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**Geological evaluation of hydrocarbon resources in Poland:
tender procedure materials for prospection, exploration and exploitation of hydrocarbons concessions – stage III
Project no. 22.5004.1901.01.1**

HYDROCARBON PROSPECTIVITY OF POLAND

KRYSTIAN WÓJCIK

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1. PREFACE

The assessment of hydrocarbon prospectivity of Poland is prepared every year since 2015 according to the Polish Geological and Mining Law (Act of 9 June 2011; Journal of Laws of 2011, no. 163, item 981). This document is the result of the project "Geological evaluation of hydrocarbon resources in Poland: tender procedure materials for prospection, exploration and exploitation of hydrocarbons concessions – stage III" financed by National Found for Environmental Protection and Water Management.

The assessment includes the description of petroleum provinces in Poland, including as follows:

- their boundaries, acreages and maps,
- petroleum systems,
- hydrocarbon fields and their resources.

The most prospective areas for discovery of new hydrocarbon fields have been selected and described in the document. These areas are free from other hydrocarbon concessions and have an acreage less than 1200 km^2. The description of the prospective areas includes:

- coordinates,
- acreage,
- data on geological and petroleum systems,
- list of deep wells and seismic surveys,
- oil and gas deposits discovered on the area and in its neighborhood,
- hydrocarbon prospectivity summary.

2. EASTERN PETROLEUM PROVINCE
2.1. DESCRIPTION

Boundaries. According to the tectonic interpretations proposed in the Geological Atlas of Poland (Nawrocki and Becker, 2017; compare to: Aleksandrowski, 2017a, Aleksandrowski and Buła 2017, Aleksandrowski and Mazur, 2017, Krzywiec et al., 2017) the extent of the Ediacaran-Paleozoic sedimentary cover of the East European Platform in the SE Poland defines the boundaries of the province. In this context, it includes: (1) Ediacaran and Lower Paleozoic of the Podlasie Syneclize, (2) Ediacaran and Lower Paleozoic basement and its Devonian-Carboniferous cover of the Variscan Foreland, and (3) Devonian and Carboniferous of the Lublin Fold Belt (Ad. 1–2). Above, the Permian-Mesozoic (barren) succession occurs, forming the Mazury-Podlasie Monocline and Koszalin-Zamość Synclinorium (Aleksandrowski, 2017b; Ad. 3).

Acreage. ~42 500 km^2.

Geology. The crystalline rocks of the East European Platform form the basement of the Eastern Petroleum Province. The sedimentary cover is built of the following structural stages (the elements of petroleum systems are underlined):

- Ediacaran-Lower Paleozoic,
- Devonian-Carboniferous,
- Permian-Mesozoic,
- Cenozoic.

Petroleum systems.

1. Devonian-Carboniferous petroleum system:
   Source rocks – Devonian and Carboniferous fine-grained clastic rocks, Lower Paleozoic shales (Radkovets et al., 2017).
   Reservoir rocks – Devonian and Carboniferous sandstones and carbonates.
   Traps – structural in the Devonian, structural and lithological in the Carboniferous.
   Seal – Devonian and Carboniferous fine-grained clastic rocks.
   Hydrocarbon deposits – 2 gas fields (Mełgiew A+B and Ciecierzyn) and 1 oil and gas field (Glinnik) in the Devonian; 1 gas field (Wilga) and 1 oil and gas field (Stężyca) in the Carboniferous.

Natural gas

Prospecting horizons	Number of deposits as of 31.12.2017	Anticipated economic resources as of 31.12.2017	Economic resources in place as part of anticipated economic resources as of 31.12.2017	Production in 2017
		[mln m^3]		
Upper Devonian	3	1162.71	343.43	35.18
Carboniferous	2	401.79	105.33	0.03

According to the Balance of Mineral Resources Deposits in Poland as of 2017.

Crude oil

Prospecting horizons	Number of deposits as of 31.12.2017	Anticipated economic resources as of 31.12.2017	Economic resources in place as part of anticipated economic resources as of 31.12.2017	Production in 2017
		[kt]		
Upper Devonian	1	7.10	4.49	0.27
Carboniferous	1	86.57	8.05	0.05

According to the Balance of Mineral Resources Deposits in Poland as of 2017.

2. Lower Paleozoic petroleum system:
   Source rocks – Lower Paleozoic shales.
   Reservoir rocks – Lower Paleozoic shales.
   Traps – unconvenional and continous for shale gas and shale oil.

Wells. 921 deep wells (> 500 m) were drilled in the Eastern Petroleum Province, including 52 deep wells in the last 10 years (beginning from 2009).

Hydrocarbon concessions. One concession of an acreage ~609 km^2 is provided in the Eastern Petroleum Province (Ad. 1).

Petroleum subprovinces and regions. One subprovince, in which a petroleum system occurs, and three regions with unconfirmed prospectivity have been distinguished in the Eastern Petroleum Province (Ad. 1–2).

Lublin Subprovince

The Lublin Subprovince includes the Lublin Fold Belt. Two petroleum systems – Devonian-Carboniferous (active) and Lower Paleozoic (hypothetical) occur therein.

Płock-Warszawa Region

The Płock-Warszawa Region includes NW part of the province. Hypothetically, the Lower Paleozoic and Devonian-Carboniferous petroleum systems work in the area.

Chełmno Region

The Chełmno Region is located in the eastern part of the province, east from the Lublin Fold Belt. The Lower Paleozoic and Devonian-Carboniferous petroleum systems are supposed to work therein.

Podlasie Region

The Region includes the northern part of the province with hypothetical Lower Paleozoic petroleum system.

Prospective areas. Rejowiec Fabryczny (acreage 896.33 km^2).

2.2. PROSPECTIVE AREAS
2.2.1. REJOWIEC FABRYCZNY
(Adam Wójcicki)
Fig. 2.1

Coordinates:

Border points	PL 1992	
	X	Y
1	384 719.21	799 654.16
2	385 544.79	813 899.18
3	357 769.83	815 600.98
4	355 745.40	780 547.43
5	366 856.82	779 942.57
6	371 470.35	779 691.43
7	383 524.22	779 035.27
8	383 992.00	781 307.00
9	375 496.00	790 915.00

Acreage: **896.328 km^2**

Geology and petroleum systems:

a) geological location: Lublin Fold Belt, Variscan foreland basin;
b) basement: East European Platform;
c) tectonic-structural stages of sedimentary cover: Ediacaran-Lower Paleozoic, Devonian-Carboniferous; Permian-Mesozoic, Cenozoic;
d) petroleum location: Lublin Subprovince, Chełm Region;
e) type of expected deposits: shale gas and shale oil;
f) petroleum systems: Lower Paleozoic;
g) potential reservoir rocks: Lower Silurian shales;
h) potential source rocks: Lower Paleozoic shales;
i) seal rocks: Middle and Upper Silurian shales, Devonian and Carboniferous fine-grained clastic rocks;
j) thickness of the overburden: 3000–4000 m;
k) expected traps: unconventional – continuous for shale gas and shale oil.

Wells: **46 deep wells > 800 m**

Well name	Depth [m TVD]	Stratigraphy at the bottom
CHEŁM 10	879.0	Carboniferous
CHEŁM 11	926.5	Carboniferous
CHEŁM 12	910.0	Carboniferous
CHEŁM 19	860.0	Carboniferous
CHEŁM 5	915.8	Carboniferous
CHEŁM IG-1	1611.7	Upper Silurian
CHEŁM IG-2	1304.0	Carboniferous
CHEŁM-14	1049.0	Carboniferous
CHEŁM-15	942.0	Carboniferous
CHEŁM-16	879.5	Carboniferous
CHEŁM-17	1472.0	Silurian
CHEŁM-20	920.0	Carboniferous
CHEŁM-21	860.0	Carboniferous
CHEŁM-24	847.1	Carboniferous
CHEŁM-25	859.0	Carboniferous
CHEŁM-6	1000.0	Carboniferous
CHEŁM-7	905.0	Carboniferous
CHEŁM-8	960.0	Carboniferous
DOBRYNIÓW OU-1	3674.0	Lower Ordovician
DOROHUCZA IG-1	2750.0	Lower Devonian
DOROHUCZA IG-2	1350.5	Carboniferous
DOROHUCZA IG-7	1368.0	Carboniferous
DOROHUCZA IG-8	1325.0	Carboniferous
KRASNYSTAW IG-2	1232.3	Carboniferous
KRASNYSTAW IG-3	1100.0	Carboniferous
KRASNYSTAW IG-5	1014.0	Carboniferous
KRUPE-1	3800.0	Middle Cambrian
MARYNIN 1	1805.0	Lower Devonian
MARYNIN 2	2000.0	Lower Devonian
MARYNIN BG-4	1399.0	Lower Carboniferous
MARYNIN-3	1804.0	Devonian
MILEJÓW IG-1	1406.1	Carboniferous
PAWŁÓW 1	2003.0	Upper Silurian
PAWŁÓW 3	900.2	Carboniferous
PAWŁÓW 4	860.0	Carboniferous
PAWŁÓW 5	881.0	Carboniferous
PAWŁÓW 6	865.0	Carboniferous
PAWŁÓW 7	850.0	Carboniferous
PAWŁÓW 8	850.0	Carboniferous
PAWŁÓW 9	820.0	Carboniferous
REJOWIEC IG-1	1500.0	Carboniferous
REJOWIEC IG-2	1123.8	Carboniferous
REJOWIEC IG-3	1332.0	Carboniferous
REJOWIEC IG-4	1191.0	Carboniferous
SIENNICA-1	1810.0	Devonian
ŚWIĘCICA	2569.0	Ediacaran

