New insights of the crustal structure across Estonia using satellite potential fields derived from WGM-2012 gravity data and EMAG2v3 magnetic data.

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Objectives

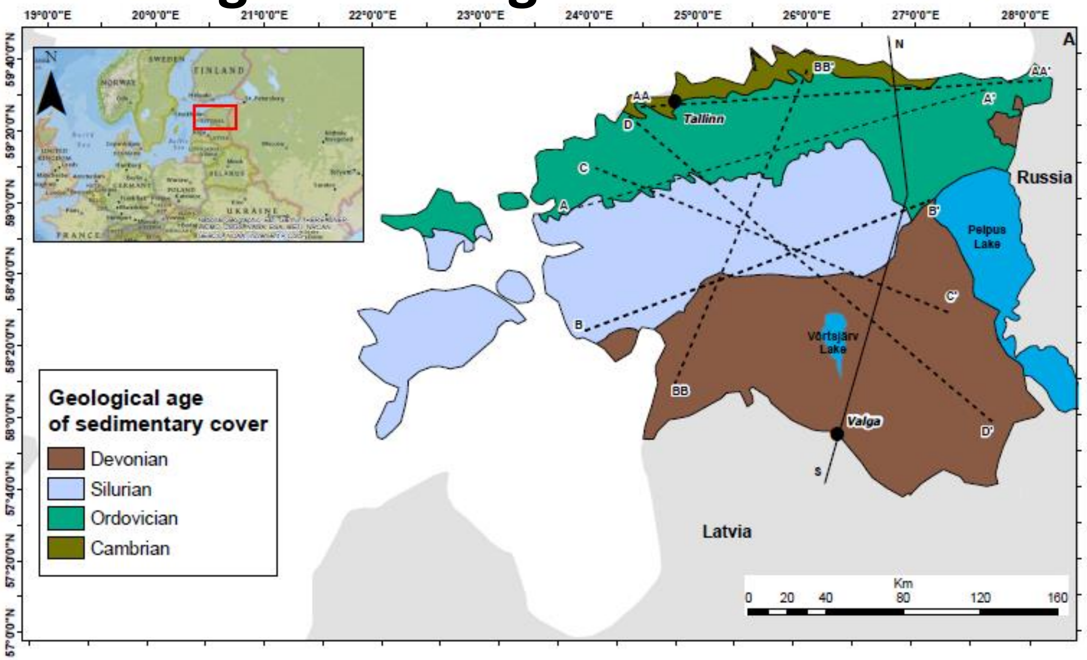
- The main goal of this work is to detail the magnetic and gravity signatures and structure of the Estonian crust **(i.e Curie depth point, Moho and Conrad discontinuities, and shallow potential spectra)**, also enhancing the structural divisions of the Estonian basement.

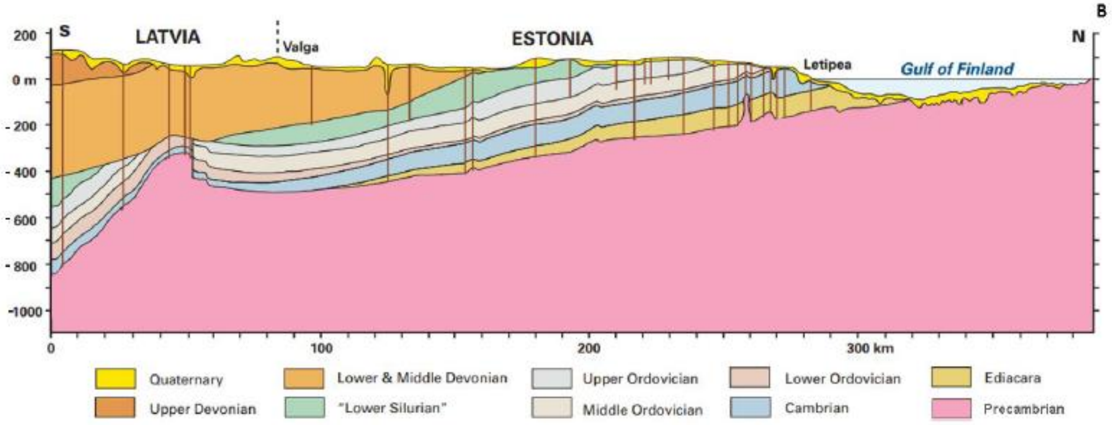
- Recognise geological structures retained on basement rocks as main features or those connected to subsequent metamorphic/igneous overprints.

- Potential anomaly processing and matching filters are used in this research, allowing the shallow and deep geophysical responses of these structures and domains to be compared.

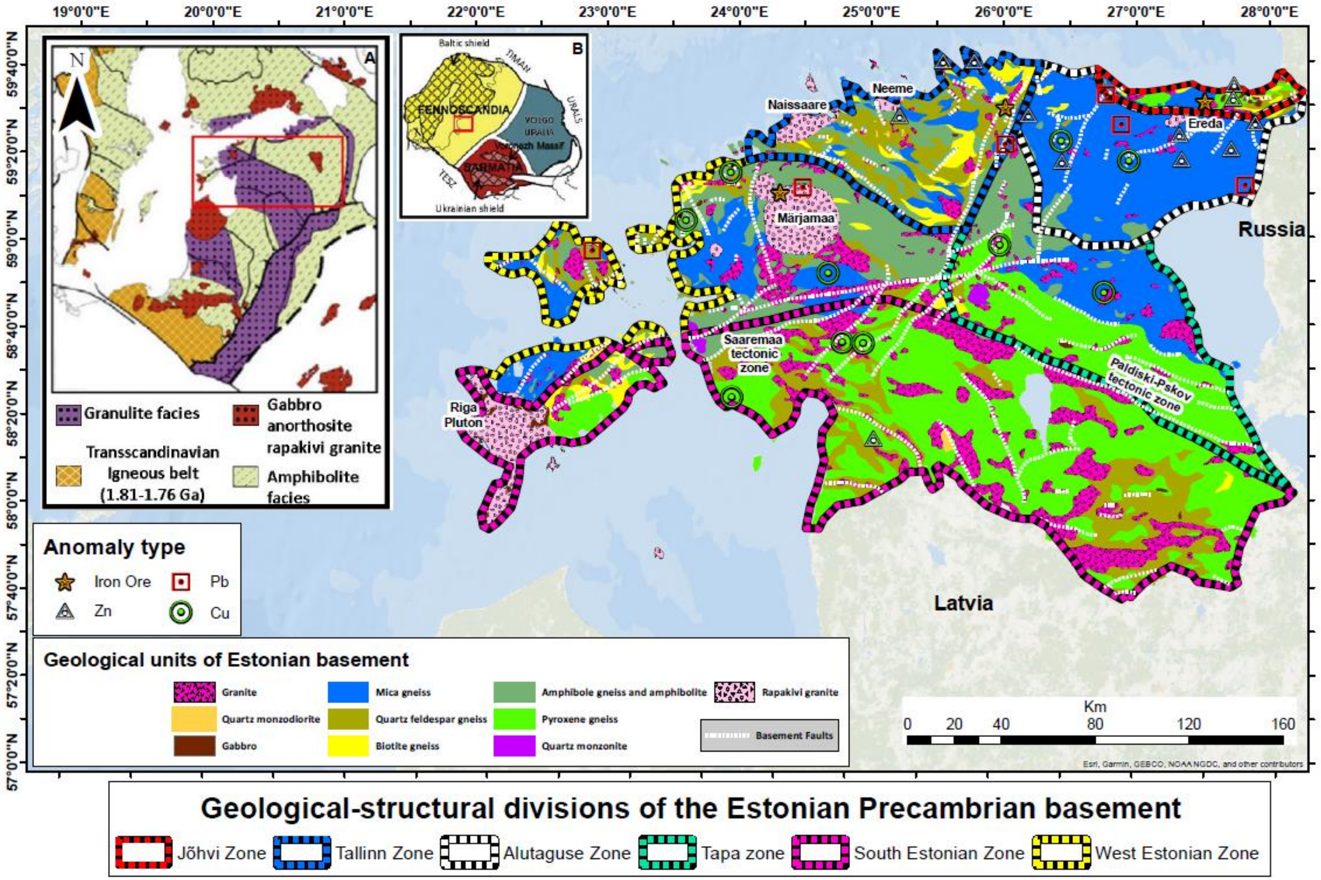
The geophysical modeling and interpretations provided here will help understand the better geological formation of the Estonian basement and the possible overprinting of the Sveconfennian orogeny in Estonia and contribute to the debate on tectonic amalgamation theories (Bogdanova et al.,(2015)).

