



Subject offered for a contract starting october 2015

SUBJECT TITLE: Volatility and Fractionation of Nominally Refractory Elements

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Financing: Doctoral contract with or without assignment

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Presentation of the subject: (1 or 2 pages)

The major-element composition of the Earth is a result of the fundamental processes that occurred very early in its history, roughly in the first 100 Ma. Accretion, giant impacts, core formation and magma ocean crystallisation play major roles in isolating, volatilising, and fractionating elements. The elemental and isotopic abundances of Si, Mg, Fe, Al, and Ca are known accurately for the different meteorite groups (in particular the undifferentiated meteorites, called chondrites) and to certain extent for the upper mantle by doing some assumptions, but they are only postulated for the lower mantle and core. The lower-mantle and core are unsampled reservoirs, and their compositions are usually modelled using a standard geochemical mass balance considerations (BE= Bulk Earth, CHUR= chondrites, UM= upper mantle, LM=lower mantle, C=core):

$$C_{BE} = C_{CHUR} = C_{UM} + C_{LM} + C_C$$

As mentioned above, the composition of the reservoirs CHUR and UM have a known and it is possible to measure their compositions, whereas the composition of LM and C are not known. This is seemingly an open-ended problem as we have more unknowns than constraints. However, another constraint can be brought by two other equations to close the problem, and they are based on experimental determination of partition coefficients between liquid and solid silicates on the one hand, and between metal and silicates on the other:

$$C_{UM}/C_{LM} = D^{liq/sol} \quad C_C/(C_{UM}+C_{LM}) = D^{met/sil}$$

The experimental study of metal-silicate partitioning during core formation, as well as liquid-solid partitioning during magma ocean crystallisation is therefore an essential tool to study the global composition of the Earth.

However, one can always take the problem one step back; there is no fundamental reason why the BE must be identical to the CHUR for all elements. In other words, there are reasons why the Earth should not be chondritic (for all elements), the most important being the volatility. We know that Earth is non chondritic in volatile elements, because these are volatilised during accretion. We know that the Earth is chondritic for the very refractory elements like the REEs, Al,

Ca, Mg, as these are not fractionated in the upper mantle. But we do not know whether Si¹ and Fe are present in chondritic abundance. Could these be depleted in the BE by very high temperature volatilisation during accretion?

We can reproduce and study high-temperature volatilisation occurring during accretion, in the lab, by performing laser-levitation high-temperature experiments. The aim of this thesis is to produce a series of devolatilised chondritic compositions (from the three different chemical groups: carbonaceous, ordinary, enstatite) as well as a range of peridotitic/pyrolytic compositions. They will be levitated at very high temperature and quenched to glasses. These will be analysed for the bulk elemental and isotopic compositions. These will be studied as a function of temperature, time, and bulk chemistry. The aim is to see variations in Si/Mg, Fe/Mg, as well as associated isotopic fractionation in these elements, while maintaining Al/Mg and Ca/Mg contents in the starting material; these could provide a paradigm shift in our understanding of the accreting Earth and its major-element isotopic composition, especially for two of its most important elements: Silicon and Iron.

The work will follow a unique multidisciplinary approach (experimental petrology + isotope geochemistry) and will tackle one of the most important problems in the planetary sciences.

¹ Actually Si does not fall on the chondritic fractionation line, and is depleted in the BSE, but this has been explained by the fact that it is a siderophile element and that some of it can be trapped in the core