3D MORPHOMETRIES OF ESKERS ON MARS, AND COMPARISONS TO ESKERS IN FINLAND. F. E. G. Butcher[1], M. R. Balme[1], C. Gallagher[2,3], R. D. Storrar[4], S. J. Conway[5], N. S. Arnold[6], S. R. Lewis[1], and A. Hagermann[7], [1]School of Physical Sciences, The Open University, UK (frances.butcher@open.ac.uk), [2] UCD School of Geography, University College Dublin, Ireland, [3]UCD Earth Institute, University College Dublin, Ireland, [4]Department of the Natural and Built Environment, Sheffield Hallam University, UK, [5]CNRS, UMR6122, LPG Université de Nantes, France, [6]Scott Polar Research Institute, University of Cambridge, UK, [7]Biological and Environmental Sciences, University of Stirling, UK.

Introduction: We present new, high-resolution measurements of the 3D morphometries of eskers associated with debris-covered glaciers in the Phlegra Montes [1] and NW Tempe Terra [2] regions of Mars' northern mid-latitudes. We compare them with the ancient south polar 'Dorsa Argentea' eskers on Mars [3], and first large database (n > 20,000) of 3D morphometries of terrestrial eskers, from SW Finland [4].

Eskers are ridges of glaciofluvial sediment deposited by meltwater flowing through tunnels within or beneath glaciers. They are vital tools for reconstructing the dynamics, extent, and environmental drivers of wet-based glaciation on Earth and Mars. For example, reconstructions of Mars' climate conditions at the Noachian-Hesperian transition [e.g., 5] have relied heavily upon insights from the Dorsa Argentea eskers [e.g., 3], which record basal melting of a large south polar ice sheet ~3.5 Ga.

Morphometric studies of candidate eskers on Mars are vital both for testing hypotheses of their origins as eskers [e.g., 3], and for informing insights into the magnitude and dynamics of meltwater flows that formed them [e.g., 5–6]. Previously, such work has been limited by a lack of large-scale surveys of the 3D morphometries of eskers on Earth, to which the martian landforms can be compared. A new database comprising >20 000 measurements of 3D esker morphometries from SW Finland provides new opportunities for such-comparisons, which we exploit in this study [4].

Methods: We used 1–2 m/pixel digital elevation models generated from High Resolution Imaging Science Experiment (HiRISE) images to measure esker heights (H) and widths (W) from cross-sectional transects spaced at 10 and 20 m intervals along the Phlegra Montes and NW Tempe Terra eskers, respectively (following [3]). We calculated average slopes across cross-sectional transects (θ) as: $\tan^{-1}(H/0.5W)$. We classified transects into sharp-, multi-, and round- crested morphologies according to the scheme of [6]. The NW Tempe Terra esker comprises two 'stacked' esker ridges (see [7], this conference) which we treat separately in the present study.

Storrar and Jones [4] obtained similar H, W, and θ measurements at 10 m intervals along ~70 km of Quaternary-aged eskers in SW Finland, using 2 m/pixel elevation data from airborne LiDAR.

We also compare our measurements to those of the Dorsa Argentea eskers obtained by [3]. However, due to data resolution limits (~100s m/pixel), these measurements represent only the largest Dorsa Argentea ridges (widths up to ~6 km and heights up to ~100 m).

Results and Discussion: Figure 1 shows our new measurements of the Phlegra Montes and NW Tempe Terra eskers, and comparisons to the Dorsa Argentea (Mars) and eskers in SW Finland.

Morphology-morphometry relationships: Sharp-crested and sharp-to-multi-crested portions of the Phlegra Montes and NW Tempe Terra eskers have similar heights, widths and average cross-sectional slopes (Fig 1), though these portions of the Phlegra Montes esker are somewhat wider relative to their heights than for the NW Tempe Terra esker. We suggest that this results from differences in esker degradation state between the sites. The Phlegra Montes esker is located ~35 km beyond the terminus of its parent glacier [1] whereas the NW Tempe Terra esker remains partially buried by its parent glacier [2]. This indicates that the Phlegra Montes esker has an older exposure age and suggests that mass wasting of its flank slopes may be more advanced [2]. We observe similar differences in slope between the sharp-crested section of the NW Tempe Terra esker (zone IV in [7]) that extends into the foreland of the parent glacier and a sharp- to multi-crested portion that is still contact with the parent glacier (subzones IIb–IIIb upper member ridge in [7]). The glacier-proximal section has a pristine crestline, whereas the crest of the glacier-distal section is heavily pitted [2]. This is consistent with more advanced loss of interstitial ice content (and associated flank slope degradation) from glacier-distal esker sediments with older exposure ages.

Round-crested portions of the NW Tempe Terra esker are typically ten times taller and wider than those of the Phlegra Montes esker (Fig 1). Despite these absolute heights and width differences, they have very similar H-W relationships, and θ values. θ values for round-crested portions may be less sensitive exposure age than sharp-crested portions due to lower susceptibility to mass wasting on lower slopes.