Geological Setting



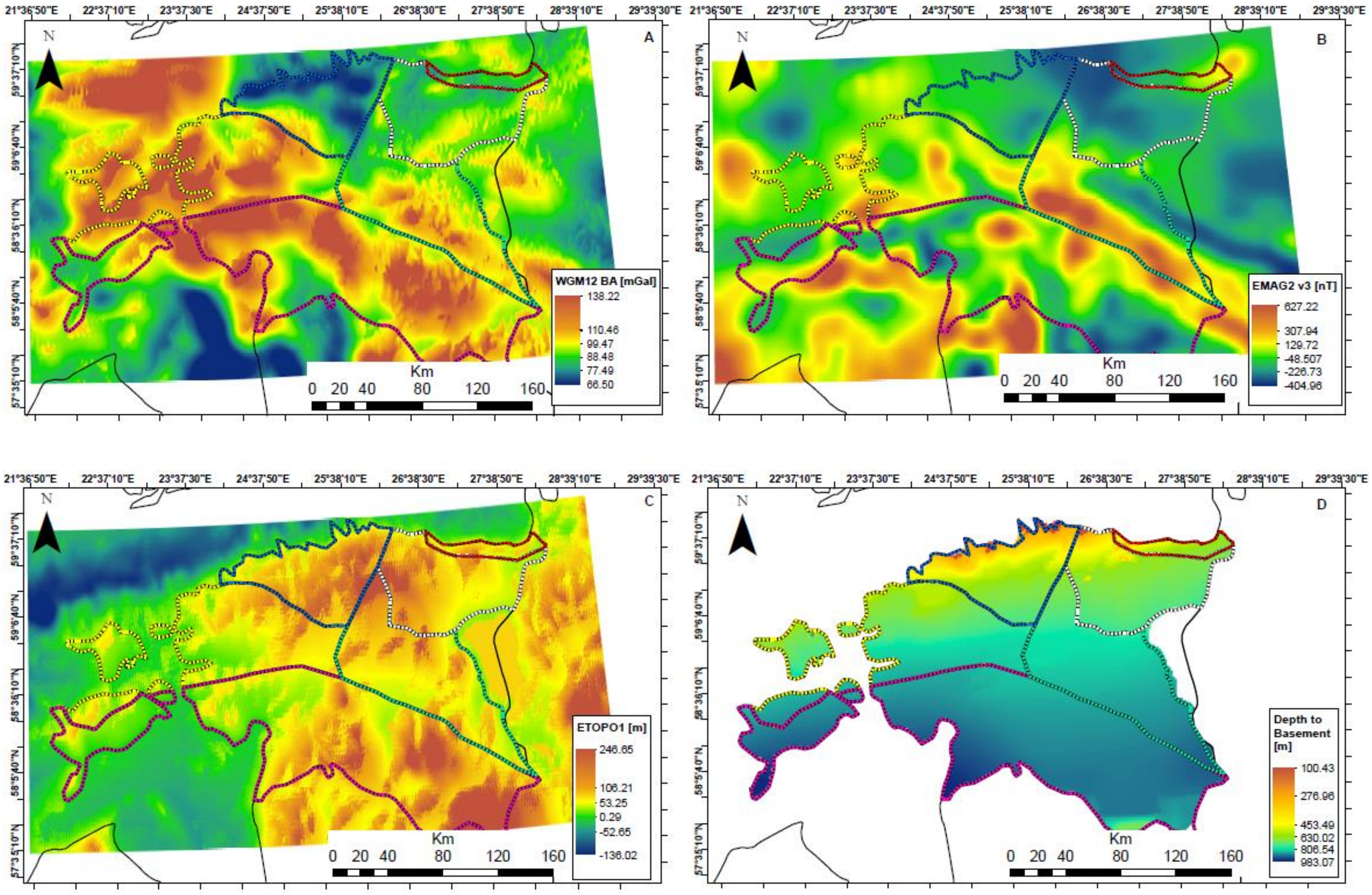


Geology schemes of Estonia. A) Generalized map with the sedimentary cover of Estonia shows outcrop areas of lower and middle Paleozoic rocks. Dash lines correspond to the profiles used to analyze potential data; B) Geological cross-section profile of Estonia. Vertical lines correspond to drill cores.



