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Mountain building, from subduction to collision and erosion: insights from 30 years of field and analog modeling studies (Stephan Mueller Medal Lecture)

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Through a rapid overview of my research career, I will outline the role of the primary mechanisms and processes, which exert a strong control on mountain building. Field observations (both from structural geology on-land and marine geophysical surveys at sea), and analog modeling are the two main approaches that I used and developed during more than 30 years of research studying mountain belts at Montpellier University. The substantial contributions made through collaborations and exchanges with colleagues and students will be acknowledged.
As mountain belts are long lived structures, their evolution involves numerous processes that interact since the early history, beginning during oceanic subduction and ending during the late orogenic evolution which leads to erosion and the ultimate destruction of topography. Most orogens form in subduction settings due to plate convergence involving large horizontal shortening and strong deformation of the crust developing into an overall wedge shape during their evolution. I will focus on orogens caused by subduction of a continental margin lower-plate under an oceanic or continental upper-plate following oceanic subduction, a process also commonly known as collision. After development of a sedimentary accretionary prism and closure of the oceanic domain, continuous subduction of the lithospheric mantle induces deformation of the continental crust and controls the structural asymmetry of the mountain belt. Since the pioneer works by Dahlen, Davis and Suppe in the Eighties, mountain belts have been often considered by geologists as crustal scale accretionary wedges whose deformation mechanisms can be satisfactorily described by a Coulomb behavior. The theory offers a simple mechanical framework allowing a division into different tectonic regimes depending on wedge stability : critical, undercritical, overcritical. Since then, it has been shown that orogens commonly adopt a distinct geometry with a low-tapered pro-wedge facing the subducting plate, and a high-tapered retro-wedge on the internal side. Erosion has rapidly been added as a significant parameter because the impact of material transfer on the mechanics and structural evolution of sub-aerial wedges relative to submarine ones is major. Following this general approach, I will address major open questions regarding the global and local responses (i.e. at orogenic scale and at the scale of faults or ridges) of an orogenic wedge under the impact of tectonic or climatic forcing at different time scales. Insights from analog models are used to; - characterize the behavior of orogenic wedges subject to different geometric, kinematic and rheologic boundary conditions and - to show how the interactions between surface processes and tectonics influence the structures, kinematics of deformation, exhumation mechanisms, and long-term evolution. Impact of first order parameters such as the initial geodynamic subduction setting, material transfer in the wedge, structural inheritance (OCT and inherited extensional structures), and their role on the tectonic evolution of orogenic wedges will be successively reviewed.
Several case studies of active or fossil orogens (Taiwan, the western Alps and the Variscan belt) representative of first order tectonic processes will be presented in the light of field observation and analog experiments.