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Crustal structure in the transition zone from the Precambrian to Palaeozoic platform in the southern Baltic Sea – inferences from newly acquired potential field and seismic data

Małgorzata Ponikowska[1], Stanislaw Mazur[1], Michał Malinowski[2], Christian Hübscher[3], Ingo Heyde[4], Tomasz Janik[2], and Dariusz Wójcik[2]

[1]Institute of Geological Sciences, Polish Academy of Sciences, Kraków, Poland (m.ponikowska@ingpan.krakow.pl)
[2]Institute of Geophysics, Polish Academy of Sciences, Warszawa, Poland
[3]Institute of Geophysics, University of Hamburg, Hamburg, Germany
[4]Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover (BGR), Germany

1. Introduction

The focus of our research is on the structure of Phanerozoic sedimentary cover in the transition zone from the Precambrian to Palaeozoic platform in the southern Baltic Sea Sea using new geophysical data.

The southern Baltic Sea area is located in the transition zone between the Fennoscandian Shield as part of the East European Craton (EEC) and the West European Platform. This area is characterised by a mosaic of various geological blocks separated by several fault zones formed throughout the Phanerozoic. The most prominent tectonic feature is the NW–SE trending Sorgenfrei-Tornquist Zone, crossing the southern Baltic Sea area between Scania in Sweden and Pomerania in Poland (Pharaoh, 1999).

In March 2016 the “BalTec” cruise took place with the German R/V Maria S. Merian in the Baltic Sea (cruise MSM52). During the cruise the new multi-channel seismic data (MCS) was acquired. In addition hydroacoustic and gravity data were collected along the same profiles.

1. Introduction

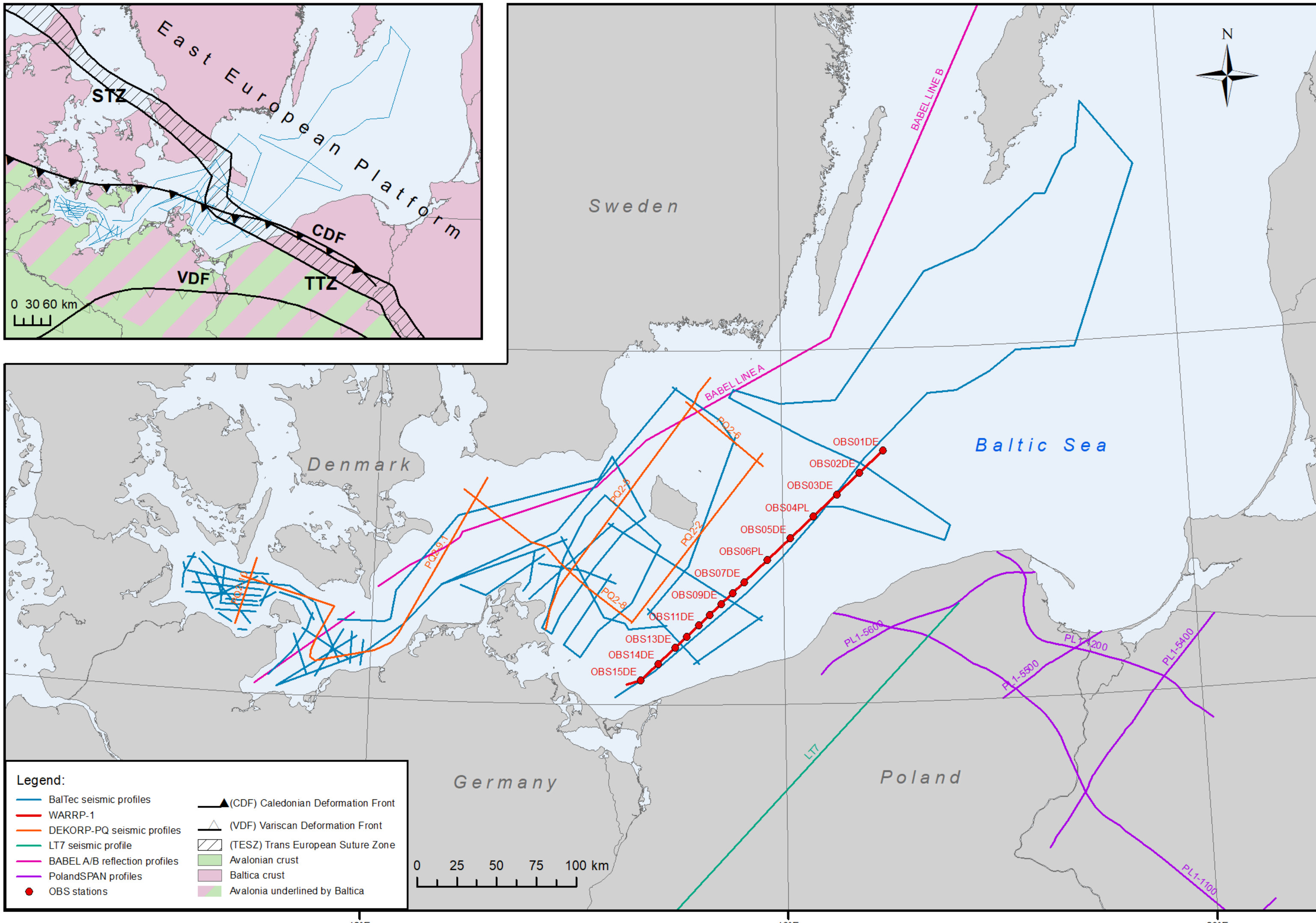


Fig. 1 Seismic profiles acquired during the MSM52 BalTec cruise, the WARR OBS profile and selected previous studies: DEKORP-PQ (Meissner and Krawczyk, 1999), BABEL (BABEL Working Group, 1993), onshore LT7 profile (Dadlez 2000) and onshore PolandSPAN survey (Mazur et al. 2017). Inset shows location of the BalTec profiles at the background of the tectonic map (after Mazur et al. 2016 and Mazur et al. 2020) showing main tectonic features: TTZ – Teisseyre-Tornquist Zone, STZ – Sorgenfrei- Tornquist Zone.

