Morphometric characterisation of eskers associated with an extant mid-latitude glacier on Mars.

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Evidence for basal melting of modern putative debris-covered glaciers (DCGs) on Mars is extremely rare.

- Modern DCGs are likely **frozen to their beds**, but has this always been the case?
- Gallagher and Balme [1] identified **sinuous ridges** in the foreland of a **late-Amazonian-aged (~150 Ma) DCG** in Phlegra Montes (Figs 1-3).
- They interpreted these ridges as **young eskers** (Fig 4) – the **first of their kind** identified in association with a modern DCG on Mars.

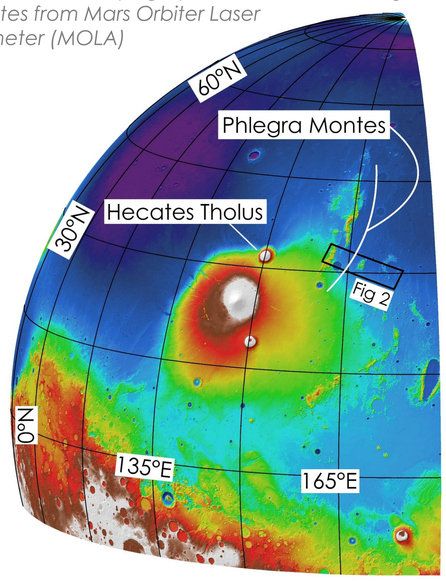


Fig 1: Global topographic context of Phlegra Montes from Mars Orbiter Laser Altimeter (MOLA)

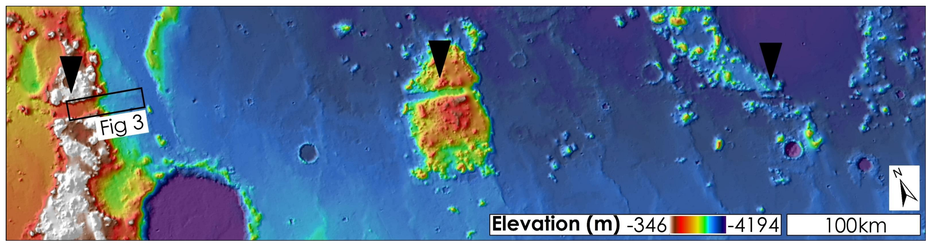


Fig 2: Regional topographic context from MOLA. Black arrows show sections of a regional graben, in which the candidate esker is located. Extent in Fig 1.

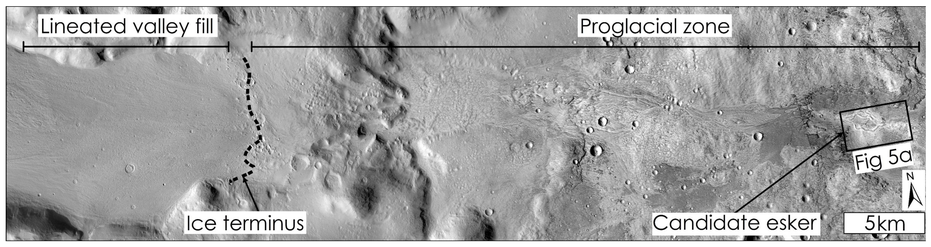


Fig 3: Context Camera (CTX) image mosaic of candidate esker in proglacial zone of the parent DCG (lineated valley fill). Extent in Fig 2.

Eskers are diagnostic of glacial melting.

- Eskers are **ridges of sediment** deposited by **meltwater** in ice-walled, typically **subglacial drainage conduits,** and subsequently exposed by glacier retreat (Fig 4).
- Their **morphometry** is strongly controlled by the geometry of their parent meltwater conduits which, in turn, is **controlled by hydraulic conditions** within them [e.g. 2].

