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Crustal-scale complexity of the contact zone between the Palaeozoic Platform and the East European Craton in the NW Poland

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Hypotheses on the trace and nature of the SW margin of the East European Craton (EEC) are reviewed. As new geophysical data was acquired, the location of the EEC margin was repeatedly revised. Magnetic anomalies associated with the SW part of the EEC and their relationship with the contact zone between the EEC and the Palaeozoic Platform are described. Based on an analysis of magnetic anomalies, seismic cross-sections, the LT-7, P1, P2 and P4 wide-angle reflection and refraction profiles, and the results of recent geothermal modeling, the geometry of the contact zone between the EEC and the Palaeozoic Platform in NW Poland has been redefined. Three important boundaries are distinguished, namely the Teisseyre-Tornquist Line marking the SW limit of the EEC at upper and middle crustal levels, the SW margin of the West Pomeranian Magnetic Anomaly that delimits the NE extension of the reversely magnetised lower crust of the Palaeozoic Platform, and the SW termination of the high velocity lower crust of the EEC. These boundaries and their characteristics reflect the tectonic complexity of the SW margin of the EEC in its Polish sector.

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PALAEOGEOGRAPHIC SETTING OF NW POLAND

The principal crustal blocks abutting the East European Craton (EEC) along the Trans-European Suture Zone (TESZ) were accreted to Baltica in three stages, namely the Brunovistulian, Łysogóry and Małopolska terranes during the Cambrian, East Avalonia during end-Ordovician/Early Silurian times, and the Armorican Terrane Assemblage during the Early Carboniferous (Winchester and the PACE TMR Network Team, 2002). Geophysical data, faunal criteria and radiometric ages of magmatic rocks confirm that the Avalonian crust extends from the Anglo-Brabant Deformation Belt through the NE German Basin to north-west and perhaps even into Central Poland (Cocks *et al*., 1997; Tschernoster *et al*., 1997). Crustal-scale wide-angle reflection and refraction seismic data suggest that during the Caledonian orogeny the crust of East Avalonia and its accretionary prism were thrusted onto the margin of the EEC that is characterized by a high velocity lower crust (Bayer *et al*., 2002; Krawczyk *et al*., 2002). In SW Poland, elements of the Variscan Orogen are thought to cover the junction between the Armorican Terrane Assemblage and the Brunovistulian and Małopolska blocks to the east and East Avalonia to the north (Banka *et al*., 2002).

After the accretion of crustal blocks during the Caledonian and Variscan orogenies, the Variscan Orogen and its northern foreland were disrupted during the latest Carboniferous and Early Permian by a pulse of wrench faulting that was accompanied by intense magmatic activity, resulting in thermal destabilization of the lithosphere (Ziegler, 1990; Van Wees *et al*., 2000; Ziegler *et al*., 2004). Subsequently, thermal relaxation of the lithosphere, accompanied by mild tensional reactivation of Permo-Carboniferous fracture systems controlled the Late Permian to Cretaceous subsidence of the Mid-Polish Trough that was inverted during the latest Cretaceous and Paleocene (Kutek, 2001; Stephenson *et al*., 2003; Krzywiec, 2006). These tectonic processes overprinted Caledonian structures in the area of Poland where the definition of accreted terranes and the character of their contact with the EEC has been the subject of numerous geophysical and geological studies.

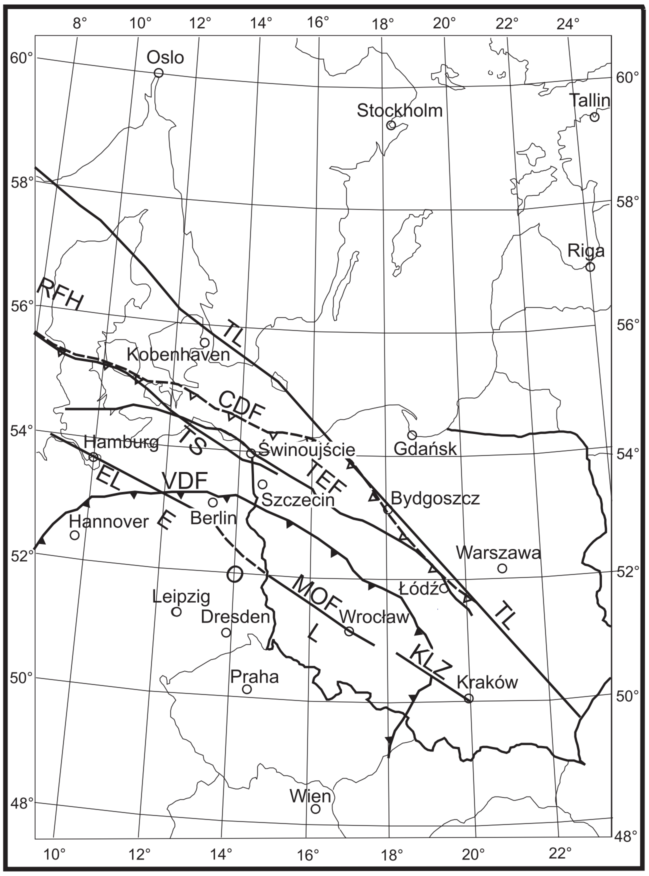

Fig 1. Tectonic elements along the margin of the East European Craton in North and Central Europe

RFH — Rynkøbing-Fyn High, TL — Tornquist Line, CDF — Caledonian Deformation Front, VDF — Variscan Deformation Front (after Dadlez *et al*., 1994), TEF — Trans-European Fault, TS — Thor Suture, EL — Elbe Line, MOF — Middle Odra Fault, EOL — Elbe–Odra Line, KLZ — Kraków–Lubliniec Zone

