Comment on “Depth-to-basement for the East European Craton and Teisseyre–Tornquist Zone in Poland based on potential field data” by Mikołajczak et al.

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Abstract

The comment outlines arguments questioning the concept of a gradually dipping crystalline basement of the East European Craton across the Teisseyre–Tornquist Zone, as argued by Mikołajczak et al. (Int J Earth Sci 108:547–567, 2019). The results of the gravity modelling and qualitative structural interpretation presented in the commented paper should be taken with care, particularly so when considered as a basis for further far-reaching regional interpretations.

Keywords Teisseyre–Tornquist Zone · Crystalline basement · Gravity modelling · Magnetic gradients

The commented paper is the most recent of successive publications following the study by Mazur et al. (2015) who proposed “downgrading” of the Teisseyre–Tornquist Zone (TTZ) of Central Europe to a Precambrian intraplate suture. Mikołajczak et al. (2019) present results of mapping the depth to the crystalline basement and to the Neoproterozoic top by modelling the gravity field using the Barnes and Barraud (2012) method. This approach was earlier applied for the northern Poland (Mazur et al. 2015, 2016) and has been recently extended to the entire TTZ length in Poland (Mazur et al. 2018). The results are in line with the earlier conclusions by Mazur et al. (2015) of a uniformly dipping “Paleoproterozoic” basement and a lack of basement-rooted faults controlling the course of the TTZ. Consequently, the authors support the earlier interpretations by Berthelsen (1998) and Bayer et al. (2002), among others, of the cratonic basement continuously extending to western Poland and further to north-eastern Germany.

Mikołajczak et al. (2019) consistently use in their text the term “Paleoproterozoic basement” to denote the crystalline basement. Such approach is only partly justified, however, as large parts of the crystalline basement of the East European Craton (EEC) in Poland are younger than Paleoproterozoic.

E.g. the northern part is composed of the AMCG Mazury Complex of the Mesoproterozoic age (ca. 1.4–1.6 Ga; Krzemińska et al. 2017). Moreover, attributing to Paleoproterozoic the basement to the west of the TTZ contrasts with the interpretation of the Sveconorwegian accretion (age ca. 1 Ga) which, according to Mazur et al. (2016), is responsible for the suturing along their TTZ. Confusingly, Mikołajczak et al. (2019) name this area as the Palaeozoic Platform, the term applied for the region whose basement has been consolidated in the Palaeozoic (Narkiewicz and Petecki 2017).

The method of modelling the depth to surfaces of a presumed density contrast, based on the inversion of gravity data (Barnes and Barraud 2012), has been critically commented by Narkiewicz and Petecki (2016). One of the limitations of the method is its insensitivity to lateral density gradients, which may be considerable in the highly heterogeneous area of the crystalline EEC basement (range of density—2.39–3.25 g/cm³; Dąbrowski 1974). The commented study assumes the default density contrast equal to 0.2 g/cm³ and 0.1 g/cm³ for the crystalline basement vs. overlying sediments and Ediacaran vs. Phanerozoic sediments, respectively. This seems a risky generalization as the Ediacaran is lithologically heterogeneous—ranging from continental clastics in Pomerania (Jaworowski and Sikorska 2003), to mixed clastic and (mafic) volcanic rocks in the Lublin Basin (Paczeńska 2014) to weakly metamorphosed marine clastics of the Małopolska Block (Buła et al. 2008). In addition, the Łysogóry Block to the SW of the Lublin Basin is characterized by a 4–8 km thick succession of the Ediacaran and

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Lower Cambrian (Narkiewicz et al. 2015) which likely contains a large proportion of synrift mafic volcanics of elevated density (Narkiewicz and Petecki 2017).

It is evident that the direct constraints on the commented modelling results by borehole data are restricted to depths of ca. 5 km or less, while the seismic data have depth limitation related to their resolution decreasing with depth but also to a deficit of calibrating wells. This is particularly true for a belt adjacent to the TTZ (as defined by Narkiewicz et al. 2015), in particular to the Łysogóry Block. The oldest strata documented in boreholes in this area are Middle Cambrian in age, while seismic data lack good stratigraphic calibration of deeper horizons. This may be clearly seen in the Fig. 9 of the commented paper showing a broad corridor lacking adequate well control between the NE part of the Lublin Basin in the north and NE part of the Małopolska Block in the south. It should be stressed that even the resolution of the recently performed “deep” seismic reflection lines has some limitations. This refers to the POLCRUST-01 profile in which the unequivocally interpreted top of the crystalline crust extends only to the Łysogóry Block in the SW, but also to the PolandSPAN lines. In particular, the PL1-5100 profile shows only vague reflectors corresponding to the basement top down beyond the TTZ (Malinowski 2016), while the PL1-5300 line has a poor resolution of this horizon in general (see ESM 1 in the commented paper; Narkiewicz and Petecki 2017).

