Polish Geological Institute
National Research Institute

Polish Geological Survey
Polish Hydrogeological Survey

POLISH GEOLOGICAL INSTITUTE

HYDROCARBON PROSPECTIVE OF POLAND

BESTWINA-CZECHOWICE TENDER AREA

ENGLISH ABSTRACT

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IV LICENSING ROUND
CONCESSIONS FOR HYDROCARBON
PROSPECTION, EXPLORATION AND PRODUCTION
IN POLAND

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for Environmental Protection
and Water Management

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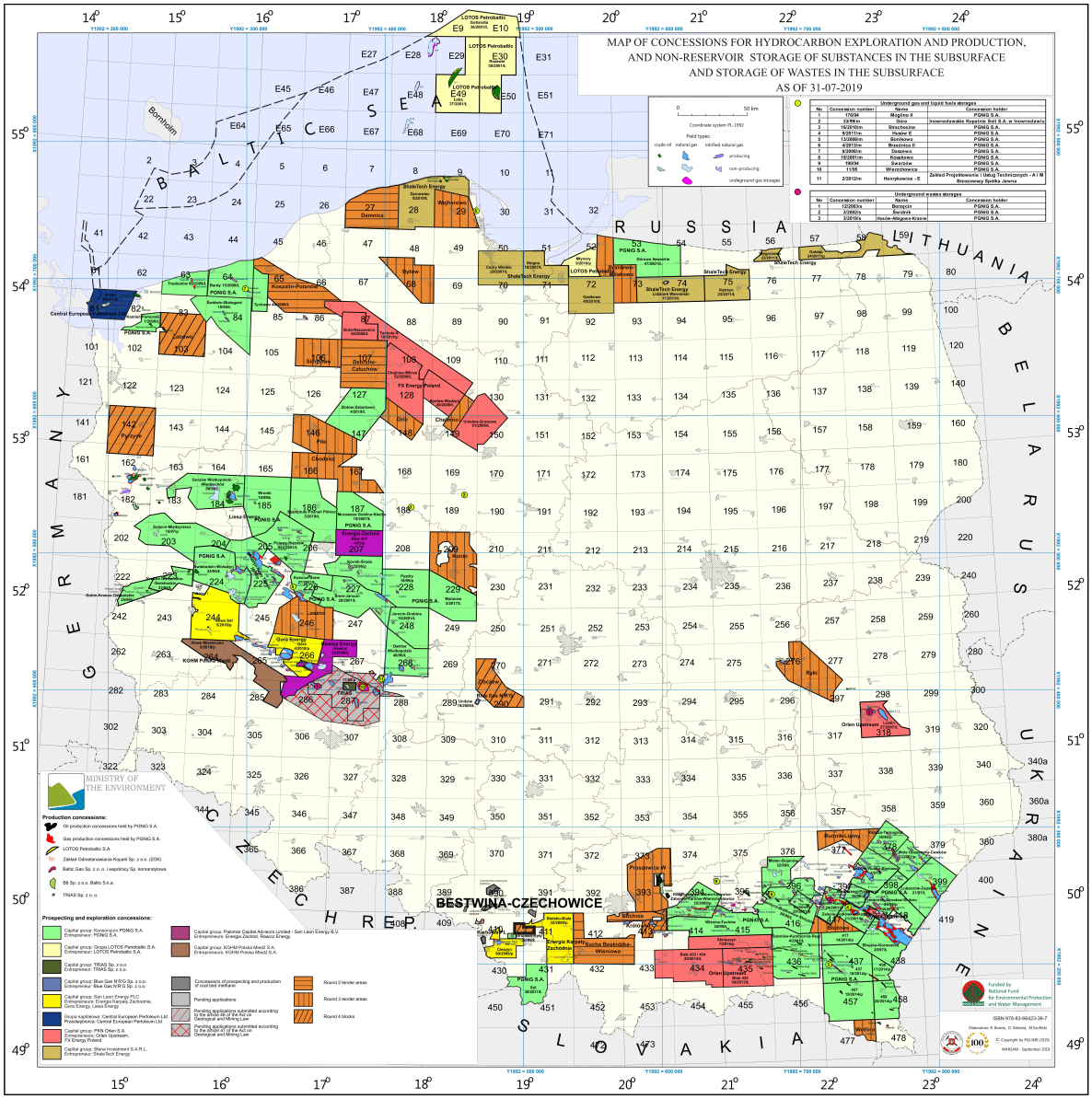


Location of the Bestwina-Czechowice tender area on the map of concessions for hydrocarbon exploration and production, and non-reservoir storage of substances in the subsurface and storage of wastes in the subsurface as of 31-07-2019.

1. GENERAL INFORMATION

The Bestwina-Czechowice tender area is located onshore in the southern Poland, in the 410 and 411 concession blocks (Fig. 1). The precise location is defined by geographical coordinates listed below.

Border points	1992 coordinate system	
	X	Y
1	229 422.37	493 418.39
2	229 341.87	499 174.04
3	229 313.02	499 187.43
4	229 289.57	500 124.17
5	226 858.38	500 124.08
6	226 943.36	507 622.42
7	222 293.28	507 622.86
8	222 190.12	494 662.22
9	222 153.81	493 303.33

Tab. 1. Border points coordinates of the Bestwina-Czechowice tender area (Fig. 1).

Administrative centre:

- Śląskie province; Bielsko-Biała county, communes: Czechowice-Dziedzice (participation in the tender area 61.41%), Jasienica (2.47%), Bestwina (20.97%), Wilamowice (2.11%); urban Bielsko-Biała county, commune: urban Bielsko-Biała (6.12%); Pszczyna county, commune: Goczałkowice-Zdrój (6.92%).

The Bestwina-Czechowice tender area was previously subjected to hydrocarbon prospection and exploration concessions No. 20/99/p "Strumień-Kęty" (PGNiG – Polish Oil and Gas Company) and 59/2009/p "Bestwina" and 69/2009/p "Cieszyn" (Aurelian Oil & Gas Poland PLC).

Currently, two hydrocarbon concessions are located in the neighbourhood:

- 32/2009/p „Bielsko-Biała" (Energia Karpaty Zachodnie),
- 20/99/Ł „Strumień-Kęty" (PGNiG – Polish Oil and Gas Company).

There are still no oil and gas discoveries in the Bestwina-Czechowice tender area, so far. However, the area is prospective, since three gas fields have been discovered in the autochthonous Miocene deposits of the Carpathian Foredeep in the southern neighbourhood. These are Dębowiec Śląski, Kowale and Pogórz fields, which are good analogues for further investigations in the tender area.

The main exploration targets in the Bestwina-Czechowice tender area are related to conventional and unconventional/hybrid gas accumulations in the:

- autochtonous Miocene sediments (Dębowiec and Skawina Formations) of the Carpathian Foredeep,
- Paleozoic (Devonian and Carboniferous) basement of the Carpathian units.

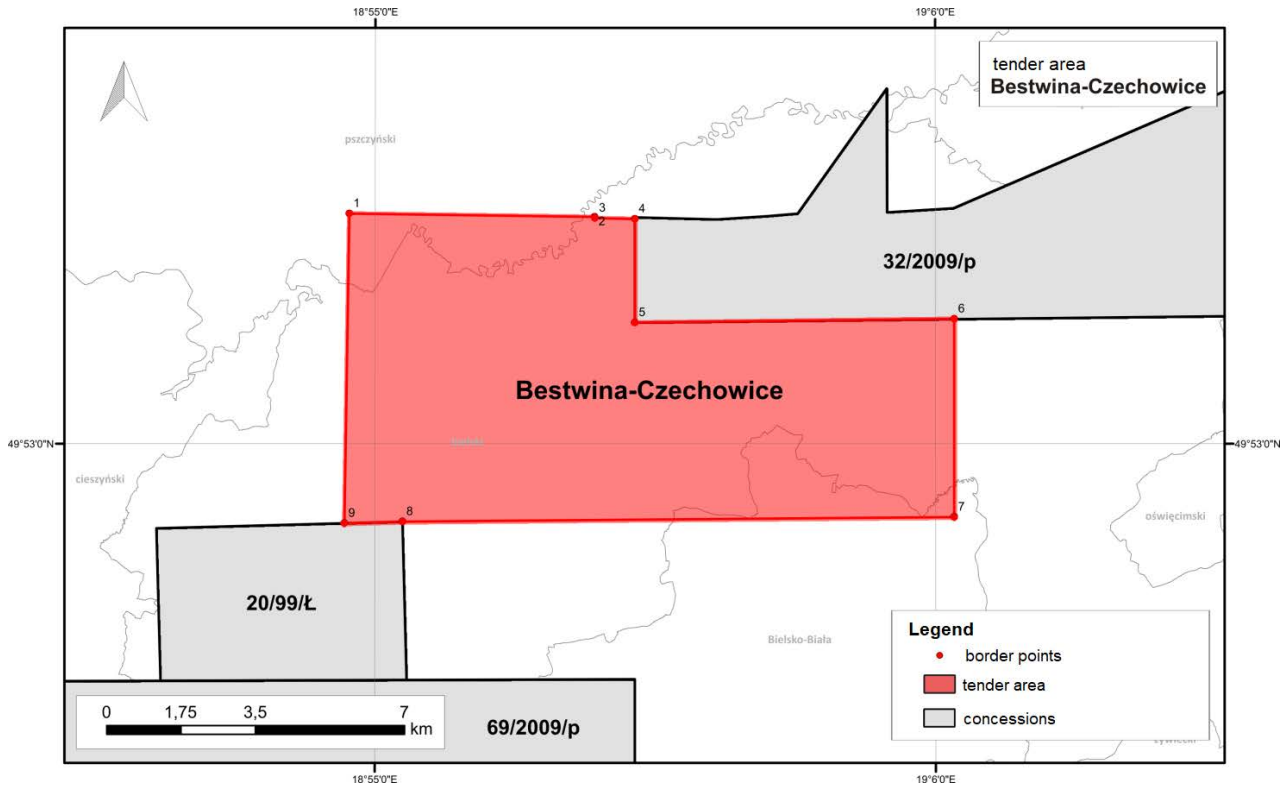


Fig. 1. Border points of the Bestwina-Czechowice tender area and location of the hydrocarbon concessions in the neighborhood as of 31-07-2019 (CBDG, 2019).

2. GEOLOGY

2.1. GENERAL GEOLOGICAL DESCRIPTION

The Bestwina-Czechowice tender area is located in the southern Poland. It lies at the border of Carpathians and Carpathian Foredeep (Fig. 2–4). The Proterozoic crystalline rocks of the Upper Silesian Block (Bielsko-Biała Dome) with its Paleozoic (Cambrian, Devonian, Mississippian and Pennsylvanian) sedimentary cover occur below the Carpathian units (Fig. 2–7).

The stratigraphy and litology of the Carpathians, Carpathian Foredeep and its basement are recognized in numerous wells located within the Bestwina-Czechowice tender area and its close neighborhood. These are: Bestwina IG-1, Bestwina III, Bielsko 1, Bielsko 2, Bielsko 4, Bielsko 5, Bronów I, Brożyska 1, Czechowice R-1, Czechowice C, Czechowice E, Czechowice IG-1, Czechowice-Dziedzice 1, Czechowice-Dziedzice 3, Dziedzice B, Goczałkowice IG-1, Kęty 7, Ligota 1, Ligota A, Ligota D, Ligota II, Ligota III, Ligota IV, Ligota V and Zagrzeb 1 (see Fig. 15 for location; wells located within the tender area are highlighted).

2.2. TECTONIC

Four structural stages are distinguished in the Bestwina-Czechowice tender area. The oldest – Precambrian stage – includes metamorphic and crystalline rocks of the basement of the Upper Silesian Block. Above, Cambrian sandstones of the Caledonian stage and Devonian–Carboniferous succession of the Variscan stage occur. The youngest – Alpine/Saawian-Styrian stage includes the Upper Jurassic to Lower Miocene flysch succession of the Carpathian Sub-Silesian and Silesian units and autochtonous Miocene deposits of the Carpathian Foredeep.

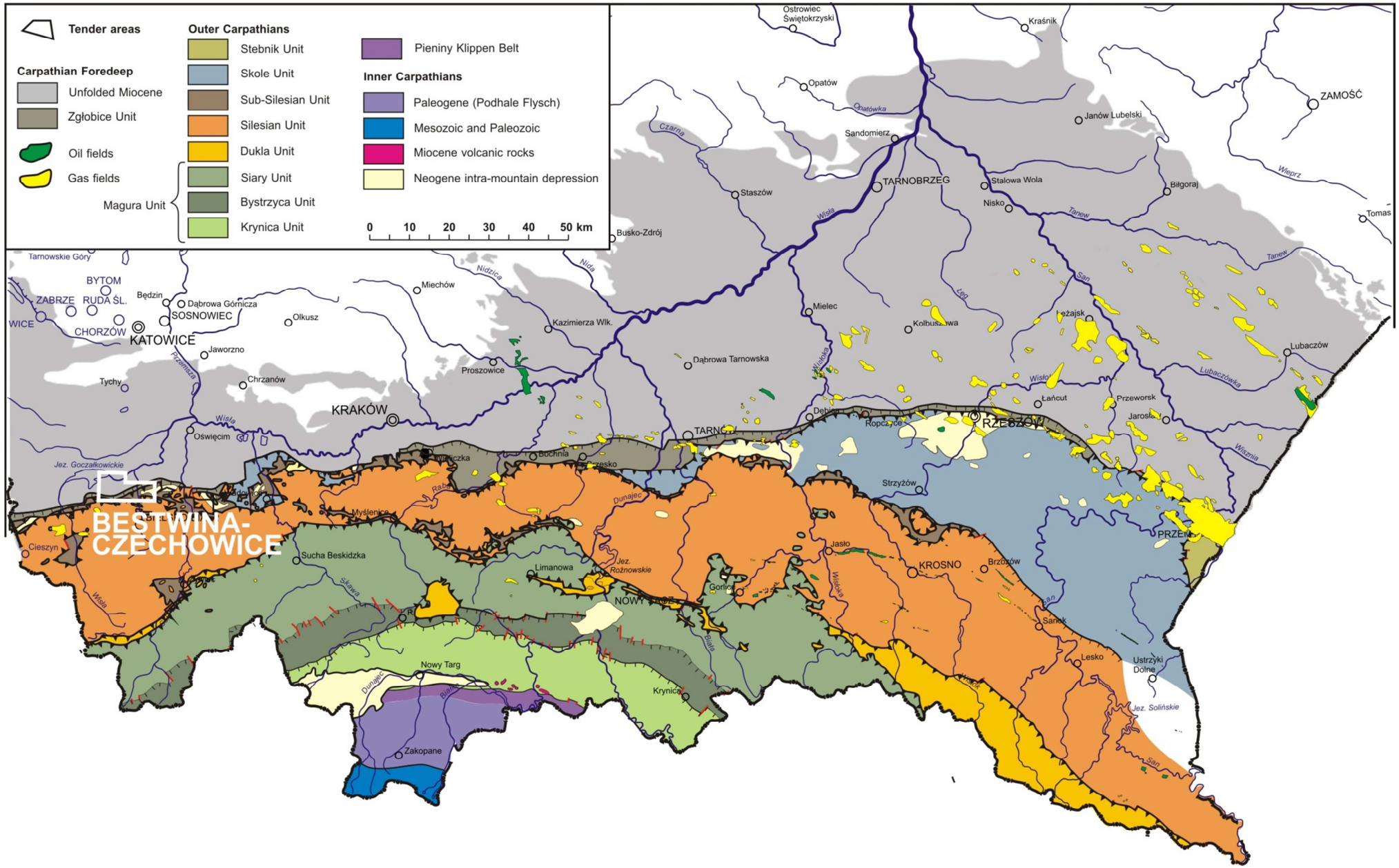


Fig. 2. Location of the Bestwina-Czechowice tender area on the structural-geological map of the Polish Outer Carpathians (after Poprawa et al., 2010, and citations therein; modified).

