Eskers associated with mid-latitude glaciers on Mars and their palaeoenvironmental implications

Conference or Workshop Item

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Abstract

We have discovered two eskers associated with ~110–150 Myr old glaciers, in the Phlegra Montes [1] and NW Tempe Terra [2] regions of Mars' northern mid-latitudes. Eskers are sinuous sedimentary ridges deposited by meltwater flowing in glacial drainage conduits. Mars' present climate is extremely cold and arid and, until recently, it was widely thought that mid-latitude debris-covered glaciers on Mars had been pervasively cold-based since their formation 10s–100s Myr ago. However, eskers associated with existing glaciers indicate that localised wet-based glaciation has occurred during Mars' most recent geological period.

The mid-latitude glacier-linked eskers are both located within glaciated tectonic rift valleys or grabens. This suggests that, under cold recent climate conditions, locally-elevated geothermal heat flux (above the modelled global average of 23–27 mWm^{-2}) may have been a prerequisite for glacial melting. We used a 1D model of heat flow through glacial ice to explore the environmental requirements for basal melting, incorporating the effects of strain heating for the first time [2]. We calculated the temperature at the glacier bed by comparing rates of geothermal and viscous strain heating of the basal ice with the rate of heat loss to the surface under different ice thicknesses.

We found that, under scenarios where geothermal heat is the only source of heat to the bed, basal melting requires conditions that seem unlikely for Mars' recent geologic history (surface temperatures >215 K, ice thicknesses >1100 m, and geothermal heat flux >80 mWm^{-2}). However, when we incorporated strain heating, we found that it provided up to 14.5 K of additional warming to the basal ice and reduced significantly the geothermal heat flux, surface temperature, and ice thickness required for basal melting. This arises from a highly non-linear response of strain heating to ice temperature and driving stress. Ice convergence and large deviations in driving stresses (associated with localised variations in ice surface slope and/or ice thickness) may have encouraged strain heating of basal ice within the steep-sided tectonic rifts/graben that host the glacier-linked eskers. Thus, both geothermal and strain heating likely played vital roles in encouraging geologically-recent esker-forming glacial melt events in Mars' mid-latitudes.

We have also used high-resolution (0.25–2 m/pixel) remotely-sensed data to: analyse the 3D morphometries of the Martian eskers; compare them to terrestrial analogues; and explore the spatio-temporal nature, and sediment-discharge dynamics of esker-forming glacial melt events on Mars [3].

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[1] Gallagher, C., and Balme, M.R., (2015), Earth. Planet. Sci. Lett. 431, 96-109, [2] Butcher, F.E.G., et al. (2017), J. Geophys. Res. Planets. 122(12), 2445-2468, [3] Butcher, F.E.G., et al. (2019), This Conference.