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Lithospheric structure of the western part of the East European Craton investigated by deep seismic profiles

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The Palaeoproterozoic collision of Archaean Fennoscandia, Volgo-Uralia and Sarmatia, viewed as a large composite of terranes, each with an independent history during Archaean and Early Proterozoic time, formed the East European Craton. This paper summarizes the results of deep seismic sounding investigations of the lithospheric structure of the southwestern part of the East European Craton. On the basis of the modern EUROBRIDGE'94–97, POLONAISE'97 and CELEBRATION 2000 projects, as well as of data from the Coast Profile and from reinterpreted profiles VIII and XXIV, the main tectonic units of Fennoscandia and Sarmatia are characterized. The crustal thickness in the whole area investigated is relatively uniform, being between 40 and 50 km (maximum about 55 km). For Fennoscandia, the crystalline crust of the craton can be generally divided into three parts, while in Sarmatia the transition between the middle and lower crust is smooth. For both areas, relatively high P-wave velocities (7.0 km/s) were observed in the lower crust. Relatively high seismic velocities of the sub-Moho mantle (~8.2–8.3 km/s) were observed along most of the profiles. The uppermost mantle reflectors often occur *ca*. 10 to 15 km below the Moho. Finally, we show the variability in physical properties for the major geological domains of Fennoscandia and Sarmatia, which were crossed by the network of our profiles.

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Key words: East European Craton, crustal structure, mantle reflectors, deep seismic refraction, seismic raytracing.

INTRODUCTION

The main aim of this paper is to summarize the results of deep seismic sounding investigations of the lithospheric structure of the southwestern part of the East European Craton (EEC). The seismic models shown are based on the network of deep seismic sounding (DSS) profiles, carried out during the last ten years within the framework of the EUROBRIDGE'94–97, POLONAISE'97 and CELEBRATION 2000 projects. Data from the Coast Profile have also been used. Additionally, we present reprocessed 2D models of the old profiles VIII and XXIV within the Ukrainian Shield (Fig. 1). The network of profiles covers an area which has not previously been studied using modern approaches. The high quality seismic data obtained reveal both the P- and S-wave structures of the crust and uppermost mantle. Furthermore, all the models discussed have been obtained using the same modern techniques, so their results can be easily compared (Grad and Tripolsky, 1995; Giese, 1998; Guterch *et al*., 1998, 1999; EUROBRIDGE Seismic Working Group, 1999, 2001; Środa *et al*., 1999; Czuba *et al*., 2001, 2002; Kozlovskaya *et al*., 2001, 2002, 2004; Lund *et al*., 2001; Grad *et al*., 2002*a*, 2003; Thybo *et al*., 2003; Majdański and Grad, 2005). The large amount of data permits, for the first time, analysis of the main features of the structure of the southwestern part of the EEC. The regional tectonic units of Fennoscandia and Sarmatia are characterized based on their P- and S-wave velocities, particularly for the

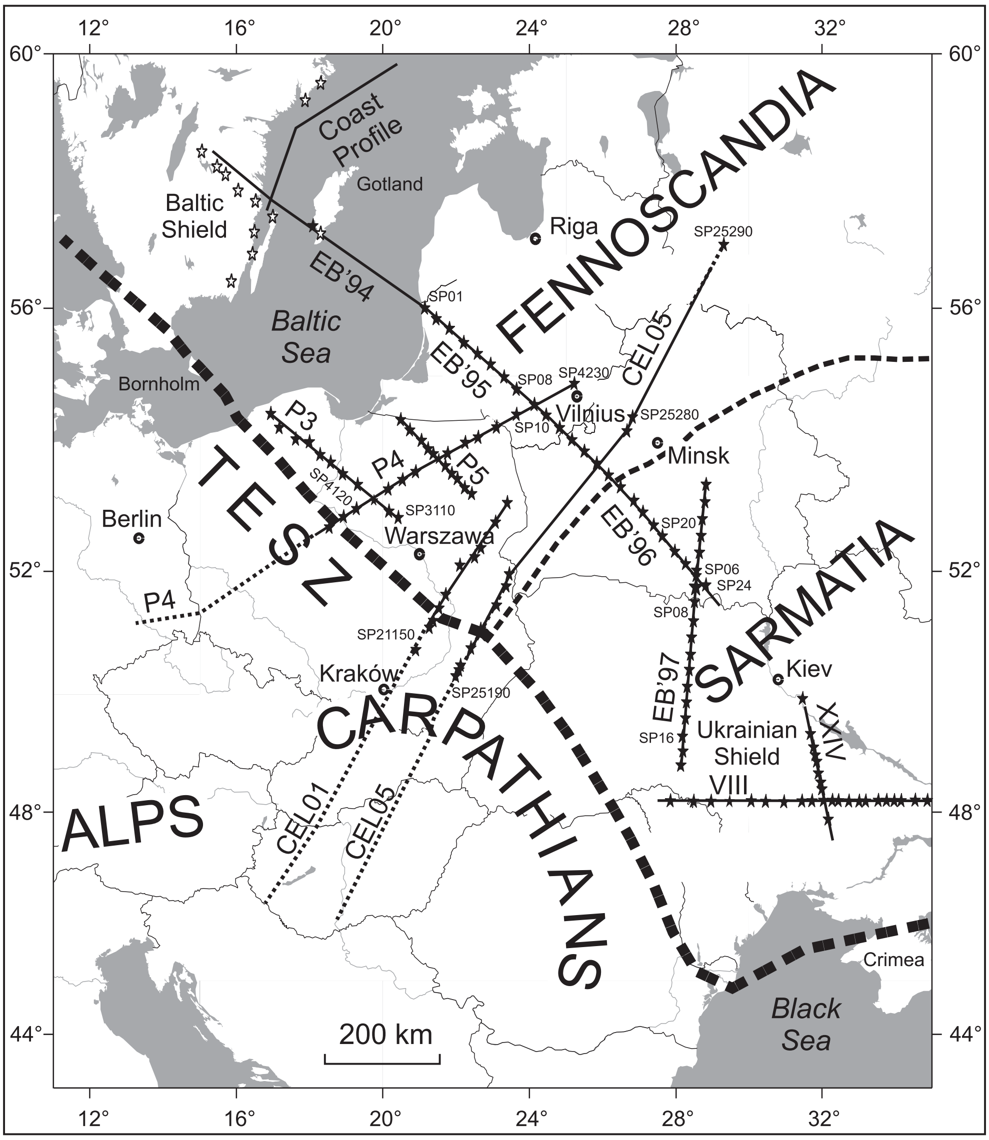


Fig. 1. Location of onshore and offshore deep seismic sounding profiles across the southwestern margin of the East European Craton

Solid straight lines — deep seismic sounding profiles in the area of southwestern margin of the East European Craton; dashed lines — parts of profiles in the TESZ and the Carpathians; black stars — the shot points of EUROBRIDGE (EB'95, EB'96 and EB'97), POLONAISE'97 (northern part of P4, P3 and P5), VIII and XXIV profiles; white stars — receiver stations of EB'94 and the Coast Profile; numbered stars — the location of shot points for which examples of record sections are shown in Figures 4 and 6A; thick dashed line — the southwestern edge of the craton (Bogdanova *et al.*, 2001); thinner dashed line — the border between Fennoscandia and Sarmatia; TESZ — Trans-European Suture Zone

sedimentary cover, upper, middle and lower crust and the upper mantle. A comparative seismic characteristics of the rapakivi and anorthosite plutons is also given.

TECTONIC BACKGROUND

The East European Craton was created in the Palaeoproterozoic by the collision of Archaean Fennoscandia, Volgo-Uralia and Sarmatia (Fig. 2; Bogdanova *et al.*, 2001). The segments are viewed as a large composite of terranes, each with an independent history during Archaean and Early Proterozoic time. The latter two protocratons formed a single continental mass already *ca.* 2.05–2.0 Ga ago, while terminal amalgamation with Fennoscandia only occurred 1.7 Ga ago. To the west of the three Archaean nuclei of the EEC is located the European part of the very large North-Atlantic accretionary belt of juvenile Proterozoic continental crust. This belt extends from Europe to Greenland and onwards across North America along the southern margin of the Laurentian Craton (Bogdanova *et al.*, 2001). In Europe, two distinctly different parts can be recognized. One of these grew outwards from Archaean Fennoscandia and the other from Sarmatia plus Volgo-Uralia while these two protocratons were still at some distance from each other.

