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Fluvial reorganization across scales

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In mountainous terrains, fluvial incision into the bedrock takes place in response to local or far-field gradients in the vertical uplift motion of crustal rocks. The spatial pattern of the drainage network – the geometry of the basins and the topology of the flow lines, should therefore reflect the gradients in the rock uplift rate.

This means that as the spatial gradients in the uplift rate vary in time, the drainage network evolves accordingly. Depending on the nature of the uplift change with respect to the orientation of the antecedent rivers, it can lead to drainage network reorganization, whereby the geometry of drainage basins and the topology of flow lines change through time by migration of water divides and river capture.

Recent studies demonstrated that unstable basins and reorganization of fluvial drainage networks are globally common, and that the processes by which basin geometry change through time could be exceptionally long-lasting and continue many tens of millions of years after a tectonic change has occurred. Despite the demonstrated ubiquity of fluvial reorganization and its importance for the evolution of fluvial landscapes, several outstanding questions remain, among which are: (1) What are the spatial relations between a particular change in the gradients of rock uplift rate and the reorganization response of the fluvial network? and (2) What are the basin or reach-scale processes that control different modes of reorganization and what are the rates at which reorganization operates?

To address the first question, we designed and constructed a one-of-a-kind apparatus for physical experiments of fluvial landscape evolution in response to space and time variable tectonic uplift rates and precipitation rates. With this apparatus, we are studying the effect of tectonic tilt in different orientations with respect to the antecedent drainage network on the spatial distribution and on the style of fluvial reorganization.

To address the second question, we conduct a field survey of reversed and barbed drainages along the rift-related western shoulders (escarpment) of the southern Arava Valley in Israel. Flow reversal toward the edge of the escarpment, as is documented in our field site, set a unique problem since the rifting process itself and the erosional unloading that is associated with escarpment retreat have been argued to produce tilt away from the escarpment, which is expected to hinder such reversal. We combine a detailed exploration of geometric, lithologic, and fluvial properties of the reorganized basins, geometric and chemical analysis of Reg soils that develop in fluvial deposits in this hyper-arid environment, and Optically-Stimulated Luminescence dating of windgaps to constrain the processes and the rates of reorganization in the proximity of the escarpment and to address the apparent mysterious reversal direction.