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Groundwater seepage landscapes with local or distal sources in experiments and on Mars

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Groundwater has probably played an important role in shaping the surface of Mars. However, the hydrological origin of many typical Martian groundwater features is hampered by the lack of coupling between subsurface processes and surface morphology. Here we focus on the formation of theater-headed valleys. The basic morphology of such valleys can form by erosion through groundwater seepage (sapping), but similar valley morphology can also be the result of overland flow with waterfall-enhanced erosion. This morphological ambiguity complicates the interpretation of such valleys on Mars, but their climatic implications are quite different. Instead of the ambiguous single-valley morphology, metrics of the entire landscape may provide a diagnostic insight into the formative hydrological conditions. We aim to increase our understanding of the formation of entire landscapes by sapping processes and their hydrological implications by providing a framework for morphological metrics of different types of sapping systems.

We study sapping from different groundwater sources using large-scale sandbox experiments in the Total Environmental Simulator at the University of Hull and combine our results with previous experiments. Importantly, flow patterns and the resulting landscapes are significantly different for the different sources of groundwater. The main differences are between sapping that results from either local or distal sources. Key results of our study are that groundwater piracy acts on distally-fed valleys, which results in a sparsely dissected landscape of many small and a few large valleys, while locally-fed valleys result in a densely dissected landscape. In addition, distally-fed valleys grow towards the direction of the groundwater source while locally-fed channels grow in a broad range of directions and have strong tendency to bifurcate, particularly on flat horizontal surfaces.

To exemplify these differences, we apply the results to aid the interpretation of two Martian cases; the valleys of Louros Valles show morphological properties of sapping by a local source whilst Nirgal Vallis shows evidence of a distal source, which we infer is probably groundwater from Tharsis.