High phosphate concentrations needed for prebiotic chemistry occur in alkaline lakes

JONATHAN D. TONER AND DAVID C. CATLING[1]

[1]University of Washington, Johnson Hall, Dept. Earth & Space Sci., Seattle, WA 98195, (e-mail: toner2@uw.edu)

Phosphate plays a central role in prebiotic chemistry because it is a key component of nucleotides, phospholipids, and adenosine triphosphate. Nucleotides and other phosphorylated organics have been synthesized in the lab [1,2], but using ~1 M phosphate because phosphate has low reactivity in water [3]. Such high phosphate concentrations are problematic because phosphate is thought to occur in μM amounts due to precipitation with Ca^{2+} in insoluble apatite minerals. These twin issues of low availability and reactivity are known as 'the phosphate problem' [4].

Here we show that up to ~3 mol kg^{-1} phosphate would have occurred in saline, alkaline lakes on early Earth. Phosphate concentrations up to ~20 mM occur in present-day alkaline lakes (Fig. 1) because Ca^{2+} precipitates in carbonate salts instead of slow-forming apatites, resulting in excess phosphate relative to Ca^{2+}. Upon evaporation, geochemical models show that excess phosphate reaches concentrations up to several molal, depending on the temperature, before precipitating as Na_2HPO_4 salt. Similar alkaline lakes would have formed on early Earth due to carbonate alkalinity released from CO_2 weathering of mafic rocks. Furthermore, phosphate concentrations would have exceeded present-day levels due to enhanced apatite weathering and the absence of phosphate-consuming microbes. These considerations point to the viability of a specific environment for the origin of life: closed-basin, alkaline lakes hosted in mafic terrains.

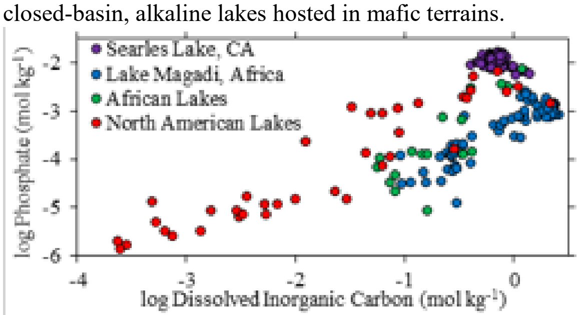

Fig. 1. Phosphate vs. inorganic carbon concentrations in present-day, closed-basin, alkaline, soda lake environments.

Ref: [1] Powner et al. (2009). *Nature*, 459(7244), 239-242. [2] Gull (2014). *Challenges*, 5(2), 193-212. [3] Pasek (2017). *Chem. Geo.*, 475, 149-170. [4] Gulick (1957). *Ann. N. Y. Acad. Sci.*, 69(2), 309-313.