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Phosphate- and cyanide-rich soda lakes support the origin of life, with cyanide sourced from inevitable post-impact reducing atmospheres

DAVID C. CATLING[1], SEBASTIAN HAAS[1], NICHOLAS F WOGAN[2] AND KEVIN J. ZAHNLE[2]

[1]University of Washington
[2]NASA Ames Research Center
Presenting Author: dcatling@uw.edu

The origin of life (OoL) is how geochemistry became biochemistry. Consequently, the OoL requires places with geochemistry that demonstrably support prebiotic synthesis. “Feedstocks” for such synthesis are environmental molecules that must be readily available and generally concentrated to drive prebiotic reactions. Two feedstocks, nitriles and phosphate, are critical for successful laboratory syntheses of the canonical ribonucleotides of RNA, over half of the amino acids of modern biochemistry, and glycerol-phosphate lipid precursors [1-4]. Nitriles include hydrogen cyanide (HCN) and cyanoacetylene (HC_3N), which have a known, substantial natural source in chemically reducing atmospheres.

Although outgassing of the early Earth was probably only weakly reducing, strongly reducing, Titan-like atmospheres were inevitable after big impacts, and such atmospheres would make substantial HCN and cyanoacetylene, on post-impact timescales of millions of years [5]. Cyanide can be captured into ferrocyanides in evaporative, soda (sodium carbonate-rich) lakes [6]. Na-ferrocyanide evaporites can even stockpile cyanide, which can be released much later for prebiotic reactions upon hydration and ultraviolet or thermal decomposition [6].

Soda lakes are common in closed basins on volcanic rocks and concentrate phosphate, too. Last Chance Lake, Canada (Fig. 1), is the world’s most phosphate-rich soda lake, seasonally reaching ~40 mM phosphate – the only natural waterbody that encompasses levels used in prebiotic synthesis of nucleotides [7]. Furthermore, dryness (Fig. 1a) in wet-dry cycles of such lakes (Fig 1a, b) would favor biopolymer condensation [8].

The known concentration mechanisms for feedstocks, the possibility of wet-dry cycles, and the availability of UV light to activate reactions and destroy unwanted side-products, all arguably make soda lakes the most demonstrably plausible environment for the OoL in the current literature.

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