2. Geological setting

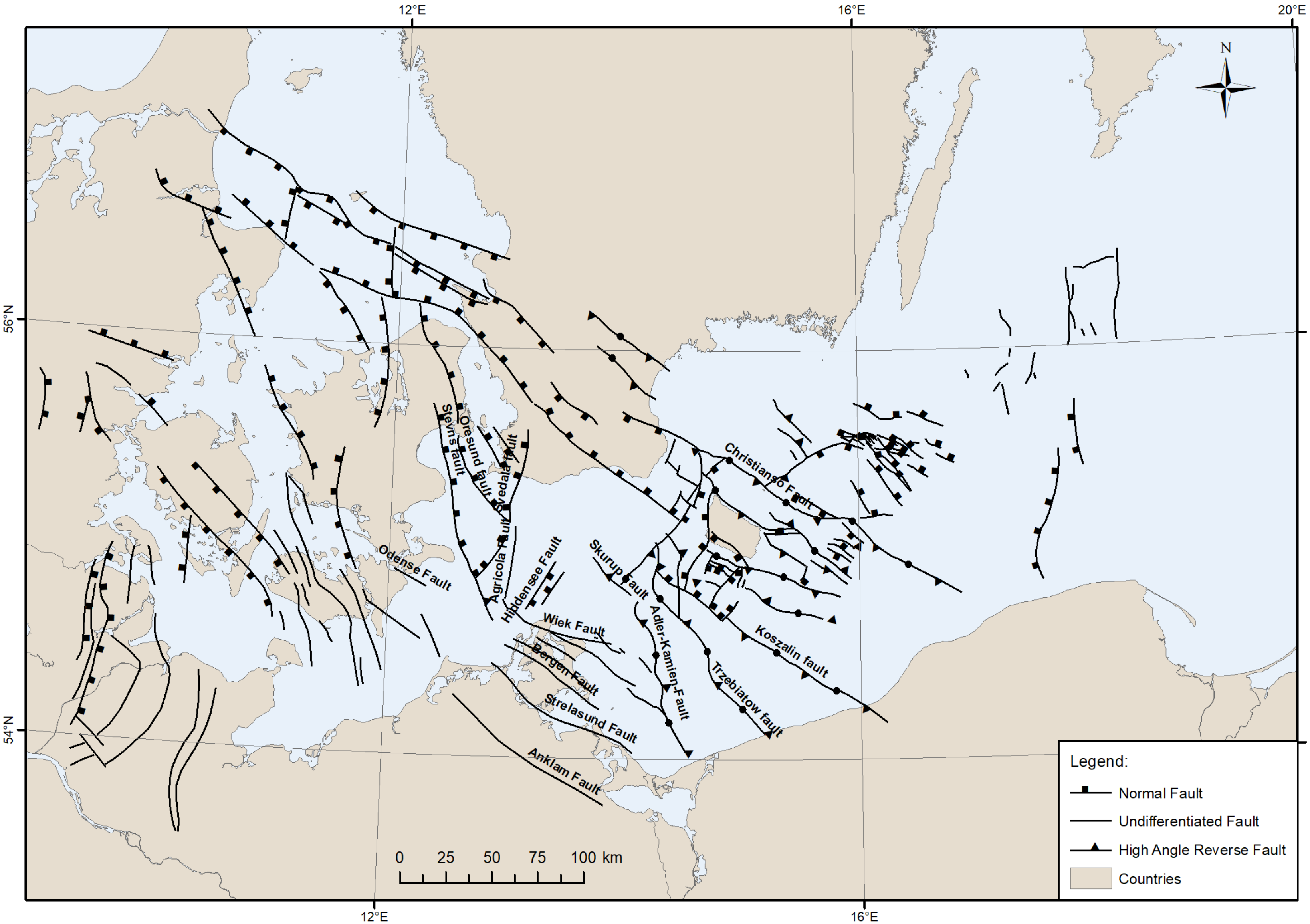


Fig. 2 Structural map modified from several sources including: Vejbæk et al. (1994), Schlüter et al. (1998), Sopher and Juhlin (2013), Sopher et al. (2016), Al Hseinat and Hübscher (2017), Poulsen et al. (2017), Seidel et al. (2018).

3. Data sources

MSM52
BalTec

RV Maria S. Merian - cruise MSM52 BalTec

01-8.03.2016

- MSM52 BalTEC data:
  - 3500 km of multi-channel seismic data (850 km in the Polish economic sector)
  - 7000 km gravity data – along the ship track
  - Wide-angle data from 15 OBS along 220 km long profile crossing TTZ
  - 6000 km parametric sediment profiler (Parasound)

- Open source gravity data – Sandwell and Smith v. 24.1 (Scripps Institution of Oceanography, University of California)

- Reduced-to-Pole (RTP) magnetic data

3. Data sources

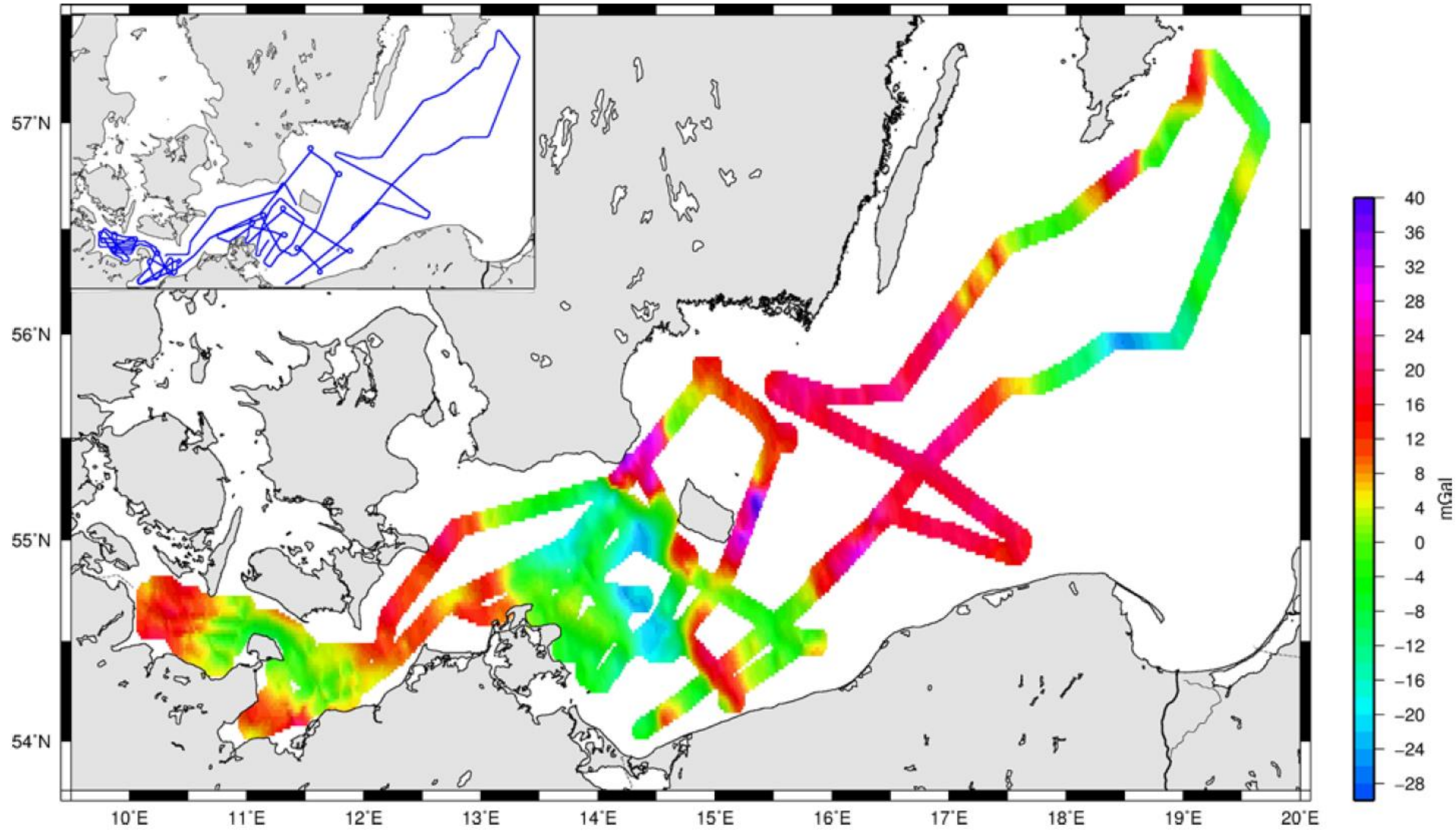


Fig. 3 Map of the free-air gravity anomalies acquired during the profiles of the MSM52 BalTec cruise. The map is drawn up to a distance of 5 km from the ship tracks. The map is based on a 1x1 (arc-) minutes grid. Inset shows the BalTec cruise profiles with useful gravity measurements are shown (Hübscher et al., 2017).

