

The potential for abiotic organic synthesis in an ancient ore deposit: Echoes of an iron-sulfur world?

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To make progress in understanding the origin of life, we require a deeper understanding of abiotic organic synthesis in geological systems. One way to obtain new information is to explore environments on the modern Earth that contain evidence of abiotic organic synthesis. Hydrothermal vents can serve as analogues of early Earth environments, and they have provided insights that continue to guide studies of prebiotic chemistry. However, there is another modern environment that is less publicized but contains evidence of abiotic organic synthesis [1] – deep fracture fluids hosted in the Kidd Creek volcanogenic massive sulfide ore deposit in the Canadian Shield. The sulfide mineralogy may make this environment an analogue to the hypothesized iron-sulfur world of prebiotic chemistry [2], and there may be plenty of time for a complex organic chemistry to develop based on the >1.5 Ga residence times derived from noble gases in these saline fluids [3].

Our team has collected a large amount of geochemical data from field work in the Kidd mine. As a first step in assessing its relevance to prebiotic chemistry, we used the field data to evaluate the thermodynamic potential (chemical affinity, A) for the synthesis of a variety of organic compounds (e.g., hydrocarbons, aldehydes, fatty acids) using an approach similar to [4]. The results of our calculations support the hypothesis of abiotic organic synthesis at Kidd Creek [1]. In calcite-buffered fracture fluids, we find that almost any organic compound can be synthesized from CO_2 with respect to the reaction energetics. The synthesis of CH_4 is most favorable ($A = 140$ kJ/mol), consistent with its abundance [1]; but even traditional “high-energy” compounds such as glyceraldehyde and pyruvate can be formed ($A > 0$) with activities as high as $\sim 10^{-4}$. Kidd Creek appears to be a promising new model system for prebiotic chemistry, as the low temperatures and high fugacities of H_2 [5] are very conducive to abiotic organic synthesis. We are presently exploring possible mechanistic pathways, and expanding the calculations to include N-bearing species.

[1] Sherwood Lollar et al. (2002) *Nature* **416**, 522-524. [2] Wächtershäuser (1992) *Prog. Biophys. Mol. Bio.* **58**, 85-201. [3] Holland et al. (2013) *Nature* **497**, 357-360. [4] Shock & Canovas (2010) *Geofluids* **10**, 161-192. [5] Sherwood Lollar et al. (2014) *Nature* **516**, 379-382.