Surface morphology of fans in the high-arctic periglacial environment of Svalbard

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Unique morphology of fans in high-arctic periglacial environments?

Fan-shaped landforms occur in all climatic regions on Earth. They have been extensively studied in many of these regions, but there are few studies on fans in periglacial, arctic and antarctic regions. Fans in such regions are exposed to many site-specific environmental conditions in addition to their geological and topographic setting: there can be continuous to discontinuous permafrost and snow avalanches and freeze-thaw cycles can be frequent. Do these conditions lead to a unique fan morphology in high-arctic periglacial environments?

Objectives

Here we present an overview of the morphology of fans in the high-arctic environment of Svalbard to (1) increase our fundamental knowledge on the morphology of fans in high-arctic periglacial environments, and (2) to identify the specific influence of periglacial conditions on the surfaces of fans in these environments.

Main fan types in the Longyearbyen area on Svalbard

1. Snow-avalanches fans (talus cones) (Fig. 2).
2. Debris-flow fans (Fig. 3).
3. Fluvial fans (Fig. 4).

Fan type distribution

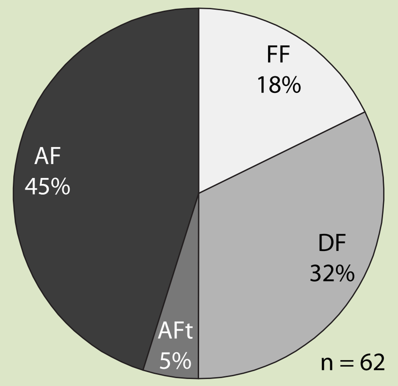

Fig. 1) Breakdown of fans by dominant formative mechanism. Fan type abbreviations: AF = cone-shaped snow avalanche-dominated colluvial fan, AFt = tongue-shaped snow avalanche-dominated colluvial fan, DF = debris-flow-dominated fan, FF = fluvial-flow-dominated fan.

Secondary modification

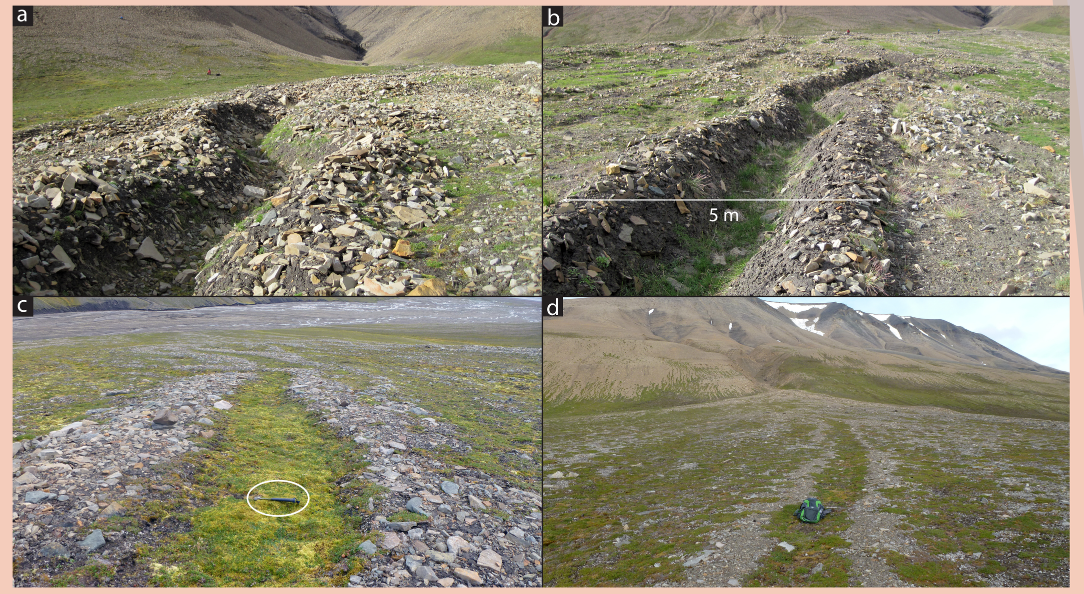

Fig. 5) Debris-flow channels of different age and degree of beveling. (a,b) Relatively young debris-flow channels, with pronounced levees and deepened channels by meltwater erosion. (c,d) Relatively old, heavily bevelled debris-flow channels, on which relief is decreased to <10 cm. Levelling is probably caused by the erosive action of snow avalanches as well as by solifluction and frost weathering.

