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Characterizing a new type of nelsonite recognized in the Damiao anorthosite complex, North China Craton, with implications for the genesis of giant magmatic Fe-Ti oxide deposits

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Abstract

Nelsonite (Fe-Ti oxide-apatite rock) devoid of silicates offers a rare opportunity to investigate the magma processes for the formation of magmatic Fe-Ti oxide deposits. Both fractional crystallization and silicate liquid immiscibility have been put forward, but the lack of robust evidence has hindered unambiguously distinguishing the role of these two processes in Fe-Ti mineralization. The nelsonite and associated Fe-Ti-P-rich rocks hosted in the Proterozoic Damiao anorthosite complex represent a typical example for studying Fe-Ti ore-forming processes. We recognized a new type of nelsonite (type-I) in the Damiao complex, which is distinct from the two known types of nelsonite (type-II and type-III) from the same complex. The type-I nelsonite is characterized by its coexistence with oxide-apatite gabbronorite and granite in the same dike, and all these rocks have identical emplacement ages (1740 ± 7 Ma), subparallel REE patterns, and major-element compositions lacking intermediate compositions, suggesting derivation from conjugate Fe- and Si-rich melts generated by silicate liquid immiscibility. The large type-II nelsonite bodies form irregular dikes along fractures in anorthosite and constitute the major ore type. The type-III nelsonite occurs as conformable layers or pods within oxide-apatite gabbronorite and pyroxenite, and occupies the end part of the type-II dike. The latter two types of nelsonites formed by extensive fractional crystallization of residual magma with crystal accumulation and subsequent hydrothermal replacement. During residual magma evolution, silicate liquid immiscibility was crucial for Fe-Ti-P enrichment, fractional crystallization was responsible for enhancing oxide-apatite concentrations, and hydrothermal replacement was effective for mobilizing oxide-apatite concentrations. Our newly recognized nelsonite provides an unambiguous, outcrop-scale, field evidence for the operation of silicate liquid immiscibility process. We show that giant magmatic Fe-Ti oxide orebodies can form by a combination of processes involving silicate liquid immiscibility, fractional crystallization and hydrothermal mobilization.

Keyword: Fe-Ti oxide deposits, nelsonite, silicate liquid immiscibility, fractional crystallization, anorthosite