Geophysical Research Abstracts
Vol. 15, EGU2013-13505, 2013
EGU General Assembly 2013

Partial melting and the efficiency of mantle outgasing in one-plate planets

Ana-Catalina Plesa (1,2) and Doris Breuer (1)

(1) German Aerospace Center (DLR), Institute of Planetary Research, Berlin, Germany (ana.plesa@dlr.de), (2) University of Muenster (WWU Muenster), Institute of Planetology, Muenster, Germany

The generation of partial melting can have a major impact on the thermo-chemical evolution of a terrestrial body by the depletion of the mantle material in incompatible elements such as radioactive elements and volatiles, crust formation and volcanic outgassing. During some period in the thermal history of a terrestrial planet, the temperature in regions of the upper mantle, either below tectonic plates or a stagnant lid, rises above the solidus - the temperature at which the mineral with the lowest melting temperature among those that form the silicate mantle mixture starts to melt. The melt than rises toward the surface, forms the crust, and releases volatiles into the atmosphere. In case of one-plate (stagnant lid) planets the thickness of the present-day crust can 'tell' us already about the efficiency of mantle melting and mantle degassing – the thicker the crust the more mantle material experienced melting and thus the more efficient can be the outgassing. However, it has been shown with parameterized convection models [1] but also 2-3D convection models [2] that crustal delamination is a common process in one-plate planets. Crustal delamination allows that possibly much more crust is produced during the entire evolution (and thus more mantle material experienced differentiation) than what is observed today, implying also more efficient outgassing than expected. Crustal delamination is therefore a process that may help to generate a substantial planetary atmosphere.

In the present work we investigate the influence of partial melt on mantle dynamics and the volcanic outgassing of one-plate planets using the mantle convection code GAIA [3] in a 2D cylindrical geometry. We consider the depletion of the mantle, redistribution of radioactive heat sources between mantle and crust, as well as mantle dehydration and volcanic outgassing [4]. When melt is extracted to form the crust, the mantle material left behind is more buoyant than its parent material and depleted in radioactive heat sources. The extracted heat producing elements are then enriched in the crust, which also has an insulating effect due to its lower thermal conductivity compared to mantle values. In addition, partial melting can influence the mantle rheology through the dehydration (water depletion) of the mantle material by volcanic outgassing. As a consequence, the viscosity of water depleted regions increases more than two orders of magnitude compared to water saturated rocks [5] and results in slower cooling rates. All these effects together tend to suppress the efficiency of partial melting, crustal delamination and mantle degassing.

References

[1] A. Morschauser, M. Grott and D. Breuer; Icarus (2011)

[2] T. Keller and P.J. Tackley; Icarus (2009)

[3] C. Huettig and K. Stemmer; PEPI (2008)

[4] A.A. Fraeman and J. Korenaga; Icarus (2010)

[5] G. Hirth and D.L. Kohlstedt; EPSL (1996).