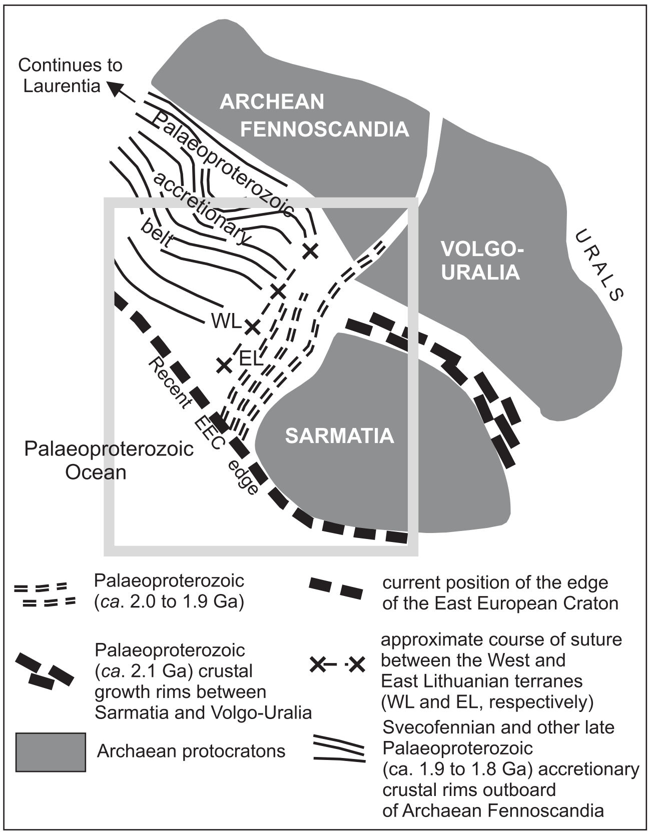


Fig. 2. A model of Palaeoproterozoic accretionary growth of the crust in the East European Craton (EEC), modified from Bogdanova *et al.* (2001); the grey rectangle shows the study area

SEISMIC PROFILES, DATA ACQUISITION AND OBSERVED WAVE FIELD

In the area adjoining the southwestern margin of the EEC, a net of profiles was made during 1994–2000 (Figs. 1 and 3). In the EUROBRIDGE project, seismic data were acquired along two lines in the region between the Baltic and Ukrainian shields (the EB'94–96 transect and the EB'97 profile), of a total length of about 1500 km (Giese, 1998; EUROBRIDGE Seismic Working Group, 1999, 2001; Thybo *et al.*, 2003), and along the Coast Profile offshore of southeastern Sweden (Lund *et al.*, 2001). Three from the five profiles of the POLONAISE'97 experiment are included in this paper. These are the 300 km long profile P3, the 180 km long profile P5 and the 500 km long NE part of the profile P4, all located within the EEC (Guterch *et al.*, 1999; Środa *et al.*, 1999; Czuba *et al.*, 2001, 2002; Grad *et al.*, 2003). Two other profiles, CEL01 and CEL05 from the CELEBRATION 2000 experiment, are also included. Their northern part in the EEC are *ca.* 470 and 770 km long, respectively. The EUROBRIDGE, POLONAISE'97 and CELEBRATION 2000 experiments were carried out using modern digital seismic recorders spaced *ca.* 1.2–4.0 km apart along profiles. Shot points with a charge of 300–1000 kg of TNT were located every 30–40 km. In the Coast Profile a ship-borne airgun array was used to generate seismic waves.

Additionally, we present two models of the reprocessed profiles VIII and XXIV within the Ukrainian Shield (Sollogub, 1982; Grad and Tripolsky, 1995). Field measurements were carried out in 1967–1972 along the 600 km long profile VIII and the 320 km long profile XXIV (Figs. 1 and 3). Shots with charge reaching 2000 kg of TNT and spacing with mean value of about 30 km were recorded by analog multichannel seismic stations with a distance between the channels of 100 m.

The wave field recorded within the southwestern part of the EEC is, in general, of very high quality. Because of thin sedimentary cover, the refracted waves diving in the crust (*Pg*) produced clear first arrivals with apparent velocities between 6 and 7 km/s. Strong reflected waves from the Moho boundary (*PmP*) were observed starting from the offset of 80 to 120 km. Selected examples of record sections from EUROBRIDGE, POLONAISE'97 and CELEBRATION 2000 profiles are shown in Figure 4. Substantial differentiation of arrival times, exceeding 2 s for *Pg*, *PmP* and *Pn* phases, was observed (lowermost right diagram in Fig. 4). Such a large scattering of arrival times reflects differentiation of the structure in the crust and the uppermost mantle.

CRUSTAL AND UPPERMOST MANTLE MODELS

The seismic data for all EUROBRIDGE'94–97, POLONAISE'97 and CELEBRATION 2000 profiles were modelled by two-dimensional tomographic (Hole, 1992; Zelt and Barton, 1998) and raytracing (Červený and Pšenčík, 1983) techniques. The raytracing models were altered successively by trial and error, and travel times with synthetic seismograms were calculated repeatedly for the times for a suite of models until close agreement was obtained between the observed and model-derived travel times and amplitudes. In the modelling of the Coast Profile the raytracing software of Zelt and Smith (1992) was used.

The collection of P-wave velocity models of the crust and uppermost mantle along profiles in the southwestern part of the EEC is shown in Figure 5 (Grad and Tripolsky, 1995; Giese, 1998; EUROBRIDGE Seismic Working Group, 1999, 2001; Środa *et al.*, 1999; 2006; Czuba *et al.*, 2001, 2002; Lund *et al.*, 2001; Grad *et al.*, 2003, 2006; Thybo *et al.*, 2003).

The modelling of S-waves was performed in order to determine the *Vp/Vs* ratio for each layer. The final P-wave seismic models were used as the starting models to change the *Vp/Vs* ratios by trial and error until they fitted the observed S-wave travel times (Grad and Tripolsky, 1995; EUROBRIDGE Seismic Working Group, 1999; Środa *et al.*, 1999; Czuba *et al.*, 2001; Thybo *et al.*, 2003). The S-wave velocity model and the *Vp/Vs* ratio distribution for EUROBRIDGE'97 profile are shown in Figure 6. Features of the structures related to the tectonic units of Fennoscandia and Sarmatia, based on the P- and S-wave velocities, are summarized in Tables 1 and 2. In general, both the P- and S-wave velocity models show similarities with the results previously obtained for Scandinavia and the Baltic Sea (e.g. Grad and Luosto, 1987, 1994; Guggisberg *et al.*, 1991; BABEL Working Group, 1993; Ostrovsky *et al.*, 1994).

