Martian Groundwater Outflows in Flume Experiments
Processes and Morphological Properties

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INTRODUCTION

- There are many channels on Mars, but climate conditions were different than on Earth.
- Different sources of water have been proposed for Mars, including groundwater as main source for channel formation [1,2,3].

AIMS

- Knowledge on groundwater-induced channels is minimal due to limited occurence on Earth.
- We aim to extend the knowledge on related processes and resulting morphology for these systems from scaled flume experiments.

METHODS

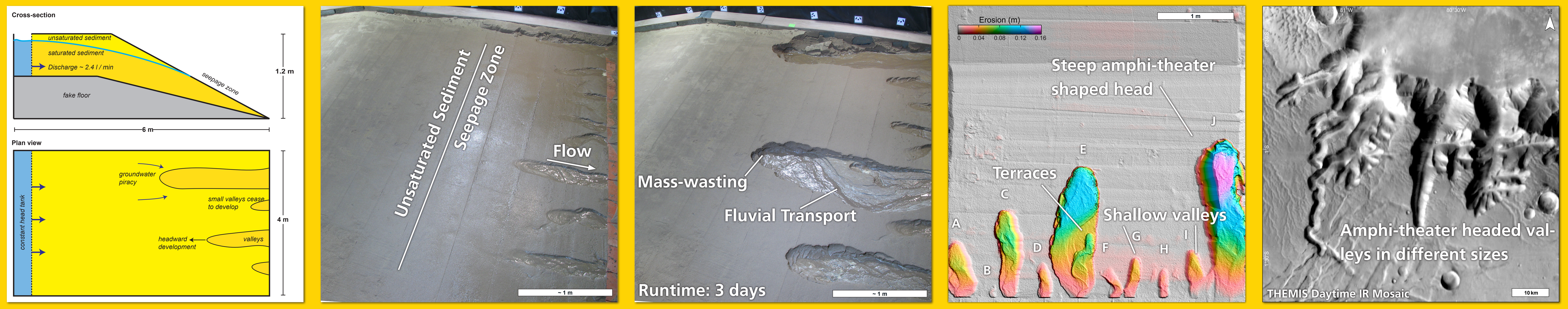
- Experimental setup consists of a flume of 6 m long x 4 m wide and 1.20 m deep.
- Simulation of seepage from sub-surface groundwater level from a distant source using a constant head tank.
- Seepage from a local source (e.g. melt or precipitation) was simulated by rain simulators.
- Pressurized aquifer release using a subsurface drainage pipe with forced discharge, at:
  - sub-lithostatic pressure (only seepage)
  - super-lithostatic pressure (sediment lifted by water pressure)
- Data: time-lapse imagery and laserscan DEMs.

EXPERIMENT MOVIES

http://goo.gl/gfUbO

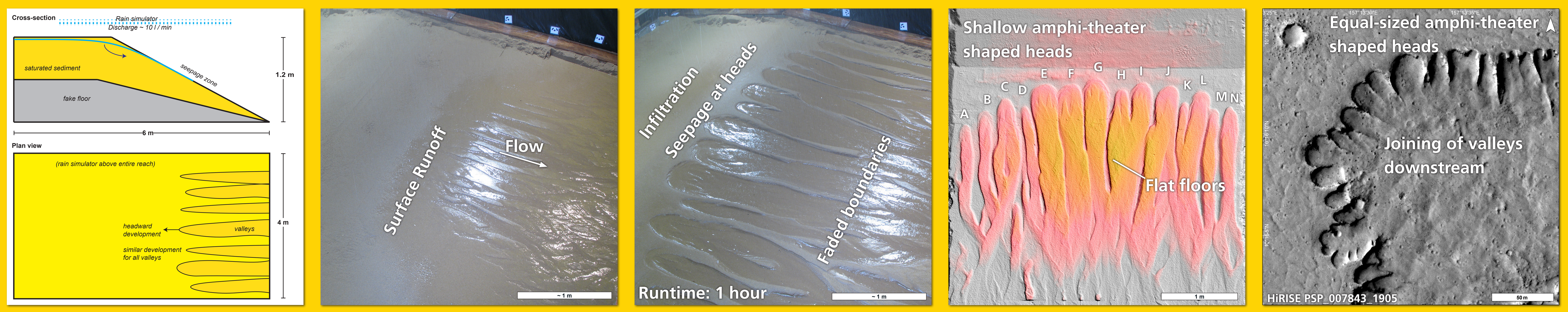
EXPERIMENT SETUP | EARLY STAGE MORPHOLOGY | FINAL MORPHOLOGY | SHADED DEM | MARS LOOK-ALIKE | KEY FEATURES