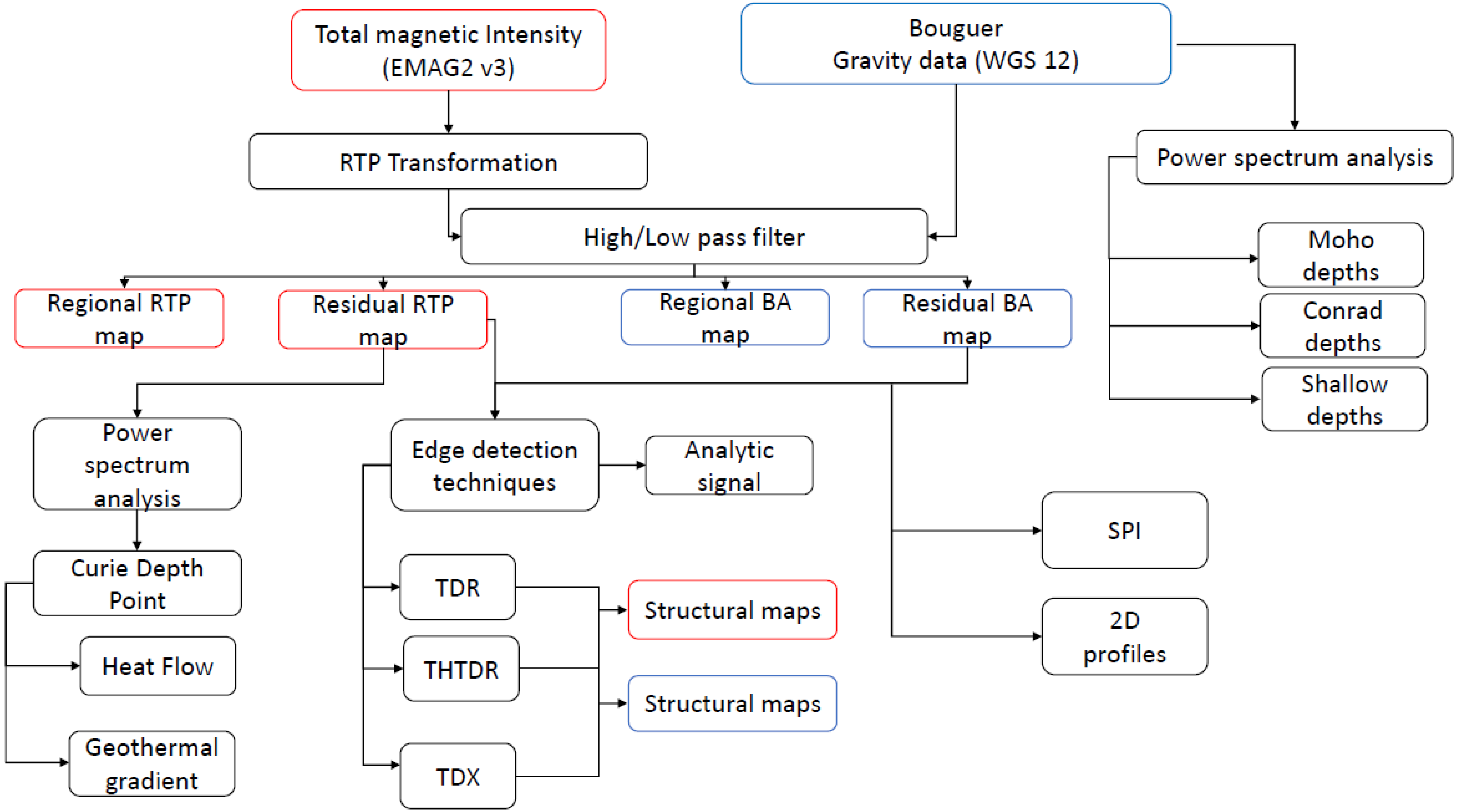
Geological map scheme of the Precambrian basement of Estonia, showing geochemical anomalies according to Soesoo et al., (2020) . A) Major Palaeoproterozoic tectonic domains in the Baltic Sea area (modified after Bogdanova et al.,(2015)); B) Crustal segments of the East European craton (modified after Gorbatschev and Bogdanova (1993)).

Data used



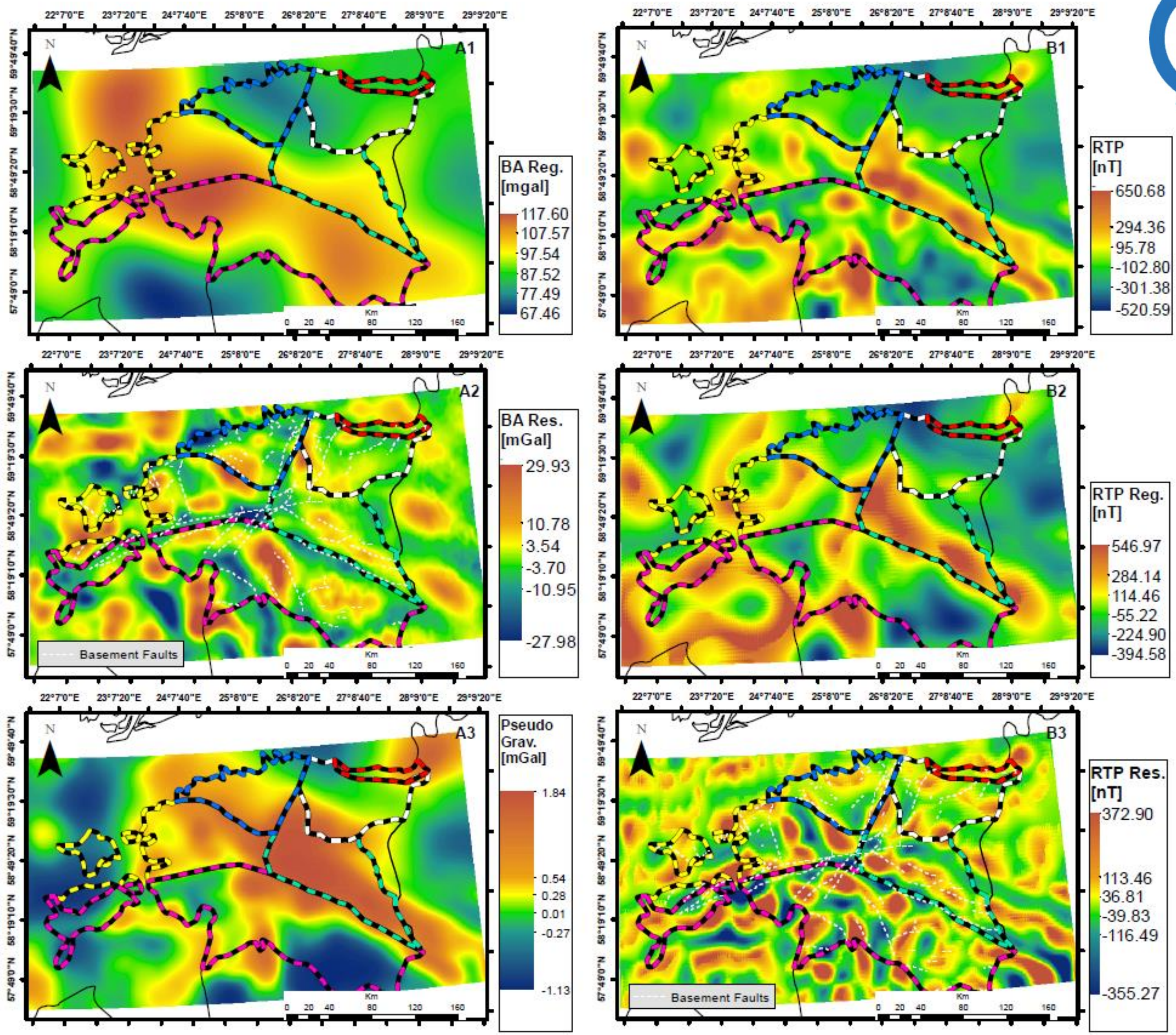
Base data used in this research. A) EGM12 Bouguer anomaly (CBA).; B) EMAG2v3 Magnetic anomaly.; C) ETOPO1 Height altitude.; D)Depth to the Basement from drill cores.

Gravity and magnetic data processing I

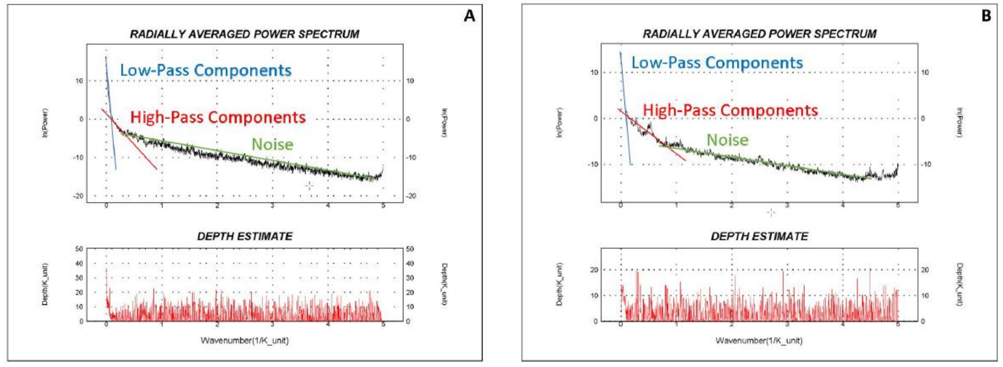


The process used to get the relevant maps depicted in a flowchart.

