THREE-DIMENSIONAL GRAVITY INVERSION FOR DEPTH-TO-BASEMENT – A CASE STUDY FROM THE WESTERN PART OF THE POLISH OUTER CARPATHIANS

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Introduction

The top of the Precambrian crystalline basement in the westernmost Polish Outer Carpathians remains one of the least-recognized structural features of this fold-and-thrust belt. Most of boreholes do not reach the top of basement and seismic imaging of the basement architecture is poor. Therefore, the main idea of this work is to use good quality gravity data supported by two-dimensional (2D) gravity and magnetic forward model built upon a recently acquired seismic section (Mikołajczak et al. 2019) and public-domain well data (Central Geological Database 2018) to map basement architecture and depth.

Samples and methods

The gravity data were provided in a digital format by the National Geological Archive (Central Geological Database 2018) of the Polish Geological Institute (http://baza.pgi.gov.pl). The gravity data set used in this study consists of high-resolution gravity measurements derived from terrestrial ground stations and gridded at a 500 m interval. The Free Air Gravity data were enhanced by a complete Bouguer reduction for an infinite horizontal slab density of 2.67 g/cm^3.

Our approach to inverting of gravity data is based on the spatial method published by Barnes and Barraud (2012). Inverting potential field data is a non-uniqueness problem. The above mentioned method reduces this problem through a joint inversion of gravity data and independent data sets as depth information. This approach is particularly useful when combining gravity data with depth horizons estimated from interpreted 2D seismic profiles to create a high-resolution three-dimensional (3D) inversion for imaging subsurface geological bodies. In our case, depth valuation originates from borehole tops and an earlier published gravity and magnetic 2D model (Mikołajczak et al. 2019).

Results

Outcomes of the depth-to-basement study are presented for the westernmost Polish Outer Carpathians. The terrestrial gravity data are inverted for the top of Precambrian crystalline basement. Our joint inversion incorporated depth measurements, including well tops and the 2D top basement horizon from gravity and magnetic modelling. The results are visualised as a block-diagram and isobath map. The latter (Fig. 1) is supplemented with the results of qualitative structural interpretation based on gravity and magnetic anomalies and their derivatives.

The model shows the smooth top of crystalline basement descending southwards from nearly 1 km u.s.l. to over 6 km u.s.l. The maximum basement depth in the southern part of the study area is much larger than previously proposed (Paul et al. 1996). The 3D model visualise the top basement configuration with a satisfactory accuracy, but it contains a number of simplifications related to gridding technique. To emphasize an impact of basement rooted structures, the initially mapped structural elements (Fig. 1) were used in a Spline with Barriers tool, available in ArcGIS environment, to recreate fault-related basement steps that were smoothed out by gridding.

Conclusions

Our results confirmed the usefulness of gravity and magnetic data in determination of the basement structure in a structurally complex area. Based on the depth-to-basement study presented, we unequivocally proved that the crystalline basement of the westernmost Polish Outer Carpathians lies much deeper than previously anticipated, especially in the southern part of the study area. A thick (>5km) cover of mostly allochthonous sediments (Silesian Nappe) is irreconcilable with the previous basement maps (Paul et al. 1996; Buła and Habryn 2008). Consequently, it is also possible that a continuous cover of autochthonous sediments overlies the crystalline basement, potentially comprising Palaeozoic (Devonian and Carboniferous) sediments and/or the Miocene succession of the Carpathian foredeep.

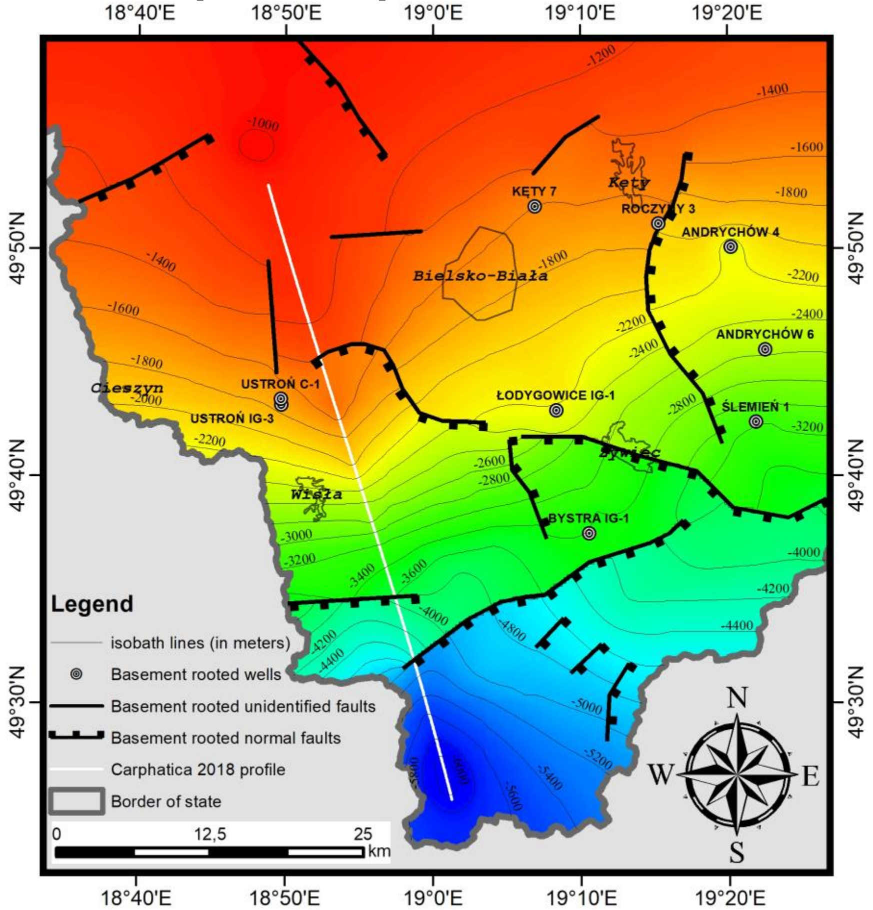

Figure 1. Depth to Precambrian crystalline basement together with interpreted basement-rooted structural elements and isobath contour lines.

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