Seismic survey (owner):*
1974 – 3 lines Lublin Trough 2D (ST)
1976–1977 – 4 lines Puchaczów 2D (ST)
1977 – 1 line Puchaczów-Milejów 2D (ST)
1978 – 1 line PGSS PAN (ST)
1979 – 9 lines Chełm-Grab.-Hrubieszów 2D (ST)
1979 – 2 lines LZW Wierzbica 2D (ST)
1979–1985 – 19 lines Łuków-Hrub. 2D (ST)
1980 – 6 lines Chełm-Grab.-Hrubieszów2D (ST)
1980 – 1 lines Op. Lub.-Lublin-Bychawa 2D (ST)
1981 – 5 lines Chełm-Grabowiec-Hrub. 2D (ST)
1991 – 9 lines Chełm-Hrub. 2D (PGNiG S.A.)
2000 – 1 line CELEBRATION 2000 (ST)
2012 – 5 lines Milejów 2D (ST)
2010–2011 – 3 lines Lublin 2D (ST)
69 lines 2D of total length 655.816 km
*ST – State Treasury

Oil and gas deposits discovered on the area and in its neighborhood: **1 field**

Field name	Type
Mełgiew A and Mełgiew B	GAS

Prospectivity:
The results of the Orlen Upstream and Exxon Mobil research and drilling provided in last years proved the occurrence of gas accumulations in the Lower Paleozoic shales, especially in Lower Silurian Pelplin and Pasłęk formations. The thickness of these shales is over 60 m. However, an important problems are related to low TOC contents, low gas contents, and complicated geology.

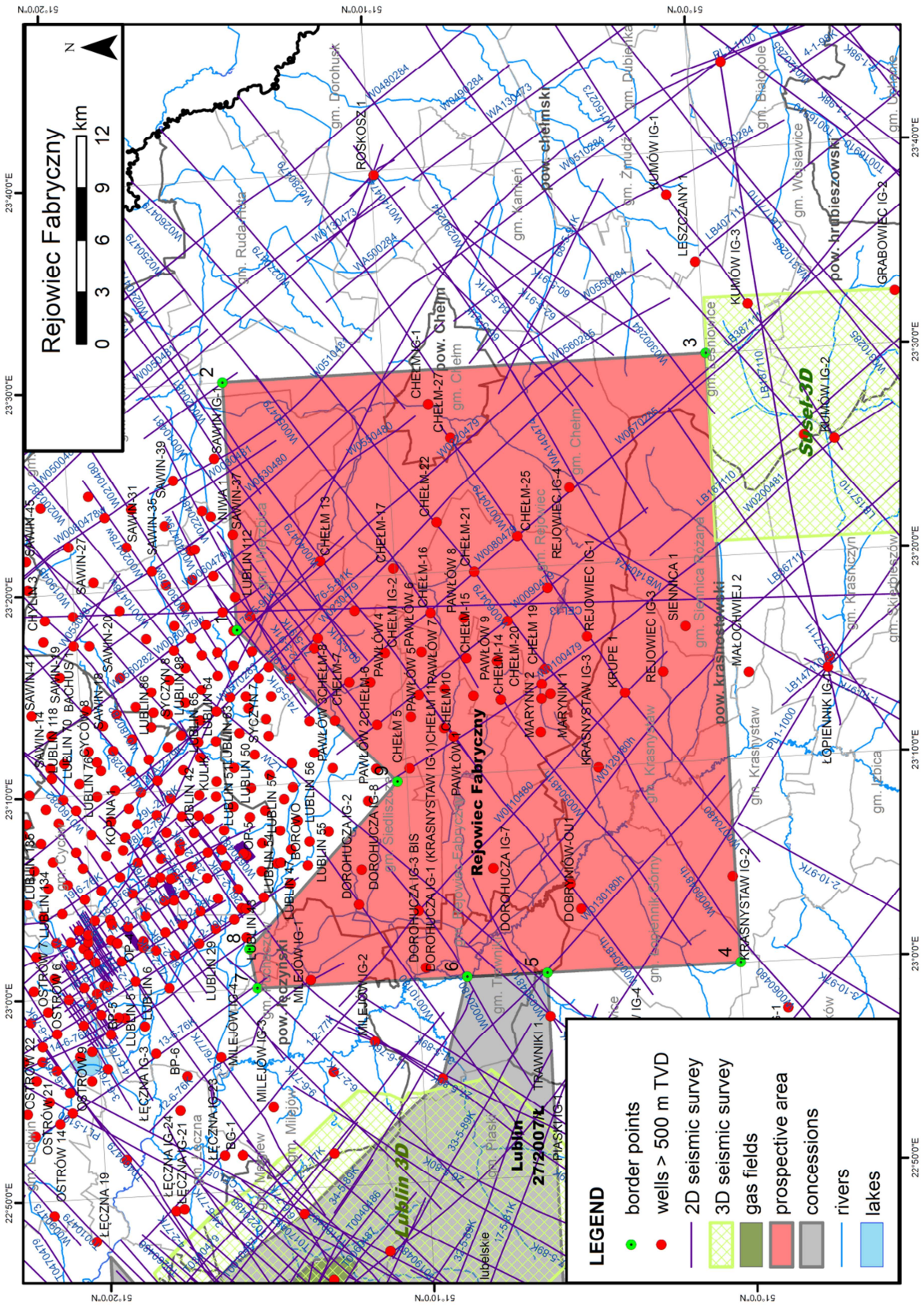

Fig. 2.1. Border points, seismic surveys, wells, hydrocarbon fields and hydrocarbon concessions on the Rejowiec Fabryczny area and in its neighborhood as of 28.02.2019 (CBDG, 2019).

3. SOUTHERN PETROLEUM PROVINCE
3.1. DESCRIPTION

Boundaries. The Southern Petroleum Province (Ad. 1–3) was earlier described as the Małopolska Province (Karnkowski 1997, 2007). The province includes the Carpathian units with its Paleozoic-Mesozoic basement and foreland of the Małopolska and Upper Silesian blocks (Narkiewicz, 2007; Buła et al., 2008; Żelaźniewicz et al., 2011; Nawrocki and Becker, 2017). In this sense, the boundaries of the province are defined as:

- Holy Cross Fault and range of the Carpathian Foredeep to the north;
- range of the Carboniferous deposits of the Variscan Externides to the north-west;
- Boguszowice thrust to the west;
- Pieniny Klippen Belt to the south.

Acreage. ~ 50 600 km^2

Geology. The following tectonic units are included to the Southern Petroleum Province:

- Outer Carpathians,
- Carpathian Foredeep,
- Upper Silesian Block,
- Małopolska Block.

Outer Carpathians, as a belt of alpine structures, are divided into several tectonic units (nappes), following from south to north (all of them are the elements of the petroleum systems):

- Magura Unit,
- Fore-Magura/Dukla Unit,
- Silesian Unit,
- Sub-Silesian Unit,
- Skole Unit,
- Stebnik/Zgłobice Unit.

These units are built of sediments originated in different parts of wide sedimentary basin, which was located between European Plate and ALCAPA and Tisza microplates (Mazzoli et al., 2010; Jankowski and Probulski, 2011). The closure of the basin ended in the Middle Miocene in its Polish part. Consequently, the sediments have been detached and thrusted northwardly, forming several tectono-stratigraphic units/nappes. The successions within the nappes have different stratigraphic range (from the Upper Jurassic to the Middle Miocene) and lithology (with predomination of flysch sediments and minor proportion of other clastics, carbonates and volcanic rocks). The Carpathian units are thrusted over the Carpathian Foredeep Miocene sediments at a distance of at least 35–40 km.

Carpathian Foredeep is built of Lower to Middle Miocene (Badenian and Sarmatian) sediments deposited in the shallowing basin originated at the front of the Carpathians. The foredeep sediments lie in four tectonic positions (all of them are the elements of the petroleum systems):

- as unfolded and autochthonous sediments of the outer part of the Carpathian Foredeep;
- as unfolded and autochthonous sediments of the inner part of the Carpathian Foredeep (below the Carpathian Overthrust);
- as unfolded and para-autochthonous sediments of the Rzeszów and Gdów gulfs (originated over the Carpathian nappes);
- as allochtonous Miocene sediments of the Zgłobice and Stebnik units folded and thrusted along the front of the Carpathians.

