Experimental segregation of the Earth's core under reducing conditions

J. SIEBERT[1], F. GUYOT[2], V. MALAVERGNE[3], F.J. RYERSON[3]

[1]Lawrence Livermore National Laboratory, University of California, USA
[2]Institut de Physique du Globe de Paris, France
[3]Lunar and Planetary Institute, Houston, USA

The purpose of the present study is to provide new experimental constraints on the chemical evolution of metal under the putative conditions of a growing Earth and discuss its implications for the nature of core's chemical impurities (which light elements enter its composition) and mantle mineralogy. Silicon-rich iron alloys have been reacted with silicates and carbonates at 10-25 GPa and 1700-2200°C. The experiments were carried out in multianvil high-pressure systems. Oxygen fugacity was estimated by analyzing metal and silicate phases relative to the iron/wüstite and the silicon/stishovite buffers.

A major interest of these new compositional data is that they were obtained by using silicon rich metal alloys as starting materials. This allowed to investigate very low oxygen fugacities: at four log units below the iron/wustite (IW) buffer, silicates were found in equilibrium with Si-rich metallic alloys, up to 17wt% of Si in Fe at 20 GPa and 2200°C. The silicon content in metal increases with increasing pressure and decreasing oxygen fugacity.

Calculated P, T conditions for generating a core containing 7 wt % Si and a mantle with current FeO content in silicates are consistent with core segregation scenarios. Similar experiments performed in sulphur-bearing systems showed that Fe-Si-S alloys were single phased at high pressure and temperature suggesting the closure of the liquid immiscibility gap at these conditions. The main particularity of these (Fe-S-Si) alloy/silicate experiments carried out under reducing conditions (i.e., with Si in metallic phase) is the formation of a magnesium sulphide MgS. If this sulfide formed during the differentiation of the Earth, it would not segregate to the core due to its low density.

Reaction of Fe-Si alloys with FeCO3 siderite yielded the formation of 10-30 µm sized diamonds embedded in the metal phase. These experiments provide a new possible mechanism for spontaneous growth of diamond in the Earth's primitive mantle. Calculated fO2 of our experiments permit to discuss the stability of carbonates in the P, T conditions relevant for the formation of an Si-rich core. These experiments provide also a good way for constraining the maximum amount of carbon in the Earth's core.