Sediment transport and deposition in experimental groundwater sapping channels

Wouter A. Marra[1], Daan A. Wesselmans[2], Wouter J.R. Poos[2] & Maarten G. Kleinhans[1,P]

1) Utrecht Univeristy, Faculty of Geosciences, Dep. of Physical Geography, w.a.marra@uu.nl 2) Students Earth Sciences (extended BSc Thesis research) Utrecht University P) Presenting author

P43C-1692

Universiteit Utrecht

Martian River and delta morphodynamics Research group


Wouter Marra


Maarten Kleinhans

Background

A better understanding in channel formation processes on Mars and the role of water in these processes will provide accurate estimates of the amounts and nature of water on Mars. This study focuses on channels formed by seepage of groundwater.

Introduction

Groundwater sapping channels on Mars

- 'Theatre-headed' valleys on Mars are often attributed to groundwater seepage (Fig 1).
- Channels appear in different forms: single channels and channel networks, various sizes, often observed on crater or vallis edges.

Hypothesised requirements for channel formation

- Water source:
  - Global groundwater system, or
  - Local, precipitation-fed, recharge
- Erosion mechanism:
  - Erosion of loose sediment (Howard & McLane 1998),
  - Erosion of rock (Lamb et al., 2006),
  - Typical form caused by weathering processes (Pelletier & Baker, 2011).

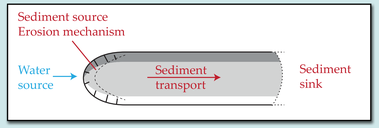

Fig 2) *Requirements to form a sapping channel. Several hypothesis exist for each element.*

Missing links in reseach

- Sediment transport processes always come with considerable assumptions:
  - Only small grains are present due to weathering (Luo & Howard, 2008)
  - Occurs episodic with high flow intensities to remove material (Luo & Howard, 2008; Pelletier & Baker, 2011).
- Sediment sink:
  - In previous experiments, sediment was removed using a drain,
  - Possible sediment sinks on Mars: deep downstream valley, delta / fan deposits.

Reseach questions

- Are the channels capable of transporting the eroded sediment?
- Sufficient amount of water from sapping?
- What are the effects of deposition of sediment?

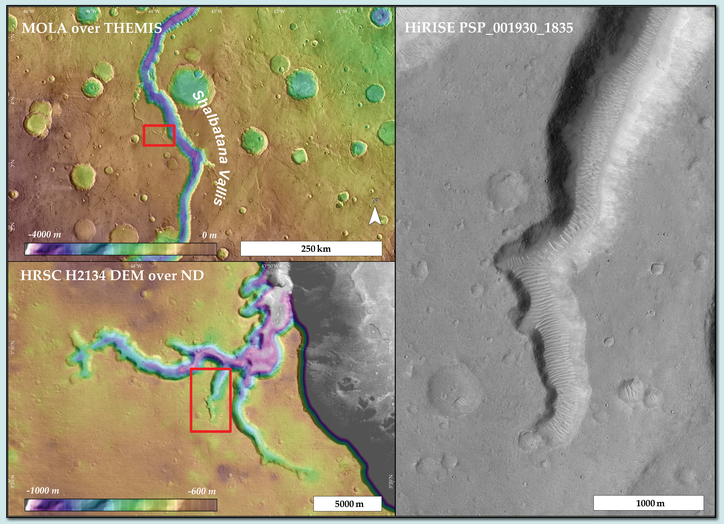

Fig 1) *Channels on the edge of Shalbatana Vallis (Mars). The typical shape (stubby tributaries, theatre-shaped head and the absence of an upstream channel) is often attributed to groundwater seepage.*

Experiments in unconsolidated sediment

Previous work

- Experiments by Howard (1988): groundwater flow through a steep wedge of sediment in narrow flume:
  - Sapping groundwater triggers mass wasting (slumping) processes at and just above the seepage points,
  - Sediment is removed from the sapping channel by fluvial processes.
- In a wider flume
  - Multiple, parallel, long channels form.

New experiments

- In the experiments of Howard sediment flowed out of system via a drain,
- In our experiments the deposition of sediment takes place inside the experiments.

Key results

- In a narrow flume, single channel (Fig 4):
  - Deposition of slumped material causes stabilisation of the channel head,
  - The slumping / mass wasting area remains inactive (stabilized) until deposits are removed by fluvial processes: the system shows cyclic behaviour (Fig. 3),
  - Downstream deposits stabilize the entire sapping channel when the gradient becomes too low for fluvial transport.
- In a wide flume (Fig 5):
  - Headward erosion of a channel is hampered by downstream deposition of a fan or delta, in these cases the channel widens due to avulsions in the downstream fan.
  - If sediment is removed (artificially), the sapping channel develops by headward erosion and much quicker than with the formation of a downstream fan.

