Palaeoflow and sediment delivery reconstructions from

Martian delta morphology

by combined physics-based numerical modelling and HRSC DTM analysis

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Universiteit Utrecht

DLR Deutsches Zentrum für Luft- und Raumfahrt e.V. in der Helmholtz-Gemeinschaft


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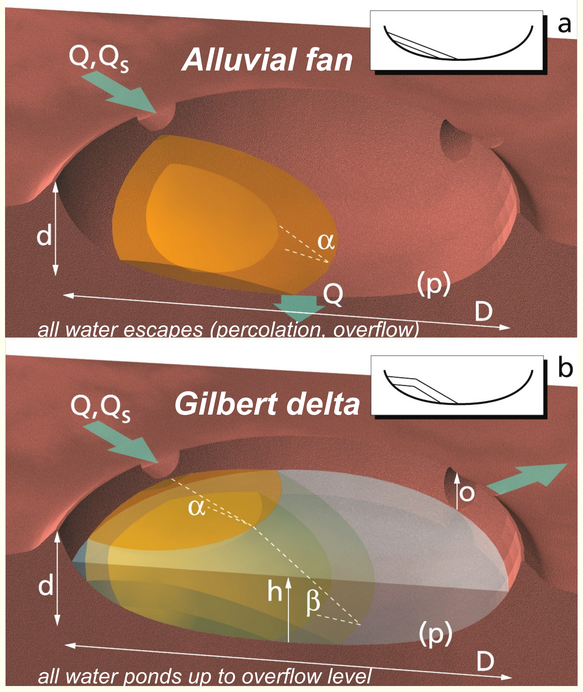
1. Objective

Our aim is to determine the formation time of Martian deltas, to unravel how these deposits record past hydrological conditions.

2. Modelling delta formation in a lake

- physics-based model for water and sediment flux
- geometrical model for fan/delta growth: "*cone on top of a cone*"



Water and sediment input[1]:

- water flux Q from upstream channel slope, width, depth (and g)
- sediment flux Q_s from upstream flow conditions and sediment calibre

Initial conditions in lake:

- depth d from diameter D[2]
- crater wall shape from D[2]
- flat floor at prefill depth p

Imposed fan/delta parameters:

- measured subaerial fan slope α
- subaqueous delta slope β (angle of repose)
- max shoreline height from (breached) crater overflow height o

Model output:

- water level per time step
- delta profile per time step from "cone on top of cone" piled on top of previous step

→ match modelled and observed profile?

→ formative time scale

3. Data and case studies

Data:

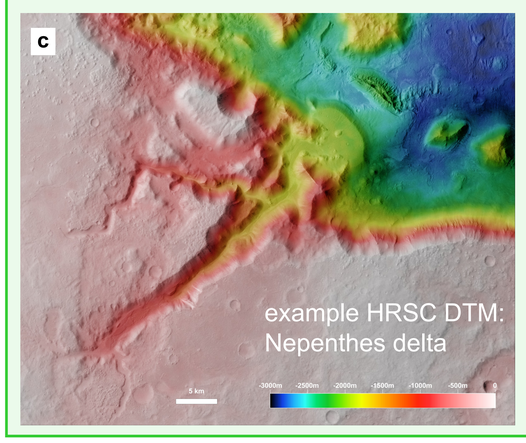
- HRSC DTMs and images
- MOLA (for one case)

