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Autogenic dynamics of debris-flow fans

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Tjalling de Haas
Ask me for the movies!!!

Introduction

Autogenic dynamics

- Alluvial fans develop their semi-conical shape by cyclic avulsions of their geomorphologically active sector from a fixed fan apex. These avulsions have been attributed to both allogenic and autogenic forcings.
- Autogenic dynamics on debris-flow fans have neither been modelled nor experimentally simulated, in contrast to fluvial fans. Furthermore field studies at relevant spatiotemporal scales are hardly available.

Objectives

- We aim to:
  - Study the generic autogenic dynamics of debris-flow fans under constant allogenic forcings.
  - Provide insight in the processes that govern the autogenic dynamics of debris-flow fans.
  - Compare the dynamics of debris-flow fans to those on other fan types.

Approach

- We experimentally created a debris-flow fan by consecutive stacking of debris flows under constant extrinsic forcings (i.e., constant topography, debris-flow magnitude, composition and rheology).
- See EGU2015-3397 by De Haas et al. for further details on the experimental debris flows.

Experimental setup

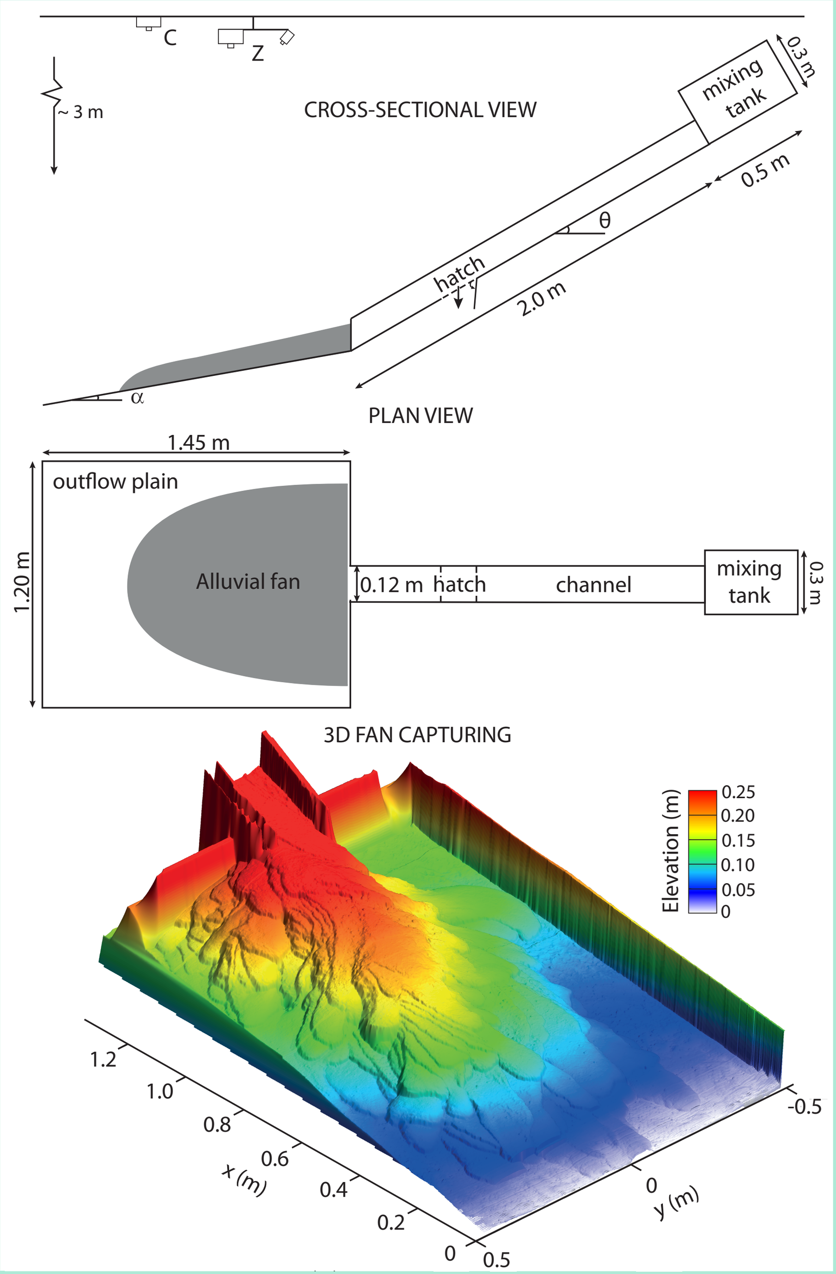


Fig. 1) Experimental setup. The channel slope is 30°, outflow plain slope is 10°.

