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Lithosphere Tectonics and Enhanced Geothermal Systems Exploration in Europe

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Knowledge of temperature at drillable depth is a prerequisite in site selection for geothermal exploration and development of enhanced geothermal systems (EGS). Equally important, the thermo-mechanical signature of the lithosphere and crust provides critical constraints for the crustal stress field and basement temperatures where borehole observations are rare. The stress and temperature field in Europe is subject to strong spatial variations often linked to polyphase extensional and compressional reactivation of the lithosphere, in different modes of deformation. The development of innovative combinations of numerical and analogue modelling techniques is key to thoroughly understand the spatial and temporal variations in crustal stress and temperature.
We present an overview of advances in 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 modelling of present-day and paleo-stress fields in selected areas yield new constraints on the causes and the expression of intraplate stress fields in the lithosphere, driving basin (de)formation. 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 the rheological structure 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. These findings demonstrate that sedimentary basins are sensitive recorders of the intraplate stress field. The long lasting memory of the lithosphere, in terms of lithospheric scale weak zones, plays 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 connecting lithospheric forcing and upper mantle dynamics to crustal vertical motions and stress, 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 and stress, as a result of changing patterns in lithospheric strength and rheological layering. The models provide useful constraints for geothermal exploration and production, including understanding and predicting crustal stress and basin and basement heat flow.