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Oxygenic photosynthesis in the Mesoarchean confirmed by La-Ce geochronology

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Significant debate exists on the origin of oxygenic photosynthesis on Earth. Geochemical data from ancient sediments indicates localized or ephemeral photosynthetic O_2 production prior to Great Oxidation Event (GOE) ca. 2.5-2.3 billion years (Ga) ago and currently suggests Archean origins, around 3 Ga ago or earlier. However, sedimentary records of the early Earth often suffer from important preservation issues, and poor control on the timing of oxidation leaves geochemical proxy data for the ancient presence of O_2 open to significant critique. Here we report rare earth element data from three different Archean carbonate platforms (Steep rock, Red lake and Woman lake). The carbonate platforms are preserved in greenstone belts of the NW Superior Craton (Canada) and were deposited by the activity of marine photosynthetic bacteria at 2.93 Ga, 2.86 Ga, and 2.80 Ga ago. All three present clear evidence of O_2 production before the GOE in the form of significant depletions in cerium (Ce), relative to its neighbouring elements, reflecting oxidative Ce removal from ancient seawater, as occurs today. In a novel application of the ^{138}La-^{138}Ce radioisotope geochronometer, we demonstrate that La/Ce fractionation, and thus cerium oxidation, occurred at the time of deposition. These results firmly place the origin of oxygenic photosynthesis in the Mesoarchean or earlier.