Geophysical Research Abstracts
Vol. 15, EGU2013-13487, 2013
EGU General Assembly 2013

Early magma ocean and core formation on Vesta

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The Dawn mission confirms predictions that the asteroid 4 Vesta is differentiated in an iron rich core, a silicate mantle and a basaltic crust, supports its identification as the parent body of the HEDs and provides revised values of e.g. the mass, the bulk density and the dimensions of the asteroid 4 Vesta. Although no distinct volcanic regions have been identified, resurfacing by igneous processes distinguishes Vesta from asteroids like Ceres with its primitive surface, or Lutetia, which retained its primordial surface composition (and may still be partially differentiated[1]). Vesta's core radius is estimated to be 107-113 km[2] (derived from the mass concentration towards the centre). We performed numerical calculations of the thermo-chemical evolution of Vesta adopting the new data obtained by the Dawn mission (mass, bulk density, radius). We have expanded the thermo-chemical evolution model of [3], which includes accretion, compaction, melting, associated changes of the material properties, advective heat transport and differentiation by porous flow, by considering convection and thus effective cooling in a magma ocean to analyse its formation and evolution on Vesta. For melt fractions below the rheologically critical melt fraction (RCMF) of $\approx$50% the heat transport by melt segregation is modeled assuming melt flow in porous media and by supplementing the energy balance equation with additional advection terms. Above the RCMF the effective thermal conductivity k_{eff} is computed from the convective heat flux in the soft turbulence regime[4]. The parameter k_{eff} mimics the vigorous convection and heat flux of the magma ocean with a low viscosity. It amounts to $O(10^6)$ W m^{-1}K^{-1} and substitutes the thermal conductivity in the energy balance equation. We consider both instantaneous and continuous accretion (assuming late runaway material accumulation). In particular, we compare the evolution scenarios arising from the instantaneous accretion of Vesta at different formation times t_0 (relative to the formation of the CAIs) with those for which the accretion durations t_a is between 0.5 and 2.0 Ma. According to our results core formation is possible for formation times of up to 2.5 Ma after the CAIs. An important process for the formation and evolution of a magma ocean is the partitioning of ^{26}Al and its relocation with the silicate melt. Previous models[5] suggest the formation of an internal magma ocean throughout the whole mantle beneath a solid crust. Thereby, the partitioning of ^{26}Al is neglected. In contrast to that, if partitioning of ^{26}Al into the melt is considered we obtain an about 1 km thick superficial magma ocean due to the enrichment of the radioactive nuclides in the liquid phase and redistribution towards the surface with the rising melt (for t_0 <1.5 Ma). Above this region a basaltic crust forms. Due to the extrusion of ^{26}Al at the surface and the radioactive decay this thin magma ocean vanishes after $O(10^4) - O(10^5)$ a. Simultaneously the interior differentiates into a core which is heated by ^{60}Fe and a mantle which is depleted in the heat sources. The mantle remains partially molten below the RCMF and no internal magma ocean forms.

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