Gravity and magnetic data processing II

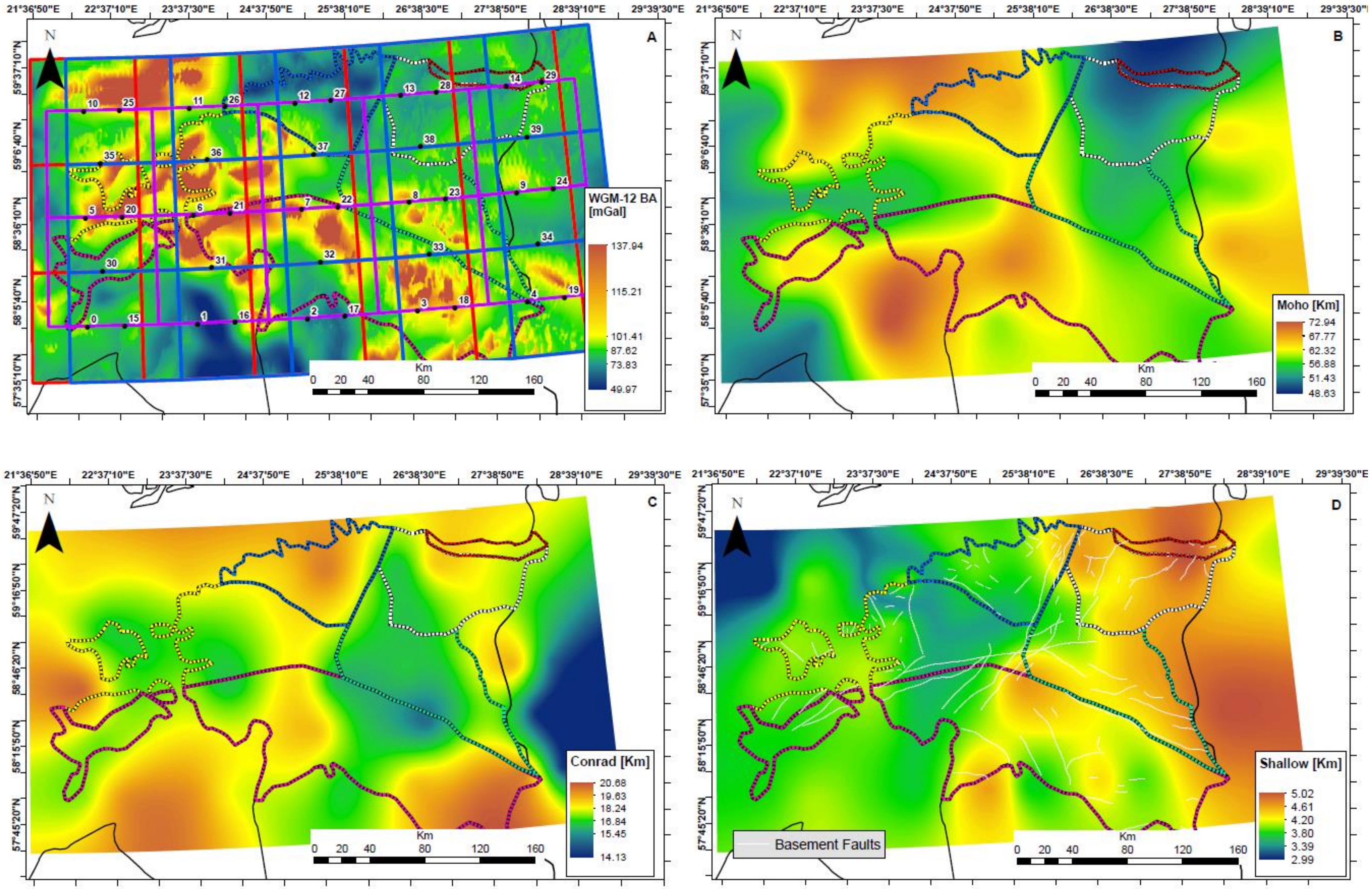


Transform map results of the potential data of Estonia. A1) Low-pass filtered gravity (regional) anomaly map.; A2) High-pass gravity (residual) anomaly map.; A3) Pseudo-gravity map obtained from the RTP results.; B1) Reduction-to-Pole (RTP) magnetic anomaly map.; B2) Low-pass filtered RTP magnetic (regional) anomaly map.; B3) High-pass filtered RTP magnetic (residual) anomaly map.

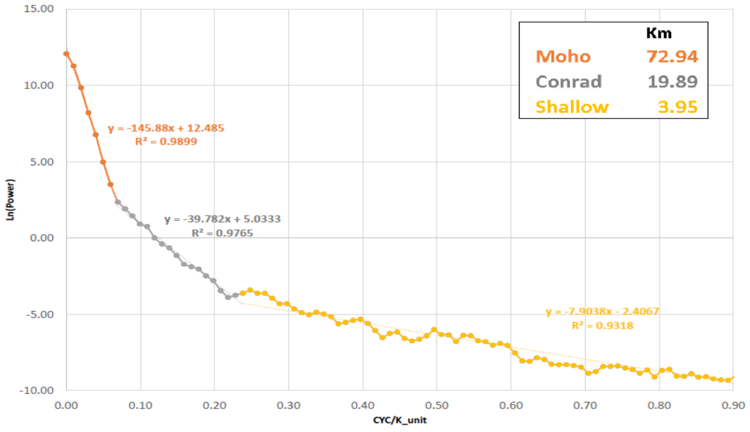


A) The radial averaged power spectrum of the CBA data used to create residual and regional gravity anomaly maps.; B) The radial averaged power spectrum of the RTP data used to create residual and regional magnetic anomaly maps.

Moho and Conrad discontinuities from WGM12 Bouguer anomaly



Map results of the layer discontinuities obtained after the power spectra analyses of the Bouguer WGM-12 model. A) 150x150km block grids over the CBA WGM-12 that were analyzed individually to obtain the depth results of the Moho and Conrad discontinuities and the depths of the shallowest records of the signal.; B) Moho discontinuity depth map.; C) Conrad discontinuity depth map.; D) shallowest depths of the recorded spectrum map.



Example of the radial average power spectrum of CBA gravity data for block 1, showing three defined segments (i.e., Moho discontinuity, Conrad discontinuity, and the shallow signal recorded) due to the decay of power with respect to frequency.

