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The Power of the Abiotic Baseline: Insights on finding biological needles in an abiotic haystack

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Investigation of chemolithotrophic microbial ecosystems has been a major driver in expanding our understanding of Earth's habitability in both the marine lithosphere and the > 70% of the continental lithosphere comprised of Precambrian rocks. Underground research laboratories and mines worldwide provide access to the deep subsurface in Precambrian settings, and targets for investigation of subsurface life. Kidd Creek Observatory on the Canadian Shield is one such iconic site. Investigation of fracture fluids to 3 km here revealed H_2 production via radiolysis and serpentinization; production of methane and higher hydrocarbons via abiotic organic synthesis; and fracture fluids with mean residence times of more than a billion years.

The past 40 years of work on these topics has simultaneously quietly driven a major paradigm change at the core of biosignature research. The current generation of graduate students might be surprised to learn that to work on abiotic organic synthesis in the 1980s could be viewed being on "the lunatic fringe" of science. Despite the fact that abiotic organic chemistry is the foundation of many chemical engineering processes, and the bench-top chemistry being well-established, the predominance of our scientific thinking was that on a planet so dominated by life as Earth, any record of abiotic organic chemistry in the environment – at real field sites – must be rare to impossible to identify - like searching for an abiotic needle in a biological haystack. We now recognize there are locations on Earth in which the record of abiotic organic chemical reactions can be teased out. Such locations provide critical analogs to determine what the "abiotic baseline" might have looked like on prebiotic Earth, and might look like on other planets and moons. As such, the information from this now well-developed discipline of abiotic analog science, informs the investigation of life and habitability on Earth and a more sophisticated understanding of biosignatures. Further it has had major impact on fundamental best practice and planning for exploration missions and for missions focused on sample return – all cases where the inverse problem is the challenge – the search for biological needles in an abiotic haystack.