

Geodynamic Controls on Metallogenic Loci in Magmatic-Metamorphic Domes: Insights from Thermo-Mechanical Modeling

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Magmatic-metamorphic domes in extensional settings serve as critical tectonic loci for large-scale hydrothermal mineralization. In the Qin-Hang Metallogenic Belt of the Jiangnan Orogen (South China), intense shear deformation and crustal exhumation are widely recognized as primary drivers of fluid flow. However, the quantitative spatiotemporal constraints linking these deep-seated geodynamic processes to shallow ore-forming systems remain poorly resolved. Utilizing coupled thermo-mechanical finite-element modeling based on the Lianyunshan dome, we define the precise spatiotemporal windows wherein metal source activation, highly permeable structural pathways, and favorable physicochemical trapping conditions synchronously intersect. The modeled fluid trajectories and predicted highly prospective zones exhibit a striking spatial correlation with the known distribution of polymetallic deposits along the Changping fault zone.

Our numerical simulations reveal that optimal conditions for mineralization are dictated by the dynamic interplay between master detachment faulting and deep magmatic emplacement. The structural architecture and the resultant metallogenic windows are fundamentally controlled by regional extension rates, structural inheritance, and lithospheric rheology. Crucially, we delineate two first-order metallogenic loci (primary windows): (1) the exhumed footwall domain of the master active normal fault, and (2) the distal extensional margin characterized by conjugate normal fault arrays. These specific domains facilitate the optimal spatiotemporal convergence of mobilized metal sources, focused fluid channeling, and effective precipitation sites. Conversely, second-order targets (subsidiary windows)—situated within hanging-wall splay fault systems and internal dome fracture networks—display lower metallogenic endowment. This is primarily attributed to their structural complexity, transient permeability, and comparatively brief lifespans of active deformation. Parametric sensitivity analyses corroborate the robustness of these structure-mineralization relationships across varying geodynamic boundary conditions. Ultimately, this integration of high-resolution geodynamic modeling provides a rigorous, quantitative targeting framework for polymetallic exploration and advances our understanding of fluid-structure-rock coupling in complex extensional regimes.