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Cu and Fe Isotope Contrasts Between the Paleoproterozoic Haib Porphyry Copper Deposit and Representative Phanerozoic Porphyry Systems

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Abstract:
Porphyry copper deposits are the world's primary source of copper — an essential critical metal in the green energy sector. These deposits were typically formed in the Phanerozoic Eon and occur principally at convergent plate boundaries. The Haib copper-molybdenum deposit (dated at 1920 to 1880 Ma) is one of the few porphyry copper deposits to occur in the Precambrian of Africa and is exposed at mid- to upper-crustal levels. The deposit, host to disseminated-, massive- and vein- type Cu-Mo mineralization, is situated in the Richtersveld Subprovince of the Namaqua-Natal Province. In this work we use new geochemical data, including Fe and Cu isotopes, to better understand the metallogenesis and unique temporal position of the Haib deposit. Results show that the mineralization is characterized by two phases: disseminated-massive (heavier δ^{65}Cu of 0.06–0.21 ‰ and δ^{56}Fe of 0.02–0.06 ‰) and vein-type (lighter δ^{65}Cu of -0.08–0.11 ‰ and δ^{56}Fe of 0.11– -0.01 ‰). The δ^{65}Cu signatures of the disseminated chalcopyrite grains overlap with magmatic-hydrothermal or hypogene sulphides (-1 to 1 ‰). The results indicate that the ore-forming fluid evolved and progressively precipitated various generations of sulphide minerals with fractionated δ^{65}Cu and δ^{56}Fe isotope signatures, due to sequential mineral crystallization and temperature changes related to variable equilibration of minerals and fluids. The overlap of the δ^{56}Fe signature of the disseminated sulphides with the δ^{56}Fe signature of the mantle suggests a mantle source for the copper. The limited range in the δ^{65}Cu and δ^{56}Fe signatures of the Paleoproterozoic Haib deposit, relative to Phanerozoic deposits, is consistent with the deeper levels of this porphyry system, suggesting that the shallower levels, where isotopic fractionation is likely to have occurred, have been eroded away. Cu and Fe isotopes can therefore provide important exploration proxies for estimating the crustal level of porphyry systems.