Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.36780

Magmatic controls on REE-rich apatite in the Neoarchean Nekuashu intrusion, northern Canada: from Fe–Mg–Ti–P-rich magmatic domains to magnetitic nelsonite assemblages

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Apatite is a common accessory mineral in igneous rocks that readily incorporates REE and other trace elements, making it a sensitive recorder of magmatic evolution. Here, we present new major- and trace-element compositions of magmatic apatite from the Neoarchean (ca. 2.55 Ga) alkalinitic Nekuashu intrusion in the Core Zone of the southwestern Churchill Province (Quebec). The Nekuashu intrusion represents an important precursor to later Mesoproterozoic peralkaline magmatism in the region [1], including the REE–Zr–Nb-rich Strange Lake pluton (ca. 1.24 Ga).

Electron microprobe analysis and laser ablation–inductively coupled plasma–mass spectrometry were conducted on three texturally distinct apatite populations, all interpreted as primary magmatic: (A) apatite hosted in augite monzonite; (B) apatite incorporated in magnetite–ilmenite–pyroxene blebs; and (C) apatite occurring within magnetite and ilmenite (magnetitic nelsonite) zones, with Types B and C themselves hosted by the augite monzonite. The resulting dataset shows that these textural populations correspond to distinct geochemical signatures. All apatite types are REE-rich (average ΣREE=0.82±0.46 wt.%, up to 1.68 wt.%) and display chondrite-normalized, LREE-enriched "birdwing-shaped" patterns with pronounced negative Eu anomalies.

Systematic compositional differences among apatite populations suggest contrasting crystallization processes. Bleb-hosted apatite is characterized by higher concentrations of P_2O_5, CaO, and Sr, but lower concentrations of SiO_2, F, ΣREE, Y, Th, U, and Pb than both host-rock apatite and nelsonite apatite, consistent with crystallization from relatively less evolved, Fe–Mg–Ti–P-rich primitive magmatic domains. Host-rock apatite generally displays intermediate compositions for these elements, bridging bleb-hosted and nelsonite apatite. In contrast, nelsonite apatite typically shows the highest SiO_2, F, ΣREE, Y, Th, U, and Pb contents and defines a distinct REE-enriched endmember, with the greatest ΣREE concentrations, particularly in the LREE. The elevated ΣREE and LREE signatures reflect late-stage concentration of incompatible elements within Fe–Ti–P-rich residual melts or immiscible liquids that crystallized as nelsonitic assemblages.

These results demonstrate that apatite from the Nekuashu intrusion records a progressive magmatic evolution, from early crystallization in Fe–Mg–Ti–P-rich domains to pronounced REE enrichment in magnetitic nelsonite assemblages.

[1] Mohammadi, Corrigan, Sappin, Rogers, Rayner, Sandeman, Wodicka (2025), *Economic Geology (*(2025) 120 (2): 449–473)

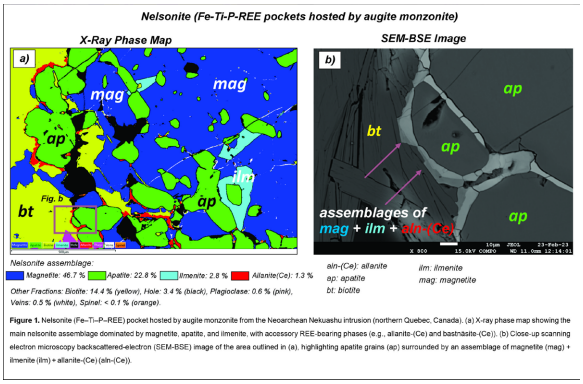


Figure 1. Nelsonite (Fe–Ti–P–REE) pocket hosted by augite monzonite from the Neoarchean Nekuashu intrusion (northern Quebec, Canada). (a) X-ray phase map showing the main nelsonite assemblage dominated by magnetite, apatite, and ilmenite, with accessory REE-bearing phases (e.g., allanite-(Ce) and bastnäsite-(Ce)). (b) Close-up scanning electron microscopy backscattered-electron (SEM-BSE) image of the area outlined in (a), highlighting apatite grains (ap) surrounded by an assemblage of magnetite (mag) + ilmenite (ilm) + allanite-(Ce) (aln-(Ce)).

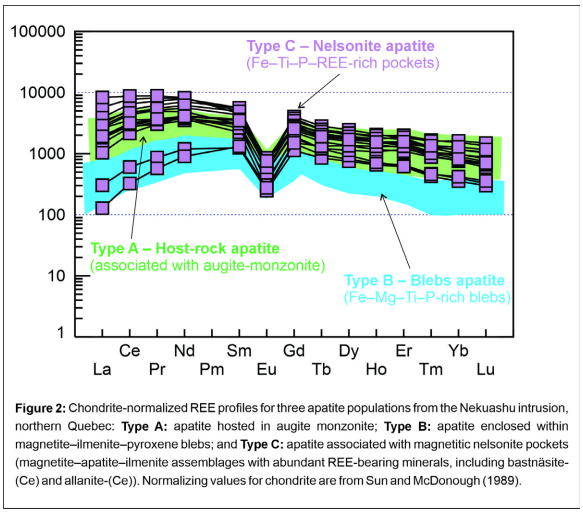


Figure 2: Chondrite-normalized REE profiles for three apatite populations from the Nekuashu intrusion, northern Quebec: **Type A:** apatite hosted in augite monzonite; **Type B:** apatite enclosed within magnetite–ilmenite–pyroxene blebs; and **Type C:** apatite associated with magnetitic nelsonite pockets (magnetite–apatite–ilmenite assemblages with abundant REE-bearing minerals, including bastnäsite-(Ce) and allanite-(Ce)). Normalizing values for chondrite are from Sun and McDonough (1989).