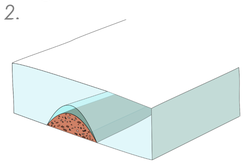


Fig 4: Schematic of subglacial esker formation

We characterise candidate esker morphometry with new high-resolution 3D data

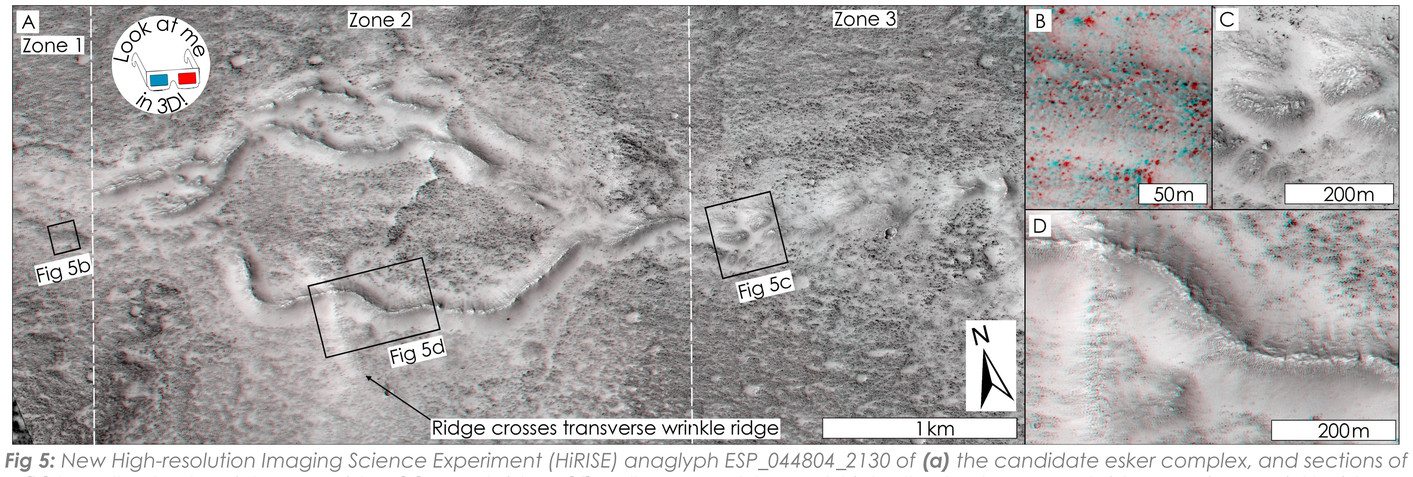


*Fig 5: New High-resolution Imaging Science Experiment (HiRISE) anaglyph ESP_044804_2130 of **(a)** the candidate esker complex, and sections of **(b)** low-albedo clast-rich zone 1 ridge **(c)** zone 3 ridges **(d)** well-preserved, layered, high-albedo, sharp zone 3 ridge crossing a wrinkle ridge.*

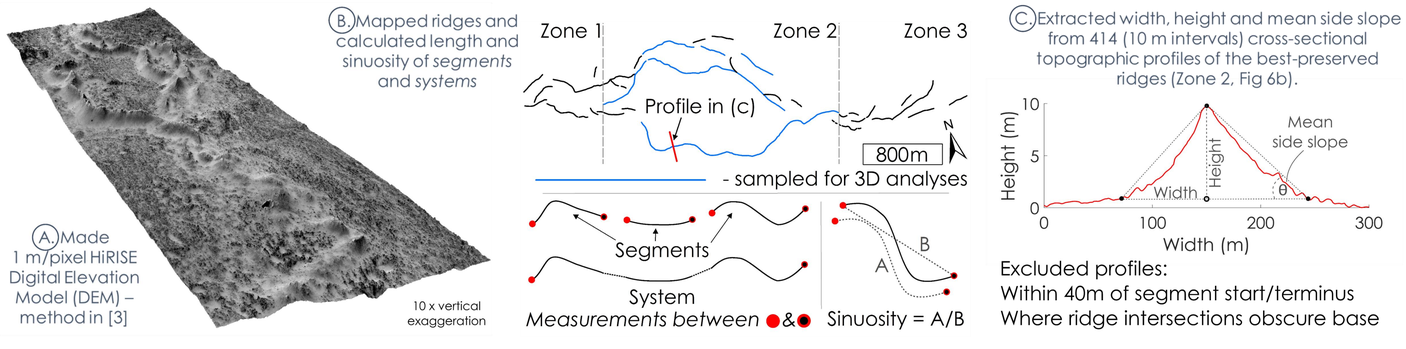


*Fig 6: Methods: **(a)** oblique view of orthophoto overlain on DEM generated from HiRISE images ESP_044316_2130 and ESP_044804_2130, **(b)** mapped segments and plan-view geometry extraction, **(c)** cross-sectional profile (location shown in b) and 3D geometry extraction.*

Plan-view geometry

Table 1: Segment and system sinuosity statistics for Phlegra Montes candidate eskers (PM), Dorsa Argentea (DA)[4], and Canadian eskers, Earth (CA) [5].