3. Data sources

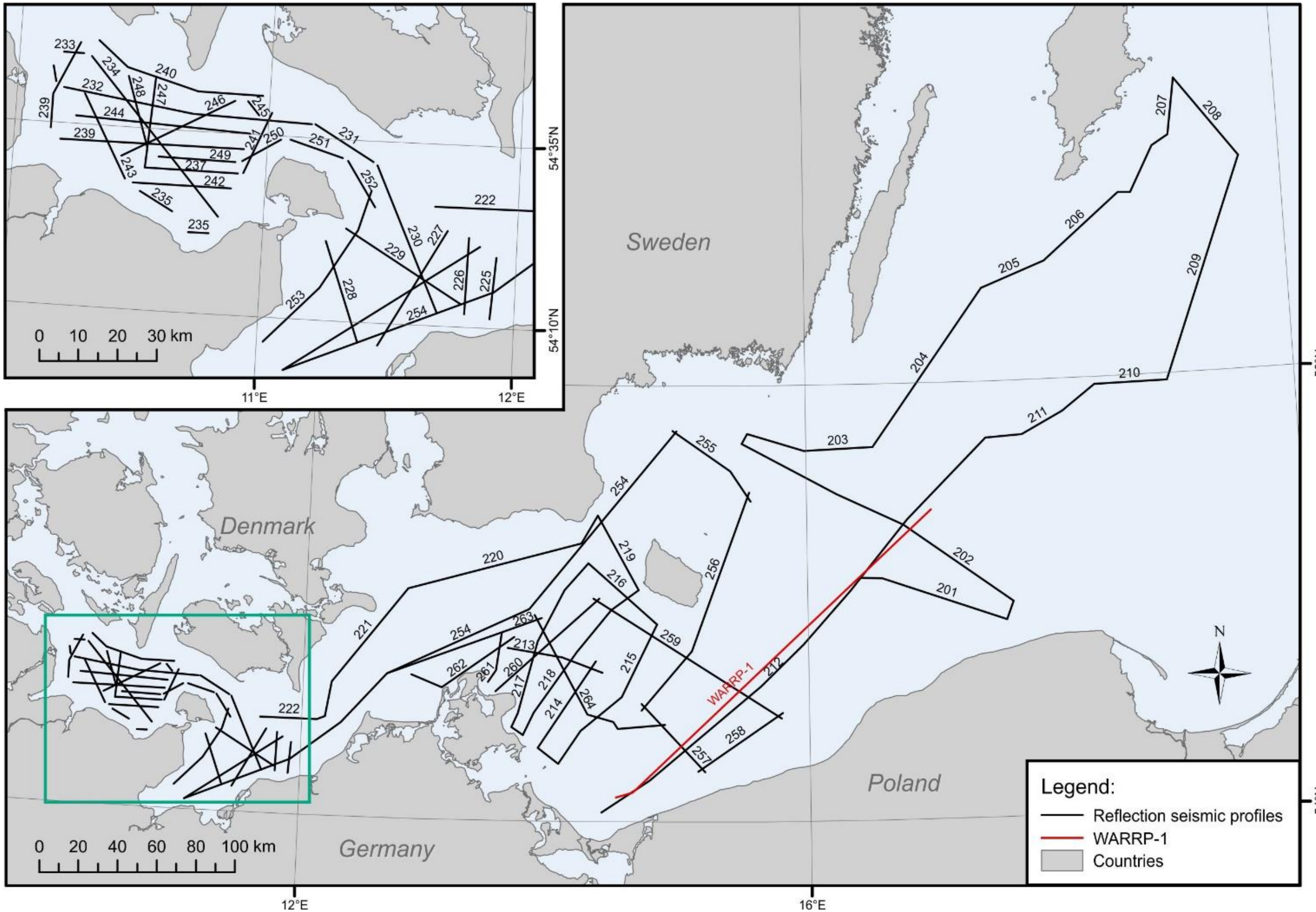


Fig. 4 Reflection seismic profiles of BalTec cruise (Hübscher et al., 2017 - modified).

4. Geophysical data processing

The first step in analysis of potential field data was integration of marine gravity with a regional gravity dataset. The result was a coherent gravity grid, which was used for further advanced processing, involving calculation of transformations and derivatives.

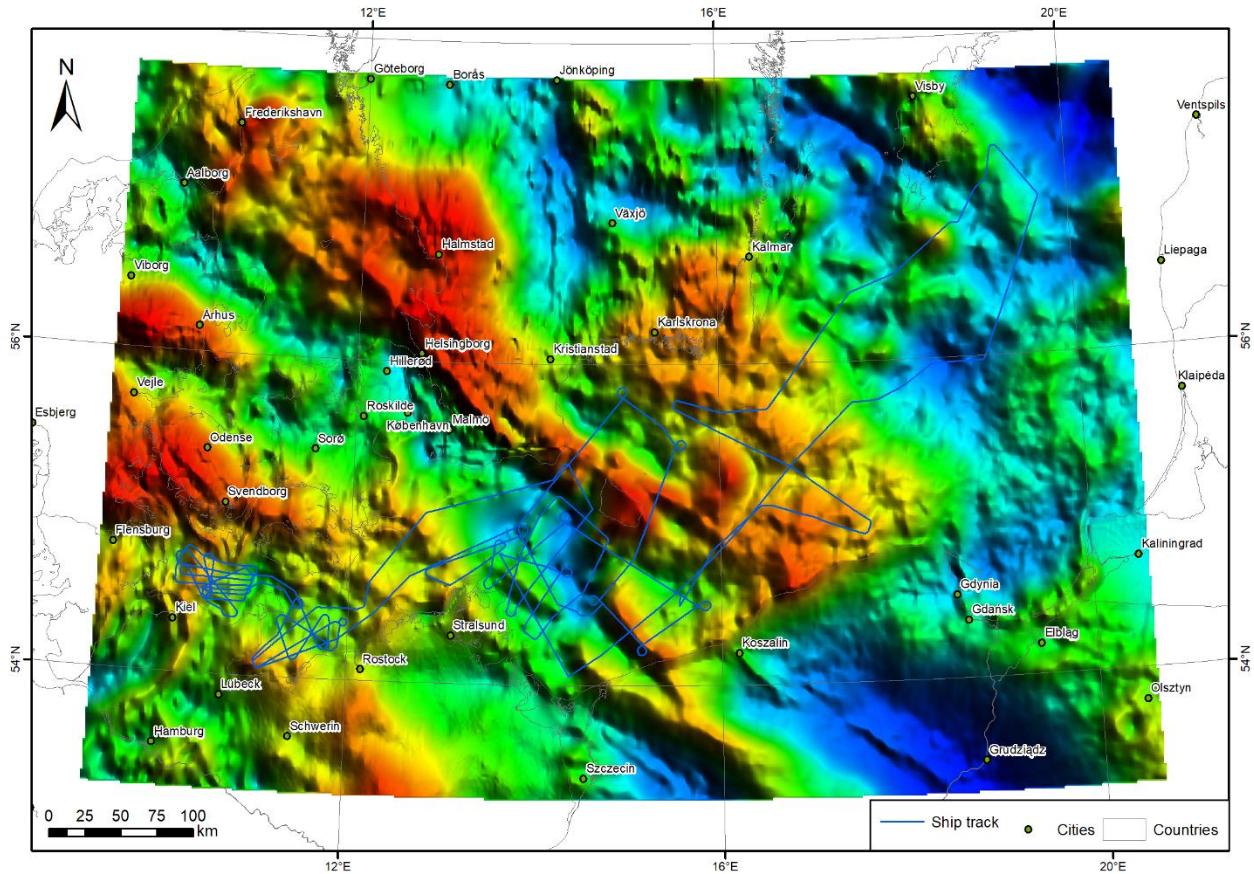


Fig. 5 Merged marine ship track and regional gravity data with resolution 1730x1730 m. The coordinate system used is WGS_1984_UTM_Zone_33N that is based on the WGS_1984 datum, WGS_1984 spheroid and the Transverse Mercator projection with 15°E as a central meridian.