The crystalline rocks and Paleozoic-Mesozoic sedimentary succession of the Upper Silesian and Małopolska blocks occur in the basement of the Carpathians and Carpathian Foredeep.

The Upper Silesian Block is an element of the Brunovistulicum (Dudek, 1980; compare to Kotas, 1982, 1985) of cadomian consolidation, limited by the Kraków-Lubliniec Fault Zone to the east, Moldanubian Thrust Zone to the west and Northern Boundary Fault Zone of the Pieniny Klippen Belt to the south. The Kraków-Lubliniec Fault Zone separates the Upper Silesian and Małopolska blocks (Buła, 1994, 2000; Buła et al., 1997; Żaba, 1999). The basement of the Upper Silesian Block is built of crystalline and anchi-metamorphosed rocks of Archean to Ediacaran age (Dudek, 1980; Buła and Żaba, 2005, 2008; Buła et al., 2015; Żelaźniewicz et al., 2009). The sedimentary cover is built of three stratigraphic-structural stages (all of them are the elements of the petroleum systems):

- Cambrian-Silurian;
- Devonian-Carboniferous (Variscan Stage), including Lower Devonian continental clastics, Middle to Upper Devonian and Lower Carboniferous carbonates, Lower Carboniferous Kulm clastics and Upper Carboniferous marine to continental clastic sediments with coal-beds (Paralic Series, Upper Silesian Sandstone Series, Siltstone Series, Cracow Sandstone Series);
- Permian-Mesozoic (Laramian Stage) of the European Plate.

The Małopolska Block is built of highly-deformed Ediacaran clastics in the basement and Paleozoic-Mesozoic cover divided into four stratigraphic-structural stages (all of them are the elements of petroleum systems):

- Cambrian (Sandomirian Stage),
- Ordovician-Silurian (Caledonian Stage),
- Devonian-Carboniferous (Variscan Stage),
- Permian-Mesozoic (Laramian Stage).

Petroleum systems.

1. Carboniferous of the Upper Silesian Coal Basin (USCB) petroleum system:

Source rocks – USCB coal beds.

Reservoir rocks – coal beds of the Siltstone Series and Upper Silesian Sandstone Series; tight gas in the Paralic Sandstone Series; conventional gas deposits in the Carboniferous sandstones with gas generated from coal beds.

Hydrocarbon deposits – numerous coal bed methane deposits exploited as mine gas; tight gas deposits still not recognized (Poprawa, 2018; Poprawa et al., 2018); two conventional gas deposits: Marklowice (Upper Silesian Sandstone Series) and Silesia (Cracow Sandstone Series).

Natural gas

Prospecting horizons	Number of deposits as of 31.12.2017	Anticipated economic resources as of 31.12.2017	Economic resources in place as part of anticipated economic resources as of 31.12.2017	Production in 2017
		[mln m^3]		
Upper Silesian Sandstone Series and Cracow Sandstone Series	2	-	-	-
coal beds methane	62	96947.7	5691.32	543.04

According to the Balance of Mineral Resources Deposits in Poland as of 2017.

2. Paleozoic-Mesozoic petroleum system:

Source rocks – Ordovician, Silurian and Lower Devonian fine-grained clastics, Middle and Upper Devonian and Lower Carboniferous clastics and carbonates, Middle Jurassic fine-grained clastics.

Reservoir rocks – Ediacaran sandstones (hypothetically), Lower Devonian sandstones, Middle and Upper Devonian, Lower Carboniferous, Upper Jurassic and Upper Cretaceous carbonates.

Hydrocarbon deposits – 19 gas fields, including 3 fields in the Devonian (Lachowice-Stryszawa, Zalesie and Załęże), 1 field in the Lower Carboniferous carbonates (Nosówka), 1 field in the Triassic Keuper (Niwiska), 11 fields in the Jurassic limestones (Brzezówka, Góra Ropczycka, Grobla, Korzeniów, Korzeniów – gas, Lubaczów, Łapanów, Łąkta, Tarnów, Wierzchosławice and Żukowice) and 3 fields in the Cretaceous (Rajsko, Rylowa and Wierzchosławice); 11 oil fields, including 1 field in the Carboniferous carbonates (Nosówka) and 10 fields in the Jurassic and Cretaceous (Brzezówka, Grobla, Jastrząbka Stara, Korzeniów, Lubaczów, Łąkta, Mniszów, Pławowice, Tarnów and Wierzchosławice).

3. Miocene of the Carpathian Foredeep petroleum system:

Source rocks – Upper Badenian and Lower Sarmatian fine-grained clastics; Paleozoic-Mesozoic basement including USCB coal beds.

Reservoir rocks – Upper Badenian and Lower Sarmatian sands and sandstones for conventional accumulations; hybrid and unconventional accumulations in the fine-grained clastics and heterolithes.

Hydrocarbon deposits – 3 gas fields: Dębowiec Śląski, Pogórz and Kowale in the western part of the Carpathian Foredeep; 89 gas fields in the eastern part; 1 oil field (Cetynia).

Natural gas

Prospecting horizons	Number of deposits as of 31.12.2017	Anticipated economic resources as of 31.12.2017	Economic resources in place as part of anticipated economic resources as of 31.12.2017	Production in 2017
		[mln m^3]		
Precambrian + Miocene (undivided)	1	345.77	207.30	26.99
Devonian + Miocene (undivided)	3	2246.80	241.75	144.91
Lower Carboniferous	1	4.49	4.90	0.44
Triassic	1	-	-	-
Jurassic and Cretaceous + Miocene (undivided)	14	1977.35	710.35	81.23
Miocene of the Carpathian Foredeep	74	28961.2	7419.94	1057.65

According to the Balance of Mineral Resources Deposits in Poland as of 2017.

Crude oil

Prospecting horizons	Number of deposits as of 31.12.2017	Anticipated economic resources as of 31.12.2017	Economic resources in place as part of anticipated economic resources as of 31.12.2017	Production in 2017
		[kt]		
Lower Carboniferous	1	44.05	27.50	3.21
Jurassic and Cretaceous	10	476.35	33.33	12.75
Miocene of the Carpathian Foredeep	1	45.00	-	-

According to the Balance of Mineral Resources Deposits in Poland as of 2017.

4. Carpathian petroleum system:

Source rocks – Oligocene Menilite Beds (Kotarba et al., 2014; Matyasik et al., 2015) with important restrictions on the immaturity of these beds and no geochemical correlation between oils and Menilite shales in broad

Carpathian region; Jurassic-Cretaceous Spa, Istebna and Verovice shales; Oligocene-Miocene Krosno Beds; fine-grained clastics in the Paleozoic-Mesozoic basement (Jankowski, 2015).

Reservoir rocks – Grodziszcze, Lgota, Godule, Istebna, Inoceramian, Ciężkowice, Cergów, Magdalena, Kliwa and Krosno sandstones of the Dukla, Silesian, Sub-Silesian and Skole units.

Hydrocarbon deposits – 36 gas fields and 29 oil fields.

Natural gas

Prospecting horizons	Number of deposits as of 31.12.2017	Anticipated economic resources as of 31.12.2017	Economic resources in place as part of anticipated economic resources as of 31.12.2017	Production in 2017
		[mln m^3]		
Carpathians	36	1144.90	297.38	31.34

According to the Balance of Mineral Resources Deposits in Poland as of 2017.

Crude oil

Prospecting horizons	Number of deposits as of 31.12.2017	Anticipated economic resources as of 31.12.2017	Economic resources in place as part of anticipated economic resources as of 31.12.2017	Production in 2017
		[kt]		
Carpathians	29	680.55	143.93	22.49

According to the Balance of Mineral Resources Deposits in Poland as of 2017.

Wells. 7467 deep wells (> 500 m) were drilled in the Southern Petroleum Province, including 198 wells in the last 10 years (beginning from 2009).

Hydrocarbon concessions. 34 prospecting concessions of total acreage about 16681 km^2 (Ad. 1).

Petroleum subprovinces and regions. Three subprovinces, in which a petroleum systems occur, and one region with unconfirmed prospectivity have been distinguished in the Southern Petroleum Province (Ad. 1–2).

Upper Silesian Subprovince

The presence of the Carboniferous petroleum system of the USCB with hydrocarbons generated from the Carboniferous coal beds is characteristic feature of the subprovince. The presence of other petroleum systems (Paleozoic-Mesozoic, Miocene of the Carpathian Foredeep and Carpathian) is common in the remaining area of the Southern Petroleum Province. The boundaries of the subprovince are defined as the extent of the Ediacaran and Paleozoic of the Upper Silesian Block (compare to: Narkiewicz et al., 2017).

