RNAAS RESEARCH NOTES OF THE AAS

Reconstructing In-channel Processes from the Eberswalde Delta on Mars

To cite this article: Rebecca Warrilow *et al* 2024 *Res. Notes AAS* **8** 298

Reconstructing in-channel processes from the Eberswalde delta on Mars

Rebecca Warrilow [1] Louisa J. Preston [1] Andrew Coates [1] Bobby Andrews,[2] Sam Blunden,[2] Katie Carter,[2] Isaac Collings,[2] Mark Di Paolo,[2] Edward Gilbert,[2] Elwyn Gravestock,[2] Ollie Hagon,[2] Ruby Kenny,[2] Dior Knorr,[2] Luke Pizzey,[2] Isolde Ruse,[2] Harry Sedgwick,[2] Luca Sibelly,[2] Fraser Williams,[2] Kayla Williamson-White,[2] and William Dunn [3]

[1]*Department of Space and Climate Physics. Mullard Space Science Laboratory (MSSL), University College London, Dorking, UK*
[2]*Blenheim High School, Longmead Road, Epsom, UK*
[3]*Department of Physics and Astronomy, University College London, Gower Street, London, UK*

ABSTRACT

Studying ancient fluvial landforms on Mars is essential for understanding the planet's climate history and can provide valuable insights into the intensity and duration of liquid water activity. This research used an Earth-based model to constrain local estimates of fluvial activity at the Eberswalde crater delta on Mars and sharpen our understanding of the sedimentary record with novel grain size and sediment flux calculations at this site. Remote sensing methods were used to reconstruct in-channel processes and estimate the delta formation by sediment transported in intermittent flows over ∼71,500 years. Such sustained hydrological activity may have once provided habitable conditions at Eberswalde.

Keywords: Mars, rivers, hydrology, remote sensing, Eberswalde

INTRODUCTION

Mars has an extensive fluvial history, evident from geomorphological features dated to the Noachian-Hesperian climates (>3 Ga) when surface runoff was most abundant (Kite et al. 2019). Our current understanding of global Martian palaeohydrology relies on data gathered from orbit, with high-resolution images and topographic datasets allowing scientists to examine the Martian climate record in finer detail. However, the magnitude of fluvial activity remains poorly constrained, partly because environmental reconstructions still rely upon measurements of parameters from alternative regions, such as transported grain size (*e.g.,* Mangold et al. 2012). Improved data and models can support studies attempting to reveal insights into the climatic conditions under which Martian rivers persisted. In particular, delta structures are excellent candidates for study due to their formation requiring liquid water and nutrient-rich sediment deposits (Hughes et al. 2023). However, it is essential to investigate sites beyond regions explored by in-situ rovers to develop a more global picture of hydrological activity across the Martian surface and, thus, improve interpretations of the environment in which rivers formed.

Eberswalde Delta

The Eberswalde delta sits on the western margin of the crater floor. The exact timing of deposition is unknown, but delta formation has been constrained to after ∼3.65 Ga (Mangold et al. 2012). It is one of the best-preserved fluvial distributary networks on Mars (Figure 1a), with palaeochannels expressed in inverted relief (Figure 1b) (Malin & Edgett 2003), making it a potential target of interest in the ongoing exploration of Mars' past habitability. However, previous estimates of palaeohydrological activity at Eberswalde are ambiguous (Figure 1c).

METHODOLOGY

Birch et al. (2023) established a framework that uses dimensionless hydraulic geometry relations to calculate the properties of alluvial rivers using only channel width and slope measurements based on the calibrated results of rivers on Earth. Applying these methods at Eberswalde allows for reconstructions of ancient fluvial processes accounting for physical differences between planets, such as Mars's lower gravity. This approach has thus far been used only on sedimentary deposits at Gale and Jezero craters, where surface observations of sediment captured by in-situ rover imagery validate estimates.

Data

The High-Resolution Imaging Science Experiment (HiRISE) instrument onboard the Mars Reconnaissance Orbiter provides orthorectified imagery projected at a resolution of 0.25 m/pixel and stereo-derived digital elevation models (DEM) available at 1 m/pixel. Image data was also collated from the High-Resolution Stereo Camera (HRSC) onboard the Mars Express orbiter at 12.5 m/pixel with a DEM available at 125 m/pixel for a more comprehensive site view.

