

Thermo-Mechanical Models for Basin (De)formation

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Polyphase extensional and compressional reactivation of basins is a common feature in basin evolution. To differentiate between the different modes of basin formation and reactivation of passive margins and extensional basins, the development of innovative combinations of numerical and analogue modeling techniques is key. In this paper we present an overview of our advancement developing and applying analogue and numerical thermo-mechanical models to quantitatively assess the interplay of lithosphere dynamics and basin (de)formation.

Field studies of kinematic indicators and numerical modeling of present-day and paleo-stress fields in selected areas have yielded new constraints on the causes and the expression of intraplate stress fields in the lithosphere, driving basin (de)formation. Temporal and spatial variation in the level and magnitude of intraplate stress have a strong impact on the record of vertical motions in sedimentary basins. Over the last few years increasing attention has been directed to this topic advancing our understanding of the relationship between changes in plate motions, plate-interaction and the evolution of rifted basins.

The actual basin response to intraplate stress is strongly affected by the rheological structure of the underlying lithosphere, the basin geometry, fault dynamics and interplay with surface processes.

Integrated basin studies show that rheological layering and strength of the lithosphere plays an important role in the spatial and temporal distribution of stress-induced vertical motions, varying from subtle faulting to basin reactivation and large wavelength patterns of lithospheric folding, demonstrating that sedimentary basins are sensitive recorders to the intraplate stress field. The long lasting memory of the lithosphere, in terms of lithospheric scale weak zones, appears to play a far more important role in basin formation and reactivation than hitherto assumed. A better understanding of the 3-D linkage between basin formation and basin reactivation is, therefore, an essential step in research that aims at linking lithospheric forcing and upper mantle dynamics to crustal vertical motions, and their effect on sedimentary systems and heat flow. Vertical motions in basins can become strongly enhanced, through coupled processes of surface erosion/sedimentation and lower crustal flow. Furthermore patterns of active thermal attenuation by mantle plumes can cause a significant spatial and modal redistribution of intraplate deformation, as a result of changing patterns in lithospheric strength and rheological layering.

Novel insights from numerical and analogue modeling aid in quantitative assessment of basin history and shed new light on tectonic interpretation, providing helpful constraints for basin exploration, including understanding and predicting vertical motions (eroded sedimentation record), source fill relationships, and heat flow.