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Mass dependent fractionation in pyrite from the Golden Mile: Evidence for a mantle connection during gold mineralization

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The Archean Golden Mile deposit in the Kalgoorlie Terrane of Western Australia displays three distinct mineralization styles that overprint the regional chlorite-carbonate-epidote metamorphic facies: 1) Fimiston style is comprised of brittle-ductile interconnected shear zones associated with ankerite-pyrite-gold-telluride±hematite±magnetite in the proximal alteration zone and by chlorite-carbonate in the distal alteration zone, 2) Oroya style consists of breccia pipe bodies with ankerite-sericite-roescolite-pyrite-gold-telluride±pyrrhotite in the proximal and chlorite-epidote-rutile-ilmenite alteration in the distal alteration zone, and 3) Mount Charlotte mineralisation style which consists of sheeted quartz vein arrays with proximal ankerite-sericite±albite-pyrite-pyrrhotite±gold alteration zones.

In all three mineralization styles, pyrite is in equilibrium with gold, therefore has been used as a proxy to record $\delta^{34}S$, $\Delta^{33}S$ and $\Delta^{36}S$ isotopic evolution in the Golden Mile. In addition, multiple sulphur analyses were conducted on syngenetic pyrite of the Kapai Slate. For gold-pyrite, both the large range in $\delta^{34}S$ pyrite analyses (from -12.60 to +23.51 ‰) and the oxide-sulphide-sulphate paragenesis suggests that both oxidizing ($\delta^{34}S$ < 0‰) and reducing ore forming conditions ($\delta^{34}S$ > 0‰) were prevalent. The negative $\delta^{34}S$ values that predominate in Fimiston style mineralization are compatible with dominant oxidized fluids during the ore-forming process, as evidenced by the presence of hematite-pyrite-magnetite-gold assemblage and fluid inclusion evidence for phase separation during D2 shear zone movement. Conversely, the positive $\delta^{34}S$ values that dominate in the Mount Charlotte and Oroya mineralization styles reflects the reduced oxidation state, as evidenced by the presence of pyrite-pyrrhotite-gold assemblages. The range of $\Delta^{33}S$ values (from -1.05 to +1.15 ‰) and the $\Delta^{33}S$-$\Delta^{36}S$ array (r^2 ~0.4) suggest that various sulphur sources are involved in the formation of pyrite at the Golden Mile. Gold-related pyrites in the Fimiston, Mount Charlotte and Oroya Stage III mineralization styles yield values of $\Delta^{33}S$ close to the Mass Dependent Fractionation (MDF) field ($\Delta^{33}S$≈0 ‰) for a large range of $\delta^{34}S$ values. Conversely, the $\Delta^{33}S$ values in pyrite from the Kapai Slate and early, stages I and II in the Oroya style record $\Delta^{33}S$ values with recognisable Mass Independent Fractionation (MIF). Syngenetic pyrite from the Kapai Slate yield positive $\Delta^{33}S$ values (mean +1.76 ‰) likely related to photolytic reduction of SO_2 to S_8, whereas Stage I pyrite of the Oroya style yield negative $\Delta^{33}S$ values (mean -1.00 ‰) and Stage II pyrite display both positive and negative $\Delta^{33}S$ values (from -0.90 to +1.06 ‰, mean+0.4 ‰). Negative $\Delta^{33}S$ values are commonly interpreted as photochemically reduced sulphur deposited in a seawater environment. We propose that the $\Delta^{33}S$-MIF values of pyrite in the Kapai Slate and stages I and II in the Oroya style mineralization reflect the atmospheric conditions during the deposition of sedimentary and volcanic rocks in the Golden Mile, whereas the gold related pyrite $\Delta^{33}S$ values inside the MDF field are compatible with a mantle source. The presence of a prominent lamprophyre dike in the Oroya Shoot, broadly synchronous with Oroya style mineralization 2,642±6 Ma, is also compatible with a mantle connection.