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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).

Eskers indicate past glacial melting.

1 Ice at glacier bed melts.
2 Meltwater carves a tunnel through the ice.
3 Meltwater deposits sediment in the tunnel.
4 A ridge of sediment (an esker) is left when the ice retreats.

Are glacier-linked sinuous ridges in Chukhung Crater eskers?


![Image](https://example.com/image.png)

**Unit Interpretations**
- Fresh impact material (>200m craters)
- Highland mantle unit: ice-rich aerial deposit
- Viscous flow feature: remnant debris-covered glaciers.
- Glacial-terminal ridges: glacial-marine ridges or pre-glacial crater wall slump deposits (e.g. 4).
- Ridge complex units: scarp-rimmed ground moraines.
- Southern sinuous ridges: esker-like ridges extending from surrounding material.
- Transverse Areolae ridges: occupying topographic lows, possibly sourced from bas.
- Isolated pockmark-like pits of unknown origin: possible aerial deposit.
- Central pillar-like: closely spaced areal bedform.
- Material sourced from Spirit.
- Smooth pillars and mesas: isolated or linear deposit (e.g. 11 km long) within the crater walls.
- U-shaped smooth plains: linear plains continuous with inverted channeled sinuous ridges, resistant fluvial deposits.
- Intermediate smooth plains: deposits containing by the surrounding material, leaving a ridge.
- Ridges extending from surrounding material, leaving a ridge.
- Crater walls filled with fluvial deposit.
- Neotectonic features: crater rim, and central pillar.

**Chukhung Crater hosts two populations of sinuous ridges.**

- **Esker-like ridges** (Srr, 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).

![Image](https://example.com/image.png)

**Structure**
- Valley: Impact crater rim
- Valley: Impact crater rim

**Fig 3:** Geomorphologic 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.

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.

![Image](https://example.com/image.png)

**Fig 5:** (a) Esker-like ridge (Srr) 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.

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 inferred from differential erosion under the alternative inverted channel hypothesis, rather than a primary feature.

![Image](https://example.com/image.png)

**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_023303_2183.

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 glaciological characterization with 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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