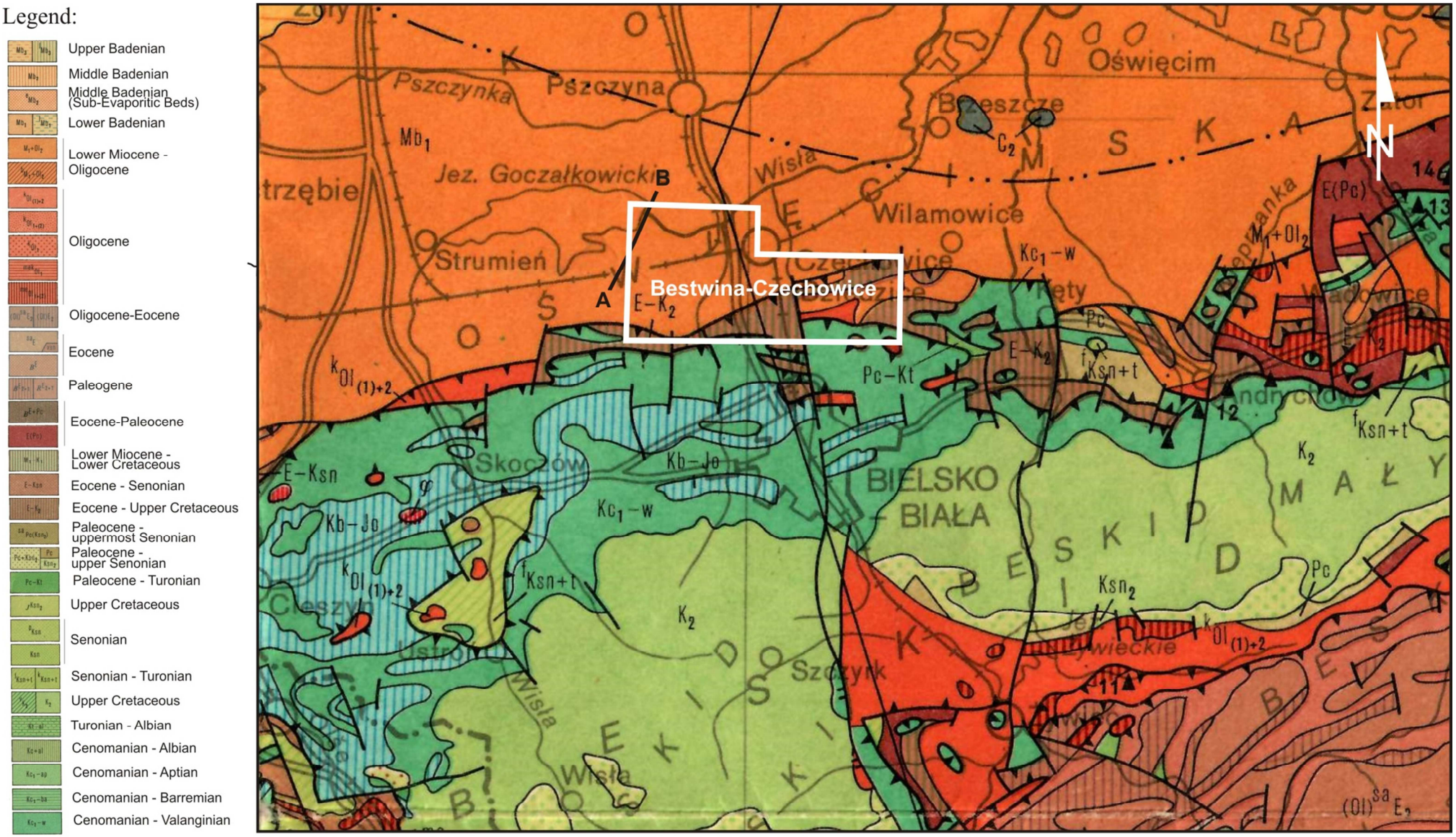


Fig. 3. Location of the Bestwina-Czechowice tender area on the geological map of the Outer Carpathians (Żytko et al., 1989; modified).

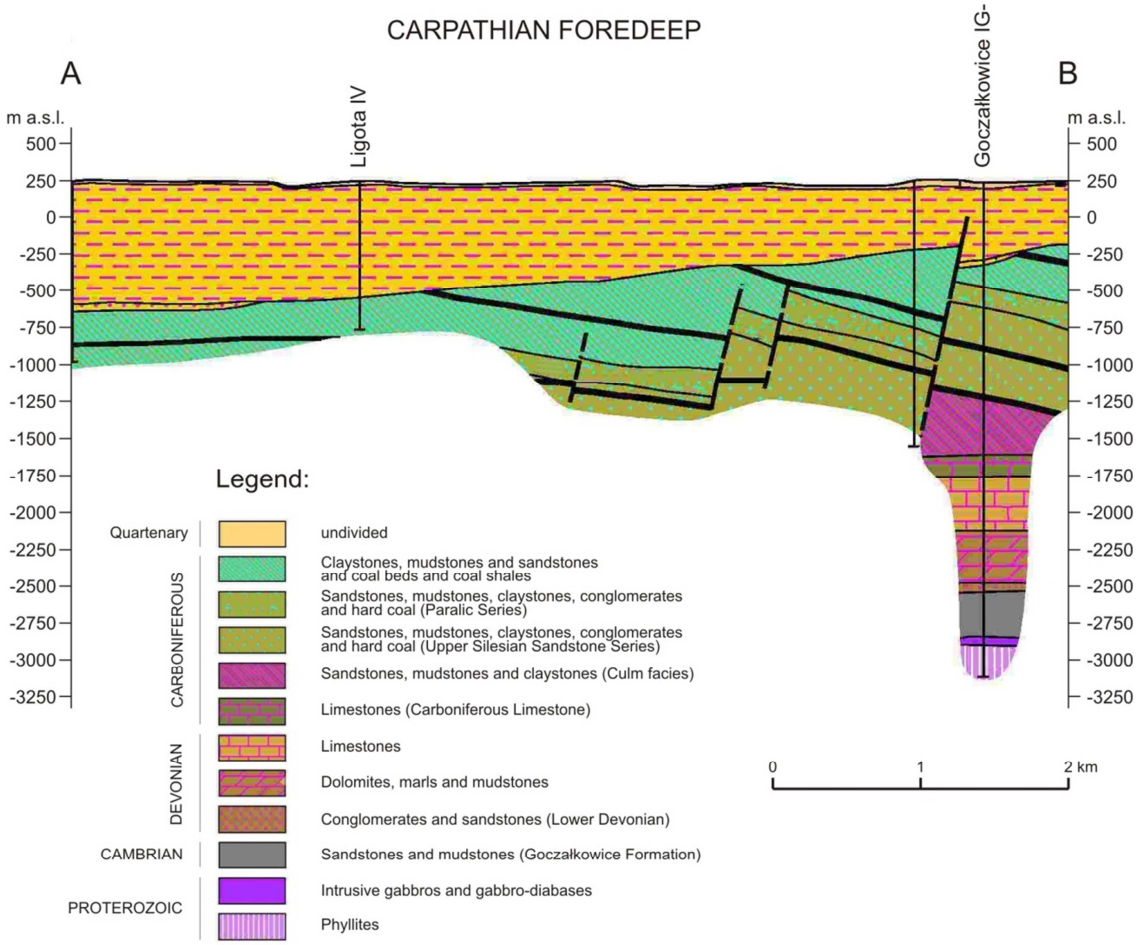


Fig. 4. Geological cross-section A–B through the Carpathian Foredeep – western part of the Bestwina-Czechowice tender area (Wójcik and Nescieruk, 2000; modified). See Fig. 3 for location.

2.3. STRATIGRAPHY AND LITHOLOGY

Precambrian

Lithology: gneisses, mica schists, granites, gabbros.
Wells and depth: Bielsko 5 (1673.0–1700.7 m),
Kęty 7 (1650.0–1756.0 m).
References: Konior and Tokarski, 1959; Heflik and Konior, 1965, 1967, 1974; Wieser, 1975; Żytko, 1978; Moryc and Heflik, 1998; Żelaźniewicz and Żaba, 2001; Żelaźniewicz et al., 2002, 2004.

Cambrian

Lithostratigraphy: Goczałkowice Formation divided into the Mogilany Skolithos Sandstone Member in the lower part and Głogoczów Bioturbated Sandstone Member in the upper part.
Lithology: fine-grained conglomerates and varigrained sandstones of the Mogilany Member; fine- and medium-grained quartz and greywackic sandstones laminated with siltstones of the Głogoczów Member.
Wells and depth: Bielsko 5 (1518.0–1673.0 m),
Goczałkowice IG-1 (2957.0–3129.2 m),
Kęty 7 (1495.0–1650.0 m).
Thickness (according to wells): 155.0 m.
References: Ślączka, 1976a, b, 1982; Kotas 1982a, b; Jachowicz and Moryc, 1995; Buła and Jachowicz, 1996; Buła, 2000; Pacześna, 2005; Buła and Habryn, 2010; Jachowicz-Zdanowska, 2010, 2014.

Lower Devonian

Lithostratigraphy: Andrychów Gritstones, Sandstones and Mudstones Formation.
Lithology: sandstones with intercalations of mudstones, claystones and conglomerates.
Wells and depth: Bielsko 5 (1482.0–1518.0 m),
Goczałkowice IG-1 (2722.8–2765.5 m),
Kęty 7 (1460.0–1495.0 m).
Thickness (according to wells): 36.0 m.
References: Buła, 2000; Buła and Żaba, 2005; Narkiewicz, 2005; Buła and Habryn, 2010.

Devonian–Carboniferous carbonate complex (Fig. 5)

Lithology: dolomites and limestones.
Wells and depth: Bestwina IG-1 (1513.6–1572.6 m),
Bielsko 5 (1022.0–1482.0 m),
Bielsko 3 (985.0–1098.0 m),
Bielsko 2 (1117.0–1362.2 m),
Goczałkowice IG-1 (1898.5–2722.8 m),
Kęty 7 (996.0–1460.0 m).
Thickness (according to wells): >59.0–460.0 m.
References: Kotas, 1982a, 1995; Narkiewicz, 2005; Buła and Habryn, 2008.

Carboniferous clastic complex (Culm facies; Fig. 6)

Lithology: mudstones and claystones with intercalations of fine-grained sandstones and marly limestones.
Wells and depth: Bestwina IG-1 (1245.5–1513.6 m),
Czechowice IG-1 (1409.2–1511.0 m).
Thickness (according to wells): 101,8–268.1 m.
References: Kotas, 1982a; Jureczka and Kotas, 1995a; Buła, 2000, 2001; Buła and Krieger, 2004.

Carboniferous coal-bearing succession (Fig. 7)

Lithostratigraphy: Paralic Series, Upper Silesian Sandstone Series and Mudstone Series.
Lithology: mudstones and claystones with intercalations of fine-grained sandstones and marly limestones.
Wells and depth: Bestwina IG-1 (775.5–1245.5 m),
Bielsko 1 (859.5–1203.0 m),
Bielsko 2 (793.5–1117.0 m),
Bielsko 5 (1000.0–1022.0 m),
Brożyska 1 (1008.0–1208.5 m),
Czechowice IG-1 (684.3–1409.2 m),
Czechowice R-1 (720.0–1109.0 m).
Thickness (according to wells): 22.0–470.0 m.
References: Buła, 2000; Buła and Żaba, 2005; Jureczka and Kotas, 1995a, b.

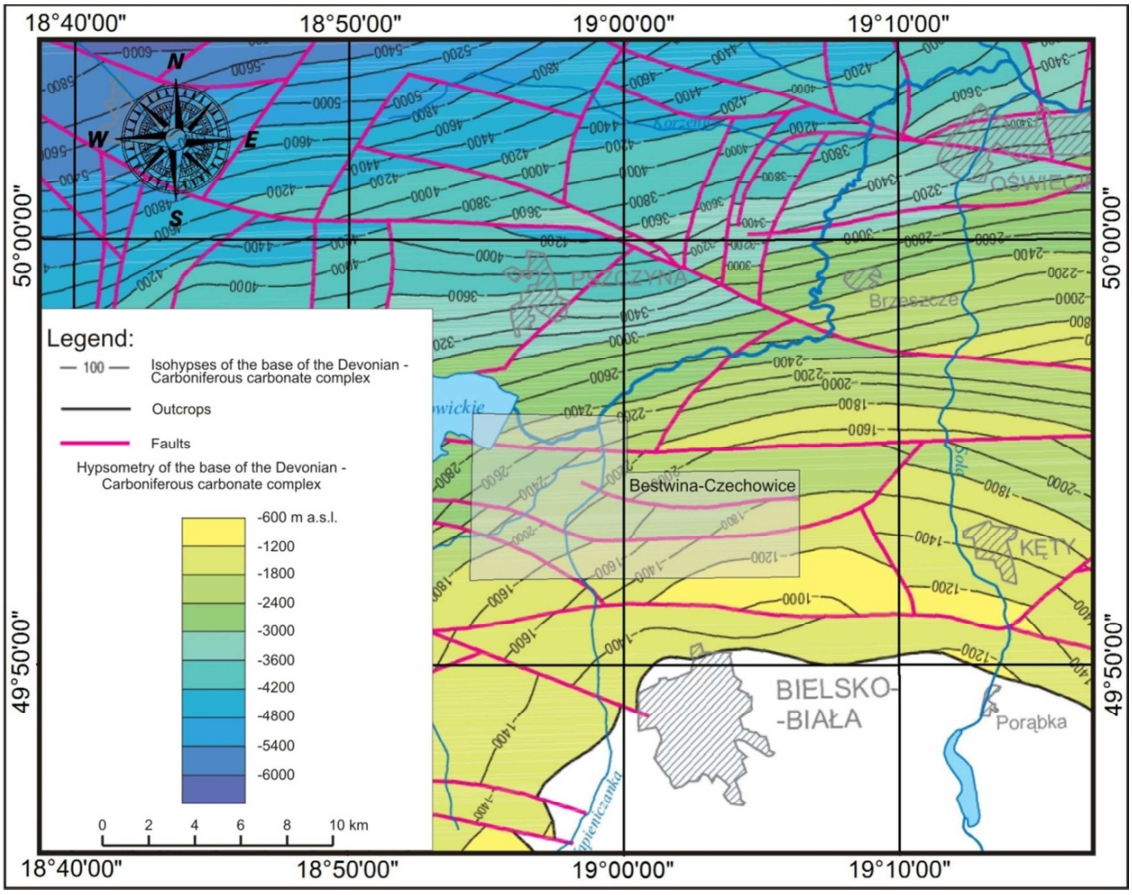


Fig. 5. Location of the Bestwina-Czechowice tender area on the structural map of the base of the Devonian–Carboniferous carbonate complex in the Upper Silesian and Małopolska Blocks (Buła and Habryn, 2008; modified).

