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Hydrological and geochemical coevolution of landscapes and their streams

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Streams integrate fluxes of water, solutes, and sediment from their catchments, and thus are mirrors of the surrounding landscape. Conversely, fluxes of water, solutes, and sediments shape the hydrological, chemical, and geomorphological evolution of landscapes, and thus in turn, their drainage systems. Here I summarize several lines of evidence illustrating the coupling between landscapes and the streams that drain them. 1) Branching angles of valley networks are systematically wider in humid regions than arid ones, consistent with simple models of drainage network evolution under the influence of diffusive subsurface seepage and overland flow erosion. The correlation of mean junction angles with aridity is stronger than with topographic gradient, downstream concavity, or other geometric factors that have been proposed as controls of junction angles. Thus, it may be possible to identify channelization processes from valley network geometry in relict landscapes, such as those on Mars. 2) Active drainage networks dynamically extend and retract, and connect and disconnect, both seasonally and in response to individual rainfall events, dynamically mapping out variations in subsurface transmissivity and in the balance between precipitation and transpiration. 3) Stable isotope cycles in rivers indicate that steeper landscapes tend to have have less – not more – young streamflow than flatter landscapes. This superficially counterintuitive result illustrates how steep topographic gradients create rock stresses that fracture bedrock, enhance permeability, and promote deep infiltration. 4) Concentration-discharge relationships in streams are often much flatter than simple dilution models would predict, suggesting that catchments behave like chemostats, with rates of solute production that are nearly proportional to water fluxes, on both event and inter-annual time scales. However, site-to-site variations in mean concentrations are strongly negatively correlated with long-term average precipitation and discharge, suggesting strong dilution of stream concentrations under long-term leaching of the critical zone. The picture that emerges is one in which, on event and inter-annual time scales, stream solute concentrations are chemostatically buffered by groundwater storage and fast chemical reactions, but on much longer time scales, the catchment's chemostatic "set point" is altered by climatically driven critical zone evolution.

Examples such as these will be presented to illustrate the close coupling between landscapes and the waters that drain them, and to demonstrate how streams can be used as windows into landscape processes.