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On the growth and erosional decay of mountain belts

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The time scale necessary for mountain belts to reach steady-state between uplift and erosion is poorly known. Observations such as the time evolution of the sedimentary flux into adjacent basins or that of oxygen isotopic ratios in lake deposits indicative of the establishment of an orographic barrier, imply that it must be of the order of a few millions of years. Here we show that this time scale is simply equal to the ratio of the steady-state mountain peak height and the uplift rate scaled by an isostatic factor or rate of isostatic rebound per unit surface erosion. At steady-state, the uplift rate is the erosion rate, which can be measured by thermochronology. The isostatic factor can be computed from the value of the EET (Effective Elastic Thickness) of the lithosphere, which has now been estimated by coherence studies for most orogenic systems. We present a compilation of the response time (i.e. time taken to reach steady-state) of many orogenic systems that are at or close to steady-state, independently of any assumption concerning the nature of the erosional process and/or its parameterization. The values we obtain range from 1 to 10 Myr. We also show that isostasy plays an important role as postulated by Ahnert (1970).

Using simple parameterizations for the erosional process (stream power law, non linear diffusion, etc) we demonstrate that during the growth phase of an orogenic system, mountain peak height evolves exponentially with time. We also show that the relaxation or post-orogenic phase is also characterized by an exponential evolution with time, but only in cases where the erosional process scales linearly with height (through topographic height, slope or curvature). If the assumed erosional process is a non-linear function of height, the post-orogenic phase is characterized by a power law time evolution, which explains why old orogenic systems have topographic expressions that may last tens to one hundred millions of years, i.e. much longer than the duration of the growth stage.

Finally, we show how the values of the response time that we calculated independently of any assumption made on the nature of the erosional process can be used to provide constraints on the non-linearity of erosional laws such as the stream power law.

Ahnert, F. (1970). Functional relationships between denudation, relief, and uplift in large mid- latitude drainage basins. Am. J. Sci., 268:243-263.