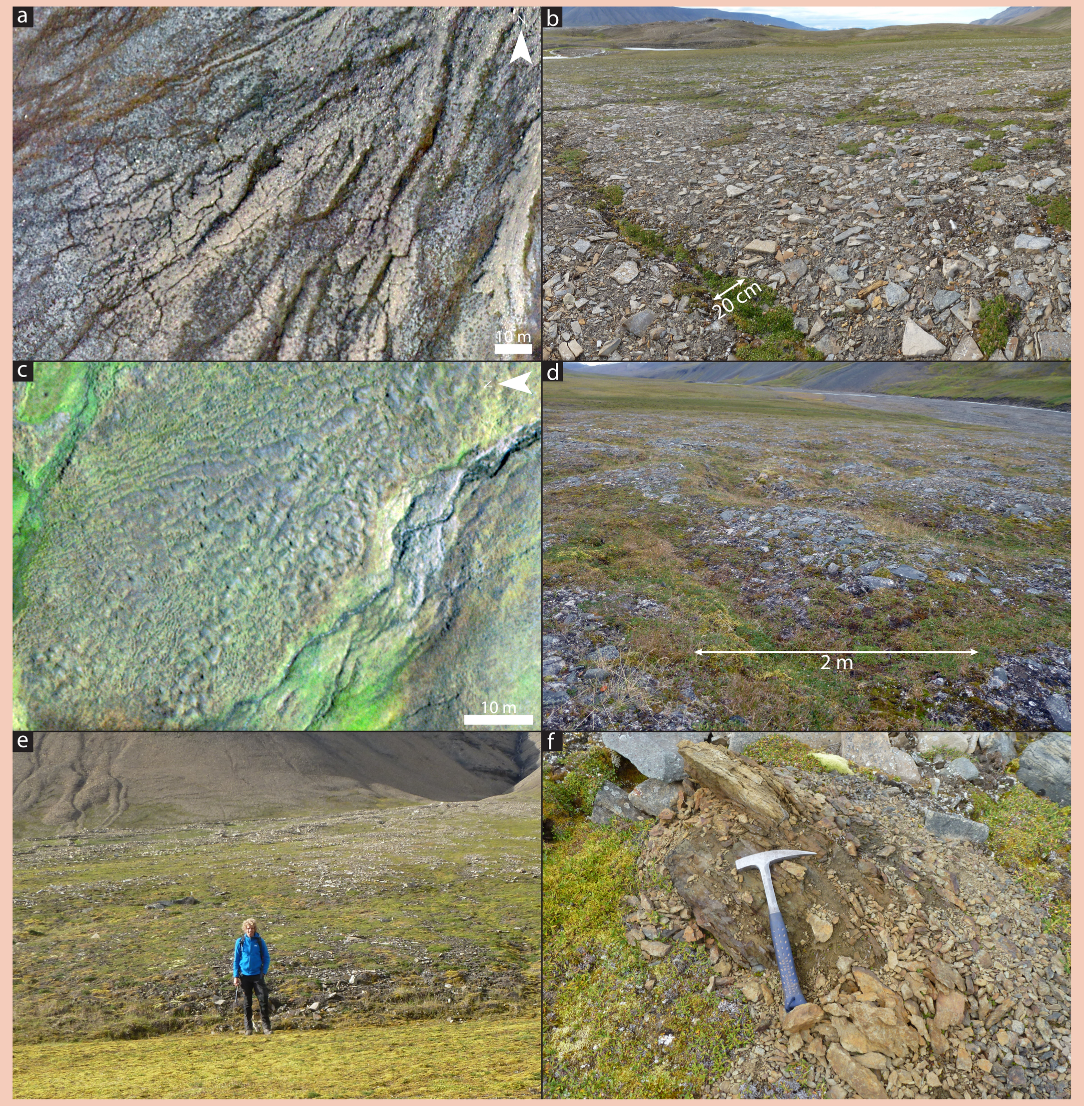

Fig. 6) Morphology of inactive fan surfaces. (a) Polygonal ground on an inactive debris-flow fan surface. (b) Ground picture of polygonal ground shown in picture a. (c) Hummocks on an inactive fluvial fan surface. (d) Ground picture of hummocks in picture c. (e) Stepped profile formed by solifluction at the foot of a debris-flow fan. (f) Heavily fractured cobble by frost weathering.

Snow-avalanche fans

Fig. 2) Snow avalanche-dominated fans. (a) Tongue-shaped snow avalanche fan. Note the snow avalanche flattened proximal domain, and the more grayish (more lichen) sediment along the sides and lower parts of the fan. Letters denote picture locations. (b) Tongue-shaped avalanche fan. The steepness of the step at the base of the fan is enhanced by basal erosion by the river. (c) Cone-shaped avalanche fans. (d) Debris-tail formed by snow avalanche erosion. (e) Fine-grained texture due to avalanche erosion on the proximal fan domain. (f) Debris-horns on proximal fan domain. White arrows point at the debris-horns. (g) Accumulation of coarse sediment on distal fan domain. (h) Perched boulder. Black arrows denote flow direction.

