Early Archaean oxygenic photosynthesis - The observational approach.

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There is evidence for the presence of life on Earth 3800 Ma ago from the ratio of carbon isotopes in graphite from metamorphosed sediments from Isua, West Greenland (Rosing, 1999). If we accept this carbon as biogenic in origin, the chemistry of the metasediments is in part the result of metabolic interaction between life and the sedimentary environment. We might therefore be able to extract information about metabolic strategies from the geochemistry of the rocks. The first order observation is that shale, which was most probably deposited in the open ocean distant from emergent continents, contains ca. 0.5 wt. % reduced carbon. This high abundance of reduced carbon in the sediment suggests that the biological rate of productivity was high in the environment from which the sediment was derived, particularly in the light of evidence from Platinum Group Element abundances that the rate of pelagic sedimentation was high enough to mask the background cosmic contribution (Koeberl et al., 1999). A high rate of biomass production cannot be sustained by chemoautotrophy in extensive environments for long periods of time, simply because the energy required for biomass production is not available. From the observation of the high carbon contents of the protolith shale, we must conclude that photosynthesis of some form must have been active. Anoxygenic photosynthesis most likely preceded oxygenic photosynthesis in the history of life (Olson & Blankenship, 2000). Anoxygenic photosynthesis requires a chemical source of reducing power, where reduced iron, sulphur or perhaps hydrogen was most abundant in Archaean surface environment. The metasediments have far too low abundances of Fe and S to redox-balance their carbon contents, and there is thus no direct evidence that these components were involved in any significant way in the biomass production. Hydrogen could still have been a possible electron donor. From Pb isotopes it can be established that the metasediments experienced a strong enrichment in U without any introduction of Th at the time of sedimentation. The selective transport of U to the site of sedimentation required the presence of a redox-contrast in the sedimentary environment, and indicates that part of the environment was mildly oxidized in order to stabilize soluble uranyl complexes. This is not consistent with high H2 activity, but is consistent with an aquatic environment with biologic production of oxygen and the presence of organic debris to scavenge U to the sediment. There are significant quartz-magnetite banded iron formation occurrences in the section that also contain the graphitic shales. This indicates that there was a lateral separation between the environment where BIF and shale were deposited. This suggests that oxidation power could be communicated over large distances in the Isuan ocean, which is also consistent with oxygen as a waste product from abundant biomass production. Observations from the Isua supracrustals are consistent with the operation of oxygenic photosynthesis 3800 Ma ago.

References

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