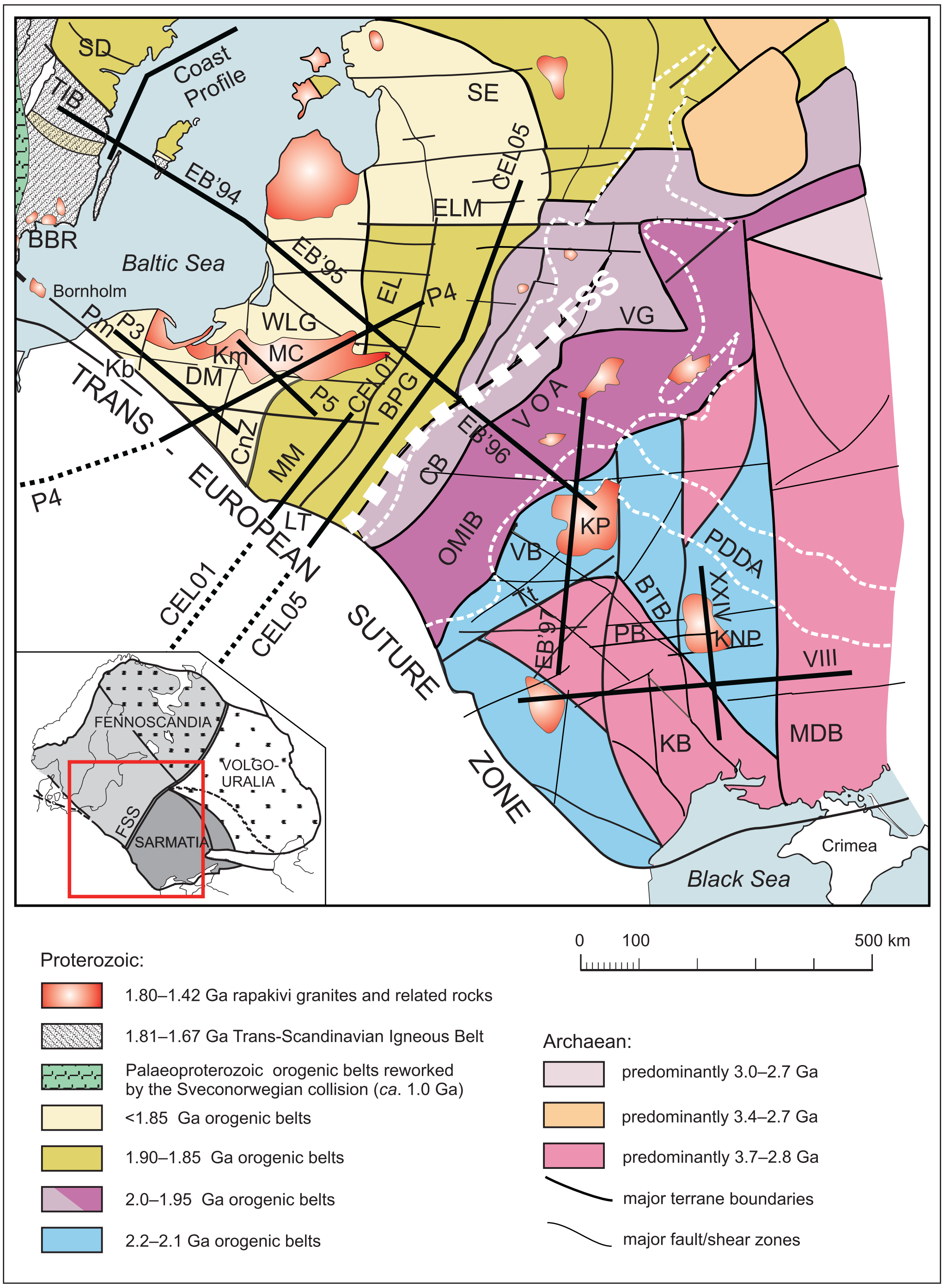


Fig. 3. Location of refraction and wide-angle reflection deep seismic sounding profiles on a simplified tectonic map (after Bogdanova *et al.*, 2001) of the southwestern margin of the East European Craton

BBR — Blekinge–Bornholm region; BPG — Belarus–Podlasie Granulite Belt; BTB — Belaya–Tserkov Belt; CB — Central Belarus Belt; CnZ — Ciechanów Zone; DM — Dobrzyń Massif; EL — East Lithuanian Domain; ELM — East Latvian Massif; FSS — Fennoscandia–Sarmatia Suture; KB — Kirovograd Block; Kb — Kaszuby Block; Km — Kętrzyn Massif; KNP — Korsun–Novomirgorod Pluton; KP — Korosten Pluton; LT — Lublin Trough; MDB — Middle Dnieper Block; MM — Mazowsze Massif; MC — Mazury Complex; OMIB — Osnitsk–Mikashevichi Igneous Belt; PB — Podolian Block; Pm — Pomorze Massif; PDDA — Pripyat–Dnieper–Donets Aulacogen; SD — Svecofennian Domain; SE — South Estonian Granulites; TIB — Trans-Scandinavian Igneous Belt; Tt — Teterev Belt; VB — Volyn Block; VG — Vitebsk Granulite Domain; VOA — Volyn–Orsha Aulacogen; WLG — West Lithuanian Granulite Domain; white dashed lines show boundaries of aulacogens; other explanations as on Figure 1

The results related to the various parts and aspects of the lithosphere in the southwestern part of the East European Craton are summarized in the following sections.

SEDIMENTARY COVER

The sedimentary cover of the southwestern part of the EEC is rather thin, being about 1–2 km thick. Exceptions are shield areas, where these strata are either absent or thinner than a few tens of metres only (as a rule <100 m). In the various parts of the Pripyat Trough and along the Trans-European Suture Zone (TESZ; e.g. in the Polish Basin and Lublin Trough), however, the thickness of the sedimentary cover is between 4 and 20 km (e.g. for profiles EB'96, P4, CEL01, CEL05; Fig. 5). In general, the thickest Phanerozoic cover deposits in the region studied correspond to seismic layers with P-wave velocities between 2 and 5 km/s.

CRYSTALLINE CRUST

The crystalline crust in the area surveyed can generally be divided into three parts: with P-wave velocities of 6.1–6.4, 6.5–6.8 and 6.9–7.2 km/s for the upper, middle and lower crust, respectively. Relatively low velocities of *ca*. 5.7 km/s in the uppermost crystalline basement were found locally in the Mazowsze and West Lithuanian Domains, and in the Belarus–Podlasie Granulite Belt.

The upper crystalline crust is the most inhomogeneous, with low velocity zones (LVZ) and high velocity bodies (HVB) alternating along some parts of the profiles. Usually, the LVZs are not very pronounced; they reach *ca*. 5 km in thickness and have a velocity contrast of 0.1–0.2 km/s. Mostly they occur at the depth between 4 and 15 km. Low velocity layers in the upper crust have been found in the Trans-Scadinavian Igneous Belt, the West Lithuanian Granulite Domain, and the Volyn, Podolian, Kirovograd and Middle Dnieper Domains of Sarmatia, while the region of the Mazury Complex, the Central Belarus Belt (Suture Zone), the Volyn and Kirovograd Domains feature high velocity bodies in the upper crust.

The middle crust is more homogeneous than the upper crust, but its thickness varies from 7 to 25 km; it has P-wave velocities of 6.5–6.8 km/s. In most of the southwestern part of the EEC area, the thickness of the lower crust is between 10 and 20 km, and the velocity is between 6.9 and 7.2 km/s. Only in the Svecofennian Domain of Fennoscandia does the thickness decrease to *ca*. 5 km (*cf*. the northern part of the Coast Profile region in Fig. 5). The Blekinge–Bornholm region of Fennoscandia (Fig. 3) and the Podolian Domain in Sarmatia (*cf*. the EUROBRIDGE'97 profile in Fig. 5) appear to entirely lack a high velocity layer (Vp = 6.9–7.2 km/s) in the lower crust. In general, high P-wave velocities (7.0 km/s) are typical for the lower crust of the EEC. However, it is necessary to emphasize that, for some areas of the southwestern edge of the EEC, relatively low velocities (6.75–6.9 km/s) are observed in the lower crust down to the Moho boundary. See for example in Figure 5: West Lithuanian Granulite Domain (profile EB'94–96), Kirovograd Block (profile VIII), Belaya–Tserkov Belt (profile XXIV), Belarus–Podlasie Granulite Belt (profile CEL01, NE part of CEL05 profile).

The lowermost crust is characterized by high P-wave velocities, reaching incidentally a maximum of 7.5 km/s (HVLC) in the part of the Volyn Domain underlying the Korosten Pluton. Characteristically, that particular region lacks the high reflectivity in the lower crust that is otherwise common in the Volyn Domain. This may suggest that the lower-crustal high velocity layer beneath the Korosten Pluton is a zone of transition between the lower crust and the upper mantle.

The crystalline crust in the southwestern part of the EEC has mostly low velocity gradients and small velocity contrasts at the seismic boundaries. Only in some places, as for instance in the Central Belarus Belt (Suture Zone), the Osnitsk–Mikashevichi Igneous Belt, and parts of the Volyn, Podolian, Kirovograd and Middle Dnieper Domains, high reflectivity has been observed.

Vp/Vs RATIOS

The average values of the Vp/Vs ratios in the crystalline crust are 1.69, 1.70 and 1.76 in its upper, middle and lower parts, respectively. It follows that the S-wave velocities in the upper and middle crust are relatively high in comparison to the P-wave velocities, whereas in the lower crust Vs is relatively low (lower than Vp). This implies a relatively larger contrast of S-wave velocities at the Moho and may explain the strong *SmS* reflections seen, for instance, in the central part of the EUROBRIDGE'97 profile (Fig. 5).

HIGH VELOCITY PLUTONS IN THE UPPER CRUST

The high velocity bodies in the upper crust coincide with the well-known Mazury, Korosten and Korsun–Novomirgorod Plutons comprising rapakivi-granitic and anorthositic rocks (Fig. 3).

