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Key factors controlling the late Mesozoic uranium mineralization potential in the Luzong basin, South China

XIN XIONG[1] AND DAN YANG[2]

[1]Institute of Mineral Resources, Academy of Geological Sciences

[2]MNR Key Laboratory of Metallogeny and Mineral Assessment，Institute of Mineral Resources, Chinese Academy of Geological Sciencesal Sciences

The Late Mesozoic Luzong basin in the Middle-Lower Yangtze River Metallogenic Belt hosts syenitic and granitic intrusions with contrasting uranium endowments, yet the controls on this fertility spectrum remain debated. This study integrates geochronological, whole-rock geochemical, Sr–Nd–Hf isotopic, and zircon geochemical data from 123–133 Ma intrusive rocks to establish an integrated genetic model for uranium mineralization potential in back-arc extensional settings.

Two petrogenetic suites are identified: (1) 128–133 Ma highly fractionated I-type granites (U-barren to subeconomic), and (2) 123–129 Ma A-type granites (U-barren to U-bearing). These suites exhibit a clear southeastward spatiotemporal migration, coinciding with the transtensional to extensional transition. U-mineralized syenites originated from partial melting of enriched lithospheric mantle metasomatized during Neoproterozoic subduction, whereas U-bearing A-type granites resulted from mixing of this metasomatized mantle with juvenile lower crust, triggered by paleo-Pacific slab rollback. The evolving extensional regime is the first-order control on the spatial heterogeneity of uranium fertility.

U-bearing A-type granites are characterized by highly fractionated magmas with elevated silica and alkali contents, low Sr/Y ratios, and strong negative Eu anomalies, reflecting low magmatic water content and plagioclase-dominated fractionation. Their low zircon ΔFMQ values indicate extensive differentiation under reduced conditions—a critical threshold distinguishing high-temperature (syenite-hosted) from low-temperature (A-type granite-hosted) uranium mineralization styles under favorable tectonic and source conditions.

Despite sharing overlapping Sr–Nd–Hf–O isotopic signatures, highly differentiated compositions, and similarly reduced redox states with U-bearing systems, some A-type intrusions remain barren. Their ore-forming capacity is intrinsically limited by subeconomic pluton dimensions and inefficient fracture permeability, inhibiting uranium mobilization into hydrothermal fluids. We propose that primary uranium enrichment is governed by the convergence of extensional tectonics, mantle-crust interaction, extreme fractional crystallization, reduced conditions, and sufficient magma volume with permeable pathways. This model provides an exploration framework applicable to analogous back-arc extensional settings worldwide.

Figure. 1 Photographs and micrographs of the Liutun U-mineralized syenites and Huangmeijian U-bearing A-type granites from the Luzong basin. Abbreviations: Zrn = zircon; Uth = uranothorite; Th = thorite.