Calculation of the Curie point depth, geothermal gradient and heat flow

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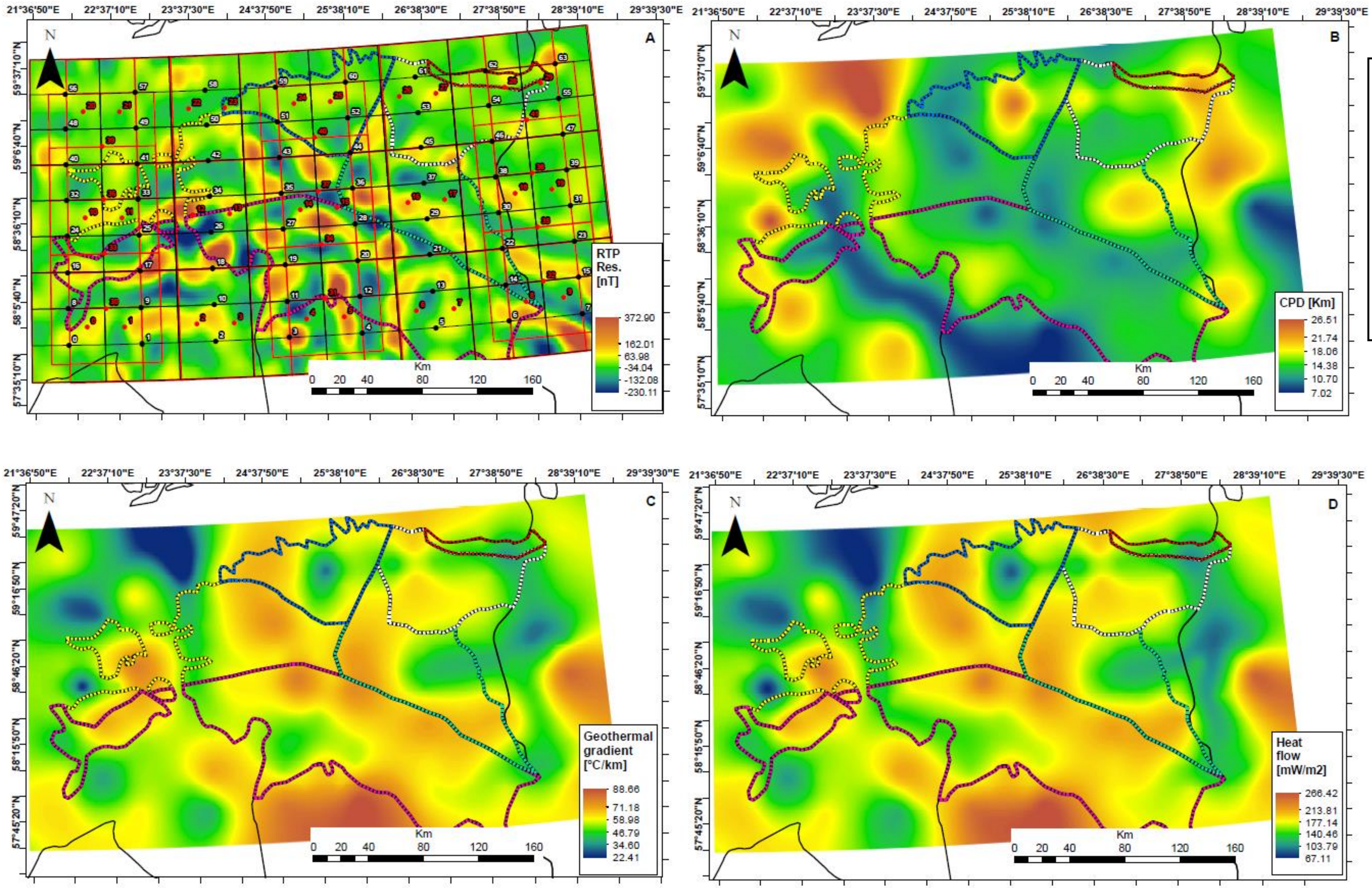
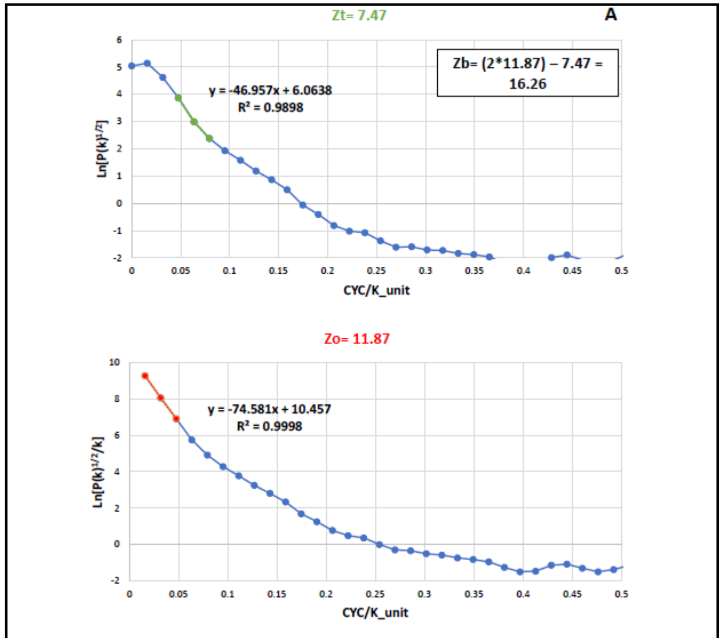
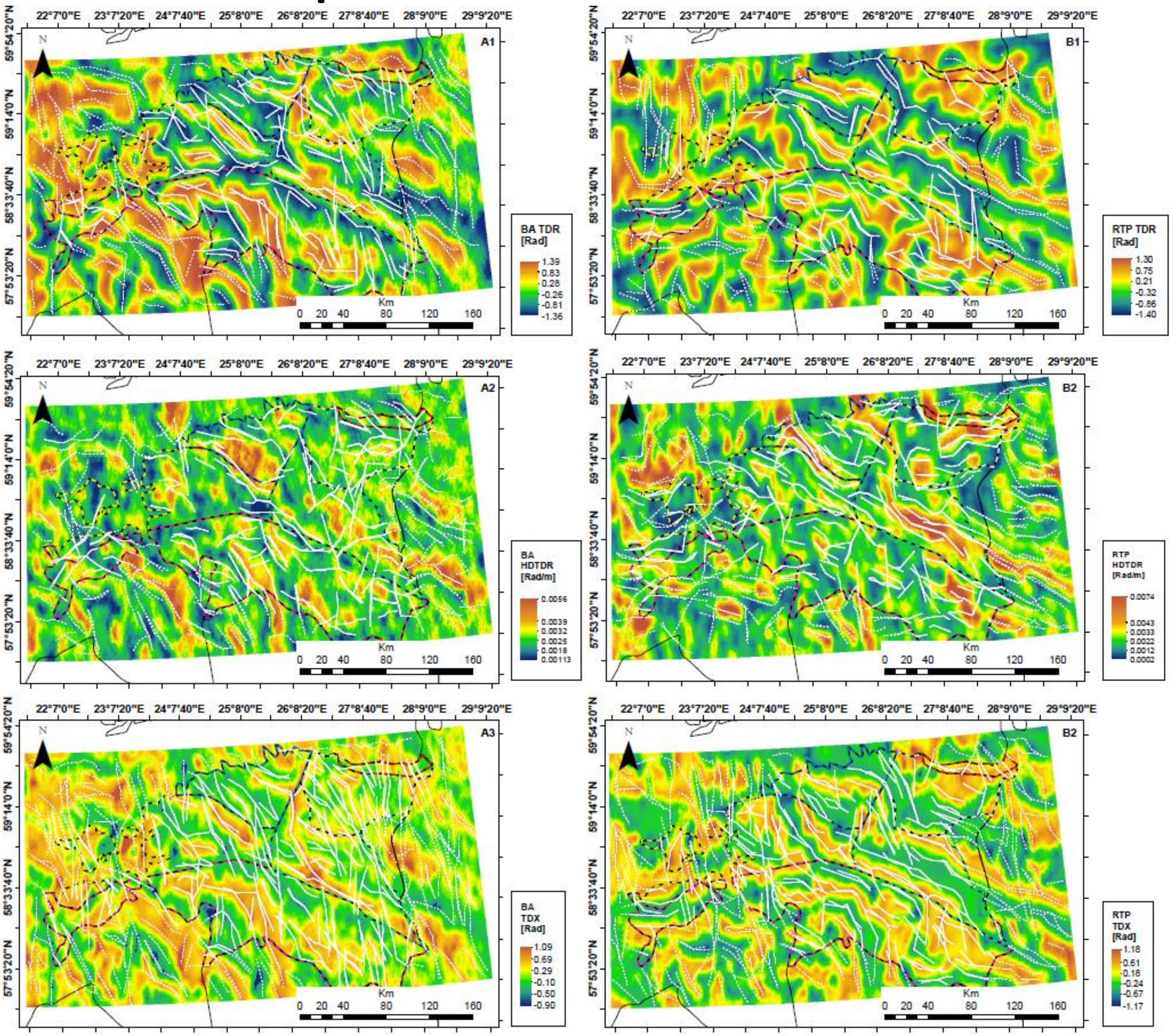