LOCATION OF THE EAST EUROPEAN CRATON MARGIN IN NORTH AND CENTRAL EUROPE

From the beginning of the 20th century the margin of the East European Craton, including the Baltic Shield and the Russian Platform, was thought to extend from northern Jutland through Scania to Bornholm and via Koszalin, Przemyśl, along the East Carpathian arc to the Dobrogea and Black Sea (Tornquist, 1908). Until the 1960's this line was referred to as the Tornquist Line (TL) (Fig. 1). During the early 1960's the TL was renamed to the Teisseyre-Tornquist Line (TTL) in honour of W. Teisseyre who had initiated studies on the EEC margin in 1893. Dadlez (2000) described in detail various interpretations of the trace of the EEC margin and discussed related geotectonic concepts.

Results of boreholes in Denmark, mainly on the Rynkøbing-Fyn High and in Scania, as well as in northern Germany have, however, shown that Precambrian basement is present on both sides of the TL, and that the Caledonian Deformation Front (CDF) is located in southernmost Denmark from where it extends into Poland (Fig. 1; Ziegler, 1982, 1990). Therefore, the northern part of old TL was renamed into Sorgenfrei-Tornquist Zone and the margin of the EEC was redefined as being located at middle and lower crustal levels south of the Caledonian Deformation Front in the area of the postulated Trans-European Fault (TEF). According to Berthelsen (1992), this fault extends from the North Sea through northern Friesland (Schleswig), along the German Baltic shore to the Świnoujście area (Fig. 1). With the application of plate tectonic concepts to the evolution of the European Palaeozoic Platform and the margin of the EEC, their contact in the area of the TL was identified as the suture between the East Avalonian Terrane and Baltica (Fig. 1; Berthelsen, 1992; Pharaoh, 1999).

Based on the results of deep seismic sounding profiles that were recorded in Poland in the 1960's and 1970's (Guterch *et al*., 1986), the TTL was reinterpreted and renamed the Teisseyre-Tornquist Zone (TTZ). Constructed seismic cross-sections presented structural models of the Earth's crust although seismic velocity data were too poor and insufficient for geological interpretations. Nevertheless, the margin of the EEC was identified as coinciding with a deep crustal fracture that marked the NE border of the TTZ (Znosko, 1979; Dadlez, 1982).

Pharaoh (1999) suggested in his review of structural-tectonic problems related to the TESZ that the boundary between Baltica and East Avalonia is a suture, and referred to it as the Thor Suture that resulted from closure of the Tornquist Sea and ensuing collision of these two continents. At shallow crustal levels, this suture is thought to be closely associated with the Caledonian Deformation Front (CDF on Fig. 1) that extends from the Central North Sea through Southern Jutland along the southern flank of the Rynkøbing-Fyn High, and further to the east along the NE Germany coast just south of Rügen, and towards the southern coast of the Szczecin embayment. In its easternmost parts, the Thor Suture coincides with the Anklam Fault that is assumed to form the southern branch of the Trans-European Fault (Grosse *et al*., 1990; Franke *et al*., 1996). The deep DEKORP-BASIN'96 near-vertical reflection-seismic line that crosses the Thor Suture in NE Germany reveals that it is associated with an increase of the Moho depth from 30–32 km in the south to 38 km in the north (Bayer *et al*., 1999).

Recent interpretations of the results of the POLONAISE 1997 seismic experiment (Jensen *et al*., 1999; Mazur *et al*., 2001; Bayer *et al*., 2002) indicate that the lower crust of the EEC may extend from the TTZ by as much as 150–200 km to the south-west beneath the European Palaeozoic Platform. The southern termination of the high velocity EEC lower crust may correspond to the Elbe–Odra Line (Fig. 1). In this respect, the TTL presumably corresponds to the boundary between the relatively high velocity upper crust of the EEC and the low velocity upper crust of the Palaeozoic European Platform, whereas the Trans-European Fault may delimit the EEC at middle and lower crustal levels to the south-west.

As some crustal blocks of the TTZ display Baltica affinities, they were presumably derived from the EEC and later re-accreted to it. This pertains e.g. to the Małopolska Block that was presumably detached from the EEC (Baltica) to the south-east of its present position, was translated northwestwards along the TTZ and re-accreted to Baltica during the Caledonian orogenic cycle (Dadlez *et al*., 1994; Narkiewicz, 2002). Similarly, the Pomeranian and Kuiavian blocks are thought to represent crustal elements that were detached from the EEC and were re-accreted to it during Ordovician-Early Silurian times (Dadlez *et al*., 2005). Since the lower and middle crust of these terranes (or suspected terranes) shows similarities with that of the EEC, some authors place the margin of the latter along the Elbe lineament (Tanner and Meissner, 1996; Cocks *et al*., 1997). Its continuation in SW Poland might be the Middle Odra Fault (Fig. 1; Bayer *et al*., 2002) and the tectonic Kraków–Lubliniec Zone (Pharaoh, 1999).

