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Biogenesis on Earth and the search for life on Mars

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The environments of early Earth and Mars have much in common, which suggests that early Earth may be the best Martian analog available to us. Our present understanding of Earth's biosphere suggests that life appeared relatively early in the planet's history and that it was driven to greater complexity by the evolution of the planet. Because of its smaller size the internal energy of Mars was expended early in its history which, along with the loss of its atmosphere and hydrosphere (and magnetosphere), suggests that, if life appeared on Mars, it must have done so early and that it was probably extinguished shortly thereafter as the planet's internal energy reserves were exhausted. The search for life on Mars will thus need to focus on biogeochemical traces of a primitive biosphere preserved in ancient sediments. Consequently, if we are to approach the search for life on Mars pragmatically, we must have an understanding of prebiotic conditions on Earth as well as an understanding of the earliest biosphere – that is, we must understand biogenesis. The realization that many of the life forms occupying the deepest roots of Earth's tree of life were hyperthermophiles suggests that biogenesis may have occurred in and around high temperature hydrothermal vents. Numerous models for various stages in biogenesis have been developed on the basis of these conclusions. Most are based on data derived from the modern biosphere. However, modern organisms, whilst inheriting an ancient genetic legacy have been shaped by billions of years of evolution. The only substantial evidence of biogenesis and the environment of prebiotic Earth is preserved in the ancient rock record.

Evidence of hydrothermal activity is widespread in Earth's earliest rock record, especially so on the Archean Pilbara Craton of Western Australia. Over the past seven years we have mapped and sampled three of the earliest of these well-preserved hydrothermal systems contained in rocks that range in age from 3.5 to 3.4 Ga. Black

carbonaceous cherts are abundant in these early rocks and have been shown to extend to paleo-depths of as much as two kilometres in the hydrothermal system. Preliminary analysis of the carbonaceous components of cherts from hydrothermal veins and bedded sediments using *Ultra*-Microprobe Two-Step Laser Mass Spectrometry show that a variety of low-molecular-weight compounds are preserved. The results, following multivariate analysis, will lead to the identification of robust organic signatures, both prebiotic and biotic, that have survived the extremes of thermal maturation over a vast time period. The data will ultimately help define the environment of prebiotic Earth and provide an objective basis for modeling biogenesis. With an improved understanding of terrestrial biogenesis and a well-defined suite of robust biomarkers at hand we can approach the search for life on Mars objectively.