

RATES OF FLUVIO-THERMAL EROSION ON MARS. J. Aguirre-Puente⁽¹⁾

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On Mars, most of the outflow channels start from chaotic terrains and exhibit a rather straight valley of 1500 km long and 25 km large with few tributaries. Different interpretations of these outflow channels have been proposed. Lucchitta (1) considers them as possible glacial valleys, and Komar (2) proposed some comparisons with submarine rivers. Carr (3) suggests that these valleys were produced by catastrophic release of water from confined aquifers and Baker (4) considers them as highly turbulent catastrophic floods. In order to take into account the cold climate conditions of Mars, the presence of ground-ice and the large scale of outflows, a thermal erosion was first proposed by Costard (5). From a quantitative point of view, three thermal mathematical models were analyzed and discussed by Aguirre-Puente et al. (6).

In Arctic regions, thermal erosion is considered as the result of the ground thawing produced by the heat exchange between the water flow and ground-ice followed by a transport of sediments. On the basis of direct geomorphic evidence (Are, 7), rates of thermal erosion, in various parts of Siberian river banks, are on the order of 15 to 25 m per year.

By analogy with Arctic regions, it is reasonable to assume that the rate of thermal erosion, for Martian outflow channels, is far more efficient than the rate of fluvial erosion. The interesting case for our Martian model is a hypothetical situation where ground-ice exists with the presence of liquid water to the surface. In such a case, short duration Martian outflow channels are believed to have survived under cold climatic conditions and produced thermal erosion against frost banks.

In order to get some ideas about the order of magnitude of fluvio-thermal recession rate, a mathematical thermal model for Martian outflow channels is proposed. This model corresponds to a system undergoing a permanent thermal regime where the surface temperature is constant and equal to the phase change temperature (due to the immediate removal of melted materials). This is an ablation model. For its application, estimations of the heat transfer coefficient h , and thermal flux q are necessary. Determination of these coefficients needs the calculation of dimensionless numbers (Reynolds, Prandtl, Nusselt), and the consideration of turbulent regime of the flow.

For estimations, the following parameters are considered:

Water temperature: $T = 5^{\circ}\text{C}$ and $T = 10^{\circ}\text{C}$

Ground-ice temperature: $t = 0^{\circ}\text{C}$

River cross section: 10 km

River discharge: $Q = 3.86 \cdot 10^4 \text{ m}^3 \text{ s}^{-1}$

Velocity of the water: $v = 0.4 \text{ m s}^{-1}$

Reynolds number: $Re = 3 \cdot 10^5$

Nusselt number: $Nu = 1562$

Prandtl number: $Pr = 11.19$ (for water at 5°C)

Thermal conductivity of the frozen soil: $k = 0.57 \text{ W m}^{-1} \text{ K}^{-1}$

Heat transfer coefficient: $h = 780 \text{ W m}^{-2} \text{ K}^{-1}$

Thermal flux: $q = 3900 \text{ W m}^{-2}$ for $\Delta T = 5 \text{ K}$, 780 W m^{-2} for $\Delta T = 1 \text{ K}$.

For such a model, it is assumed that the surface keeps a constant melting temperature, and that the thermal flux is constant. For ground characteristics, two different soil porosities are

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considered: 80% and 40% (the pores being filled with ice). With these assumptions, thermophysical properties are calculated:

Porosity ϵ :	0.4	0.8
Density β :	$2.04 \cdot 10^3 \text{ kg m}^3$	$1.347 \cdot 10^3 \text{ kg m}^3$
Specific Heat c_p :	$1.453 \cdot 10^3 \text{ J kg}^{-1} \text{ K}^{-1}$	$8 \cdot 10^3 \text{ J m}^{-1} \text{ K}^{-1}$
Thermal conductivity k :	$1.572 \text{ W m}^{-1} \text{ K}^{-1}$	$0.6941 \text{ W m}^{-1} \text{ K}^{-1}$
Thermal diffusivity μ :	$0.5303 \cdot 10^{-6} \text{ m}^2 \text{ s}^{-1}$	$0.184 \cdot 10^{-6} \text{ m}^2 \text{ s}^{-1}$
Latent Heat L :	$6.52 \cdot 10^4 \text{ J kg}^{-1}$	$1.98 \cdot 10^5 \text{ J kg}^{-1}$

The results obtained from the application of the ablation model give some interesting informations about the recession banks on Martian outflow channels. From the figure 1, rates of fluvio-thermal erosion are on the order of 22 m and 35 m, for one Martian month with $\Delta = 1\text{K}$, respectively for soil porosities' 0.8 and 0,4.

These values confirm that thermal erosion might be a strong sapping process along Martian outflow channels. As for Siberian rivers, the interaction between thermal and mechanical processes during thousand of years might contribute to the formation of large Martian outflow channels.

Our model of fluvio-thermal erosion needs some modifications to bring it closer to the reality. In order to take into account interaction between thermal processes and mechanical erosion for both one-dimensional and two-dimensional models, a research program is proposed.

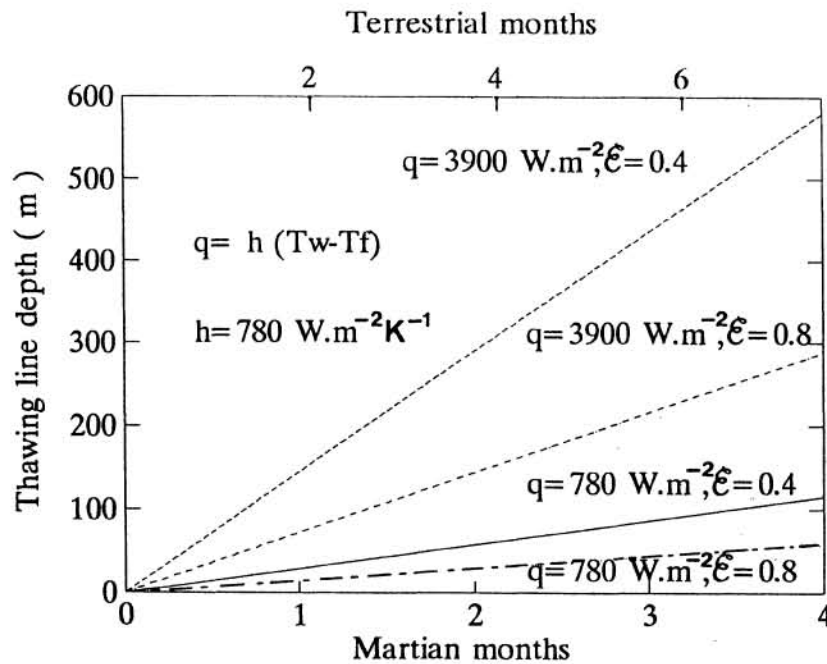


fig 5. Ablation model for short period

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