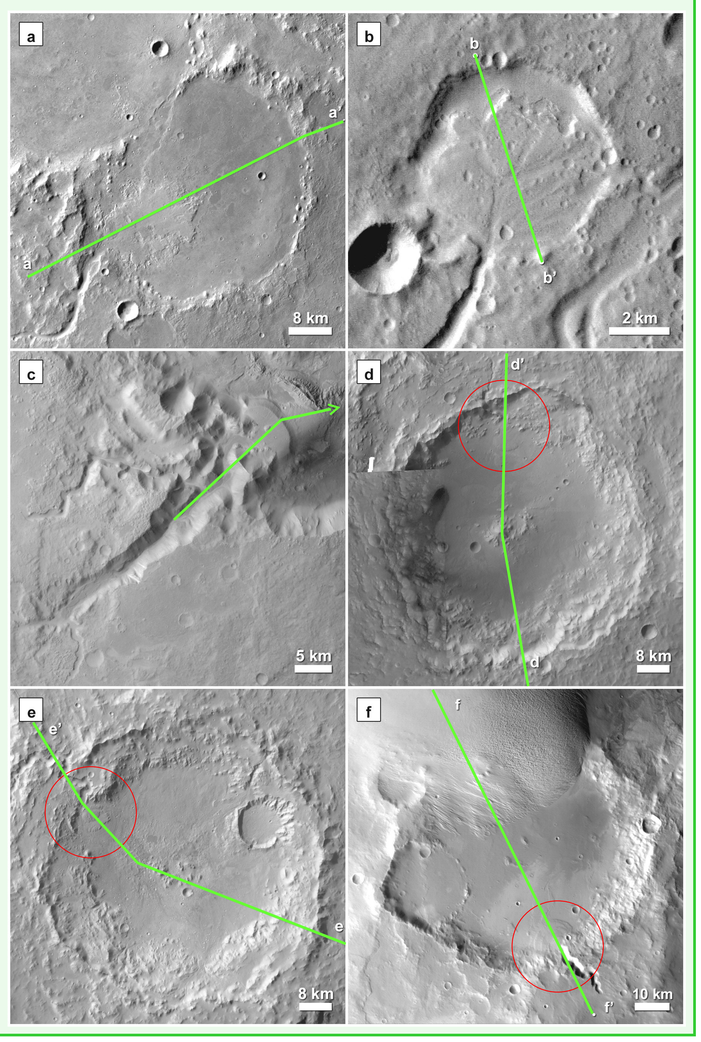
Derivatives:

- delta volume and channel volume
- delta gradients and channel gradient
- channel width and depth

Cases[3,4]:

Fig	Case	Type
a	Sabrina fan	Alluvial fan
b	Nanedi delta	Gilbert delta
c	Nepenthes delta	Gilbert delta
d	Stair-stepped delta, Xanthe Terra	Stepped delta
e	Tyras delta	Stepped delta
f	Stair-stepped delta, Terra Sirenum	Stepped delta

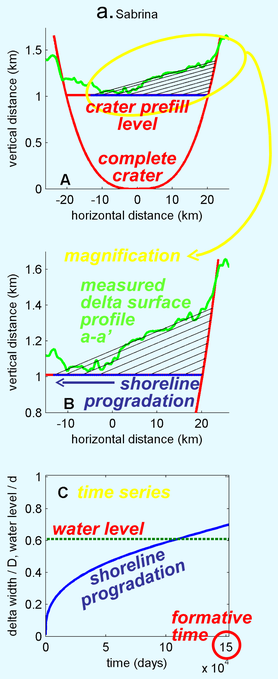




4. Model results

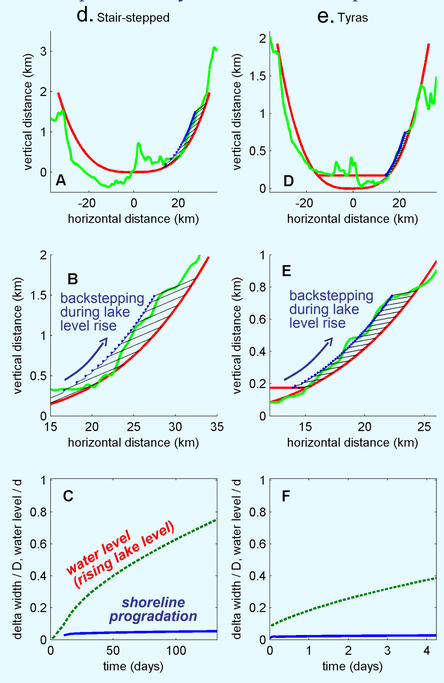
Alluvial fan

unconstrained by water level!