Carpathian Subprovince

The Carpathian Subprovince includes Polish part of the Outer Carpathians and its basement (excluding the area with the Ediacaran and Paleozoic of the Upper Silesian Block in the basement). The Paleozoic-Mesozoic, Carpathian and Carpathian Foredeep petroleum systems work in the subprovince.

Fore-Carpathian Subprovince

The Fore-Carpathian Subprovince includes Polish part of the Carpathian Foredeep and its basement between the front of the Carpathians (to the south and erosional range of the Carpathian Foredeep sediments (to the north). The Paleozoic-Mesozoic and Carpathian Foredeep petroleum systems work in the subprovince.

Małopolska Region

The Małopolska Region includes the NW part of the Małopolska Block, outside of the Carpathian units. The Paleozoic-Mesozoic petroleum system is supposed to work therein. However, there are still no oil and gas discoveries on the area.

Prospecting areas. Chybie, Kalwaria Zebrzydowska–Dobczyce, Żegocina and Nowa Dęba (total acreage 1781.175 km^2).

3.2. PROSPECTIVE AREAS

3.2.1. CHYBIE

(Rafał Laskowicz, Jerzy Hadro)

Fig. 3.1

Coordinates:

Border points	PL 1992	
	X	Y
1	222 153.81	493 303.33
2	222 035.78	488 885.90
3	218 455.96	488 980.84
4	218 434.63	482 690.08
5	226 659.30	482 557.17
6	228 475.40	483 189.30
7	229 417.61	483 167.35
8	229 422.37	493 418.39

Acreage: **100.697 km^2**

Geology and petroleum systems:

a) geological location: Outer Carpathians and Carpathian Foredeep;
b) basement: crystalline rocks of the Bielko-Biała dome, Upper Silesian Block (Żelaźniewicz et al., 2011);
c) tectonic-structural stages of sedimentary cover: Devonian and Carboniferous including USCB (Buła and Habryn, 2008; Kotas, 1982, 1983), Miocene of the Carpathian Foredeep, Silesian and Sub-Silesian units of the Carpathians;
d) petroleum location: Southern Petroleum Province, Upper Silesian Subprovince;
e) type of expected deposits: conventional and unconventional for gas;
f) petroleum systems: Carboniferous of the USCB, Paleozoic-Mesozoic, Miocene of the Carpathian Foredeep, Carpathian;
g) potential reservoir rocks: Middle and Upper Devonian and Lower Carboniferous carbonates, Lower Devonian and Upper Carboniferous sandstones, siltstones and sandstones of the Miocene Skawina Formation, sandstones of the Istebna, Ciężkowice and Krosno beds;
h) potential source rocks: Silurian shales, Middle and Upper Devonian carbonates, Lower Carboniferous fine-grained clastics (Kulm facies), Carboniferous coal beds, Badenian claystones and mudstones, Menilite Beds, Cieszyn Beds, Verovice Beds;
i) seal rocks: fine-grained clastic interbeds in the Miocene of the Carpathian Foredeep, fine-grained clastic interbeds in the Carpathian flysch successions;
j) thickness of the overburden: 100–1000 m;
k) expected traps: structural, lithological, unconventional.

Wells: **4 deep wells > 500 m**

Well name	Depth [m TVD]	Stratigraphy at the bottom
Chybie IG-1	1800.0	Upper Carboniferous
Zabłocie-1	1096.0	Upper Carboniferous
Zabłocie	1099.7	Upper Carboniferous
Zabłocie Korona	671.0	Miocene

Seismic survey (owner):

1977–1988 – 7 lines GZW 2D (State Treasury)
1990–1991 – 15 lines Skoczów 2D (PGNiG S.A)
22 lines 2D of total length 126.046 km

Oil and gas deposits discovered on the area and in its neighborhood: **4 fields**

Field name	Type
Kowale	GAS
Dębowiec	GAS
Pogórz	GAS
Silesia	CBM

Prospectivity:

The gas fields discovered in the Miocene of the Carpathian Foredeep and in the Carboniferous of the USCB in the neighboorhood, as well as gas shows observed in the Chybie IG-1 well, indicate high prospectivity of the area.

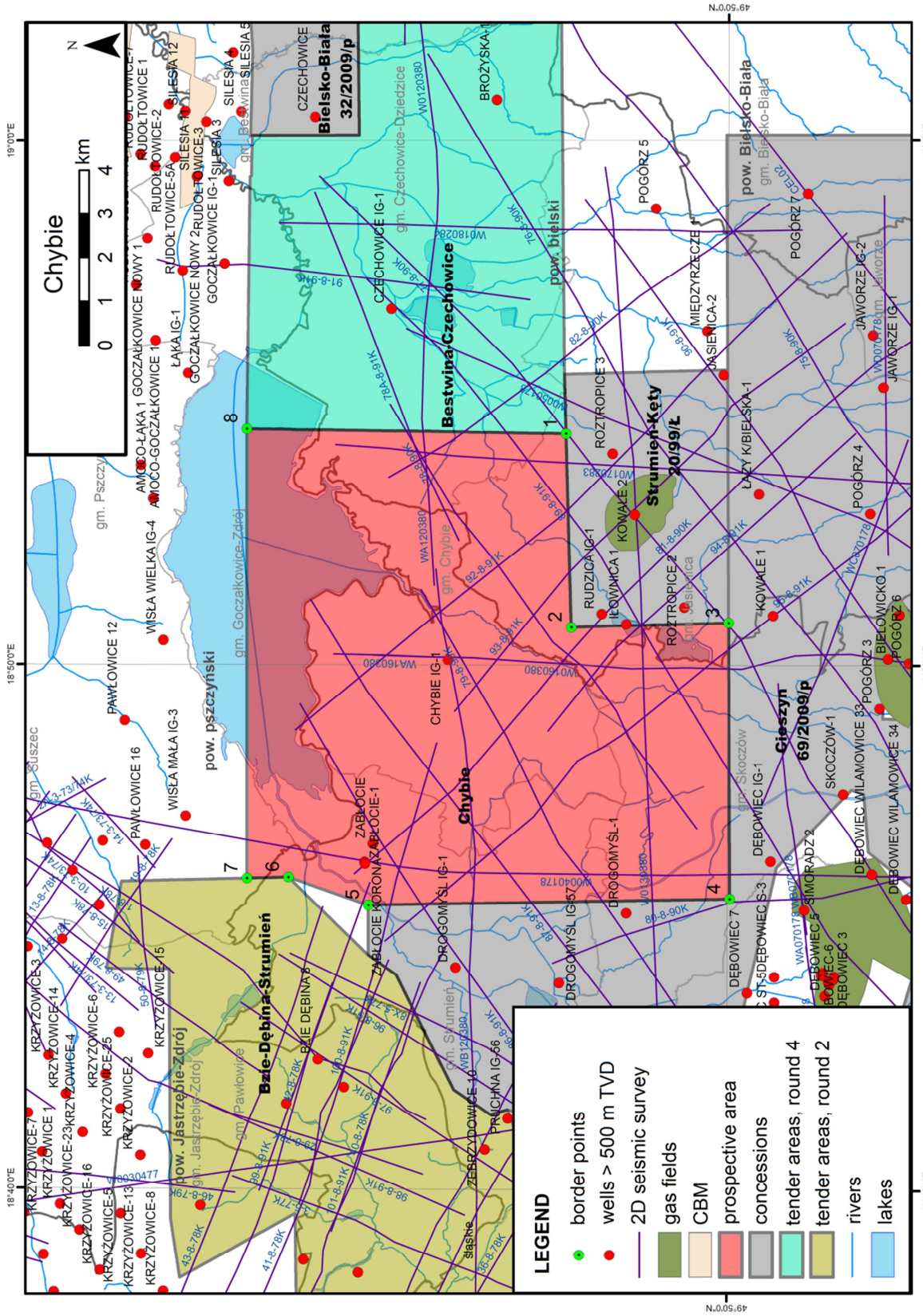

Fig. 3.1. Border points, seismic surveys, wells, hydrocarbon fields and hydrocarbon concessions on the Chybie area and in its neighborhood as of 28.02.2019 (CBDG, 2019).

