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From Source to Crystallization: REE Distribution in Southeast Asian Tin Belt Magmas

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Rare earth elements (REE) enrichment is a defining characteristic of magmas within the Southeast Asian Tin Belt, yet the processes driving this metal concentration remain poorly understood. In this study, we investigate the petrological and geochemical characteristics of magmatic suites from two representative areas—Belitung and West Borneo, to understand the tectonic and magmatic controls on the REE budgets in the region. The Belitung granitoids exhibit S-type affinities and strong association with syn-collisional setting. These magmas show elevated REE and other incompatible elements, coupled with depleted Sr–Ba and strong negative Eu anomalies. These characteristics culminate in substantially higher ΣREE values, suggesting late-stage, multi-phase feldspar fractionation as the primary enrichment mechanism. On the other hand, the West Borneo granitoids, predominantly I-type, show lower levels of melt evolution and ΣREE, with strong geochemical signals of subduction-related early-arc magmatism. REE-enriched phases are present, but volumetrically low, in Belitung magmas, and are absent in the West Borneo suite. Our in-situ crystal analysis of non-REE-bearing major rock-forming phases (e.g., amphibole, plagioclase, K-feldspar, and biotite) highlights amphibole as a key REE-hosting phase in volatile-rich magmas. This evidence suggests that the delayed crystallization of REE-bearing accessory minerals may elevate REE in residual melts which likely increases REE uptake of these major phases. Finally, our petrogenetic model suggests that distinct tectonic context controls on magma evolution may result in the contrasting REE signatures between Belitung and West Borneo, providing a solid framework for targeted critical-mineral exploration in Southeast Asia.