Map results of the CPD, GG, and HF. A) RTP residual map showing the overlapping squared blocks (100x100 km2 in black grids and 150x150 km2 in red grids) for estimating the CPD. Each block is label with a centered dot.; B) CPD map estimated from the power spectrum analysis of the RTP residual magnetic data.; C) Geothermal gradient map estimated from the CPD analysis.; D) Heat flow map estimated from the typical CPD analysis



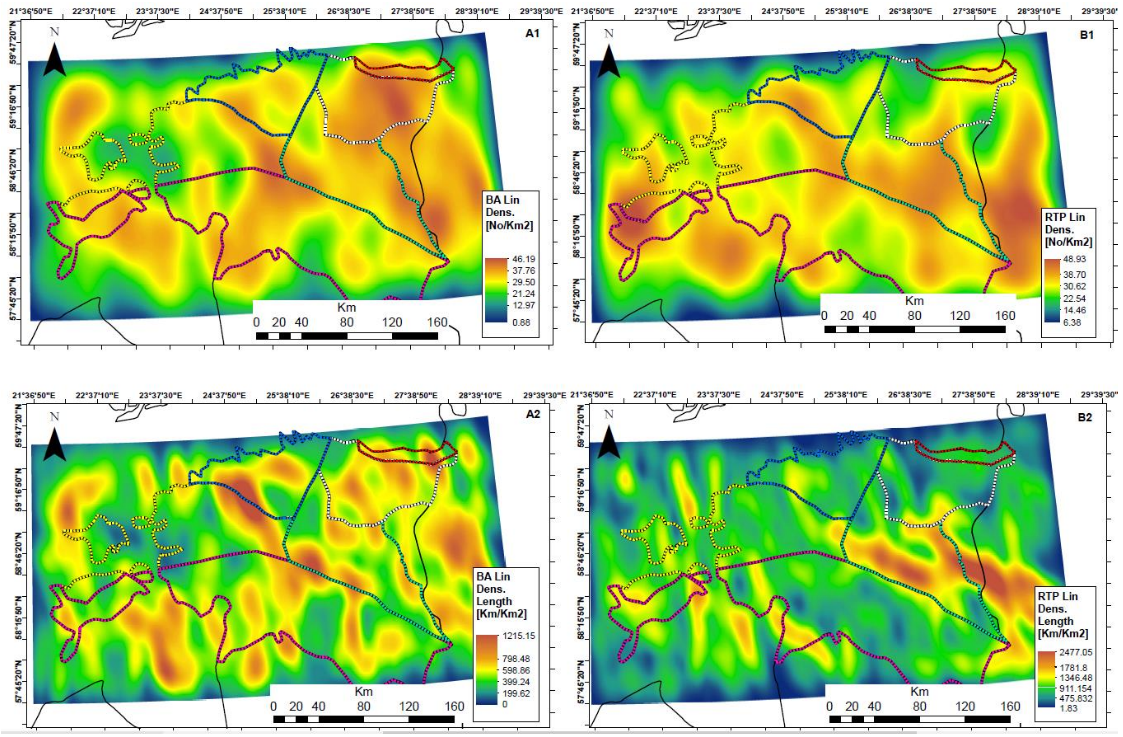
Examples of the power spectrum analysis to estimate the depth to the base of magnetic sources (CPD). Representative 100x100 km2 block (block 34).

Edge and lineaments detection methods of residual potential data I

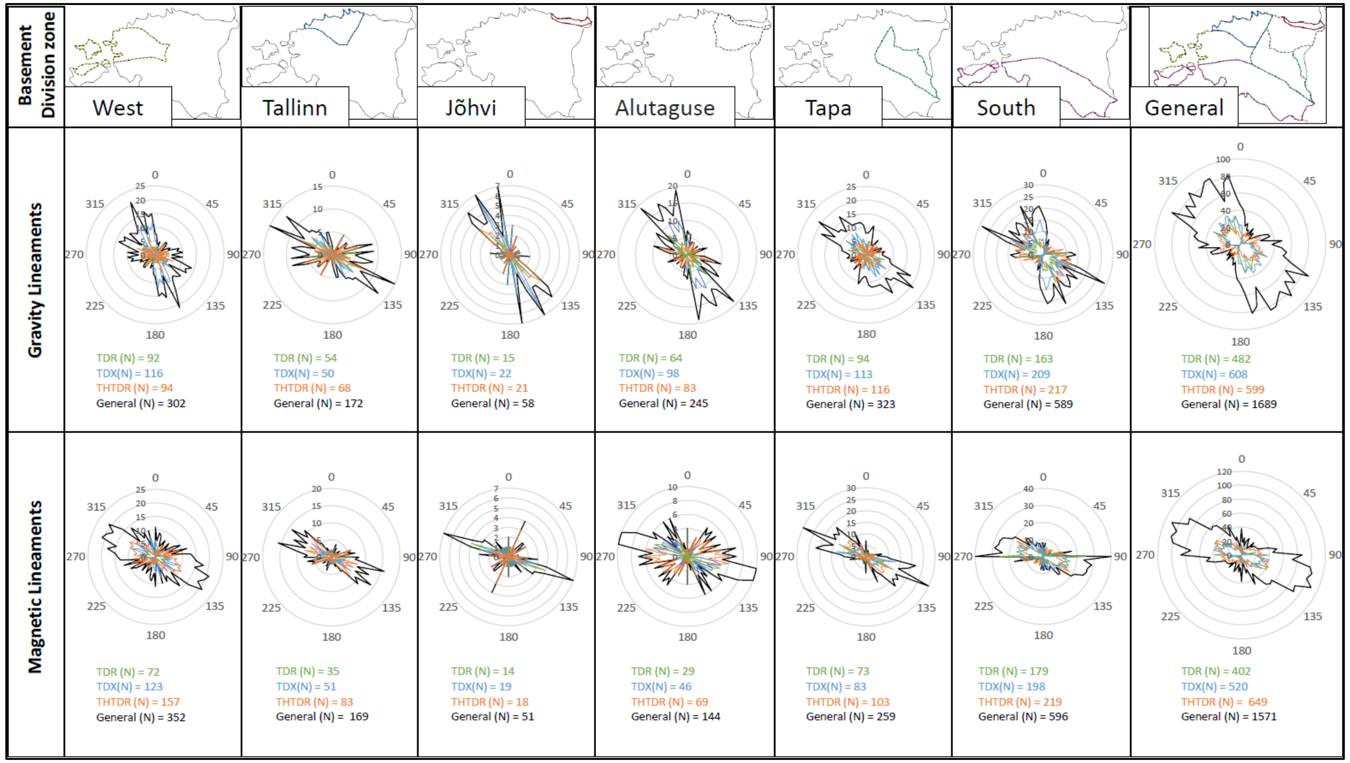


Derivative technique maps and their lineaments from potential data from A) Residual Bouguer anomalies and B) Residual magnetic anomalies.; 1) TDR.; 2) HDTDR.; 3) TDX.

