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The Effect of Plate Dynamics on the Convective Mixing of Chemical Heterogeneities in the Earth's Mantle

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An improved understanding of the destruction of chemical heterogeneities by mixing processes is required, in order to obtain a better link between geochemical and geophysical models of the Earth's mantle. Numerical model studies of convection in two dimensions (2D) generally indicate that convective homogenization is efficient on all length scales and that the mantle should be well mixed within a relatively short time scale (Hoffmann and M^{c}Kenzie, 1985). Investigations of simple convective flows in a three dimensional (3D) geometry do not confirm the 2D results. In contrast, they indicate that mixing within a single convective cell is effective, whereas mixing across cell boundaries is poor (Schmalzl et al., 1996). Potentially, this could explain the existence of different chemical reservoirs, without calling for vertical layering of the mantle. In a recent paper, Ferrachard and Ricard (1998) pointed out that simple 3D models with stationary flow patterns do not account for a toroidal component in the velocity field, and such a component is introduced by the movement of lithospheric plates. This indicates that plate tectonics may enhance mixing and lead to faster convective homogenization of the mantle.

Advances in numerical techniques and available computer resources have only very recently permitted the simulation of the generation and subduction of lithospheric plates in a self-consisting manner (Trompert and Hansen, 1998). We have used such a model, which implicitly includes a toroidal velocity component due to the movement of the plates, to investigate the effect of plate dynamics on the mixing properties of the mantle. This is the first study to investigate the stirring efficiency of convection in the presence of self-consistent plate movements. Several aspects of the numerical model, however, are still simple and many important features such as phase boundaries, internal heating, chemical effects on the buoyancy of subducted heterogeneities are presently not considered. Nonetheless some important, first-order conclusions can be derived from the numerical experiments.

The mixing efficiency of the mantle is increased by the incorporation of plate dynamics into 3D convective simulations. In the absence of plate movements, chemical heterogeneities are efficiently isolated within convection cells that are internally well mixed. The movement of the plates, however, is observed to enhance mixing across cell boundaries. The coupling of large-scale mixing with plate dynamics is furthermore associated with a strong preferential orientation of chemical homogenization, because mixing is enhanced in the direction of plate motion, whereas homogenization is poor orthogonal to the plate movement. Our numerical experiments indicate that passive chemical heterogeneities can persist in the mantle for several complete plate tectonic cycles, equivalent to a timescale of approximately 1 - 2 Gyr, if the orientation of the plate movements has a preferred direction. We note that such a scenario may be relevant for the Earth, because at present the majority of the divergent and convergent margins display a N-S orientation. Some plate tectonic reconstructions furthermore indicate that plate dynamics may have been characterized by the same prevalent orientation for the last 650 Myr (Scotese, 1997). This indicates that at least some ancient (1 - 2 Gyr old) large scale geochemical anomalies of the Earth's mantle can be explained by the incomplete mixing of passive heterogeneities. This conclusion contrasts with the results of other recent 3D convective simulations (Ferrachat and Ricard, 1998; van Keken and Zhong, 1999), which predict complete homogenization of the mantle on significantly shorter timescales.

Ferrachat S & Ricard Y, *Earth Planet. Sci. Lett.*, **155**, 75-86, (1998).
Hoffmann NRA & M^{c}Kenzie DP, *Geophys. J. R. Astr. Soc.*, **82**, 163-206, (1985).
Schmalzl J, Houseman GA & Hansen U, *J. Geophys. Res.*, **101**, 21847-21858, (1996).
Scotese CR, *Paleogeographic Atlas, PALEOMAP Progress Report 90-0497*, (1997).
Trompert R & Hansen U, *Nature*, **395**, 686-689, (1998).
van Keken P & Zhong S, *Earth Planet. Sci. Lett*, **171**, 533-547, (1999).