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Subduction channel vs. orogenic wedge model: numerical simulations, impact of serpentinites and application to the Alps

Lorenzo G. Candioti[1], Stefan M. Schmalholz[2], and Thibault Duretz[3]
[1]Université de Lausanne, Institut des sciences de la Terre, Lausanne, Switzerland (lorenzo.candioti@unil.ch)
[2]Université de Lausanne, Institut des sciences de la Terre, Lausanne, Switzerland (stefan.schmalhoz@unil.ch)
[3]Univ. Rennes 1, UMR CNRS 6118, France (thibault.duretz@univ-rennes1.fr)

In this study, we use a state-of-the-art 2D numerical algorithm solving the standard thermo-mechanically coupled equations of continuum mechanics for slow flowing viscoelastoplastic material to model the evolution of rifting, thermal relaxation and convergence-to-collision of Alpine-type orogens in three stages. (1) A ca. 360 km wide basin that is floored by exhumed mantle and bounded by two conjugate magma-poor hyper-extended passive margins is generated during a 50 Myrs rifting period. An absolute extension velocity of 1 cm/yr is applied. (2) The passive margin system is thermally equilibrated during a subsequent cooling period of 60 Myrs without significant deformation in the lithosphere (no extension velocity). At this stage, we parameterise a serpentinization front on top of the exhumed mantle by replacing the dry peridotitic mantle by serpentinized mantle in one series of simulations. The thermally equilibrated system is used as a self-consistently generated initial configuration for the subsequent period of convergence lasting for 70 Myrs applying an absolute convergence velocity of 1.5 cm/yr. Values for the duration of deformation periods and for deformation velocities are chosen to allow for comparison between simulation results and petrological data from the Central and Western Alps. Density of all materials is either precomputed for characteristic bulk rock compositions and read in from precomputed thermodynamic look-up tables (Perple_X), or calculated during run time via a linearized equation of state (EOS).

We quantify (1) the impact of a serpentinization front of the exhumed mantle on the subduction dynamics by increasing systematically the strength of the serpentinites, (2) the peak pressure and temperature conditions of subducted crustal material from the passive margins of the overriding and subducting plate by tracking pressure (P)-temperature (T)-time (t)-depth (z) paths of selected particles and (3) the driving forces of the system. Last, (4) the impact of metamorphic phase transitions is investigated by parameterising densification of crustal material. We compare the results of simulations in which density is computed as a simple linearized EOS to results of simulations in which density is a more realistic function of P and T using precomputed thermodynamic look-up tables.

We discuss geometric similarities between the simulation results and 2D geodynamic reconstructions from field data, quantify the P-T-t-z-history of selected particles and compare it to P-T-t data obtained from natural rocks. First results indicate that the strength of the serpentinites controls whether the deformation within the orogenic core is driven by buoyancy forces (subduction channel model) or by far-field tectonic forces (orogenic wedge model). There is a transition from subduction channel to orogenic wedge model from low to intermediate strength of the serpentinites.