3.2.2. KALWARIA ZEBRZYDOWSKA–DOBCZYCE

(Leszek Jankowski, Andrzej Szydło)
Fig. 3.2

Coordinates:

Border points	PL 1992	
	X	Y
1	234 844.36	560 392.57
2	230 642.81	560 453.66
3	230 896.96	571 608.57
4	230 992.76	574 100.13
5	230 011.54	572 315.44
6	228 395.66	572 458.46
7	229 408.06	574 430.69
8	229 434.99	575 429.65
9	230 147.53	577 410.08
10	230 743.62	578 393.80
11	230 687.12	577 395.51
12	231 067.40	576 041.64
13	231 446.80	585 909.50
14	231 619.15	587 161.05
15	230 387.33	586 612.41
16	230 574.94	585 908.57
17	230 006.10	585 907.97
18	219 097.84	585 896.39
19	219 005.58	580 176.25
20	221 144.84	580 743.36
21	221 028.90	577 051.28
22	218 918.27	574 085.44
23	218 677.07	553 795.86
24	219 634.17	553 786.28
25	218 661.71	552 238.18
26	218 462.26	543 731.87
27	227 842.28	543 481.10
28	237 088.56	543 233.92
29	237 383.66	566 195.31
30	236 207.60	566 125.53

Acreage: **615.816 km^2**

Geology and petroleum systems:

a) geological location: Outer Carpathians and Carpathian Foredeep;
b) basement: crystalline rocks of the Upper Silesian Block and Ediacaran of the Mało-polska Block (Żelaźniewicz et al., 2011);
c) tectonic-structural stages of sedimentary cover: Cambrian, Silurian, Devonian, Carboniferous, Jurassic and Cretaceous, allochtonous Miocene of the Zgłobice Unit, autochtonous Miocene of the Carpathian Foredeep, flysch of the Carpathian Silesian, Sub-Silesian and Skole units;
d) petroleum location: Southern Petroleum Province, Carpathian and Fore-Carpathian subprovinces;
e) type of expected deposits: conventional and unconventional for gas and oil;
f) petroleum systems: Paleozoic-Mesozoic, Miocene of the Carpathian Foredeep, Carpathian;
g) potential reservoir rocks: Ediacaran sandstones, Middle and Upper Devonian, Lower Carboniferous and Upper Jurassic carbonates, Badenian and Sarmatian siltstones and sandstones of the Carpathian Foredeep, Carpathian Istebna and Ciężkowice sandstones;
h) potential source rocks: Silurian shales, Middle and Upper Devonian carbonates, Lower Carboniferous fine-grained clastics (Kulm facies), Badenian claystones and mudstones, Menilite Beds, Cieszyn Beds, Grodziszcze Beds, Lgota Beds;
i) seal rocks: fine-grained clastic interbeds in the Miocene of the Carpathian Foredeep, fine-grained clastic interbeds in the Carpathian flysch successions;
j) thickness of the overburden: 500–1000 m;
k) expected traps: structural, lithological.

Wells: **28 deep wells > 500 m**

Well name	Depth [m TVD]	Stratigraphy at the bottom
BILCZYCE 4	1008.0	Upper Triassic
BOREK SZLACHECKI 1	1003.4	Carboniferous
BORZĘTA IG-1	3700.0	Lower Cambrian
BRZEZINKA 32	551.9	Carboniferous
BRZEŹNICA 25	840.5	Quartenery
DOBCZYCE 1	2188.0	Jurassic
DOBCZYCE 11	1682.0	Upper Jurassic
DOBCZYCE 2	2580.0	Triassic
DOBCZYCE 3	2125.0	Permian
DOBCZYCE 4	2256.0	Precambrian
DOBCZYCE 5	1912.0	Miocene
DOBCZYCE 6	1983.0	Jurassic
DOBCZYCE 8	2408.0	Carboniferous
DOBCZYCE 9	1960.0	Upper Jurassic
GDÓW 1	959.1	Jurassic
GDÓW 5	755.0	Jurassic
GŁOGOCZÓW IG-1	3800.0	Cambrian
LEŃCZE IG-1	1682.0	Carboniferous
NIŻOWA 1	1605.0	Triassic
NOWE DWORY	870.4	Miocene
RACIBORSKO 6	955.0	Miocene
RZESZOTARY	840.3	Miocene
RZESZOTARY 2	965.2	Miocene
STADNIKI 1	505.0	Miocene
WIATOWICE 1	514.5	Miocene
WIATOWICE 3	860.0	Jurassic
WIŚNIOWA 4	2602.0	Triassic
WIŚNIOWA 6	2456.0	Precambrian

Seismic survey (owner):*

1972 – 1 line Andrychów-Jordanów 2D (ST)
1973 – 1 line Andrychów-Myślenice 2D (ST)
1974 – 1 line Myślenice-Sucha-Rabka 2D (ST)
1975 – 1 line Sucha-Rabka-Nowy Targ 2D (ST)
1978–1984 – 7 lines GZW 2D (ST)
1978 – 4 lines Żywiec-Wadowice-Gdów 2D (ST)
1986–1988 – 13 lines Sk.-Wadowice 2D (ST)
1987 – 1 line Niepołomice-Myślenice 2D (ST)
1989–1992 – 17 lines Dobcz. 2D (PGNiG S.A.)
1992–1995 – 10 lines Myślen. 2D (PGNiG S.A.)
1993–1995 – 12 lines Lachow. 2D (PGNiG S.A.)
1994 – 4 lines Liplas-Żukowice 2D (PGNiG S.A.)
2000 – 1 line CELEBRATION 2000 (ST)
2001–2002 – 11 lines Raciech. 2D (PGNiG S.A.)
2004 – 5 lines Kamyk-Niep. 2D (PGNiG S.A)
89 lines 2D of total length 561.692 km

* State Treasury

Oil and gas deposits discovered on the area and in its neighborhood: **7 fields**

Field name	Type
Grabina-Nieznanowice	GAS
Grabina-Nieznanowice S	GAS
Lachowice-Stryszawa	GAS
Łapanów	GAS
Łąkta	GAS
Raciborsko	GAS
Słopnice	GAS

Prospectivity:
The gas fields discovered in the Miocene of the Carpathian Foredeep and in the Jurassic basement in the neighboorhood, as well as high-resolution geological data, indicate high prospectivity of the area.

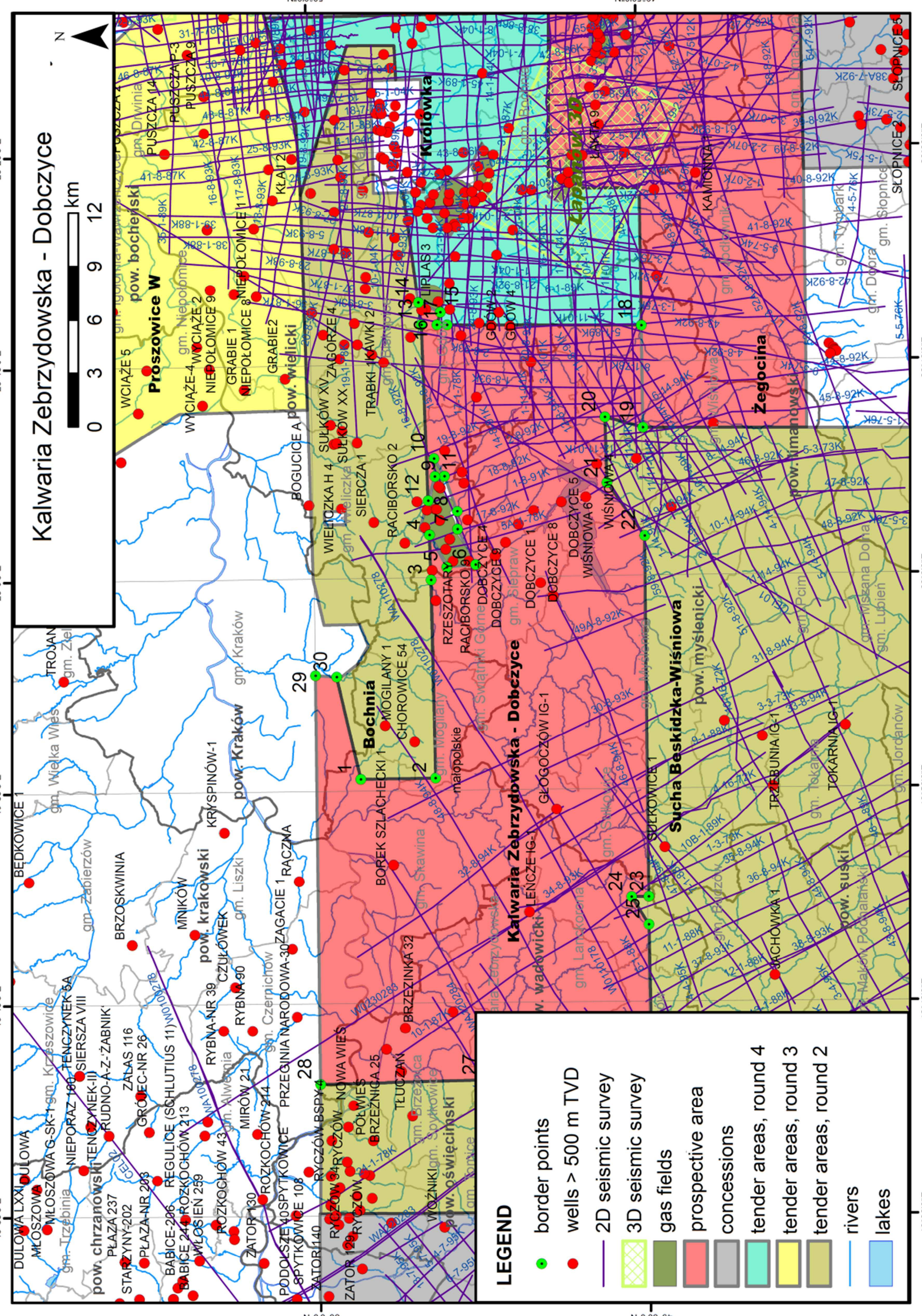

Fig. 3.2. Border points, seismic surveys, wells, hydrocarbon fields and hydrocarbon concessions on the Kalwaria Zebrzydowska–Dobczyce area and in its neighborhood as of 28.02.2019 (CBDG, 2019).

