SIBERIAN RIVERS AND MARTIAN OUTFLOW CHANNELS : AN ANALOGY. F. COSTARD[1] and E. GAUTIER[2]. [1]Laboratoire de Géologie Dynamique de la Terre et des Planétes,Université Paris-Sud, 91405 Orsay Cédex, France, [2]Laboratoire de Géographie Physique, CNRS 92195 Meudon Cédex, France. fcostard@geol.u-psud.fr

Introduction. Examination of the Martian conditions leads to the idea that analogies may be considered between the Martian and Terrestrial periglacial climates. Particularly, the formation processes for Martian outflow channels and Siberian valleys seem to be similar on both planets : the presence of ground-ice and wide rivers observed on Mars and in Siberia, suggests the occurrence of thermal erosion during the flooding event. In Siberia, thermal erosion of rivers banks produces large-scale slumps and favors accelerated scarp retreat. Thermo-mechanical action probably exists resulting from the thawing of the ground and the subsequent transport of thawed sediments. We assumed that thermal erosion could be an actual erosion process for Mars. If temperatures were below freezing and water flowed over the surface, then it may have been possible for streams to survive on Mars.

The goal of this study is to analyse the relation between thermal erosion and fluvial dynamics. The fluvial pattern depends mainly on floods and sediment supply (1). Therefore, plan forms are analysed.

Thermal erosion on Siberian rivers. The continental Yakutia climate in Siberia is dominated by long and cold periods with minimum surface temperatures of -72°C. During the summer, the maximum surface temperature can reach 38°C. Low precipitation, high evaporation and sublimation rates are characteristics of a very dry climate (Katasonow and Soloviev, 1969). The temperature of continuous permafrost at the depth of minimum annual seasonal change varies from -5°C to -13°C (2).
The thin snow cover favors the existence of a deep permafrost layer. The maximum depth of frozen soil in O'miakon (Yakutia) is about 1 500 m and the thickness of the average Siberian permafrost is about 350 m (3). Unfrozen ground is nevertheless present under river beds as taliks (4) of varying depths and sometimes as isolated taliks (soil without ground-ice).

Annually, the strong flows of water during the spring and summer seasons interact with ice and other frozen obstacle resulting in erosion of the river banks. The large rising flood carries sediments and spreads them along the terraces, especially at the river mouth. This process involves the heat transfer that takes place between the warm water and the frozen ground, followed by the collapse of materials and the transport of sediments (5). Are (6) has observed recession rates of Siberian river banks from 19 to 24 m $\times$ year^{-1} (40 m $\times$ year^{-1} in front of islands). These values confirm that thermal erosion is a strong sapping process of valleys and shores.

Experimental studies of fluvio-thermal erosion utilizing simulated ground-ice indicated that fluvial-thermal erosion can be a very efficient process for Siberian rivers and Martian outflow channels (7). It appears that the dominant factors that commonly operate are, firstly, the water temperature, and secondly the Reynolds number (8)

Morphometric approach on Martian outflow channels and siberian rivers. The comparison of several fluvial variables (slope, specific stream power, width / depth ratio, number of channels, bars and islands, sinuosity) between Siberian rivers and Martian channels reveals analogies which suggest that similar processes have been active on both fluvial systems. A very specific fluvial pattern is observed : a large number of shallow and wide channels separating very long islands.

Most Martian outflow channels are 10 km to 30 km wide (Ares, Tiu, Simud and Kasei Valles). Particularly, Ares Vallis exhibits a rather straight outflow, 1500 km long and 25 km wide, without tributaries. High resolution Viking images of Ares Vallis reveal details of multiple system of secondary channels separated by residual hills (9).
Different interpretations of these outflow channels are proposed. Lucchitta (10) considers them as possible glacial valleys and Komar (11) thinks they are subject to comparisons with submarine rivers. Carr (12) suggests that these valleys were formed by sudden release of water from confined aquifers producing catastrophic floods and Baker (9) considers them as highly turbulent catastrophic floods.
The Lena river is comparable in scale to most Martian outflow channels. The total length of the Lena river exceeds 4000 km. During the flood season, its widening is 25 km downstream Yakutsk (62°N) with a mean annual discharge of 200 km^3.

