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A hydrothermal setting for early life

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Introduction: Geological evidence and most global climate models suggest that the early Earth was hot [1-5]. Our studies of Early Archaean formations in the 3.5-3.33 Ga Barberton (South Africa) and Pilbara (Australia) greenstone belts document important hydrothermal inputs into the ancient environment to the extent that early life can be considered to be largely meso- to thermophilic. We here provide a detailed evaluation of the influence of hydrothermal activity on chemotrophic and phototrophic life forms in the 3.33 Ga Josefsdal Chert, Barberton [5].

Results: The Josefsdal Chert is a laterally extensive layer of volcanic and hydrothermal sediments sandwiched between pillow lavas deposited in shallow water environments at depths ranging from wave-base to the exposed beach [6,7]. The sediments were lithified by silica-saturated seawater (~96 to 99%). The presence of hydrothermal fluids throughout the period of sedimentation is attested by both morphological and trace element tracers. Contemporaneous hydrothermal infiltrations provoked soft sediment (and microbial biofilm) deformation at all levels, hydrothermal fluids deposited silica gel 'chemical sediments', while elemental tracers, such as Fe, Ni, Cu, As, Zn and Ba were scavenged by the volcanic particles, as well as the carbon associated with the biosignatures

We find widespread traces of microbial colonisation in these sediments [6,7]. Phototrophic biofilms developed on the surfaces of the shallow water sediments in all environments, including oligotrophic ones, espousing the underlying sediment surfaces, stabilising them, and trapping detrital particles, forming other identifiable MISS textures such as wrinkled laminae, erosional fragments, and sinoidal biofilm structures (after [8]). These films are preserved as packets of thin (~10µm) carbonaceous films or as siderite-replaced films. Two types of chemotrophic colonies are observed, (1) forming thick carbon coats on volcanic grains or (2) "free-floating" colonies within the hydrothermal fluids/gels themselves. The latter were limited in biomass development to locations close to the hydrothermal vents, where intimate intergrowth of phototrophic biofilms and chemotrophic colonies also occurred (Fig. 1). Preservation of the biosignatures was due to rapid silicification.

B

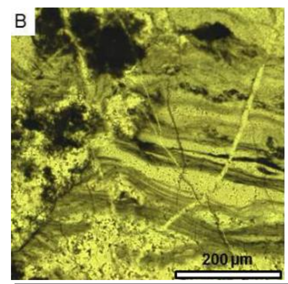

Figure 1. Coexistence of clotted chemotrophic colonies and phototrophic biofilms preserved in hydrothermal silica

Conclusions: The overwhelming morphological and geochemical evidence for contemporaneous hydrothermal activity and input into the Josefsdal Chert environment on a ubiquitous scale suggests that its microbial inhabitants must have been at least mesophilic, if not thermophilic.

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