GEOCHEMISTRY, PROVENANCE, AND TECTONIC SETTING OF PALEOPROTEROZOIC METAVOLCANIC AND METASEDIMENTARY UNITS OF THE ALUTAGUSE ZONE, N ESTONIA

A COMPARATIVE STUDY WITH THE SOUTH SVECOFENNIAN ZONE

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.

GEOLOGICAL CONTEXT

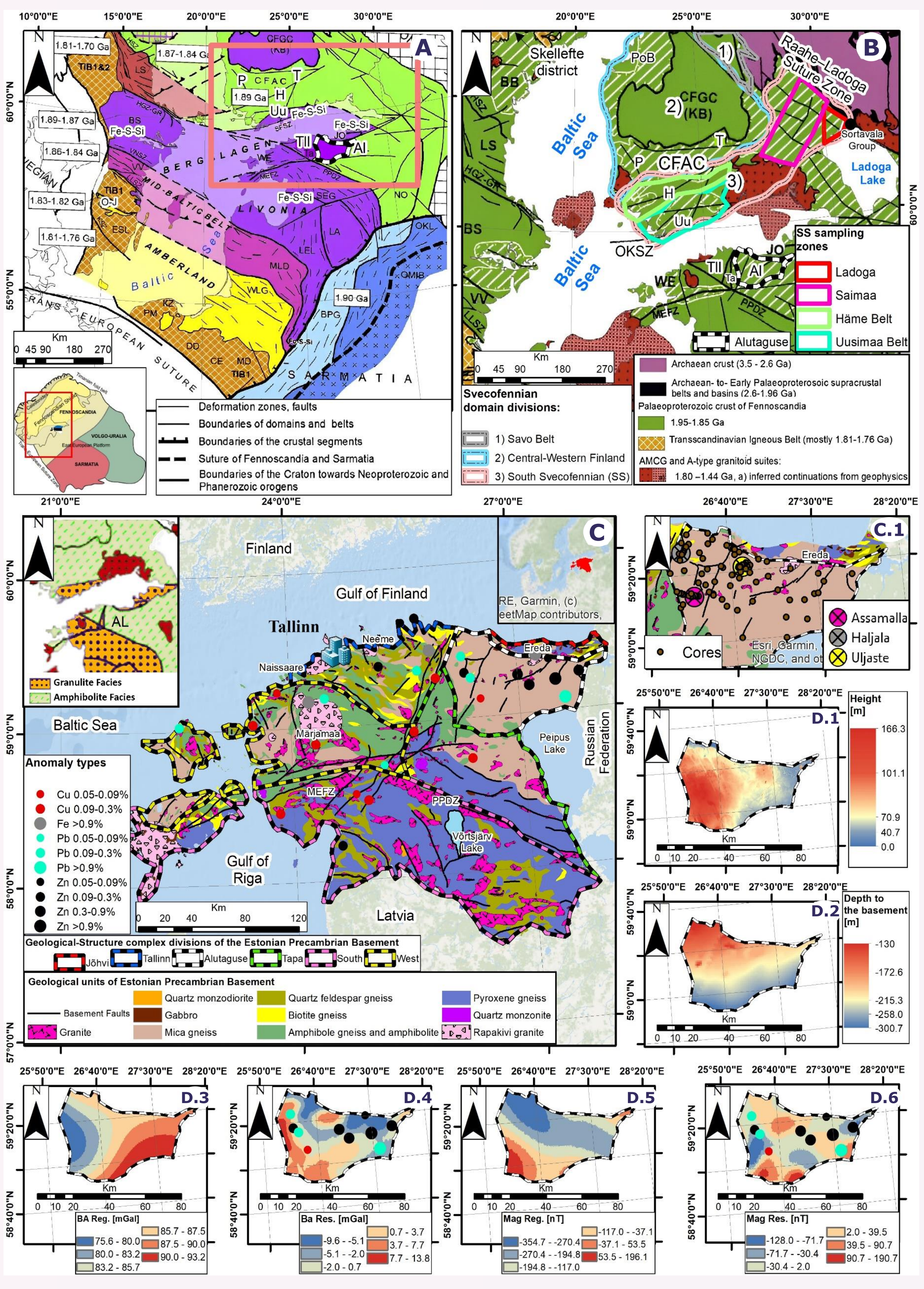


Fig. 1. Geological setting of the study zone, highlighting key features

A. Central and southern Svecofennian orogen's crustal structure across Baltic Sea.
B. Major Palaeoproterozoic tectonic zones over the Fennoscandian area.
C. Geological map scheme of Estonian Precambrian basement, showing geochemical anomalies according to *Soesoo et al. (2020).* Upper right-corner inset showing the distribution of granulite-amphibolite facies metamorphic rocks. Red symbols relate to Rapakivi lithologies. Modified from *Bogdanova et al. (2015).* Anomaly symbols represent the most prominent metal of the mineralisation. 1. Zoom of the basement map of the Alutaguse, depicting cores location and prominent metallogenic zones.
D. Geophysical maps of the Alutaguse zone depicting the: 1. 10x10m 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.

The study explore geochemical aspects of Paleoproterozoic metasedimentary and metavolcanic formations in the Alutaguse zone of North Estonia, and the South Svecofennian (SS): Ladoga, Saimaa, Häme Belt, and Uusimaa Belt **(Fig.1)**. The aim is to provide a deeper understanding of the tectonic evolution of the Sveco-fennian Orogeny across Eastern Fennoscandia.

The metasedimentary formations are known as micaceous gneisses (Grt-Crd-Sill, and graphite in Alutaguse), while meta-volcanic formations are associated to amphibolites and pyroxenic gneisses, derived from basaltic-amphibolitic melts **(Fig.3E)**.

This work combined historical records with recent sampling. Low-silica (<63 wt%) samples were comparable to *graywackes* and *shales*, whereas High-silica (>63 wt%) metasediments were found to be constant with *litharenites*. According to the TAS classification, metavolcanic formations fell into the sub-alkaline range. Numerous weathering indices, like CIA, PIA, CIW, and ICV, were employed for metasedimentary samples, while AI, CCPI, WIP, and SI were used for metavolcanic ones **(Fig.2B)**.

