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Calcium as a Control on Inputs of Dissolved Inorganic Phosphorus Concentrations on Ocean-Covered Planets

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On Earth, the weathering of subaerial felsic continents is critical for phosphorus (P) delivery to the oceans. However, P inputs, and therefore the potential for nutrient limitation on life, must be different on planets completely covered in oceans. Absent subaerial continents, the sole source of P is the subaqueous dissolution of ocean crust, where P is present as a trace element in mafic rocks. Because dissolved species in the ocean must ultimately be sourced from reactions between the seawater and seafloor, the chemical composition of the ocean crust must be the primary influence on ocean chemistry. As such, we use geochemical modeling to explore the relationship between seafloor lithology and aqueous P availability. We find that abundant dissolved inorganic phosphorus (DIP) is thermodynamically favorable under a wide range of conditions. However, DIP decreases proportionally to the amount of calcium (Ca) in the system. More specifically, increased aqueous Ca raises the saturation state of fluorapatite, a calcium phosphate mineral, which draws DIP out of solution when it precipitates. This process is also coupled to the precipitation of secondary Ca-bearing carbonate minerals (e.g., dolomite). For example, a decrease in dolomite formation and consequent increase in apatite formation leads to lower DIP. Because ocean crust Ca abundance controls how much Ca is available for weathering, we demonstrate the importance of considering lithological controls on ocean chemistry when assessing the habitability of ocean-covered planets.