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Radiogenic and Stable Isotope Constraints on the Genesis of the Eloise Cu-Au Deposit, Cloncurry District, Northwest Queensland

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Abstract

New radiogenic ($^{40}Ar/^{39}Ar$) and stable (oxygen, hydrogen, and sulfur) isotope analyses of metamorphic and metasomatic minerals constrain the age, metasomatic evolution, and genesis of the Eloise Cu-Au deposit (3.1 Mt @ 5.5% Cu, 1.4 g/t Au, and 16 g/t Ag). Biotite from a pre- to syn-D_2-stage vein has an $^{40}Ar/^{39}Ar$ age of 1555 ± 4 Ma which is interpreted to coincide with a regional metamorphic event synchronous with D_2. Six later stages of alteration and mineralization are recognized, all of which postdate peak metamorphism and D_2. Stages I to III are volumetrically the most significant and comprise early albitization (stage I), quartz-hornblende-biotite veins and alteration (stage II), and Cu-Au mineralization (stage III). Stages IV, V, and VI are localized vein events and postdate the main Cu-Au mineralization. Stage II vein and alteration hornblendes have $^{40}Ar/^{39}Ar$ ages of 1530 ± 3 Ma. Biotite from the same stage has an $^{40}Ar/^{39}Ar$ age of 1521 ± 3 Ma. Muscovite from a postore shear zone has an $^{40}Ar/^{39}Ar$ age of 1514 ± 3 Ma. These results provide a maximum (ca. 1530 Ma) and minimum (ca. 1514 Ma) age for the mineralizing event. However, the intimate relationship between stage II mafic-silicate veins and alteration and the stage III Cu-Au event combined with fluid inclusion results which indicate that a cooling, evolving high-salinity fluid was responsible for both stages suggests that the older age is likely to be closer to the age of mineralization. The stage II biotite age of ca. 1521 Ma is interpreted to record thermal resetting during postore ductile deformation. The results suggest that micas in the Cloncurry district are more susceptible to later thermal resetting than amphiboles which may have significant implications for deposits which have only been dated by micas.

Quartz from stages II, III, and IV have $\delta^{18}O_{quartz}$ values ranging between 10.1 and 11.9 per mil. Stage II biotite has a lower $\delta^{18}O$ composition (5.6‰) than biotite from a pre-D_2 vein (6.9‰), but both have identical δD compositions (–84‰). Stage II hornblende has lower $\delta^{18}O$ (6.8 and 7.4‰) and δD (–88 and –90‰) values than does stage III actinolite (8.0 and –84‰, respectively). The $\delta^{34}S$ values for chalcopyrite, pyrrhotite, and pyrite fall in a narrow range between 0.0 and 2.3 per mil. A distinct trend can be recognized with $\delta^{34}S$ values becoming progressively greater from south to north, thus reflecting the zoned alteration system (magnetite-pyrite-rich in the south through to pyrrhotite-rich in the north). The change in mineralogy and sulfur isotope values may be due to cooling and sulfidation processes which resulted in changes in oxygen and sulfur fugacities. The oxygen, hydrogen, and sulfur isotope data, combined with high-temperature and high-salinity fluid inclusion data, indicate a predominantly magmatic origin for the ore forming fluids. The deposit is interpreted to have formed from magmatic hydrothermal fluids which were tapped by deep-seated crustal structures.