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Possible emergences of cyanobacteria and sulfate-reducing bacteria before the emergence of anoxygenic photoautotrophs

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The conventional view by earth scientists and biologists on the evolution of life on early Earth is that anoxygenic photoautotrophs that utilize H_2S (and/or native sulfur) as an electron donor in biosysnthesis (Reaction 1), preceded oxygenic photoautotrophs that utilize H_2O as an electron donor (Reaction 2):

$4CO_2 + 5H_2S = 4CH_2O + 4S^0 + SO_4^{2-}$ (1)

$CO_2 + H_2O = CH_2O + O_2$ (2)

This view was developed mostly because of the belief that molecular O_2 was virtually absent in the atmosphere and oceans prior to ~2.5 Ga ago, except for the minor amounts of O_2 that were produced by abiotic photodissociation of H_2O.

Thermodynamic analyses of the stability relationships among aqueous/gaseous/solid species in the H-C-O-S-Fe system suggest that Reaction (1) may become important only in environments where native sulfur and SO_4^{2-}, as well as $H_2S_{(aq)}$, become stable at $m\sigma SO_4^{2-} \geq mH_2S_{(aq)}$. Fe-bearing minerals that are in equilibrium with native sulfur are marcasite/pyrite (FeS_2), rather than pyrrhotite (FeS) or iron (hydr)oxides (e.g., $Fe(OH)_2$, FeOOH, $Fe(OH)_3$, Fe_3O_4, Fe_2O_3). Such conditions are typically created in local basins where $H_2S_{(aq)}$ is produced by sulfate-reducing bacteria utilizing SO_4^{2-} in seawater; SO_4^{2-}—rich seawater is generated from the oxidation of pyrite in igneous and sedimentary rocks during soil formation on land. Therefore, the emergence of H_2S-utilizing anoxygenic photoautotrophs likely occurred after the emergences of cyanobacteria and sulfate-reducing bacteria.