Edge and lineaments detection methods of residual potential data II

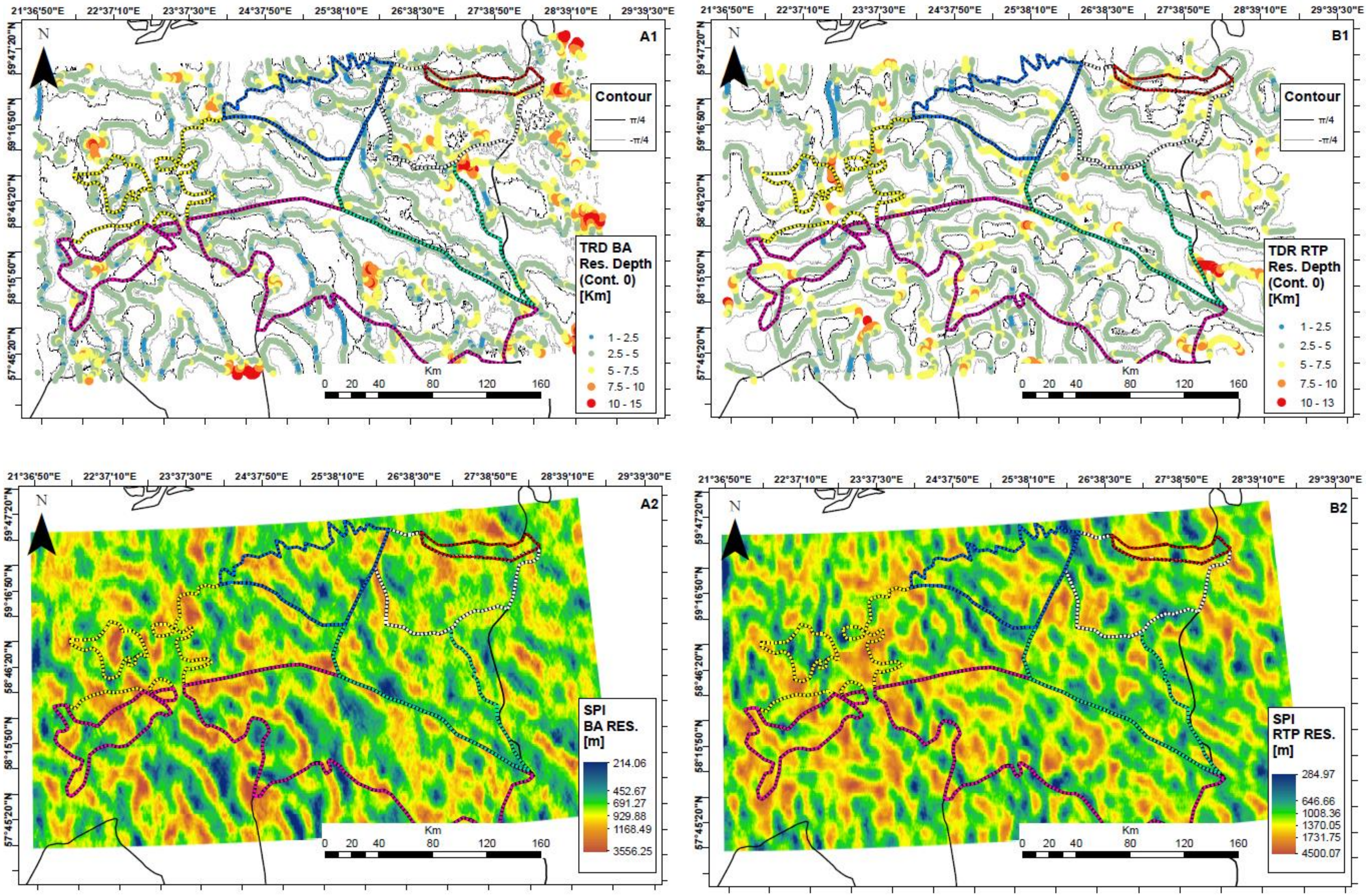


Density maps from geophysical lineaments. A1) Spatial density map of the gravimetric lineaments.; A2) Length density map of the gravimetric lineaments.; B1) Spatial density map of the magnetic lineaments.; B2) Length density map of the magnetic lineaments.



Rose diagrams from potential subdivided into the geological-structural divisions of the Estonian Precambrian basement.

Theoretical depths of potential anomalies



Theoretical depth maps from residual potential data. A1) TDR depth map from gravity data.; A2) SPI depth map from gravity data.; B1) TDR depth map from magnetic data.; B2) SPI depth map from magnetic data.