4. Geophysical data processing

We also included a regional magnetic grid in the advanced processing:

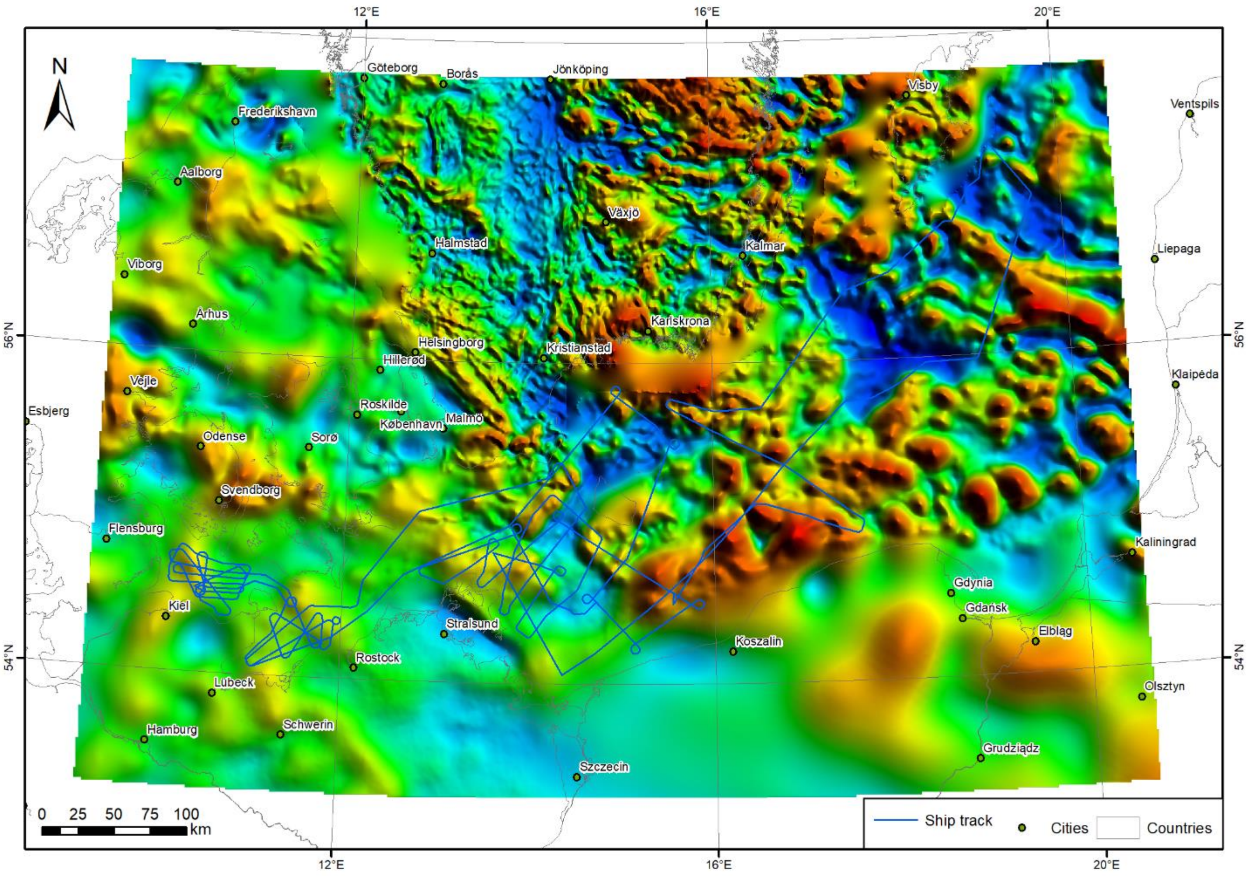


Fig. 6 Reduced-to-Pole magnetic data with resolution 871x871 m. The coordinate system used is WGS_1984_UTM_Zone_33N that is based on the WGS_1984 datum, WGS_1984 spheroid and the Transverse Mercator projection with 15°E as a central meridian.

4. Qualitative Analysis

Filters and derivatives of gravity and magnetic data were applied in qualitative analysis and interpretation of the structural elements throughout the area.

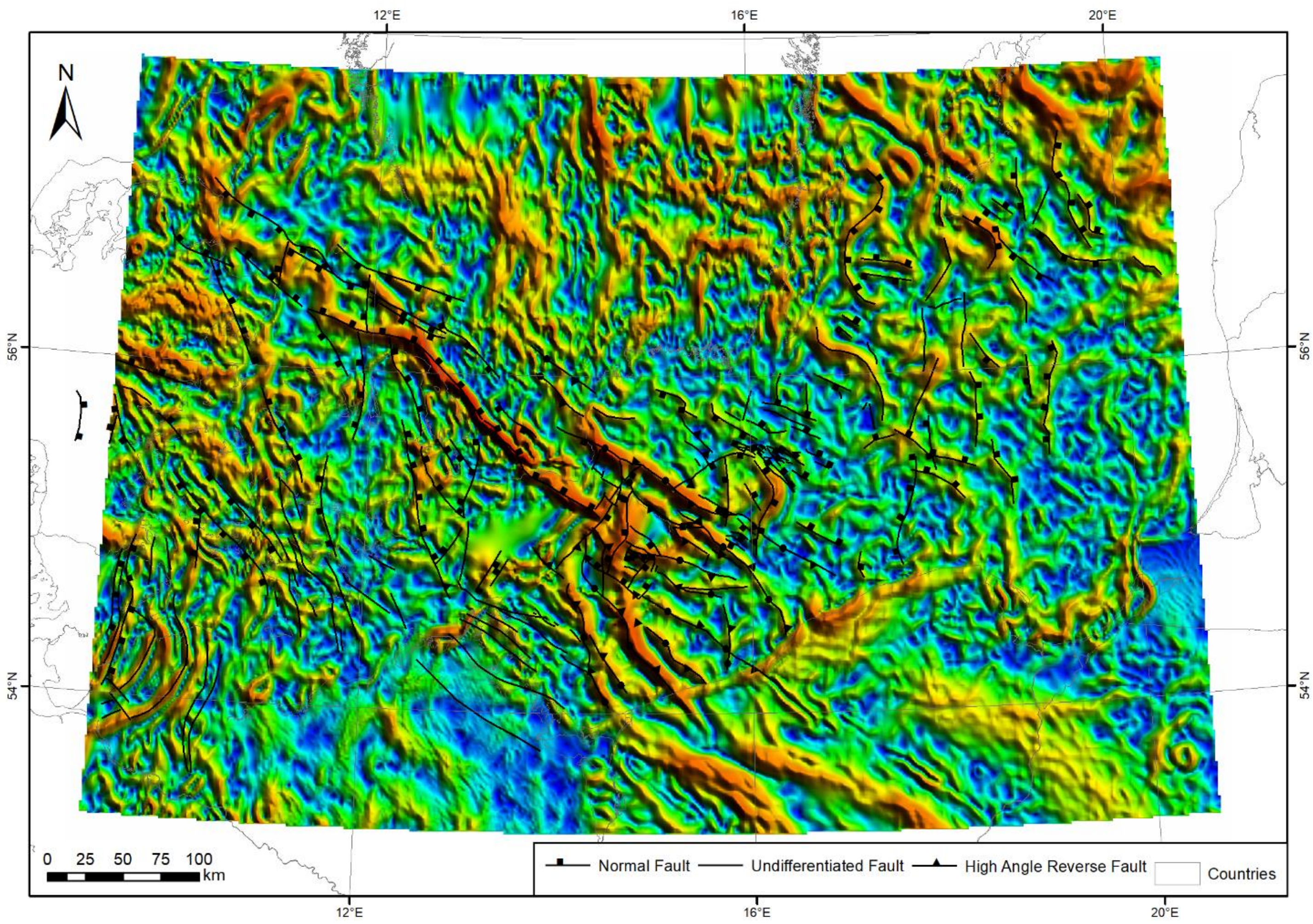


Fig. 7 Structural elements overlaid on the Total Horizontal Derivative (THD) of the merged gravity data.