	Segments			Systems		
	PM	DA	CA	PM	DA	CA
Min	1.00	1.00	-	1.01	1.01	-
Median	1.02	1.02	1.04	1.07	1.07	1.06
Mean	1.05	1.04	1.06	1.08	1.10	1.08
Max	1.22	1.75	2.21	1.25	1.91	2.45

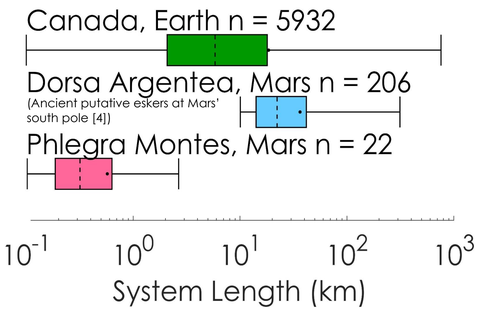
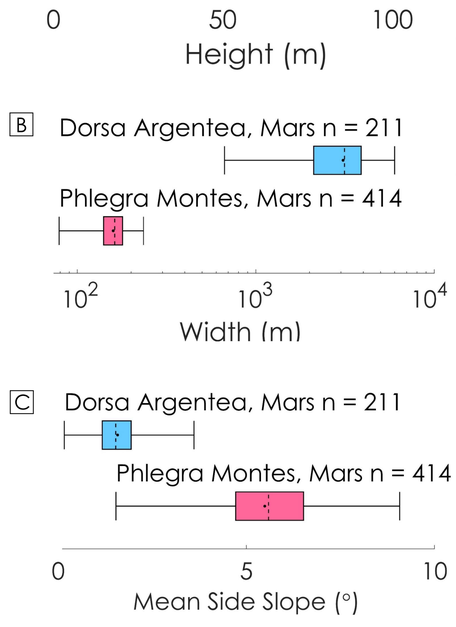


Fig 7: System lengths for the Phlegra Montes candidate eskers, Dorsa Argentea [4] and Canadian eskers [5]. Boxes - interquartile range, bars - range, dashed lines - median, points - mean.

- **Similar length and sinuosity** to **Canadian eskers** (Fig 7, Table 1).
- **Similar sinuosity** to, but **shorter** than, ***ancient*** (Early Hesperian) **putative eskers** near Mars' south pole (Dorsa Argentea) (Table 1).
- **Known candidate eskers** on Mars occupy the **full range of terrestrial esker lengths (10s m – 100s km).**



Cross-sectional morphometry (Zone 2)

- **Similar heights** to Icelandic eskers (~1 – 14 m [6]) (Fig 8a).
- **Widths** more similar to terrestrial eskers (~10s m – 2 km [2,6]) than Dorsa Argentea [4] (Fig 8b).
- **Intermediate side slopes** between Icelandic eskers (~11-22° [6]) and Dorsa Argentea, Mars [4] (Fig 8c).
- **Lower side slopes than terrestrial eskers** could result from fundamental **differences in subglacial hydrology** between Earth and Mars, which should be explored further.

*Fig 8 (left): **(a)** height, **(b)** width, and **(c)** mean side slope of the Phlegra Montes candidate eskers (zone 2) and Dorsa Argentea [4]. Boxes - interquartile range, bars - range, dashed lines - median, points - mean.*

Ongoing work

Phlegra Montes candidate esker morphometry

- Tests for esker-like response of **ridge height** to **longitudinal bed slope**.

NEW DCG-linked candidate esker in a similar graben setting

- **Abstract #1234**, this conference.
- Supports the hypothesis that **elevated geothermal heat** was a **pre-requisite** for **recent basal melting** of mid-latitude glaciers on Mars [1].

Modelling environmental conditions required for basal melting in Phlegra Montes

- Exploring atmospheric **temperature and geothermal heat** scenarios using the JPL/University of California **Ice Sheet System Model** (ISSM) [8].

References: [1] Gallagher, C., and Balme, M.R. (2015), Earth Planet. Sc. Lett., 431, 96-109, [2] Shreve, R.L. (1985), Geol. Soc. Am. Bull., 96, 639-646, [3] Kirk, R.L. et al. (2008), JGR Planets, 113(E3), E00A24, [4] Butcher, F.E.G. et al. (2016), Icarus, 275, 65-84, [5] Storrar, R.D. et al. (2014), Quat. Sci. Rev., 105, 1-25, [6] Storrar, R.D. et al. (2015), Earth Surf. Proc. Land., 40(11), 1421-1438, [7] Butcher, F.E.G. et al. (2017) LPSC XLVIII, Abstract #1234, [8] Larour, E. et al. (2012) JGR Earth Surf., 117(F1), F01022.

Acknowledgements: FEGB is funded by STFC grant ST/N50421X/I and is grateful for travel support from the 2017 PSI Pierazzo International Student Travel Award. We are grateful to R.D. Storrar for the Canadian esker data.