Rare-earth elements mineralization and post-orogenic alteration in the northernmost Arabian-Nubian Shield (southern Israel)

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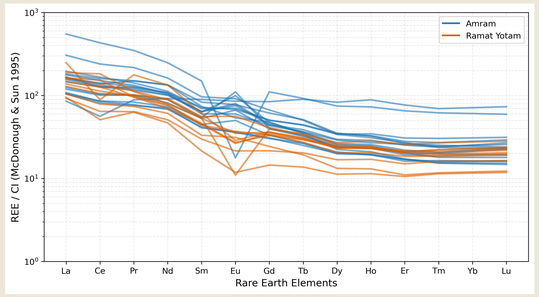
INTRODUCTION

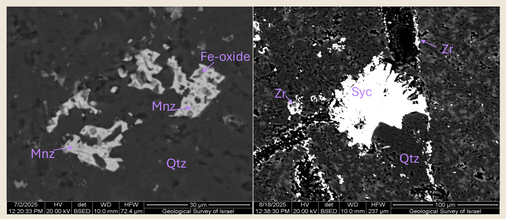
Rare earth elements (REE) are critical for renewable energy, high-tech, and defense applications, yet economically viable deposits are rare. Post-orogenic alkaline magmatic systems are key settings for REE enrichment via magmatic concentration and hydrothermal remobilization. Here we study late Neoproterozoic alkaline rocks in the northern Arabian-Nubian Shield (S Israel) to assess REE enrichment in calcite veins and their host rocks and to constrain the origin and temperature of the mineralizing fluids.

Magmatic REE enrichment and remobilization

The alkaline rocks are REE enriched (100–700 ppm), and particularly LREE enriched).

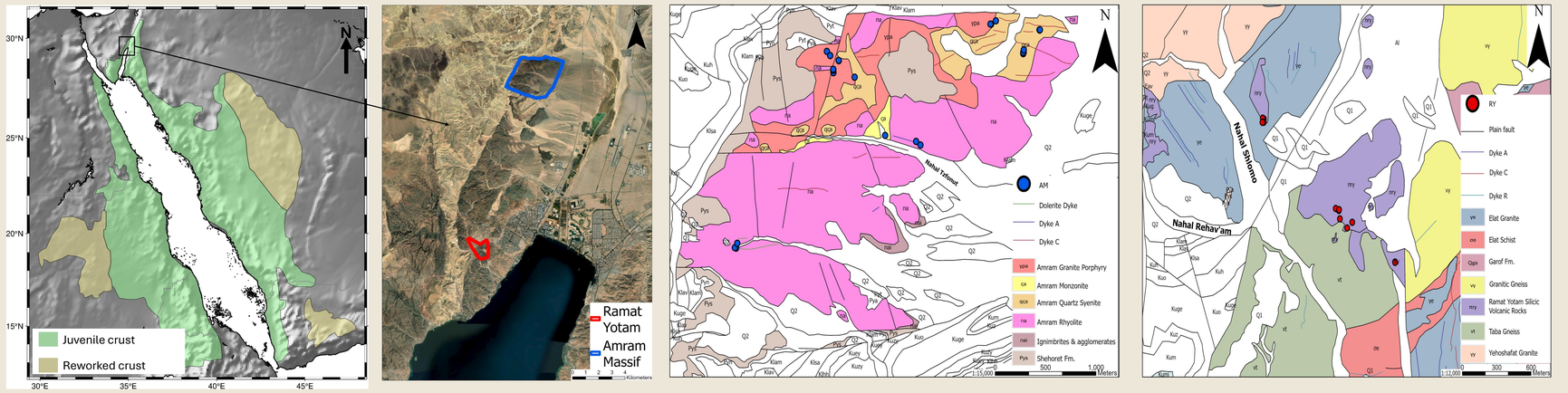


Partial replacement of primary magmatic monazite (Mnz) by hydrothermal synchisite (Syc) in Amram granite indicates in situ REE remobilization by fluids.



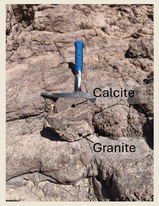
Study area

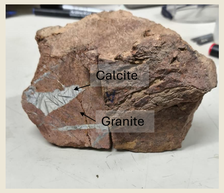
The study area is located at the northern tip of the Arabian-Nubian Shield near Elat in southern Israel. Within this region, we focus on two late Neoproterozoic post-orogenic alkaline magmatic centers: the Amram Massif, which exposes shallow alkaline plutons and sub-/volcanic rhyolites, and the Ramat Yotam area, which preserves the silicic volcanic rocks of the Yotam Caldera. Rocks of both localities are heavily altered and cut by dense networks of calcite, barite and Mn-oxide veins.

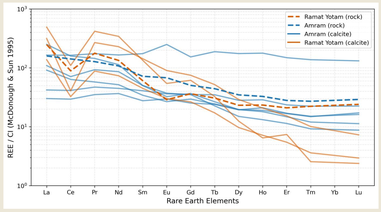


REE-rich calcite veins

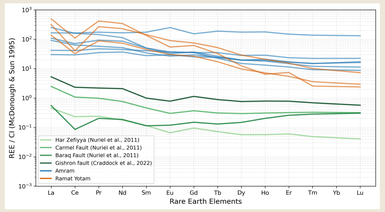
Calcite veins from the Amram Massif and Ramat Yotam contain high total REE (100–700 ppm) and typically show LREE-enriched chondrite-normalized patterns, in some cases comparable to their alkaline host rocks.





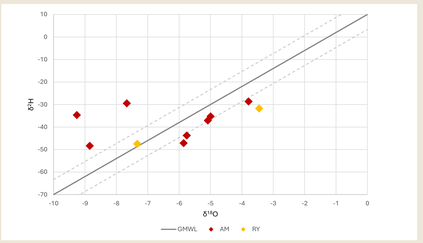


When compared with later calcite veins along the Dead Sea Transform, these veins exhibit REE contents that are higher by several orders of magnitude.

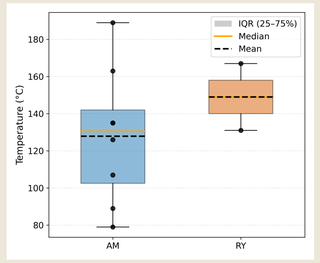


Isotope Ratios of Fluid inclusions

Bulk δ^2H–$\delta^{18}O$ values of calcite-hosted aqueous fluid inclusions, measured by Cavity ring-down spectroscopy, plot close to the global meteoric water line, indicating a meteoric-dominated hydrothermal system.



Oxygen isotope thermometry yields entrapment temperatures of 120–150 °C, suggesting that calcite precipitated from relatively hot fluids consistent with deep circulation of meteoric waters through the basement.



Conclusions

- Moderately high REE contents (100–700 ppm) characterize post-orogenic alkaline rocks of the ANS.
- Primary magmatic monazite (REE-phosphate) is partially replaced by hydrothermal synchisite (REE-F-carbonate).
- REE are enriched in associated calcite veins, crosscutting the hydrothermally altered basement rocks.
- O and H isotope ratios of calcite and hosted fluid inclusions indicate hydrothermal circulation of meteoric water heated to 120–150°C.
- The REE-rich calcite veins may represent a Late Neoproterozoic hydrothermal event in the northernmost ANS.
- Calcite veins are found in clasts contained by Latest Neoproterozoic conglomerate beds supporting their Neoproterozoic formation.

Acknowledgments

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