

Controls of Coupled Deep and Shallow Processes on Giant Copper Skarn System in the Tongling District: Insights From Geodynamics Simulations

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Copper skarn deposits are an important type of copper resource. The Tongling copper district represents the Chinese most significant copper skarn ore cluster, where the copper mining history is over 2000 years. In the Tongling district, many small dioritic intrusions host numerous skarn orebodies of various size in highly heterogeneous and complex spatial distributions. The Dongguashan deposit, the largest one in the district, is characterized by the unique giant stratiform orebody and its distinctive ore constituents as juxtaposition of massive sulfide ores with sulfide-bearing serpentinite ores.

While magmatic intrusions are universally recognized as the primary driver for skarn mineralization, the distinct petrological and geochemical differences among mineralized intrusions in Tongling have led previous studies to attribute the district-scale mineralization heterogeneity primarily to variations in magma source. However, our recent magnetotelluric survey reveals that all mineralized stocks are connected to a unified, giant magma chamber at depth, implying a common magmatic source. This necessitates a shift in focus from source composition to the dynamic mechanical and hydrological processes during magma cooling and fluid exsolution to explain the observed heterogeneity of mineralization.

To investigate these magma-driven hydrothermal processes at the district scale, we constructed a coupled mechano-thermo-hydrological model to simulate the cooling of the entire magma system within its host rocks. Our dynamic simulations demonstrate that the spatial distribution of skarn orebodies is fundamentally controlled by the dynamic coupling of deep and shallow physical processes. Key ore-controlling factors include the relative position of individual stock intrusions with respect to the deep parental magma chamber and the local hydrological environment surrounding these intrusions. The model identifies that favorable orebody locations correspond to zones of maximum fluid focusing and elevated temperature gradients. The Dongguashan ore field is shown to possess the optimal configuration for this deep-shallow coupling, thereby explaining its exceptional endowment.