Fan morphology

- Stacking of 55 debris flows.
- Distinct depositonal lobes up to a few centimeters in thickness.
- Self-formed levees, up to ~1 centimeter in thickness.
- Final longitudinal fan slopes: 15-20°, final lateral slopes exceeding 30°.
- Experimental fan morphology similar to the morphology of natural debris-flow fans.

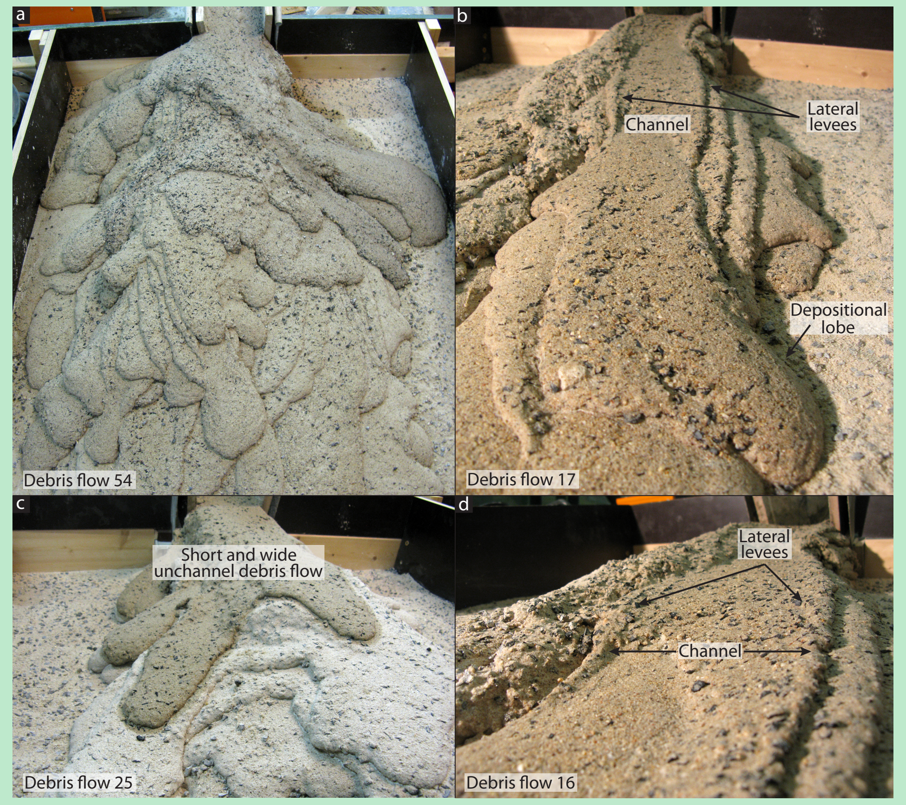


Fig. 2) Morphology and texture of the experimental fan. (a) Fully developed fan. (b) Fan in a channelized state. (c) Fan in an unchannelized state. (d) Detail of a channel.

Autogenic cycles

- The experimental debris flow fan formed by two autogenic cycles. These cycles involved a sequence of (1) backfilling, (2) avulsion and (3) channelization (Fig. 3, 4, 5).
- The autogenic cycles are symmetric, and debris-flow length and width are similar prior to backfilling and avulsion (Fig. 4).

