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Geochemical and multiple sulfur isotope constraints on the formation of a 3.53 Ga old VMS deposit, Nondweni Greenstone Belt, Kaapvaal craton

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The Paleoarchean Nondweni Greenstone Belt is located at the southern margin of the Kaapvaal craton in South Africa and contains a thick sequence of ultramafic-mafic lava flows (komatiitic and tholeiitic basalts) associated with minor felsic volcanic rock units represented by massive rhyolites and deformed quartz-feldspar-mica schists. We report on a Zn-Cu-Pb-Ag VMS-type mineralization hosted within meta-rhyolite units. The sulfide mineralization is dominated by sphalerite, pyrrhotite and chalcopyrite, together with minor amounts of pyrite, galena and acanthite. The newly determined CA-ID-TIMS U-Pb zircon age of 3531.91 ± 0.46 Ma for the rhyolite unit that hosts the mineralization suggests that this small VMS deposit may be the oldest preserved of its kind. Geochemical modelling suggests a petrogenetic link between the rhyolites and the tholeiitic basaltic lava flows, where moderate degrees of partial melting of hydrothermally altered basalt at low pressures led to local felsic magma production. The multiple sulfur isotopic compositions of the tholeiitic basalts, rhyolites and sulfide mineralization are used to constrain the sulfur sources and the cycling of this element of life on the early Earth. The tholeiites record unfractionated $\delta^{34}S$ and $\Delta^{33}S$ compositions ($\delta^{34}S$ = +0.6 to +1‰ and $\Delta^{33}S$ = -0.05 to -0.03‰) consistent with a juvenile magmatic sulfur source. The rhyolites have $\delta^{34}S$ values typical of seawater-altered basaltic oceanic crust, with slightly fractionated $\Delta^{33}S$ values (-0.26 and -0.15‰). These only little fractionated $\Delta^{33}S$ compositions rule out significant input of sediment-sourced sulfur during local partial melting of the ca. 3.53 Ga old basaltic oceanic crust. In contrast, the much more negative $\Delta^{33}S$ signature (-0.53‰, which is a fully resolved S-MIF signature) recorded by the rhyolite-hosted VMS mineralization suggests a significant contribution of surficial sulfur (sediment- or seawater-derived?) to the magmatic-hydrothermal fluids that circulated through the Paleoarchean ocean-floor near an active back-arc ridge.