THE EEC MARGIN IN THE LIGHT OF GRAVITY DATA

The regional gravity field of NW Poland is characterised by the NW–SE trending Szczecin–Mogilno–Miechów Low, the Pomerania High, the Pomerania and Kuiavia lows, and the large Silesia High that is located to the south of these units (Fig. 2; Królikowski and Petecki, 1995). These gravity anomalies are interpreted as being related to the combined effects of the sedimentary fill of the Middle Polish Basin, large magmatic intrusions in crustal layers, crustal thickness variations and petrologic variations in the uppermost mantle layers (Grabowska

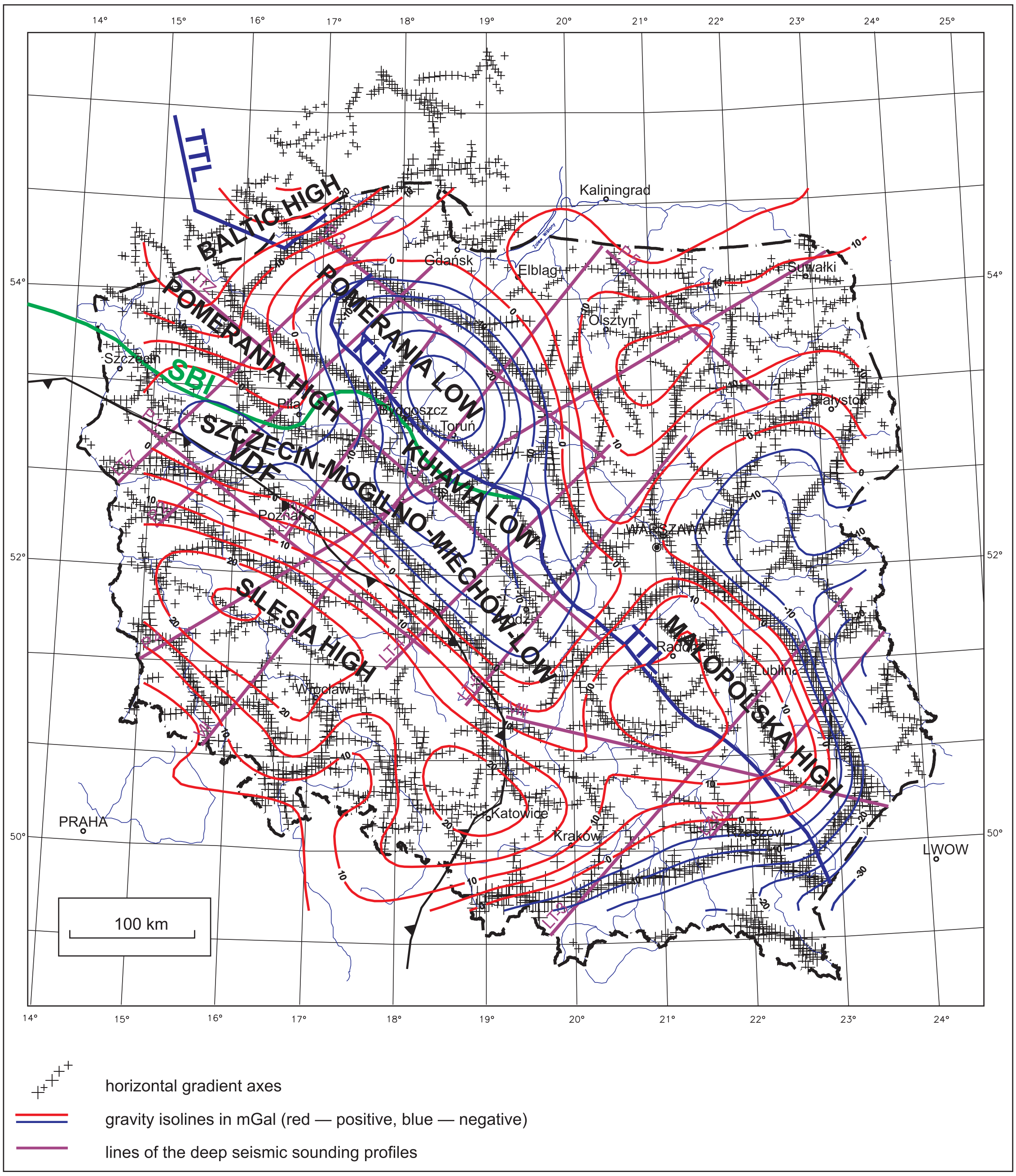

Fig. 2. Axes of the horizontal gradient against the background of the gravity anomalies (after Królikowski and Petecki, 1995)

TTL — Teisseyre-Tornquist Line, SBI — SW margin of the magnetic West Pomerania Anomaly (WPA — *cf*. Fig. 3), VDF — Variscan Deformation Front *et al*., 1998). This renders it difficult to isolate the effect of individual components, the most crucial one of which is the Moho depth. Therefore, it is much easier to investigate various field elements such as gravity discontinuities giving rise to axes of horizontal gradient zones (Królikowski *et al*., 1996), and to relate these to other geophysical data and to geological structures.

Two NW–SE trending gradient zones delimit the Pomerania High (Fig. 2). Its weaker southwestern gradient axis was regarded as reflecting the continuation of the Trans-European Fault. Its trace was defined in NE Germany primarily on the basis of gravity interpretations (Grosse *et al*., 1990), where it is supposed to run slightly to the south of Rügen, through Uznam Island to Świnoujście (Fig. 1). Its assumed continuation in NW Poland could presumably mark the concealed margin of the EEC, and at the same time, the root zone of the Caledonian nappes that overrode it. Under such a scenario, the crust of the EEC would underlay the Pomeranian segment of the TESZ (Fig. 2; Królikowski *et al*., 1996). This is compatible with the interpretation of gravity anomalies in the Polish part of the EEC (Królikowski *et al*., 1999) that permitted to trace the probable course of the EEC margin along the southwestern side of the Pomerania High. However, further towards the south-east the trace of this discontinuity, adjacent to the Kuiavia Low and Małopolska High, was still poorly defined (Fig. 2).