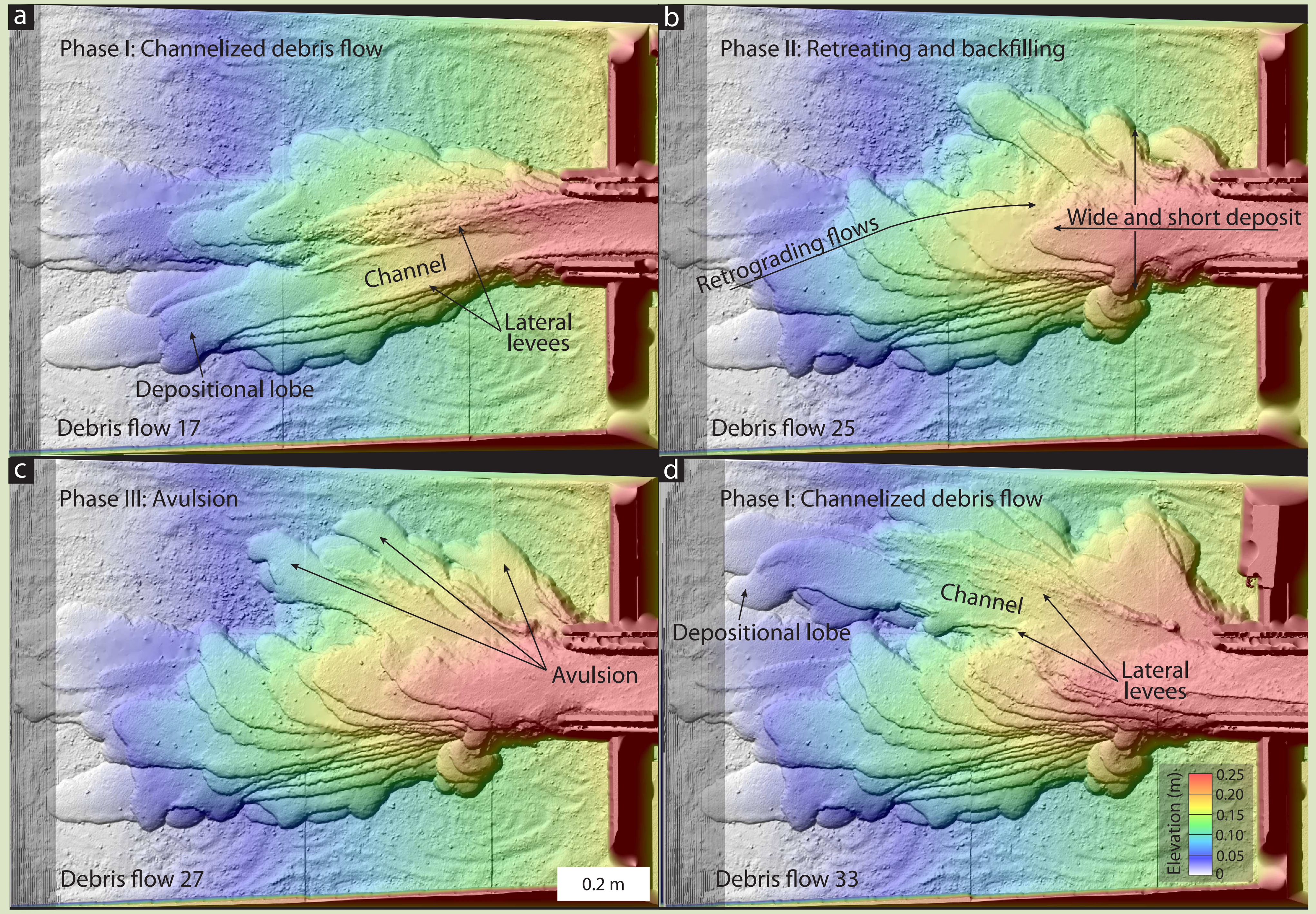


Fig. 3) Autogenic cycle on the experimental debris-flow fan. (a) Channelized debris flow. A channel is present on the proximal and medial domain of the debris-flow fan, through which debris flows are transported to deposit on the distal domain of the fan. (b) Retreating and backfilling. After the debris flows have reached their maximum extent backfilling commences. Debris flows become progressively shorter and wider until the channel is completely filled. (c) Avulsion. In the absence of an apex channel, the debris flows progressively avulse towards the most preferential, steepest, flow path. (d) Channelized debris flow. After avulsion, the debris flows progressively channelize until the fan is in a fully channelized state again.

