The effect of continents on the initiation and configuration of plate tectonics.

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At their surface, numerical models of convection for the mantle of the Earth can exhibit tectonic plates obtained in a self-consistent way when a specific rheology is used (e.g. Moresi and Solomatov 1998, Tackley 2000). This rheology consists in a strongly temperature-dependent viscosity combined with a plastic behavior at points in the model where a certain yield stress is reached. The temperature-dependent viscosity stiffens the cold upper part of the model in a viscous rigid lid, while the use of a plastic behavior above an imposed yield stress allows this viscous rigid lid to break into plates, whose geometry is then not imposed a priori but free to develop in response to the forces imposed by the convecting mantle.

The purpose of the present study is to constrain the parameters of mantle rheology that allow plate tectonics to develop and lead to a satisfying configuration of tectonic plates. Plate tectonics obtained in numerical models is often unstable and only episodic, with periods when the imposed yield stress is not attained anywhere in the model, resulting in a global cold rigid lid. A yield stress significantly lower than the one predicted by laboratory experiments on rocks (around 500 MPa, e.g. Kohlstedt et al. 1995) often has to be used.

Continents are introduced in our models as rigid blocks, with specific thermal boundary conditions at their base, floating at the surface of the mantle and moving freely in response to the shear stress imposed by it. We carry out experiments in cartesian geometry, either two- or three-dimensional, and we show that models including continents exhibit more stable plate tectonics than models without continents: once started, the plate-like regime with continents does not switch back to a rigid lid regime. The initiation of plate tectonics seems enhanced by the presence of continents as well: models starting with a conductive profile of temperature develop plate tectonics at least five times faster with continents than without. Furthermore, it is not required to use a low yield stress in experiments with continents.

The pattern of convection obtained in two-dimensional experiments without continents is not Earth-like, with convergence zones being subvertical. With continents, subduction zones are one-sided as in the Earth, and trench roll-back is commonly observed. In three-dimensional models with continents, large curved subduction zones are obtained. We carry out a systemical study of the parameters, for the rheology of the mantle and for the insulating effect and geometry of the continents, that allow stable and Earth-like plate tectonics to develop.

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