Mikołajczak et al. (2019) indicate in their Fig. 9 the boreholes reaching Ediacaran in the northern part of the Małopolska Block north of the Ryszkowa Wola Fault. In this area, the Cambrian has been encountered in several wells but no older strata have been documented so far (e.g. Buła et al. 2008). Due to the lack of adequate calibration by boreholes, the topography of the crystalline basement top south-west of the TTZ and the depth to the Ediacaran between the TTZ and Małopolska Block should be regarded as merely hypothetical. It is, therefore, not surprising that the comparison between the depth of the crystalline basement modelled by Mikołajczak et al. and that based on a network of seismic refraction profiles (Majdański 2012) shows a striking discrepancy in the belt along the EEC margin, demonstrated in Fig. 11b in the commented paper. It reflects the contrastingly different topography of the crystalline crust top emerging from the seismic data: a sharp gradient (= step) along the TTZ with an amplitude on the order of 10 km, instead of a gradual deepening as argued in the commented paper.

The new aspect of the commented study is the qualitative structural interpretation aimed at tracing “faults, thrusts and lineaments” based on gravity and magnetic data. However, the resulting basement-rooted faults indicated on Bouguer gravity maps (Fig. 5) do not correspond—with a few exceptions—to those on magnetic anomalies (Fig. 6)—the discrepancy not discussed in the

commented paper. The “magnetic” lineaments have been chosen to represent an array of “basement-rooted structural elements” superimposed on isobath maps (Figs. 7, 8) and analysed further in the text.

Nevertheless, comparison with published data reveals that the “basement-rooted structural elements” represent a rather random selection of well-known structures (such as the Grójec Fault or the Kock Fault Zone) and hypothetical lines lacking borehole or seismic documentation in the literature or in the commented paper (e.g. most of the faults shown in the Fig. 6a in Pomerania). Moreover, not shown are many previously documented thick-skinned discontinuities, including some of the faults marked on the map by Krzemińska et al. (2017) in the area of NE Poland. Also absent are several faults in the basement of the Lublin Basin, such as the Święcica Fault and other parallel faults shown on the map by Żelichowski (in: Żelichowski and Kozłowski 1983, Table 7), and recently visualized in the PolandSPAN 1100 seismic profile (Krzywiec et al. 2017). Also, the prominent longitudinal fault along the axis of the Lublin Basin—Stężycza Fault and its extension to the SE (e.g. Narkiewicz et al. 2007) is neglected as are the faults forming the eastern termination of the Łuków Horst (e.g. Pożaryski 1986), and the Janów Fault crossing entire crust down to the Moho level in SE Poland (Narkiewicz et al. 2015). Notably, almost none of the magnetic gradient zones associated with the TTZ (except for a single normal fault west of Warsaw) is interpreted by Mikołajczak et al. as a basement-rooted fault. This is in spite of NW–SE-oriented magnetic lineaments shown in their map (Fig. 6a), for example to the north and east of the Holy Cross Mts. area and in the Pomeranian sector where the relationship to deeply rooted Koszalin–Chojnice Zone is well visible (e.g. Dąbrowski 1984).

Concluding, the lineaments marked in Figs. 7 and 8 reflect magnetic gradients controlled by “lateral lithological changes and magnetic mineralization” not only in the cratonic interior (as pointed out by Mikołajczak et al.) but in other areas as well. Only partly these gradients correspond to earlier demonstrated tectonic discontinuities, while at the same time they apparently did not allow to trace many well-documented thick-skinned faults, including those related to the TTZ. It is still more important, however, that the “qualitative structural interpretation” neglected—without explanation—the clearly expressed first-order magnetic gradient zone along the entire length of the TTZ. The magnetic contrast between the EEC and the Palaeozoic Platform has been known since the times of Tornquist in the late nineteenth century. It was later quantitatively expressed as a narrow gradient zone whose course was refined by several workers, including Dąbrowski et al. (1981, Fig. 1) and Królikowski et al. (1999, Fig. 8). How can this feature be explained under the assumption of a gradual deepening of the Precambrian

basement? The question, asked by Narkiewicz and Petecki (2016) in their comment, still awaits the answer.

In the last section of their paper (“Discussion and conclusions” section), Mikołajczak et al. draw some general conclusions involving tectonic development of the TTZ and areas to the west of it. The discussion with these concepts exceeds the scope of the present comment and deserves a separate consideration. At the moment, it may be noted that such far-reaching implications deserve a better founded evidence than that presented in the commented paper.

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