In the Mazury Complex, a high velocity body with P-wave velocities of between 6.4 and 6.7 km/s coincides well with the anorthosite Kętrzyn Massif. The Vp/Vs ratio in that body is estimated to be 1.75. The lower crust is significantly reflective in the Mazury Complex. The Moho interface has an undulating shape at depths in the range of 42–46 km, and a depression in the Moho boundary is located beneath the Kętrzyn Massif.

In the Volyn Domain, the Korosten Pluton is imaged as a high velocity anomaly (6.35–6.7 km/s) to depths of at least 11 km (instead of 6 km as previously interpreted), possibly connected to a lower crustal high velocity anomaly. The Vp/Vs ratio is high (1.77–1.79), indicative of a basic composition, consistent with a mafic body of mantle-derived melts with a contribution from the lower gabbroic crust.

In the Podolian Domain, the Korsun–Novomirgorod Pluton rocks with velocities 6.1–6.7 km/s reach depths of 11–12 km, and Vp/Vs there is about 1.73.

In general, all these three plutons in the upper crust are 6 to 11 km thick and are characterized by high P- wave velocity (from 6.1 to 6.7 km/s). The Vp/Vs ratio is 1.75 on average (ranging from 1.73 to 1.79), indicating quite normal S-wave velocities, typical for the upper crystalline crust (Table 2).

Another high velocity body was found beneath the CEL01 profile (Fig. 5). The relatively uniform structure of the EEC

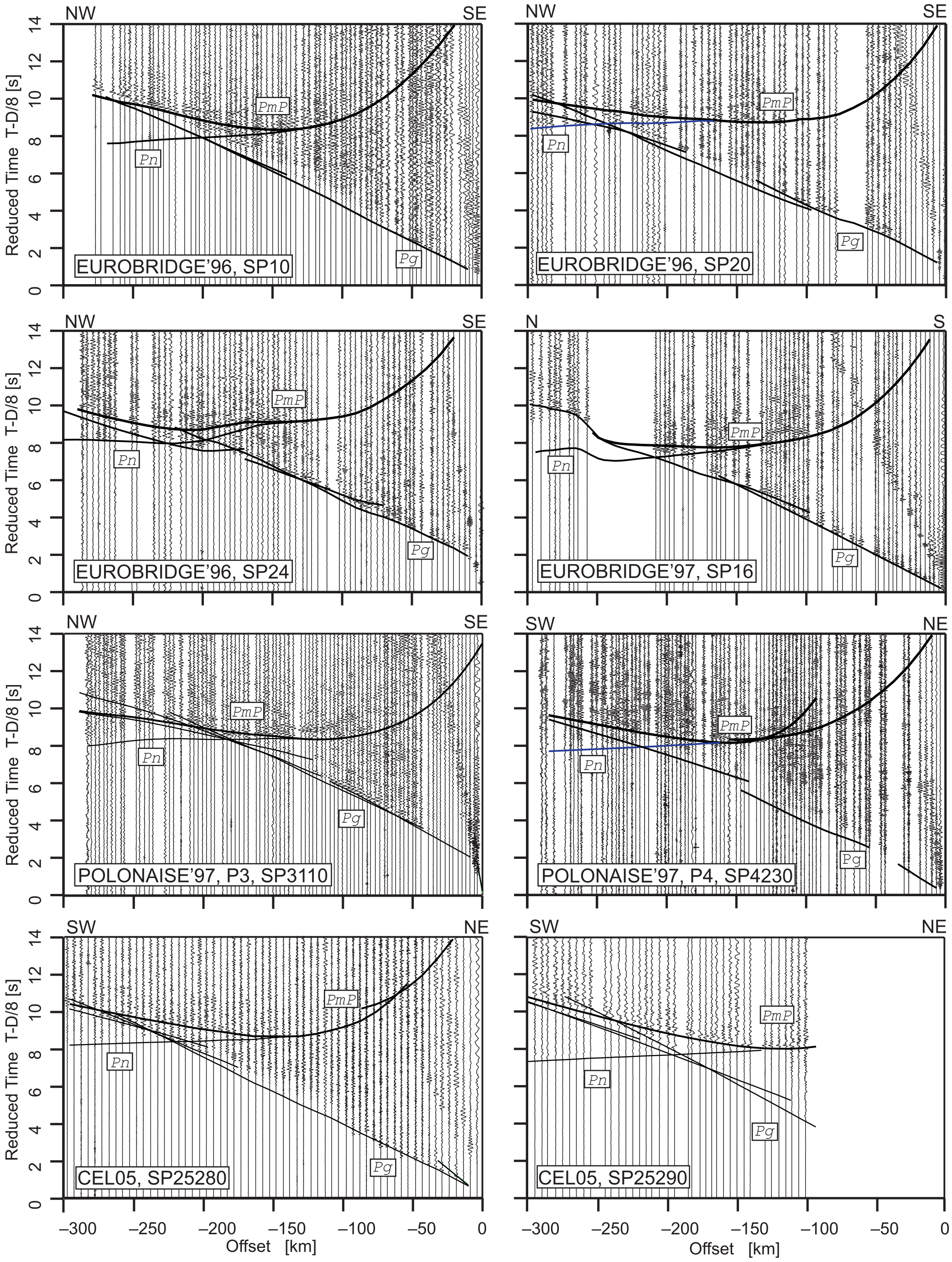
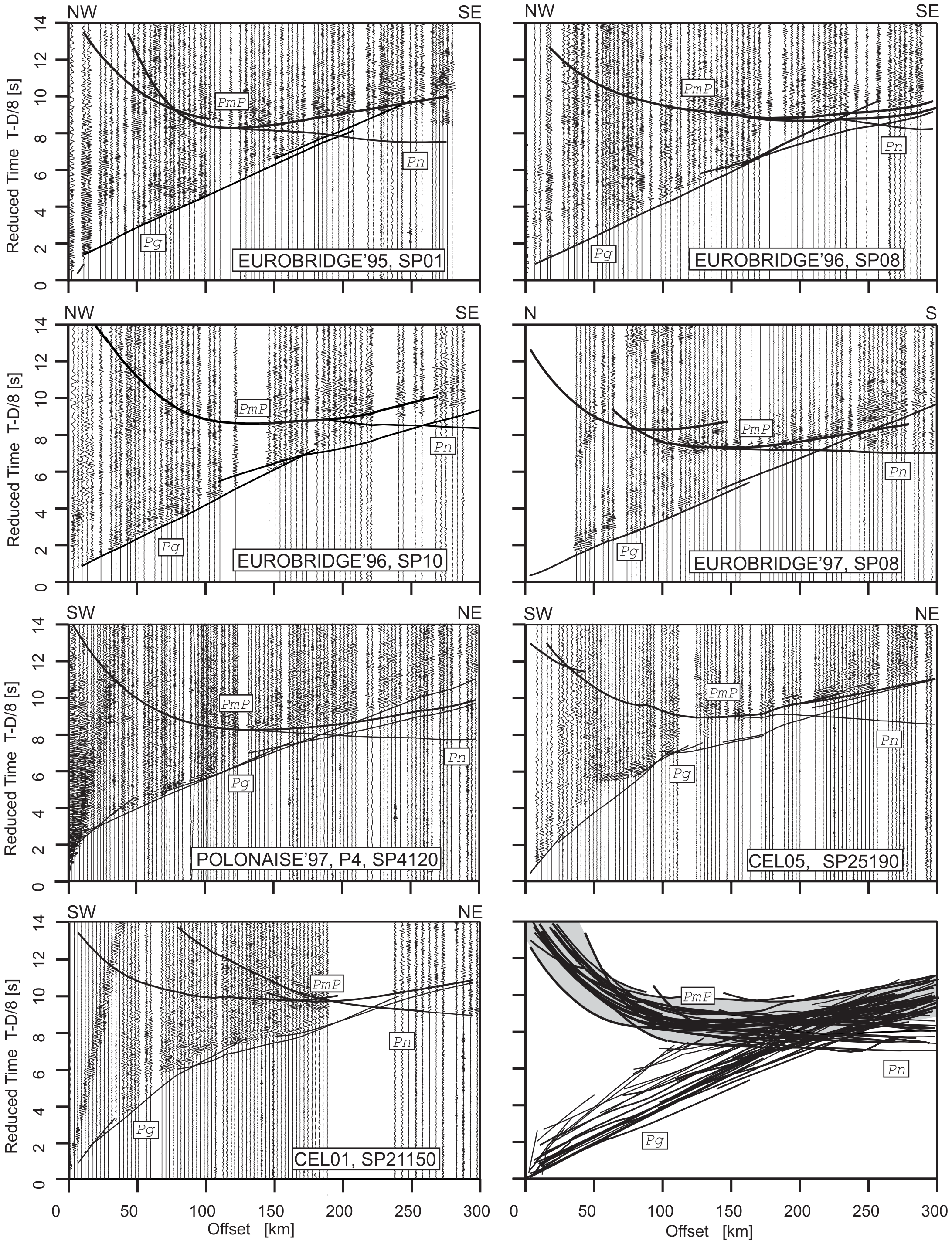


