Goldschmidt 2021 Abstract
https://doi.org/10.7185/gold2021.3819

Evolution of the phosphorus cycle: sources, sinks, and recycling pathways

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Phosphorus (P) is a key limiting nutrient for global productivity [1]. The availability of P to life over Earth history is therefore of great relevance to reconstructions of global redox and biogeochemical evolution [2]. Global P cycling is dependent on the rate of chemical and physical weathering processes [3], as well as the size and efficiency of sinks in the environment [4]. However, there are currently few quantiative estimates of the global weathering input of P over deep time, and numerous setting-dependent features of the marine P cycle are currently not resolved by available models [5]. In order to re-assess the evolution of P weathering fluxes, we model the abundance, weatherability, and distribution of P in crustal minerals over time.

Secondly, we examine how the changing redox stratification of Earth's surface environments has moderated sinks and recycling pathways for P. Specifically, we use the Carbon-Oxygen-Phosphorus-Sulphur-Envionment (COPSE) code to study the evolution of abiotic and biological sinks for P in response to changing redox conditions. By resolving the redox structure of the Earth system in relation to specific geological and biological processes, we are able to refine the relationships between atmospheric and oceanic oxygenation and global P availability.

Overall, we demonstrate that future models of P cycling should include sensitivity of (1) weathering to mineral speciation and (2) burial to surface redox-stratification. Our results have important implications for the timing of Earth surface oxygenation, as well as associated revolutions in the biological realm.

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