Origin studies showed that high-silica metasediments were more aligned with felsic sources, as confirmed by A–CN–K plot, K-Rb correlations, and Al_2O_3/TiO_2 ratios, thus resembling the Upper Continental Crustal (UCC). Conversely, low-silica metasediments inclined towards mafic to intermediate sources, similar to the post-Archean Australian shale (PAAS), with TiO_2–Ni relations emphasising *sedimentary patterns* in Alutaguse, and *magmatic patterns* in most of SS data.

Sorting and recycling processes were assessed using proxis like SiO_2/Al_2O_3, Zr/Sc, and Al_2O_3/TiO_2. Data indicate *major sedimentary reprocessing* in SS meta-sediments. Discriminant function diagrams were employed to interpret tectonic environments, showing a predominant alignment with continental rift settings in both regions **(Fig.3A-B)**.

Crystallisation and partial melting trends in metavolcanic samples were analysed using *La/Yb vs. Zr/Nb* and *La/Sm vs. Sm/Yb* plots, crossing the spinel-lherzolite trend, closest to the Primitive mantle (PM) reference. The magma sources, pointed to origins from the asthenospheric mantle for Alutaguse and influences of subducted oceanic crust for SS.

Tectonic characteristics of the metavolcanics were unraveled using *Y/15-La/10-Nb/8*, *TiO_2-10(MnO)-10(P_2O_5)*, and *Hf/3-Th-Nb/16* plots **(Fig.3D)**. Data emphasised compressional arc propensities in Alutaguse, and a broader range of influences in SS. However, both primarily showed oceanic arc tendencies. The study proposes that the Alutaguse zone originated as a back-arc to the Uusimaa belt on the Bergslagen microcontinent's northern edge around *1.90-1.89 Ga*, succeeded by the accretion of the Uusimaa and Häme belts around approximately *1.87 Ga*, coinciding with the closure of the Svecofennian ocean.