However, the much steeper northeastern gradient axis of the Pomerania High, is associated with major deep crustal fracture, as evidenced by the deep seismic profiles LT-7 (Guterch *et al*., 1994) and P2 (Janik *et al*., 2002). This fracture, located 45–50 km to the north-east of the assumed continuation of the TEF, coincides with the margin of the upper and (partly) of the middle cratonic crust. Therefore, the southwestern termination of the Pomerania High cannot be associated with the margin of the EEC, but rather with a tectonic or petrologic discontinuity in the low velocity upper crust of the Palaeozoic Platform or/and a significant decrease of the Moho depth from the north-east to the south-west (see profiles LT-7 and P2; *op. cit*.).

A set of the gravity discontinuities corresponding to the boundaries of structural units (Królikowski *et al*., 1996), clearly indicate the transverse segmentation of the TESZ. These transverse gravity discontinuities are thought to be associated with deep crustal fractures that delimit the different segments of the TESZ (Fig. 2). The Baltic segment of the TTZ, which extends from Bornholm to the Szczecin–Łeba transverse fracture, is poorly expressed by the gravity data as it is mostly located within the Precambrian crust of the EEC. Results of tomographic analyses (Jensen *et al*., 2002) show a similar structural pattern as in the southward adjacent Pomerania segment that terminates at transverse fractures in the vicinity of Bydgoszcz. The crustal structure of the Pomerania segment is clearly documented by the LT-7 and P2 seismic profiles (Dadlez, 2006). The southeastward adjacent Kuiavian segment is delimited against the Małopolska segment by the Grójec Fault. The Małopolska segment in turn terminates at the Jarosław–Lubacz transversal fracture that lies in the prolongation of the repeatedly reactivated Palaeoproterozoic Volyn suture of the Fennoscandian and Sarmatian cratons (Bogdanova *et al*., 1996).

It should be noted that: (1) gravity discontinuities delimiting the Małopolska High to the south-west and north-east are displaced to the north-east along the Grójec Fault by about 20–50 km as compared to those outlining the Pomerania and Kuiavian segments, and (2) gravity anomalies associated with the TESZ are consistent with its regional strike and structural configuration.

MAGNETIC ANOMALIES ASSOCIATED WITH THE MARGIN OF THE EEC

Based on limited measurements of magnetic field components, Tornquist (1908) noticed for the first time considerable difference in the magnetic signature of areas to the west and east of the Vistula River. The line separating these domains was thought to form the boundary between the EEC and the Palaeozoic Platform of Western and Central Europe. Following more detailed magnetic surveys in the 1930's and just after the World War II, the trace of this line was identified as corresponding to a zone characterized by a maximum magnetic field gradient (Pawłowski, 1947).

The relationship between the southwestern margin of the EEC and the associated termination of major magnetic anomalies was further supported by investigations on the magnetic heterogeneity pattern of the EEC (Paszkiewicz *et al*., 1993; 1996). Based on the interpretation of satellite gravity data, acquired by the "Magsat" satellite, the distribution of significant anomalies was mapped on the entire EEC, indicating that large anomalies (>150 nT) occur along its marginal zones, whereas low anomalies (<150 nT) are concentrated in its central areas. The marginal zones are generally heterogeneous and consist of large blocks or segments of the crust that were repeatedly enriched by basic material, and are characterized by lateral changes in crustal thickness and deep crustal fractures.

The Polish part of the EEC margin is characterized by large gravity and magnetic anomalies. The magnetic anomalies form part of the marginal Baltic–Kursk Zone that is characterized by high intensity anomalies (>1400 nT). These are perhaps related to early Vendian rifting and associated magmatic activity (Volyn flood basalts) preceding opening of the Tornquist Sea and the development of the southwestern EEC margin into a passive margin (Nikishin *et al*., 1996). The lower termination of magnetic heterogeneities coincides with the Moho surface (petrologic boundary) or with the Curie isothermal surface (physical boundary).

By contrast TESZ is characterized by low magnetic anomalies (is magnetically quiet) and involves an accretionary prism consisting of low-grade metamorphic sedimentary series (see Dadlez, 2006).

MAGNETIC ANOMALIES IN NW AND CENTRAL POLAND

From the above it is evident that TTL coincides with a magnetic discontinuity that can be related to the margin of the EEC. The trace of this discontinuity corresponds to the axis of the horizontal gradient that was calculated on the base of regional magnetic anomalies that were mapped during recent magnetic

