Cobalt Distribution and Enrichment in Skarn Iron Deposits: A Case Study of the Zhuchong Skarn Fe-Cu-Co Deposit, Eastern China

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Skarn Fe deposits are important sources of Co reserves, accounting for approximately 15% of such deposits. Here we present a comprehensive investigation into the spatial distribution and occurrence of cobalt in a typical skarn deposit, the Zhuchong Fe-Cu-Co deposit, located in Eastern China. This deposit contains 50 Mt of Fe @50.5%, 4.3 Mt of Cu @1.15%, and ~9,700 t of Co metal with a grade of 0.019%. The trend of Co contents in Zhuchong ore and gangue minerals is as follows: pyrite> pyrrhotite> sphalerite> magnetite > diopside > chalcopyrite> garnet. Mass balance calculations revealed that pyrite is the most significant Co carrier in Zhuchong, accounting for ~5,000 tonnage of Co (average Co ~7,000 ppm). A negative correlation between Co and Fe in pyrite indicated that the dominant substitution for Co in pyrite is $Fe^{2+} \leftrightarrow Co^{2+}$. Although magnetite has low Co content, it is the most abundant ore mineral in Zhuchong, accounting for approximately half of the total Co resources. Depth profile analysis found that the Co-enriched pyrite is mainly developed in the contact zone between the diorite pluton and the skarn iron orebody, with pyrite far from the pluton having lower Co contents ranging from several ppm to thousands of ppm. Co in pyrite is temperature dependent. The Co/Ni ratios of pyrite in Zhuchong range from 0.001 to 10,000, indicating that Co/Ni ratio is not a reliable indicator for distinguishing hydrothermal and sedimentary pyrite. Overall, this study demonstrates that estimating the amount of cobalt resources in each mineral phase of skarn iron deposits combined with economic availability is crucial for accurately evaluating the economic value of the critical metal Co in such deposits. Recovery and utilization of Co as a by-product from skarn iron deposits has a broad future, especially given current demand for cobalt.