GROUNDWATER SAPPING — DISTANT SOURCE



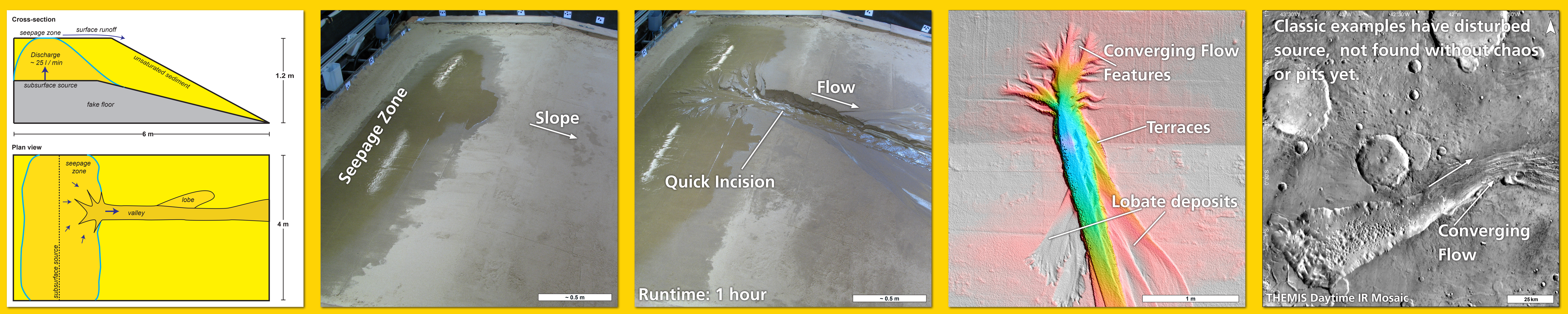
- Different sizes of valleys due to flow piracy.
- Theater-shaped valley heads due to mass wasting processes.
- Valley depth relates to groundwater level.
  - Further developed valleys are deeper as groundwater level is deeper upstream.

GROUNDWATER SAPPING — LOCAL INFILTRATION



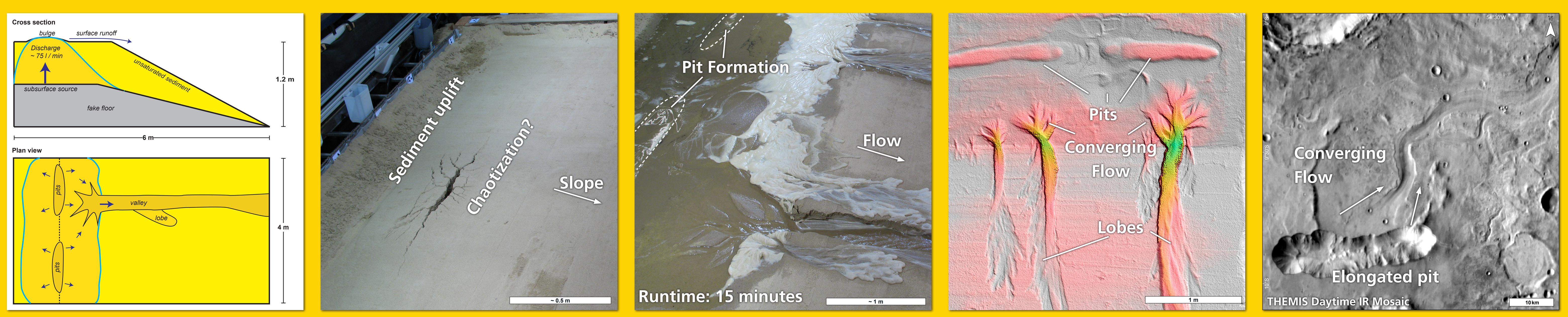
- Several valleys similar in size, due to absence of flow piracy.
- Headward development by mass wasting.
- Shallow valleys, due to high groundwater level.
- Simulated in experiment as precipitation, but could be melt of snow or subsurface ice.