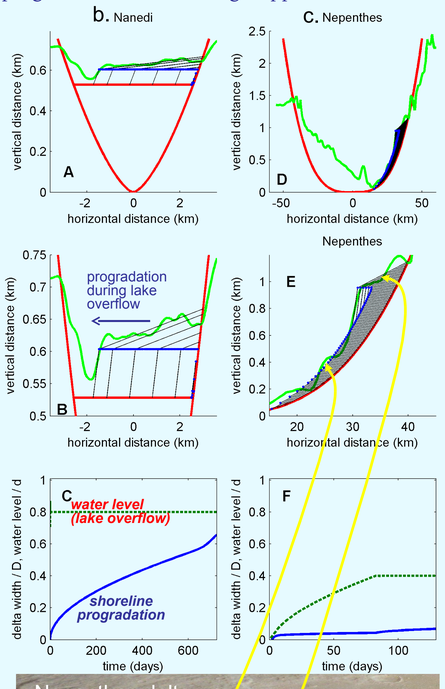
Stepped deltas: lake level rose

steps caused by channel wall collapses[4]



Gilbert deltas: lake spills over

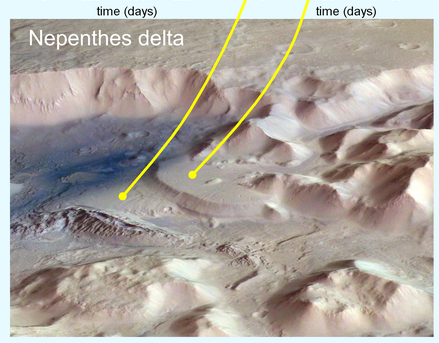
progrades over a drowning stepped delta[5]



Genetic classification by lake level and sediment flux

- Bedload from long low-gradient feeder channels
- Suspended load from short steep feeder channels

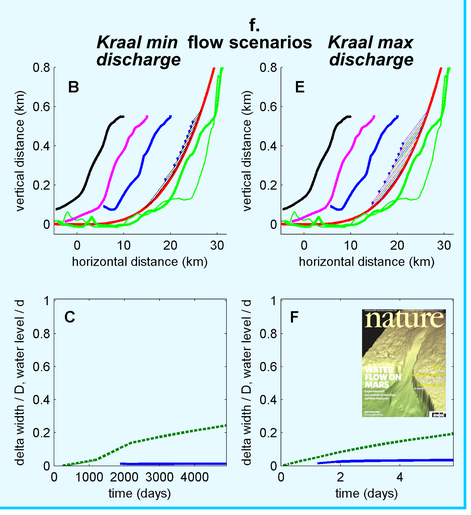
	no ponding, or low lake level	partially filled basin	overspilling (breached) basin
dilute flow: bedload	low-gradient alluvial fan *Sabrina*	(unknown)	Gilbert delta *Nanedi*
dilute flow: suspended load	low-gradient alluvial fan	stair-stepped delta *Xanthe, Tyras, Sirenum*	Gilbert delta *Nepenthes*
density flow	high-gradient alluvial fan	(unknown)	(unknown)



Counterfactuals:

- *Suppose wave action caused steps?* Formative duration not long enough, wall collapse experimentally proven[4]
- *Suppose debris flow (density flow)?* Then much shorter duration and wrong delta shape
- *Suppose different channel depth or sediment size?* Then Q_s/Q would differ and wrong delta shape
- *Suppose over/underestimated fluxes (and time scale)?* Then Q_s/Q would differ and wrong delta shape

(see case with Kraal[4] scenarios: only max flow produces right delta shape)



5. Conclusions

- Deltas formed *fast* in single-event dilute flow within years
- Stepped fan deltas formed much faster than Gilbert-type deltas; stepped delta feeder channels were steeper and provided more sediment and less water
- Geometrical deposition model and physics-based flow and sediment transport model predict morphology as observed with HRSC well
- New problem: why so short, while mega-outflow channels required more water? What were timing and triggers of fluid water episodes?

6. References:

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