4. Qualitative Analysis

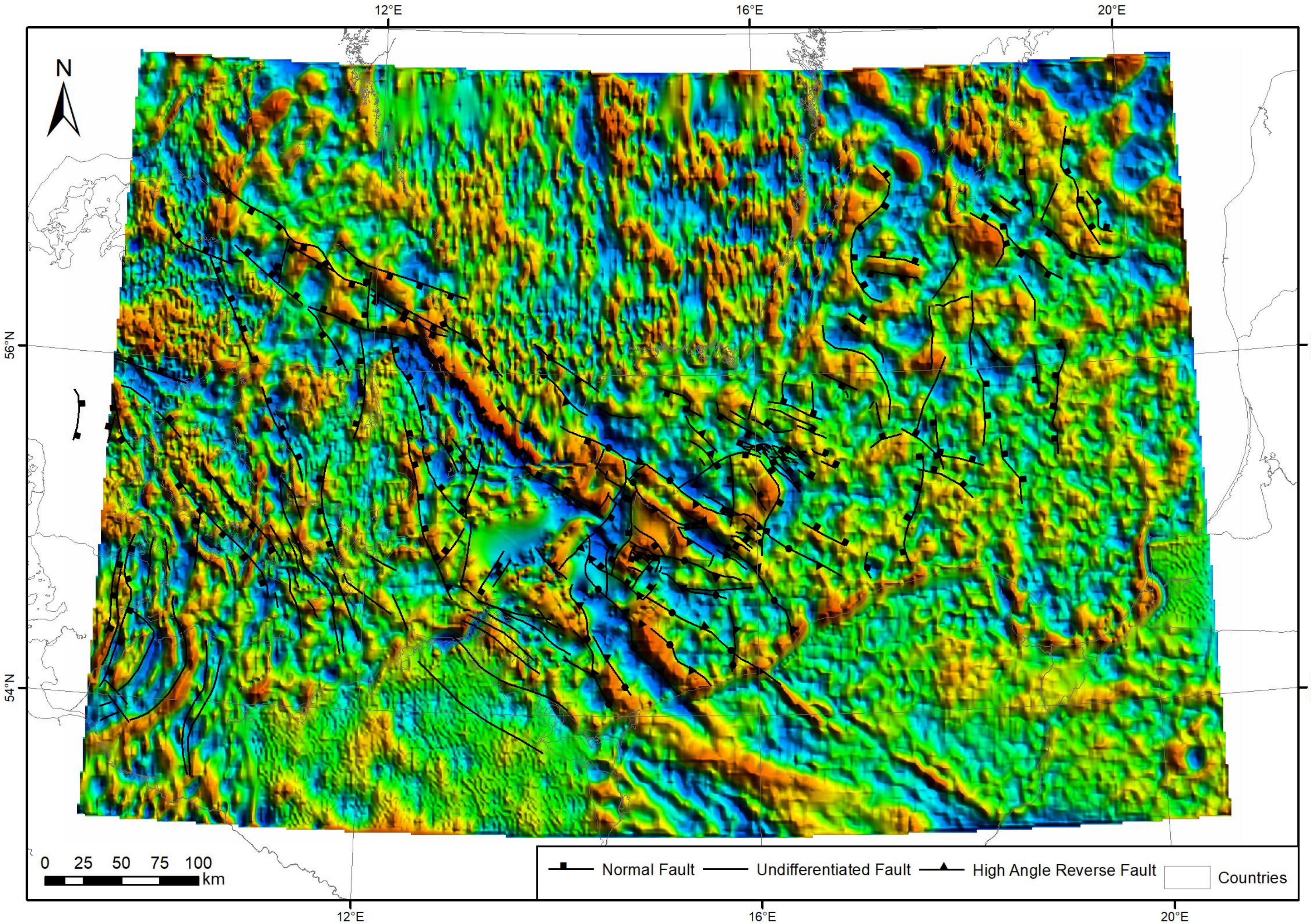


Fig. 7 Structural elements overlaid on the First Vertical Derivative (1VD) of the merged gravity data.

4. Qualitative Analysis

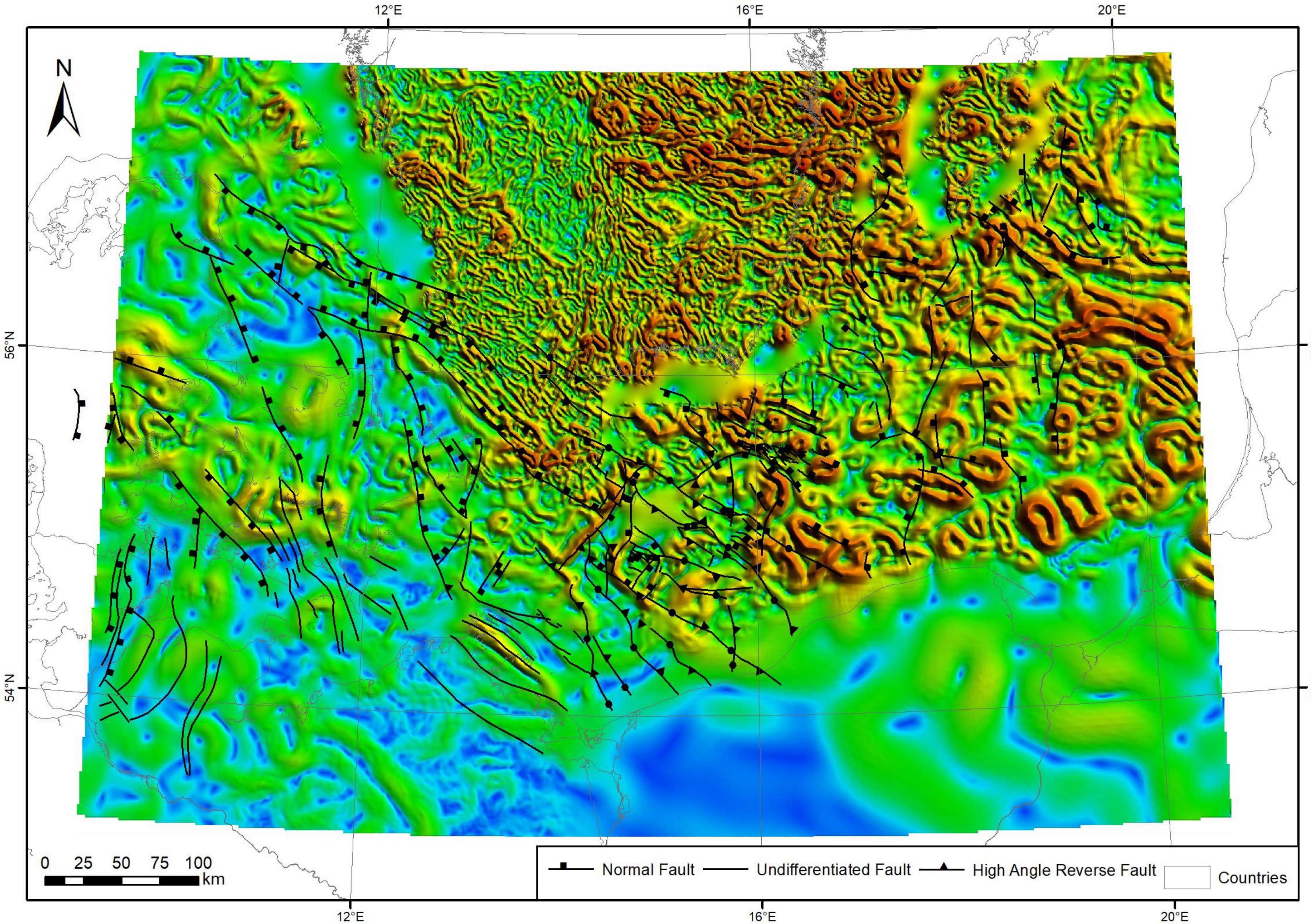


Fig. 8 Structural elements overlaid on the Total Horizontal Derivative (THD) of the Reduced-to-Pole magnetic data.

