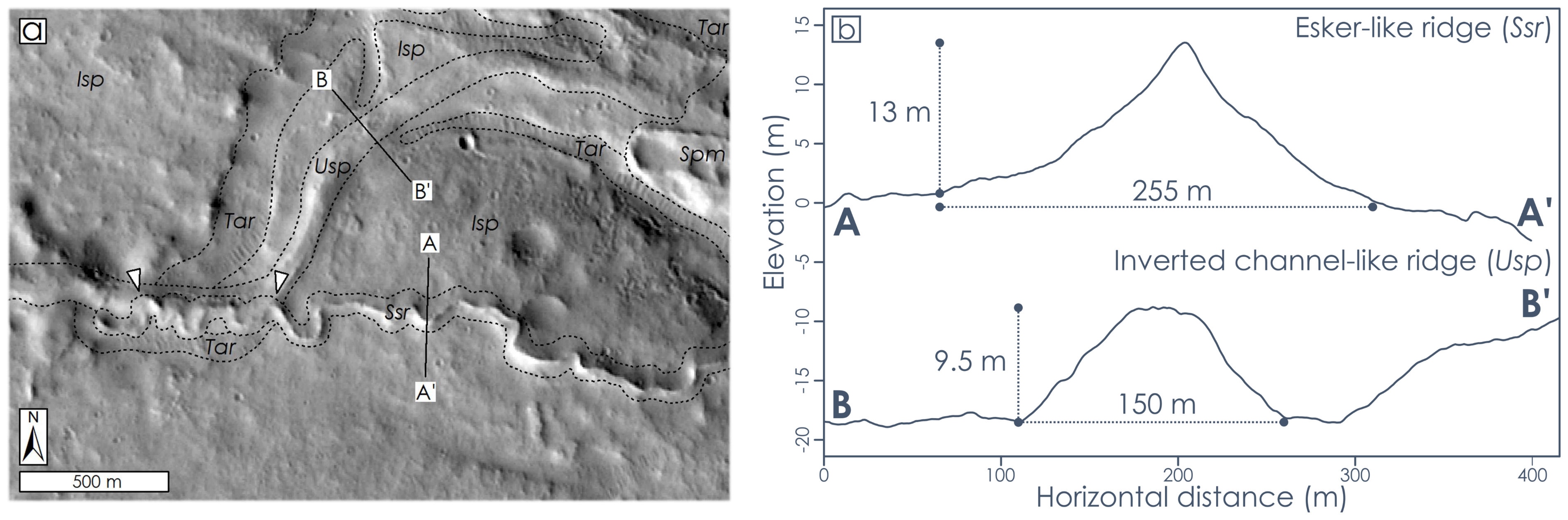


***Fig 5:** **(a)** Esker-like ridge (Ssr) superposing inverted channel-like ridge (Usp) (extent in Fig 3. CTX image P04_002577_2186_XN_38N072W), and **(b)** topographic profiles AA' and BB' from (a) extracted from digital elevation model generated from HiRISE images ESP_017477_2190 and ESP_018545_2190 [6].*

The esker-like ridges ascend valley walls.

- Esker-forming meltwater can **ascend bed slopes** under hydraulic pressure in **subglacial tunnels** [8]. Ascent of valley walls (Fig 6b) is **inconsistent** with deposition under **gravity-driven flow** in subaerial fluvial channels.
- However, ascent of slopes could be **inherited from differential erosion** under the alternative inverted channel hypothesis, rather than a primary feature.

