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Contrasting Skarn Fe Fertilities of Coeval Intrusive Rocks in the Laiwu Ore Field, North China Craton: Insights from Zircon and Apatite compositions and implications for exploration

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The key processes that lead to skarn Fe mineralization, as well as how to confirm the target for skarn Fe exploration, are still a mystery. To address these issues, we present an integrated dataset of zircon and apatite and whole-rock geochemical results for diorites from both the skarn Fe deposit-related Kuangshan and barren Jiaoyu, Jinniushan, and Tietonggou plutons in the Laiwu ore-field.

Both ore-related and barren intrusions were primarily produced by partial melting of an enriched lithosphere mantle with varying crustal contamination, according to a combination of bulk rock compositional and Sr-Nd isotopic features. Magma mixing modelling based on whole rock Sr-Nd isotopes suggests that middle Ordovician evaporite-bearing carbonates were particularly assimilated into Kuangshan and Jinniushan diorites than Jiaoyu and Tietonggou diorites.

Bulk rock, apatite, and zircon compositions revealed that both ore-related and barren intrusions were hydrous and oxidized. Initial magma Cl concentrations, calculated by apatite compositions, of Kuangshan (0.15-0.77 wt%) and Jinniushan diorite (0.30-0.71 wt%) are higher than Jiaoyu (0.15-0.48 wt%) and Tietonggou diorite (0.06-0.36 wt%). For Kuangshan diorite, calculated magmatic Cl concentrations and apatite OH contents drop as magma evolves. In barren diorites, on the other hand, opposing trends are detected. These opposing tendencies suggest that fluids are expelled more efficiently from Kuangshan diorite than from barren equivalents. These findings show that increased Cl concentrations of magmas, as well as the effective separation of Cl-rich aqueous fluids from magmas, may have play a key role in the formation of skarn Fe deposits.

The present results indicate fertility-indicator signatures of zircon and apatite, which have previously been used to identify fertile intrusions associated with porphyry Cu deposits, might likewise be used to confirm fertile intrusions related to skarn Fe deposits. However, our findings suggest that those fertility indicators are ineffective in separating barren intrusions with fertile characteristics (i.e., H_2O, Cl-rich), such as Jinniushan diorite, from fertile equivalents. Given the separation of volatile-rich magmatic fluids is a key stage leading to mineralization, we argue that declines in magmatic Cl and apatite OH concentrations with magma evolution might be useful in refining target for exploration.