Geological Survey of Finland

2023

EU SuperCluster Lapland Geoconference – October 30–31, 2023, Hotel Santa Claus, Rovaniemi, Finland

Abstracts

Vesa Nykänen, Nick Cook and Juha Kaija (eds)

GTK Open File Research Report 55/2023

Funded by the European Union

GTK

GEOLOGICAL SURVEY OF FINLAND

Open File Research Report 55/2023

EU SuperCluster Lapland Geoconference – October 30–31, 2023, Hotel Santa Claus, Rovaniemi, Finland

Abstracts

Edited by Vesa Nykänen, Nick Cook and Juha Kaija

Figures in each abstract are prepared by the author(s) of that specific abstract.

Front cover: EU SuperCluster Lapland Geoconference – Abstracts.
Picture by LGI Sustainable Innovation, Paris, France.

Layout: Elvi Turtiainen Oy

Espoo 2023

Nykänen, V., Cook, N. & Kaija, J. (eds) 2023. EU SuperCluster Lapland Geoconference – October 30–31, 2023, Hotel Santa Claus, Rovaniemi, Finland. *Geological Survey of Finland, Open File Research Report 55/2023*, 212 pages, 69 figures and 9 tables.

The EU SuperCluster Lapland Geoconference brings together representatives from academia, research institutions and industry to discuss important issues related to critical raw materials within the European Union. The SuperCluster Geoconference included 28 talks and 21 poster presentations covering topics related to innovative mineral exploration, earth observation in exploration and mining, environmental, social and governance in exploration and mining, critical raw materials supply, and new frontiers for exploration. The compilation of the extended abstracts of the oral and poster presentations given in the EU SuperCluster Lapland Geoconference forms this proceedings publication of the Geological Survey of Finland.

Keywords: mineral exploration, geology, mining, critical raw materials, sustainable development, European Union

Vesa Nykänen
Geological Survey of Finland
P.O. Box 77
FI-96101 Rovaniemi
Finland

E-mail: vesa.nykanen@gtk.fi

Nick Cook
W.H. Bryan Mining Geology Research Centre
Sustainable Minerals Institute
The University of Queensland
40 Isles Road Indooroopilly QLD 4068
Australia

E-mail: nick.cook@uq.edu.au

Juha Kaija
Geological Survey of Finland
P.O. Box 96
FI-02151 Espoo
Finland

E-mail: juha.kaija@gtk.fi

GEOCHEMISTRY, PROVENANCE, AND TECTONIC SETTING OF PALEOPROTEROZOIC METAVOLCANIC AND METASEDIMENTARY UNITS OF THE ALUTAGUSE ZONE, NORTH ESTONIA – A COMPARATIVE STUDY WITH THE SOUTH SVECOFENNIAN ZONE

by

Juan D. Solano-Acosta[1], Rutt Hints[1] and Alvar Soesoo[1]

[1] Department of Geology, Tallinn University of Technology, Ehitajate tee 5, Tallinn, Estonia
E-mail: juan.solano@taltech.ee, rutt.hints@taltech.ee, alvar.soesoo@taltech.ee

The research delved into the geochemistry of Paleoproterozoic metasedimentary and metavolcanic units in the Estonian Alutaguse and South Svecofennian (SS) zones (i.e. Ladoga, Saimaa, Häme Belt, Uusimaa Belt zones), offering insights into the Svecofennian Orogeny's tectonic progression over Eastern Fennoscandia (Fig. 1) Metasedimentary units generally correspond to micaceous gneisses (± Grt ± Crd ± Sil), and the metavolcanic ones to ortho-amphibolites and pyroxenic gneisses (Bogdanova et al. 2015. Soesoo et al. 2020). By merging historical data with new samples, classifications emerged, with High-SiO_2 (> 63 wt%) metasediments aligning with litharenites and Low-SiO_2 (< 63 wt%) samples with graywackes and shales. TAS classifications placed metavolcanic units in the sub-alkaline series. Weathering indices, including CIA, PIA, CIW, and ICV, were applied to metasediments, while AI, CCPI, WIP, and SI were used for metavolcanic samples.

High-SiO_2 (>63 wt%) samples from both zones mirror UCC characteristics, while Low-SiO_2 (<63 wt%) align with PAAS, highlighting varied source materials and high weathering degrees. In metavolcanics, Alutaguse presents elevated weathering and alteration indices, enhanced Th/U ratios, and high SO_3 wt% values, indicating high weathering and possible hydrothermal processes. Conversely, SS metavolcanics indices suggest limited alteration. A summary of sample major element data concentrations is presented in Figure 2.