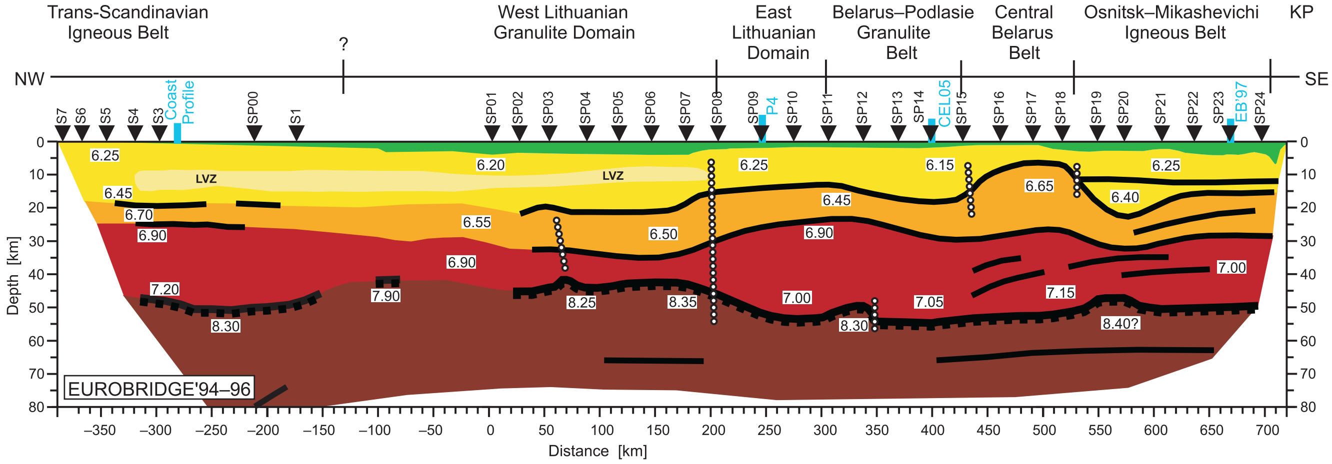
Fig. 4. P-wave record sections for seismic profiles across the

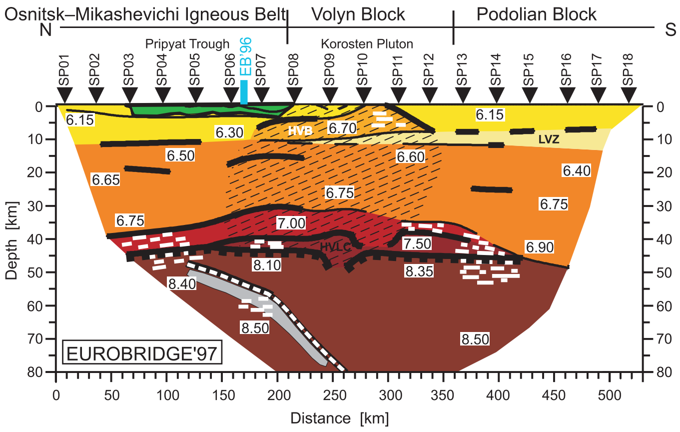
Pg, *PmP* and *Pn* — crustal and Moho phases; lowermost right diagram shows travel times of *Pg*, *PmP*, *Pn* phases, note a big for shot point locations see Figure 1

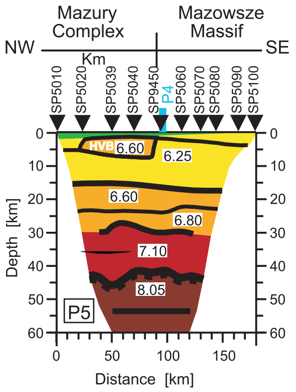


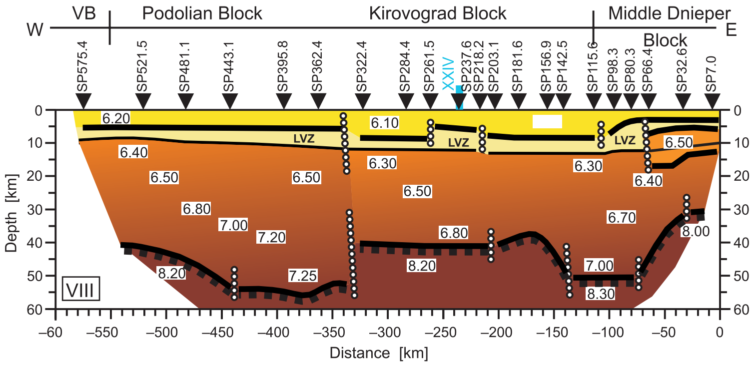
southwestern margin of the East European Craton

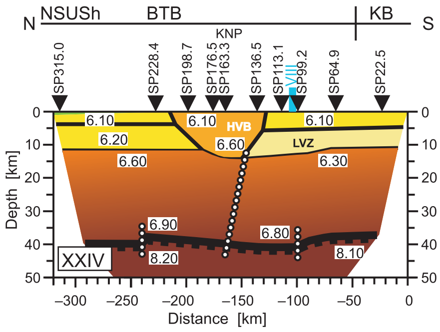
variability of the arrival times (exceeding 2 s), which reflects differentiation of the crustal and uppermost mantle structure;

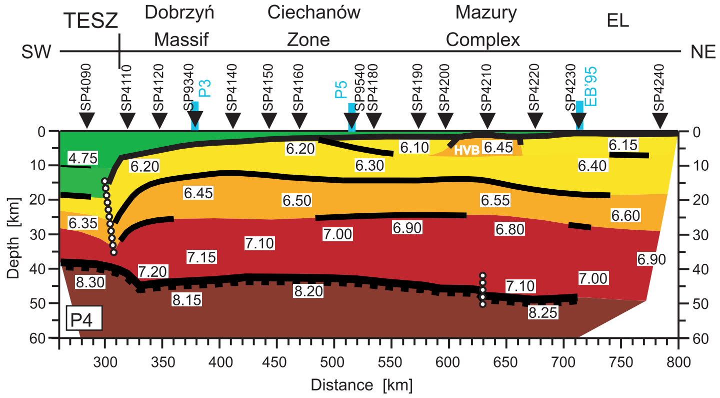

Trans-Scandinavian Igneous Belt
?
West Lithuanian Granulite Domain
East Lithuanian Domain
Belarus–Podlasie Granulite Belt
Central Belarus Belt
Osnitsk–Mikashevichi Igneous Belt
KP
NW
SE
S7 S6 S5 S4 S3 Coast Profile SP00 S1 SP01 SP02 SP03 SP04 SP05 SP06 SP07 SP08 SP09 P4 SP10 SP11 SP12 SP13 SP14 CEL05 SP15 SP16 SP17 SP18 SP19 SP20 SP21 SP22 SP23 EB'97 SP24
6.25
LVZ
6.45
6.70
6.90
7.20
8.30
7.90
6.20
6.55
6.90
8.25
6.50
8.35
6.25
6.45
6.90
7.00
8.30
6.15
6.65
7.05
7.15
6.40
6.25
7.00
8.40?
EUROBRIDGE'94–96
Depth [km]
0 10 20 30 40 50 60 70 80
–350 –300 –250 –200 –150 –100 –50 0 50 100 150 200 250 300 350 400 450 500 550 600 650 700
Distance [km]