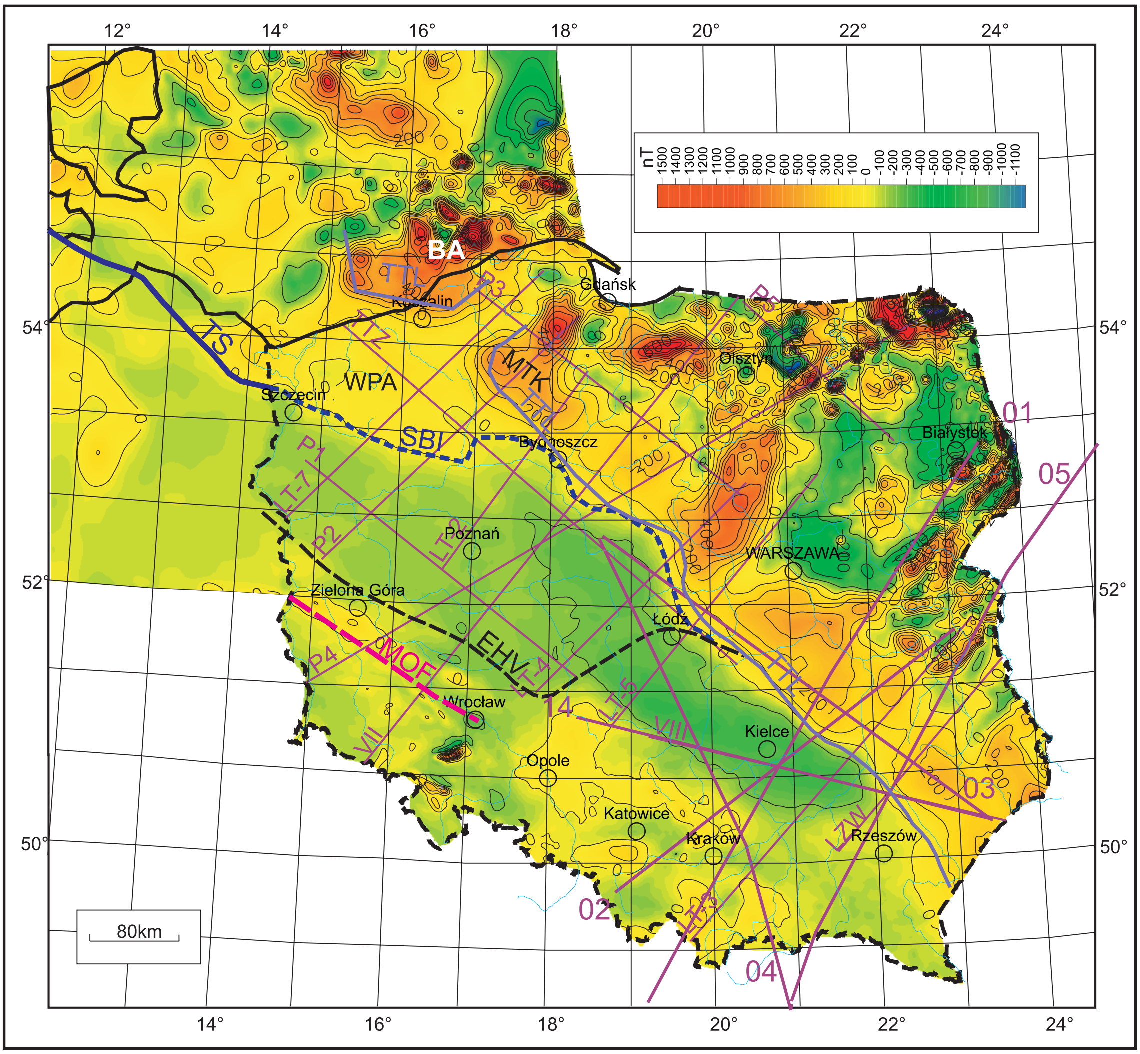

Fig. 3. Magnetic anomalies map of Poland and adjacent NW area (after Petecki *et al.*, 2003)

BA — Baltic anomaly; MTK — Miastko–Tuchola–Kościerzyna anomaly, EHV — extent of the high velocity lower crust; for other explanations see Figures 1 and 2

surveys (Fig. 3). The thus defined TTL extends from the shore of the Baltic Sea to the Polish-Ukrainian border, albeit with an interruption to the east of Koszalin.

In Western Pomerania, a weak but extensive magnetic anomaly (WPA) with amplitudes of 100–150 nT occurs to the west of the TTL (Fig. 3). Its western limit is located in NE Germany near Anklam, about 100 km from Szczecin city. Its southern margin in German territory approximately coincides with the Anklam Fault (Hoffmann *et al.*, 1996) that is thought to form the southern branch of the Trans-European Fault. In Poland, the southern margin of the WPA runs roughly from Szczecin through Bydgoszcz to Inowrocław and is marked by a distinct gradient zone referred to as the SW margin of the WPA (SBI in Fig. 3). Northward, the WPA extends into the Baltic Sea, whilst to the SE of Koszalin city it seems to extend eastward onto the EEC.

Petecki (2001*a, b*) estimated the depth to the WPA magnetic body at 18.5 km that, according to seismic data, corresponds to the base of the low velocity upper crustal complex (*Vp* <6000 m/s) (Gruterch *et al.*, 1994; Pharaoh, 1999; Jensen *et al.*, 1999). Therefore, the source of this anomaly is located in the middle crust (*Vp* 6.50–6.65 m/s) or possibly in the high velocity lower crust (Vp 6.90–7.25 m/s), the velocities of which are similar to those of the respective crustal layers of the EEC.

North of Bydgoszcz, the Miastko–Tuchola–Kościerzyna anomaly (MTK) is located to the NE of the TTL and is characterized by three culminations with amplitudes reaching 500 nT (Fig. 3). Magnetic modelling (Petecki, 2001*b*) showed that batholithic-shaped magnetic bodies with a magnetisation twice as high as the surrounding crust may be located within the middle and upper crust. These could be a Volyn-type early Vendian mafic intrusions. The gravity map (Fig. 2) shows in that area a large gravity depression, referred to as the Pomerania Low.

To the south of the WPA, a very extensive negative anomaly occurs with amplitudes in the range of 150 ÷ 0 nT that terminates to the SW approximately at the Middle Odra Fault and extends to the SE to the Vistula River. Petecki (2001*a*, *b*) suggested that this anomaly is related to the inversely magnetised lower crust of the Palaeozoic Platform. It is not likely that this negative anomaly could have its sources in the thick low velocity sediments located above the relatively thin high velocity middle and lower crust as the sediments (or metasediments), as a rule, are non-magnetic. The negative magnetic anomaly comprises different gravity units or their components (Pomerania High, Kuiavia Low, Małopolska High, Szczecin–Mogilno–Miechów Low and Silesia High) and does not show any relation to the gravity signature (Fig. 2).