The High-SiO_2 metasediments, for both Alutaguse and SS, lean towards felsic origins. Alutaguse has a marginally higher Al_2O_3/TiO_2 ratio, indicating a more pronounced felsic source. A–CN–K triangular plots, discriminant plots, and K-Rb relationships all corroborate this intermediate to felsic magmatic origin. For Low-SiO_2 metasediments, Alutaguse samples primarily suggest mafic to intermediate origins, with notable graphite-bearing mica gneisses in the mafic zone. In contrast, SS gravitates towards intermediate sources. South Svecofennian Low-SiO_2 samples follow the magmatic trend towards mafic compositions. However, while most of these samples show signs of a magmatic origin, a subset from the Ladoga and Saimaa regions have characteristics more commonly associated with sedimentary addition. TiO_2–Ni plots and transition element concentrations further differentiate the two areas, with Alutaguse samples aligning more with sedimentary trends, while SS samples lean towards mafic magmatic compositions. Ratios such as La/Sc and La/Co underscore a similar intermediate-mafic trend for Low-SiO_2 samples.

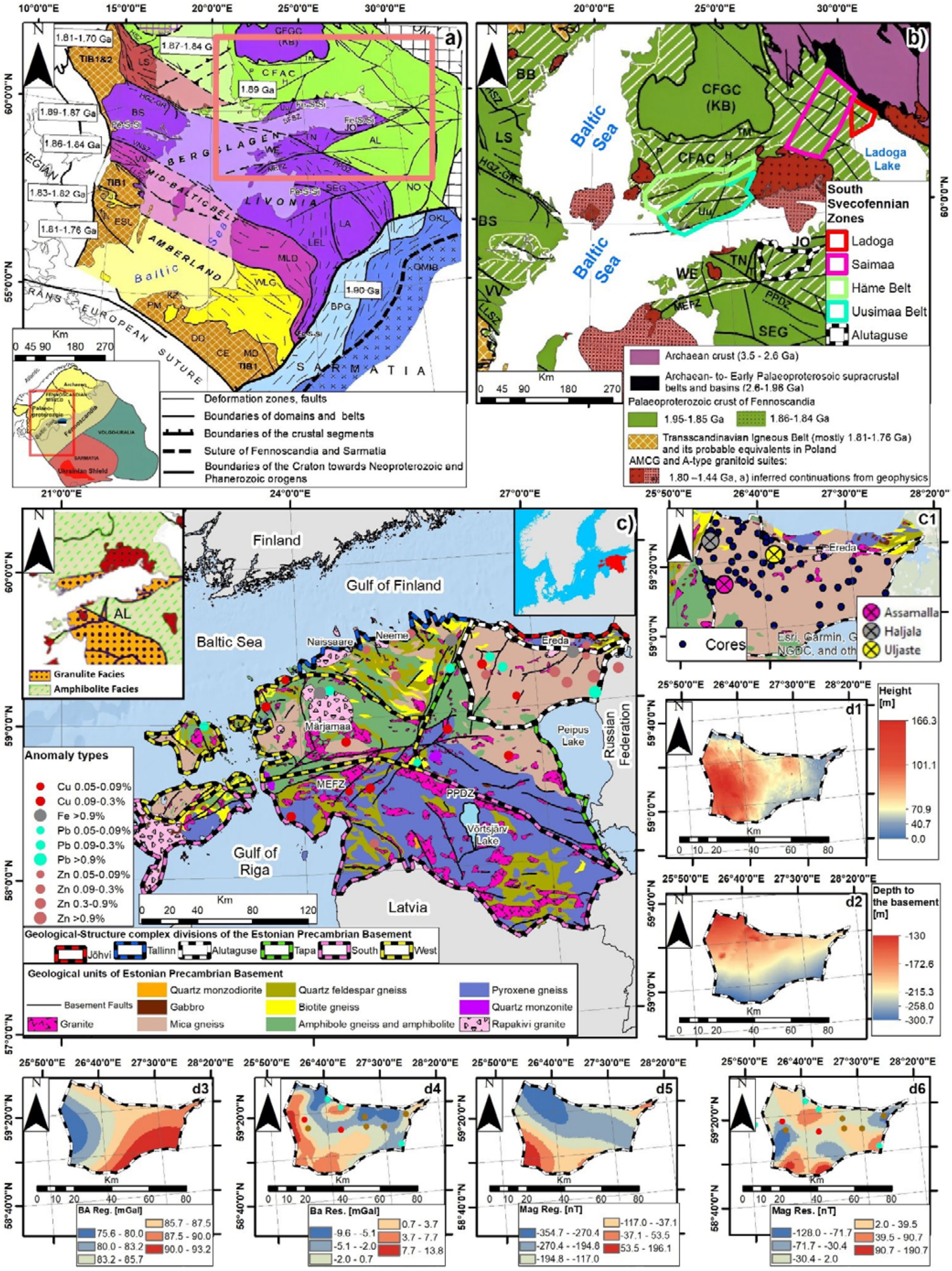

Fig. 1. Geological setting of the study zone, highlighting key features: a) Central and southern Svecofennian orogens (SO) crustal structure crosses the Baltic Sea. b) Major Palaeoproterozoic tectonic zones over the Fennoscandian area. c) Geological map scheme of the Precambrian basement of Estonia, showing geochemical anomalies according to Soesoo et al. (2020), and the upper right-corner inset showing the distribution of granulite- and amphibolite facies metamorphic rocks. Redish symbols correspond to Rapakivi lithologies. modified from Bogdanova et al. (2015). The anomaly symbols represent the most prominent metal of the mineralisation c1) Zoom of the geological basement map of the Alutaguse zone, depicting the location of the cores and the prominent metallogenic Alutaguse zones. d) Geophysical maps of the Alutaguse zone depicting the 1) 10 x 10 m topography, 2) Depth to basement, 3) Bouguer gravitational anomaly, 4) residual Bouguer anomaly, 5) Regional magnetic anomaly, 6) Residual magnetic anomaly. Please refer to Bogdanova et al. (2015), Soesoo et al. 2020, Solano-Acosta et al. 2023 for further information and a comprehensive understanding.