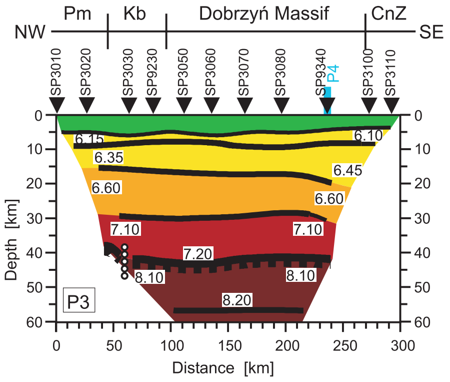

Osnitsk–Mikashevichi Igneous Belt
Volyn Block
Podolian Block
N
S
Pripyat Trough
Korosten Pluton
SP01 SP02 SP03 SP04 SP05 SP06 EB'96 SP07 SP08 SP09 SP10 SP11 SP12 SP13 SP14 SP15 SP16 SP17 SP18
6.15
6.30
HVB
6.70
6.15
LVZ
6.50
6.60
6.40
6.65
6.75
6.75
6.75
7.00
HVLC
7.50
6.90
8.10
8.35
8.40
8.50
8.50
EUROBRIDGE'97
Depth [km]
0 10 20 30 40 50 60 70 80
0 50 100 150 200 250 300 350 400 450 500
Distance [km]


Mazury Complex
Mazowsze Massif
NW
SE
Km
SP5010 SP5020 SP5039 SP5040 SP9450 P4 SP5060 SP5070 SP5080 SP5090 SP5100
HVB
6.60
6.25
6.60
6.80
7.10
8.05
P5
Depth [km]
0 10 20 30 40 50 60
0 50 100 150
Distance [km]


VB
Podolian Block
Kirovograd Block
Middle Dnieper Block
W
E
SP575.4 SP521.5 SP481.1 SP443.1 SP395.8 SP362.4 SP322.4 SP284.4 SP261.5 XXIV SP237.6 SP218.2 SP203.1 SP181.6 SP156.9 SP142.5 SP115.6 SP98.3 SP80.3 SP66.4 SP32.6 SP7.0
6.20
LVZ
6.40
6.50
6.50
6.80
7.00
7.20
8.20
7.25
6.10
LVZ
6.30
6.50
6.80
8.20
6.30
LVZ
6.50
6.40
6.70
7.00
8.00
8.30
VIII
Depth [km]
0 10 20 30 40 50 60
–60 –550 –500 –450 –400 –350 –300 –250 –200 –150 –100 –50 0
Distance [km]


N
NSUSh
BTB
KB
S
KNP
SP315.0 SP228.4 SP198.7 SP176.5 SP163.3 SP136.5 SP113.1 VIII SP99.2 SP64.9 SP22.5
6.10
6.20
6.10
HVB
6.60
6.10
LVZ
6.60
6.30
6.90
6.80
8.20
8.10
XXIV
Depth [km]
0 10 20 30 40 50
–300 –250 –200 –150 –100 –50 0
Distance [km]


TESZ
Dobrzyń Massif
Ciechanów Zone
Mazury Complex
EL
SW
NE
SP4090 SP4110 SP4120 SP9340 P3 SP4140 SP4150 SP4160 P5 SP9540 SP4180 SP4190 SP4200 SP4210 SP4220 SP4230 EB'95 SP4240
4.75
6.20
6.20
6.10
HVB
6.45
6.15
6.30
6.40
6.45
6.50
6.55
6.60
6.35
7.00
6.90
6.80
7.15
7.10
6.90
7.20
8.30
8.15
8.20
7.10
7.00
8.25
P4
Depth [km]
0 10 20 30 40 50 60
300 350 400 450 500 550 600 650 700 750 800
Distance [km]


Pm
Kb
Dobrzyń Massif
CnZ
NW
SE
SP3010 SP3020 SP3030 SP9230 SP3050 SP3060 SP3070 SP3080 SP9340 P4 SP3100 SP3110
6.15
6.10
6.35
6.45
6.60
6.60
7.10
7.10
7.20
8.10
8.10
8.20
P3
Depth [km]
0 10 20 30 40 50 60
0 50 100 150 200 250 300
Distance [km]

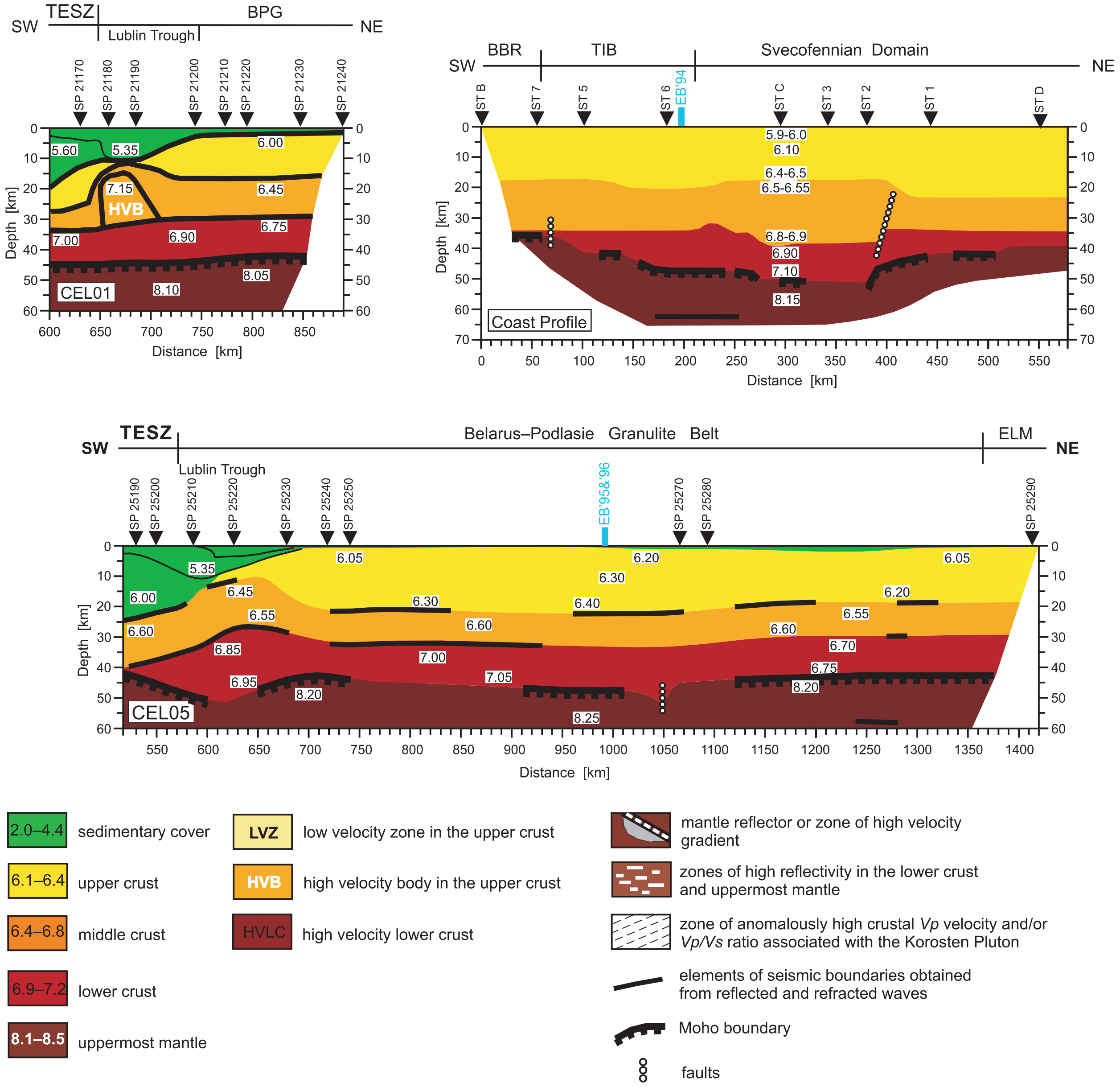


Fig. 5. Crustal and uppermost mantle models along the EUROBRIDGE transect (EB'94, EB'95 and EB'96) and profiles EB'97, VIII, XXIV, the POLONAISE'97 profiles P4 (northern part), P5 and P3, CELEBRATION 2000 profiles CEL01 and CEL05 and Coast Profile

P-wave velocities are given in km/s; NSUSh — Northern Slope of Ukrainian shield; arrows — positions of shot points; the crossing points with other profiles are marked in blue; in all models the vertical exaggeration is 3:1; other explanations as on Figure 3

crust is disturbed in its marginal part, beneath the Lublin Trough, where unusually high velocities of 7.1 km/s are observed at a depth of 17 km. This anomaly seems to be a continuation of a high velocity/high density body located farther to SE, detected by previous seismic and gravity modelling (Grabowska and Bojdys, 2001).

