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Getting out of the Extreme: Possible Indications of Pre-3700 Ma Oxygenic Photosynthesis from Isua, West Greenland

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Metamorphosed pelagic shale from the >3700 Ma Isua supracrustal belt in West Greenland contains graphite with $\delta^{13}C$ values down to -22.8‰. This isotopic signature and the mode of occurrence of the carbon particles suggest that the carbon is derived from planktonic photoautotrophic organisms. The metasediment now contains ca 0.5 wt.% reduced carbon, indicating a significant organic contribution to the original sediment. The sediments have been affected by amphibolite facies metamorphism that may have altered their trace element compositions to an unknown extent. The concentrations of redox sensitive elements in the metasediment samples are therefore not likely to represent those of the primary sediment. However, the ratio of uranium to lead, which is sensitive to redox reactions between water and sediments during sedimentation and diagenesis, can be evaluated by the isotopic composition of lead in the metasediments. The isotopic composition of Pb reflects the integrated U/Pb history of the rocks. The large difference in half-life for $\delta^{235}U$ and $\delta^{238}U$ allows distinction between Pb produced by U decay during the earliest Archaean and Pb produced during later stages in Earth history. Pb isotopes can thus be used to assess the U/Pb ratio of the sediments during the earliest Archaean. The metasediments show Pb isotopic compositions indicating high U/Pb and low Th/Pb ratios during the early Archaean followed by pronounced U-loss and Th-enrichment at ca 2800 Ma. This signature is not observed in associated basaltic units. This indicates that the high U/Pb ratio originated during sedimentation or diagenesis, probably by scavenging of U from seawater. Transport of uranium into organic-rich sediments can be driven by contrast in oxygen fugacity across the seawater sediment interface. The high U/Pb and low Th/Pb ratios of the primary sediment suggests that U was transported in solution to the site of sedimentation and fixed by reaction with organic components in the sediments. The presence of redox contrast in the sedimentary environment and the apparent transport of uranium as an oxidised solute, suggest that the oceans comprised relatively oxidised compartments before 3700 Ma. This may indicate that the Isuan planktonic organisms released oxygen to their environment, and that oxygenic photosynthesis had evolved > 3700 Ma ago.