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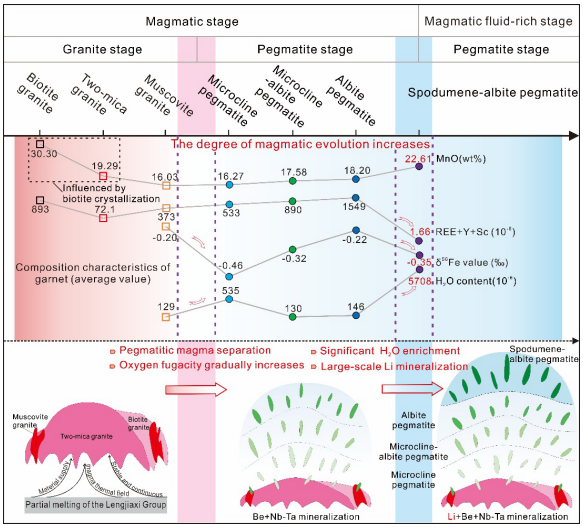
Magmatic evolution and rare-metal mineralization in a granite-pegmatite system: Insights from the Mufushan complex, South China

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Pegmatites, commonly regarded as products of highly evolved granitic magmas, together with their parental granites form a continuous granite-pegmatite magmatic system. However, magmatic evolution and rare-metal mineralization in granite-pegmatite systems typically involve complex H_2O enrichment and changes in physicochemical conditions, which have led to ongoing debates on pegmatite rare-metal mineralization mechanisms.

The Mufushan district, located in the middle central Jiangnan Orogen, represents one of the most important rare-metal ore concentration areas in Southeast China. Multistage homologous magmatism formed a large composite granitic complex that records a complete granite-pegmatite system, making it an ideal natural laboratory for studying magmatic evolution and rare-metal mineralization in granite-pegmatite systems.

In this study, garnet and apatite, common accessory minerals in granites and pegmatites, are used to constrain the magmatic evolution and rare-metal mineralization of the Mufushan complex. The results show that garnet MnO and REE contents, as well as apatite REE contents and Y/Ho ratios, display continuous evolutionary trends, indicating that the granite-pegmatite system in Mufushan complex formed through continuous fractional crystallization of multistage homologous magma (Fig. 1). Fractional crystallization represents the fundamental process controlling pegmatite formation and the initial enrichment of rare metals. During magmatic evolution from granites to pegmatites, systematic variations in garnet $\delta^{56}Fe$ values, $Fe^{3+}/\Sigma Fe$ ratios, and apatite Ce-Eu anomalies indicate a gradual increase in oxygen fugacity, reaching relatively high levels during the spodumene-albite pegmatite stage. At the same time, melts at this stage exhibit significant H_2O enrichment and may have experienced minor fluid exsolution, marking a transition from the magmatic stage to the magmatic-hydrothermal transitional stage. Superimposed on continuous fractional crystallization, the increase in oxygen fugacity and significant H_2O enrichment in late-stage pegmatitic melts enhanced the enrichment and mobility of Li and other rare metals, providing favorable conditions for large-scale spodumene crystallization and Li mineralization[1]. These results provide new insights into rare-metal mineralization processes in granite-pegmatite systems and may have important implications for the genesis of pegmatite-type rare-metal deposits associated with large granitic complex worldwide.

[1]Jiang PF, Li P, Li JK et al. (2025), GSA Bulletin,