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Pomeranian Caledonides, NW Poland – A collisional suture or thin-skinned fold-and-thrust belt?

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ABSTRACT

A main goal of this study was to understand the character of the Caledonian Deformation Front in Pomerania, NW Poland and its relationship to the adjoining Teisseyre-Tornquist Zone (TTZ), in the context of the Avalonia-Baltica early Palaeozoic collision. Since the Pomeranian Caledonides are concealed beneath 1–4 km thick platform cover of upper Palaeozoic and Mesozoic sediments, we used a combination of potential field, seismic and well data to investigate the basement architecture and structure of the lower Palaeozoic rocks. Starting from a qualitative review of gravity and magnetic data, we built a 2D gravity and magnetic model upon the PolandSPAN™ PL1-5600 seismic reflection line and applied 3D gravity inversion for a depth-to-basement study. Using well tops, a top lower Palaeozoic horizon and lower Palaeozoic isopach map were created. We found out that the Pomeranian Caledonides represent a thin-skinned fold-and-thrust belt involving Ordovician and Silurian sediments of the Caledonian foreland basin. The deformation front was developed due to the buttressing effect of a basement ramp occurring directly above the TTZ. The latter corresponds to a Precambrian suture zone overprinted by successive extensional tectonics and buried beneath the foreland basin. In northern Poland, the suture is defined by a remnant crustal keel still preserved underneath the TTZ, probably resulting from Precambrian collision during formation of the Rodinia paleocontinent. We propose that the extension of the Thor suture separating Baltica and Avalonia must exist west from the TTZ, probably in the Rügen area. In our interpretation, the TTZ represents an intra-cratonic crustal discontinuity comparable to its NW prolongation, the Sorgenfrei-Tornquist Zone that runs across the Baltic Sea, Sweden and Denmark. Consequently, the basement underlying the Palaeozoic Platform in NW Poland may be considered to have been part of Baltica in early Palaeozoic times.

1. Introduction

The position of the Caledonian collisional suture, i.e., the Thor Suture (Berthelsen, 1998; Pharaoh, 1999), south-east of Rügen Island remains unclear due to the scarcity of geological and geophysical evidence. A prevailing hypothesis postulates its prolongation beneath the Baltic Sea to merge with the Teisseyre-Tornquist Zone (TTZ) in Poland and continue farther SE towards the Carpathian front (Fig. 1; e.g., Dadlez et al., 2005; Narkiewicz et al., 2015). This view is supported by the occurrence of a narrow belt of folded lower Palaeozoic rocks subcropping along the NW section of the TTZ and defined as the Pomeranian Caledonides (Fig. 1; Dadlez et al., 1994; Dadlez, 2000). The latter are juxtaposed along the Caledonian Deformation Front against undeformed sediments of the lower Palaeozoic Baltic Basin located farther east (Fig. 1). However, if the Pomeranian Caledonides extend along the Thor suture the Caledonian Deformation Front at a shallow crustal level would be located directly above a junction of two basement terranes juxtaposed in the TTZ. This is hardly possible if the postulated suture is not of strike-slip character. Therefore, we revisit the geological setting of the Pomeranian Caledonides with the intension to verify whether the Caledonian Deformation Front in Poland indeed coincides with a Caledonian terrane boundary. Using new data and advanced modelling technics, we support conclusions of some earlier works envisaging the location of the Thor suture much farther west (Berthelsen, 1998; Pharaoh, 1999; Grad et al., 2002).

The hitherto proposed interpretations of the Pomeranian Caledonides have been based on archive borehole data and industrial shallow seismic data, the latter not easily available in the public domain, and characterized by poor-quality seismic imaging beneath the Zechstein evaporitic cover (e.g., Dadlez, 1978, 1993; Mazur et al.,

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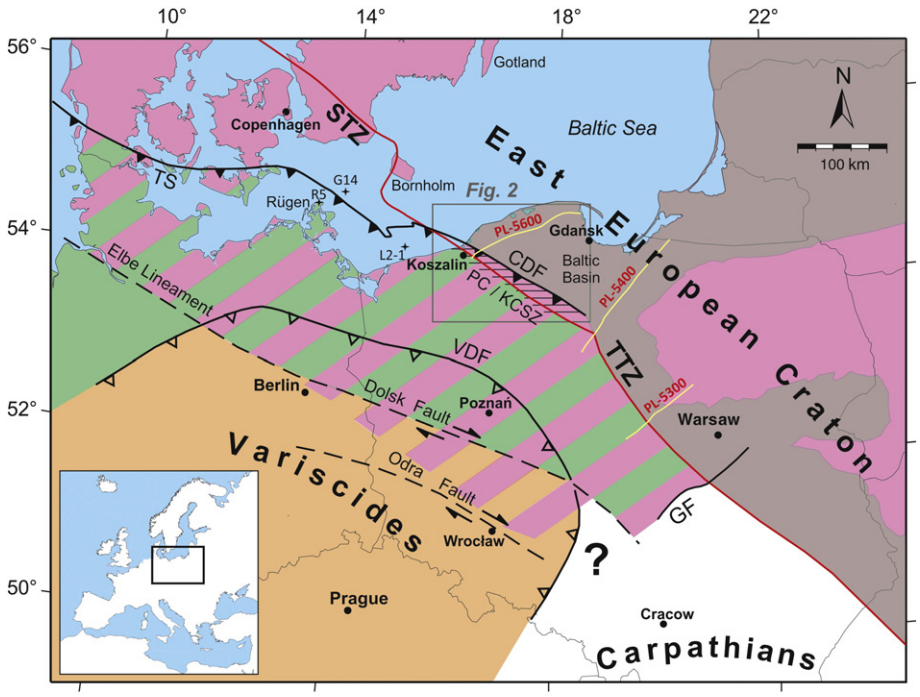