DATA AND METHODS

Our study focuses on the geochemical characterisation of metasediments and metavolcanic rocks from the Alutaguse and SS regions. The major elemental data for these new samples was complemented by integrating findings from *Kivisilla et al. (1999)*. Trace elemental data was supplemented using records from the Estonian Geological Service. For the SS region, we referenced samples and data from *Rasilainen et al. (2007)* of Finland and *Kotova et al. (2009, 2014)* for the Ladoga zone in Russia.

Our analytical methods for these assessments encompassed various state-of-the-art techniques, denoted by their respective acronyms, ensuring accurate and comprehensive results. Average concentrations of the Alutaguse and SS samples are presented in **Figure 2**.

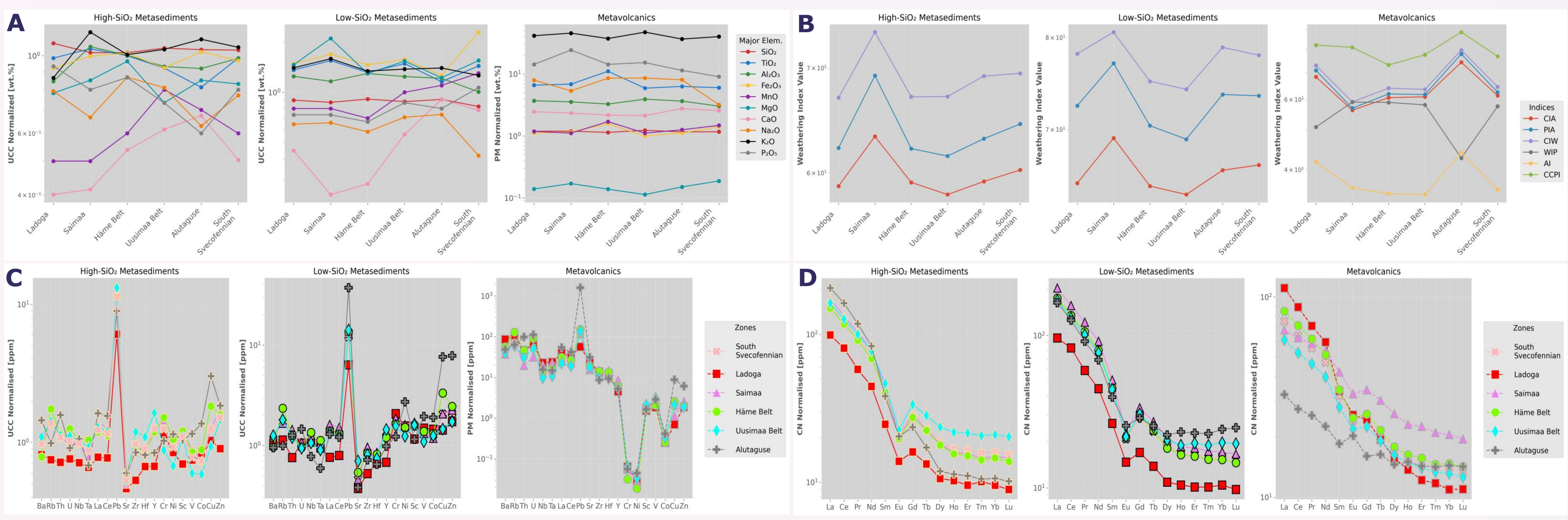
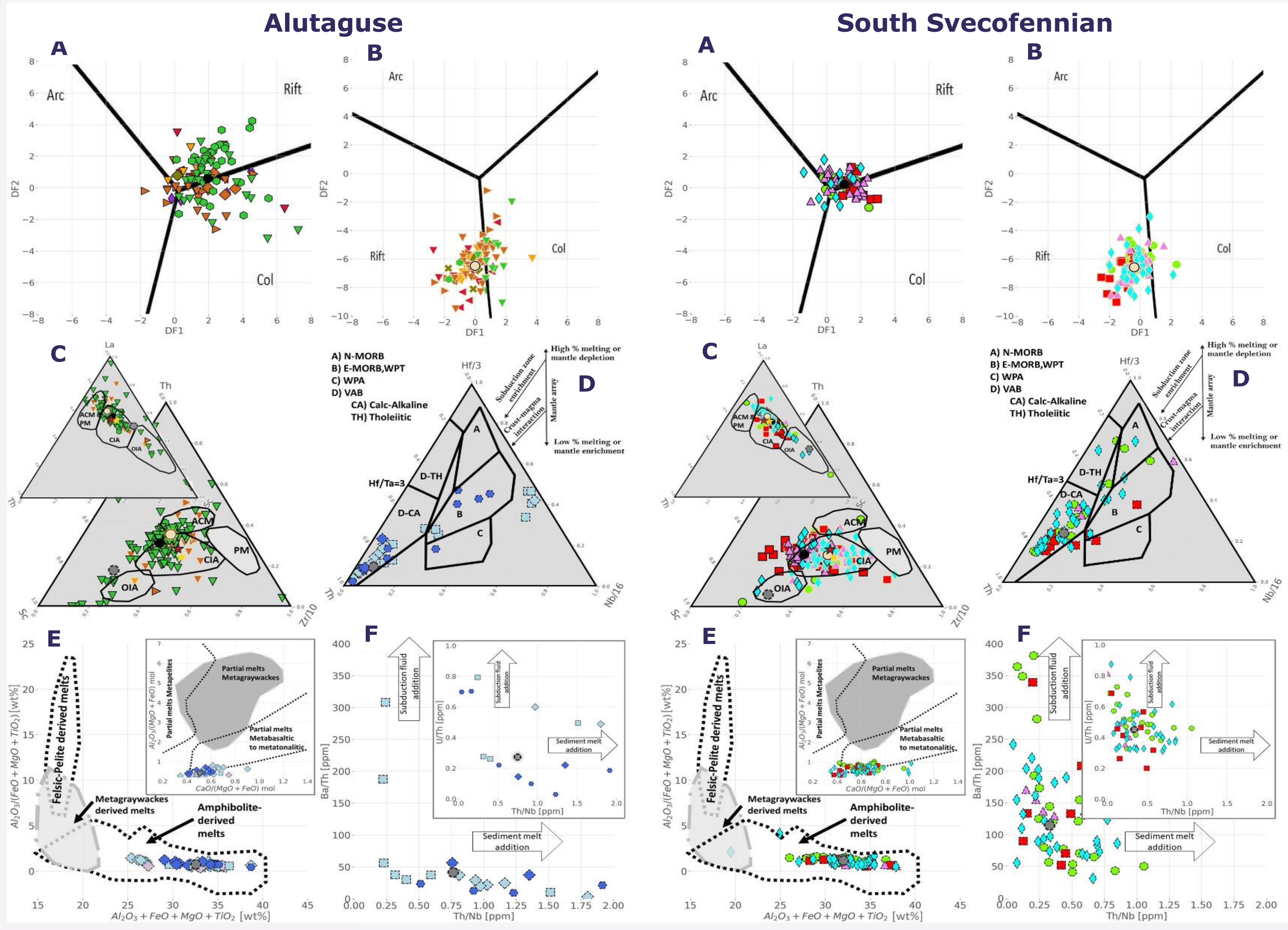
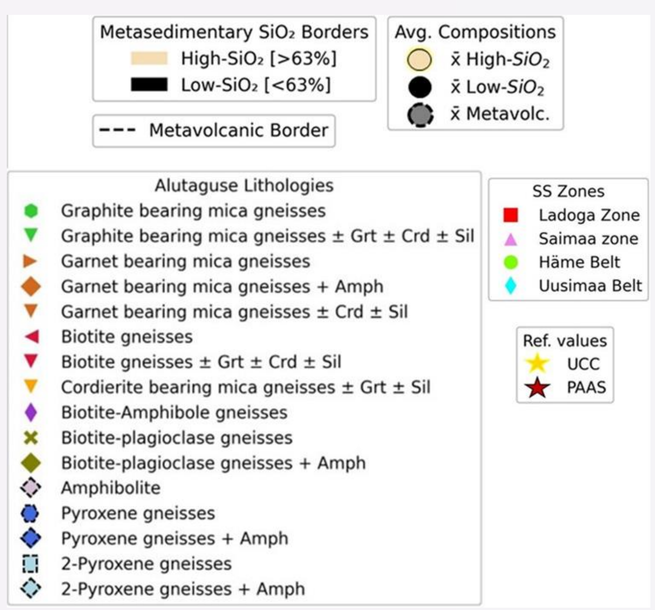


