Genesis of a 3.53 Ga Volcanogenic Massive Sulfide Deposit in the Nondweni Greenstone Belt, Kaapvaal Craton

Thendo Netshidzivhe[1,2], Sebastian Tappe[2,3], Allan Wilson[4], Harald Strauss[5], Katie Smart[3,4], Bradley Guy[6], Fanus Viljoen[2]
[1]North-West University, Potchefstroom, South Africa, [2]University of Johannesburg, Johannesburg, South Africa, [3]Institute for Mineralogy, Technical University Bergakademie Freiberg, Freiberg, Germany, [4]University of the Witwatersrand, Johannesburg, South Africa, [5]Institute for Geology and Paleontology, University of Münster, Münster, Germany, [6]Helmholtz Institute Freiberg for Resource Technology, Freiberg, Germany

Volcanogenic massive sulfide (VMS) deposits represent some of the oldest and most significant base metal ores recorded on Earth, which commonly host exploitable quantities of Cu, Zn, Pb, Au and Ag. The association of such VMS-type mineralization with felsic volcanic rock units (massive rhyolites and deformed quartz-feldspar-mica schists) in the Paleoarchean Nondweni Greenstone Belt presents a rare opportunity to investigate the link between early Earth volcanism and seafloor metallogenesis. The Nondweni Greenstone Belt at the southern margin of the Kaapvaal craton (South Africa) consists of mafic-ultramafic volcanic rock sequences, including komatiitic and tholeiitic basalts associated with minor felsic volcanics. We investigated Zn-Cu-Pb-Ag VMS-type mineralization hosted within felsic schists exposed at an abandoned exploration shaft on the St James deposit property, where the mineralogy is dominated by sphalerite, pyrrhotite, chalcopyrite with trace amounts of pyrite, galena and acanthite. We report the first high-precision CA-ID-TIMS zircon age for the felsic volcanic rocks, suggesting a rhyolite magma eruption and VMS-style mineralization age of 3531.91±0.46 Ma. The St James base metal deposit may thus record world's oldest preserved VMS-type mineralization. Rare-earth element modelling provides evidence for a petrogenetic process whereby rhyolite melt formed through 15-17% partial melting of hydrothermally altered basalts at relatively shallow depths. Sulfur isotopic compositions ($\delta^{34}S$ and $\Delta^{33}S$) reveal mantle signatures for the tholeiitic basalts consistent with a juvenile magmatic sulfur source, whereas the rhyolites are characterized by values typical for seawater-altered basaltic oceanic crust. The base metal sulfide mineralization at St James exhibits negative $\Delta^{33}S$ signatures (-0.53 ‰) indicating a mass independent sulfur isotope (S-MIF) signature. The identified S-MIF signature implies incorporation of surficial sulfur into magmatic-hydrothermal fluids that circulated through oceanic crust in an active back-arc environment ca. 3.53 Ga ago. Our results are consistent with a metallogenetic model that involves the operation of plate tectonics during the Paleoarchean.