3.2.3. ŻEGOCINA

(Leszek Jankowski, Andrzej Szydło)

Fig. 3.3.

Coordinates:

Border points	PL 1992	
	X	Y
1	224 429.40	619 471.74
2	219 993.39	619 456.98
3	219 830.52	619 456.53
4	219 734.09	619 456.21
5	219 733.96	619 456.22
6	219 733.95	619 456.07
7	219 733.92	619 454.87
8	214 616.64	619 436.49
9	210 523.09	619 421.78
10	209 976.71	594 697.07
11	209 794.17	580 172.71
12	219 005.58	580 176.25
13	219 097.84	585 896.39
14	219 222.83	593 635.80
15	222 376.00	593 612.00
16	222 475.00	595 313.00
17	223 236.00	595 405.00
18	223 368.00	594 800.00
19	224 307.00	594 218.00
20	224 314.01	603 486.16
21	224 429.40	619 471.74
22	221 109.37	600 644.87
excluding the area:		
23	220 816.08	601 652.51
24	220 862.49	603 390.93
25	220 125.97	603 450.34
26	219 833.40	602 978.16
27	220 557.32	602 379.11
28	219 798.82	601 679.44
29	219 475.77	602 687.75
30	220 292.07	604 055.74
31	220 865.93	604 200.42
32	221 457.15	604 634.48
33	222 010.11	603 619.97
34	221 956.85	601 621.88
35	221 510.53	600 634.09

Acreage: **480.493 km^2**

Geology and petroleum systems:

a) geological location: Outer Carpathians;
b) basement: crystalline rocks of the Upper Silesian Block and Ediacaran of the Małopolska Block (Żelaźniewicz et al., 2011);
c) tectonic-structural stages of sedimentary cover: Cambrian, Silurian, Devonian, Carboniferous, Jurassic and Cretaceous, allochtonous Miocene of the Zgłobice Unit, flysch of the Carpathian Silesian, Sub-Silesian and Skole units;
d) petroleum location: Southern Petroleum Province, Carpathian Subprovince;
e) type of expected deposits: conventional and unconventional for oil and gas;
f) petroleum systems: Paleozoic-Mesozoic, Miocene of the Carpathian Foredeep, Carpathian;
g) potential reservoir rocks: Precambrian sandstones (hypothetically), Middle and Upper Devonian, Lower Carboniferous and Upper Jurassic carbonates, Cretaceous sandstones, Badenian and Sarmatian siltstones and sandstones of the Carpathian Foredeep, Istebna and Ciężkowice sandstones;
h) potential source rocks: Silurian shales, Middle and Upper Devonian carbonates, Lower Carboniferous fine-grained clastics (Kulm facies), Badenian and Sarmatian claystones and mudstones, Menilite Beds, Cieszyn Beds, Grodziszcze Beds, Lgota Beds;
i) seal rocks: fine-grained clastic interbeds in the Miocene of the Carpathian Foredeep, fine-grained clastic interbeds in the Carpathian flysch successions;
j) thickness of the overburden: 500–1000 m;
k) expected traps: structural, lithological.

Wells: **31 deep wells > 500 m**

Well name	Depth [m TVD]	Stratigraphy at the bottom
CZCHÓW 1	3216.0	Upper Jurassic
IWKOWA 1	3228.0	Carboniferous
JAWORZNA 1	3214.1	Cretaceous
KAMIONNA 1	2566.9	Cretaceous
LESZCZYNA 1	2410.0	Triassic
LESZCZYNA 2	2305.0	Jurassic
LESZCZYNA 21	2564.6	Jurassic
LESZCZYNA 22	2600.0	Jurassic
LESZCZYNA 3	2550.0	Jurassic
LESZCZYNA 4	2850.0	Triassic
LIPNICA GÓRNA 1	2710.0	Jurassic
ŁAPANÓW 2/2K	2050.0	Upper Jurassic
ŁĄKTA 11	2588.0	Miocene
ŁĄKTA 13	2461.0	Upper Jurassic
ŁĄKTA 14	2473.0	Miocene
ŁĄKTA 22	2511.0	Jurassic
ŁĄKTA 24	3150.0	Jurassic
ŁĄKTA 25	2423.0	Upper Jurassic
ŁĄKTA 30K	2746.4	Jurassic
ŁĄKTA 4	2438.8	Jurassic
ŁĄKTA 9	2382.0	Upper Jurassic
MUCHÓWKA 1	2620.0	Jurassic
MUCHÓWKA 2	2804.0	Upper Jurassic
POŁOM DUŻY 2	2630.0	Jurassic
RAJBROT 1	4948.0	Silurian
RAJBROT 2	4185.0	Paleozoic
TARNAWA 1	5510.0	Upper Devonian
TYMOWA 1	3740.0	Lower Carboniferous
WIŚNIOWA IG-1	2931.2	Miocene
WOLICA 1	3177.5	Upper Permian
ŻEGOCINA 1	3509.0	Carboniferous

Seismic survey (owner):*

1974 – 1 line Limanowa-Nowy Sącz 2D (ST)
1974 – 1 line Myślenice-Sucha-Rabka 2D (ST)
1975 – 1 line PGSS PAN 2D (ST)
1975 – 2 lines Słopnice-Nowy Sącz 2D (ST)
1975 – 3 lines Sucha-Rabka-Nowy Targ 2D (ST)
1977 – 3 lines Bochnia-Czchów-Pilzno 2D (ST)
1978 – 1 line Żywiec-Wadowice-Gdów 2D (ST)
1983–1986 – 16 lines Wiśniowa-Łąkta 2D (ST)
1985 – 1 line Tuchów-Kowalowy 2D (ST)
1988 – 2 lines Niepołomice-Gdów 2D (ST)
1989–1992 – 11 lines Dobcz. 2D (PGNiG S.A.)
1992–1995 – 44 lines Myślen. 2D (PGNiG S.A.)
2000 – 1 line CELEBRATION 2000 (ST)
2004 – 9 lines Kamyk-Niep. 2D (PGNiG S.A)
2005 – 12 lines Wiśnicz 2D (PGNiG S.A)
2007 – 22 lines Tarn.-Czchów 2D (PGNiG S.A)

2012 – 13 lines Kamionna-Łososina 2D (ST)
143 lines 2D of total length 1465.855 km with fragment of the Łapanów 3D seismic survey
* State Treasury

Oil and gas deposits discovered on the area and in its neighborhood: **13 fields**

Field name	**Type**
Brzezowiec I,II	GAS
Dąbrówka	GAS
Grabina-Nieznanowice	GAS
Grabina-Nieznanowice S	GAS
Grądy Bocheńskie	GAS
Jadowniki	GAS
Łapanów	GAS
Łazy	GAS
Łąkta	GAS
Łętowice-Bogumiłowice	GAS
Raciborsko	GAS
Słopnice	GAS
Szczepanów	GAS

Prospectivity:

The gas fields discovered in the Miocene of the Carpathian Foredeep and in the Jurassic basement within and in the neighborhood of the Żegocina area indicate high prospectivity for conventional and unconventional discoveries.