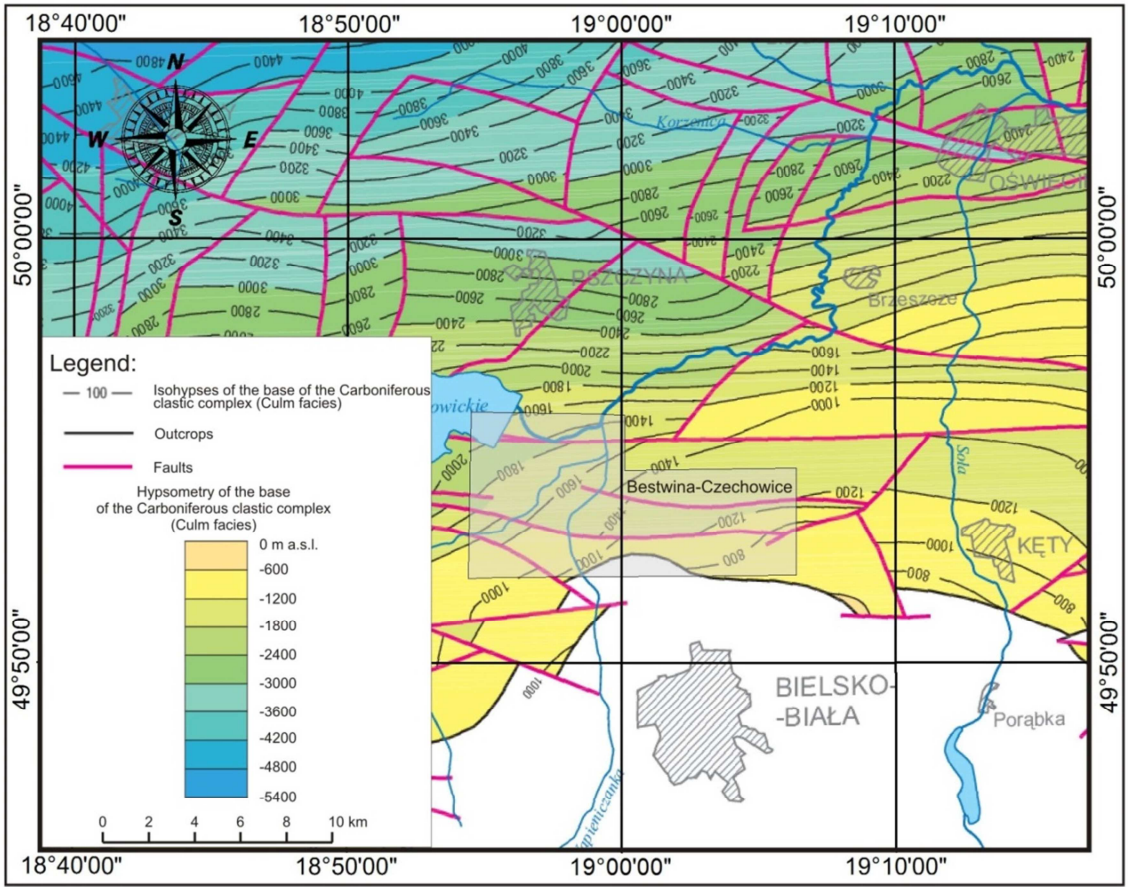


Fig. 6. Location of the Bestwina-Czechowice tender area on the structural map of the base of the Carboniferous clastic complex (Culm facies) in the Upper Silesian and Małopolska Blocks (Buła and Habryn, 2008; modified).

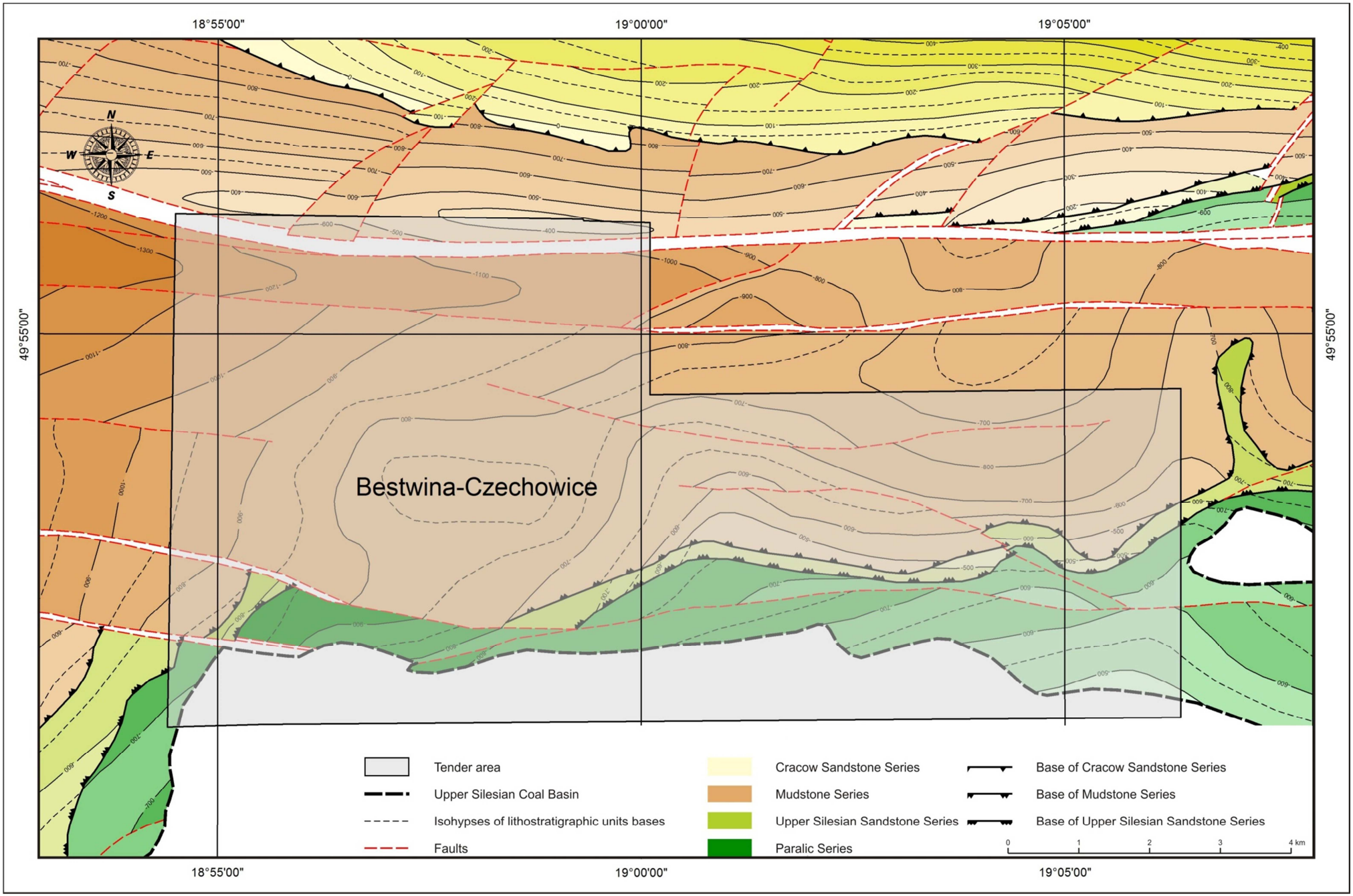


Fig. 7. Location of the Bestwina-Czechowice tender area on the geological-structural map of the Carboniferous coal-bearing succession (Jureczka et al., 2002; modified).

Miocene of the Carpathian Foredeep (Fig. 8)

Lithostratigraphy: Kłodnica Beds, Dębowiec Beds, Skawina Beds.
Lithology: sandy claystones with intercalations of marls and marly limestones in the Kłodnica Beds; conglomerates in the Dębowiec Beds; mudstones and claystones with intercalations of sandstones in the Skawina Beds.
Wells and depth: Bestwina IG-1 (3.0–775.5 m),
Bestwina III (0.0–695.0 m),
Bielsko 2 (410.0–793.5 m),
Bielsko 5 (300.0–1000.0 m),
Bronów I (10.5–930.2 m),
Brożyska 1 (306.0–1008.0 m),
Czechowice C (19.7–631.4 m),
Czechowice E (12.65–680.0 m),
Czechowice IG-1 (32.0–684.3 m),
Czechowice R-1 (78.0–720.0 m),
Czechowice-Dziedzice 1 (28.4–625.4 m),
Czechowice-Dziedzice 3 (22.6–674.7 m),
Dziedzice B (53.5–729.3 m),
Ligota 1 (35.0–853.0 m),
Ligota A (28.8–868.2 m),
Ligota D (11.5–659.0 m),
Ligota II (14.5–732.3 m),
Ligota III (15.2–733.0 m),
Ligota IV (26.7–795.0 m),
Ligota V (18.8–865.4 m),
Zagrzeb 1 (35.0–807.6 m).
Thickness (according to wells): 383.5–919.7 m.
References; Alexandrowicz and Pawlikowski, 1978; Buła and Jura, 1983; Oszczypko, 2001.

Sub-Silesian Unit of the Carpathians

Lithostratigraphy: Upper Cretaceous – Paleocene Istebna Beds, Eocene Variegated Marls and Shales, Lower Origocene Menilite Beds.
Lithology: flysch sediments including variegated marls and shales, bituminous shales and hornfelses.
Wells and depth: Bielsko 2 (20.0–410.0 m),
Czechowice R-1 (0.0–78.0 m),
Brożyska 1 (11.5–306.0 m),
Bielsko 5 (70.0–300.0 m).
Thickness (according to wells): 78.0–390.0 m.
References: Alexandrowicz, 1959; Golonka, 1981; Golonka and Waśkowska-Oliwa, 2007; Nescieruk and Wójcik, 2016.

Silesian Unit of the Carpathians (Fig. 9)

Lithostratigraphy: Upper Jurassic–Berriasian Cieszyn Limestones; Valanginian–Hauterivian Upper Cieszyn Shales; Hauterivian–Barremian Grodziszcze Beds.
Lithology: flysch sediments including limestones, marly shales and sandstones.
Wells and depth: Bielsko 5 (20.0–70.0 m).
Thickness (according to wells): 50.0 m.
References: Książkiewicz, 1977; Golonka, 1981; Słomka et al., 2006.

Quaternary

Lithology: gravels, sands, clays, tills.
Thickness: 0–78.0 m.

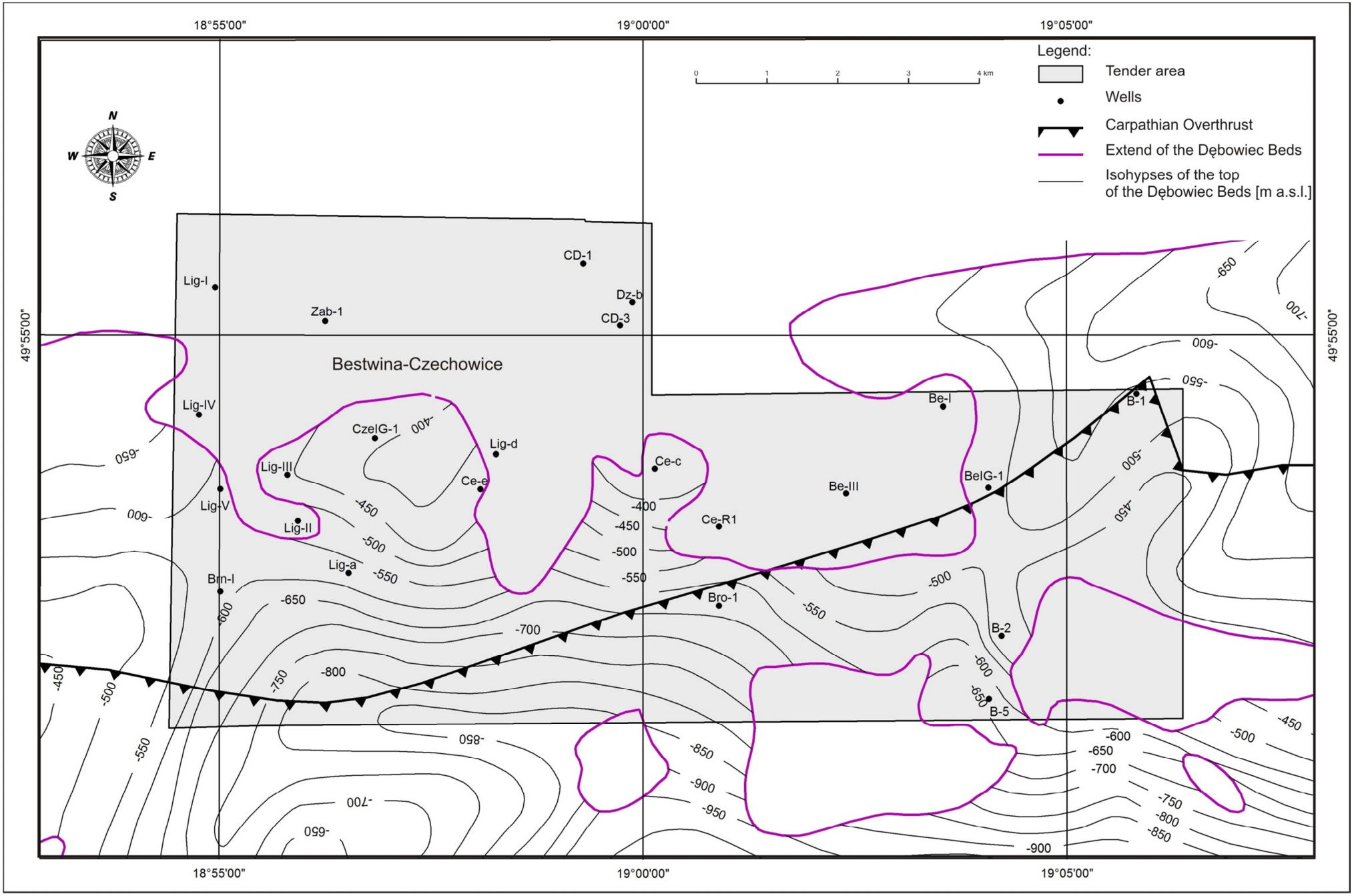


Fig. 8. Location of the Bestwina-Czechowice tender area on the structural map of the top surface of the Dębowiec Beds (Jureczka et al., 2002; modified).

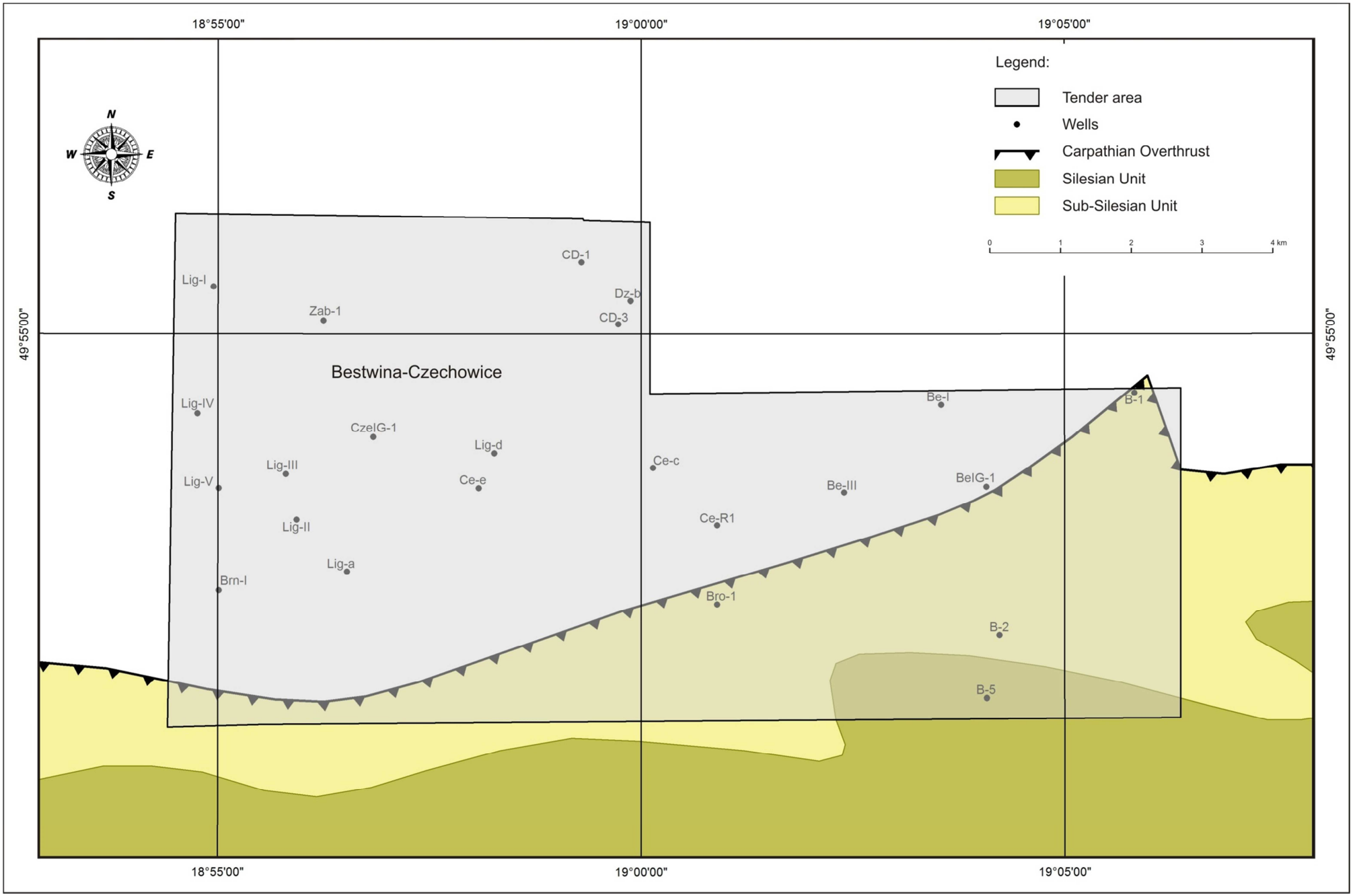


Fig. 9. Location of the Bestwina-Czechowice tender area on the tectonic map of the Polish Outer Carpathians (Golonka, 2007; modified).