Morphometric similarities to eskers in SW Finland: Whereas the Dorsa Argentea have similar heights (100s metres) and widths (up to 6 km) to the largest eskers on

Earth [3], the Phlegra Montes and NW Tempe Terra eskers have heights and widths that are more similar to the more 'typical' scales of eskers on Earth. Their heights and widths fall largely within the 3rd and 4th quartiles of those for eskers in SW Finland.

Lower side slopes than eskers in SW Finland: The Phlegra Montes and NW Tempe Terra eskers have greater width-height ratios, and hence lower θ values (median θs ~2–11 °; Fig 1c) , than typical eskers in SW Finland (median θ = 13.7 °; Fig 1c), but are more similar to typical terrestrial eskers than the Dorsa Argentea (median θ = 1.5 °; [3]). Interestingly, the only group of measurements that exceed the resolution-imposed detection limit of ridge widths for the Dorsa Argentea are for the round-crested portions of the NW Tempe Terra esker. These portions (median θ = 3 °) approach the low θ of the Dorsa Argentea (Fig 1c). This provides further evidence that eskers in different locations on Mars have broadly similar, potentially glacio-hydrologically-controlled height-width relationships, despite differences in their absolute heights and widths.

Conclusions: Morphometric similarities between portions of the Phlegra Montes and NW Tempe Terra eskers with similar crest morphologies suggests that crest morphologies of eskers on Mars are controlled by fundamental glacio-hydrological processes. Small differences in height-width relationships between sharp-crested portions may result from differences in esker exposure age and degradation state. The Amazonian-aged mid-latitude glacier-linked eskers are more similar to terrestrial eskers in their widths, heights and cross-sectional slopes than the large, ancient, Dorsa Argentea eskers. Thus, the dynamics and magnitude of the glacier melt events that formed them may be more similar to 'typical' esker formation events during Quaternary glaciations on Earth.

Our morphometric database (which also includes length and sinuosity measurements) will be made available for future reconstructions of wet-based glaciation on Mars, and for comparative studies to landforms elsewhere on Mars.

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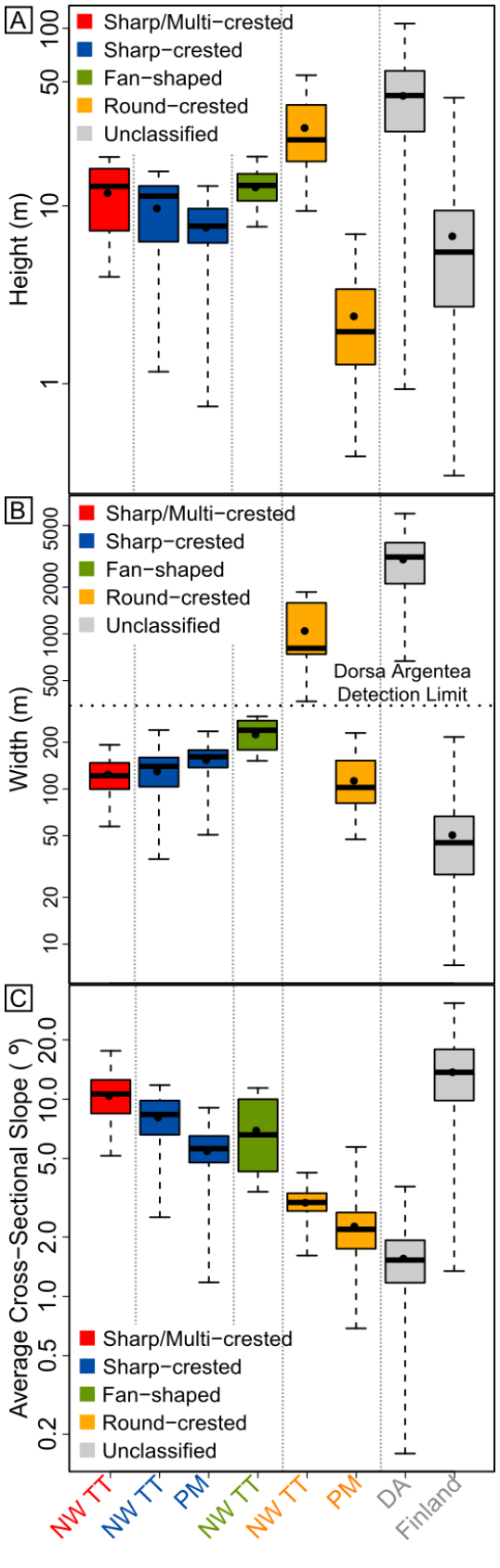

Figure 1 (right): *3D morphometries of eskers in Phlegra Montes (PM) and NW Tempe Terra (NWTT), Mars, categorized by crest morphology (colors), and comparison to the Dorsa Argentea (DA; [3]), Mars, and eskers in SW Finland, Earth [4]: **(A)** Height. **(B)** Width. **(C)** Average cross-sectional slope.*