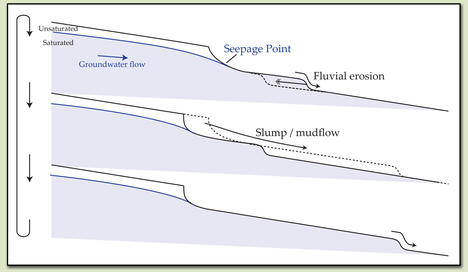

Fig 3) *Processes observed in sapping groundwater experiments: mass movements of the head of the channel and fluvial processes further downstream, the latter destabilized the channel head and triggers slumping of the channel head.*

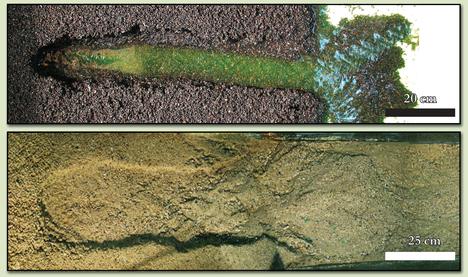

Fig 4) *Sapping experiments in narrow flume (also see Kleinhans 2010). Sapping channels form when eroded material is transported sufficiently but headward erosion stops when the channel gets 'blocked' by its own deposits.*

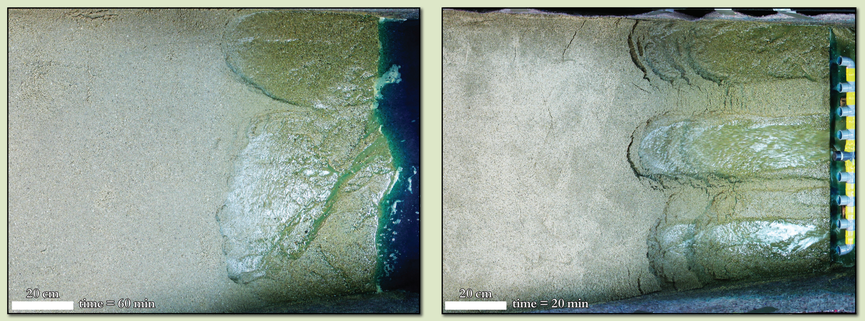

Fig 5) *Sapping experiments in wide flume. In the experiment in the left panel, eroded material is allowed to deposit, in the experiment shown in the right hand side panel, sediment is flushed out of the system. In the experiment with deposition, channels became much wider than the channels where the sediment was removed downstream. Also the latter developed much quicker.*

Discussion

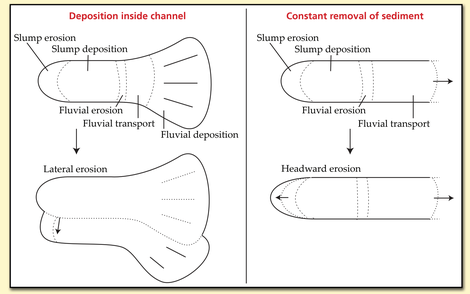

Fig 6) *Deposition of sediment causes the sapping channel to widen as the channel head is no longer destabilized and downstream avulsions trigger lateral migration of the channel. Removal of sediment is required for the sapping channel to develop in headward direction.*

- Deposition of sediment in the sapping channel causes lateral erosion, due to:
  - stabilisation of the channel head, and
  - avulsions on the downstream fan.
- For the formation of a long valley, the material needs to be transported out of the channel.
- Episodic removal of sediment is unlikely as:
  - prior to removel, the deposits would trigger lateral migration of the sapping channel,
  - there are no traces of larger (overland flow) events in most cases on Mars and almost maximum groundwater discharge is already needed for sapping.

Ongoing work

Experimental work

- To diminish scale effects on transport mobility: experiments with low-density sediment
  - Plastic sediment with natural shaped grains,
  - Scalable permeability with grain-size mixtures,
  - Low density to scale sediment mobility.
- Experiments to identify the possible roles of overland flow / precipitation.

Morphometric analysis of water sources and sediment drains

- Analysis of sapping channels on Mars to identity sources of water: local or global?
- Analysis of possible sediment sinks and deposits: where did it go?

Modelling

- Quantify the required amounts of water and time scales,
- Linking existing, physical models: groundwater (MODFLOW), surface water (using PCRASTER), erosion and deposition (diffusion model, e.g. Howard), sediment transport (Kleinhans).

Conclusions

- Eroded material must be removed in order to form long sapping channels
  - Insufficient removal of sediment causes sapping channels to migrate sideways instead of headwards
- Erosion rate increases if sediment is removed

Acknowledgement Support by the Physical Geography Laboratory at UU (Chris Roosendaal, Henk Markies and Marcel van Maarseveen) was essential for this reseach. **References** Howard, 1988, "Groundwater sapping experiments and modeling." in Sapping Features of the Colorado Plateau. Howard and McLane, 1988, "Erosion of cohesionless sediment by groundwater seepage." WRR 24(10). Kleinhans, 2010, "A tale of two planets: Geomorphology applied to Mars' surface, fluvio-deltaic processes and landforms." ESPL 35. Lamb et al., 2006, "Can springs cut canyons into rock." JGR 111. Luo and Howard, 2008, "Computer simulation of the role of groundwater seepage in forming Martian valley networks." JGR 113(E5). Pelletier and Baker, 2011, "The role of weathering in the formation of bedrock valleys on Earth and Mars: A numerical modeling investigation." JGR 116(E11). **Image credits** HiRISE: NASA/JPL/University of Arizona, HRSC: ESA/DLR/FU Berlin, MOLA: MOLA Science Team, THEMIS: NASA/JPL/ASU. **Funding** WAM is supported by NWO grant ALW-GO-PL/10-01 to MGK.

Follow our research

http://ins.academia.edu/WouterMarra

http://www.geo.uu.nl/fg/mkleinhans/