Exploring Two-Liquid Separation of Fluorosilicate Melts: Advancing Phase Relationships and Mineralization Insights for Granite Hosted REE Deposits

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The accelerating demand for rare earth elements (REE), driven by technological advancements, has heightened interest in unconventional deposits such as A-type granite-hosted REE systems. These granites can exhibit extreme REE enrichment, often attributed to fluorosilicate-silicate immiscible magmas. However, the degree of extreme REE enrichment seen in nature has proven challenging to replicate experimentally, motivating further investigation into fluorosilicate immiscible melt evolution.

This study applies novel experimental techniques to investigate thermal gradient-driven separation of immiscible melts and trace element partitioning. The results unexpectedly redefined critical aspects of the fluorosilicate-silicate immiscible system. Most notably, the fluorosilicate-silicate miscibility gap terminates at a peritectic reaction near ~940°C, significantly higher than the previously interpreted ~600°C. The research also constrains temperature-dependent fluorite saturation within the miscibility gap, providing a framework to reinterpret previously misunderstood fast-cooling metastable immiscibility and explain why thermal gradient separation of fluorine-rich immiscible melts was ineffective.

Overall, the study reveals a widening miscibility gap at temperatures above 1300°C, terminating below ~940°C, and prompts a reevaluation of REE enrichment processes in A-type granites. These results support a genetic model where progressive REE-induced solvus depression may allow initially low-REE systems to evolve into the highly enriched compositions observed in nature, although further experimental work is required to confirm this. By redefining the miscibility gap and constraining trace element partitioning controls, this research offers new insights into the genesis of granite-hosted REE systems and advances the broader understanding of fluorine-rich magmatic evolution.