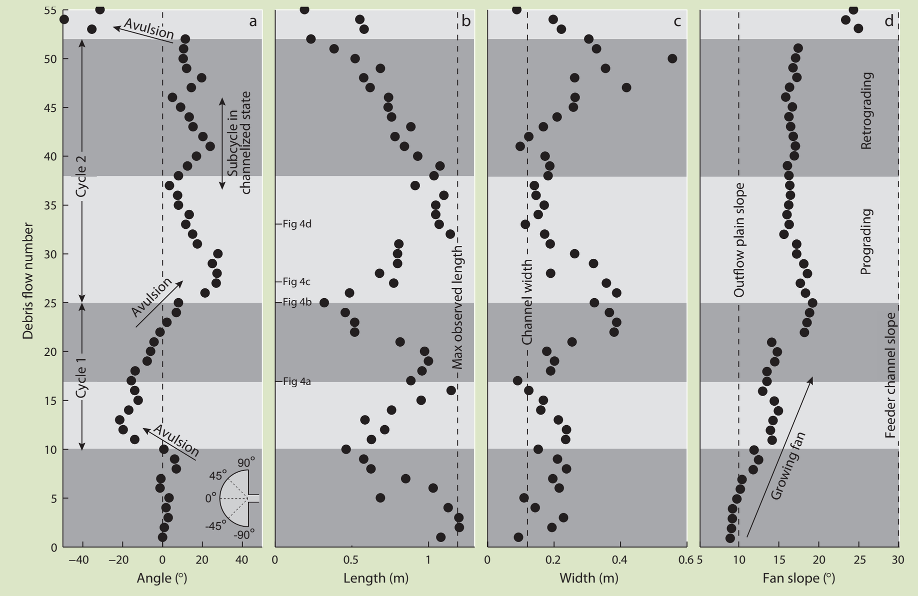


Fig. 4) Summary of the debris-flow characteristics within the autogenic cycles. (a) Debris-flow outflow angle relative to the feeder channel. (b) Debris-flow runout length. Max observed length refers to the maximum runout length over a 10 degrees sloping uniform outflow plain. (c) Debris-flow width. (d) Average fan slope along the active debris-flow path.

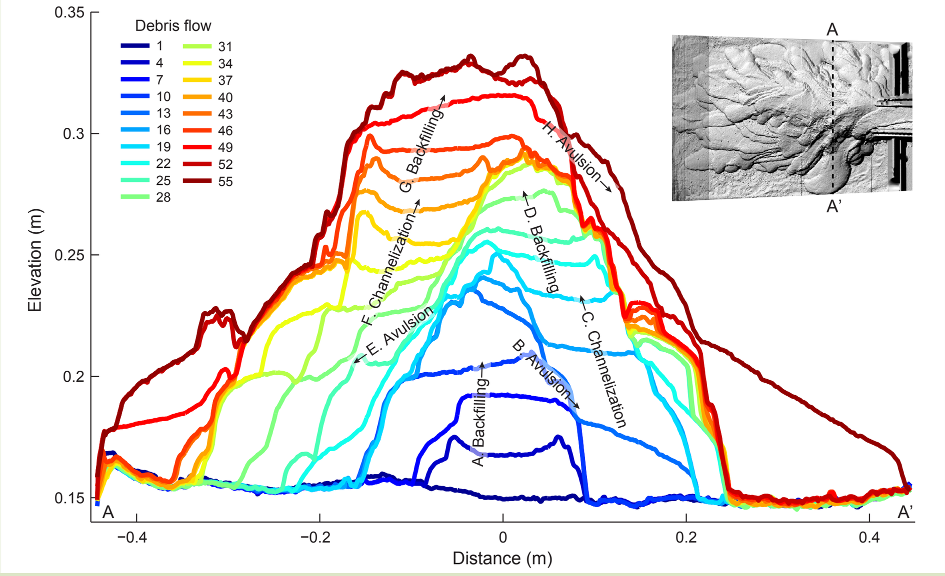


Fig. 5) Fan cross-profiles 0.23 m downstream of the fan apex. Note the alternations between channelization, backfilling and avulsion depicted in the cross-profiles.