PRESSURIZED GROUNDWATER — SUB-LITHOSTATIC PRESSURE



- Converging flow features upstream: feather-shaped head.
- Deposition of lobes after first overflow due to infiltration in unsaturated substrate (sieve deposits).
- No morphology left by actual seepage process.
- Not found on Mars without pits or chaos (see next).

PRESSURIZED GROUNDWATER — SUPER-LITHOSTATIC PRESSURE



- Similar features as sub-lithostatic pressure, but:
- Cracks and breaking of surface due to super-lithostatic pressure.
- Pits in source area carved by emerging groundwater.
- Converging flow features disconnected from source area.

MORPHOLOGICAL ANALYSIS *(SAPPING ONLY)*

- Sapping valleys fed by distal groundwater source are deeper and have more pronounced valley heads (Fig. 1).
- In both cases, valleys are steeper in the upstream part (Fig. 2). This relates to the difference in processes: mudflows in the upstream end, fluvial transport downstream.
- Valleys become more U-shaped when they develop (Fig. 3). Valleys fed by distal groundwater have a higher shape index, as the valleys have steeper cliffs.

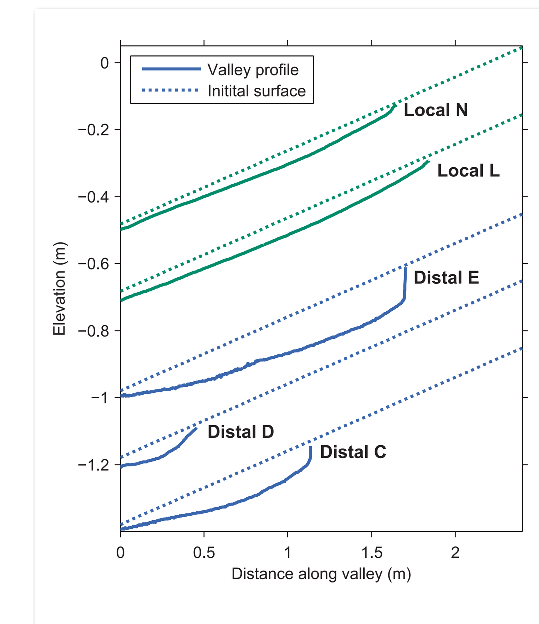


Fig. 1 *Valley profiles*

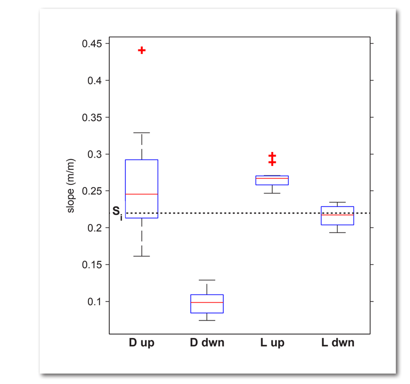


Fig. 2 *Valley slopes*

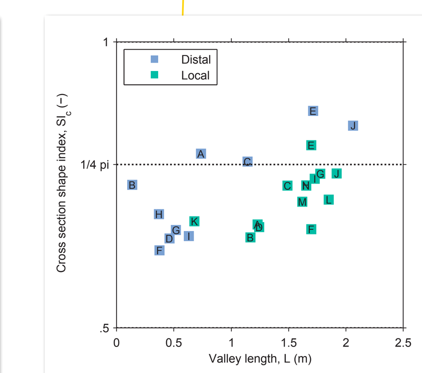


Fig. 3 *Valley shapes*

MORPHOLOGICAL DEVELOPMENT *(SAPPING ONLY)*

- Valleys become wider, deeper and longer during the experiments.
  - In the distal cases, widening slows as valleys develop (Fig. 4a). In the local case (Fig. 5a), the rate remains fairly constant.
  - Valley lengthening slows in both types of experiments (Fig. 4b, 5b).
- Erosion takes place in pulses, which are more sudden in the distal cases (Fig. 4d) due to the collapsing nature of the headward development and widening.
- In the distal experiments, the number of active valleys decreased, due to groundwater piracy.

