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Deep phosphorus cycling carried by subducted sediments

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Phosphorus is a fundamental element essential for all life on Earth, and its cycling plays an indispensable role in the emergency and evolution of life. Intraplate magmas sourced from the deep mantle, extending to the mantle transition zone or even lower mantle, commonly exhibit anomalously high P_2O_5 contents (0.6-1.8 wt%) compared to mid-ocean ridge basalts (MORBs, 0.06-0.25 wt%) and arc basalts (0.1-0.35 wt%), highlighting its critical role in deep Earth-surface phosphorus cycling. Previous studies have proposed that these anomalies are linked to recycled high-pressure phosphate phases—tuite (γ-$Ca_3(PO_4)_2$)—yet how tuite is transported into the deep mantle, and its role in deep mantle processes remains poorly constrained. Sediment is the dominant phosphorus (0.2-1 wt% P_2O_5) reservoir in the subducted slab, largely due to the biogenetic deposition process. To investigate the behaviour of phosphorus during subduction, we performed high-temperature and high-pressure experiments (6-33 GPa, 800-1600 ℃) on subducted sediment. Our results show that apatite in the sediment transforms into tuite at 6-8 GPa, and tuite remains stable to lower mantle depths (> 33 GPa) along the subducted slab geotherms. The breakdown of tuite from these high-P sediments in deep mantle further provides an efficient mechanism for supplying phosphorus to the source region of intraplate magmas. In addition, this process releases tuite-favored elements U and Th into the mantle, whose radiogenic decay may promote sustained mantle heating and magmatic activity. In contrast, within the mafic oceanic crust, phosphorus is progressively incorporated into the majoritic garnet structure with increasing pressure, and discrete phosphate phases becomes unstable pressures higher than 2 GPa. Given the refractory affinity of majorite, phosphorus stored in subducted mafic oceanic crust is unlikely to be released into mantle melts. This contrast further highlights the critical role of sediment in intraplate magmas genesis and phosphorus cycling.