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The Evolution of Chemical Mantle Reservoirs - 3D Numerical Results

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The focus of this paper is numerical modeling of crust-mantle differentiation. We begin by surveying the observational constraints of this process. The present-time distribution of incompatible elements are described and discussed. The mentioned differentiation causes formation and growth of continents and, as a complement, the generation and increase of the depleted MORB mantle (DMM). Here, we present a solution of this problem by an integrated theory that also includes the thermal solid-state convection in a 3-D compressible spherical-shell mantle heated from within and slightly from below. The conservation of mass, momentum, energy, angular momentum, and of four sums of the number of atoms of the pairs $^{238}U-^{206}Pb$, $^{235}U-^{207}Pb$, $^{232}Th-^{208}Pb$, and $^{40}K-^{40}Ar$ is guaranteed by the used equations. The pressure- and temperature-dependent viscosity is supplemented by a viscoplastic yield stress, σ_y . No restrictions are supposed regarding number, size, form and distribution of continents. Only oceanic plateaus touching a continent have to be united with this continent. This mimics the accretion of terranes. The numerical results are an episodic growth of the total mass of the continents and acceptable courses of the curves of the laterally averaged surface heat flow, qob, the Urey number, Ur, and the Rayleigh number, Ra.
Although the convective flow patterns and the chemical differentiation of oceanic plateaus are coupled, the evolution of time-dependent Rayleigh number, Ra_t , is relatively well predictable and the stochastic parts of the $Ra_t(t)$-curves are small.
Regarding the juvenile growth rates of the total mass of the continents, predictions are possible only in the first epoch of the evolution. Later on, the distribution of the continental-growth episodes is increasingly stochastic. Independently of the varying individual runs, our model shows that the total mass of the present-day continents is not generated in a single process at the beginning of the thermal evolution of the Earth but in episodically distributed processes in the course of geological time.

The reported results are derived using a first viscosity profile of the mantle based on solid-state physics and on the seismic model PREM. As the latest result, we present a second viscosity profile based on more recent geophysical results and some simple solid-state physical assumptions. Furthermore, we computed, respectively selected new profiles for the melting temperature, the specific heat at constant volume, the Grüneisen parameter, and the thermal expansivity. The improved Terra [1] works with these new parameters. In future we will systematically investigate the Rayleigh-number – yield-stress parameter space with these new functions and parameters.

References

[1] http://www.igw.uni-jena.de/geodyn/terra2011.html