# Inversion of the Rhenohercynian rift shoulder (Middle European Variscides): Implications for the strain and the metamorphism from numerical modelling

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The Rhenohercynian zone of Belgium and Germany represents the northern fold-and-thrust belt of the central European Variscides. The rocks which underwent the shortening at the end of Carboniferous consist of mainly (meta-) sediments of the Lower Palaeozoic and the Devono-Carboniferous. In the northern part of the fold-and-thrust belt (Ardenne Anticlinorium), the Lower Paleozoic rocks are exposed as a series of inliers such as the Rocroi and the Stavelot–Venn Massifs. These are surrounded by Lower Devonian detrital sediments which show a considerably thickening toward the south. This variation is due to steep-dipping normal synsedimentary faults during a rifting event (Oncken et al. 1999). During the Variscan Orogeny (Carboniferous), this zone induced a preferential strain localisation and a strong exhumation above a major ramp. In the eastern Stavelot–Venn Massif, the synsedimentary fault was inverted into a transpressive shear zone (Fielitz 1992), the so-called the Monshau shear zone. It is located between a series of south-dipping thrusts (Venn, Soiron, Aachen thrusts) in the North and the north-dipping Troisvierges–Malsbenden backthrust in the South. The southern limb of the Ardenne Anticlinorium shows mainly green-schist facies metamorphic aureoles in Lower Palaeozoic and Lower Devonian metasediments. The paragenesis and the fluid inclusions indicate that maximal P and T values of 400 MPa and 500 °C, while the paleo-geothermal gradient ranged between 30 °C/km and 60 °C/km.

We used the 2D thermomechanical finite element "DLR" software (Batt and Braun 1997) to study the strain partitioning, the exhumation and the PTt paths during the inversion of a steep-dipping normal synsedimentary fault. Different models have been applied to compare the influence of the competence contrast between the footwall and the hangingwall. The results show that without the presence of a low cohesion level along the fault and whatever the competence contrast is, the footwall is cut by a shear band which decreases the synsedimentary fault dip. The models applying a weak level show (1) in the ductile field, the strain growths along the synsedimentary fault and (2) the footwall is only cut at the brittle-ductile transition. The results of the numerical models are consistant with structures of eastern Stavelot–Venn Massif and the available PT data of the Ardenne Anticlinorium.

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*Oncken O., von Winterfeld C. and Dittmar U.* (1999): Accretion of a rifted margin: The Late Paleozoic Rhenohercynian fold and thrust belt (Middle European Variscides). Tectonics, 18 (1), 75–91.

# Dynamical evolution of orogenic wedges and continental plateaux: Insights from thermal-mechanical modelling of convergent orogens

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Orogenic belts are zones of thickened continental crust that form as a result of convergence between lithospheric plates. Deformation of the crustal layer typically comprises a phase of crustal thickening followed by a phase of widening of the zone of thick crust associated with the development of a continental plateau. Crustal thickening perturbs density interfaces such as the surface and the base of the crust (the Moho) and hence introduces lateral variations of gravitational potential energy. Thickening of the continental crust also redistributes radioactive heat-producing material. In the case of prolonged crustal thickening, thermal relaxation and radioactive heat production cause temperatures to rise in the interior of the orogenic belt. Accordingly, the dynamic evolution of an orogenic belt is controlled by the thermal and mechanical evolution of the zone of thickened crust and by the interplay between buoyancy, horizontal compression, and basal traction.

We investigate the dynamical evolution of convergent orogens assuming a physical model in which lithospheric subduction occurs beneath the region of crustal thickening. Under these conditions, orogenic evolution is controlled by the competition between tectonic and gravity forces combined with the role of temperature on the rheologic evolution of the crust. We test the ability of this physical model to reproduce first-order features of orogenic belts (thermal structure, geometry and dynamics of orogenic wedge, continental plateau, etc.), using a fully coupled thermal-mechanical numerical model based on the finite element method.

The following conclusions can be drawn from this study :

- The formation of a model orogenic wedge by accretion of heat-producing radioactive material is an efficient mechanism to generate high temperatures in the orogenic core, even while subduction and related cooling are active beneath the orogen.
- Deformation of crustal layers with constant rheologic behaviour (frictional-plastic or constant viscous) leads to the growth of back-to-back wedges with no limit in crustal thickness.
- A limited decrease in viscosity as a function of depth or temperature causes a decrease in the surface slope of the wedges. With lower values of viscosity at the base of the deformed crust the surface slope tends to zero and at this stage mechanical decoupling occurs. Further convergence is accommodated by the widening of the zone of thick crust leading to the formation of a plateau.

# Numerical modelling of coupled orogenic processes using the distinct element method

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The distinct element method is applied to study the interaction of deformation, erosion and isostasy in numerical models of continental collision zones.

The 2D plane-strain model consists of up to 20,000 cylindrical disks interacting only at contacts. The contact laws and the properties of the disks define the bulk rheology of the model. For this study a noncohesive Mohr Coulomb material was defined by assigning only surface friction, normal stiffness, shear stiffness and density to the disks. These models using only material without cohesion exhibit scale independent behaviour. The same parameters except density were chosen for the bounding walls.

In the model a rectangular array of disks represents a vertical section through a continental collision zone. Prior to the onset of deformation the disks are allowed to settle for some time to produce a gravitationally equilibrated starting model. Deformation is then induced by moving the left half of the lower boundary to the right. This results in deformation and uplift in the centre of the model were the moving lower boundary slides under the other. Progressive movement of the bounding walls leads to the formation of doubly vergent thick-skinned orogens. During deformation the lower boundary of the model is kept in isostatic equilibrium which is calculated using a flexural isostatic compensation. Deletion of particles at the surface according to preset rates simulates erosion of the orogen.

The modelling results include the kinematic evolution of the model, the stress history of particles and regions, the work performed by the bounding walls, by frictional sliding of the disks and the energy stored by elastic deformation.

The present study shows a range of models with varying crustal strengths and erosion rates as well as different elastic parameters of the lithosphere and shows the influence of these variations on the evolution of the orogen, its foreland basins, on the particle paths and the energy balance of the system.