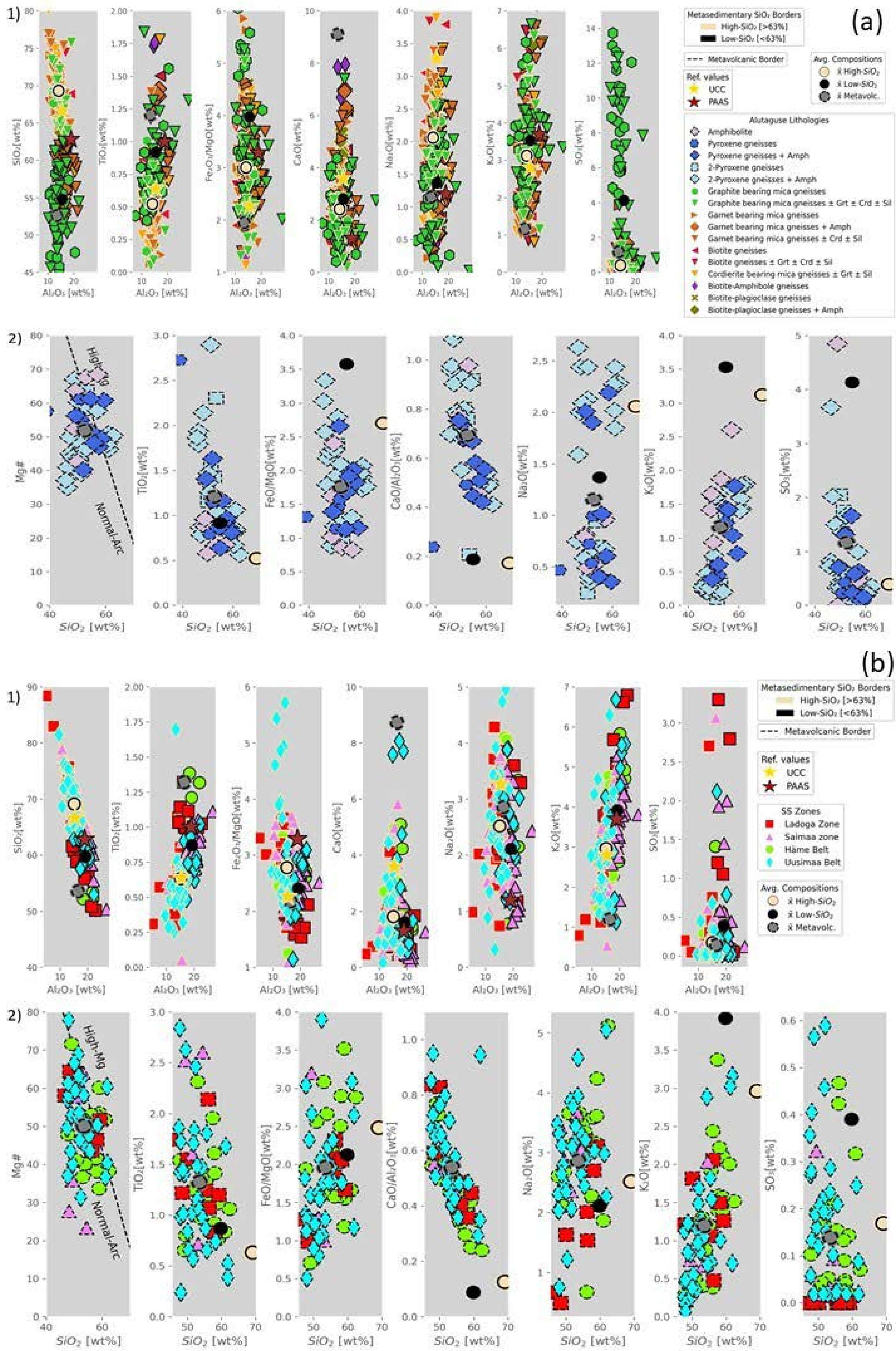

Fig. 2. a) Alutaguse and b) South Svecofennian (SS) samples bivariant Harker-plots. 1) Metasedimentary Major oxides vs. Al_2O_3. 2) Metavolcanic major oxides vs. SiO_2. Sample boundaries represent sample groups: High-SiO_2 in wheat, Low-SiO_2 in black, and meta-volcanics in dashed-grey.

In assessing sedimentary sorting, recycling, and maturation, textural maturity emerges as a crucial marker, influenced by diverse grain, morphological, mineralogical, and geochemical profiles. For High-SiO_2 samples, both Alutaguse and SS present pronounced silica enrichment, indicated by elevated SiO_2/Al_2O_3 ratios, with Alutaguse highlighting significant sorting and maturation through its high chondrite-normalised Gd/Yb values. These High-SiO_2 samples also lean towards increased Zr/Sc ratios, suggesting notable sediment reworking, especially in the SS samples. When comparing Low-SiO_2 samples, both Alutaguse and SS demonstrate heightened geochemical immaturity, with narrower Al_2O_3/TiO_2 ranges and K_2O/Na_2O ratios above unity. However, SS Low-SiO_2 samples distinctly align with mature, recycled sediments in provenance discrimination plots, signifying contributions from older rocks. Across both categories, trace elements like Zr, Th, and Sc emphasise sedimentary origins and recycling, with SS High-SiO_2 samples showing particularly enhanced sedimentary reworking. Notably, negative Sr anomalies prevalent in both Alutaguse and SS metasediments typify Archean-Proterozoic aged recycled environments.

Derived sediments illuminate the nuanced relationship between geochemical attributes and tectonic environments. Through advanced discriminant-function-based multidimensional diagrams, this study identified that high-silica samples from both Alutaguse and SS metasediments predominantly align with continental rift zones, while select low-silica samples hint at collisional settings. Stable minor elements further supported the metasediment's affinity to the continental island arc (CIA) zone. Although specific geochemical markers suggest a continental arc origin, the inherent arc-like traits of the continental crust mandate interpretive caution.

Alutaguse metavolcanics exhibit tholeiitic tendencies and are metaluminous, with elevated Nb and diminished Zr levels, hinting at enriched and depleted mantle origins. Conversely, SS metavolcanics lean towards calc-alkaline orientations and present a mixed mantle source leaning slightly towards depletion, as their δNb values indicate. Both Alutaguse and SS samples predominantly align with garnet-lherzolite melting patterns in La/Yb vs. Zr/Nb and La/Sm vs. Sm/Yb plots, showcasing their intricate tectonic processes and highlighting the influence of both mantle depletion and enrichment events.