GEOTHERMAL FIELD OF NW POLAND

The heat flow map of the study area prepared by Karwasiecka and Bruszewska (1997; Fig. 4) is based on the most complete Polish heat flow data obtained from temperature logs corrected for thermal equilibrium. The western part of the map was published by Majorowicz *et al*. (2003). Thermal conductivity values were measured on many core samples. The error of heat flow determination was estimated at 15–20%. The heat flow density distribution shows significant changes from about 40 mW/m^2 in NE part of the area to more than 80 mW/m^2 in the western part where positive heat flow anomalies occur. These NWW–SEE trending anomalies are associated with the Dolsk Fault and the Variscan Deformation Front and coincide with zones of reduced crustal thickness in the range of 30–35 km (*cf.* Fig. 4 in Guterch and Grad, 2006).

2D numerical thermal modelling (Majorowicz *et al*., 2003) shows evidence of extensive mantle-crust warming in these anomalous zones. Along the profile P1 the 600°C isotherm corresponds approximately to the axis of a thermal anomaly that occurs at depths of 22–25 km, that is significantly shallower than the Moho depth of 31–33 km. This thermal anomaly cannot be explained alone by increased heat generation in the metasediments that reach down to 20 km depth, but requires an increased mantle heat flow of 35–40 mW/m^2.

CONTACT ZONE BETWEEN THE EEC AND THE PALAEOZOIC PLATFORM

On the seismic profile LT-7, the WPA extends from the SBI gradient zone all the way to the NE end of the profile without any significant amplitude variations. At the same time the NE segment of this profile is located between two large magnetic anomalies, the Baltic anomaly (BA) to NW and the MTK

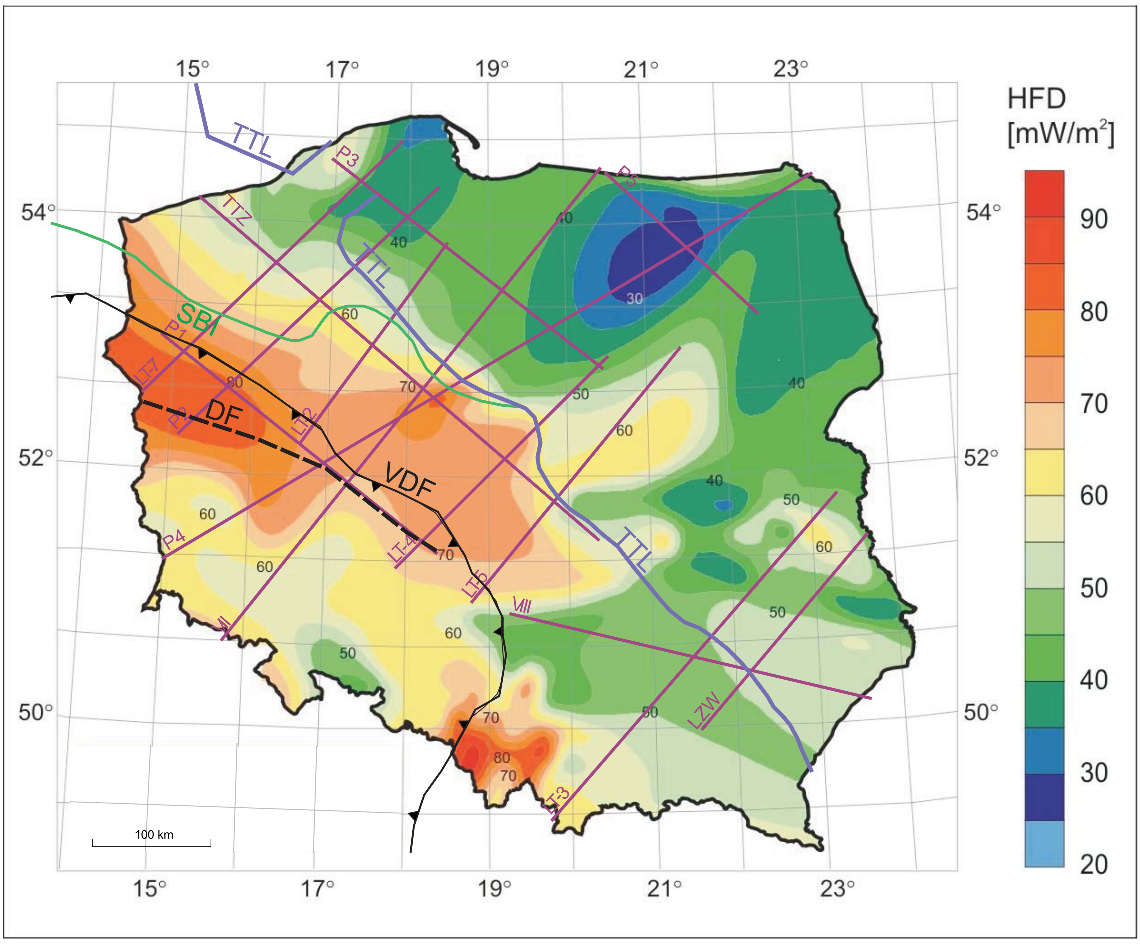

Fig. 4. Heat flow density map of Poland (after Karwasiecka and Bruszewska, 1997)