Fig. 2. Bivariate average geochemical trends of the Alutaguse and South Svecofennian (SS) zones. A. Major elemental data. B. Weathering indices. C. Trace elements. D. Rare Earth Elements (REE).

GEOCHEMISTRY

Fig. 3. Geochemical relations from the Alutaguse and SS metasedimentary units include major elemental tectonic discriminant functions.





For more detailed geochemical relations, refer to the figures in the congress repository document.

For (A) Low-SiO_2 and (B) High-SiO_2 meta-sediments, rifting settings appear to be predominant in the majority of the samples. Ternary plots (C) of La-Th-Sc (*inset*) and Th-Sc-Zr/10 (*background*) suggest a continental island arc (CIA) tectonic setting.

For metavolcanic units (D), Hf/3–Th–Nb/16 plots highlight the calc-alkaline volcanic arc-basalt (VAB) relation. Major elemental magmatic source nature (E) indicates that the magma predominantly originates from mafic basaltic sources.

Ba/Th and U/Th ratios vs. Th/Nb (F) emphasise the subduction influence over the *SS samples*, and sediment melt's predominance over the *Alutaguse sediments*, suggesting a back-arc rifting process.

CONTRIBUTIONS

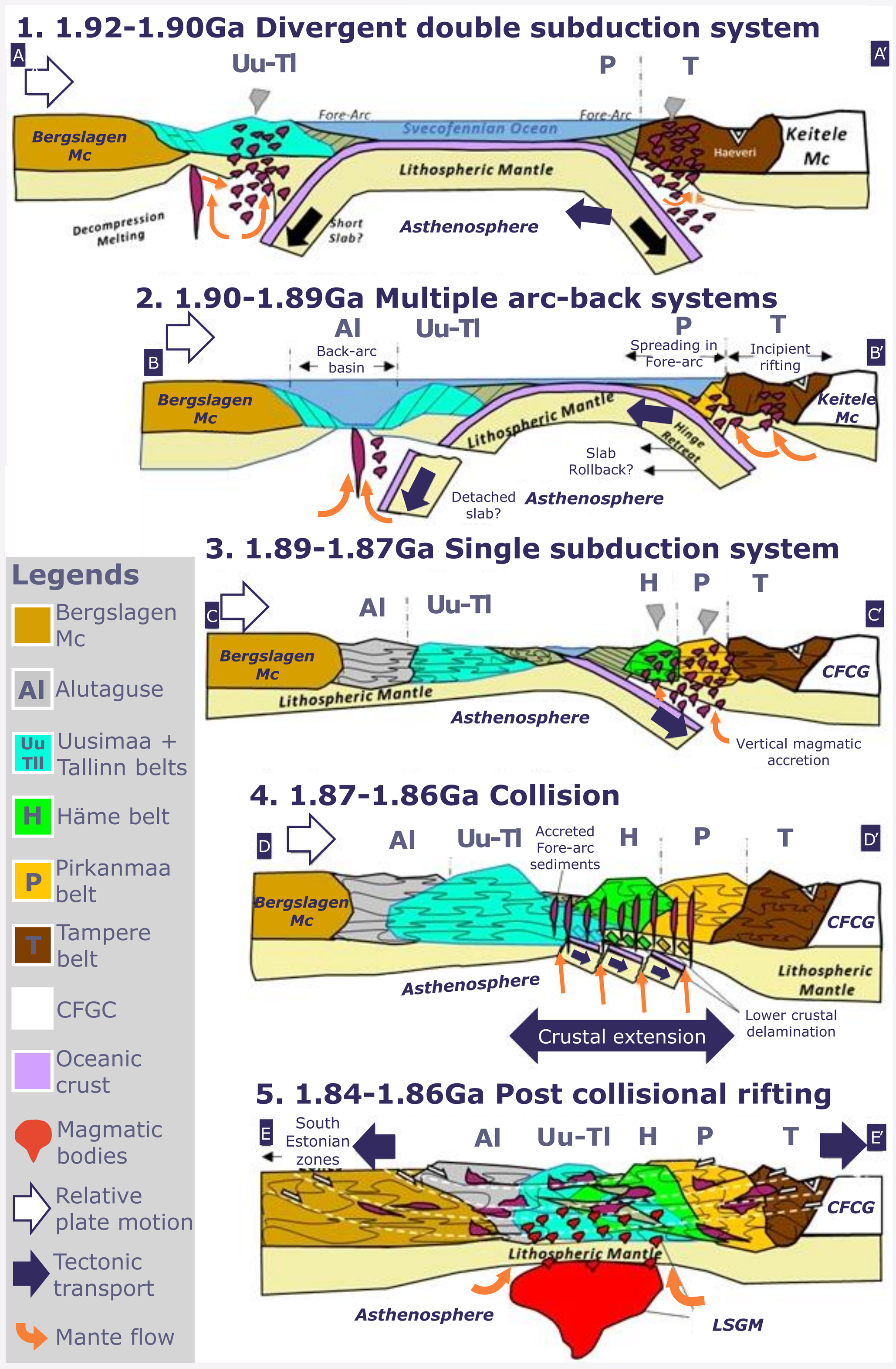


Fig. 4. Schematic Geodynamic Model (adapted from *Kukkonen and Lauri, 2009; Kara, 2021*) illustrating the evolution of Southern Finland and Northern Estonia within the context of the SO's evolution during the following periods.

In this study, our foremost contribution is enlightening the back-arc origin of the Alutaguse zone (**Figs.3F**), which its likely in genetic association with the Uusimaa units. This inference is drawn from the prominent CaO and MnO content observed in the metasediments **(Fig.2A)**.

Additionally, we posit that the most congruent model describing Fennoscandia's evolution involves a double subduction collision, culminating in the fusion of Bergslagen with southern Proto-Fennoscandia around *1.87-1.86 Ga*.

