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Groundwater–sediment controls on phosphorus availability in an alkaline lake analog for prebiotic chemistry

DR. ZOHRA ZAHIR, PHD[1], WEIBIN CHEN[1], GREG F. SLATER[2] AND BARBARA SHERWOOD LOLLAR[1,3]

[1]University of Toronto
[2]McMaster University
[3]Institut de Physique du Globe de Paris, Université Paris Cité

Phosphorus (P) is essential for life and central to hypotheses about prebiotic chemistry, yet dissolved phosphate in most natural waters is extremely low (uM), far below concentrations required for many origin-of-life reactions. Alkaline “soda” lakes on the Cariboo Plateau (British Columbia), including Goodenough Lake (GEL) and Last Chance Lake (LCL), are notable exceptions, hosting unusually high dissolved phosphate (mM)[1,2]. These lakes have recently become a topic of intense scientific interest[1–8]. Understanding why phosphate reaches such high concentrations, and why two neighbouring lakes differ by more than an order of magnitude, is important for advancing nutrient-cycling models and for interpreting the geochemical conditions that may have supported prebiotic chemistry.

Previous studies have drawn on data from lake-water chemistry and relatively limited sediment cores. Here, we present the first in situ porewater chemistry profiles (to 40cm depth below the sediment-water interface, SWI) from GEL sediments obtained using dialysis membrane chambers, which minimize disturbance and air contamination. High-resolution (centimeter-scale) profiles span overlying lake water, SWI, and deeper sediment layers, resolving redox-sensitive chemical gradients and solute fluxes not previously characterized. We report a comprehensive stable water isotope analysis ($\delta^{18}O$, $\delta^{2}H$) for GEL and LCL, including all identified spring inputs, local precipitation, and surrounding lakes enabling direct assessment of precipitation-groundwater–lake relationships. Field observations demonstrated that GEL is hydrologically open, fed by at least seven springs. In addition, this study provides the carbon isotope analysis for the system, including $\delta^{13}C$ of dissolved inorganic carbon, methane, and organic matter. Together, these data constrain sedimentary redox processes and groundwater–sediment interactions that regulate phosphate release and persistence in an alkaline lake system that has become a recent focus of field studies and modeling central to discussions of prebiotic chemistry and origin of life.

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