Geophysical Research Abstracts
Vol. 15, EGU2013-10671, 2013
EGU General Assembly 2013

Novel particle method for modelling melt generated chemical heterogeneity in whole mantle convection.

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Many outstanding problems in Earth science relate to the geodynamical explanation of geochemical observations. Nowadays, extensive geochemical databases of surface observations exist, but satisfying explanations of underlying processes are lacking. One way to address these problems is through numerical modelling of mantle convection while tracking chemical information throughout the convective mantle.

We implemented a new way to track both bulk composition and concentration of trace elements in the well developed mantle convection code TERRA (finite element). Our approach is to track bulk composition and trace element abundance via particles. One value on each particle represents bulk composition, it can be interpreted as the basalt component. In our model, chemical separation on bulk composition and trace elements happens at self-consistent, evolving melting zones. Melting is defined via a composition dependent solidus, such that the amount of melt generated depends on pressure, temperature and bulk composition of each particle. A novel aspect is that we do not move particles that undergo melting; instead we transfer the chemical information carried by the particle to other particles. Molten material is instantaneously transported to the surface, thereby increasing the basalt component carried by the particles close to the surface, and decreasing the basalt component in the residue. For molten material that arrives at the surface, a fraction of its content of its trace elements is moved into a separate continent/atmosphere reservoir. For some trace elements, there is a delayed feedback to the top of the mantle, mimicking erosion.

Results will be presented in which we test the success and limitations of our implementation. To this end we choose to use a highly simplified setup with calculations of isoviscous, incom- pressible, low-Rayleigh number mantle convection in spherical geometry. In these we will avoid complexities such as phase changes, elastic/plastic deformation, and all coupling of variations in material properties to the Navier-Stokes equations. The trace elements we choose to follow are the Pb-isotopes and their radioactive parents. For these calculations we will show: 1: The evolution of bulk composition over time, showing the build up of oceanic crust (via melting induced chemical separation in bulk composition); i.e. a basalt-rich layer at the surface overlying a thin layer of depleted material (Harzburgite), and the transportation of these chemical heterogeneities through the deep mantle. 2: The amount of melt generated over time. 3: The evolution of the concentrations and abundances of different isotopes of the trace elements, throughout the mantle as well as the atmosphere and continent reservoir. 4: A comparison to analytical mixing speeds. 5: Numerical details on the splitting and merging of particles which is needed to ensure proper coverage and maintain numerical resolution at all times.