Alutaguse samples, with their distinct Th/Nb and Th/Zr elemental ratios, primarily point towards an asthenospheric mantle origin, emphasising a deeper connection with mantle processes. Conversely, SS samples, marked by elevated Nb/Zr, Ba/Th, and U/Th ratios, hint at a significant influence from the subducted oceanic crust. This delineation between the two sets not only showcases the profound role of elemental ratios like Nb/Zr, Th/Zr, Ba/Th, and U/Th but also emphasises the contribution of elements like HFSEs, REEs, olivine, and clinopyroxene in deciphering mafic magma sources.

The Alutaguse metavolcanics display a clear compressional arc tendency, as revealed by their REE patterns and elemental indices such as Y/15-La/10-Nb/8. This is further contrasted by the SS metavolcanics, which hint at a broader and transitional tectonic setting when analysed through the TiO_2–10(MnO)–10(P_2O_5) plot. The Hf/3–Th–Nb/16 triangular diagram accentuates their distinctions: Alutaguse gravitates towards crustal magma interactions, while SS leans towards subduction influences. Both, however, consistently show oceanic arc affinities as they align in the IAB zone. The Zr/Y values further distinguish them – Alutaguse samples explore both oceanic and continental realms, whereas SS samples remain largely continental. Nonetheless, their shared REE patterns and prominent placement in the IAB zone highlight mutual tectonic influences, indicating potential intersections in their tectonic histories (Kirs et al. 2009, Bogdanova et al. 2015, Soesoo et al. 2020, Kara 2021). The resume of these associations is found in the Zr bivariant metavolcanic plots in Figure 3.

