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Linking continental drift, plate tectonics and the thermal state of the Earth's mantle

T. Rolf (1), N. Coltice (2,3), and P. J. Tackley (1)

(1) ETH Zürich, Switzerland (tobias.rolf@erdw.ethz.ch), (2) Université Claude Bernarrd Lyon 1, ENS Lyon, CNRS, (3) Institut Universitaire de France

Continents slowly drift at the top of the mantle, undergoing episodic events like collision, aggregation or splitting. Continental drift and oceanic plate tectonics are surface expressions of mantle convection and closely linked to the thermal state of the mantle. In the present study we will present a number of 3D spherical numerical simulations of mantle convection with self-consistently generated plates and compositionally and rheologically-distinct continents floating at the top of the mantle. We will focus on the question of how continental drift, oceanic plate tectonics and the thermal state of the Earth's mantle are linked, by using different continent configurations ranging from one supercontinent to six small continents.

With a supercontinent present we find a strong time-dependence of the oceanic surface heat flow and suboceanic mantle temperature, driven by the generation of new plate boundaries. Very large oceanic plates correlate with periods of hot suboceanic mantle, while the mantle below smaller oceanic plates tends to be colder. Temperature fluctuations of subcontinental mantle are significantly smaller than in oceanic regions and caused by a time-variable efficiency of thermal insulation of the continental convection cell.

With multiple continents present the temperature below individual continents is generally lower than below a supercontinent and is more time-dependent, with fluctuations as large as 15% that may be caused by continental assembly and dispersal. The periods of hot subcontinental mantle correlate with strong clustering of the continents and periods of cold subcontinental mantle, at which it can even be colder than suboceanic mantle, with a more dispersed continent configuration. Our findings with multiple continents imply that periods of partial melting and strong magmatic activity inside the continents, which may contribute to continental rifting and pronounced growth of continental crust, might be episodic processes related to the supercontinent cycle [Rolf et al., submitted].

In a further step we will investigate the effects of the mantle Rayleigh number, heating mode (internal versus basal heating), yield strength of the lithosphere and a depth-dependent viscosity structure of the mantle.

Reference:

Rolf, T., Coltice, N. and Tackley, P.J., Linking continental drift, plate tectonics and the thermal state of the Earth's mantle, submitted to Earth Planet Science Letters