We ardently endorse examining the *metasedimentary* and *meta-volcanic* units in the Tallinn zone.

This would determine whether they are part of the Uusimaa belt in Estonia, or signify a separate arc that predated the Uusimaa belts. If the latter, they might have originated similarly to the adjacent northern arc belts.

Overall, our findings suggest that the Estonian basement is deeply intertwined with the geodynamic evolution of the Bergslagen microcontinent.

REFERENCES

Bogdanova, S. et al. (2015) Trans-baltic Palaeoproterozoic correlations towards the reconstruction of the supercontinent Columbia/nuna. Precambrian Research.

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.

Kivisilla, J. et al. (1999) Catalogue of chemical analyses of major elements in the rocks of the crystalline basement of Estonia. Eesti Geoloogiakeskus.

Kotova, L. et al. (2009) Source rocks and provenances of the ladoga group siliciclastic metasediments (Svecofennian foldbelt, baltic shield): Results of geochemical and sm-nd isotopic study. Stratigraphy and Geological Correlation, 17, 1–19

Kukkonen, I. and Lauri, L. (2009) Modelling the thermal evolution of a collisional Precambrian orogen: High heat production migmatitic granites of southern Finland. Precambrian Research, 168(3-4), 233–246.

Rasilainen, K. et al. (2007) The Rock Geochemical Database of Finland: Manual. Geological Survey of Finland.

Soesoo, A. et al. (2020) The evolution of the Estonian Precambrian basement: geological, geophysical and geochronological constraints., (2), 18–33.

Solano-Acosta, J. D. et al. (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.

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juan.solano@taltech.ee
alvar.soesoo@taltech.ee
rutt.hints@taltech.ee

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