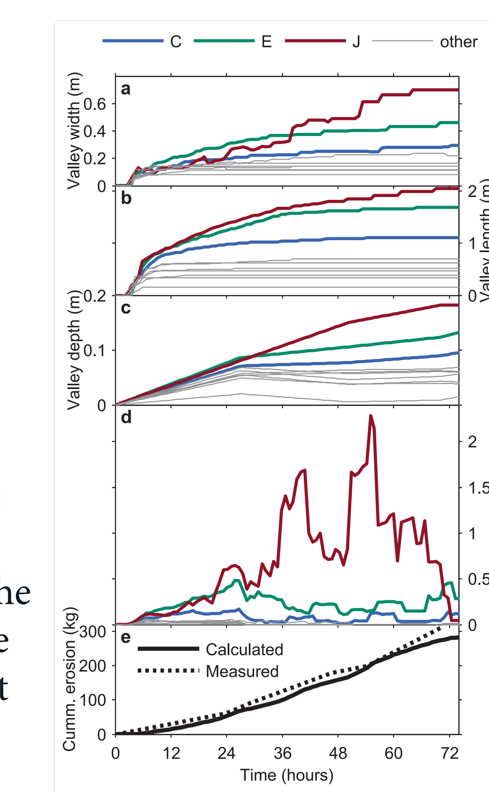


Fig. 4 *Morphological development distal sapping experiments.*

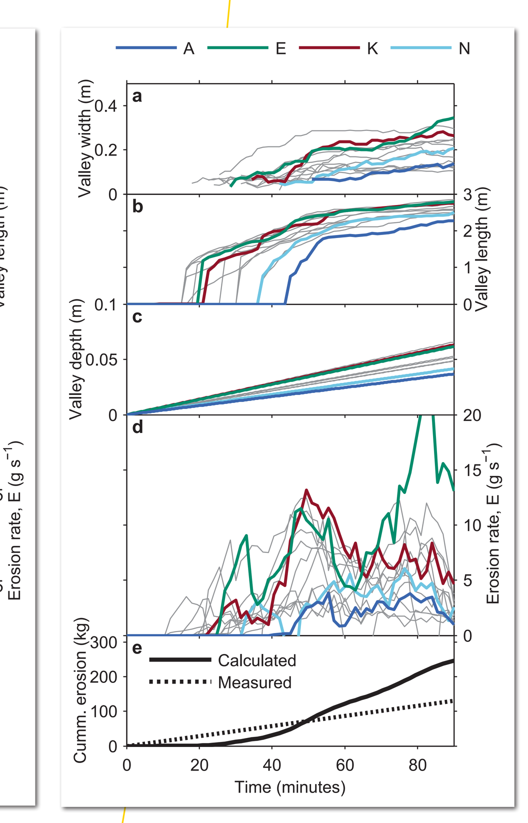


Fig. 5 *Morphological development local sapping experiments.*

CONCLUSIONS

- Different sources of groundwater for channel formation produce distinct types of valleys and channels.
- Groundwater sapping:
  - Produces theater-shaped valley heads.
  - Flow piracy occurs when the water source is distal, this focusses flow and enhances development of a few channels.
  - Two processes, mudflow and fluvial flow are shown by a break in slope.
  - Erosion takes place in pulses due to the collapsing development.
- Pressurized groundwater release:
  - Results in channel head with converging flow features.
  - Downstream lobate deposits on unsaturated sediment.
  - Super-lithostatic pressure breaks surface and forms pits in the source area.

References [1] Howard A.D. & McLane C.F. (1988) WRR 24(1), 1659-1674. [2] Kite E.S. et al. (2011) JGR 116, E07002. [3] Andrews-Hanna J.C. & Phillips R.J. (2007) JGR 112, E08001. Image credits HiRISE: NASA/JPL/University of Arizona, THEMIS: NASA/JPL/ASU. Funding WAM is supported by NWO grant ALW-GO-PL/10-01 to MGK.