3. PETROLEUM SYSTEMS

Three conventional petroleum systems are developed in the Bestwina-Czechowice tender area, in the:

- Carpathians,
- autochtonous Miocene of the Carpathian Foredeep,
- Paleozoic basemen of the Carpathian units.

They are separated by two unconformities – Carpathian Overthrust (tectonic unconformity) and sub-Miocene discordance. Both unconformities do not separate the petroleum systems each other: a migration/remigration of hydrocarbons generated in one system to the other cannot be excluded.

Petroleum system in the Carpathians

The Sub-Silesian and Silesian units of the Carpathians occur only in the southern part of the tender area. Only remains of the petroleum system occur therein. Therefore, the system cannot be treated as important exploration target in the Bestwina-Czechowice tender area.

Petroleum system in the autochtonous Miocene of the Carpathian Foredeep

Source rocks: Skawina Beds.

Reservoir rocks I: conglomerates of the Dębowiec Beds.
- Porosity: 7.73–24.05%.
- Permeability: 0.1–0.165 mD.
- Wells (source data): Bestwina IG-1, Czechowice IG-1, Bielsko 2.

Reservoir rocks II: sandstones, sands and mudstones of the Skawina Beds.
- Porosity: 4.96–39.28%.
- Permeability: 0.2-3.5 mD.
- Wells (source data): Bestwina IG-1, Bielsko 2.

Seal rocks: claystones of the Skawina Beds, fine-grained flysch sediments of the Carpathian Sub-Silesian and Silesian units.

Thickness of the overburden: 0–733 m b.g.l.

Traps: structural (compaction anticlines developed over elevations of the Paleozoic basement, compression anticlines developed below the Carpathian Overthrust), stratigraphic (related to narrowing of sandstone layers and to intra-Miocene unconformities). The traps developed in the Miocene of the Carpathian Foredeep have multi-horizontal character.

Hydrocarbon fields: Dębowiec Śląski, Kowale, Pogórz.

References: Kotarba, 1992, 1998, 2011; Kotarba and Jawor, 1993; Kotarba et al., 1998, 2005, 2011a, b; Myśliwiec, 2004a, 2004b; Myśliwiec et al., 2006; Kotarba and Koltun, 2006; Kotarba and Pluta, 2009; Kotarba, 2011; Kotarba and Peryt, 2011; Więcław, 2011.

Petroleum system in the Paleozoic basement of the Carpathian units

Source rocks I: Carboniferous clastic complex (Culm facies).
- TOC = 1.44%
- T_{max} = 444°C
- R_o= 0.77–0.88%
- Kerogen type: III.
- Wells (source data): Bestwina IG-1.

Source rocks II: Carboniferous coal-bearing succession – Paralic Series.
- TOC = 3.2%.
- T_{max} = 429°C.
- R_o = 0.76–0.85%.
- Kerogen type: III (III/II).
- Wells (source data): Bestwina IG-1.

Source rocks III: Carboniferous coal-bearing succession – Upper Silesian Sandstone Series and Mudstone Series.
- TOC = 6.5%.
- T_{max} = 425–433°C.
- R_o = 0.67–0.78%.
- Kerogen type: III.
- Wells (source data): Bestwina IG-1.

Reservoir rocks I: Lower Devonian sandstones.
- Porosity: 1.02–15.25%.
- Permeability: 0 mD.
- Wells (source data): Bielsko 5.

Reservoir rocks II: Devonian–Carboniferous carbonate complex.
- Porosity: 0.0–31.37%.
- Permeability: 0.0–45.0 mD.
- Wells (source data): Bestwina IG-1, Bielsko 2, Bielsko 5.

Reservoir rocks III: sandstones of the Carboniferous coal-bearing succession – Paralic Series.
- Porosity: 0.0–17.55%.
- Permeability: 0.1–13.3 mD.
- Wells (source data): Bestwina IG-1, Bielsko 2, Czechowice IG-1.

Reservoir rocks IV: sandstones of the Carboniferous coal-bearing succession – Upper Silesian Sandstone Series.
- Porosity: 4.6–17.54%.
- Permeability: 0.1–24.0 mD.
- Wells (source data): Bestwina IG-1, Czech. IG-1.

Reservoir rocks V: sandstones of the Carboniferous coal-bearing succession – Mudstone Series.
- Porosity: 1.48–26.75%.
- Permeability: 0.1–460.0 mD.
- Wells (source data): Bestwina IG-1, Czech. IG-1.

Reservoir rocks VI: Carboniferous coal beds.

Seal rocks: fine-grained sediments of the Carboniferous coal-bearing succession and autochtonous Miocene of the Carpathian Foredeep.

Thickness of the overburden: 684–1048 m b.g.l.

Traps: structural, stratigraphic.

Hydrocarbon fields: Marklowice CBM.

References: Kotarba et al., 2004a, 2004b, 2004c; Kotarba and Pluta, 2009; Buła and Habryn, 2010.

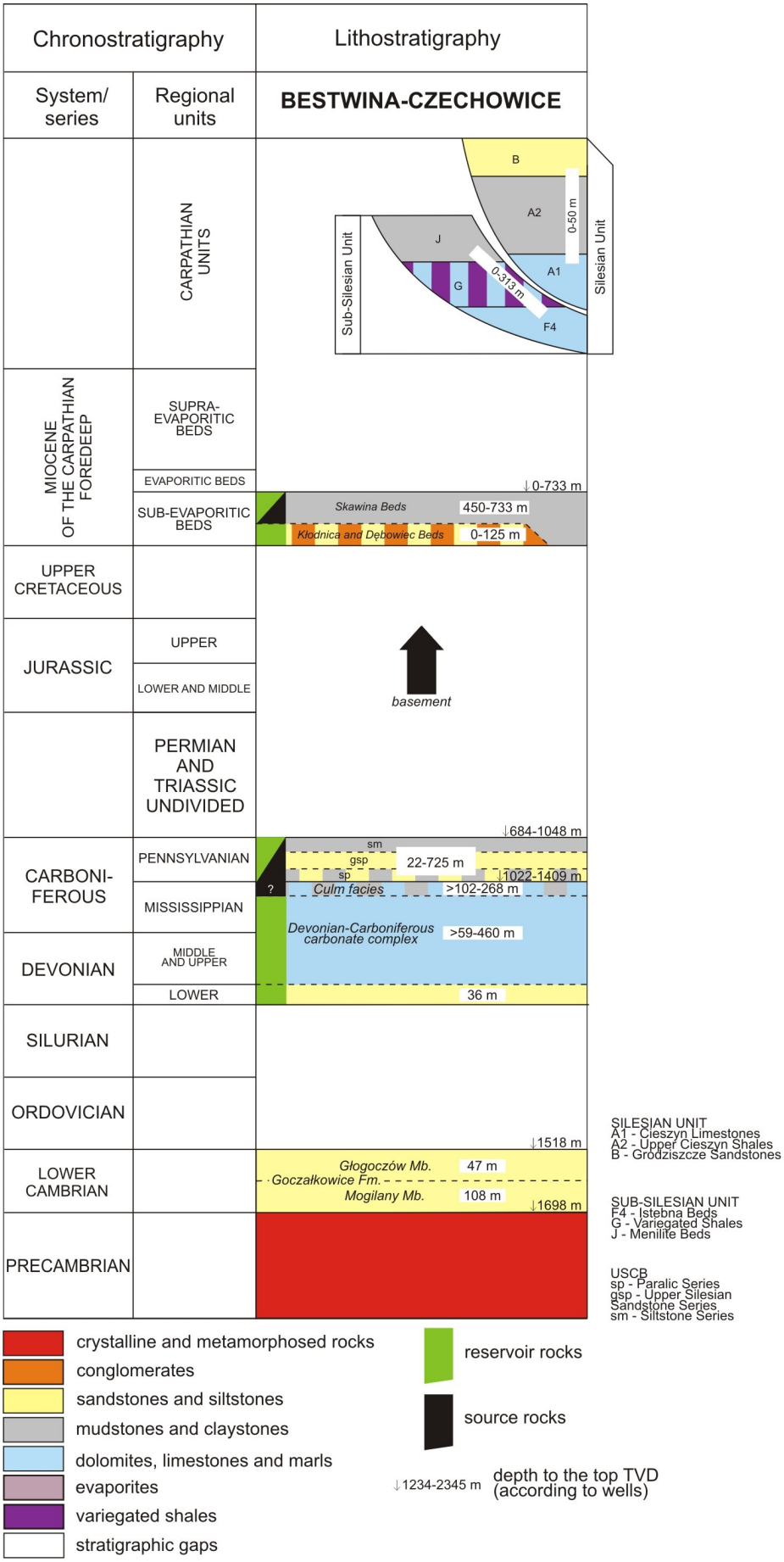


Fig. 10. Stratigraphy, lithology and major elements of petroleum systems (main horizons of source and reservoir rocks) in the Bestwina-Czechowice tender area. (Jagielski et al., 2019; modified).

4. HYDROCARBON FIELDS

Three gas fields have been discovered in the south-western vicinity of the Bestwina-Czechowice tender area. These are (Fig. 11):

- Kowale gas field (GZ 13971),
- Pogórz gas field (GZ 1295),
- Dębowiec Śląski gas field (GZ 1296).

All of them are still exploited.

Concession for prospection, exploration and exploitation of hydrocarbons from a deposit in Poland 2018

BESTWINA-CZECHOWICE TENDER AREA

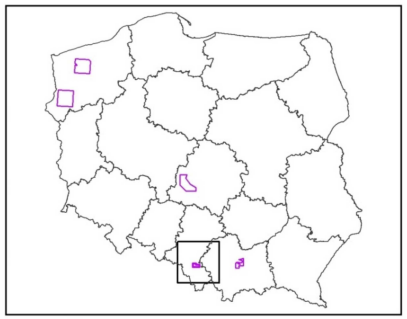
0 1 2 4 6 8 10 km

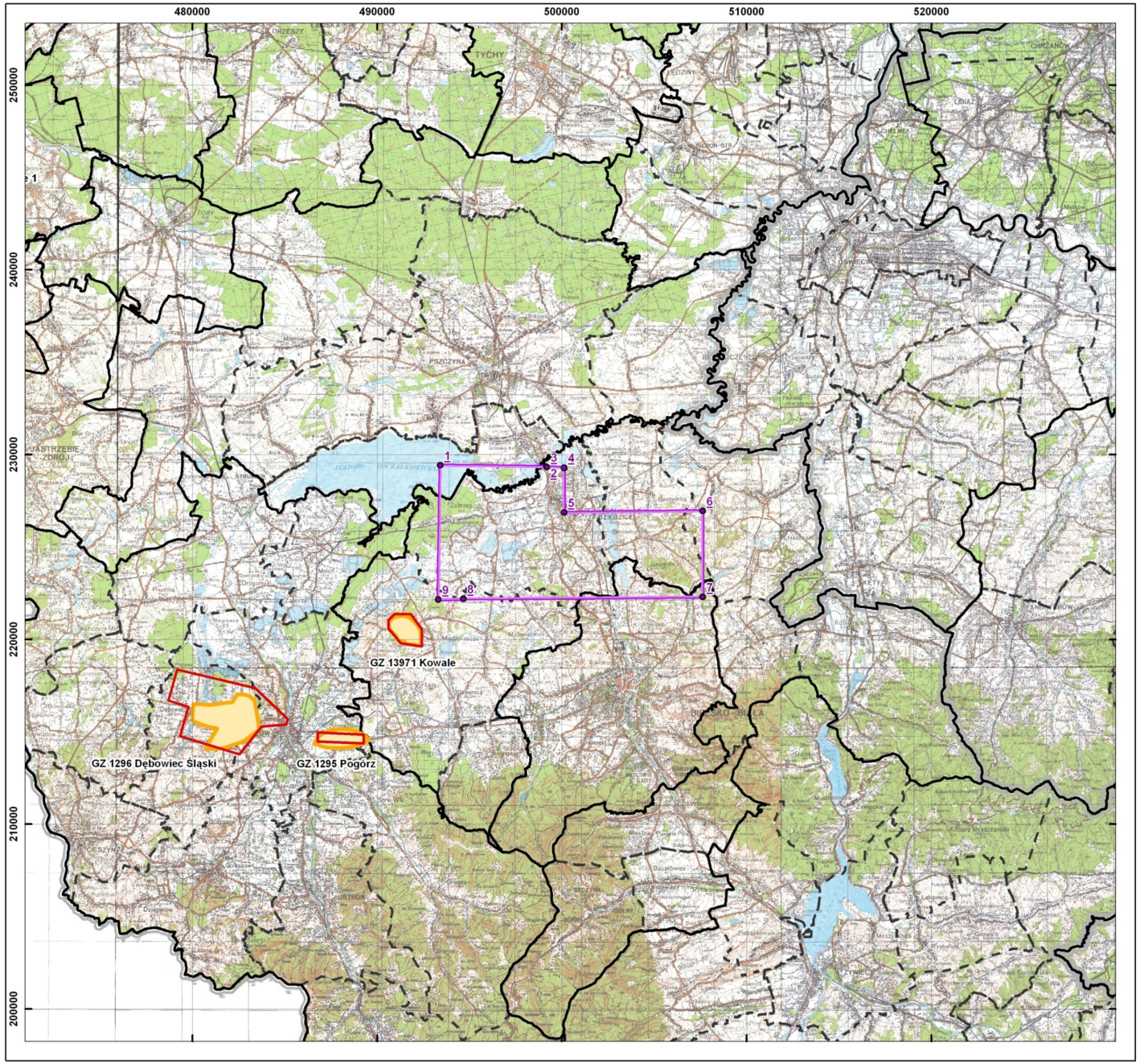
Legend

- tender area
- oil and gas fields
- mining areas
- communes
- counties
- voivodeships

Border points
coordinate system - PL 1992

Point no.	X	Y
1	229422.37	493418.39
2	229341.87	499174.04
3	229313.02	499187.43
4	229289.57	500124.17
5	226858.38	500124.08
6	226943.36	507622.42
7	222293.28	507622.86
8	222190.12	494662.22
9	222153.81	493303.33





The source of data:
System of management and protection of mineral resources in Poland - MIDAS

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Fig. 11. Gas fields in the neighborhood of the Bestwina-Czechowice tender area.

