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Laboratory flume experiments for characterising Martian channels formed by distinct groundwater systems

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Channels on Mars have been found in many locations and across all possible scales, suggesting the presence of flowing water in the past. Several hypotheses for the formation of these channels have been proposed, including a role for groundwater. In this study we explored the development of channel morphology for three types of groundwater systems: 1) seepage from a regional groundwater system, 2) seepage from local precipitation and 3) groundwater release from a pressurised aquifer.
We performed a series of scale experiments to study the morphological development of different scenarios. Smaller scale experiments were conducted in a setup of 1x3x0.25 m (at UU) using lightweight plastic sediment. Larger scale experiments were conducted in a setup of 4x6x1 m (at UoH) using sand. To simulate the three aforementioned hydrological conditions, 1) a constant sub-surface hydraulic head was applied using a header tank connected to the sediment, 2) a series of rainfall simulator nozzles were used (UoH setup only) and 3) a super-surface hydraulic pressure was applied to a perforated pipe beneath the sediment. The two scales of experiments allow us to assess the scalability to real-world conditions. We collected detailed DEMs and time-lapse imagery of the morphological development of the sediment surface.
In the regional groundwater experiments, elongated valleys with circular, steep head walls developed, with depths down to the groundwater table. The valley heads and sides developed as a result of mass wasting processes; within the valley material was transported by fluvial processes. Multiple parallel valleys formed initially, but one or two eventually capture most of the outflow and became larger than the pirated valleys. In the precipitation-fed seepage experiments, groundwater flowed from all directions into valleys rather than just from upstream. Again, multiple parallel valleys with semi-circular heads formed but the valleys were shallower and wider. Channel formation by the release of pressurised groundwater was very fast. Initially, sieve deposits formed on the flanks of a small channel, since the sediment downstream from the source was not yet saturated. With increasing pressure, sand volcanoes developed in the source area and distinct features produced by converging flow were observed in the source area towards the resulting channel.
Generally, we show that channels require very diverse timescales to form by the different sources of groundwater (ranging over several orders of magnitude). Correct identification of the process and water source is therefore key when assessing the formative timescales of Martian channels. Discriminative properties, that are unique for different sources of groundwater, are evident in the final valley morphology (break in slope, valley shape), regional characteristics (drainage density) and several non-channel morphologies (features in source area, preserved initial-stage deposits).