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.