Driving mechanisms

- The autogenic dynamics are driven by two interconnected feedback mechanisms:
  - Feedbacks of fan morphology (Fig. 5).
  - Feedbacks of debris-flow flow-dynamics (Fig. 6).

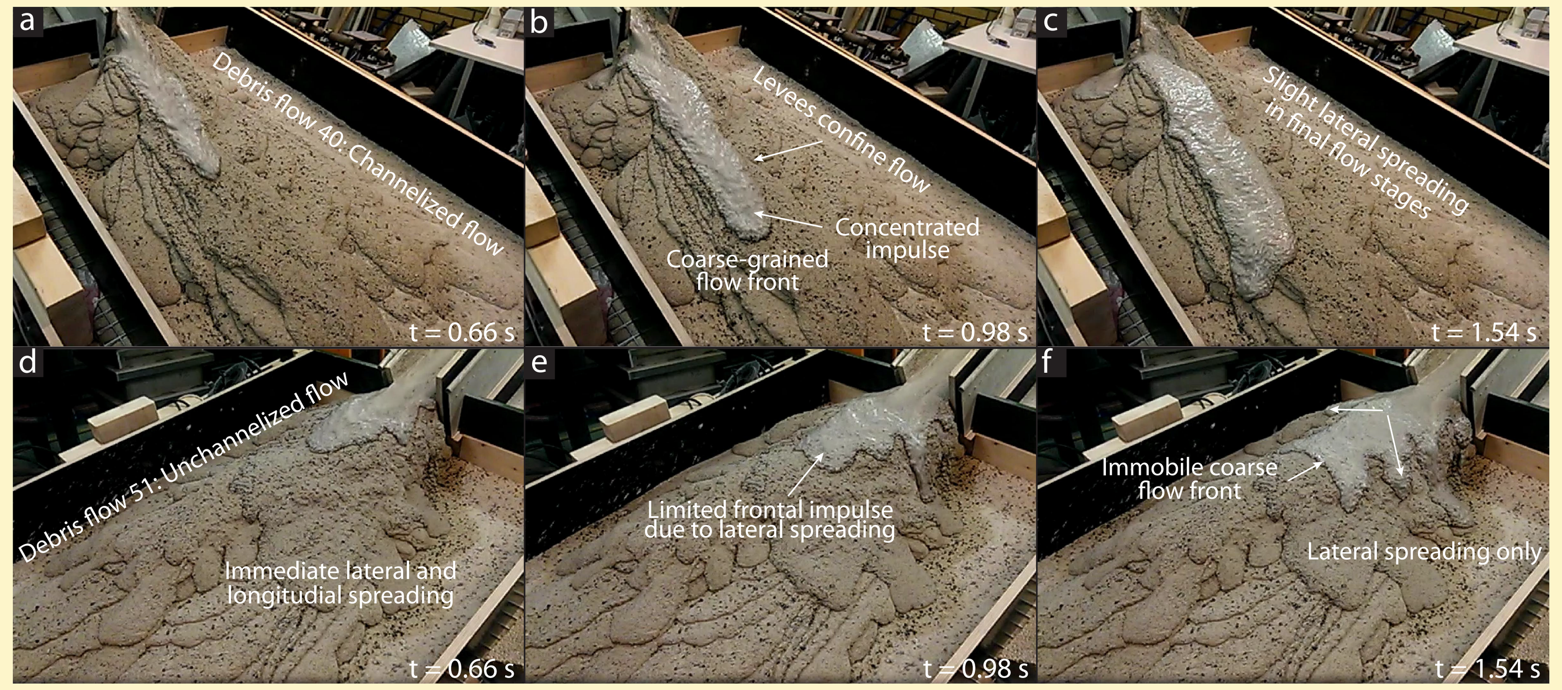
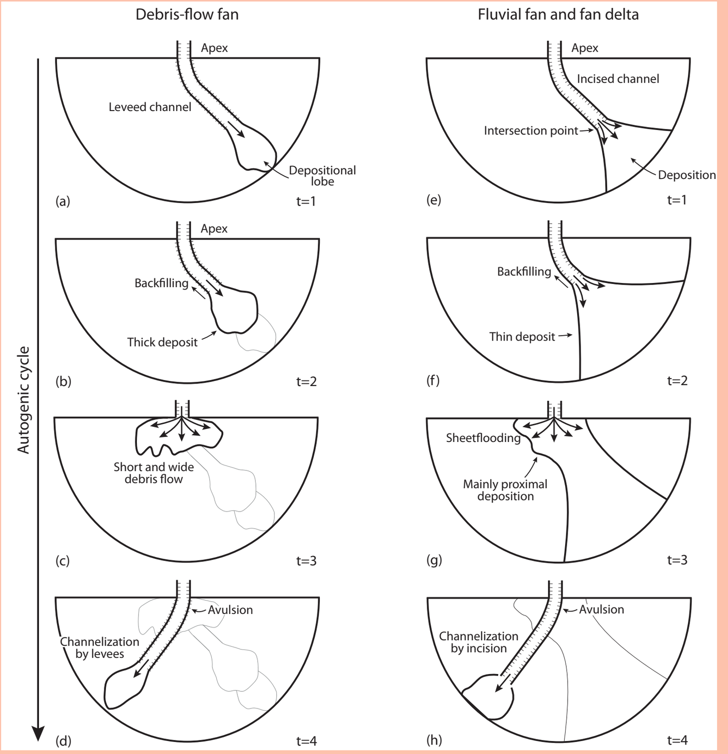


