Abstract Book

16TH IAGOD QUADRENNIAL SYMPOSIUM

The Role of Geoscience in the Energy Transition

At Faculty of Sciences of the University of Porto

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Faculty of Sciences, University of Porto

August 31-September 2, 2026

Suggested citation for an individual paper:

Gonçalves, A., Sant'Ovaia, H., Noronha, F. (2026). Granites related to mineralizations from Borralha W (Mo) Deposit (Northern Portugal): constraints from geochemistry and U–Pb dating. 16th IAGOD Quadrennial Symposium, Abstract volume, Porto, Portugal, 206-207 pages

Critical Raw Material Potential and Mineral System Architecture of the Northeastern Estonian Basement (Eastern Fennoscandia): Integration of Drill-Core Geochemistry, Geostatistics, and Geophysical Insights

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Keywords: Critical raw materials, Fennoscandian Shield, Geostatistics, Potential field data, Estonian Proterozoic basement

Summary

A comprehensive presentation of geological, geochemical, geostatistical, and geophysical data for the concealed Precambrian basement in northeastern Estonia, covering the Tallinn–Alutaguse–Jõhvi (Tll–Al–Jh) regions. The research utilizes over 500 drill cores from the Geological Survey of Estonia (EGT), including whole-rock geochemistry analyses (wet chemistry, XRF, ICP), complemented by MSCL-XYZ data and geophysical inversion of gravity and magnetic measurements. Multi-element patterns (Cu–Zn–Pb; Au–Ag–As–Sb; Ni–Co–Cr; Nb–Y–P) are associated with magnetite-rich quartzites and sulphide–graphite gneisses. Data analysis through the centred log-ratio (clr) transformation enhances comparability among diverse datasets and aids in identifying consistent geochemical trends. The findings reveal multiple mineral systems within a Paleoproterozoic arc–back-arc setting and propose new exploration targets for critical raw materials.

Introduction

The northeastern Estonian basement (Tll–Al–Jh domains) forms part of the eastern Fennoscandian Shield and records Paleoproterozoic crustal evolution related to the Svecofennian orogeny (~1.90–1.87 Ga) (Bogdanova et al., 2015; Soesoo et al., 2020). It represents an arc–back-arc system comparable to mineralised belts in southern Finland and central Sweden, including the Bergslagen province (Kara, 2021). Previous work highlights strong lithological and geophysical heterogeneity linked to tectonic segmentation and basin development (Solano-Acosta et al., 2023,2026). This study integrates EGT drill-core datasets, MSCL-XYZ data, and geophysical methods to characterise the mineral system architecture and assess the critical raw material potential.

Geological Setting

The Tallinn, Alutaguse, and Jõhvi domains are distinct, genetically related crustal segments within a Paleoproterozoic back-arc system (Bogdanova et al., 2015), formed ca 1.90-1.88 Ga (Figure 1). The Tallinn domain reflects arc-related magmatism, while Alutaguse corresponds to a back-arc basin with metasedimentary and metavolcanic sequences. The Jõhvi domain is a structurally controlled sub-basin characterized by magnetite-rich quartzites and high magnetic anomalies (Nirgi and Soesoo, 2021). These domains contain metavolcanic and metasedimentary successions intruded by Svecofennian granitoids, metamorphosed under amphibolite- to granulite-facies conditions (Soesoo et al., 2020). Bouguer and magnetic datasets from the Estonian Geological Survey indicate strong lateral contrasts in density and magnetic susceptibility, reflecting lithological variability and structural controls (Solano-Acosta et al., 2023,2026).

Discussion and conclusions

Base- and precious-metal anomalies (Cu–Zn–Pb; Au–Ag–As–Sb) are associated with magnetite-bearing quartzites and sulphide–graphite gneisses. Drill-core geochemistry reveals significant enrichment, reaching up to ~2230 ppm Cu, ~2650 ppm Zn, and ~4030 ppm Pb, supporting a metal-rich system within the Alutaguse domain. MSCL-XYZ data (Nirgi et al., 2024) further highlight complex element associations indicative of multi-stage metal enrichment. Whole-rock datasets were analysed using clr transformation, reducing closure effects and improving multivariate consistency. Principal component analysis and spatial visualisation enhance the identification of coherent geochemical trends and reduce artefacts related to heterogeneous sampling density.

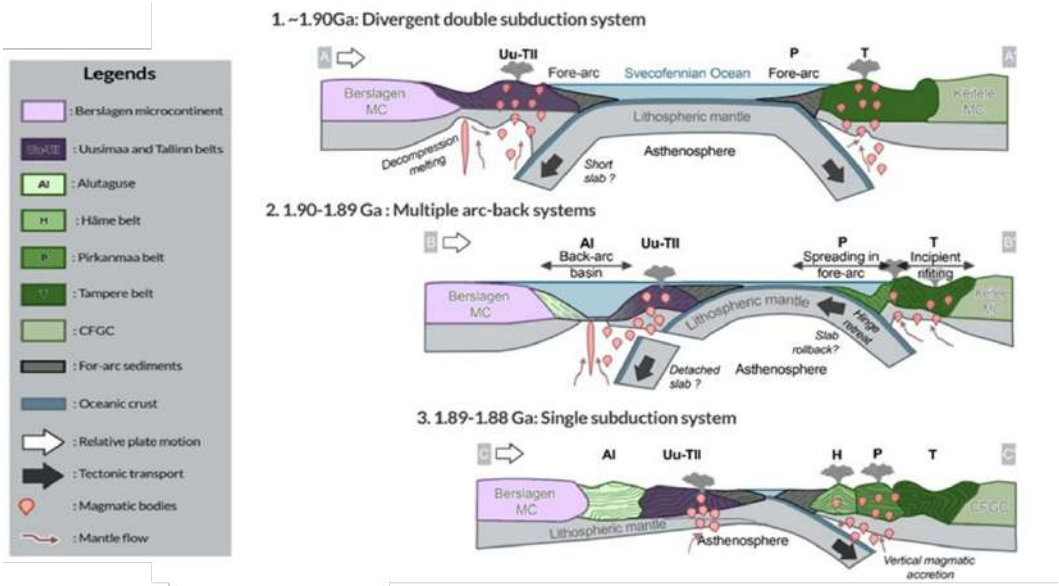

Figure 1. Schematic geodynamic model (modified from Solano-Acosta, 2026) illustrating the evolution of Fennoscandia from ~1.90 Ga to 1.88 Ga. Conceptual and not to scale.

Geophysical inversion reveals subsurface density and magnetic susceptibility, linking geochemical anomalies to lithology (Solano-Acosta et al., 2023). Continuous features indicate stratigraphic control, while discontinuities align with fault systems serving as fluid pathways. These resemble mineralised systems in the southern Svecofennian domain and Bergslagen (Solano-Acosta et al., 2025; Solano Acosta et al., 2026). The Tll–Al–Jh corridor forms an arc–back-arc system: Tallinn as the arc front, Alutaguse as a back-arc basin, and Jõhvi as Fe-rich. Presence of Fe–S–Si lithologies, polymetallic sulphides, and stratabound geometries suggests a VMS affinity, possibly transitional to SEDEX. Combining geochemical, geostatistical, and geophysical methods, a detailed metallogenic framework for NE Estonian basement highlights new raw material targets.

Acknowledgments

This work was supported by the Horizon Europe DEXPLORE project (VHE24051; project ID 101178897).

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