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Multiple S-isotopes and trace elements of pyrite from the Witwatersrand auriferous conglomerates

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The Witwatersrand goldfields of South Africa host the world's largest accumulation of Au known. Gold is hosted in thin, but laterally continuous quartz-pyrite conglomerates (reefs) that overlie regional scale erosional surfaces. Recent models for Au mineralisation emphasize the role of Kaapvaal craton-scale weathering and erosion of continental rocks, which operated from ca. 3.1 Ga. According to these models, dissolved gold deriving from extensive weathering of mafic-ultramafic volcanic greenstone successions was transported by acid surface waters to coastal flood plains where sulfate-reducing bacteria incorporated it into sedimentary diagenetic pyrite.

Here, we present new petrographic observations, trace element and multiple S-isotope Secondary Ion Mass Spectrometry (SIMS) analyses of pyrite from different reefs that complement previous datasets, spanning in age from ca. 3.0 to 2.6 Ga. Gold contents in reworked sedimentary-diagenetic pyrite grains in the conglomerates (extending up to 7 ppm, median 1.5 ppm) and high Au/Ag (mostly ranging from 0.1 to 1) exceeding the values of Mesoarchaean-Neoarchaean marine pyrite indicate an efficient trapping of continentally derived Au in coastal plains. The large range of $\delta^{34}S$ (from --9.6 to +21.4‰) indicates that various S sources and pyrite formation mechanisms are involved, including closed-system microbial sulfate reduction. Multiple S-isotope analyses of massive detrital and sedimentary-diagenetic pyrite indicate muted mass-independent fractionation ($\Delta^{33}S$ values range from -0.8 to +0.7 ‰), which mirror previous analyses of Mesoarchaean pyrite worldwide. Further, despite a predominance of near-zero $\Delta^{33}S$ values (average -0.18 ±0.22‰) in diagenetic pyrite from the reefs, negative $\Delta^{33}S$ values (down to -0.6‰) and mildly negative $\delta^{34}S$ present in some grains indicate preferential derivation of S from atmospheric photolytic sulfate or altered continental crust, and fixation by microbial sulfate reducers.

We interpret the data in a context of large-scale craton emergence above sea level, triggering weathering, erosion, and transport of Au and other metals by rivers and run-off. Slow submergence affecting large portions of the craton would have accommodated thick shallow-marine sedimentary successions composed of quartz arenite and quartz-pyrite conglomerates. The efficient trapping of Au in coastal environments hosting microbial activity is considered a key step in forming the Au deposits of the Witwatersrand Basin.