4. Qualitative Analysis

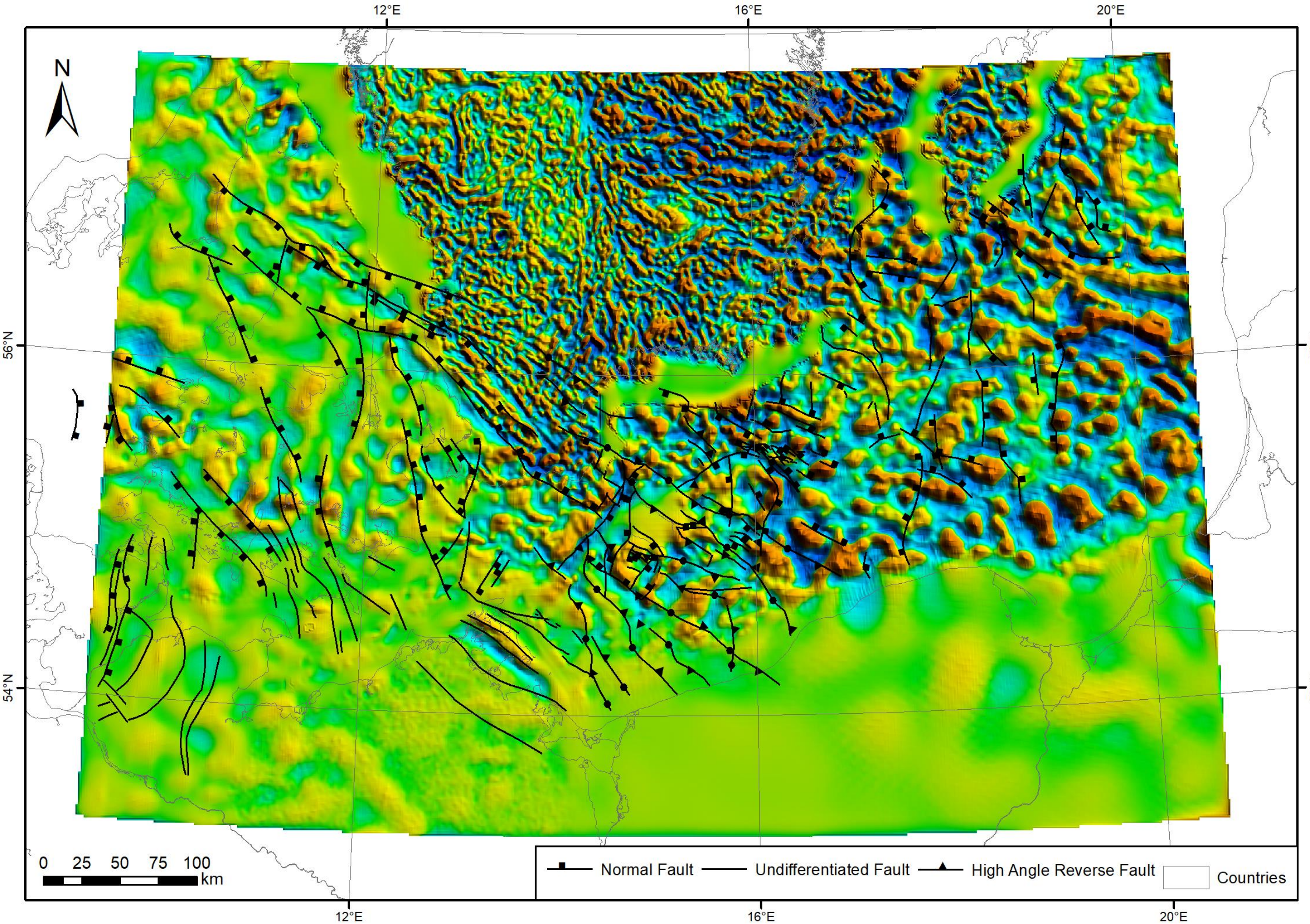
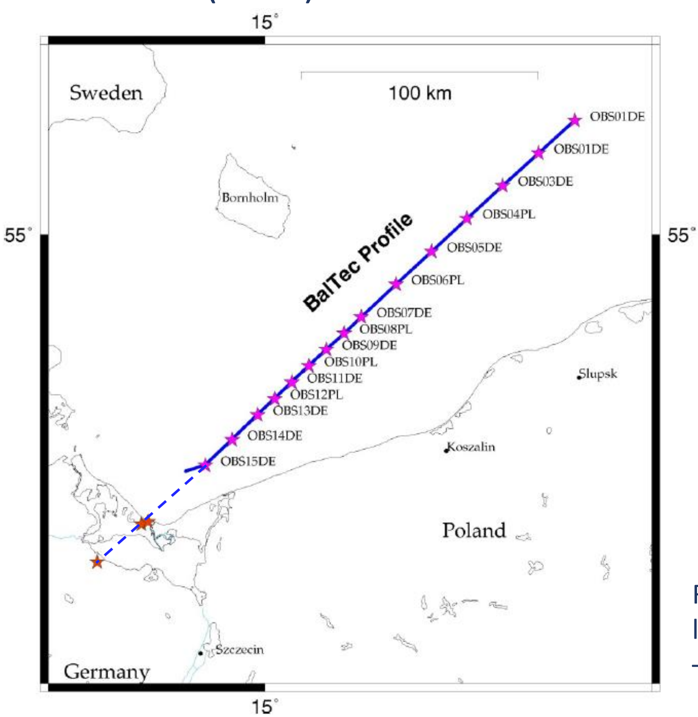


Fig. 9 Structural elements overlaid on the First Vertical Derivative (1VD) of the Reduced-to-Pole magnetic data.

5. Two-dimensional models along WARR profile

Preliminary 2D models were produced along the WARR profile to verify compatibility of the seismic model with potential fields. The first model (Fig. 11) was built on the basis of three grids with resolution 1500x1500m: base Permian, top basement and MOHO extracted from regional grids by Maystrenko and Scheck-Wenderoth (2013). The geometry of the next three models (Fig. 12-14) is derived from the refraction data (see Wójcik et al. 2020, EGU2020-7394, GD4.2/SM4.8/TS11.4). Densities in these models were derived from seismic velocities using Brocher (2005) formula.



Layer/Block	Density [g/cm^3]
Post- Carboniferous sediments	2.35
Lower and Middle Palaeozoic	2.61
Crystalline Crust	2.83
Upper Mantle	3.3

Tab. 1 Density Values used in the modeling of WARR profile – version 1 (Fig. 11)

Fig. 10 Location of the WARRP-1 profile. Purple stars – OBS locations. Orange stars – location of the land stations. Blue dots – shot point locations (Hübscher et al., 2017).

