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Decoupled evolution of surface oxygenation and crustal magmatic redox during the Great Oxidation Event

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The Archean-Proterozoic transition represents one of the most profound intervals in Earth history, encompassing the emergence of modern-style plate tectonics, major climatic perturbations, and the oxygenation of the atmosphere. The redox state of magmas provides a valuable archive of deep Earth evolution, yet whether magmatic redox conditions changed systematically during the Great Oxidation Event (GOE) remains poorly constrained. Here we reconstruct magmatic redox evolution across the GOE using combined zircon-hosted apatite sulfur and zircon-based proxies from detrital zircons derived from three Archean cratons: the North China, Pilbara, and Superior cratons. Both proxies record a coherent decrease in magmatic oxygen fugacity from approximately FMQ+2 to FMQ−1 across the GOE, in stark contrast to the contemporaneous rise in atmospheric oxygen levels. Notably, this secular decrease in magmatic oxygen fugacity covaries with progressive crustal thinning both locally and globally. These observations suggest a global decoupling between surface oxidation and magmatic redox evolution during the GOE, with tectonic processes likely exerting the primary control on magmatic redox conditions. The decrease in magmatic oxygen fugacity further suggests that magmatic redox evolution was unlikely to have triggered atmospheric oxygenation, placing new constraints on proposed mechanisms for the onset of the GOE.