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Lithospheric Architecture, Heterogenities, Instabilities, Melting – insight form numerical modelling

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The seismological structure of the Earth's lithosphere is identified to be strongly heterogeneous in terms of thermal and rheological structures. Lithospheric discontinuities (sharp changes in the thermal and/or compositional structure) are thought to be long lived and are mostly correlated with major tectonic boundaries that commonly have been reactivated and which subsequently are the foci of magma intrusion and major mineralization. Resent studies have shown that mantle metasomatism is also controlled by such boundaries.

This paper explores the control that lithospheric heterogeneity exerts on the thermal and chemical evolution during deformation subsequent to the development of the heterogeneity. We explore the behaviour of the rheological heterogeneous lithosphere in a compressional regime. The occurrence of such variations may be caused for instance by amalgamation of micro-continents such as is thought to be characteristic of the Yilgarn, Western Australia or South Africa. Theses micro-continents, due to diverse histories may be characterised by various thermal and rheological structures.

The models are simplistic but illustrate the basic principles. The code used in this study is based on a conservative finite-difference, multi-grid, marker in cell method. Devolatilisation reactions and melting can affect the physical properties of rocks and are incorporated in a self-consistent manner. We use a petrological-thermomechanical modelling approach with all rock properties including mechanical properties calculated in the Lagrangian scheme for rock markers at every time step based on Gibbs free energy minimization as a function of the local pressure, temperature and rock composition.

The results illustrate that initial structural complexity is necessary for and has a dramatic effect on fault and development, the growth of deep basins, core complex formation, melting and devolatilisation within the lithosphere. The horizontal and vertical variation in plastic yield stress of the blocks (representing heterogeneous fused material) nucleates localised deformation and creates conditions for delamination via a Rayleigh-Taylor instability. Above the site of localised delamination of the mantle lithosphere, a series of deep crustal faults develop that may extend into the upper mantle. These deep structures can act as the pathways for mantle derived $CO2 \pm H2O$ fluids and alkaline igneous complexes. Isotherms are commonly elevated throughout the lithosphere in the hanging wall of deep through-going structures and are depressed in the footwalls. This means that some architectures favour devolatilisation and melting in the hanging wall. A large spectrum of behaviour is observed and results from minor changes in the orientation and strength of the blocks.