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Field constraints on the evolution of phosphorus concentrations during saline lake formation

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Most of the vital elements for life – carbon, hydrogen, nitrogen, phosphorus, and sulfur – are readily available in natural waters, but phosphorus stands out as being generally plentiful in rocks but not water. This lack of phosphorus has come to be known as the "phosphate problem" in the study of the origins of life on prebiotic planetary surfaces. Recent work has demonstrated that alkaline (Na-HCO_3) lakes, which lose nearly all of their Ca as carbonate minerals precipitate during the early stages of evaporation, achieve extremely elevated P concentrations due to the associated, relaxed limits on apatite group mineral solubility. Yet, the unique aqueous geochemical requirements for these lakes' formation (a preponderance of alkali cations such as Na^+ over carbonate forming cations such as Ca^{++}) suggest they would be of limited importance on primordial, mafic planetary surfaces such as early Earth and Mars. Rather, orbital evidence from Mars implies that evapo-concentration of groundwater-fed lakes on early Mars would have produced highly concentrated $MgSO_4$ lakes, which are ultimately recorded as the global 'sulfate bearing unit' often thought to signify the conclusion of warm and wet conditions on Mars. Interestingly, these lakes, too, have a significant limitation on their Ca concentration associated with the precipitation of calcium sulfate. By analogy with the alkaline lakes, a logical outcome of this Ca limitation should be elevated concentrations of P in the resultant brines. Here, we will evaluate the hypothesis that $MgSO_4$ lakes characteristic of mafic planetary surfaces can overcome the "phosphate problem" via their own, unique sulfate-limited Ca concentrations. To do this, we will summarize five years of geochemical analyses of groundwater, lake water, and pore waters from saline lakes in the Cariboo Plateau (British Columbia, Canada), and discuss the implications of these results for the phosphate problem in relation to evaporative environments on prebiotic planetary surfaces.