Debris-flow fans

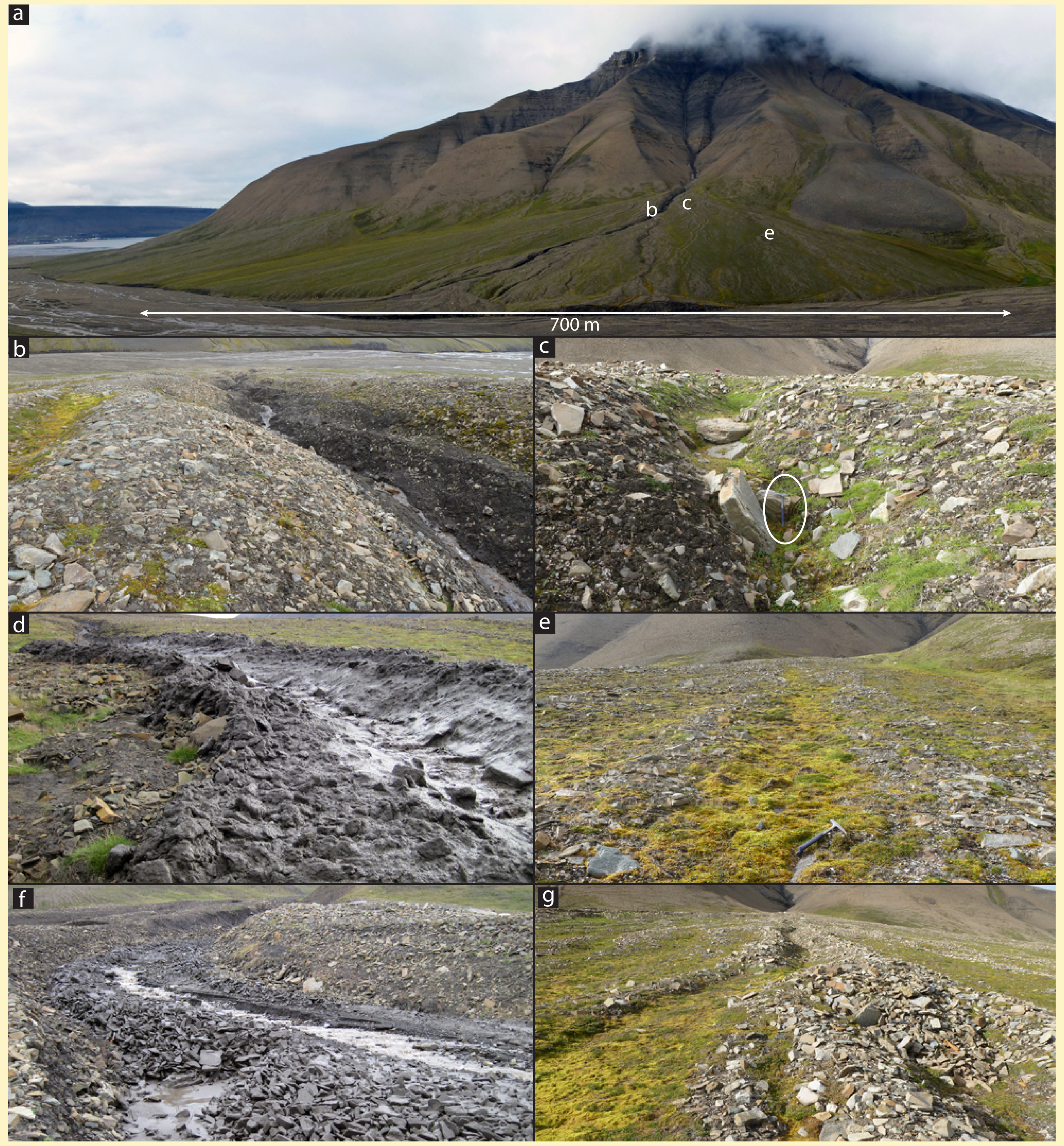

Fig. 3) Debris-flow-dominated fans. (a) Debris-flow-dominated fan (b) Debris-flow channel, incised by a meltwater stream. (c) Formerly incised debris-flow channel. Step-pool morphology implies reworking by runoff. Hammer for scale. (d) Very recent (1-3 days) debris flow. (e) Heavily bevelled and levelled debris flow. (f) Very recent (1-3 days) debris flow (g) Bifurcated meltwater stream in debris-flow channel. Meltwater streams often bifurcate and leave debris-flow channels where flow is ponding behind a debris-flow lobe.

