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Formation of D” reservoir during late stages of Earth`s accretion: Multi-isotope-systematic geochemical modelling

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According to recent accretion models the moon-forming giant impact on the proto-Earth with a Mars-size planet (~ 4540 Ma ago) did not terminate accretion, which continued at a slower rate (until ~3900 Ma). During this interval small bodies, fragments, particles, dust, including much chondrite-like material, were irradiated by intense solar wind and fell on an early-formed, incompatible-element-enriched basaltic crust without causing extensive melting. The bulk density of this crust thus exceeded that of the bulk silicate mantle, which had already lost its metallic iron to the core, and when subducted, the material was stabilized between the metal core and silicate mantle by this density contrast, forming D”.

We investigate this scenario by geochemical transport models similar to [1,2]. Earth accretion is modelled as a mass flux from a homogeneous reservoir with a composition similar to that of the bulk Earth, with the following accompanying processes: mantle melting and fractionation, core segregation, formation and recycling of basaltic crust, mantle degassing, and gas loss from the atmosphere. D” is formed during late accretion as outlined above. The model then portrays entrainment of D” material by mantle convective flow, mantle fractionation, growth and recycling of the oceanic and continental crust, degassing of mantle and crustal reservoirs, and evolution of the atmosphere.

Comparison of calculated parameters, e.g., masses of the principal terrestrial reservoirs, their chemical and isotopic compositions, and those actually observed allows solution of the model. A high amount of heat-producing elements in D”, ~20 % of the BSE inventory, is one of the most important results of modeling. D” is the major ^{40}Ar*-, ^{129}Xe*- and ^{3}He-bearing reservoir in the Earth. Rare gas modeling gives a lower flux from D” into the overlying mantle, ~20 % of the D” mass per 4.5 Ga with a present-day value of $\leq 0.05 \times 10^{16}$ g yr^{-1}, by a factor of ~100 lower than the rate of ridge magmatism. These and other results of the modeling, discussed in this presentation, characterize D” as a geochemicaly important reservoir.

References

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The early Earth evolution

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Recent geophysical observations, experiments and modelling point more and more to the idea that the Earth’s mantle has evolved for a very long time and probably from the beginning as a two level convection system, which is also the main conclusion of isotope and trace element studies conducted for about thirty years on the depletion and outgassing of the mantle. It is less and less evident geochemically that the mantle below 1100 kilometer depth contributes important fluxes to the transport of mantle products to the surface.

The long term stability of this two level convection system calls for a significant difference in composition of the two mantles. The EH global composition, pointed out by several isotope indicators, satisfies this criterion. It corresponds to greater Si and Fe and lower U and Th concentrations in the lower mantle [1]. Schematically this lower mantle is very close to pure Fe-Mg perovskite

Hence the density contrast between both mantles has a strong chemical component which stabilizes the two-level convection mantle inherited from the earth’s formation time, the great impact and core formation..

When tested by global convection models that composition give much better results than any other concerning problems such as the anticorrelation features of seismic velocities, temperature contrasts and the long term thermal evolution [2].

In such a model the 650 kilometers discontinuity is only a phase transition limit, whose presence strongly impedes the convection in the upper mantle and helps develop transition zone characteristics in the region between 650 and 1000-1100 km depth.

The EH composition implies key transformations during the Earth accretion, of which the most important is the coupled silica reduction and iron oxidation, which gives rise to silicon dissolution into the core and iron oxide transport and partition through the mantle and down to the core.

That Redox evolution has also strong implications on the possibility of water outgassing and on the building of the present terrestrial water masses.

References

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