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Absence of significant levels of oxygen on the early Earth: the fossil record

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Environments suitable for organisms making use of sunlight as an energy source existed in abundance on the early Earth. The 3.5-3.3 Ga terrains from the Pilbara in Australia and from Barberton, South Africa, record numerous shallow water as well as littoral environments in which volcaniclastic (and chemical) sediments were deposited [1]. These sediments hosted micoorganisms that colonised different microenvironments: small colonies occur on the surfaces of volcanic particles within the pore spaces of the aqueous sediments, probably microbes had colonised the surfaces of subaqueous lava flows, and microbial mats formed on the surfaces of subaqueous and littoral sediments [2-5]. The microorganisms were well-preserved by rapid silicification. Among the microbial mats formed in shallow water to littoral environments, different mats exhibit different characteristics. One mat formed in a littoral environment (Barberton) consists of parallel oriented filaments (0.3 μm diameter, tens μm in length) with a suite of evaporite minerals embedded in its surface. Pyrite crystals are associated with the mat. Another mat formed in a mud-flat environment (Pilbara) consists of a consortium of filamentous (0.3 μm diameter, tens μm length), coccoidal (two types, one 0.5 μm diameter and the other 0.8 μm) and rod-shaped (0.8 μm length) microorganisms. No pyrite occurs in this sample but the geochemical analyses show that the environment was reducing [6].

Carbon isotope measurements in the range of -22‰ and - 30‰ from both samples could imply microbial fractionation (both anoxygenic and oxygenic photosynthesisers, as well as other types of microorganisms, fractionate carbon within this range), but non-biological processes can also partly imitate this signal and therefore caution is needed in interpreting the δ^{13}C value in isolation.

None of the microorganisms observed exhibits the morphological characteristics listed by Schopf (1993) for cyanobacteria and such structures as described by Schopf (1993) have not been observed in these shallow water to littoral where other types of microorganisms are common.

Summarising, (1) the environmental habitats for organisms with sunlight-using metabolisms existed on the early Earth (3.5-3.3 Ga), (2) filamentous microbial mats formed on the sunlight-bathed sediment surfaces, (3) the δ^{13}C signatures of the layers containing the mats are consistent with those produced by photosynthesising microorganisms, (4) the environment was reducing, and (5) there is no evidence for the presence of cyanobacteria-like organisms in these environments. It is concluded that, although non-oxygenic photosynthesising organisms could have existed in this period, there is no microfossil and geochemical evidence for the existence of oxygenic photosynthesisers, nor for significant levels of oxygen in the environment of the early Earth.

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