DF — Dolsk Fault; for other explanations see Figure 2

Table 1

Structural and crustal seismic velocity data on POLONAISE profiles

Profile	Negative anomaly area			WPA area		
	V [km/s]		Moho [km]	V [km/s]		Moho [km]
	middle crust	lower crust		middle crust	lower crust	
LT-7	6.52	7.15–7.20	32	6.52	7.15–7.25	36
P2	6.10–6.50	6.70–7.10	30–35	6.20–6.60	6.70–7.20	35–37
Mean				**6.46**	**7.07**	**36.0**
				MTK anomaly area		
P4	6.30–6.35	6.90–7.10	31	6.40–6.55	6.80–7.20	38
P1	6.10–6.35	6.70–7.15	31–33	–	–	–
P3	–	–	–	6.55–6.65	7.05–7.20	37–43
Mean	**6.34**	**7.00**	**31.8**	**6.54**	**7.06**	**39.0**

anomaly to SE (Fig. 3). At the presumed position of the TTL this profile transects a deep crustal fracture across which the top of the crystalline basement steps down from 7–8 km in the NE to nearly 20 km in the SW (see Dadlez, 2006). However, this fracture is not expressed in the magnetic field (Fig. 3). To the SW of this fracture, low velocity layers (*Vp* 5.75–5.90 km/s) occur in the depth range of 5–8 to 19–21 km that are attributed to non-magnetic metasediments (Dadlez, 2006). The interpretation of the WPA confirmed their very low magnetisation and showed that the depth to the magnetic body is greater than 18 km (Petecki, 2001*a*). As such, and according to seismic data (Grad *et al*., 1999; Pharaoh, 1999; Jensen *et al*., 1999), this magnetic body is located beneath the low velocity upper crust. This suggests that in the area of the WPA the middle and part of the lower crust are moderately magnetized.

In the seismic profiles LT-7 and P2, the SBI gradient zone coincides with a step in the Moho depth from 30–32 km in the SW to 35–39 km in the NE (Guterch *et al*., 1994; Janik *et al*., 2002). Table 1 summarizes changes in seismic velocity across the SBI gradient zone and shows that in profiles LT-7 and P2 the average velocity of the lower crust is 7.07 km/s and practically constant. At the same time, the Moho depth, as noted above, increases from 31.8 to 36.0 km on average. It should be noted that the observed increase in Moho depth coincides with a thickness increase of the lower crust. The seismic profiles P4, P1 and P3, which are located outside of the WPA, reveal similar features.

A closer look at the velocity distribution in the lower crust reveals in the area of the negative magnetic anomaly a significantly higher vertical velocity gradient (e.g. profile P1) as compared to cratonic areas (e.g. profile P3). The respective values are 0.049 s^{-1} and 0.012 s^{-1} and thus four times higher in the negative anomaly area than on the EEC. The velocity values in the basal parts of the lower crust are comparable and range between 7.15 and 7.20 km/s, whilst in its upper parts they are 6.70 km/s in area of the Palaeozoic Platform and 7.05 km/s in the EEC.

Based on magnetic modelling of two profiles running parallel and near the profile P2, Petecki (2001*b*) advanced the hypothesis that during the Caledonian collision of East Avalonia with Baltica the reversely magnetised lower crust of East Avalonia was thrusted beneath the crust of Baltica. This concept is not compatible with the results of the DEKORP-BASIN'96 line. It is more likely that the lower crust was permeated by Permo-Carboniferous mantle-derived mafic material, as seen elsewhere in the Variscan domain and in the North German Basin (see Ziegler *et al*., 2004). This material may have cooled down to below the Curie point prior to the Illawarra magnetic reversal. Interestingly, Guterch and Grad (2006) indicate for Pomerania a laminated lower crust, probably reflecting the intrusion of multiple mantle-derived basic sills (Ziegler *et al*., 2004).

Along the southern margin of the WPA and further southwards the high velocity lower crust retains high seismic velocities in the range 6.70 to 7.20 km/s but looses its normal magnetisation presumably owing to its temperature having increased to above the Curie point. Geothermal modelling along profiles P1, P3 and LT-7 (Majorowicz *et al*., 2003) shows that in this area the Curie isotherm is located at depths of 22–25 km that is considerably shallower than the Moho discontinuity. The combined analysis of magnetic anomalies, crustal structure, seismic velocity distribution, vertical velocity gradients and geothermal modelling suggest that the lower crust of the Palaeozoic Platform was thrusted over the high velocity lower crust of the EEC.

Figure 5 provides a tectonic sketch of the lower crust in vicinity of the LT-7 and P2 profiles. The following arguments speak for such a configuration:

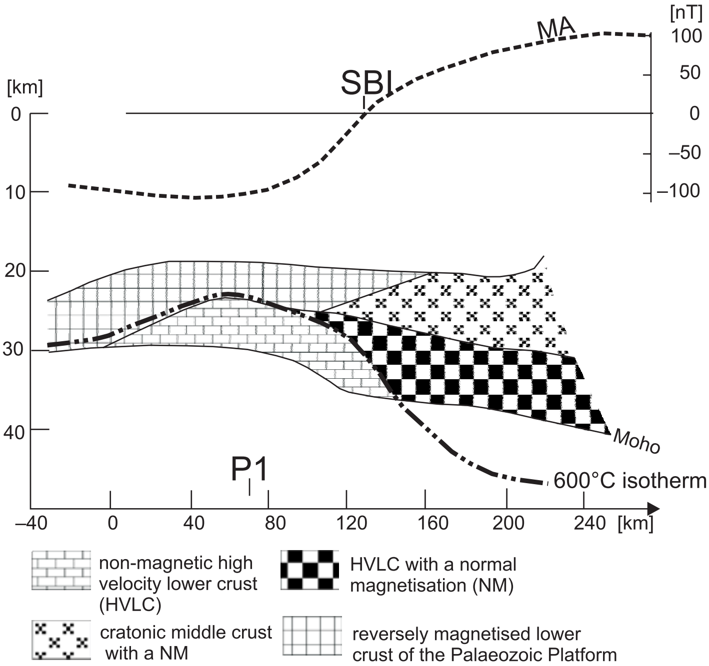

Fig. 5. Model of the lower crust in the vicinity of profiles LT-7 and P2

MA — approximate magnetic anomaly as a mean of the magnetic anomalies along the LT-7 and P2 profiles

