What comprised the free energy converters needed to launch life at a submarine alkaline hydrothermal vent?

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We present a reformulation of the submarine alkaline hydrothermal theory for the emergence of life in response to recent experimental findings as well as discoveries in the life sciences [1]. This reformulation sees life, like other self-organizing systems in the Universe, as an inevitable and rapid outcome of particular disequilibria. In this case the disequilibria were two: in redox potential, between hydrothermal hydrogen plus methane with the circuit-completing electron acceptors such as nitrite, nitrate, ferric iron and carbon dioxide in the Hadean Ocean, and in pH gradient between this mildly acidic external ocean and the alkaline hydrothermal fluid. Both CO_2 and CH_4 were equally the ultimate sources of organic carbon, and the metal sulfides and oxyhydroxides acted as protoenzymatic catalysts. The realization, now fifty years old, that membrane-spanning gradients rather than organic intermediates, play a vital role in life's operations calls into question the idea of "prebiotic chemistry". It informs our own suggestion that experimentation should look to the kind of nano-engines that must have been the precursors to molecular motors – such as pyrophosphate synthetase and the like driven by these gradients – that make life work [2]. It is these putative free energy or disequilibria converters, presumably constructed from minerals comprising the earliest inorganic membranes that, as obstacles to vectorial ionic flows, present themselves as the candidates for future experiments.

[1] Russell *et al* 2014 The drive for life on wet and icy worlds. *Astrobiology*, in press. [2] Baltscheffsky, H. & Persson, B. (2014) On an early gene for membrane-integral inorganic pyrophosphatase in the genome of an apparently pre-LUCA extremophile, the archaeon *Candidatus Korarchaeum cryptofilum*. *J Mol Evol* DOI 10.1007/s00239-014-9610-7.