Fig. 6) Stills of debris flows during motion. (a-c) Channelized debris flow (debris-flow 40). Long runout due to focused flow momentum. (d-f) Unchannelized debris flow (debris-flow 51). Short runout due to lateral spreading of flow and momentum. Time (t) denotes time since the debris flow left the apex and outflow over the fan started.

Discussion



- Autogenic dynamics of debris-flow fans and fluvial fans both involve cycles of channelization, backfilling and avulsion.
- On a large scale cycles are driven by topographic compensation, on a smaller scale the processes differ between fan types.

Fig. 7) Schematic portrayal of an autogenic cycle on experimental debris-flow fans and fluvial fans and fan delta's. (a-d) Autogenic cycle on the experimental debris-flow fan. Initially, the presence of a leveed channel results in distal deposition. Debris flows start to retograde over many successive debris flows until the debris flows become short and wide and the channel is completely backfilled. In the absence of a channel, subsequent debris flows start preferentially flowing towards the steepest slopes and avulsion occurs. Debris flows now gradually, over the course of multiple succesive flows, start channelizing and increase in length until a next cycle of retrogradation and backfilling commences. (e-h) Autogenic cycle observed on multiple experimental fluvial fans and fan delta's. Initially, apex incision results in deposition near the fan toe. Then the channel start backfilling and the intersection point moves upfan. Once the channel is completely filled sheetflooding results in proximal deposition, leading to oversteepening of the apex region until an inherent stability threshold is exceeded. This initiates avulsion by the formation of a new channel by erosion in the direction of the topographically lower areas of the fan. Sediment deposition is now concentrated distally again, until a next backfilling cycle commences.

Conclusions

- We experimentally created a debris-flow fan in the absence of extrinsic forcings.
- This debris-flow fan formed by autogenic cyclic avulsions.
- The autogenic cycles comprised a backfilling, avulsion and channelization phase.
- The autogenic cycles were driven by interconnected feedbacks in morphology and flow-dynamics.
- Over large spatio-temporal scales autogenic dynamics of debris-flow fans and fluvial fans are similar.
- Topographic compensation (i.e., compensational stacking) appears to be an overarching mechanism in the formation of fans, regardless of their depositonal process.

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