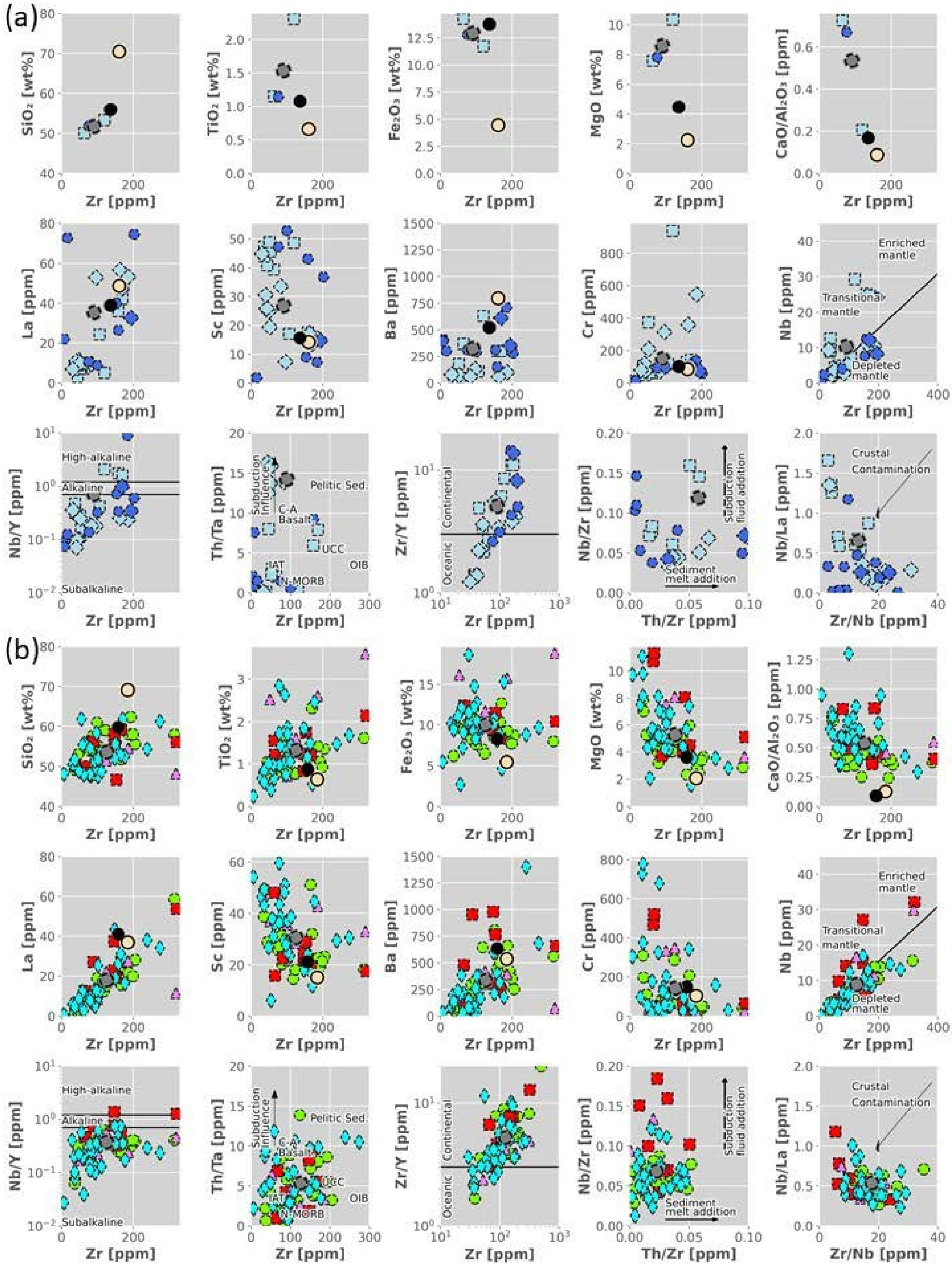

Fig. 3. Metavolcanic Zr binary plots versus major, trace and REE elements for a) Alutaguse and b) South Svecofennian (SS) zones. Legend as in Figure 2.

The Alutaguse metavolcanics display a clear compressional arc tendency, as revealed by their REE patterns and elemental indices such as Y/15-La/10-Nb/8. This is further contrasted by the SS metavolcanics, which hint at a broader and transitional tectonic setting when analysed through the TiO_2–10(MnO)-10(P_2O_5) plot. The Hf/3–Th–Nb/16 triangular diagram accentuates their distinctions: Alutaguse gravitates towards crustal magma interactions, while SS leans towards subduction influences. Both, however, consistently show oceanic arc affinities as they align in the IAB zone. The Zr/Y values further distinguish them–Alutaguse samples explore both oceanic and continental realms, whereas SS samples remain largely continental. Nonetheless, their shared REE patterns and prominent placement in the IAB zone highlight mutual tectonic influences, indicating potential intersections in their tectonic histories (Kirs et al. 2009, Bogdanova et al. 2015, Soesoo et al. 2020, Kara 2021). The resume of these associations is found in the Zr bivariant metavolcanic plots in Figure 3.

When juxtaposed, the Alutaguse and SS samples present a compelling tapestry of tectono-magmatic environments, revealing the complex interplay of geological processes. In conclusion, the evidence predominantly suggests that the Alutaguse and SS basins were situated in a continental arc setting. The SS basin appears to represent a