

SEG 2023 Conference: Resourcing the Green Transition

Hydrothermal Apatite: A Distal Proxy for Potassic Alteration in Porphyry Cu Systems?

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The chemistry of detrital apatite is a promising tool for identifying traces of porphyry copper deposits (PCDs) in distal settings. Apatite is particularly useful because it is abundant in PCD environments and has a large variety of trace element substitutions that re-equilibrate with hydrothermal fluids. However, the extent to which apatites from different alteration zones around PCDs have unique chemical identities has been understudied. This precludes the separation of ore-bearing potassic alteration from un-mineralized alteration in detrital sediments.

In this study, we investigated the chemistry of apatites in fresh and altered rocks from PCDs of the Baguio Mineral District, Philippines. Unaltered rocks contain fresh magmatic apatite with enriched Th, Sr, Mg, and LREEs (>3,500 ppm). By contrast, apatites from altered samples are depleted in LREEs, Th, XOH, and Sr and enriched in XF and HREEs. Specifically, apatites from central ore-associated potassic alteration were most enriched in XF, Mn (>1,500 ppm), and HREEs (e.g., Yb >10 ppm). This reflects changes in fluid temperature, pH, and composition with increasing proximity towards the deposit centre.

Using linear discriminant analysis, we created a model for predicting alteration assemblage based on apatite chemistry. The model was constructed using a global apatite database including metamorphic, magmatic, and PCD terranes to test the effectiveness of this tool in detrital mineral studies. An overall accuracy of 89% was achieved for this model, effectively identifying apatites from PCDs. Furthermore, apatites from potassic alteration were well delineated from all other affinities (95% accuracy, false positive rate <0.01).

Our results demonstrate that apatites from economically significant potassic alteration are markedly distinct from those in barren propylitic and non-porphyry terranes. This furthers the utility of detrital apatite not only for recognising PCD alteration, but also for identifying the presence of ore-bearing alteration from afar.