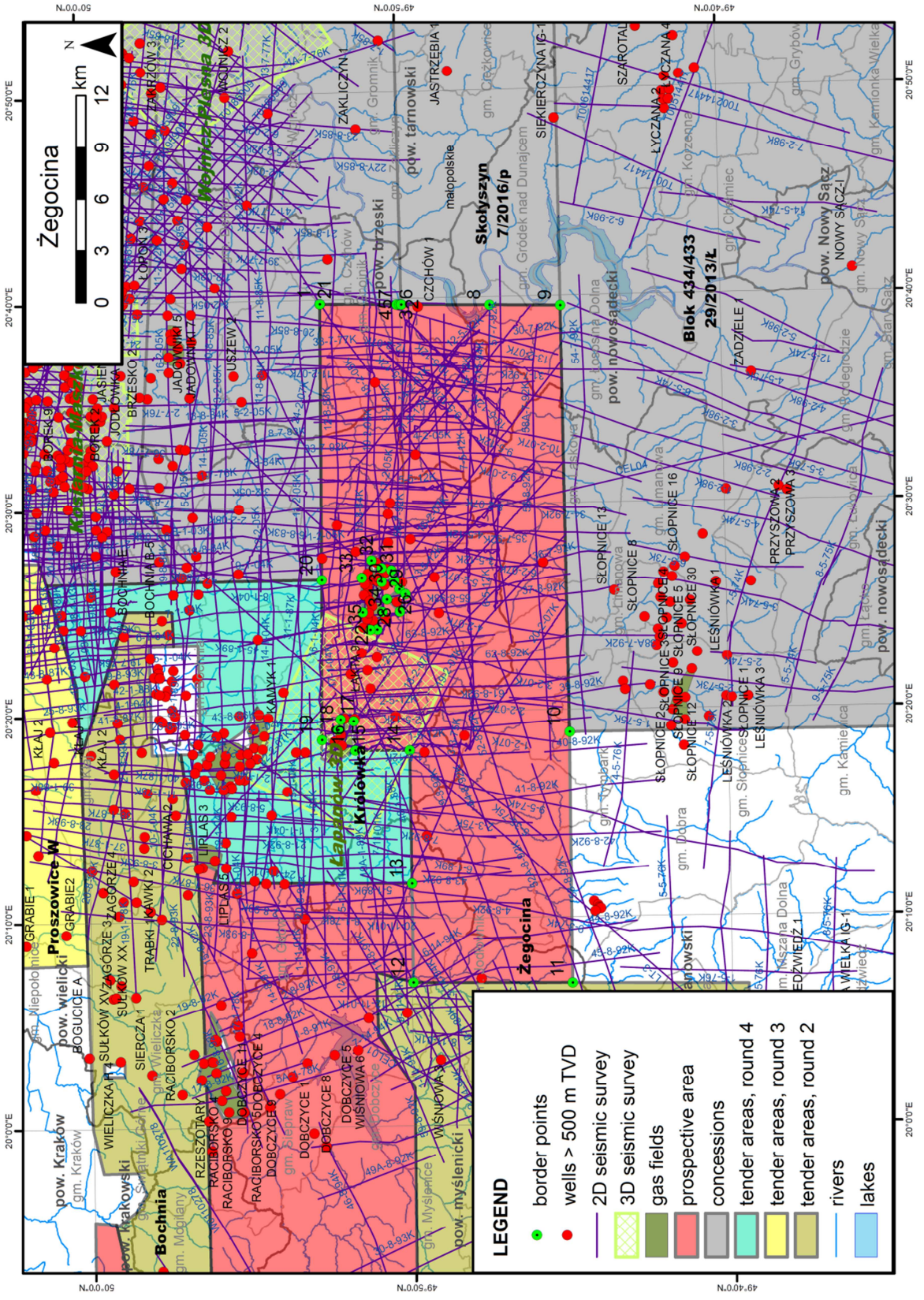

Fig. 3.3. Border points, seismic surveys, wells, hydrocarbon fields and hydrocarbon concessions on the Żegocina area and in its neighborhood as of 28.02.2019 (CBDG, 2019).

3.2.4. NOWA DĘBA

(Małgorzata Garecka, Leszek Jankowski, Andrzej Szydło)

Fig. 3.4

Coordinates:

Border points	PL 1992	
	X	Y
1	296 831.15	712 681.39
2	282 871.88	713 244.88
3	278 512.41	703 100.24
4	278 002.46	677 845.11
5	294 522.05	677 289.44
6	291 497.74	682 596.08
7	291 459.64	685 375.92
8	295 800.79	685 256.08
9	296 510.27	704 411.18

Acreage: **584.168 km^2**

Geology and petroleum systems:

a) geological location: Carpathian Foredeep;
b) basement: Ediacaran of the Małopolska Block (Żelaźniewicz et al., 2011);
c) tectonic-structural stages of sedimentary cover: Cambrian, autochtonous Miocene of the Carpathian Foredeep (Kowalewski, 1957; Łyczewska, 1972; Wągrowski, 1992; Garecka and Jugowiec, 1999; Krakowska et al., 2018);
d) petroleum location: Southern Petroleum Province, Fore-Carpathian Subprovince;
e) type of expected deposits: conventional and unconventional for gas;
f) petroleum systems: Miocene of the Carpathian Foredeep;
g) potential reservoir rocks: Ediacaran and Cambrian sandstones (hypothetically), Badenian and Sarmatian siltstones and sandstones of the Carpathian Foredeep;
h) potential source rocks: Badenian and Sarmatian claystones and mudstones;
i) seal rocks: fine-grained clastic interbeds in the Miocene of the Carpathian Foredeep;
j) thickness of the overburden: 5–100 m;
k) expected traps: structural, lithological.

Wells: **14 deep wells > 500 m**

Well name	Depth [m TVD]	Stratigraphy at the bottom
BRAZYLIA 1	1001.8	Miocene
BRZOSTOWA GÓRA 1	811.0	Precambrian
DURDY 123	515.0	Miocene
GWOŹDZIEC 1	745.8	Cambrian
GWOŹDZIEC P-10 BIS	582.0	Precambrian
KOMORÓW 1	829.2	Cambrian
KOMORÓW 2	737.0	Precambrian
KOMORÓW 3	691.0	Precambrian
KORABINA P-8	591.0	Miocene
KRZĄTKA P-12	514.0	Precambrian
KRZĄTKA P-9	580.0	Miocene
PORĘBY DĘBSKIE P-11	500.0	Precambrian
PORĘBY DĘBSKIE P-12	544.5	Miocene
ROZALIN 51	513.0	Miocene

Seismic survey (owner):*

1978 – 1 line PGSS PAN 2D (ST)
1987–1992 – 19 lines Mielec 2D (PGNiG S.A.)
1992 – 2 lines Krzeszów-Łańcut 2D (ST)
2000 – 1 line CELEBRATION 2000 (ST)
2001–2002 – 3 lines Mielec 2D (PGNiG S.A.)
26 lines 2D of total length 191.086 km
* State Treasury

Oil and gas deposits discovered on the area and in its neighborhood: **12 fields**

Field name	Type
Blizna-Ocieka	GAS
Jata	GAS
Jeżowe NW	GAS
Korzeniów	GAS
Korzeniów (gas)	GAS
Kupno	GAS
Lipnica-Dzikowiec	GAS
Niwiska	GAS
Niwiska	GAS
Nowosielec	GAS
Sarzyna	GAS
Sokołów	GAS

Prospectivity:

Numerous conventional gas fields discovered in the neighborhood, possible unconventional accumulations in the fine-grained sediments and heterolithic series of the Miocene succession, as well as simple geological structural features indicate high prospectivity of the Nowa Dęba area.