Dębowiec Śląski gas field

Acreage: 690.92 ha
Depth: from 380.0–534.0 m b.g.l.
Stratigraphy: Miocene (Skawina Formation).
Resources:

- Extractable balance resources as of 2017: 31.23 million m^3 of natural gas in cat. A,
- Economic resources in place as of 2017: 1.69 million m^3 of natural gas,
- Production in 2017: 1.56 million m^3 of natural gas.

Parameter	Average value	Unit	Comment
actual pressure	0.39	MPa	II horizon
actual pressure	1.38	MPa	III horizon
initial reservoir pressure	3.07	MPa	II horizon
initial reservoir pressure	4.33	MPa	III horizon
porosity	8.93	%	–
permeability	23.30	mD	–
total efficiency V_{tot}	9.00	Nm^3/min	II horizon
total efficiency V_{tot}	9.60	Nm^3/min	III horizon
maximum efficiency V_{max}	3.00	Nm^3/min	II horizon
maximum efficiency V_{max}	2.82	Nm^3/min	III horizon

Tab. 3. Quality parameters of the Dębowiec Śląski natural gas field (MIDAS, 2019 according to Socha, 2014).

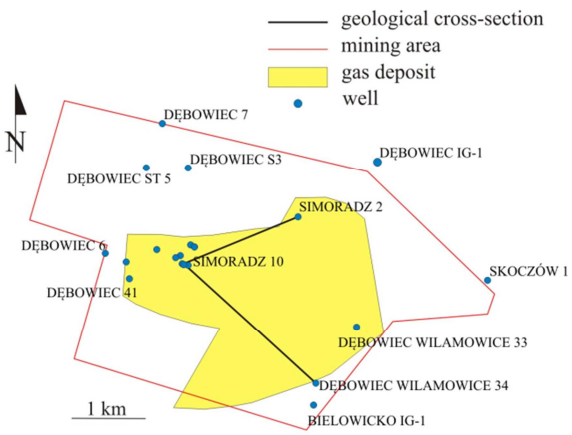
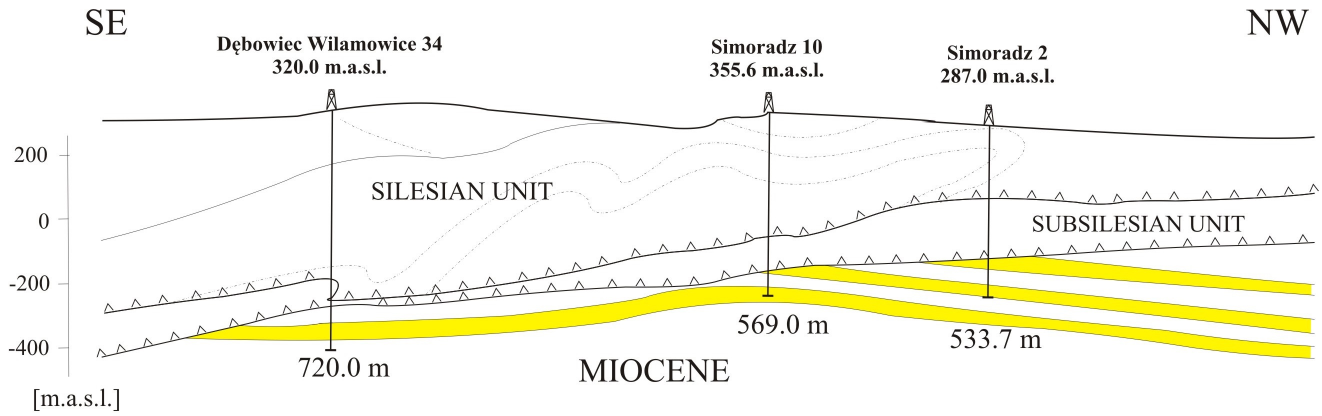
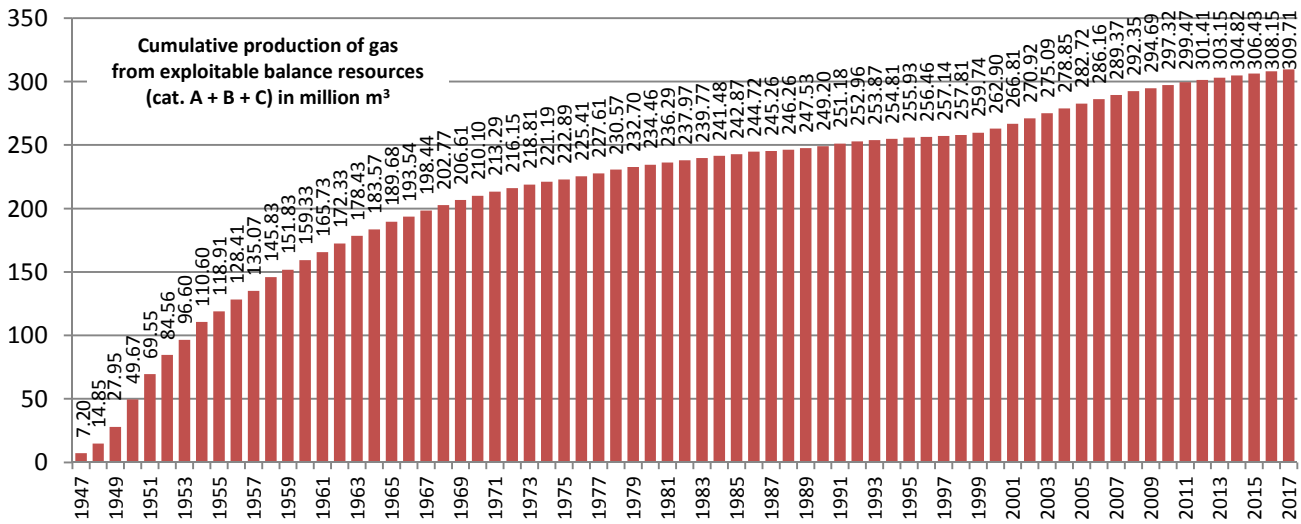


Fig. 12. Map and geological cross section through the Dębowiec Śląski gas field (CBDG, 2019; Florek, 2002).





Kowale gas field

Acreage: 209.00 ha.
Depth: 382.5–446.0 m b.g.l.
Stratigraphy: Miocene (Skawina Formation).
Resources:

- Extractable balance resources as of 2017: 82.75 million m^3 of natural gas in cat. C,
- Economic resources in place as of 2017: 26.66 million m^3 of natural gas,
- Production in 2017: 1.79 million m^3 of natural gas.

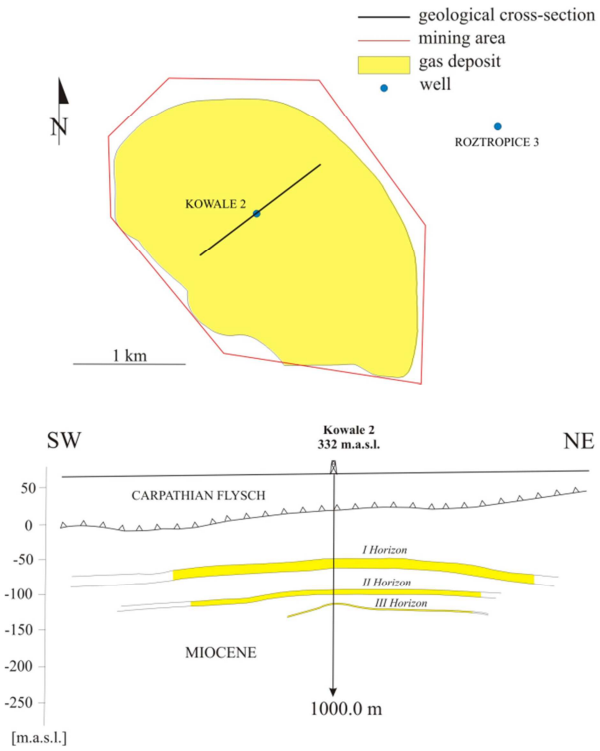
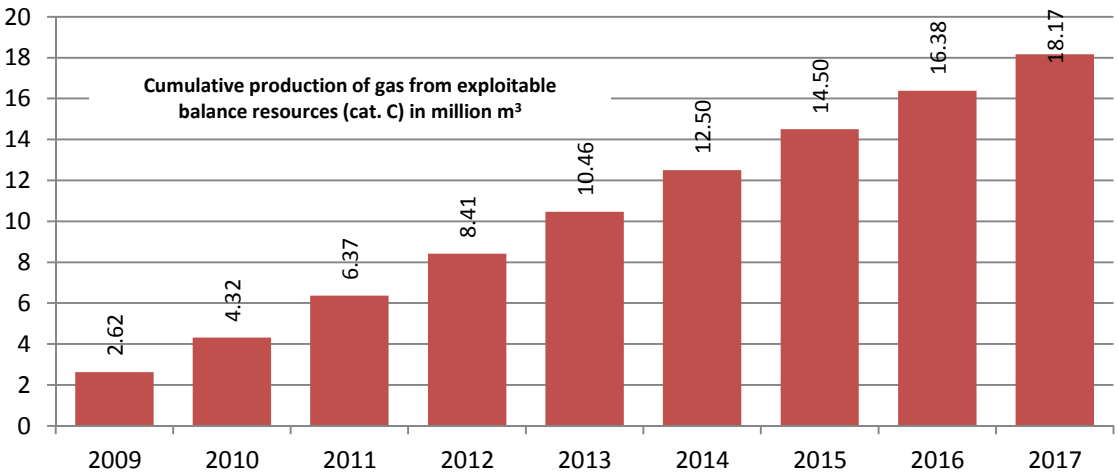


Fig. 13. Map and geological cross section through the Kowale gas field (CBDG, 2019; Polakowski, 2009).

Parameter	Average value	Unit	Comment
formation pressure	3.180	MPa	I horizon
formation pressure	3.320	MPa	II horizon
formation pressure	3.390	MPa	III horizon
net pay	13.00	m	I horizon
net pay	4.00	m	II horizon
net pay	1.50	m	III horizon
bed volume	25 650 000	m^3	I horizon, total volume
bed volume	11 480 000	m^3	II horizon, total volume
bed volume	600 000	m^3	III horizon, total volume
bed volume	24 701 000	m^3	I horizon, effective volume
bed volume	6 544 000	m^3	II horizon, effective volume
bed volume	600 000	m^3	III horizon, effective volume
effective porosity	17.00	%	I horizon
effective porosity	10.00	%	II horizon
effective porosity	20.00	%	III horizon
deposit surface	1.90	km^2	I horizon
deposit surface	1.64	km^2	II horizon
deposit surface	0.40	km^2	III horizon
permeability	36.30	mD	I horizon
permeability	5.14	mD	II horizon
permeability	100.00	mD	III horizon
total efficiency V_{tot}	35.00	Nm^3/min	I horizon
total efficiency V_{tot}	8.00	Nm^3/min	horizon II and III tested jointly
maximum efficiency V_{max}	5.00	Nm^3/min	I horizon
maximum efficiency V_{max}	0.80	Nm^3/min	value accepted jointly for horizon II and III

Tab. 4. Quality parameters of the Kowale natural gas field (MIDAS, 2019 according to Polakowski, 2009).



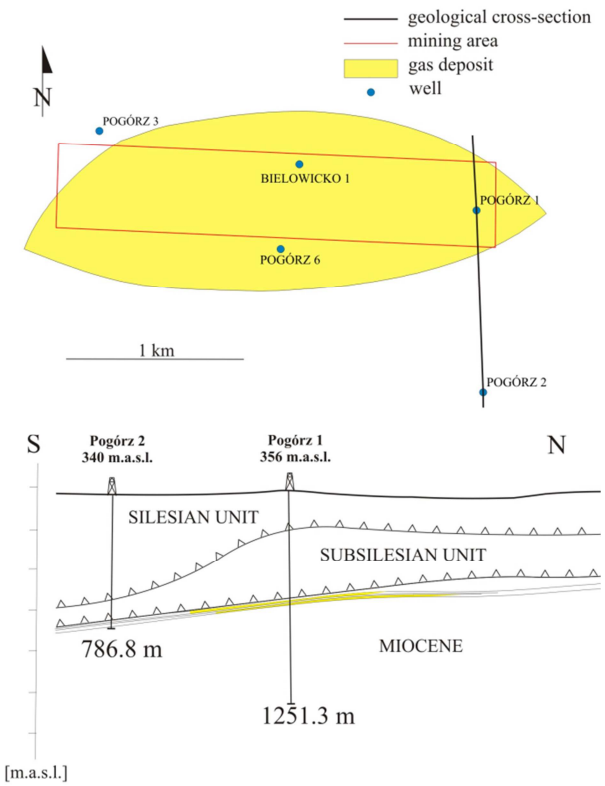
Pogórz gas field

Depth: from 540.0–705.0 m b.g.l.
Stratigraphy: Miocene (Skawina Formation).
Resources:

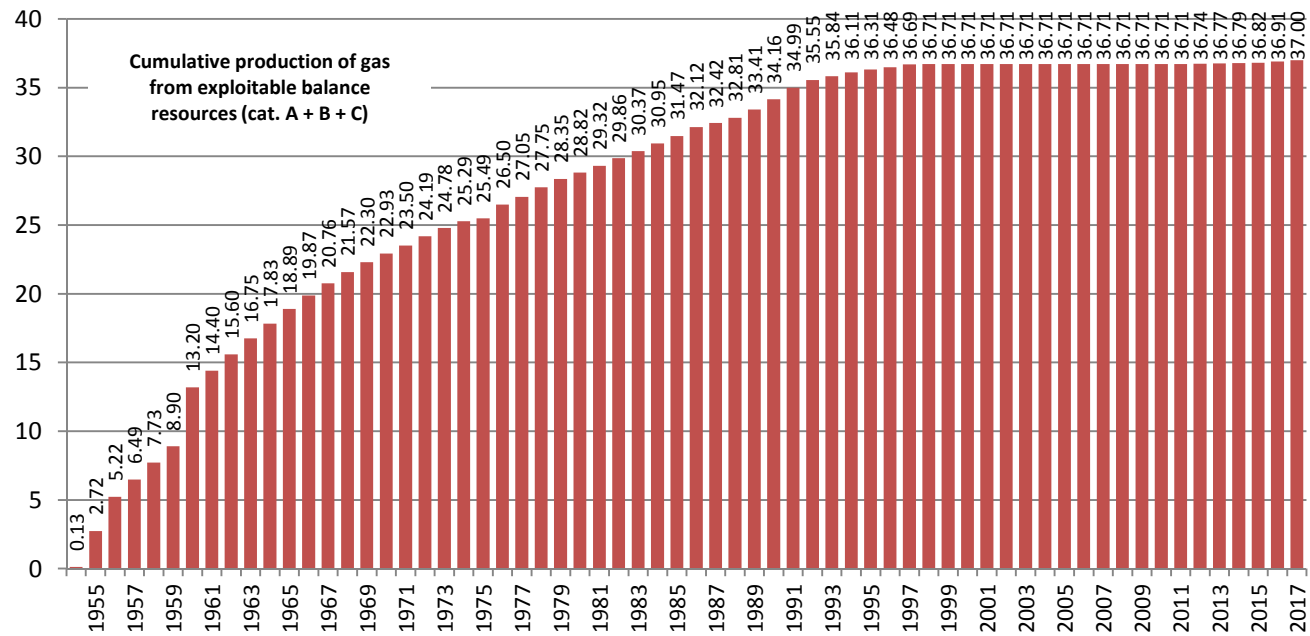
- Extractable balance resources as of 2017: 11.91 million m^3 of natural gas in cat. A+B,
- Economic resources in place as of 2017: 11.83 million m^3 of natural gas,
- Production in 2017: 0.09 million m^3 of natural gas.

