

CONCENTRATION AND RETENTION OF ORGANICS IN AN OPEN-FLOW HYDROTHERMAL SYSTEM.

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Introduction: Alkaline hydrothermal vents are natural electrochemical flow reactors that could have driven abiotic carbon reduction at the origin of life [1,2]. While yields of organics from H₂ and CO₂ under these conditions may be low [3], organic synthesis is continuous and exergonic under far-from-equilibrium conditions [1,3]. Equally importantly, thermal gradients across microporous labyrinths in alkaline vents have the potential to concentrate organics to high levels by thermophoresis.

Thermophoresis concentrates organics via the processes of thermal convection and diffusion (**Figure 1**). Alkaline vents have natural temperature gradients (hydrothermal fluids at 45-90°C flow into the bulk ocean at 5-20°C) and an interconnected, microporous structure, where mixing takes place. Theoretical simulations suggest that convection currents and thermal diffusion within alkaline hydrothermal vents could concentrate large organics such as short-chain RNA and DNA to an extreme degree, potentially 10⁹-fold [4]. Smaller organics such as nucleotides should also concentrate, albeit to a lesser degree, calculated to be ~1000-fold. Experimental work in simple closed systems has corroborated that thermophoresis does concentrate organics (see [5] and [6] as examples), but until our preliminary studies using ceramic foam [3], no research had shown that organics could be concentrated in an open system such as a hydrothermal vent, in which organics could potentially flow straight through to be lost into the ocean.

We have built a vent simulation reactor which contains microporous ceramic foam to mimic the internal structure of the vent [3]. Using a conservative temperature gradient (~30°C), flowing in concentrations of 1μM to 1nM of different UV-active organics, we show a concentration factor of between 5000- and 30-million fold, depending on the chemical properties of the dye, in an open flow system by thermophoresis (**Figure 2**).

The retention and concentration of organics favours condensation and polymerization reactions, ultimately facilitating the formation of polypeptides, RNA and DNA, as well as spontaneous vesicle formation through the concentration of fatty acids and other amphiphiles. The ability to concentrate essential organics in an alkaline vent system therefore increases the likelihood of molecular evolution in these environments.

Our results show that thermophoresis can concentrate even small organics to an extraordinary degree in open hydrothermal systems, potentially driving the origins of biochemistry.



Figure 1: Schematic of thermophoresis showing the processes of thermal convection (a.) and thermal diffusion (b.) inside the substrate in the vent simulation reactor. By using this process, a low concentration of organic molecules (1μM to 1nM) are concentrated by transport to cooler regions within the substrate where, due to thermal and kinetic stability, they accumulate and are retained inside the substrate.

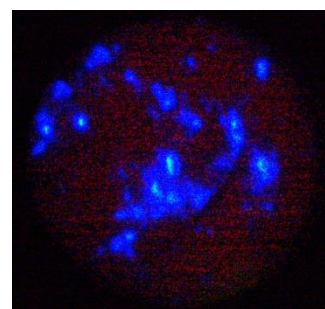


Figure 2: Photograph of a ceramic foam substrate section exposed to UV light (254 nm excitation) showing areas of intense emission caused by concentrated pockets of quinine created by thermophoresis.

References: [1] Martin W. & Russell M.J. (2007) Phil Trans Roy Soc Lond B **367**, 1887–1925. [2] Russell M.J. & Hall A.J. (1997) J. Geol. Soc. Lond., **154**, 377–402. [3] Herschy B. et al. (2014) J. Mol. Evol., **79**(5-6), 213–227. [4] Baaske P. et al. (2007), Proc. Nat. Acad. Sci., **104**, 9346–9351. [5] Budin I et al. (2009) J. Am. Chem. Soc. **131**, 9628–9629. [6] Mast C.B. et al. (2013) Proc. Nat. Acad. Sci. **110**(20), 8030–8035.