5. Two-dimensional models along WARR profile

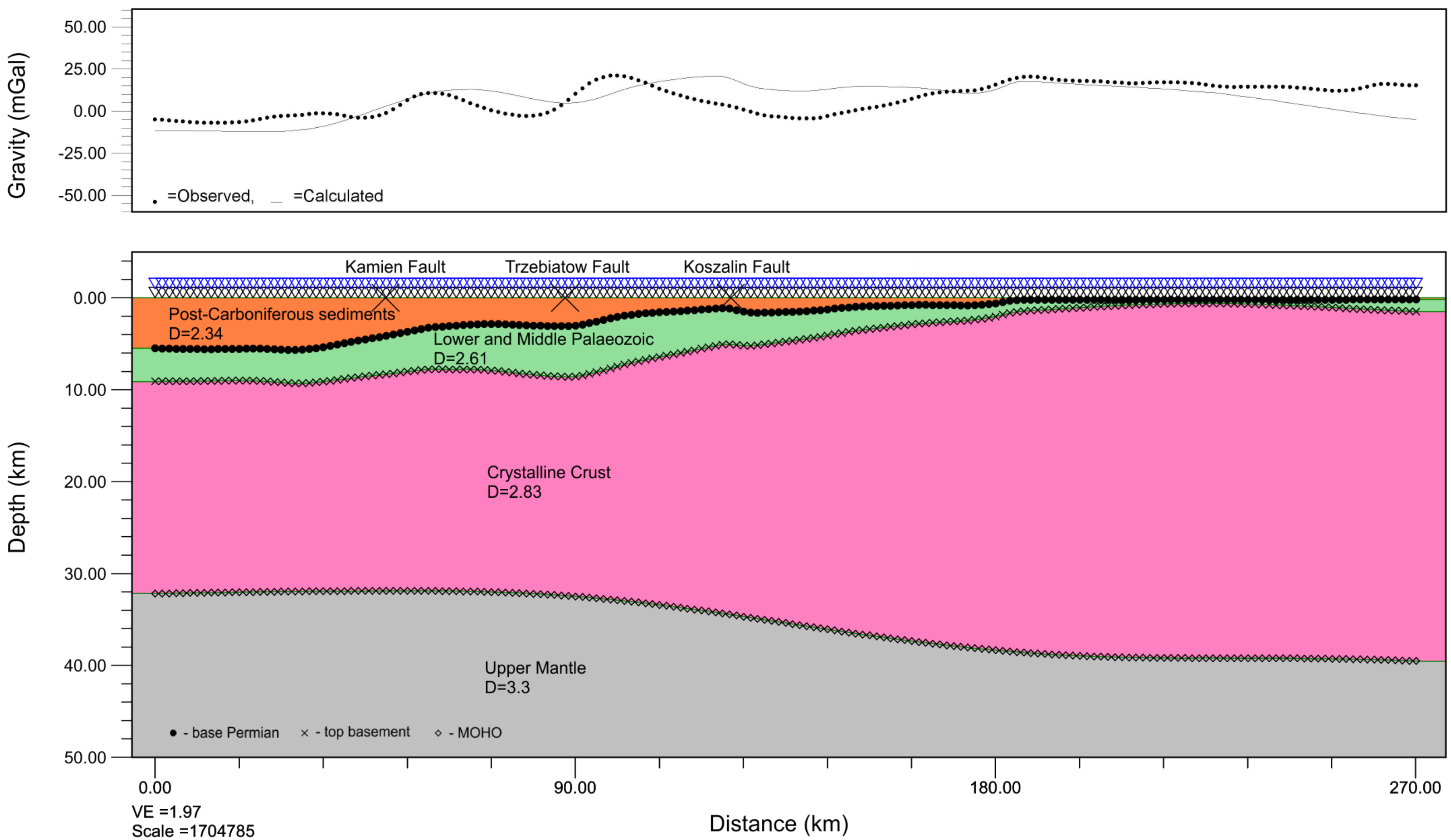


Fig. 11 Two-dimensional gravity forward model along the WARR profile – version 1. Upper panel shows gravity data. Dotted and solid black lines signify observed and modelled gravity data, respectively. Lower panel shows an initial model. Abbreviations means: D- densities in g/cm^3 , VE – vertical exaggerations. Base Permian, top basement and Moho horizons extracted from regional grids by Maystrenko and Scheck-Wenderoth (2013).

5. Two-dimensional models along WARR profile

Preferred seismic model

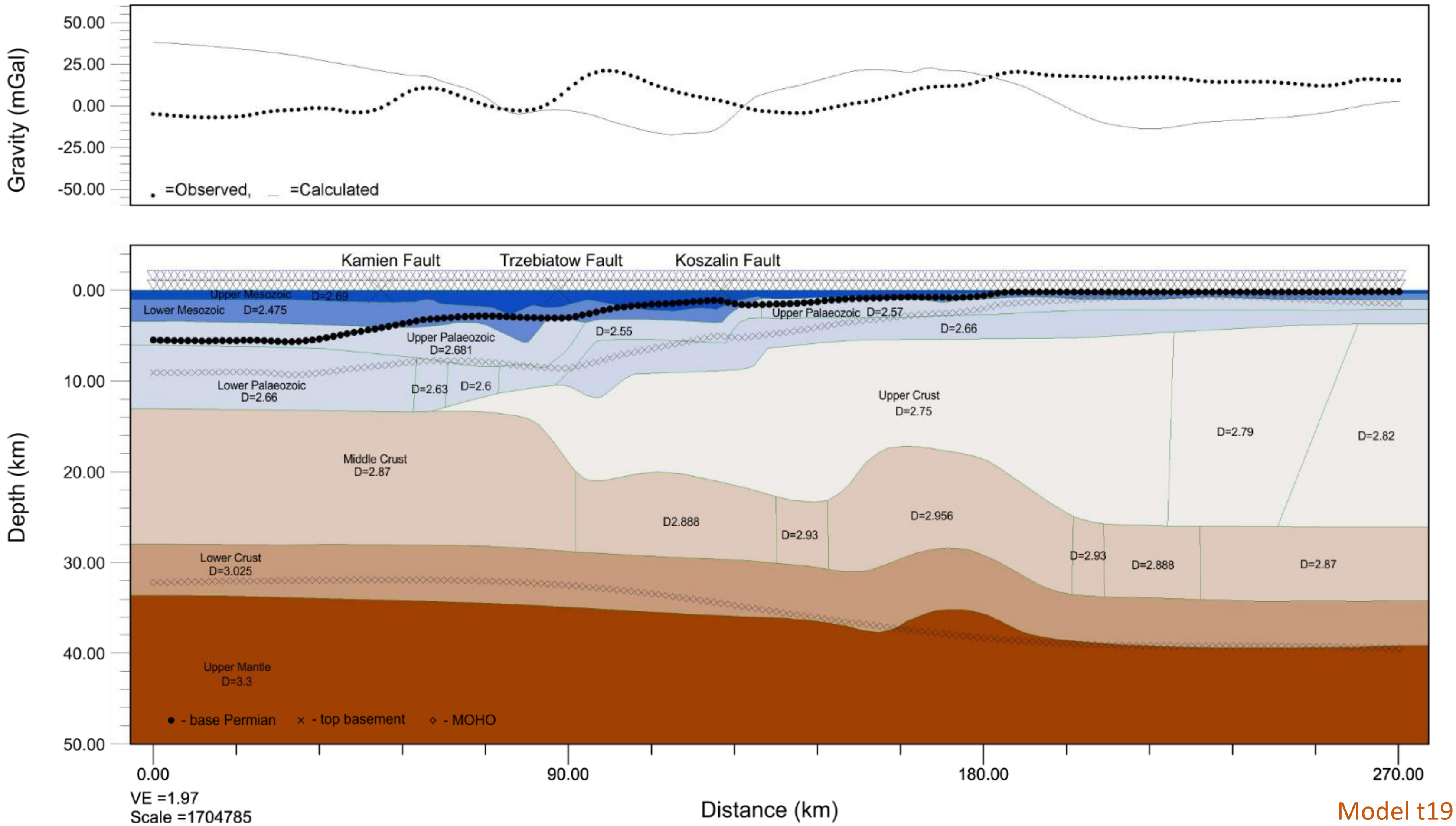


Fig. 12 Two-dimensional gravity forward model along the WARR profile – version 2. Upper panel shows gravity data. Dotted and solid black lines signify observed and modelled gravity data, respectively. Lower panel shows an initial model. Abbreviations means: D- densities in g/cm^3, VE – vertical exaggerations. Base Permian, top basement and Moho horizons extracted from regional grids by Maystrenko and Scheck-Wenderoth (2013).