Measurements

QGIS software was used to digitise channel width, interpreted as the distance between inverted bank edges perpendicular to the channel centreline, measured at 20 random intervals. The median width, W, was 79.3 m (Figure 1c). Using the HiRISE DEM, the vertical difference between two points on the delta surface was divided by their longitudinal distance to obtain a gradient, or slope, S, of 0.002. The delta perimeter was mapped to quantify the areal extent of the deposit, A, of 117 km^2 (Figure 1c). The HRSC DEM was clipped to the delta extent, and the delta volume, V, was estimated above the interpolated base plane at 11.8 km^3 (Figure 1c). Irwin et al. (2015) report a topographically defined watershed of 17,000 km^2, which was used to constrain the drainage basin area.

Due to its erosional resistance, it is assumed that Eberswalde was a bedload-dominated river, so the appropriate calculations from Birch et al. (2023) (Eq. 4a-c, 6, and 9) were used for median transported grain diameter, D_{50}; river discharge, Q; sediment flux, Q_s; dimensional depth, H; and surface runoff, M. Delta formation timescales were estimated using a washload fraction, γ, of 2 (>40% suspended sediment), with an intermittency factor, I, of 0.01 (runoff on ∼1% of days generated bankfull flows).

RESULTS AND DISCUSSION

When liquid water was shaping the surface environment at Eberswalde, D_{50} was estimated to be 7.6 cm (Figure 1c), considered a fine cobble. Even though lower surface gravitational acceleration on Mars would reduce bed shear stress and friction velocity, which decreases fluvial sediment transport rates (Braat et al. 2024), larger grains than would typically be expected on Earth can be picked up and transported in suspension and a lower settling velocity operate to increase sediment mobility (Hoke et al., 2014; Braat et al., 2024). These geomorphic processes are evident from widespread boulder transportation in the ancient Eberswalde river channels (*e.g.,* Howard et al. 2007) and from mixed grain sizes observed in some layers of meander scarps (Hoke et al. 2014).

Q was estimated to be ∼310 m^2/s, which fits within previous estimates for Eberswalde (Figure 1c). Q_s was estimated at 0.0047 m^3/s, and H was ∼2.67 m. As the river depth and discharge increase, the faster flows distribute transported sediment at greater distances, with any fine-grained material likely deposited beyond the delta-forming region (Hoke et al. 2014). The exceptional preservation of the delta is likely a product of this process, as the inverted channels are filled with coarser, well-lithified and therefore more resistant sediments (Wood 2006).

M required to produce the Eberswalde flows was estimated to be ∼0.04 cm/day. Runoff is directly related to physical and climatic characteristics, and this estimate indicates a scarcity of precipitation comparable to the conditions of ephemeral, arid-region rivers on Earth. The formation time for the Eberswalde delta was estimated to be 71,489 years, indicating the presence of liquid water may have been sustained for durations long enough to support habitable conditions here in the past. However, flows of fluctuating discharge and sediment concentrations likely formed the Eberswalde delta. This estimate is likely conservative, owing to extensive surface erosion since the cessation of the river networks on Mars, but it does sit within the ranges estimated in previous studies (Irwin et al. 2015).

CONCLUSION

This study provides the first attempt at applying this Earth-based hydrological model beyond rover-explored sites on Mars. It demonstrates that the Eberswalde delta may have formed over a timescale spanning tens of thousands of years. Estimates herein provide insights into the grainsize distribution at this site, which help refine the current understanding of the sedimentary and hydrological processes that shaped ancient Martian landscapes. Thus, this study facilitates the first steps for improving reconstructions of the broader climate dynamics on Mars.

ACKNOWLEDGEMENTS

This research was supported by the Orbyts programme (Ogden Trust, UKSA, ERC Inspire award, and UCL's Widening Participation Department) and STFC Studentship UKRI Consolidated Grant ST/Y509784/1.

