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Crustal Deformation, River Anticlines and the Location of the Highest Mountains

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The formation of orogens is the result of the interaction between crustal deformation and erosion. Phenomena such as river anticlines and high peaks which are sometimes far away from the main drainage divide illustrate that erosion has a strong feedback on deformation. This feedback is studied systematically by combining the two perhaps most simple models of fluvial erosion and crustal deformation. Erosion is modeled by the stream power approach where the erosion rate is a power law function of slope and drainage area. For modeling deformation, we assume linear viscous behavior and that only vertical movement is allowed. Driving force only results from bouyancy, so that crustal deformation is just a response to erosion without active tectonics.

If the coupled model is transformed to nondimensional variables, only one parameter remains. It characterizes the viscosity of the lithosphere in relation other parameters such as spatial scale, uplift rate, and erodibility. Even for rather high viscosities of 10^{22} Pa s, viscous deformation becomes significant if the width of a mountain belt exceeds about 200 km. Both the location of the highest mountain peaks and the profiles of the main rivers change in this regime. The highest peaks move from the region around the main drainage divide to locations quite close to the border of the mountain belt, so that the main rivers are deeply incised between these peaks and form anticlines. While river profiles are always concave for high viscosities, the profiles of the major rivers become straight or even concave in their lower part as soon as viscous deformation becomes significant.