Parameter	Average value	Unit	Comment
actual pressure	2.63	MPa	–
actual pressure	3.94	MPa	I horizon
actual pressure	4.04	MPa	II horizon
aquifer depth	350.00	m	–
net pay	1.4–3.0	m	I horizon
net pay	1.8–3.4	m	II horizon
porosity	12.50	%	I horizon
porosity	15.0	%	II horizon
deposit surface	5.37	km^2	I horizon
deposit surface	6.62	km^2	II horizon
permeability	15.00	mD	–
production index	0.80	–	exploitation up to pressure 0.2 MPa
production index	0.70	–	exploitation up to pressure 1.2 MPa

Tab. 5. Quality parameters of the Pogórz natural gas field (MIDAS, 2019 according to Zacharski, 2002).



←Fig. 14. Map and geological cross section through the Pogórz gas field (CBDG, 2019; Zacharski, 2002).



5. WELLS

Twenty-one deep wells (> 500 m TVD) reached the prospective intervals within the Bestwina-Czechowice tender area (Fig. 15), but only for six of them are included in CBDG database (CBDG, 2019). These are: Bestwina IG-1, Bielsko 2, Bielsko 5, Brożyska 1, Czechowice R-1 and Czechowice IG-1.

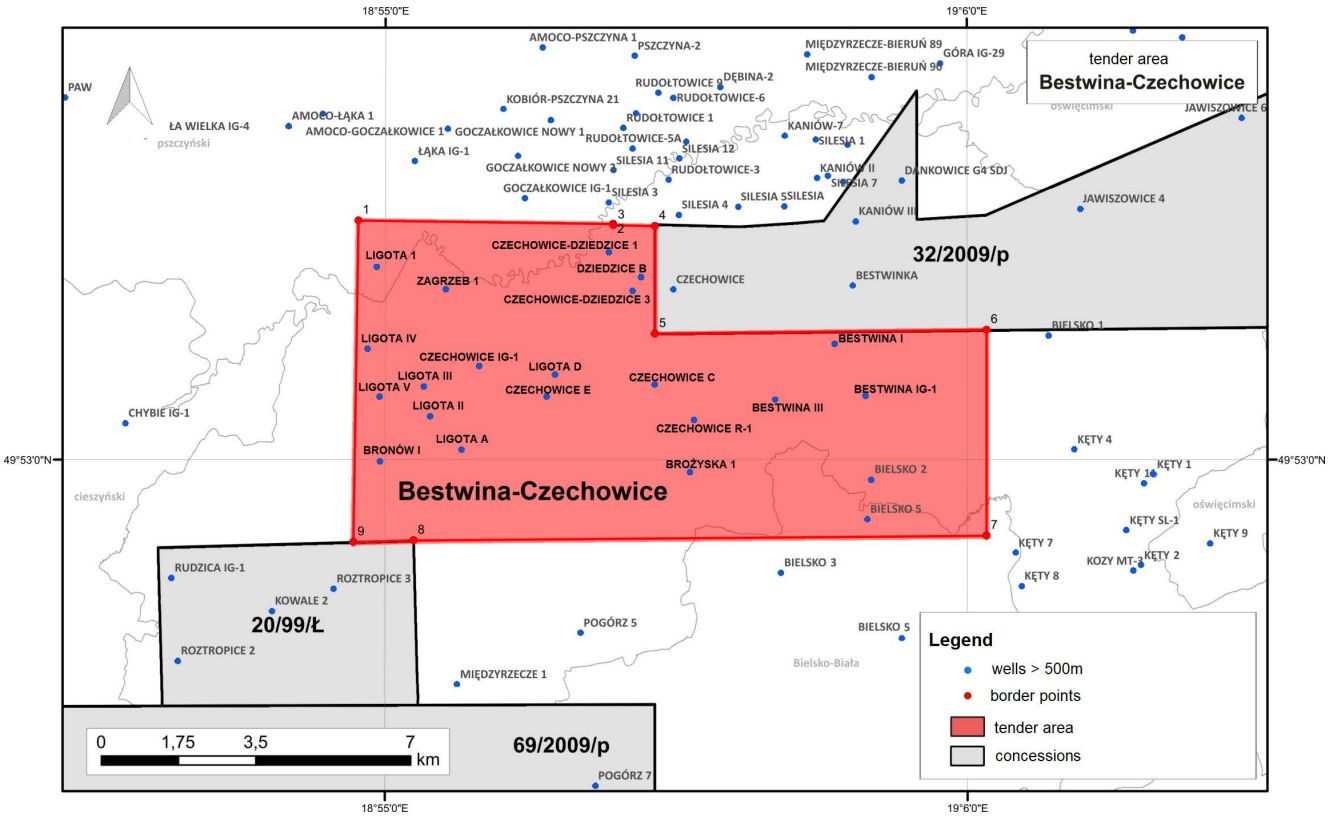


Fig. 15. Deep wells (> 500 m TVD) reaching the prospective horizons in the Bestwina-Czechowice tender area and in its close surroundings.

	BESTWINA IG-1				BIELSKO 2				BIELSKO 5				BROŻYSKA 1		CZECHOWICE R-1		CZECHOWICE IG-1			
	top	bottom	Porosity min–max [%]	Permeability min–max [mD]	top	bottom	Porosity min–max [%]	Permeability min–max [mD]	top	bottom	Porosity min–max [%]	Permeability min–max [mD]	top	bottom	top	bottom	top	bottom	Porosity min–max [%]	Permeability min–max [mD]
Quaternary	0.00	3.00			0.00	20.00			0.00	20.00			0.00	11.50			0.00	32.00		
Subsilesian Nappe					20.00	410.00			20.00	300.00	0.36		11.5	306.00	0.00	78.00				
Autochtonous Miocene	3.00	775.50			410.00	793.50			300.00	1000.00	3.71–16.93	0.0–10.35	306.00	1008.00	78.00	720.00	32.00	684.30		
Skawina Beds	*3.00*	*736.40*	*9.77–39.28*	*0.2–0.82*	*410.00*	*783.00*	*4.96–20.8*	*3.5*	*300.00*	*934.00*										
Dębowiec Beds	*736.40*	*775.50*	*22.31–24.05*		*783.00*	*793.50*			*934.00*	*1000.00*									*7.73–21.13*	*0.1–0.165*
Kłodnica Beds																				
Carboniferous	775.50	1546.90			793.50	1184.00			1000.00	1022.00	0.21–1.10		1008.00	1208.50	720.00	1109.00	684.30	1511.00		
Mudstone Series (Załęże Beds)	*775.50*	*1030.85*	*3.33–26.75*	*<0.10–460.0*													*684.30*	*1043.30*	*1.48–21.26*	*0.1–7.5*
Upper Silesian Sandstone Series (Ruda Beds)	*1030.85*	*1104.50*	*4.60–17.54*	*<0.10–24.0*													*1043.30*	*1120.35*	*4.9–16.17*	*0.1–5.1*
Paralic Series	*1104.50*	*1245.50*	*2.08–17.55*	*<0.10–13.30*	*793.50*	*1117.00*	*1.32–12.15*	*0.1–1.5*									*1120.35*	*1409.20*	*0.0–15.19*	*0.1–2.5*
Culm facies (Malinowice Beds)	*1245.50*	*1513.60*	*2.61–15.26*	*<0.10–1.16*	*1117.00*	*1184.00*	1.65–7.36	0.0–1.2									*1409.20*	*1511.00*		
Lower Carboniferous carbonate complex	*1513.60*	*1546.90*	0.00–31.73	<0.10–45.00																
Upper Devonian	1546.90	1572.60			1184.00	1362.20	0.0–1.68	0.0	1022.00	1225.00	0.26–1.05	0.0–7.86								
Middle Devonian									1225.00	1482.00		0.12–2.55								
Cambrian and Lower Devonian									1482.00	1673.00	1.02–15.25	0.0								
Crystalline basement									1673.00	1700.70	2.45–4.28									

Tab. 6. Stratigraphy and petrophysical characteristics in the Bestwina IG-1, Bielsko 2, Bielsko 5, Brożyska 1, Czechowice R-1 and Czechowice IG-1 wells (based on: Karwaciński et al., 1986; Buła, 1984; Jawor and Mikucka-Reguła, 1967; Brzostowska, 1970).

Well:	BESTWINA IG-1	BIELSKO 2	BIELSKO 5	BROŻYSKA 1	CZECHOWICE R1	CZECHOWICE IG-1
Depth:	1572.6 m	1362.2 m	1700.7 m	1208.5 m	1109.0 m	1511.0 m
Drill core – storage	NAG: Hołowno, Kielniki	NO core	NO core	NAG: Kielniki	NAG: Kielniki	NAG: Hołowno
PK	0.00 – 1570.00		25.00 – 1700.00			0.00 – 1495.00
PŚr	0.10 – 1571.50	25.00 – 125.00	10.00 – 1503.00			0.10 – 1499.90
mPŚr			147.00 – 1503.00			
PAdt	44.30 – 1573.50					163.50 – 1454.00
PAt1	44.25 – 1573.25					164.50 – 1454.50
PAt2	44.50 – 1573.00					164.50 – 1454.25
PG	0.30 – 1573.75	30.00 – 1202.00	5.00 – 1693.00			0.30 – 1499.75
PGG	719.25 – 1574.75					612.20 – 1499.75
PNG	1.70 – 1573.80	30.00 – 1202.00	5.00 – 1693.00			3.60 – 1499.90
PNNnt	740.25 – 1573.75					3.75 – 1499.50
PS	28.25 – 1574.25	8.00 – 1202.00	10.00 – 1695.00			222.50 – 703.75
PO – standard	27.00 – 1572.00	8.00 – 1202.00				29.00 – 1496.00
	EL02 A0.5M0.1N 28.25 – 1572.50		B4.48A1.62M 10.00 – 1103.00			A0.25M0.1N 695.00 – 1496.00
	EL03 A1.0M0.1N 28.25 – 1571.75		B5.7A0.4M 10.00 – 1103.00			EL02 A0.5M0.1N 696.00 – 1497.75
	EL07 A2.5M0.25N 30.25 – 1572.50		M0.5A0.1B 1102.00 – 1695.00			EL02 M0.5A0.1B 29.25 – 697.75
	EL09 30.25 – 1572.50		M1.0A0.1B 1102.00 – 1695.00			EL03 A1.0M0.1N 694.00 – 1497.75
	EL14 A4.0M0.5N 22.25 – 1572.50		M2.5A0.25B 1102.00 – 1695.00			EL03 M1.0A0.1B 30.25 – 697.75
	EL26 A8.0M0.5N 25.75 – 1572.75		M4.0A0.5B 1102.00 – 1695.00			EL07 A2.5M0.25N 695.25 – 1497.75
	EN10 N1.0M0.1A 20.25 – 1573.25		M5.28A0.82B 10.00 – 1103.00			EL07 M2.5A0.25B 28.50 – 697.75
			M8.0A0.5B 1102.00 – 1695.00			EL09 28.40 – 1498.40
						EL09 M2.5A0.25B 28.25 – 221.25
						EL14 A4.0M0.5N 695.25 – 1498.75
						EL14 M4.0A0.5B 28.50 – 697.75
						EL26 A8.0M0.5N 694.25 – 1498.50
						EL26 M8.0A0.5B 28.25 – 698.50
						EN04 B1.0A0.1M 593.60 – 698.80
						EN10 B2.5A0.25M 28.50 – 698.50
						B2.5A0.25M 29.00 – 698.00
						B1.0A0.1M 29.00 – 698.00
mPO			A1.0M1.0N 1100.00 – 1695.00			
			A2.0N 1100.00 – 1695.00			
POp	N1.0M0.1A 27.00 – 1572.00					
POpł	10.75 – 1572.00			100.00 – 931.40		
POst			1000.00 – 1698.00			695.00 – 1496.00
POst LL3						692.50 – 1497.75
PT				187.50 – 931.40		
POpł						6.50 – 1498.50
PTu	47.00 – 1538.00					1.50 – 1511.00
Velocity survey	20.00 – 1540.00					20.00 – 1460.00

Tab. 7. Geophysical survey – well logs (underlined intervals are available in LAS format). NAG – National Geological Archive, PK – deviation log, PŚr – caliper, mPŚr – caliper – microlog, PAdt – interval transit time – acoustic log, PAt1 – travel time T1 – acoustic log , PAt2 – travel time T2 – acoustic log, PG – gamma ray log, PGG – density log, PNG – neutron-gamma ray log, PNNnt – epithermal neutron log, PS – spontaneous potential log, PO – conventional electric log (EL – lateral, EN – normal), mPO – electric microlog, POp – electric log using N1.0M0.1A potential probe, POpł – salinity log, POst – focussed electric log, POst LL3 – focussed electric log using LL3 probe, PT – temperature log, PTu – temperature log in thermal equilibrium, velocity survey.

Well	Top [m]	Bottom [m]	Stratigraphy	Flow
Bielsko 2	525.0	530.0	Skawina Beds	brine
	613.0	649.0		gas and brine
	655.0	666.0		
	675.0	689.0		
	695.0	706.0		
	715.0	721.0		
	725.0	735.0		
	740.0	756.0		
	768.0	775.0		
Bielsko 5	1483.7	1510.0	Lower Devonian	NO
	1637.2	1700.7	Lower Devonian and crystalline basement	brine
Brożyska 1	849.0	852.0	Skawina Beds	NO
	900.0	906.0		brine
		950.0	Dębowiec Beds	brine
Czechowice IG-1	653.0	662.0	Dębowiec Beds	gasificated brine
	695.0	945.0		gasificated brine

Tab. 8. Tests during drilling.

Well	Top [m]	Bottom [m]	Stratigraphy	Shows
Bielsko 5		1312.10	Devonian	spirt loss – 20 m^3
		1417.0	Devonian	spirt loss – 4 m^3
		1606.0	Devonian	spirt loss – 3 m^3
Brożyska 1	108.0	110.0	Subsilesian Unit	gas shows
	926.0	940.0	Dębowiec Beds	background gas
	950.0	960.0		brine

Tab. 9. Hydrocarbon shows during drilling.

