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What controlled early terrestrial habitability: sedimentology or geochemistry ?

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The Palaeoarchaean environment was anoxic and subject to relatively frequent impacts, with ubiquitous volcanism, stronger tides and storms owing to a closer moon, warmer seawater and a different ocean chemistry. Given this setting, the question arises as to what were the actual controls on microbial life? A case study involving the 3.33 Ga Josefsdal Chert, Barberton Greenstone Belt, South Africa, provides some answers to this question.

The Josefsdal Chert comprises a succession of volcanogenic, chemical and biogenic sediments, similar to other shallow water sedimentary basins formed in the Palaeoarchaean. Sandwiched between outpourings of basaltic lava, the sediment composition reflects the fluctuating influence of volcanism and terrestrial runoff. Superimposed upon these conditions were fluctuations in access to open seawater, as well as crustal emanations from hydrothermal vents. These are the large-scale factors, lasting for tens to hundreds of thousand years or more, that exerted a large-scale effect on environmental habitability in the Paleoarchean. In addition, short-scale and small-scale factors reflected daily to seasonal influences, and would have included, temperature, pH, sediment influx (or not), and nutrient influx, which would have affected metabolic strategies for various life forms. Such fluctuations are recorded in the geochemical record. Thus, the Josefsdal Chert sediments document a dampening of benthic phototrophic growth during volcanic eruptions and sediment transport while, on the other hand, hydrothermal activity associated with the volcanism provided nutrients for chemotrophic development. In contrast, periods of quiescent volcanism permitted the exuberant development of benthic phototrophic mats (and their associated chemotrophic degraders). Within these gross distinctions, individual metabolic strategies would have reflected day to day or season to season micro-environmental variability, but are rarely preserved.

Prokaryotes are superlative environmental adapters (and shapers) living on short time scales and rapidly affected by environmental changes. Therefore, different temporal and spatial scale factors need to be taken into account in any discussion of habitability. However, taphonomy, physical degradation, and metamorphism render elucidation of individual metabolic strategies in deep time arduous. Nevertheless, the 3.33 Ga Josefsdal Chert sediments reflect these varying influences, thus providing a representative window into Palaeoarchaean shallow water environments.