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Evolution of continental collision styles since the Precambrian

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The relevance of modern tectonics to ancient orogens is a matter of international debate. Ultrahigh-pressure (UHP) methamorphic rocks of continental origin provide evidence for subduction of the continental lithosphere to mantle depths over 100 km. While UHP eclogitic rocks and high-pressure (HP) blueschists mainly occure in Phanerozoic oregenic belts, they rarely found in Precambrian terranes. To investigate a possible change of collisional style back in time which could lead to disappearing of UHP complexes from the geological surface records we performed 2D petrological-thermomechanical numerical model (I2VIS code (Gerya and Yuen, 2003)) of oceanic-continental subduction followed by continent-continent collision.

The reference model was chosen in such a way that it can produce UHP complexes during transition from oceanic-continental subduction to continent-continental collision and deliver them to the surface. Based on this model we performed series of experiments varying upper-mantle temperature (up to 250 degrees higher then present), lithosphere thickness for continental plates (100,140 and 180 km) and density of subcontinental lithospheric mantle (difference with underlying mantle 20 kg/m3 corresponds to present day; 50 kg/m3 corresponds to Proterosoic). The reference model shows continental plate subducting up to 250 km depth whereupon slab break-off occurs and continental plate starts to relax. During the relaxation stage continental crust starts to melt and partially detach from the slab. There are two ways of moving this material from high depths upwards: 1) going upwards vertically as a buoyant plume and crossing both the mantle wedge and the overriding mantle lithosphere (thanks to weakening of the lithospheric rocks by melt propagation); 2) going back along the plate as a buoyant wave and penetrating into subduction channel. Both ways can lead to HP-UHP rocks formation in the end. Increasing the upper-mantle temperature we determined sharp transition from modern style of collision with formation of HP-UHP rocks to a different tectonic regime at upper mantle temperature rising by around 100 – 200 degrees (depending on the lithosphere thickness) above the present value. From this point continental plate subducts and induces the rising of melt-bearing hot mantle in the mantle wedge. The area of the melt-bearing mantle is not big (up to 150 km width) and after some time at the compressional conditions it starts to contract and melt starts to crystallize back. Further increase in the mantle temperature (by around 200-250 degrees above present) causes transition to another regime with the vast amount of melt-bearing mantle areas which give rise to plates sinking into the mantle without any contact with the surface anymore.

Based on our experiments there is no big influence on the collision style of density contrast between subcontinental lithospheric and underlying mantles, on the other hand collisional evolution strongly depends on the upper-mantle temperature and lithosphere thickness. The fact that slab breakoff and relaxation of the continental plate leads to melting and detachment of the continental crust from the continental plate is interesting, and may be the mechanism by which the UHP history is erased from gneiss complexes whereas UHP history tends to be preserved in mafic and ultramafic boudins within these complexes (and sometimes within zircons within the gneisses). The transition from the modern style of collision to the determined regime with melt-bearing mantle in the mantle wedge may correspond to disappearing of UHP after 600 Ma in the continental geological record.