5. Two-dimensional models along WARR profile

Alternative seismic model 1

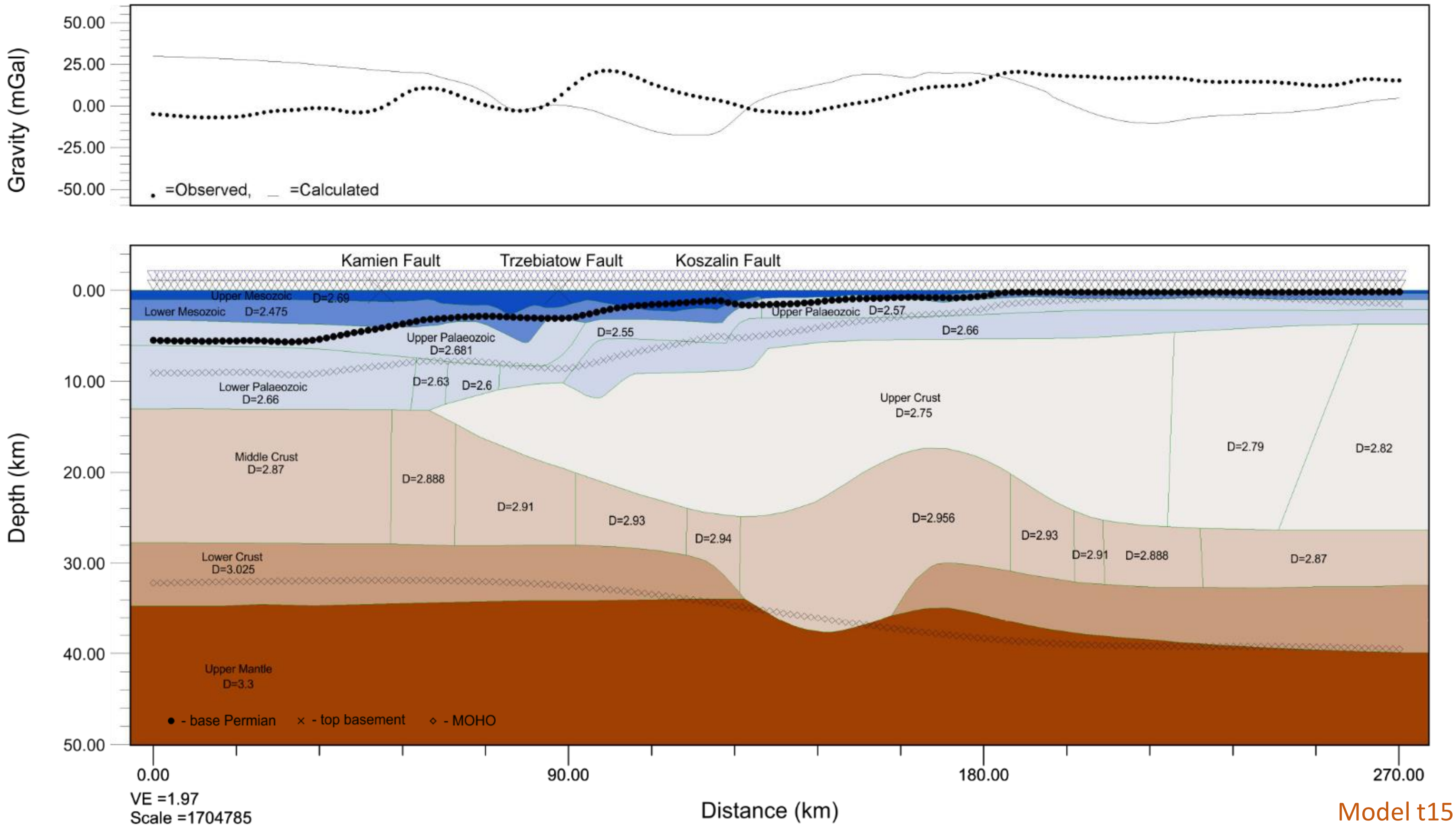
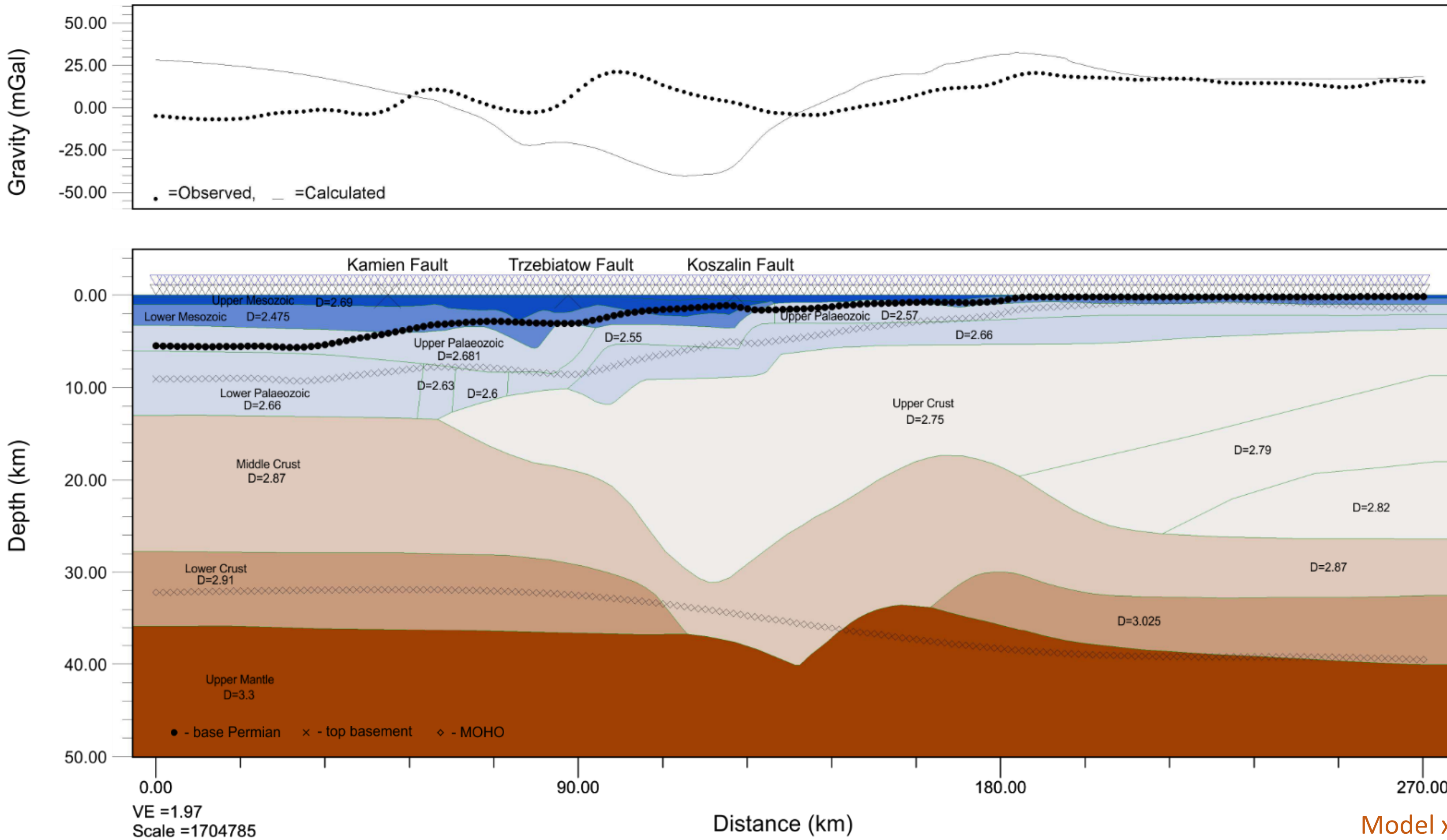


Fig. 13 Two-dimensional gravity forward model along the WARR profile – version 3. Upper panel shows gravity data. Dotted and solid black lines signify observed and modelled gravity data, respectively. Lower panel shows an initial model. Abbreviations means: D- densities in g/cm^3 , VE – vertical exaggerations. Base Permian, top basement and Moho horizons extracted from regional grids by Maystrenko and Scheck-Wenderoth (2013).

5. Two-dimensional models along WARR profile

Alternative seismic model 2



Model x69t

Fig. 14 Two-dimensional gravity forward model along the WARR profile – version 4. Upper panel shows gravity data. Dotted and solid black lines signify observed and modelled gravity data, respectively. Lower panel shows an initial model. Abbreviations means: D- densities in g/cm^3 , VE – vertical exaggerations. Base Permian, top basement and Moho horizons extracted from regional grids by Maystrenko and Scheck-Wenderoth (2013).

6. Further Work

1. 2-D forward modelling using:
   - satellite and marine gravity data and Baltec seismic reflection profiles
2. 3-D inverse modelling:
   - top crystalline basement
   - crustal structure down to MOHO
3. Testing the capability of marine vs satellite gravity to reflect the geometry of shallow tectonic structures

Acknowledgements

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