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Impact of Water Circulation and Protolith on the Symmetry of Detachment Faults

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Metamorphic phase changes have a strong impact on the physical and mechanical properties of rocks including buoyancy (body forces) and rheology (interface forces). As such, they exert important dynamic control on tectonic processes. It is generally assumed that phase changes are mainly controlled by pressure (P) and temperature (T) conditions. Yet, in reality, whatever the PT conditions are, phase changes cannot take place without an adequate amount of the main reactants. Petrologic studies point out that water, as a limiting reactant, is responsible for the lack of retrograde metamorphic reactions observed in exhumed tectonic units outside of shear zones. Present day geodynamic models neglects the limiting influence of water content. As a result, no high-grade metamorphic rocks actually make there way to the surface of the models, since they are all retro-morphed to low-grade state during their exhumation.

In order to study the impact of fluid content on the structure of metamorphic core complexes, we have coupled a geodynamic thermo-mechanical code Flamar with a fluid-transport and water-limited thermodynamic phase transition algorithm. We have introduced a new parameterisation of Darcy flow that is able to capture source/sink and transport aspects of fluid transport at the scale of the whole crust with a minimum of complexity. Within this model, phase transitions are controlled by pressure temperature and the local amount of free fluid that comes from both external (meteoric) and local (dehydration) sources. The new implementation is tested with an application metamorphic core complexes.

The numerical experiments suggest a strong positive feedback between the asymmetry of the tectonic structures and the depth of penetration of meteoric fluids. In particular, bending-stress distribution in asymmetric detachment zones drives the penetration of meteoric fluids to greater depths. The model results show that while the development of an asymmetric weak midcrustal shear zone is triggered by metamorphic reactions limited by water content a strong dependence on the inherited chemical composition exist and symmetric or asymmetric exhumation pattern can naturally emerge from the chemical composition.