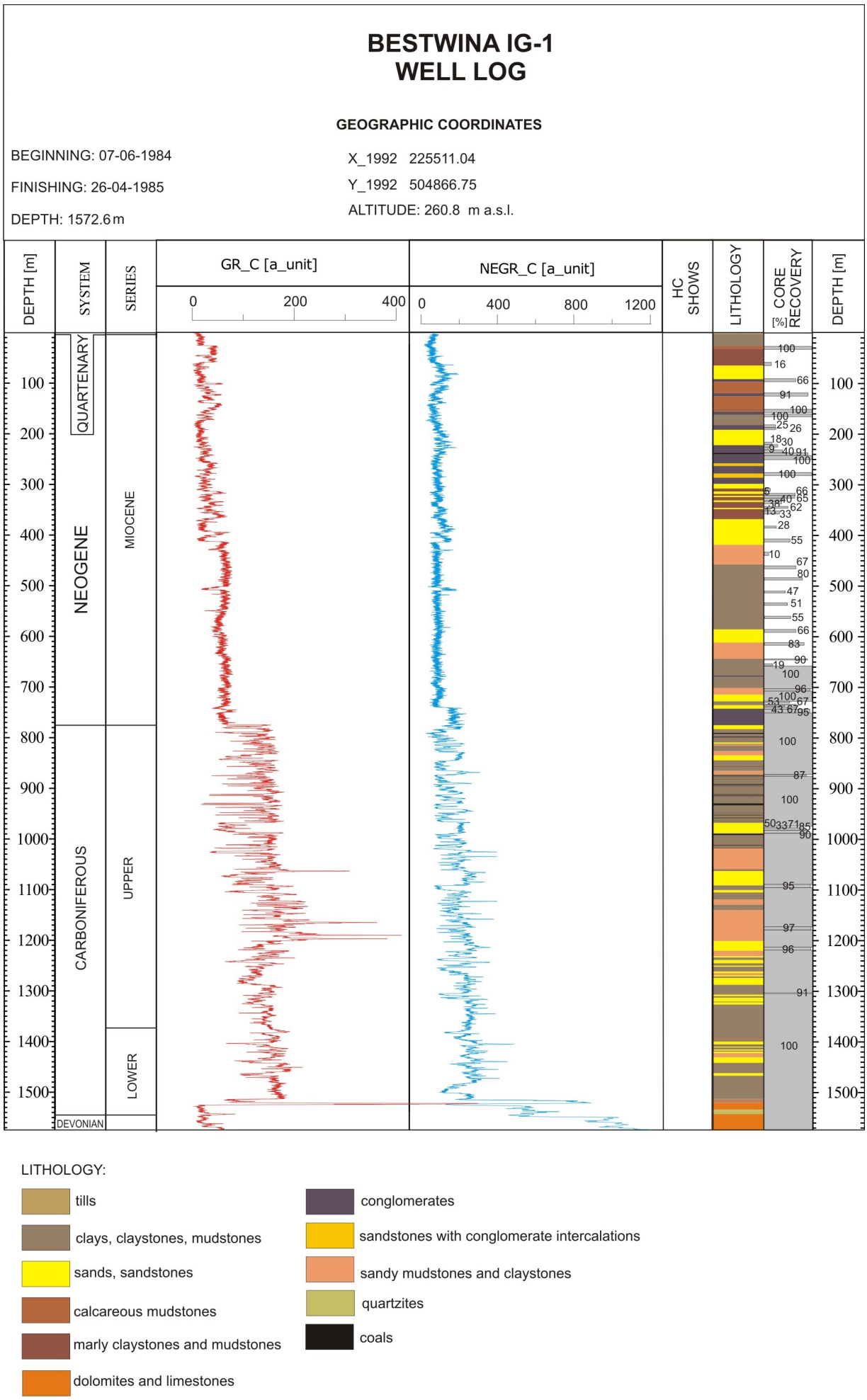


Fig. 16. Well log of the key well Bestwina IG-1 (Buła, 1984).

6. SEISMIC SURVEYS

The Bestwina-Czechowice tender area is explored by 2D seismic surveys done in 1976-1991 (18 lines of total length of 388.36 km; Tab. 10, Fig. 17). In the western part, the distance between seismic lines is about 1–1.5 km.

In 1976-1978, seven 2D profiles were conducted for the "Upper Silesian Coal Basin" project (Majewski and Hałoń, 1979). Interpretation of seismic horizons within the Carboniferous coal-bearing succession and description of tectonics elements at the top surface of the Devonian carbonate complex were the main aims of the project. Because of a long distance between seismic profiles, the interpreted horizons could not been mapped, unfortunately. An acquisition of five more 2D profiles for the "Upper Silesian Coal Basin" project and its interpretation was made in 1980s (Białek, 1981, 1982).

In 1990-1991, another 2D seismic survey – "Skoczów-Wadowice-Sucha" – was carried out in the Bestwina-Czechowice area (Cianciara, 1994). Searching of narrowings and structural highs within the Miocene succession of the Carpathian Foredeep and in its Paleozoic basement was the main goal of the project. Four seismic horizons were interpreted, which are as follows: the bottom surface of the flysch deposits (Flp), the bottom surface of the Miocene (Msp), the bottom surface of the Carboniferous (Csp), and possible top surface of the Devonian carbonate succession (D). Consequently, several structural objects were identified, some of them are located within the tender area.

The Czechowice-Dziedzice and Kozy objects (Fig. 17) are interpreted at the bottom surface of the Miocene (Msp). They are probably related to structural highs of the Carpathian Foredeep basement. In the first case, potential trap is characterized by 80 m amplitude, acreage about 5.5 km^2, and contour -425 m a.s.l. No wells have been drilled in this structure, so far. The Kozy object (Fig. 17) has about 50 m amplitude, acreage 0.7 km^2, and contour -500 m a.s.l. The object was partly drilled by the Bielsko 2 well, in which gas shows in brine were observed in the Miocene (Tab. 8).

Another two objects were identified at the top surface of the Devonian carbonate succession – Czechowice A and Czechowice B (Fig. 17). The Czechowice A object has about 150 m amplitude, acreage of about 8 km^2, and contour -2100 m a.s.l. Although the Czechowice IG-1 well was drilled in the area, the well didn't reach the Devonian. The Czechowice B object is similar to the first one. It has 370 m amplitude, acreage of about 4.5 km^2, and contour -2000 m a.s.l. No wells have been drilled in this structure, so far.

The Roztropice object was identified within the Devonian–Carboniferous interval (Fig. 17). The structure has 70 m amplitude and acreage more than 3,5 km^2 in the Carboniferous, and 150 m amplitude and acreage about 6,5 km^2 in the Devonian. The Roztropice 3 well was drilled in 1996, in which background gas was noticed in the Carboniferous, but no tests have been performed in the interval. The hydrocarbon prospective of the Devonian–Carboniferous carbonate complex has not been clarified.

The most recent seismic survey in the Bestwina-Czechowice tender area were carried out in 2012 by Aurelian Ltd., and next by San Leon Ltd. Seismic data grid become more detailed, but the results of these measurements have not be delivered to the Polish Geological Survey up to date.

Name	Year	Project	Owner	Length [km]
W0050178	1978	Upper Silesian Coal Basin	State Treasury	21.08
W0120380	1980			10.71
WA120380	1980			7.15
W0120283	1983			40.13
W0190284	1984			19.20
W0180284	1984			11.89
77-8-90K	1990	Skoczów-Wadowice-Sucha	PGNiG S.A.	27.59
75-8-90K	1990			24.97
82-8-90K	1990			10.69
76-8-90K	1990			27.56
78-8-90K	1990			11.99
78A-8-91K	1991			86.03
70-8-91K	1991			15.11
89-8-91K	1991			21.45
91-8-91K	1991			8.55
73-8-91K	1991			19.77
71-8-91K	1991			10.63
74-8-91K	1991			13.86
			SUMMARY:	
			State Treasury	110.16
			Investors	278.20
			Total amount	388.36

Tab. 10. Seismic surveys in the Bestwina-Czechowice tender area (CBDG, 2019).

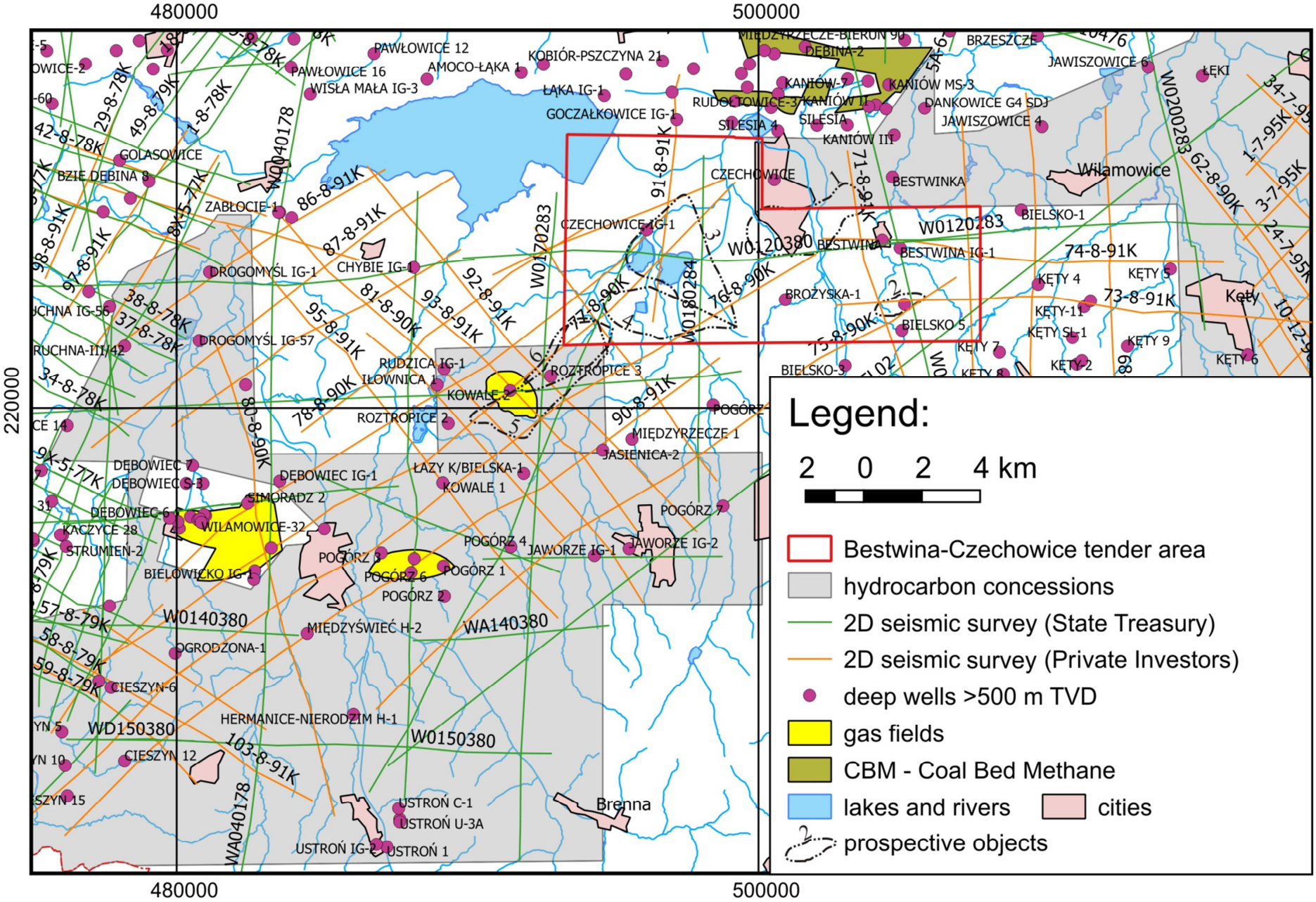


Fig. 17. Map of seismic surveys in the Bestwina-Czechowice tender area and in its neighborhood (CBDG, 2019) with location of prospective objects: 1 – Czechowice-Dziedzice (bottom surface of the Miocene), 2 – Kozy (bottom surface of the Miocene), 3 – Czechowice A (top surface of the Devonian carbonate succession), 4 – Czechowice B (top surface of Devonian carbonate succession), 5 – Roztropice (top surface of Devonian carbonate succession), 6 – Roztropice Csp (bottom surface of the Carboniferous).

7. GRAVIMETRY, MAGNETOMETRY AND MAGNETOTELLURICS

7.1 GRAVIMETRY

Two gravimetric surveys were completed in the Bestwina-Czechowice tender area. First of them is the "Upper Silesian Coal Bed" (Reczek, 1973) – with average density of 4 stations/km^2 (Fig. 18). The second – "Western Carpathians" (Reczek, 1978) – supplements the data coverage at the south-eastern corner of the map. Database of both surveys is available in CBDG (2019).

Królikowski and Petecki (1995) proposed a division of Poland into several gravity regions. Thus, the Bestwina-Czechowice tender area belongs to the Upper Silesian High – subregion of the Silesian High – which includes the Silesian-Cracow Monocline and Upper-Silesian Foredeep. From the south, the Silesian High is bordered by the Carapathian Low. The gradient zone, appearing at north-eastern corner of the Bouguer anomaly map (Fig. 19), is related to the Jawiszowice Fault Zone (Lemberger, 1976). Moreover, strong positive anomaly, appearing to the NE from the gradient zone, reflects the uplift of the Carboniferous deposits, while relatively negative anomaly (about 3 mGal) to the west results from the Łaziska beds, composed of lower density rocks (Lemberger, 1976). A zone of a smoother, sublatitudinal gradient, passing through the Bielsko 3 well, marks a Carpathian Deformation Front (Lemberger, 1976). Negative anomaly to the south from the gradient, results from the Carpathians themselves.

7.2. MAGNETOMETRY

The Bestwina-Czechowice tender area and its close neighborhood is highly urbanized, with high level of artificial noise. Despite several attempts, there is no uniform magnetic data coverage. The aeromagnetic survey (Fig. 20 – green points; Wasiak, 1982), with highest density of gravimetric stations, had to be filtered to remove the noise coming from electrified railways. In effect, only regional anomaly image was obtained. Some ground measurements (Fig. 20 – blue crosses; Kosobudzka and Wrzeszcz, 2005) were performed only at the eastern part of the analysed area. Southern and western part of the area is covered by older semidetailed survey of Z-component of magnetic field (Fig. 20 – orange crosses; Małoszewski, 1953). The survey of the Z-component at Skoczowa-Bielsko-Żywiec (Fig. 20 – pink crosses; Cieśla, 1976) is the only detailed survey in the neighborhood of the Bestwina-Czechowice tender area. These two Z-component surveys were used to fill the gap on the new magnetic map of Poland (Petecki et al., 2003; Petecki and Rosowiecka, 2017).

The magnetic map is divided into several regions with different magnetic characteristic. The Bestwina-Czechowice tender area is located within the Upper Silesia-Malopolska domain (USMd), in which several magnetic, regional highs occur. Southern part of the USMd is dominated by three positive anomalies: Tychy, Jordanów and Nowy Sącz. The source of the Tychy anomaly (Fig. 21) is supposed to be located at the depth of 4–6 km (Lemberger, 1976). Both – the Tychy anomaly and the area of weaker magnetic field at the southern part of the map – should be related to crystalline basement rocks.

7.3. MAGNETOTELLURICS

No magnetotelluric surveys are completed within the Bestwina-Czechowice tender area.

