The solubility of lithophile elements in iron during core formation, and its subsequent exsolution; or how on Earth can we generate an ancient magnetic field?

JAMES BADRO[1,2], JULIEN SIEBERT[1], FRANCIS NIMMO[3]

[1]Institut de Physique du Globe de Paris, France
[2]École polytechnique fédérale de Lausanne, Switzerland
[3]University of California Santa Cruz, USA

Terrestrial core formation occurred by gravitational segregation of immiscible metal and silicate melts in an extensively molten proto-Earth. This stripped the magma ocean of most of its siderophile elements, which were concentrated in the core, and left behind the lithophile elements that constitute the bulk silicate Earth (BSE). By performing metal-silicate equilibration experiments at extreme pressures and temperatures using the laser-heated diamond anvil cell, we find that two major lithophile components of the BSE, namely MgO and Al_2O_3, also become soluble in the metal. At 4400 K, our experiments show that up to 1.6% MgO and 1.1% Al_2O_3 can be incorporated in iron-rich metal. The solubility of the MgO component in the metal is fully consistent with DFT calculations of solvus closure in the Fe–MgO system [1]. Our experiments finally confirm that significant amounts of magnesium can be added to the early core, provided that a process generates high enough temperature [2].

We used our data to develop a thermodynamic and fluid dynamical model of MgO–metal interaction, and we show that the Earth's core may have contained up to 3.5% MgO in the aftermath of the Moon-forming giant impact. Even in the case of a small giant impactor [3], close to 2% MgO can be brought to the core. The exsolution of that MgO due to core cooling should provide a significant source of energy, capable of driving an early dynamo and generating a magnetic field. The chemical buoyancy that we find generates more energy than that provided by inner core growth in the modern Earth, and is therefore sufficient to produce enough power over extended periods of time (up to 1 Ga), and should produce an ancient magnetic field [4] consistent with the geological record.

[1] S. M. Wahl and B. Militzer, *EPSL* **410**, 25 (2015) [2] J.J. O'Rourke and D. J. Stevenson, *Nature* **529**, 387 (2016) [3] M. Cuk and S. T. Stewart, *Science* **338**, 1047 (2012) [4] J. A. Tarduno *et al.*, *Science* **349**, 521 (2015)