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Cr stable isotopic signatures of 2.32 to 2.9 Ga old marine chemical sediments

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Abundances of redox sensitive elements and their stable isotopic signatures in ancient marine sediments have recently been used to trace paleoredox conditions in Earth's surface environments. In this regard, especially stable Cr isotopes – reported as $\delta^{53}\text{Cr}$ values – have been implied to be a very sensitive tool to investigate the mode and timing of the oxygenation of the atmosphere and oceans. Frei et al. [1] proposed an onset of oxygenic Cr weathering and thus the existence of free atmospheric oxygen starting 2.75 billion years (Ga) ago based on significantly fractionated stable Cr isotopic compositions of banded iron formations (BIF) from various localities. More recently, Crowe et al. [2] suggested the first free oxygen to have appeared already 3 Ga ago based on $\delta^{53}\text{Cr}$ variations and uranium enrichments in the Ijzermijn BIF and the Nsuze paleosol of the Pongola Supergroup in South Africa. Notably, this places the oxidation of Earth's atmosphere approximately 600 million years earlier than the Great Oxidation Event (GOE), which was previously suggested to mark the first significant rise of atmospheric oxygen levels. The timing of the GOE was first approximated to an age of 2.3 Ga, based on observations of redox-sensitive elements and stable isotope variations of volatiles in the Neoproterozoic-Paleoproterozoic rock record [3]. It was later refined to an age between 2.32 and 2.45 Ga by the disappearance of mass-independent sulfur isotope fractionation (MIF-S) in authigenic sediments from that time on [4].

Planavsky et al. [5] recently reported unfractionated $\delta^{53}\text{Cr}$ values from drillcore and surface samples of the Ijzermijn BIF, Pongola Supergroup, apparently contradicting the previously published data by Crowe et al. [2]. However, direct comparison of these two datasets is difficult, because samples were taken at different localities within the Pongola Supergroup and thus might represent different depositional settings. Knowledge of depositional environments and the preservation of pristine isotope geochemical information in ancient chemical sediments, however, is crucial to investigate global redox changes in the atmosphere and the oceans over extended geological timescales.

The aim of this study was to further test the applicability of stable Cr isotopes as a sensitive paleoredox tracer by investigating ca. 2.95 to 2.32 Ga old chemical sediments from various well-studied depositional environments of the Pongola and Transvaal Supergroups, South Africa. Trace element patterns reveal typical features of Archean and Paleoproterozoic seawater, which is strong evidence for the pristine character of our samples. In combination with major element compositions and detailed mineralogical investigations we are confident that our samples are well-suited for a robust paleoenvironmental reconstruction at their time of deposition.

References:

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