Mechanism of core formation in the light of geochemical constraints and of the great impactor hypothesis

M. Javoy

Laboratoire de Geochimie des Isotopes Stables, Institut de Physique du Globe, 2 Place Jussieu, 75251 Paris Cedex 05, France

Geochemical considerations on the formation of the core are generally concentrated on the nature and concentrations of the light elements needed to lower the density of an Fe-Ni alloy by the right amount of 10-11% in order to fit the core density. Geochronological additional constraints are eventually discussed.

Very little is said about the *mechanism* of core differenciation, except generally to insist on its 'low pressure' character meaning that the very reducing conditions necessary for the core composition could not fit with the oxidized state of mantle iron, so that liquid metal had to move down as large bodies preformed at low pressure in order to prevent subsequent oxidation.

That type of model has also to imagine a rather sharp change in the redox conditions in the middle of the Earth's formation for the oxidized mantle to occur, nothing being said about the reasons for such a change. Finally no attention is paid to the energetical implications of the presently most popular model for the *moon* formation namely the great impactor, whose first effect is to reduce to shambles the preexisting proto Earth and bring, in a matter of seconds, about 30% of the Earth's total gravitational energy.

No attention is paid either to important isotope characteristics of the Earth Moon system.

It is interesting to imagine less ad hoc conditions in a model which would i)take into account the isotopic constraints, ii) consider the energetical aspect of the great impact and iii) not impose an ad hoc change in redox conditions.

In addition to these constraints, the isotopic indications point out to a precise class of meteorite components, thus providing a priori the global chemical composition of the planet, which is evidently a valuable asset when dealing with the chemical modelling of a differentiated planet.

In the frame of the integral enstatite chondrite model of the Earth [Javoy, 1995], the core chemical composition is obtained from that a priori global composition, the derivation of the Upper Mantle composition from the knowledge of its refractory elements' (Ca, Al, Mg) ratios, the upper mantle Si/Al *vs* Mg/Al relationship and its Mg number, and the core composition density relationships. The resulting core composition is compared in Table 1 to other recent estimates.

So the difference lies not so much with the core composition, which is strongly constrained by the density considerations primarily, than with the bulk and mantle composition, and with the mechanism of core differenciation.

In fact the resulting Upper Mantle is concentrated in refractory elements by a factor 2 relative to the starting material and offers a sharp contrast with the lower mantle composition.

That concentrating effect gives the clue to some characteristics of the core formation mechanism. It is obtained by the removal of SiO2 by the sinking liquid metal, according to the general reaction:

$$SiO_{2(silicates)} + 3Fe_{liq} = FeSi_{liq} + 2FeO_{liq}$$

a reaction feasible at high temperature (> 2500–3000°C) and medium pressure (< 24GPa). The process requires an energy input precisely akin to that of the great impact, giving readily the above core composition and providing as well the Upper-Lower Mantle differenciation.

To summarize, the Earth grows from a single global composition in a single, reduced environment, obeying all the available chemical and isotopic

TABLE 1.

	This Work	Allègre *et al.*, 1995
Si	9.5	7.4
Fe	81	79.4
Ni	5.0	4.9
Co	0.25	0.25
S	2.65	2.3
O	1.6	4.1

constraints. The autoredox mechanism which explains the differenciation of the Upper Mantle, is also the mechanism of the necessary uptake of light elements by the core. The driving force for such events is the Moon-forming great impact.

References

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