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Phosphorus in the deep Earth: An experimental investigation of Ca-phosphates at upper- to lower-mantle P-T conditions

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During subduction and dehydration of oceanic crust, P can be transported into the mantle wedge by fluids or melts, and either enters silicate phases, in particular garnet and olivine, or, if bulk P concentrations are sufficiently high, forms apatite. This P-enriched peridotite will then be dragged down with the subducted slab into the deep mantle. When apatite reaches its upper pressure stability limit, the anhydrous Ca-phosphate tuite will form. While the role of Ca-phosphates in the global P-cycle is well understood for the crust and shallow upper mantle, this is not the case for the deep silicate Earth near and below 660 km depth.

In this study we investigated the *P-T* stability, phase relations, and compositional evolution of tuite in a peridotitic bulk composition at *P-T* conditions of the upper- to lower-mantle transition. For this purpose, multianvil experiments were performed at 15 to 25 GPa and 1600 to 2000°C. A synthetic peridotite, based on the composition of a moderately fertile spinel lherzolite, was used as starting material. This peridotite was doped with 3% synthetic β-$Ca_3(PO_4)_2$, 1% of a trace element mix containing a range of HFSE, LILE and REEs, and approx. 2200 µg/g of Br and Cl each.

The coexisting phases stable within the studied *P-T* range include tuite, majoritic garnet, ringwoodite, forsterite, clinoenstatite, bridgmanite, davemaoite, ferropericlase, and melt. Tuite breaks down between 1700 and 1750°C at 20 to 25 GPa and between 1750 and 1800°C at 15 GPa, which yields a negative slope for the tuite-out reaction.

Beyond the *P*-stability of apatite, tuite and/or garnet are the main P carriers in a typical peridotite dependent upon the bulk P content. With increasing depth, the modal amount of Ca-phosphates decreases due to a progressive phosphate-to-silicate P transfer, leading to P contents of up to 1.79 wt% P_2O_5 in majoritic garnet at 1700°C and 20 GPa. However, as soon as garnet reaches its stability limit, tuite is very likely the most important P-carrying phase at subsolidus conditions while bridgmanite and davemaoite contain negligible P (< 60 µg/g and <100 µg/g respectively) even when buffered by tuite.