Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.35126

A-Type Magmatism and Hydrothermal Remobilization are Key to the Formation of REE-Rich Iron Oxide-Apatite (IOA) Deposits

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Iron Oxide-Apatite (IOA) deposits are a major source of iron ore and have recently gained attention because of their potential to host economically significant concentrations of rare earth elements (REE). The genesis of this latter mineralization, however, has received limited attention, largely because few IOA deposits contain economic REE concentrations.

This study examines the Kwyjibo IOA deposit, in the Grenville Province of Québec, Canada, which contains a measured and indicated resource of 6.29 Mt grading 2.72 wt.% total rare earth oxides. The results of this study show that the REE-bearing magnetite-apatite rocks formed during extensional A-type magmatism at ~1170 Ma and were coeval with emplacement of the host Canatiche leucogranite during the Shawinigan Orogeny. Both units share similar trace element signatures and Nd isotopic compositions, with depleted mantle affinity (median age-corrected εNd values of +2.75 and +4.07, respectively). These data indicate that the Canatiche leucogranite and associated magnetite-apatite rocks were derived from either a mantle-derived magma or partial melting of juvenile mantle-derived Mezoproterozoic lower crust. The REE were concentrated as a result of fractional crystallization and were sequestered primarily by fluorapatite during the crystallization of the magnetite-apatite rocks.

A later hydrothermal event at ~980 Ma, during the waning stages of the Rigolet Phase of the Grenville Orogeny, redistributed the REE into phosphates and silicates, including britholite, allanite, andradite, titanite and kainosite. The chondrite-normalized REE profiles of the hydrothermal REE assemblages are indistinguishable from those of the primary magnetite-apatite rocks and the Canatiche leucogranite, indicating that hydrothermal fluids redistributed and locally concentrated pre-existing magmatic REE through dissolution-reprecipitation reactions involving REE-bearing fluorapatite.

We conclude that the high concentrations of REE in the Kwyjibo ore deposit were the products of A-type magmatism during the Shawinigan Orogeny and hydrothermal remobilization during the late Rigolet Orogeny. These findings establish a genetic association between REE-rich IOA deposits and A-type granites that may explain why IOA deposits lacking this association do contain economic REE resources. Finally, they show that, although hydrothermal processes may redistribute the REE and change the nature of the ore minerals, they do not increase the overall grade and size of the deposits.