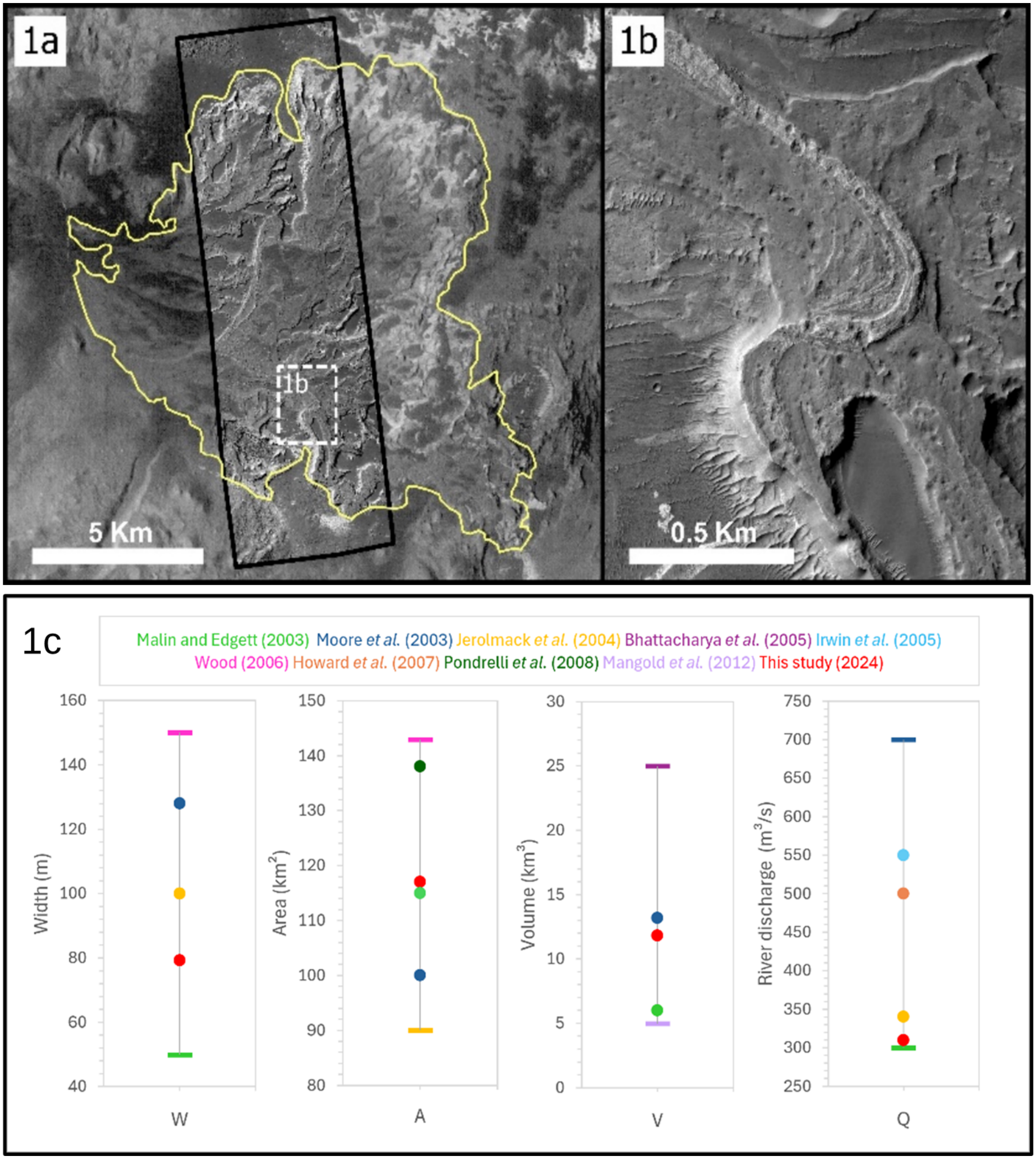

Figure 1. a) Eberswalde delta imaged by HRSC and HiRISE (black outline) with delta areal extent in yellow; b) palaeochannel meander expressed in inverted relief; c) reported results from previous literature and this study.

REFERENCES

Birch, S. P., Parker, G., Corlies, P., et al. 2023, Proceedings of the National Academy of Sciences, 120, e2206837120

Braat, L., Brückner, M. Z., Sefton-Nash, E., & Lamb, M. P. 2024, Journal of Geophysical Research: Planets, 129, e2023JE007788

Hoke, M. R., Hynek, B. M., Di Achille, G., & Hutton, E. W. 2014, Icarus, 228, 1

Howard, A., Moore, J., Irwin, R., & Dietrich, W. 2007, in 38th Annual Lunar and Planetary Science Conference No. 1338, 1168

Hughes, C., Rice, M., Barnhart, C., et al. 2023, Journal of Geophysical Research: Planets, 128, e2022JE007545

Irwin, R. P., Lewis, K. W., Howard, A. D., & Grant, J. A. 2015, Geomorphology, 240, 83

Kite, E. S., Mayer, D. P., Wilson, S. A., et al. 2019, Science Advances, 5, eaav7710

Malin, M. C., & Edgett, K. S. 2003, Science, 302, 1931

Mangold, N., Kite, E., Kleinhans, M., et al. 2012, Icarus, 220, 530

Wood, L. J. 2006, Geological Society of America Bulletin, 118, 557