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Lithospheric deformation and mantle convection, a geological approach

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Whether the deformation of continents is entirely caused by stresses transmitted from plate boundaries horizontally through the lithospheric stress-guide or also by viscous coupling with the asthenosphere flowing underneath, which was part of Arthur Holmes' early vision, is a long-standing question. An increasing amount of observations suggests an efficient coupling between mantle flow and crustal deformation far from plate boundaries, tipping the scale toward the second option. Modern seismic reflection profiles probing the entire crust down to the Moho show asymmetrical features implying simple shear at crustal scale in compressional (mountain belts) and extensional (rifts and passive margins) contexts. Comparison of crustal-scale strain field with seismic anisotropy in strongly extended regions shows homoaxiality of crustal and mantle deformation in continental rifts and back-arc regions. 2-D and 3-D numerical models show that the flow of mantle underneath these regions is faster than in the crust and drives crustal deformation. Beside seismic tomography that images ancient slabs preserved as velocity anomalies in the deep mantle but does not provide any information on the timing, the geological history of basins and orogens, although indirectly, is the only record of past mantle convection. Looking for evidence of coupling between the tectonic history of wide regions and mantle convection in parallel with numerical modelling can provide clues on how convection drives crustal deformation. The recent evolution of numerical modelling, with high-resolution 3-D experiments, can now match the first order of regional models based on geological observations, including the timing and the sequence of events, which are both crucial elements of geological models. This will allow testing complex conceptual models that have been discussed for long. In this lecture, I review different contexts where these questions are debated. Among these contexts complex in 3-D where the geological data set is abundant, the Mediterranean and the Middle East allow discussing the respective contributions of whole-mantle convection involving large plumes *vs* more local convection in the upper mantle due to slab dynamics in crustal deformation. Studying the dynamics of the India-Asia collision, and the respective roles of lithospheric-scale indentation on the one hand and asthenospheric flow due to slab retreat on the Pacific rim and to large-scale plumes, on the other hand, is also likely to bring interesting insights on how deformation propagates within continents at long distance from plate boundaries.