Fluvial fans

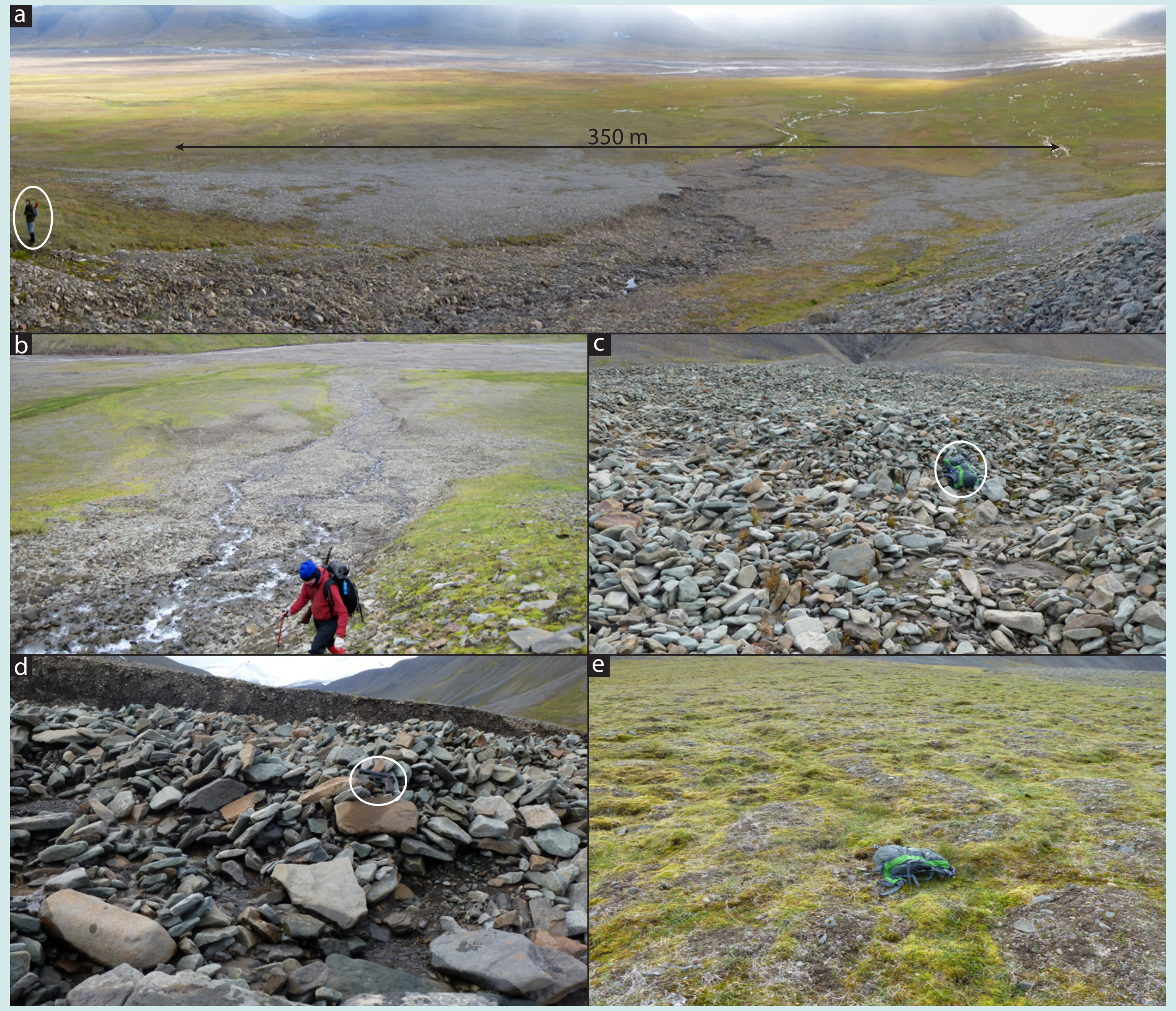

Fig. 4) Fluvial-flow-dominated fans. (a,b) These fans are generally incised, separating the active part of the fan from the inactive part. The active part generally has typical braided planform due to the continuous discharge of meltwater in spring and summer. (c) Upfan view on an active fan part. (d) Active part showing clast imbrication. Flare gun for scale. (e) Inactive fan surface with heavily modified initial morphology by hummock formation.

Conclusions

- Periglacial conditions (e.g., frequent snow avalanches, freeze-thaw cycles, active layer melting and freezing) lead to unique fan morphology on Svalbard.
- The morphology of steep talus cones is predominantly controlled by snow avalanches, in contrast with the ubiquity of rockfall-dominated cones in most other parts of the world.
- The primary morphology of inactive surfaces is rapidly beveled and leveled by snow avalanches, solifluction and frost weathering.

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