Kyanite Alteration as an Indicator for Saline Fluids and Metal Transport; Case Studies from the Central African Copperbelt

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The Central African Copperbelt (CACB) is the world's primary source of Cu and Co, producing about 70% of the metal, which is critical for battery production and other decarbonisation technologies. Highly saline fluids are associated with extensive mineralisation and alteration in the CACB. The intimate association of kyanite-bearing veins and Cu-sulphide mineralisation at low pressure and temperature indicates that unusual thermodynamic conditions facilitated the mobility of traditionally immobile elements such as Al, Ti and Ge, as well as mobilising technology metals such as Cu, Co, and Ni.

Kyanite is traditionally considered a high-pressure and high-temperature Al_2SiO_5 mineral polymorph. Common kyanite-forming reactions such as pyrophyllite or chlorite dehydration take place at ~400°C and >600°C respectively. In this study, kyanite is observed in low-temperature (i.e., sub-greenschist facies) carbonate and carbonaceous siliciclastic lithologies, hosted in post-evaporitic breccia. Kyanite occurs in hydrothermal kyanite-quartz-magnesite-chalcopyrite-monazite veins, within fractures associated with quartz + pyrite, and as porphyroblasts in host rock lithologies. The occurrence of kyanite in low-pressure–temperature rocks indicates unusual conditions of kyanite growth.

Extensive kyanite alteration is also seen throughout the higher-temperature portions of the Copperbelt in northern Zambia, where kyanite-nickel sulphide and kyanite-biotite-copper sulphide assemblages are observed in highly altered regions of intense fluid flow. Cathodoluminescence imaging, laser ablation mass spectrometry, Raman spectroscopy, and U-Pb monazite dating are used in this study to unravel the complex vein paragenesis and characterise the multiple textural generations of kyanite.

Understanding the paragenesis of kyanite in relation to Cu and Ni and the unusual thermodynamic conditions required for low-temperature kyanite growth and Al-mobilisation has implications for exploration of technology metals, as well as metal mobility in highly saline systems. The interpretation that kyanite can be part of an alteration assemblage is also potentially useful as an indicator of highly saline fluids and intense fluid flow.