Transition from subduction to collision: insight from numerical modeling and observation

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Orogeny related to continent-continent collision is among the major geodynamic processes defining geological styles and histories of continental plates Initial stages of orogeny correspond to transition from subduction to collision and are often manifested by a variety of geodynamic processes (e.g. deep subduction of the continental crust, formation of subduction/tectonic channels, lithospheric delamination, detachment of subducted oceanic slab) that play a crucial role in the generation of geological structures of the resulting orogenic system. Indeed, these initial stages are still very poorly understood. We performed 2D model calculations of transition from oceanic subduction (Andean-type) to continental collision (Alpine-type) where a spontaneously bending plate subducts at a prescribed convergence rate. We have employed different strengths of the continental lower crust to investigate the mechanical behavior of a weak, medium or strong plate. The 2D viscoplastic code I2VIS was used which includes shear heating that can strongly influence thermal structure of orogens. Furthermore, new geochemical evidence of unusually high radiogenic elements contents in the Lesser and Higher Himalaya sequences implying high (4-7 W/m3) radiogenic heat production in the crust, motivated us to explore the role of such strong heat sources in collisional settings.

Slow convergence rates (low shear heating => strongly coupled plates) and/or weak lithosphere produce a narrow and thick, double-sided symmetrical collisional zone characterized by a mushroom shaped partial melted zone that extrudes laterally. Partial melt triggers exhumation of an inverted metamorphic sequence where polyphase (15-23 kbar, > 700 °C) metamorphic rocks are thrusted over LP-LT units.

High convergence rates (high shear heating => decoupled plates) and a strong lithosphere produce a broad and thick, one-sided asymmetrical subduction zone where a vertical lithospheric body separates two upper crustal wedges with different deformation patterns. The pro-wedge is dominated by simple shear deformation and lateral extrusion of an inverted metamorphic sequence, whilst the retro-wedge is characterized by pure shear thickening.
Crustal radiogenic heat production is a crucial parameter that affects timing of slab breakoff, subduction polarity reversal and dynamics of partial melting and lateral extrusion of the inverted metamorphic sequences.

Late evolution of the models show interesting geodynamical features like slab breakoff, subduction polarity reversal and late-collisional hot channels. Crustal subduction to the deep mantle is a phenomenon occurring in all the models, with profound physical and chemical implications. Physically, the results suggest that this process is important for the crustal volume balance in collisional settings. Chemically, occurrence of such widespread of recycling of continental crust to mantle can substantially revise our views of such diverse processes as models of crustal growth, nature of reservoirs involved in ocean island basalt volcanism and the origin of high □-Os signatures in many crustal melts. We found stimulating similarities of our models with the Himalayan chain, the European Variscan chain and pre-collisional active margins (Andean-type) like the Cascadia and Central Andes subduction zones.