

Trace Element and Isotope Compositions of Apatite in the Chalukou Porphyry Deposit

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The Chalukou deposit is a supergiant porphyry Mo deposit located in northeastern China, with Mo reserves of 2.46 Mt at an average grade of 0.087%. In this study, we report the major and trace element compositions, together with Sr-Nd-O isotopes of apatite from different intrusive rocks, aiming to quantitatively constrain the variability in metallogenic potential among different magmatic pulses. The results show that magmatic apatite from ore-forming intrusions is characterized by high Cl, SO₃, and Ce₂O₃ contents, indicating a volatile-rich nature of the ore-forming magmas. In contrast, hydrothermal apatite exhibits high F but extremely low Cl and SO₃ contents, consistent with the widespread occurrence of fluorite mineralization in the deposit, and suggesting that the exsolved ore-forming fluids were F-rich systems. This study presents the oxygen isotopic compositions of apatite in a porphyry Mo system, which range from -0.1‰ to 11.8‰. The large variation in oxygen isotope fractionation can be attributed, on the one hand, to the involvement of low- $\delta^{18}\text{O}$ meteoric water during alteration, as evidenced by extremely low $\delta^{18}\text{O}$ values in some altered granite porphyry; on the other hand, it is mainly controlled by Rayleigh fractionation during hydrothermal processes, leading to elevated $\delta^{18}\text{O}$ values in hydrothermal apatite. The O-Sr-Nd isotopic variations indicate significant differences in source characteristics between ore-forming and barren intrusions. The relatively high $\delta^{18}\text{O}$ values of the barren intrusions may reflect crustal contamination, as crustal materials generally possess higher oxygen isotope compositions. In contrast, the distinctly low $\delta^{18}\text{O}$ signatures of the ore-forming intrusions are likely related to metasomatism by fluids derived from altered oceanic crust. Such processes not only lower the $\delta^{18}\text{O}$ values of the magma source but also, given the water-rich nature of altered oceanic crust, supply substantial fluids and volatiles essential for mineralization.