A clumped and stable isotope study on the sediment-hosted stratabound copper deposits of Malachite Pan, Namibia

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The Malachite Pan deposit near Witvlei, Namibia, is part of the late Proterozoic Kalahari Copperbelt (KCB) that extends from Klein Aub in west-central Namibia to the northwest of Botswana. It is often compared to the larger deposits of the Zambian Copperbelt and the Polish Kupferschiefer in terms of its ore mineralogy and the petrogenesis of the sulfide ores. Recent work has indicated that the originally syn-depositional ore is now largely structurally controlled and an epigenetic ore-genesis is considered, perhaps related to the greenschist facies Damaran metamorphism at 540-500 Ma. Copper mineralisation at Malachite Pan is hosted by reduced, green-grey calcareous siltstones and argillites within clastic red-beds; hematitic sandstones and conglomerates. No volcanic rocks have been identified in the vicinity, although mafic clasts within the red-beds may be of volcanic origin. C- and O-isotope compositions of whole rocks and veins within argillites have a range in values of -2 to about +2‰ for $\delta^{13}C$ (VPDB) and 13 to 16‰ for $\delta^{18}O$ (VSMOW). However, late-stage, calcite (and malachite) veins within conglomerates and argillites have $\delta^{13}C$ down to -12‰, but distinctly higher $\delta^{18}O$ up to 25‰. Clumped isotope compositions of the two compositional carbonate populations are compatible with a high-T metamorphic overprint (> 280ºC; Δ^{47} of about 0.34 to 0.38‰) for the former but distinctly lower temperatures (about 70 ºC; Δ^{47} of 0.59 to 0.69‰) for the latter. $\delta^{34}S$ (CDT) values between -28 to +5‰ for chalcopyrite-chalcocite, clearly support a bacterial sulfate reduction origin of the reduced sulfur. The above support a model with primary oxidized metal-bearing brines generated within a continental sequence being reduced within the organic-rich argillaceous layers during early diagenesis, followed by substantial secondary redistribution during metamorphism and yet a third post-peak metamorphic, lower-temperature overprint of the brittle-deformed rocks. This complex style of mineralization may be similar to other red-bed associated Cu deposits.