The disappearance of normal magnetisation of the high velocity lower crust in the zone where the Curie isotherm shallows to the south-west of the WPA. During the thrusting the temperature of the lower crust increased and exceeded the Curie point with all ferromagnetics becoming very weakly magnetized paramagnetics.

The negative magnetic anomaly is generated by reversely magnetised lower crust of the Palaeozoic Platform. In the area of the positive heat flow anomaly, the entire lower crust or at least a major part of it is located below the Curie isotherm. It may have acquired its magnetization during a geomagnetic field reversal and its present natural remnant magnetisation significantly exceeds the induction magnetisation.

The lower crust of the Palaeozoic Platform is characterized by a much higher velocity gradient than the high velocity crust of the TESZ. This resulted from low velocity lower crust of the Palaeozoic Platform being thrusted over the high velocity lower crust of the TESZ.

As the density of the TESZ high velocity lower crust is greater than that of the Palaeozoic Platform, it is likely that the latter was thrusted over the former, rather than the reverse.

If these interpretations are valid, where then is the margin of the EEC located? Apparently there is no single discrete margin of the Craton in a normal sense. There are three important boundaries, which characterise the tectonic complexity of the TESZ in Poland. The first one is the well-known TTL, which can be traced on the base of magnetic anomalies (Fig. 3). It is closely associated with the deep crustal fracture that was mapped by deep seismic sounding and which coincides with the horizontal gradient axis at the NE border of the Pomerania High.

The second boundary is the SBI that marks the SW margin of the WPA (Fig. 3). It is also the NE limit of the reversely magnetised lower crust of the Palaeozoic Platform and coincides with the disappearance zone of the magnetic properties of the high velocity lower crust. This boundary may be related to the negative magnetic anomaly that extends toward the SE almost to Rzeszów city. This boundary is of a magnetic and tectonic nature.

The third boundary denotes the SW extent of the high velocity lower crust of the TESZ (Fig. 3). Its approximate course was mapped on the base of the crustal-scale seismic profiles LT-7, P4 and also P2 and LT-4. It remains an open question whether it continues further to the SE along the tectonic Lubliniec–Kraków Zone or whether it terminates at the south-eastern Baltica Margin (Bayer *et al*., 2002). Reinterpretation of old seismic profiles (Grad *et al*., 2005) shows that on profile LT-4 the thickness and velocity of TESZ high velocity lower crust decreases southwestwards, whereas on profile LT-5 it terminates at the crossing of the TTL. Preliminary analysis of the CELEBRATION profiles indicates the occurrence of lower crustal velocities in the range 6.70–7.20 km/s on all profiles recorded on the Polish territory, except for the easternmost profile 05.

Provided the TESZ high velocity lower crust is of cratonic provenience, the next question is, what is the origin of the uppermost mantle, or more precisely of the lithospheric mantle? Does it also belong to Baltica or is it East Avalonia lithosphere? So far this remains an open question. According to Ziegler *et al*. (2004) post-orogenic detachment of subducted slabs and ensuing thermal attenuation of the remnant lithospheric mantle is generally followed by the re-equilibration of the asthenosphere-lithosphere system during which asthenospheric material is accreted to the lithosphere as the asthenosphere-lithosphere boundary gradually deepens. These processes may have operated during post-Caledonian times and again at the end of the Variscan orogeny. Thus part of the present mantle lithosphere may post-date the accretion of East Avalonia and the Armorican terrane assembly.

CONCLUSIONS

From this analysis the following highly probable conclusions can be drawn:

1. The main source of the weak magnetic anomaly of the Western Pomerania area (WPA) is the high velocity, moderately magnetized lower crust. The lower crust, together with the thin middle crust form the basement of the non-magnetic low velocity (<6.0 km/s) upper crust.

2. Along the southwestern margin of the WPA, the high velocity lower crust extends beneath the lower crust of the Palaeozoic Platform and dives beneath the 600°C isotherm, thus loosing its magnetisation.

3. The reversely magnetised lower crust of the Palaeozoic Platform, which occurs above the Curie-point isotherm and above the high velocity lower crust may be the source of the negative magnetic anomaly that occurs to the SW of the SBI.

4. There is not a single sharply expressed margin of the EEC. Instead, there are three important boundaries:

— the first one is the TTL, known since a long time to be associated with a deep crustal fracture, defined by the seismic investigation as the NE margin of the TTZ;

— the second one is the SW margin of the WPA (SBI in Fig. 3). This boundary coincides with the NE limit of the reversely magnetised lower crust of the Palaeozoic Platform, as well as with the line across which the high velocity lower crust looses its magnetic properties to the SW;

— the third boundary is the SW termination of the high velocity lower crust (Fig. 3), the trace of which is roughly defined by seismic data.

5. Remaining open questions pertain to the provenance of the lithospheric mantle beneath the TTZ and the Palaeozoic Platform and the location of the Thor Suture in the northern Poland.

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