subduction transference scenario, situated over a double subduction tectonic setting. Within this framework, the SS zones correspond to the northern subduction, while the Uusimaa and Tallinn Zones are aligned with the southern arc subduction process. Moreover, the Alutaguse basin might potentially represent a back-arc scenario if the Tallinn-Uusimaa Arc evolution system

REFERENCES

Bogdanova, S., Gorbatschev, R., Skridlaite, G., Soesoo, A., Taran, L. & Kurlovich, D. 2015. Trans-baltic Palaeoproterozoic correlations towards the reconstruction of the supercontinent Columbia/Nuna. Precambrian Research 259, 5–33

Kara, J. 2021. Evolution of the Svecofennian Bedrock in Southern Finland – Spatial and temporal changes in the mantle-derived magmatism and mantle-crust interaction. Docthoral thesis, University of Turku.

Kirs, J., Puura, V., Soesoo, A., Klein, V., Konsa, M., Koppelmaa, H., Niin, M. & Urtson, K. 2009. The crystalline basement of Estonia: rock complexes of the Palaeoproterozoic orosirian and statherian and Mmesoproterozoic calymmian periods, and regional correlations. Estonian Journal of Earth Sciences 58(4).

Soesoo, A, S. Nirgi, S. & Plado, J. 2020. The evolution of the Estonian Precambrian basement: geological, geophysical and geochronological constraints. Transactions of the Karelian Research Centre of the Russian Academy of Sciences (2), 18–33.

Solano-Acosta, J. D., Soesoo, A. & Hints, R. 2023. New insights of the crustal structure across Estonia using satellite potential fields derived from WGM-2012 gravity data and EMAG2v3 magnetic data. Tectonophysics, 846, 229656.