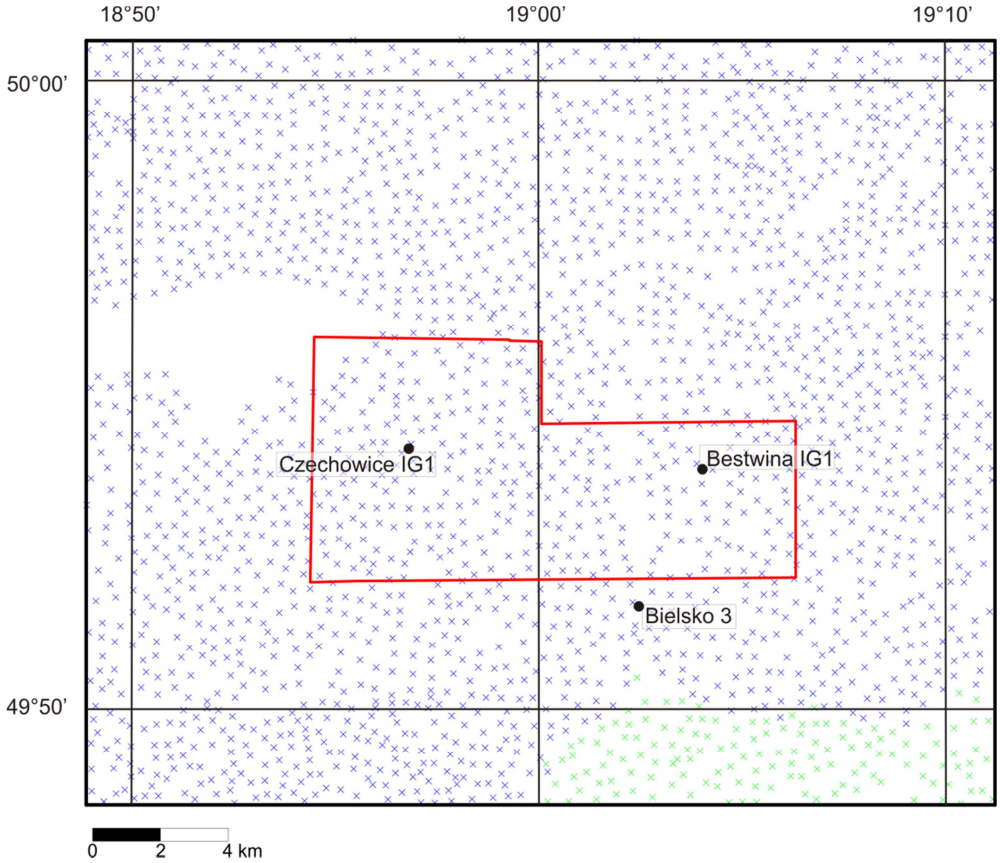


Fig. 18. Distribution of gravimetric measurements in the Bestwina-Czechowice tender area and in its close neighbourhood. Red line – boundaries of the tender area; blue points – Reczek, 1973; green points – Reczek, 1978; black dots – key wells.

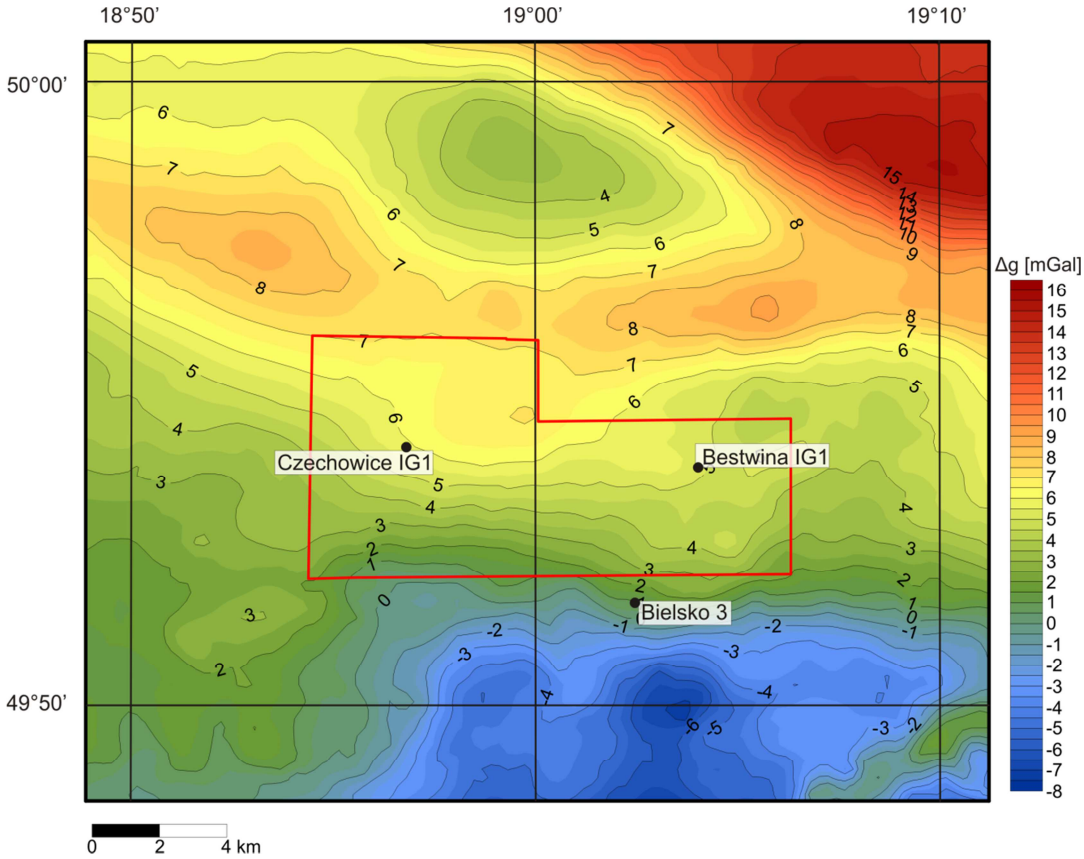


Fig. 19. Location of the Bestwina-Czechowice tender on the Bouguer gravity anomaly map of Poland, with a reduction density of 2,25 g/cm^3. Red line – boundaries of the tender area; black dots – key wells.

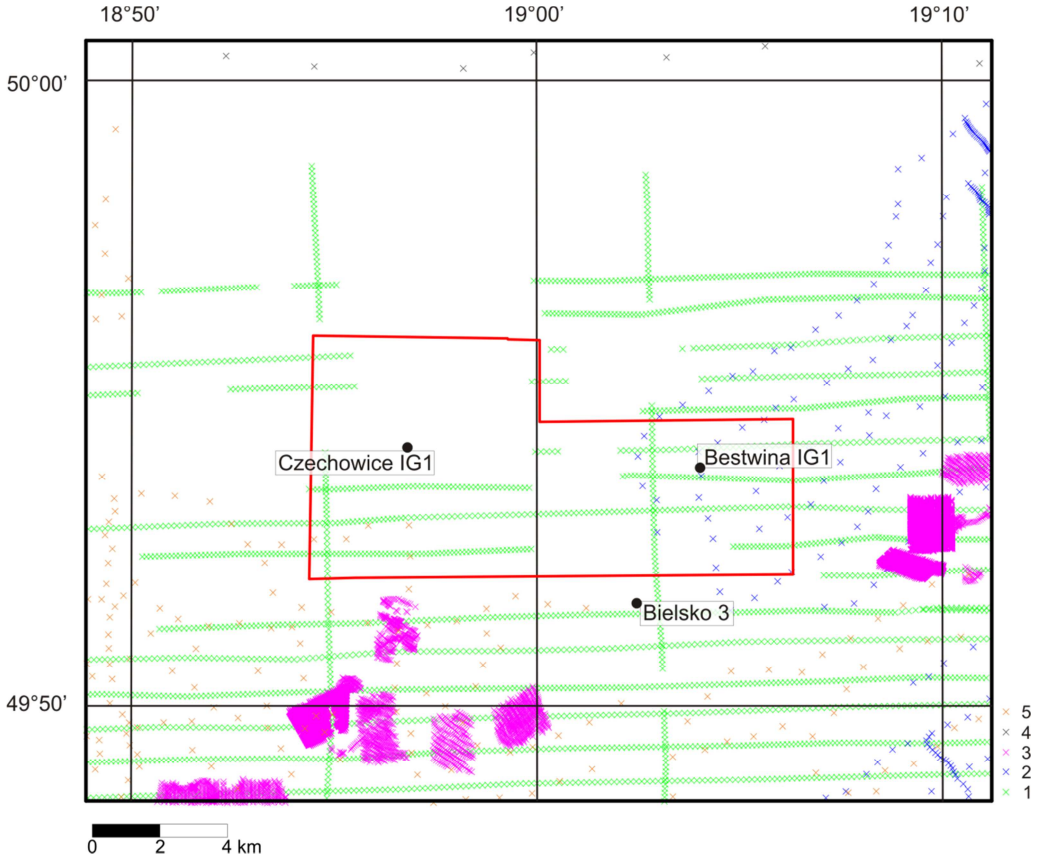


Fig. 20. Distribution of magnetic stations in the Bestwina-Czechowice tender area and in its close neighbourhood: 1 – Wasiak, 1982; 2 – Kosobudzka and Wrzeszcz, 2005; 3 – Cieśla, 1976; 4 – Kozera, 1955; 5 – Małoszewski, 1953. Red line – boundaries of the tender area; black dots – key wells.

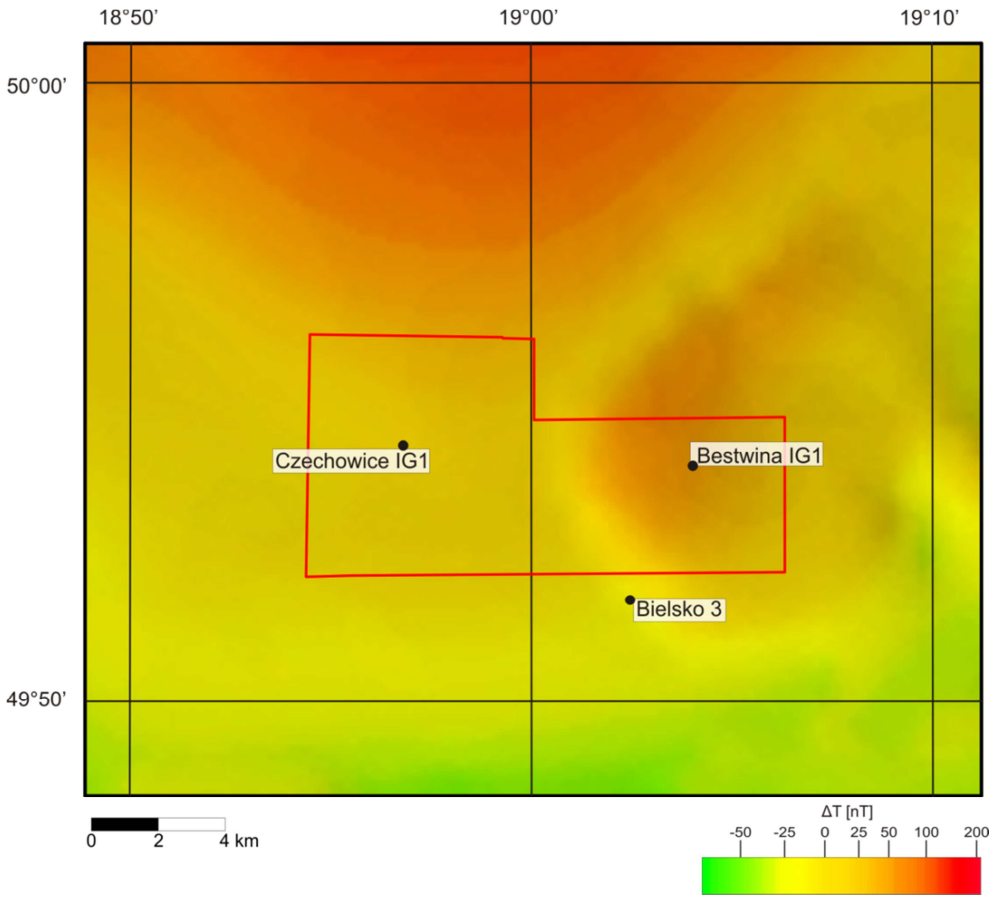


Fig. 21. Location of the Bestwina-Czechowice tender on the magnetic anomaly map of Poland (based on CBDG, 2019). Red line – boundaries of the tender area; black dots – key wells.

8. HYDROCARBON PROSPECTIVE

The Bestwina-Czechowice tender area is located in the southern Poland, in the Southern Petroleum Province (Fig. 22). The area lies at the border of the Outer Carpathians and Carpathian Foredeep. Below the Carpathian units, the Upper Silesian Block crystalline basement with its Paleozoic (Cambrian, Devonian and Carboniferous) sedimentary cover occurs.

The main phase of exploration effort in the Bestwina-Czechowice area were taken in 40's and 50's, when the Pogórz and Dębowiec Śląski gas fields have been discovered in the south-western vicinity. The accumulations of gas occurred in horizons of sandstones and mudstones within the Skawina Beds (autochthonous Miocene of the Carpathian Foredeep), just below the Carpathian Overthrust. Slight increase of exploration activity in 90's caused the Kowale field – with two gas-bearing horizons in the Miocene – have been discovered. In this case, hydrocarbon shows were also observed in the succession below and above the Miocene – in the Paleozoic basement and in the Carpathian flysch sediments.

Two independent petroleum systems work in the Bestwina-Czechowice tender area. The first occurs in the autochthonous Miocene of the Carpathian Foredeep, in which biogenic gas is generated from fine-grained sediments, being accumulated in multi-layered traps. The second system is related to the Paleozoic basement, in which gas is generated from the Carboniferous coal beds and accumulated in the Devonian-Carboniferous carbonate rocks or in clastic rocks of the Carboniferous coal-bearing succession.

Deep wells carried out in the Bestwina-Czechowice tender area indicated gas shows in the Devonian, Carboniferous and Miocene. Especially gasificated brines were observed in the Carboniferous and Miocene of the Bestwina IG-1 and Czechowice IG-1 wells. However, the production tests brought unambiguous results, probably as an effect of too heavy drilling fluids.

The Dębowiec Beds are expected as the most prospective horizon for gas accumulations in the Bestwina-Czechowice tender area, but only brine flows have been achieved, so far. The main problem is related to the detailed mapping of these beds, as they have similar seismic properties as the underlying Carboniferous deposits. It seems that only detailed seismic survey could bring identification of new traps within the Miocene succession. Currently, irregular seismic survey enables only preliminary identification of the Czechowice-Dziedzice and Kozy structural objects at the top surface of the Carpathian Foredeep basement, and Roztropice, Czechowice A and B objects within the Devonian-Carboniferous succession. Nonetheless, the multi-horizontal conventional traps for gas within the Skawina Beds are expected, as well. The presence of hybrid gas accumulations within the Devonian and Carboniferous carbonates and unconventional (tight-type) gas accumulations in the Lower Devonian sandstones and clastics of the Carboniferous coal-bearing succession are also possible.

Possible minimum work program for prospection and exploration phase:

- Stage I (12 months) – integration and reinterpretation of archival geological data;
- Stage II (48 months) – conduction of 2D seismic surveys (30 km) or conduction of 3D seismic surveys (15 km^2) and drilling of one well to maximum depth of 2500 m TVD with obligatory coring of prospective intervals.

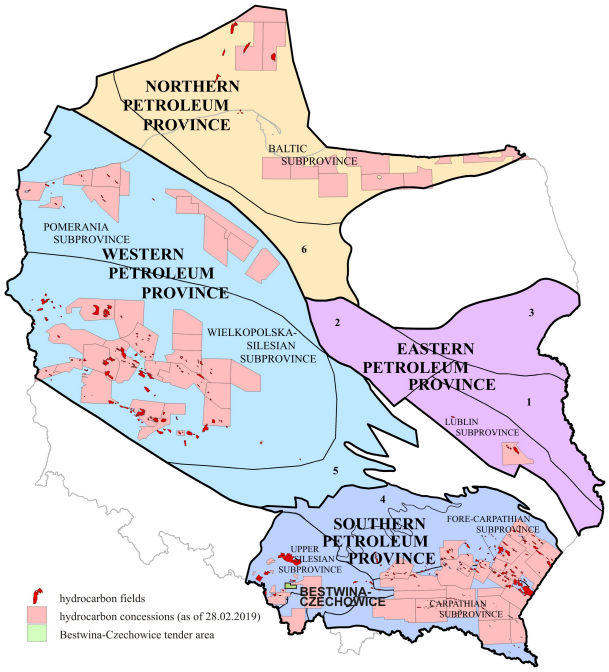


Fig. 22. Hydrocarbon subdivision of Poland (PIG-PIB, 2019) with location of the Bestwina-Czechowice tender area. 1–6 – petroleum regions (of unconfirmed/hypothetical prospective): 1 – Chełm Region, 2 – Płock-Warszawa Region, 3 – Podlasie Region, 4 – Małopolska Region, 5 – Łódź-Wieluń Region, 6 – Słupsk-Grudziądz Region.

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