The longitudinal profile of Ares Vallis is 0.001, more or less the same as for Siberian rivers (0.0001). IRTM data showed that the floor materials of Ares Vallis have much higher thermal inertia than surrounding upland. The interpretation is that the material is sand-sized (0.2-1.0mm). About Siberian rivers, fluvial terraces are mainly composed of fine grained sandy soils containing up to 80% ice.
Both Siberian valleys and Martian outflow channels exhibit an extremely episodic flow regime. High-level fluid erosion on the upland surface indicates high discharge variations for Ares Vallis (9). Indeed, Carr (12) proposes discharge rates from 2.8.10^4 m^{3}s^{-1} to 1.1 10^5 m^{3}s^{-1} for Martian outflow channels. Flow velocities of Martian outflow channels were not too different from the Lena flow velocity.

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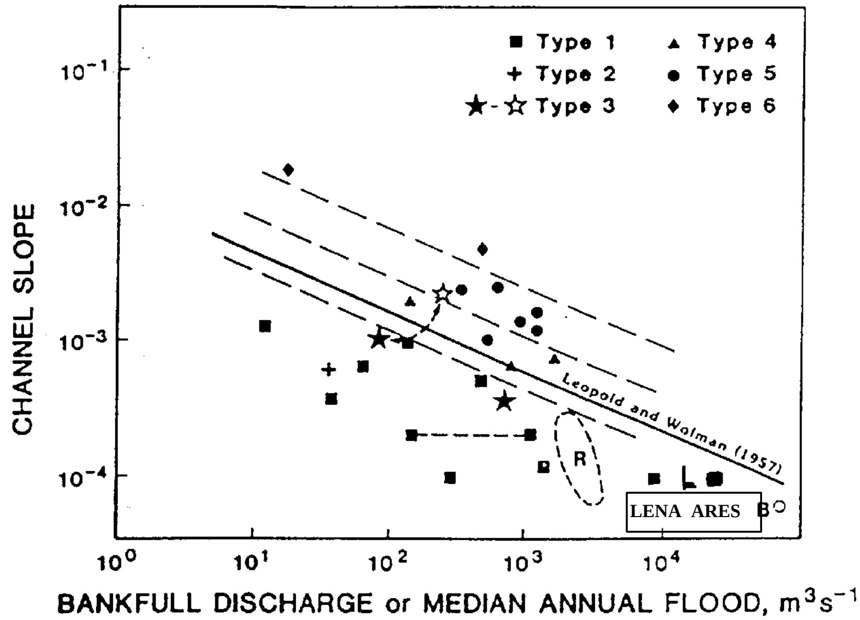

Figure 1: Position of the Lena River and Ares Vallis on a slope-discharge plot and distribution of the six types of anabranching rivers. From Leopold and Wolman (1957), Nanson and Knighton, (1996), modified.

In Central Siberia, despite of a local active bank retreat, fluvial forms seem to be stable. This specific fluvial pattern seems to depend on hydrodynamics : the flood peak can reach 100000 $m^3.s^{-1}$ on the Lena River, at the junction of one of its main tributaries, the Aldan River, but the channel-forming discharge is very short. Ice-jams and log-jams create local high variations of the water level. Such fluvial outburst elevates the water level by 8 - 10 m and inundates the first terrace above the floodplain.

Otherwise, the weakness of the specific stream power is due to the very low gradient. The longitudinal profile of the Lena river is 0.0001. For these reasons, thermal and mechanical erosion provides a sediment load which exceeds the flow capacity. Therefore, the sediment load (mainly sandy materials) probably doesn't migrate over long distances downstream and is accumulated on wide bars and long islands.

This fluvial pattern could be compared with anabranching rivers (13), which are multiple channels separated by semi-permanent alluvial islands. Their fluvial regime maximize bed-sediment transport under very low gradient (figure 1).

Conclusions. Ares Vallis and the Lena river are anabranching rivers with high w/d ratio channels. They are comparable in scale and exhibits the same hydrodynamic characteristics (high and variable discharge rate, very low longitudinal profile, sand-size materials). These analogies suggest that similar process have been active on both fluvial systems, especially fluvial-thermal erosion.

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