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Tectonic versus lithologic controls on river channel gradients

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In eroding landscapes, river systems respond to tectonics by adapting their morphology. A well-understood behaviour is a steepening of channel reaches coeval with differential rock uplift. These may generate transient upstream migration of knickpoints and knickzones or established steepened reaches. Steepness contrasts have therefore become key features to describe active landscapes. Observations have been well studied and tested against theoretical models (e.g. stream-power) to infer tectonic timing and activity from the river network. Morphometrics have been developed and widely use to quantitatively describe these steepened reaches (e.g., steepness index and its concavity-normalised equivalent). However, tectonics are not the only control on channel steepness as differential lithology also affects channel steepness as demonstrated by many studies. Isolating the influence of lithology versus contrasting rock uplift is often challenging as active faults commonly juxtapose different rock types. Similar morphologies can therefore be generated by different processes which can lead to mis-identification of active faults.

We investigate mixed tectonic/lithologic signals with modelling approach coupled with topographic analysis, geological observations, thermochronometers and CRN analysis. We extract river long profiles from DEMs and we use 1D implicit solving of the stream power equation to simulate fully tectonic and lithologic controls (and intermediate scenarios) on these. We constrain the model parameters (stream-power law exponents, erosion patterns, erodibility for lithology, rock uplift) with CRN analysis, in-situ rock strength measurements, qualitative observations and thermochronometers. Simulated long profiles are then compared to the one extracted from DEMs at steady and transient states. Rock uplift and erodibility parameters are adapted and the model runs until reaching similar morphologies between simulated and DEM-derived river profiles. Simulated rock uplift and erodibility fields are finally evaluated against external constrains, leading to the discrimination of unrealistic scenarios and the assessment of tectonic versus lithologic controls.

We test this method in the Romanian Carpathians where recent tectonics in the SE bend of the orogen have been strongly suggested by thermochronometers, geophysical observations and seismicity. Significant steepness variations are recorded and suggest ongoing differential vertical motions. However, evidence from the displacement of river terraces and GPS data do not imply the same uplift fields as indicated by channel steepness variation and each tectonic units is composed of different rock types, potentially overprinting tectonic signals. To further isolate controls, we also study the northern part of the Romanian Carpathians where there are similar tectonic units, but where active tectonics has ceased since Miocene times.

Our results suggest that neither tectonics nor lithology can fully explain all the channel steepness contrasts, and so both play a role. A consequence is that some examples where active fault displacement has been interpreted based solely on channel steepness need to be re-evaluated. Combining field data, topographic analysis and numerical modelling in our case allows the discrimination of certain scenario and therefore the refining of tectonic and landscape evolution models.