Fig. 1. Extent of different crustal types across the contact zone between the East European Craton and Palaeozoic Platform of Central Europe after Grad et al. (2002), modified. Precambrian crust of the East European Craton (pink), Avalonian crust (green) and Variscan crust (orange). Mixed green (or orange) and pink stripes mean transitional crust that may represent the attenuated Baltic margin. Twilight violet polygon shows the onshore extent of early Palaeozoic sedimentary basins onlapping the SW slope of the East European Craton. Horizontally hatched area indicates the extent of the Pomeranian Caledonides, equivalent to the Koszalin-Chojnice Structural Zone. Pale yellow lines show selected PolandSPAN™ seismic lines. Star symbols represent wells: G14, L2-1, R (Rügen) 5. CDF – Caledonian deformation front; GF – Grójec Fault; KCSZ – Koszalin-Chojnice Structural Zone; PC – Pomeranian Caledonides; STZ – Sorgenfrei–Tornquist Zone; TTZ – Teisseyre-Tornquist Zone; VDF – Variscan deformation front.

2005; Modliński and Podhalańska, 2010). Therefore, large-scale regional syntheses mostly refer to the deep refraction seismic profiles crossing the Pomeranian Caledonides, especially the LT-7 profile (e.g., Guterch et al., 1994; Dadlez, 1997, 2000). The latter, although offering valuable information for velocity and density modelling of the lithosphere, is restricted in the direct imaging of geological structure. Thus, we revisit the tectonic setting of the Pomeranian Caledonides using high resolution gravity and magnetic data and newly acquired PolandSPAN™ seismic profile PL1-5600 (Krzywiec et al., 2013). This new reflection seismic profile provides good imaging of the top of crystalline basement and reaches down to the lower crust (12 s two-way time). The PL1-5600 seismic line is used as a basis for a 2D gravity and magnetic model that is independently constrained by borehole data. The model provides new insight into the structure and tectonic setting of the Pomeranian Caledonides and constrains a regional depth-to-basement study based on the inversion of gravity data. Using this approach, we address a key question: whether the Caledonian Deformation Front at the NE limit of the Pomeranian Caledonides delineates a tectonic suture between the East European Craton (EEC) and East Avalonia that was developed after the closure of the Tornquist Ocean.

An additional inspiration for this study is our earlier work (Mazur et al., 2015) showing undisturbed lower Palaeozoic strata overlying the TTZ in central Poland. We concluded that the TTZ must represent a Precambrian suture concealed beneath the lower Palaeozoic strata and the cratonic basement of the EEC may continue farther west. However, Pomerania was excluded from this analysis since, in contrast to central Poland, the TTZ is coupled there with a zone of early Palaeozoic deformation. Therefore, we saw fit to dedicate a separate study to the Pomeranian Caledonides to better understand the basement structure in Central Europe.

2. Geological setting

The Pomeranian Caledonides are a belt of deformed Upper Ordovician and Silurian sedimentary rocks that runs NW-SE onshore and offshore NW Poland (Fig. 1; Dadlez, 1978; Dadlez et al., 1994). The fold belt is entirely concealed beneath a 1–4 km thick cover of largely undeformed younger sediments. Therefore, the Pomeranian Caledonides were discovered only in the sixties and seventies when a deep drilling programme commenced in the area (Dadlez, 1974). More than 20 deep boreholes encountered subcrop of deformed lower Palaeozoic forming a narrow and elongated uplift named the Koszalin-Chojnice Structural Zone (KCSZ; Fig. 1; Dadlez, 1978), the unit equivalent to the Pomeranian Caledonides. Towards the east, the fold belt is in contact with the undeformed lower Palaeozoic sediments of the Baltic Basin covering the East European Craton (EEC). To the west of the KCSZ, the lower Palaeozoic deepens and has not been penetrated by onshore wells.

The Pomeranian Caledonides include an Upper Ordovician and Silurian monotonous shale and siltstone succession (Teller and Korejwo, 1968; Bednarczyk, 1974; Tomczyk, 1987; Jaworowski, 2000; Podhalańska and Modliński, 2006). Various sections of this sequence from several meters to c. 1100 m in thickness were penetrated by wells. The oldest sediments are upper Llanvirnian and Caradocian in age (Bednarczyk, 1974; Podhalańska and Modliński, 2006). Ashgillian deposits have not been encountered but, instead, fragments of the entire Silurian profile, up to the Přidoli, have been found in several wells (Teller and Korejwo, 1968; Tomczyk, 1987; Podhalańska and Modliński, 2006). It seems that siliciclastic sedimentation continued from the Ordovician to Silurian and the sediments deposited are devoid of coarse-grained facies (Podhalańska and Modliński, 2006). However, the percentage of siltstones and fine-grained sandstones slightly