A new prebiotic paradigm: Early Earth environments give rise to life's chemistry

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The prebiotic chemistry that eventually gave rise to life on Earth was *necessarily* a consequence of abiotic processes that occurred in (near) surface early Earth environments. The chemical reactions that formed prebiotic molecules and primitive reaction networks were driven by natural processes and proceeded because of, and not in spite of, the totality of environmental conditions that existed across various geologic systems. Therefore, the specific conditions that distinguish early Earth systems play an essential role in prebiotic molecule formation and stability.

Global processes such as atmospheric evolution, the onset and tempo of plate tectonics, and ocean formation, broadly constrain the Hadean Earth, but are manifested differently across different geologic systems, from subaerial aqueous and evaporitic systems, to subsurface hydrothermal systems. Localized environmental conditions that likely govern prebiotic chemistry outcomes (e.g. temperature, pressure, fluid chemistry, mineralogy) are not independent, but instead co-vary within predictable ranges. Furthermore, fluid flow serves to connect different early Earth environments, allowing for the sequencing of prebiotic reactions and their products. Therefore, the potential for prebiotic synthesis can only be understood within the context realistic early Earth conditions.

In continuing experiments to evaluate the effects of environmental conditions on nucleotide polymerization, we have investigated the extent of RNA polymerization as a function of mineralogy, temperature, pressure, fluid composition, and volatile composition. These experiments reveal that (i) several mineral classes can faciliate RNA polymerization, (ii) the catalytic potential of minerals depends on other environmental parameters, (iii) RNA polymerization can proceed without a solid phase in the presence of aqueous metal cations, and (iv) RNA polymerization efficiency varies with volatile composition. Taken together, our data suggest that while overall RNA oligomer yields can vary with experimental parameters, RNA polymerization nonetheless proceeds over a range of environmental conditions, suggesting that the formation of nucleic acids from simple precursors could have been common-place on early Earth.