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The role of sulphate in Earth's great oxidation events

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Only since the Great Oxidation Event, has Earth's crustal sulphur inventory primarily been divided into both reduced and oxidised minerals, namely iron sulphide and calcium sulphate, in varying proportions. Indeed the GOE is evidenced by the first appearance of massive calcium sulphate deposition in marginal evaporite basins after about 2.3 Ga. Evaporite sulphate 'giants' formed sporadically thereafter at times of tectonically induced basin restriction at ca. 2.0 Ga, 1.6 Ga, 0.77 Ga, 0.54 Ga and at junctures throughout the Phanerozoic Era, most recently during the Miocene Epoch between about 15 and 5 My ago. Although it is generally assumed that the oxidative sulphur cycle is balanced on long time scales, the gradual accumulation of rock sulphate after the GOE represented a net oxygen sink until erosional events or anhydrite dissolution could return sulphate to the marine environment where it could replace, via pyrite burial, the oxygen that had been consumed during pyrite weathering. Here I argue that such imbalance can be evidenced in the marine carbon isotope record, whereby positive excursions (e.g. the Lomagundi-Jatuli event) represent a loss of oxidising capacity from the exogenic system and negative excursions (here I outline several such anomalies that have been evidenced from ~1.9 Ga to ~0.56 Ga) represent a gain of oxidising capacity via sulphate reduction and pyrite burial. Because basin closure or rifting and uplift control evaporite deposition and weathering, respectively, the expansion and contraction of ocean anoxia since the GOE were likely determined by grand tectonic cycles that helped to shift the relative proportions of reduced and oxidised sulfur minerals in the crust. A good example of this can be seen in the sharp transition during the NOE when ocean oxygenation and increasing sulphate concentrations during the Ediacaran Period, presumably driven by tectonic uplift and erosion events related to the amalgamation of Gondwanaland, led eventually to widespread sulphate deposition and anoxic crises of the Ediacaran-Cambrian transition interval.