THICKNESS OF THE CRUST AND SEISMIC WAVE VELOCITIES IN THE UPPERMOST MANTLE

The southwestern part of the EEC has a thick continental crust, ranging mostly between 40 and 50 km. Moho depths of *ca*. 55 km have been found in the Podolian Domain, while the shallowest Moho is in the Volyn Domain, where its depth is only *ca*. 30 km. Within some regions, such as for example, the Volyn Domain, there are large, distinct Moho elevations of a few or more kilometres, but most often such elevations coincide with the boundaries between the different crustal domains, e.g. the Podolian Domain, the West Lithuanian Domain, and the East Lithuanian Belt. Mantle P-wave velocities immediately beneath the Moho are 8.2–8.35 km/s, which is higher than the world average. Velocities of 8.0–8.15 km/s have been found only in the marginal zones of the East European Craton such as, for instance, in the Dobrzyń Domain. The average *Vp/Vs* ratio for the uppermost mantle, determined from *Pn* and *Sn* waves, is 1.75; Fennoscandia has a lower extreme of about

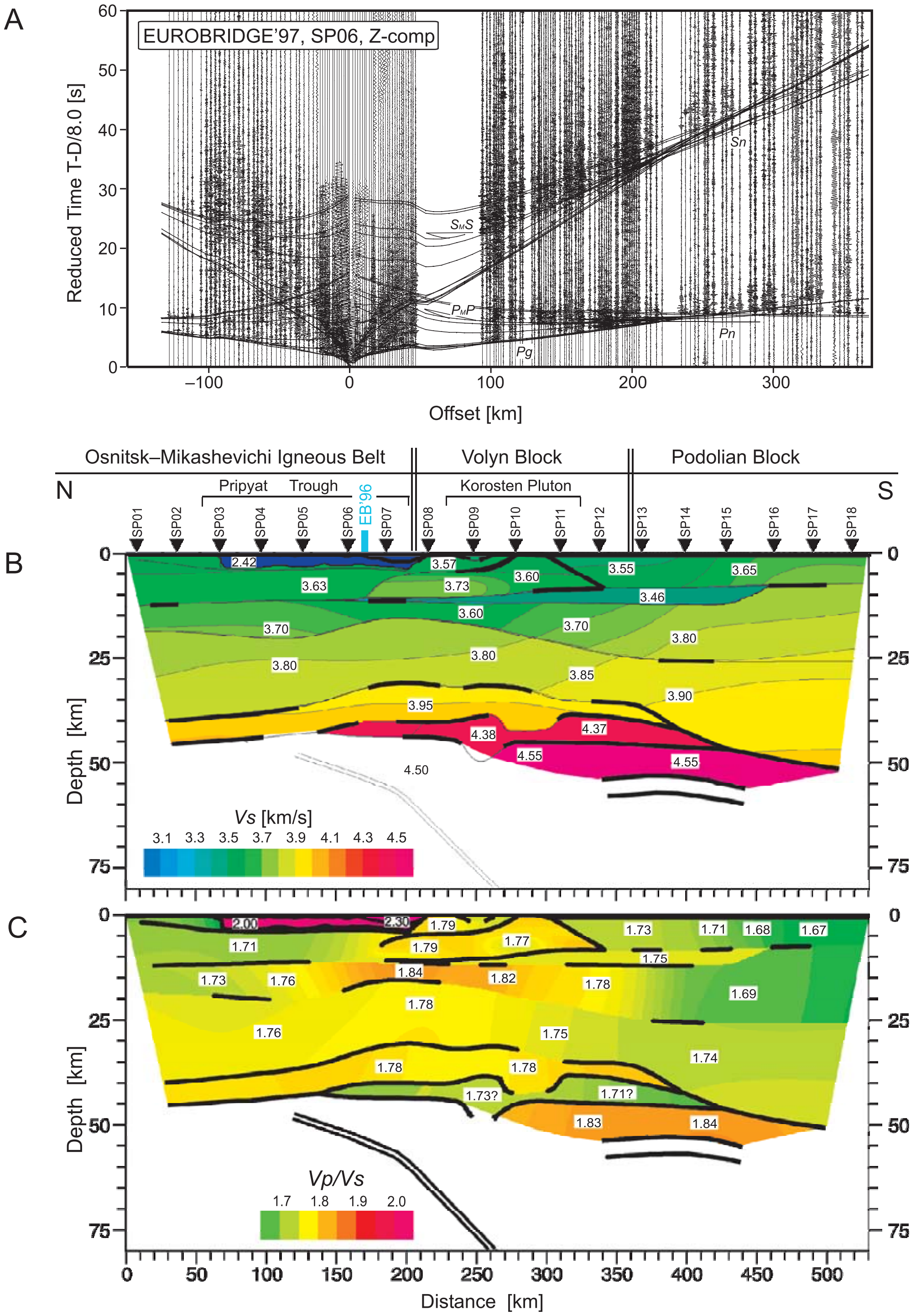


Fig. 6. Two-dimensional seismic models along the EUROBRIDGE'97 profile developed by forward ray tracing

A — example of seismic record section for SP06 with P- and S-waves; *SmS* and *Sn* — Moho phases for S-waves (for shot point location see Fig. 1); **B** — S-wave velocity model with thick lines marking those parts of the discontinuities that have been constrained by reflected and/or refracted S-waves; **C** — *Vp/Vs* ratio distribution with thick lines marking those parts of the discontinuities that have been constrained by reflected and/or refracted P- or S-waves; in both models the vertical exaggeration is 3:1; other explanations as on Figure 5

1.72 and Sarmatia a higher extreme of *ca.* 1.80. High *Vs* and *Vp* velocities in the upper mantle down to 200–400 km depth were found earlier also in other regions of the EEC (see e.g. Zielhuis and Nolet, 1994; Świeczak *et al.*, 2004).

MANTLE REFLECTORS

The uppermost mantle features numerous sub-horizontal reflectors beneath both the Baltic Shield and the East European Platform (e.g. Grad, 1992; BABEL Working Group, 1993;

Table 1

Crustal structure of southwestern part of the East European Craton (profiles EUROBRIDGE’94–97, POLONAISE’97 — P3, P4 and P5; CELEBRATION 2000 — CEL01, CEL05; Coast Profile, VIII and XXIV)

		FENNOSCANDIA							SARMATIA					
	tectonic units age [Ga]	SD 1.90–1.86	TIB 1.81–1.71	DM + CnZ <1.85	MM 1.84–1.77	WLD <1.88	EL 1.90–1.85	BPG 1.90–1.85	CB 2.00–1.95	OMIB 2.00–1.95	VB 2.22.1	PB 3.7–2.8	KB 3.7–2.8	MDB 3.7–2.8
sediments	*H* [km]	0–1	0–1	0.5–8	1–2	0.5–2.5	1–2	0.5–1	0.5–2	2–4.5	<0.1	<0.1	<0.1	<0.1
upper crust	*H* [km]	0–22	0–19	2–17	1–16	0.5–22	1–18	0.5–18	0.5–8	2–12	0–12	0–12	0–14	0–17
	Vp [km/s]	5.9–6.5	6.2–6.45	6.1–6.4	5.9–6.35	6.2–6.3	6.1–6.5	6.1–6.2	6.1–6.2	6.15–6.25	6.1–6.45	6.05–6.20	6.0–6.15	6.0–6.15
	Vp/*Vs*			1.67–1.70	1.67–1.8	1.66–1.69				1.71	1.77–1.79	1.67–1.75	1.67–1.71	1.67–1.71
	property		LVZ			LVZ			HVB?		HVB, LVZ	LVZ	HVB,LVZ	HVB,LVZ
middle crust	*H* [km]	18–38	18–25	12–28	14–30	17–28	13–30	15–30	5–22	10–32	12–37	10–55	13–50	15–50
	Vp [km/s]	6.50–6.9	6.65–6.75	6.55–6.65	6.5–6.8	6.45–6.55	6.45–6.6	6.4–6.5	6.6–6.7	6.4–6.8	6.6–6.8	6.5–7.25	6.3–7.0	6.3–7.0
	Vp/*Vs*			1.67–1.71	1.70	1.66–1.69				1.73–1.78	1.75–1.84	1.69		
	property									REFL, TR				
lower crust	*H* [km]	32–50	24–50	25–45	28–44	28–45	23–52	25–52	25–53	25–50	30–50			
	Vp [km/s]	6.9–7.1	6.8–7.3	6.9–7.2	7.05–7.15	6.85–6.95	6.8–7.1	6.9–7.05	6.9–7.2	6.9–7.1	6.9–7.1			
	Vp/*Vs*			1.73–1.77	1.76	1.77				1.76–1.78	1.78, 1.73	1.74	1.75–1.77	
	property								REFL	REFL	HVLC	TR	TR	TR
upper mantle	H_M [km]	42–50	40–50	44–46	42–44	42–45	45–52	48–52	50–53	46–50	45–50	44–55	35–40	30–50
	Vp [km/s]	8.1–8.15	8.3	8.1–8.15	8.05	8.25–8.35	8.25	8.3	8.3	8.35	8.1–8.3	8.2–8.25	8.1–8.2	8.0–8.1
	Vp/*Vs*			1.70	1.73	1.73					1.83	1.84		
	property								REFL	REFL		REFL		
	depth of mantle reflectors [km]	63		57	54	65			62–65	50–65	60–75	55, 58		