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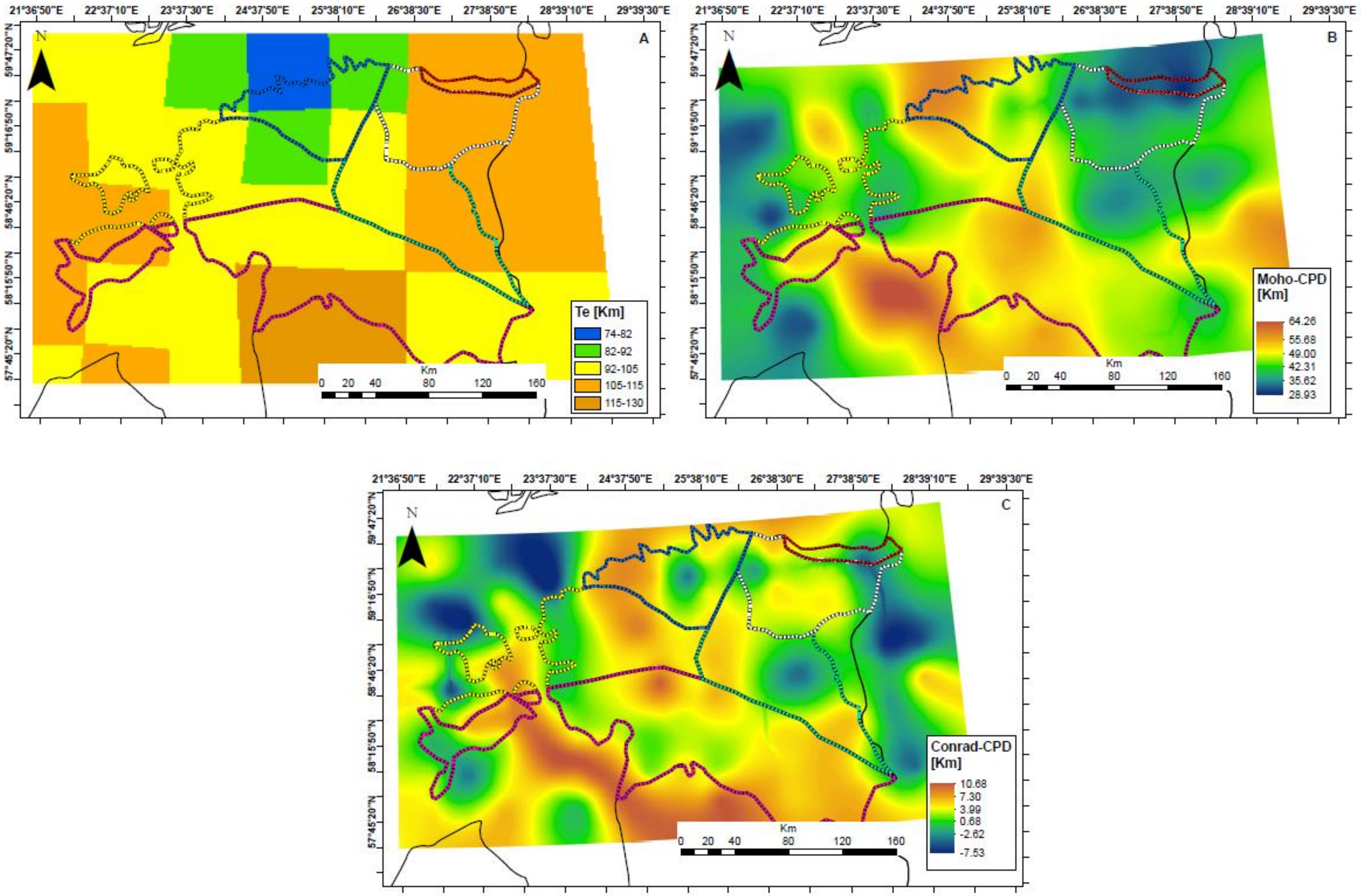
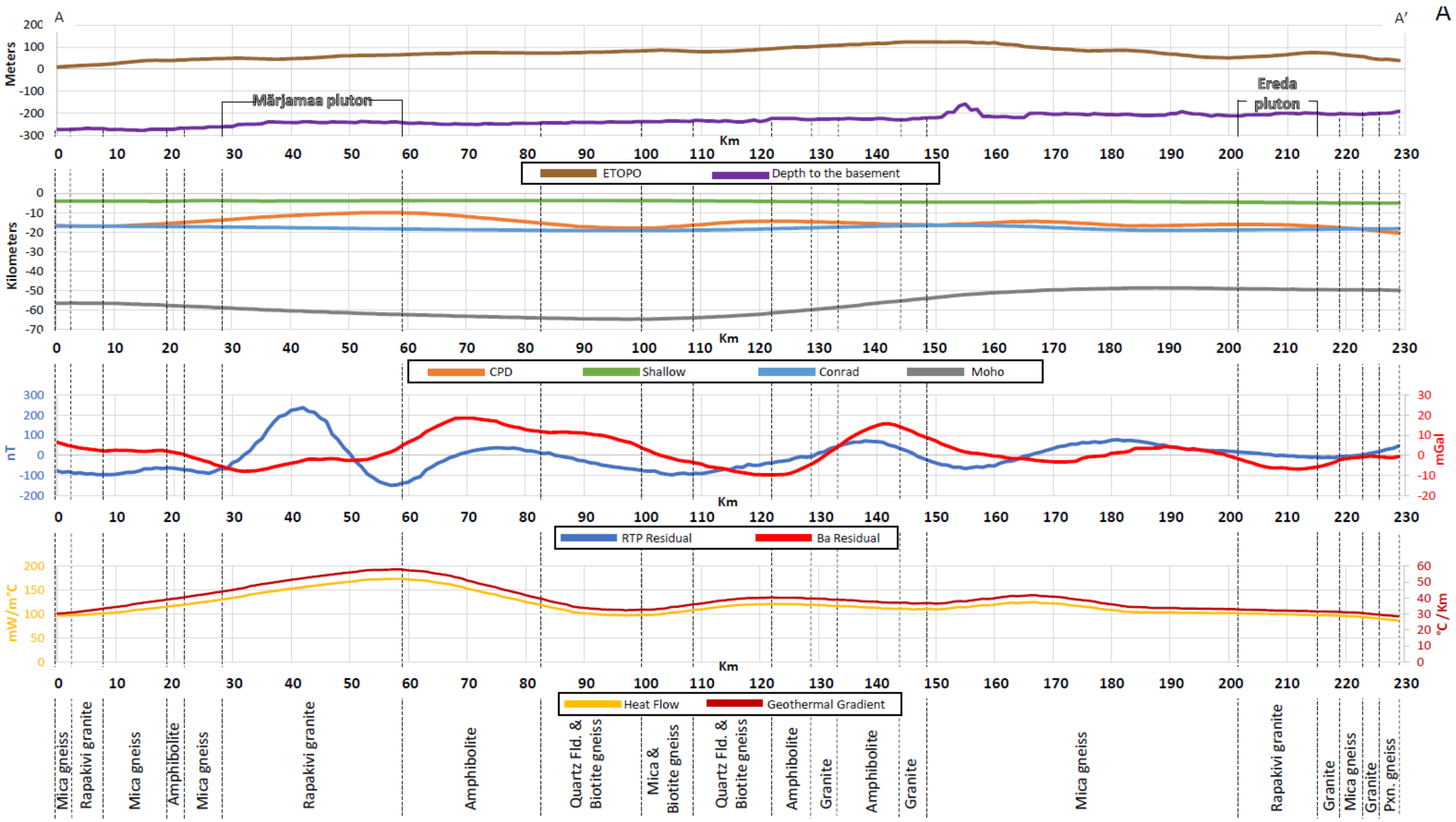
Discussion I



A) *Te* map after Perez-Gussinye et al., (2004).; B) Map showing the differences between the Moho depths and the CPD.; C) Map showing the differences between the Conrad depths and the CPD.

Discussion II (2D profiles)



Example of one of the Profiles done across Estonia showing the relations of the topography, crustal layers, residual potential anomalies and heat flow across the basement lithology.

Conclusions

- According to the base potential data, the largest gravitational and magnetic values may be found in the Saaremaa and Paldiski-Pskov tectonic zones. It is also easy to see that those values are more significant in areas with more granulite facies.

- It has been discovered that using residual data, the Tallinn and Alataguse areas enhance several zones with high values, which match with zones with metal anomalies, particularly in the Alataguse zone. Johvi zone has high and increased residual potential values, which are most likely related to the existence of iron ores.

- Detailed power spectrum analysis of the CBA map has brought out shallow sources depth map (an average depth 4.21 km), Conrad discontinuity map (an average depth 17.8 km), and the Mohorovicic discontinuity map (an average depth 60.45 km) in the study region.

- Previous research on the elastic thickness and seismic anisotropy backs up the crust thickness result (Moho boundary).

- CPD values are slightly shallow (at a depth similar to that of the Conrad discontinuity). The lowest CPD values are found in the Paldiski-Pskov tectonic zone and near the Marjamaa rapakivi pluton, in contrast to the heat flow, which has its highest values in these zones.

- The Moho-Curie difference shows that mantle magnetization is irrelevant in our research region since the magnetization is limited to the crust.

- Predominant NW-SE lineament trends are observed, supporting the theory of tectonic block convergence derived from the Svecofenian orogeny.

Some references used…

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