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
eroison 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 = 50°C and T = 10°C
- Ground-ice temperature: t = 0°C
- River cross section: 10 km
- River discharge: Q = 3.86 × 10^4 m^3 s^-1
- Velocity of the water: v = 0.4 m s^-1
- Reynolds number: Re = 3 × 10^5
- Nusselt number: Nu = 1562
- Prandtl number: Pr = 11.19 (for water at 50°C)
- Thermal conductivity of the frozen soil: k = 0.57 W m^-1 K^-1
- Heat transfer coefficient: h = 780 W m^-2 K^-1
- Thermal flux: q = 3900 W m^-2 for ΔT = 5 K, 780 W m^-2 for ΔT = 1 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
FLUVIO-THERMAL EROSION: Aguirre-Puente, J. et al.

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

<table>
<thead>
<tr>
<th>Property</th>
<th>Value 1</th>
<th>Value 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porosity ( \varepsilon )</td>
<td>0.4</td>
<td>0.8</td>
</tr>
<tr>
<td>Density ( \rho )</td>
<td>( 2.04 \times 10^3 ) kg m(^{-3})</td>
<td>( 1.347 \times 10^3 ) kg m(^{-3})</td>
</tr>
<tr>
<td>Specific Heat ( c_p )</td>
<td>( 1.453 \times 10^3 ) J kg(^{-1}) K(^{-1})</td>
<td>( 1.347 \times 10^3 ) J kg(^{-1}) K(^{-1})</td>
</tr>
<tr>
<td>Thermal conductivity ( k )</td>
<td>( 1.572 ) W m(^{-1}) K(^{-1})</td>
<td>( 0.6941 ) W m(^{-1}) K(^{-1})</td>
</tr>
<tr>
<td>Thermal diffusivity ( \mu )</td>
<td>( 0.5303 \times 10^{-6} ) m(^2) s(^{-1})</td>
<td>( 0.184 \times 10^{-6} ) m(^2) s(^{-1})</td>
</tr>
<tr>
<td>Latent Heat ( L )</td>
<td>( 6.52 \times 10^4 ) J kg(^{-1})</td>
<td>( 1.98 \times 10^5 ) J kg(^{-1})</td>
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</table>

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 \( \Delta = 1 \) 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.

Terrestrial months

![Ablation model for short period](fig 5)


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