The evolution of stress fields in the course of supercontinent cycle: numerical modeling

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The evolution of the ‘convecting mantle – floating deformable continents’ system is studied by numerical experiments, taking into account the non-Newtonian rheology and phase transitions in the Earth’s mantle. Using the model with continental crust, continental lithosphere and the material of the oceanic crust that can be subjected to eclogitization we study the stages of supercontinent cycle and the evolution of stress fields in the mantle and continents during the cycle. The model demonstrates the main features of global geodynamics: convergence and compression of continents with their subsequent stretching, breakup and divergence; opening and closing of oceans; restructuring of mantle flows; appearance and disappearance of subduction zones; oceanic crust recirculation in the mantle. Our results show that the phase transition at the depth of 660 km, as well as the viscosity jump at the same depth affect the supercontinental cycle and the emerging stress fields significantly. The typical maximum shear stresses in the mantle are less than 30 MPa; in the subduction zones and on the continent borders they are 100-250 MPa. Before the breakup, the maximum shear stress generated in the supercontinent can reach 200 MPa. We find that the detachment of the oceanic slabs (due to the phenomenon of the drop in the effective viscosity at high stresses) and their subsequent relatively rapid plunging into the mantle is a trigger for a sharp intensification of regional flows in the mantle. These flows induced by the slab immersion span vast regions of the Earth’s mantle, and may cause the continents to assemble over this area; simultaneously, the viscous stress values increase significantly. This mechanism of intensification of mantle flows can be an alternative to the avalanche mechanism where the trigger is the accumulation of large amounts of cold material above the upper/lower mantle boundary at 660 km.