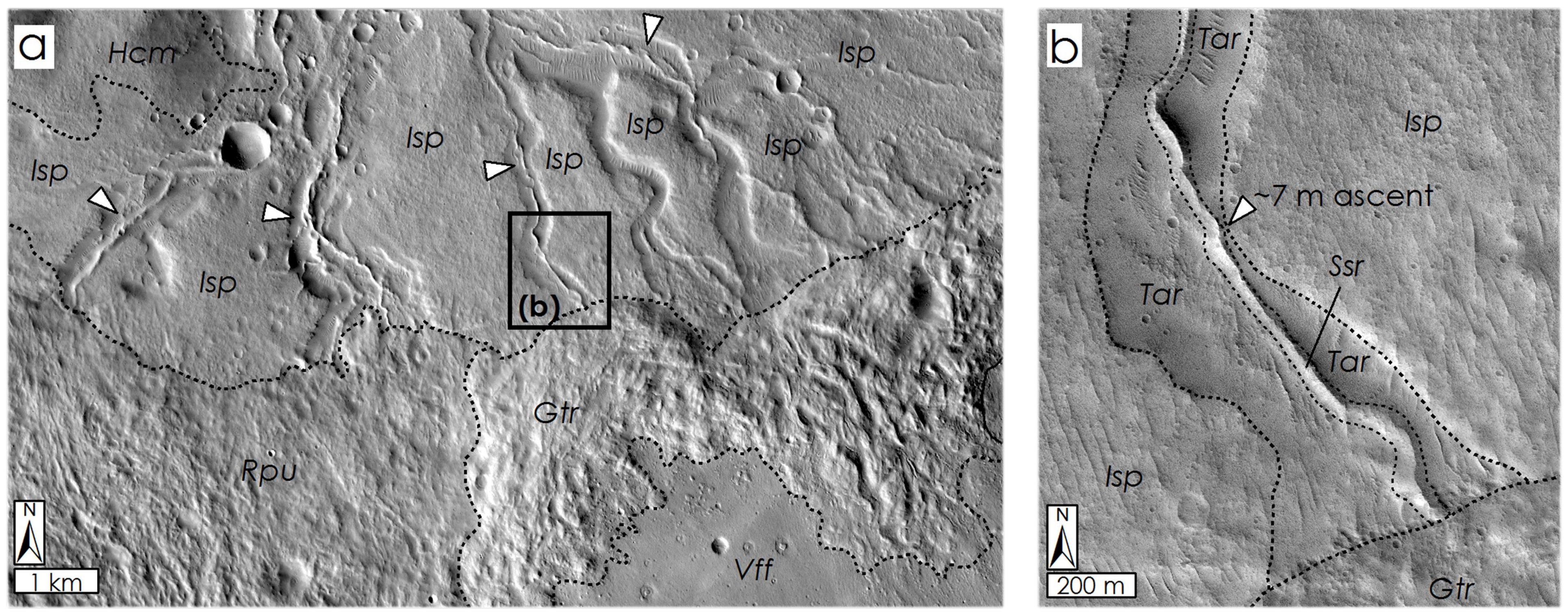


***Fig 6:** **(a)** Esker-like sinuous ridges (white arrows) emerging from moraine-like deposits (Gtr & Rpu) at glacier (Vff) termini. CTX image P04_002577_2186_XN_38N072W. **(b)** Esker-like ridge ascending a valley wall. HiRISE image ESP_023503_2185.*

There are challenges for the esker hypothesis.

- The esker-like ridges could be a **second population of inverted channels**.
- **Glacial deposits** (*Vff, Gtr, Rpu*) covering the southern crater floor hinder scrutiny of the relationship of the esker-like ridges to pre-glacial fluvial deposits.
- Eskers are **ice-contact deposits** but there is **no additional evidence** for past glaciation northward of the moraine-like deposits (*Gtr & Rpu*).
- There is one **esker-like ridge system on the northern floor**, where there is no evidence for glaciation.

Lessons from Chukhung Crater.

- Even where sinuous ridges emerge from **existing glaciers**, and where they have esker-like **non-slope-conforming topographic signatures**, conclusive identification as eskers is complicated by **similarities in form** between inverted channels and eskers [e.g. 8].
- **Regional mapping** and **quantitative 3D morphometric** analyses [e.g. 2,9] should always be performed before an esker origin can be concluded. Such analyses are ongoing for Chukhung Crater.

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