

Genesis and REE enrichment process of NYF-type pegmatite in Shanghu, Xinjiang: constraints from accessory minerals

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Granite pegmatites are critical reservoirs of rare metals, rare earth elements (REEs), and precious stones. The Shanghu NYF-type (Nb, Y, F-enriched) pegmatite in Korla, Xinjiang, classified as an REE subtype, is hosted within migmatized biotite amphibolite plagioclase of the Kuruktag Block (Tarim Craton). Its mineral assemblage comprises quartz (~40%), feldspar (sericitization, ~30%), and accessory REE-rich minerals (allanite, monazite, chevkinite), Ti-bearing (ilmenite, titanite), and Zr-bearing phases (zircon, thorite). These accessory minerals exhibit heterogeneous distribution, showing localized enrichment and mineralization, with evident hydrothermal alteration. The magma composition is characterized by high concentrations of Ca, Al, REEs, and Ti. During magmatic evolution, early monazite crystallization depleted phosphorus, while ilmenite and chevkinite co-crystallization reduced titanium. Increasing calcium promoted allanite formation, lowering REE concentrations until REE-poor apatite and feldspar crystallized. Hydrothermal alteration modifies accessory minerals such as monazite, which frequently exhibits a coronal ring structure: the residual core of monazite surrounded by secondary apatite and allanite rims, and contains numerous micro-thorite inclusions. Using TIMA and mass-balance calculations reveal that the hydrothermal fluid system is enriched in Ca, Al, and Si, and is more oxidized compared to the magmatic stage. In situ major and trace element analyses of minerals indicate that the REE content of primary REE-minerals substantially higher than secondary REE-minerals. Secondary allanite tends towards clinozoisite, while metasomatic residual monazite shows a transformation trend towards huttonite, further confirming the characteristics of Si enrichment and oxidation in hydrothermal fluid. The $\epsilon\text{Nd}(t)$ values (-23.7 to -22.3) of secondary allanite compare to those primary allanite, monazite, and chevkinite (-23.3 to -22.8), suggesting a genetic relationship between the metasomatic hydrothermal fluids and magma. These $\epsilon\text{Nd}(t)$ values are also similar to those of the basement granulite of the Tarim Craton (-24.4 to -22.4), but differ markedly from the wall rock (-14.8 to -11.2), indicating former is pegmatitic origin rock. Zircon U-Pb dating (1825 ± 4 Ma) correlates with the assembly of Columbia. We conclude that the NYF-type granite pegmatite in Shanghu, Xinjiang originated from deep crustal melting during Columbia assembly. Subsequent magmatic crystallization and differentiation facilitated the crystallization of rare earth minerals.