EARLIEST LIFE ON EARTH PRESERVED IN HOTSPRING DEPOSITS: EVIDENCE FROM THE 3.5 Ga DRESSER FORMATION, PILBARA CRATON, AUSTRALIA, AND IMPLICATIONS FOR THE SEARCH FOR LIFE ON MARS.
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Introduction: Repeated visits to the c. 3.5 Ga Dresser Formation of the Pilbara Craton, Australia, have refined our knowledge of the geological setting of the earliest life on Earth and uncovered many types of biosignatures preserved in deposits that we now recognize include a wide array of hotspring facies. These new discoveries have significantly changed our view of the setting of earliest life on Earth, lends support to an origin of life in terrestrial hotsprings, and have profound implications for the search for life on Mars.

Ancient Earth: Newly discovered hotspring facies include: hydrothermal feeder veins with concentrated organic matter, pyrite, and apatite; mineralized hotspring pools; stratiform-columnar geyserite, a siliceous sinter with laminated anatase and kaolinite-illite; tourmaline-rich boratic sinter; hydrothermally-fed evaporative lake facies; silicified microbial mats fragmented in a hotwater creek; lacustrine chert[1,2].

Within these facies, the Dresser hotspring deposits preserve a rich, diverse array of biosignatures, including: pyrite-replaced, morphologically highly variable stromatolites over m-dm scales, typical of hotspring facies but atypical of marine environments; dendroid to anastomosed hematite microbialites near vents; pallisade fabric in siliceous sinter; organic matter of probable biological origin in siliceous sedimentary rocks and hydrothermal veins; fractionated carbon and sulfur isotopes; methane fluid inclusions in hydrothermal veins; microbial linings of hotspring pools[3-6].

Origin of life: These findings, together with research in prebiotic chemistry[7] and genomics[8], support Charles Darwin's 1871 suggestion that life originated on land, in "..some warm little pond…". Specifically, our findings show that ancient geothermal fields concentrated many of the inorganic elements critical for prebiotic chemistry, including: Boron, which guides the formation of ribose found in RNA; Phosphorous, which is used in ATP, the "molecular unit of currency" of intracellular energy transfer; and habitats with a high K^+/Na^+ ratio and concentrations of Zn and Mn apparently required by the earliest life.

In contrast, submarine hydrothermal vents are unable to satisfactorily concentrate simple, dilute organic compounds and have high salt concentrations and total divalent cations (e.g., Ca^{2+} and Mg^{2+}) that inhibit lipid membrane assembly and the formation of protocells.

Geothermal fields, on the other hand, are prime sites for the wetting-drying cycles required to polymerise common, simple organic molecules to the more complex forms required to make RNA and DNA[9]. They also provide variable pH environments and three highly reactive interfaces (atmosphere/water, atmosphere/mineral, mineral/water) that promote energetic complexity over several orders of magnitude, and innovation pools leading to greater fitness. Through these cycles, any simple organic compounds present as solutes in geothermal pools become highly concentrated as films on mineral surfaces during drying and these films have the potential to polymerize organic molecules that become trapped in lipid membranes [10].

Life on Mars: These findings impact the search for life on Mars in two ways. 1) If origin of life was in deep sea vents, as currently favoured, then the probability of success in the search for life on Mars would be low, as compelling evidence for Martian oceans is lacking. On the other hand, a terrestrial origin of life would bolster the probability of success in the search for life on Mars, given that hotspring deposits are known from Columbia Hills and Nili Patera[11]. 2) Hotspring deposits throughout the geological record - extending now right back to include the 3.5 Ga deposits that host the oldest evidence of life on Earth - preserve a diverse array of biosignatures. Thus, a carefully selected suite of samples from an area with known hotspring deposits on Mars may provide the best target for signs of life in our nearest neighbor.

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