Deformation of hot orogenic crust:
Three-dimensional flow modes and flow mode thresholds

Denis Gapais*[1], Dominique Chardon[2], Thibault Duretz[3], Flora Bajolet[2], Karel Schulmann[3], Joseph Martinod[2]

[1] Géosciences Rennes, UMR 6118 CNRS-Université de Rennes 1, 35042 Rennes cedex, France

[2] LMTG (CNRS-IRD), Observatoire Midi-Pyrénées, Université Paul Sabatier, 14 avenue Edouard Belin, 31400 Toulouse, France

[3] CGS/EOSTUniversité Louis Pasteur ; 1, rue Blessig ; 67084 Strasbourg France

At lithospheric scale, compression of ultra-hot orogens exemplified by Precambrian accretionnary orogens combine horizontal flow of a thick and hot ductile crust with strain concentration along steeply dipping deformation zones along which pieces of upper crust are buried. Steeply dipping zones may simply develop as transfer zones accommodating differential horizontal flow of lower crustal masses. They may also reflect overall transpressive boundary conditions. Consistently, associated principal stretch directions may vary from down-dip to subhorizontal from one orogen to another. In contrast, crustal domains where horizontal flow dominates are characterized by flat-lying fabrics and principal stretch directions at low angle to the strikes of the orogen and of steep deformation zones. The spatial distribution of domains dominated by horizontal flow or by vertical motions depends on the coupling between weak layers and more resistant ones. Coupling is achieved through an attachment layer that accommodates the contrasted kinematic responses of the upper crust and the lower viscous crust to convergence, vertical mass transfers and longitudinal flow.

On the other hand, most modern (Phanerozoic) hot orogens are linked to crustal thickening induced by subuductional process, and are marked by horizontal fabrics related to spreading of hot lower crust above an upper mantle of variable thickness and weakness depending on root ambient geotherm. Vertical material transfers processes also occur, with hot granulitic crust exchanged with mide-upper crustal rocks. Finally, subhorizontal spreading of partially molten uplifted lower crust may also occur. A main controlling factor of deformation mode is decoupling of orogenic lower crust from the upper mantle during extrusive exhumation of low viscosity lower crust and its subsequent decoupling from rigid lid in suprastructural levels during subsurface horizontal spreading. The kinematics of flow of deep lower crust is fully controlled by the geometry of subducting continental material at early stages of root building while vertical extrusion and subsurface spreading are controlled by indentation of opposite (pro-side) continental buttress at the end of lithosphere shortening.

Precambrian ultra-hot orogens are marked by rather distributed strains compared to those involving initially cold lithospheres with a stiff and localizing lithospheric mantle and a thick brittle crust allowing strong strain localization within lithosphere-scale shear zones. Distributed deformation at crustal scale has potential important implications on local strain rates throughout hot orogens, on their geomorphology and the dynamics of associated surface mass transfers (erosion and sedimentation). In contrast Phanerozoic hot orogens are marked by homogeneous deformation during deep lower crustal flow stage and heterogeneous exhumation and subsurface spreading flow processes at later stages. The implication is a building of topography in the shortened root region at the late indentation stage. These contrasting behaviours, basically linked to initial geotherms and attached degree of strain localisation, are illustrated by field examples and analogue models.