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Evolution of crustal stress, pressure and temperature around shear zones during orogenic wedge formation: a 2D thermo-mechanical numerical study

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We study the formation of an orogenic wedge during lithospheric shortening with 2D numerical simulations. We consider a viscoelastoplastic rheology, thermo-mechanical coupling by shear heating and temperature-dependent viscosities, gravity and erosion. In the initial model configuration there is either a lateral temperature variation at the model base or a lateral variation in crustal thickness to generate slight stress variations during lithospheric shortening. These stress variations can trigger the formation of shear zones which are caused by thermal softening associated with shear heating. We do not apply any kind of strain softening, such as reduction of friction angle with progressive plastic strain. The first major shear zone that appears during shortening crosscuts the entire crust and initiates the asymmetric subduction/underthrusting of mainly the mechanically strong lower crust. After some deformation, the first shear zone in the upper crust is abandoned, the deformation propagates towards the foreland and a new shear zone forms only in the upper crust. The shear zone propagation occurs several times where new shear zones form in the upper crust and the mechanically strong top of the lower crust acts as detachment horizon. We calculate the magnitudes of the maximal and minimal principal stresses and of the mean stress (or dynamic pressure), and we record also the temperature for several marker points in the upper and lower crust. We analyse the evolution of stresses and temperature with burial depth and time. Deviatoric stresses (half the differential stress) in the upper crust are up to 200 MPa and associated shear heating in shear zones ranges between 40 – 80 °C. Lower crustal rocks remain either at the base of the orogenic wedge at depths of around 50 km or are subducted to depths of up to 120 km, depending on their position when the first shear zone formed. Largest deviatotric stresses in the strong part of the lower crust are about 1000 MPa and maximal shear heating in shear zones is approximately 200 °C. Marker points can migrate through the main shear zone in the lower crust which remains active throughout lithospheric shortening. Some pressure-temperature paths show an anti-clockwise evolution. The impact of various model parameters on the results is discussed as well as applications of the results to geological data.