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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.

Eskers are linked sinuous ridges in Chukhung Crater 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.

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.

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.

Unit Interpretations

- Fresh Impact material (>200m craters)
- Highland mantle unit: ice-rich surficial deposit?
- Viscous flow feature: remnant debris-covered glaciers.
- Glacial-terminal ridges: glacial moraine ridges or pre-glacial crater wall slump deposits (e.g. 4).
- Rupture plane unit: ice-covered ground moraine?
- Southern sinuous ridges: esker-like ridges extending from the crater rim?
- Transverse Areolae ridges occupying topographic low, material possibly sourced from lip.
- Isolated pockmarked surficial patches of unknown origin: possible subaerial depression?
- Central pit basin: closed-opened axial bedsheets: material sourced from Spirit.
- Smooth plains and mesa: alluvial or lacustrine deposits (e.g. 3). Icicles within crater.
- Upside smooth plains: terrace plains continuous with inferred channel-like sinuous ridges: resistant fluvial deposits.
- Intermediate smooth plains: dissected by broad sinuous valleys. Crater floor material or fluvial deposits, less resistant material.
- Lower smooth plains exposed within valleys dissecting dissected lower grade plains in fluvial or aeolian origin?
- Crater wall deposits filling topographic lows within crater.
- Thick and thin lacustrine deposits.
- Hypocenter material: crater rim, and central pit-walls.

Structure

- Valley
- Impact crater rim
- Flat
- Slopes

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 ridge (within Usp, Fig 3) extend from fluvial valleys on the northern crater rim. 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]

Fig 5: (a) Esker-like ridge (Ssr) superposing inverted channel-like ridge (Usp) (extent in Fig 3. CTX image P04_002377_2186_XN_38N072W) and (b) topographic profiles AA’ and BB’ from (a) extracted from digital elevation model generated from HiRISE images ESP_017477_1910 and ESP_018545_1910 [6].

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.

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.

Acknowledgements: We thank Caleb Fassett, Edwin Kite and David Mayer for drawing our attention to the study site (CT & ER), and providing F.E.M. (ER & DM). The Royal Astronomical Society and the British Society for Geomorphology funded F.E.M to attend this conference. This work was funded by STFC grants ST/N00421X/1 (FEGB) and ST/I000771/1 (MR/R019625/1). J.S.C is supported by the French Space Agency CNES.