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Continental plate collision, P-T-t-z conditions and unstable vs. stable plate dynamics: Insights from thermo-mechanical modelling

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We analyze major mechanisms of shortening of continental lithosphere (subduction, pure shear collision, folding, Rayleigh-Taylor instabilities), and, by proxy, of HP-UHP exhumation. We use a thermo-dynamically coupled thermo-mechanical numerical model that accounts for brittle-elastic-ductile rheology, surface processes and metamorphic changes. The model traces P-T-t-z paths of metamorphic facies that are compared with petrology data. Continental subduction occurs in case of relatively strong lithospheres (T_Moho $<$ 550 °C) and high initial convergence rates ($>$ 1.5-5 cm/yr). Depending on the lower-crustal rheology (strong or weak), either the whole (upper and lower) crust or only the lower crust can be involved in subduction. In case of weak metamorphic rheologies, phase changes improve chances for stable subduction. In general, exhumation of UHP-HP rocks to the surface is favored if the crustal rheological profile is characterized by two internal ductile decolement levels (between the upper and lower or intermediate crust and the lower crust and mantle lithosphere). Pure shear collision is dominant when T_Moho $>$ 550°C or convergence rates are lower than 1.5-3 cm/yr. Large-scale folding is favored in case of T_Moho=500-650°C and is more effective in case of mechanical coupling between crust and mantle (e.g., strong diabase lower crust). Gravitational R-T instabilities overcome other mechanisms for very high values of T_Moho ($>$800 °C) and lead to the development of subvertical "cold spots." The subduction channel is characterized by nearly lithostatic pressure conditions. Large-scale zones of tectonic overpressure may be built outside the channel but do not affect the exhumed rocks. Overpressure is also built inside the channel in the short moment of its closure when subduction stalls. We suggest that most continental orogenic belts could have started their formation from continental subduction. This evokes a multi-level mechanism of exhumation of UHP rocks to the surface.