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Mountain building and mantle dynamics: a journey through the Tethyan belt (Stephan Mueller Medal Lecture)

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The style of mantle convection beneath large oceanic plates is rather well established. On the other hand, we still have a loose grasp of what happen beneath continental plate, especially beneath mobile and convergent margins, where we expect to have vigorous convection.
Here, I present some considerations about the style and evolution of mantle convection beneath convergent/collisional zones as constrained by geological - seismological data and modelling. I will consider the Alpine-Tethyan belt as a case study, exploring the idea that the style of mountain building can be used as a proxy to reconstruct mantle dynamics. The Tertiary evolution of the Tethyan belt indeed offers a unique opportunity to discuss about mountain building and mantle dynamics, as it include region such as the Mediterranean, where collision is still in its incipient stage producing Apennines style orogen, to the Himalayan-Tibetan belt, where collisional process reaches its extreme consequence. We classified those two belts as end members of a wide range of orgen. On one side, the of "slab pull" orogen, where subduction is mainly confined to the upper mantle, and rollback trench motion lead to moderately thick crustal stacks and reduced topographic signal, such as in the Mediterranean. On the other side, the "slab suction" orogen, where whole-mantle convection cells ("conveyor belts") lead to the more extreme expressions of orogeny, such as the largely thickened crust and high plateaus of present-day Tibet. For the slab suction type, deep mantle convection produces the unique conditions to drag plates toward each other, irrespective of their nature and other boundary conditions. Based on mantle circulation modeling and tectonic reconstructions, we surmise that the forces necessary to sustain slab-suction mountain building in those orogens derive, after transient slab ponding, from the mantle drag induced upon slab penetration into the lower mantle, and from an associated surge of mantle upwelling beneath Africa. This surge of mantle convection drags plates against each other, generating the necessary compressional forces to create and sustain these two orogenic belts.
If this "bottom-up" tectonic model is correct, the geological records of orogeny cycle and of the topographic evolution along mobile belt can be used to decipher time-dependent mantle convection. Our main conclusion is that beneath the Tethyan belt we should imagine a multi-scale style of convection operating at different time and length scale, with a small scale convection style in the upper most part of the upper mantle embedded within a larger/slower and intermittent large scale whole mantle convection.