

Widespread reactive phosphorus in mafic and ultramafic rocks: implications for the origin of life

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Phosphorus (P), a key element for all life-forms on Earth, has been essential for the origin and early evolution of life. However, the dominant form of P, i.e., phosphate (P(V)) is sparsely soluble in water and less efficient in making phosphorylated compounds that are crucial for prebiotic chemistry. Reduced P species such as phosphite (P(III)) and condensed P species such as pyrophosphate (PP(V)) might have been more useful for this purpose as they are more soluble and/or reactive compared to P(V). The two mechanism proposed to supply these species on the prebiotic earth are dissolution of highly reduced phosphides delivered by meteorites¹ and thermal heating of phosphate salts/minerals in dry conditions^{2,3}, both of which could have been geologically restricted. Here, we propose that weathering of mafic and ultramafic rocks could have delivered a significant part of the prebiotic reactive and soluble P species to surface environments on early Earth. We extracted P species from olivine separates, peridotite, basalt, and komatiite collected from several locations using an alkaline ethylenediamine tetraacetic acid (EDTA) solution and measured P(III), P(V), and PP(V) concentration using an IC-ICPMS set-up⁴. We see a consistent presence of P(III) in the extracts, reaching up to 10% of total extracted P for olivine and peridotite, up to 0.24% for basalt, and up to 23% for komatiite. We further see that PP(V) is rare in olivine and peridotite but common in basalt and komatiite, reaching up to 0.5% and 5% of total extracted P, respectively. When accounting for the distribution of mafic lithologies in Earth's mantle and oceanic crust, we find that 1-10% of total P could be P(III). Given that P(III) is highly soluble and kinetically stable in liquid water, we suggest that aqueous alteration of mafic magmatic rocks could have delivered a significant amount of reduced and polymerized P species for the origin and early evolution of life.

1. Pasek & Lauretta *Astrobiology* **5**, 515–535 (2005). 2. Herschy, B. et al.. *Nat. Commun.* **9**, 1346 (2018). 3. Baidya et al. *Commun. Earth Environ.* **5**, 491 (2024). 4. Baidya & Stüeken, *Rapid Commun. Mass Spectrom.* **38**, e9665 (2024)