Regional tectonic units as in Figure 3; HVB — high velocity body; LVZ — low velocity zone; HVLC — high velocity lower crust; REFL — reflectivity; TR — transparent; 1.66–1.69 — values determined as a common for corresponding layers; age of the tectonic units after Bogdanowa *et al*. (2001) and MM after Krzemińska *et al*. (2005)

Table 2

Seismic characteristic of the rapakivi and anorthosites plutons

Pluton	Mazury (Km)	Korosten (KP)	Korsun–Novomirgorod (KNP)
depth to the top [km]	2–3	0–1	0–1
depth to the bottom [km]	5–8	>10	11–12
Vp velocity [km/s]	6.4–6.7	6.35–6.7	6.1–6.7
Vp/Vs	1.75	1.77–1.79	1.73

EUROBRIDGE Working Group, 1999; Środa *et al*., 1999; Czuba *et al*., 2001; Lund *et al*., 2001; Grad *et al*., 2002*b*; Yliniemi *et al*., 2004). These reflectors often occur *ca*. 10 to 15 km below the Moho. A major, southwards dipping reflector has been interpreted in the uppermost mantle beneath the EUROBRIDGE'97 profile, extending from the Moho down to depths of *ca*. 75 km (Thybo *et al*., 2003). That reflector dips SSW and coincides with a sub-horizontal reflector on the EUROBRIDGE'96 profile, close to its crossing point with the EUROBRIDGE'97 profile in Sarmatia.

The Moho depth determined with high confidence from the EB'97 profile does not coincide with the poorly determined Moho depth along the EB'96 profile at their crossing point, which is located at the SE end of the EB'96 profile. Because of that, it will be necessary to remodel this part of the EB'96 profile in the future.

DISCUSSION

Features of the structures of the southwestern part of EEC related to the tectonic units of Fennoscandia and Sarmatia, based on both P- and S-wave velocities, show many similarities. The crustal thickness in the entire area investigated is large (between 40 and 50 km, maximum about 55 km) and relatively uniform. Beneath the thin sedimentary cover the crystalline crust has velocities of 6.1–7.2 km/s, mostly low velocity gradients and small velocity contrasts at the seismic boundaries. The crystalline crust can be generally divided into three parts, with P-wave velocities of 6.1–6.4, 6.5–6.8 and 6.9–7.2 km/s for the upper, middle and lower crust, respectively; the ratios of *Vp/Vs* are 1.69, 1.70 and 1.76, respectively. The models of the southwestern part of the EEC show similarities with the models of Scandinavia and other Precambrian cratons. In the area investigated, anomalously high velocity features in the upper, middle and lower crust were found, which can be related to processes that took place in the past during, for example, accretion and craton growth. Besides the typical crustal velocity distributions described above, there are extensive areas characterized by relatively low P-wave velocities (6.75–6.9 km/s) in the lower crust. It would be interesting to speculate on the relationships between these velocities and other physical properties, heat flow and tectonic history.

Plutons in the upper crust are characterized by high P-wave seismic velocities and high *Vp/Vs* values. Such high values of *Vp/Vs* were also measured in samples of biotite-bearing gneisses and amphiboles from similar depths in the deep borehole on the Kola Peninsula in the NE part of the East European Craton (Kern *et al*., 2001). High *Vp/Vs* values usually indicate a low quartz content of the rocks or the presence of pore fluids at high pressure. These values suggest a basic composition of the rocks. The highest *Vp/Vs* ratio is compatible with a mafic, gabbroic rock with a high content of plagioclase, pyroxene or amphibole (Christensen, 1996), consistent with the presence of a magmatic body composed of anorthosite and gabbro-norite with remnants of granite-gneiss. This may be explained by the presence of a plutonic body that was formed by mantle-derived melts with additional melts originating from a gabbroic lower crust (Dovbush *et al*., 2000).

An interesting feature of the Central Belarus Belt (CB) middle crust is a high velocity domain of 6.6–6.7 km/s. We interpret the high velocities below the CB as an indication of the tectonic emplacement of high pressure metamorphic rocks. Correlation of the seismic structure with near-surface geology tentatively suggests that the contact zones between the East Lithuanian Domain (EL), the Belarus–Podlasie Granulite Domain (BPG), the CB and the OMIB all dip slightly to the north-west, wich could be related to successive docking of these terranes during craton growth. We consider that this characteristic of the CB is most likely due to uplift of this terrane during the collision of Fennoscandia and Sarmatia.

SUMMARY OF LITHOSPHERIC STRUCTURE

The analysis of crustal and uppermost mantle seismic models along profiles in the southwestern part of the EEC show some characteristic features.

The crustal thickness over the entire investigated area of the southwestern part of the EEC is relatively uniform, being between 40 and 50 km (maximum about 55 km).

The crystalline crust in the southwestern part of the EEC has mostly low velocity gradients and small velocity contrasts at the seismic boundaries. The crystalline crust can be generally divided into three parts: with P-wave velocities of 6.1–6.4, 6.5–6.8 and 6.9–7.2 km/s for the upper, middle and lower crust, respectively and with *Vp/Vs* ratios of 1.69, 1.70 and 1.76, respectively.

The Fennoscandian part of the craton has a characteristic, distinctly three-layered crust. In contrast, in the Sarmatian part the investigated transition between the middle and lower crust is smooth, practically transparent, with a transition zone of high velocity gradient. The high velocity gradient in the middle/lower crust may indicate a gradual change from felsic to mafic composition. For both parts of the EEC, generally high P-wave velocities (>7.0 km/s) were observed in the lower crust, however in some areas velocity is relatively low, 6.75–6.9 km/s.

An interesting feature of the Central Belarus Belt (CB) middle crust is a high velocity domain of 6.6–6.7 km/s. We consider that this characteristic of the CB is most likely due to uplift of this terrane during the collision of Fennoscandia and Sarmatia. Other unusually high velocities (Vp = 7.1 km/s) in the middle crust are observed beneath the Lublin Trough at a depth of 17 km.

Rapakivi-granitic and anorthositic plutons in the upper crust are characterized by high P-wave seismic velocities and high *Vp/Vs* values.

The areas nearest to the contact zone between Fennoscandia and Sarmatia, from the Central Belarus Belt (CB) to the Volyn Domain (VB), are characterized by high reflectivity zones, especially for the middle and lower crust and the upper mantle. The high velocity lower crust (HVLC) of the VB seems to be a transition zone between the lower crust and the upper mantle.

Along most of the profiles relatively high seismic velocities of the sub-Moho mantle (~8.2–8.3 km/s) were observed.

Uppermost mantle reflectors often occur *ca*. 10 to 15 km below the Moho. Similar sub-horizontal lithospheric reflectors were observed also in the TESZ (Grad *et al*., 2002*b*). A steeply southwesterly dipping mantle reflector present below the OMIB and VB correlates with a subhorizontal reflector in the NW–SE-striking EUROBRIDGE'96 profile.

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