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Composition of the First Solid Cumulates in a Deep Pyrolitic Magma Ocean

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During its formation 4.56 billion years ago, the Earth's mantle was extensively molten mainly due to the heat released through collisions (Tonks & Melosh, 1993). In particular, the last giant impact that formed the Moon gave rise to a global magma ocean that could have reached the core mantle boundary (Canup, 2004, 2008; Piet et al., 2017). After what, the planet progressively cooled down and this magma ocean started crystallising, a process that has partially shaped the structure and chemical composition of the present-day Earth's mantle and atmosphere but that is still not well understood. For instance, the composition of the first solid cumulates that formed at depth in this magma ocean remains poorly constrained although highly controlling the Earth' s crystallization path.

Thanks to a cutting edge experimental protocol of melt crystallisation in laser-heated diamond anvil cells (Nabiei et al., 2021), we measured by quantitative EDXS on an analytical transmission electron microscope the composition of the liquidus phase (i.e. the first solid cumulates) of a pyrolitic melt at four different pressures (55, 87, 107 and 130 GPa). As already suggested by previous works (Fiquet et al., 2010; Andrault et al., 2011; Nomura et al., 2014), our experiments show that bridgmanite is the first mineral to crystallize across the whole lower mantle. We further constrained theoretical bridgmanite-ferropericlase cotectics (Boukaré et al., 2015) with our experimental data set and reported them in FeO-MgO-SiO2 ternary diagrams along with the composition of our samples.

Auteur principal: Mme GENDRE, Héloïse (IPGP)

Co-auteurs: M. BOUKARÉ, Charles-Édouard (York University); Mme HÉBERT, Cécile (Swiss Federal Institute of Technology Lausanne); M. ALEXANDER, Duncan (Swiss Federal Institute of Technology Lausanne); Mme CHEN, Hui (Swiss Federal Institute of Technology Lausanne); BADRO, James (IPGP); M. WEHR, Nicolas (IPGP); M. TORRUELLA BESA, Pau (Swiss Federal Institute of Technology Lausanne); M. COZMA, Sebastian (Swiss Federal Institute of Technology Lausanne); M. BORENSZTAJN, Stéphan (IPGP)

Orateur: Mme GENDRE, Héloïse (IPGP)

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