

Rethinking the origin of life at seafloor hydrothermal vents

BENJAMIN M. TUTOLO

University of Calgary

The hypothesis that life originated in alkaline hydrothermal vents on Earth's ancient ocean floor is widely accepted amongst geologists, but critical consideration indicates the tenets of this hypothesis conflict with geochemical realities. Central to this alkaline vent hypothesis is the concept that strong proton gradients across thin, sulfide mineral membranes would have driven chemiosmosis and energy harvesting by protocells in chimney walls. Importantly, however, the oft-cited alkaline pH of the most well-studied of these systems, the Lost City hydrothermal field, is only applicable at the conditions under which we measure it – in shipboard or shore-based laboratories at ambient temperature and pressure conditions. Due to ion association, the in situ pH at the modern Lost City alkaline vents closely resembles that of ambient seawater (1). Because aqueous speciation is effectively instantaneous, the proton gradients within ancient alkaline chimney walls would therefore have been more limited than previously supposed. The hypothesized presence of thin, sulfide mineral membranes across which this proton gradient would have existed also presents a challenge. Because peridotite contains little sulfur and the ancient oceans were sulfate-poor, the elements required to produce sulfide minerals in alkaline vent chimneys would have been scarce. The generation of complex hydrocarbons required for primordial cell wells would also have been geochemically frustrated by reaction kinetics. Experimental observations (2) indicate that the generation of substantial hydrocarbons is unlikely over the estimated 0.5 - 2 years of sub-seafloor residence time at Lost City (3); abiotic methane there has instead been shown to be mined from fluid inclusions (4). Taken together, consideration of the geochemistry of ancient alkaline vent systems indicates that alkaline vent hypotheses for the origin of life as currently envisioned seem implausible and that other environments and alternative reactions should be more prominent in future origins studies.

1. Seyfried *et al.* *GCA* 163, 59–79 (2015). 2. McCollom *PNAS* 113, 13965–13970 (2016). 3. Moore *et al.* *JGR* 126, e2021JC017886 (2021). 4. Klein *et al.* *PNAS* 116, 17666–17672 (2019).