



Potential effects of topographic stresses on the emergence of streamflow (and vice versa)

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The pattern of valley incision, the availability of aquatic habitat, and rates of carbon efflux from surface waters all depend on where streamflow emerges in a landscape. Recent field observations have revealed that streamflow tends to emerge from the subsurface where valley cross-sections become more sharply curved, and that more abrupt changes in curvature are associated with more stable stream heads, even as landscapes wet up and dry out. However, the causality of this relationship is not clear: does increased curvature force water out of the ground and into stream channels? Or does the local onset of streamflow cause spatial gradients in valley curvature?

We argue that there are mechanistic explanations for both processes, and possible feedbacks between them. First, the bedrock stress field underneath valley bottoms is sensitive to the topography above. By calculating the bedrock stress field underneath synthetic valley cross-sections with different curvatures, we show that the least compressive stress is higher beneath valleys that are more sharply curved. We calculate that because greater compressive stresses tend to close fractures and reduce permeability, bedrock permeability should decrease exponentially with increasing valley curvature. This suggests that increases in valley curvature will reduce the capacity of bedrock to transmit water through the subsurface, thus increasing streamflow at the surface.

Second, stream incision increases cross-valley curvature over time. If stream heads are relatively stable over a broad range of flow conditions, this will localize the onset of stream incision, creating abrupt transitions in valley curvature (and thus topographic stresses and bedrock permeability). The positive feedback between surface flow, stream incision, topographic stresses, and bedrock permeability should tend to fix flowing stream networks in place as landscapes evolve. This could help explain, for example, why stream networks in glaciated landscapes tend to be more dynamic than those in fluvially sculpted landscapes.