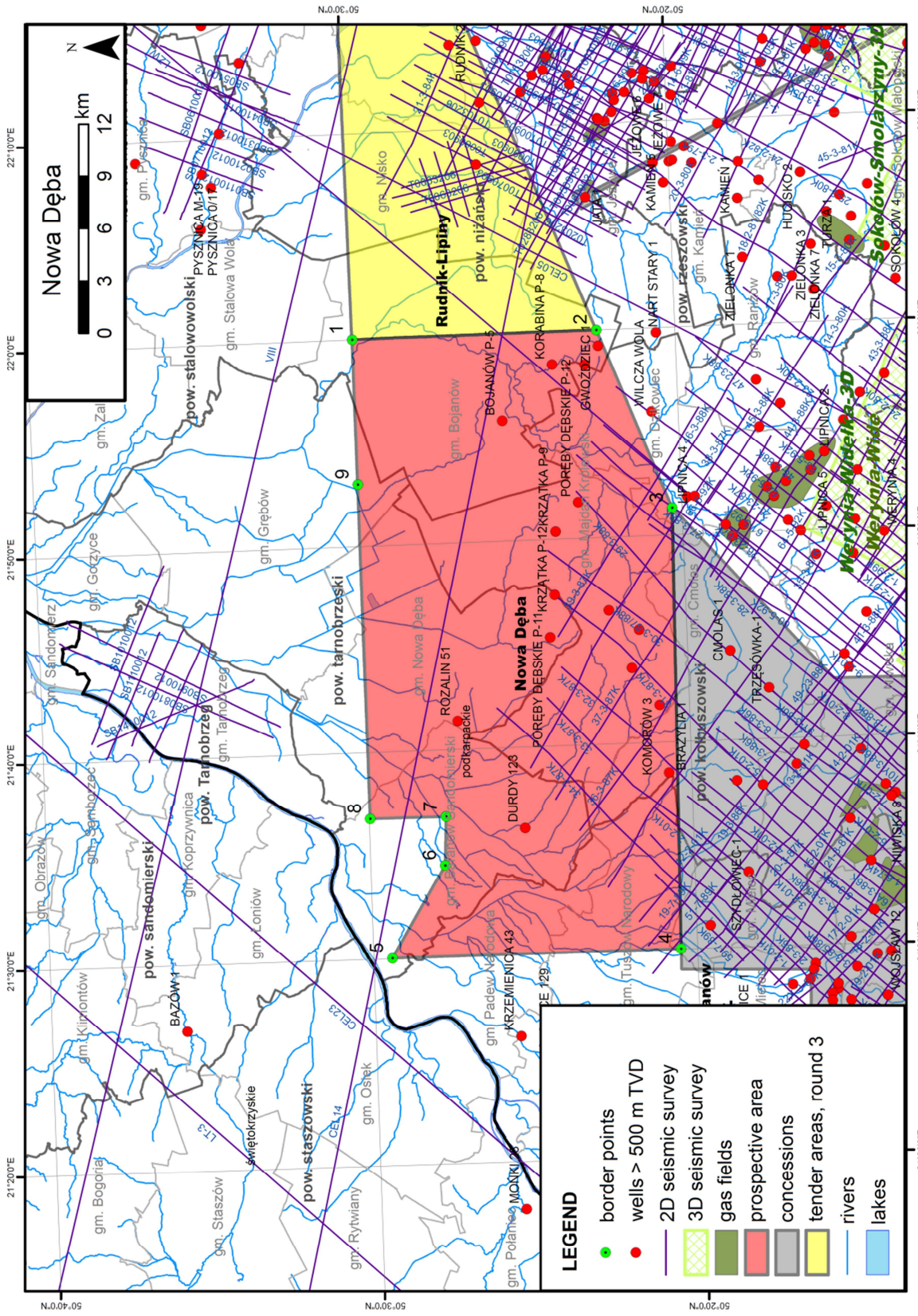

Fig. 3.4. Border points, seismic surveys, wells, hydrocarbon fields and hydrocarbon concessions on the Nowa Dęba area and in its neighborhood as of 28.02.2019 (CBDG, 2019).

4. WESTERN PETROLEUM PROVINCE
4.1. DESCRIPTION

Boundaries. According to the Geological Atlas of Poland (Nawrocki and Becker, 2017) and Tectonic Subdivision of Poland (Żelaźniewicz et al., 2011) the Western Petroleum Province includes the Variscan Externides and Variscan foreland basin with their Permian-Mesozoic cover, and the basement of the West European Platform (Ad. 1–2).

The boundaries are defined as:

- TTZ to the north;
- Odra Fault Zone to the south;
- extent of Carboniferous rocks of the Variscan foreland basin to the east.

Two petroleum provinces – Pomerania and Wielkopolska – were earlier distinguished in the western part of Poland (Karkowski, 1997, 2007). Their separation was a consequence of different geological history (Caledonian *vs* Variscan consolidation of the basement) and isolation of oil- and gas-bearing regions. However, the Rotliegend and Main Dolomite are the main reservoir horizons in both provinces. They originated after Paleozoic consolidation during younger tectonic-sedimentary (Permian-Mesozoic) cycle. This formed a complicated petroleum system, in which the distribution of source rocks (Carboniferous and older Paleozoic rocks) is related to the Variscan tectonic plan, while reservoir rocks are distributed according to the Laramide plan. Both, the Rotliegend and the Main Dolomite sediments, were deposited in large sedimentary basins, which covered the Pomerania and Wielkopolska regions. Therefore, both areas are treated as subprovinces (Ad. 1–2).

Acreage. ~118 600 km^2.

Geology. Three large-scale geological units can be distinguished in the Western Petroleum Province: Western Pomerania Block, Variscan Externides and Permian-Mesozoic cover.

Western Pomerania Block includes (Ad. 2–3):

- Lower Paleozoic rocks of the Caledonian basement (a part of the Pomerania-Kujawy Caledonian fold belt);
- Upper Paleozoic (Devonian and Carboniferous) rocks of the Variscan cover (a part of the Variscan foreland basin);
- Permian-Mesozoic cover (including Szczecin-Gorzów Depression, NW part of the Mid-Polish Anticlinorium and Koszalin Depression as the main tectonic units);
- Cenozoic cover.

The oldest rocks were recognized in the NE part of the Western Pomerania, close to the TTZ. These are the thick series of the Middle and Upper Ordovician claystones (Podhalańska and Modliński, 2006), deposited in the Caledonian Foredeep basin (Poprawa et al., 2006) and folded and thrusted during Caledonian orogeny (Żaba and Poprawa, 2006). They are locally overlain by the Silurian (Landovery, Wenlock and Ludlow) claystones and mudstones with sandstone intercalations. The Devonian and Lower Carboniferous constitute a continuous cover of the Caledonian basement being formed of marine deposits with an important contribution of carbonates (Matyja, 1993, 2009). Siliciclastics, mostly sandstones, of the Upper Carboniferous occur only in the western part of the area, being completely eroded in the eastern part during Late-Carboniferous regression and orogenic movements at the turn of the Carboniferous and Permian. The deposition of the Lower Rotliegend siliciclastics occurred in several small sedimentary basins separated by eroded tectonic blocks. A deep faults favored volcanic eruptions, pyroclastic sedimentations and lava flows. Sedimentation of the Upper Rotliegend began with an important gap of about 10 My (Nawrocki, 1995), initiated the development of the Permian-Mesozoic basins on the Polish Lowland. The Upper Rotliegend includes conglomerates, sandstones and siltstones deposited in the fluvial, aluvial and playa environments with an important contribution of aeolian sandstones (Kiersnowski and Buniak, 2006). The late-Permian transgression brought a cyclic sedimentation of thick Zechstein carbonate-evaporite series. Only in the eastern part of the Western Pomerania some tectonic blocks formed an archipelago of isolated islands (Dadlez et al., 1998).

The Triassic succession in the Western Pomerania is complete and includes clastic continental and carbonate-clastic marginal-marine deposits of the lower series, carbonate-evaporitic and clastic marine sediments of the middle series, and continental siliciclastics with evaporitic intercalations of the Upper Triassic. However, stratigraphic gaps in the Upper Triassic are observed over the salt pillows. The thickness of the Triassic succession is from 900 m (at the flanks of the Mid-Polish Anticlinorium), up to the 2500 m (at the axis). Also the Jurassic succession is complete in almost whole area. Lack of the Toarcian occurs in the axial part of the Pomerania Swell, while lack of the Lower Jurassic occurs also in the Świdwin area. The Lower Jurassic is built of interstratified complexes of continental and marginal-marine sandstones and claystone-mudstones (Pieńkowski, 2004), of total thickness of about 400–1100 m (Franczyk, 1987). The Middle Jurassic occur in the flanks of the Kujawy Swell and in the Pomerania, Szczecin and Mogilno-Łódź depressions, as well as in the NW part of the Pomerania Swell. The Middle Jurassic succession, if complete, is built of complexes of marine claystone-mudstones and sandstones of Aalenian-Callovian interval (Dayczak-Calikowska and Moryc, 1988). The maximal thickness is about 500 m. Following to the axis of the Mid-Polish Anticlinorium, the Middle Jurassic is less complete, even to the complete absent. The Upper Jurassic occur only

in the Pomerania and Mogilno-Łódź depression and near the boundary between the Pomerania Swell and Szczecin Depression (Brochwicz-Lewiński, 1987; Dembowska 1979a). The Oxfordian and Lower Kimmeridgian in the NW part is built of marine siliciclastics and clastic carbonates, while in the SE part carbonates prevail (Dembowska, 1979b). Higher part of the Upper Jurassic is built of Upper Kimmeridgian and Tithonian marls and mud-stones, while shallow-marine Tithonian limestones occur at the top. The thickness of the Upper Jurassic is from 100 to 900 m. The Lower Cretaceous occurs only in the northern part of the Szczecin and Mogilno-Łódź depressions (Raczyńska, 1979, 1987). The succession of marine siliciclastics with limestones and evaporites at the base occurs. The maximal thickness is about 400 m. The Upper Cretaceous has similar distribution, and the succession, of maximal thickness reaching 1400 m, is built of limestones, marly limetsones, marls, gaizes and "opokas" (Jaskowiak-Schoeneichowa, 1979, 1987).

The Wielkopolska part of the Western Petroleum Province includes the Variscan Externides in the basement, covered by the Permian-Mesozoic (Fore-Sudetic Monocline and NW and central part of the Szczecin-Miechów Synclinorium), and Cenozoic sedimentary covers. The oldest rocks belong to the Devonian, composed of metamorphic quartz sericite phyllites of the so-called Leszno Block (Żelaźniewicz et al., 2011; Kiersnowski, 2016). Strongly folded Lower Carboniferous Kulm facies (conglomerates, sandstones, siltstones and claystones) and marly carbonates occur above (Kiersnowski et al., 2017). The Upper Carboniferous occurs only in the NE part (Żelichowski, 1995). The total thickness of the Carboniferous is unknown, probably exceeds 2500 m (Nawrocki and Becker, 2017). The succession was strongly faulted which led to the formation of numerous ridges, grabens and half-grabens as an effect of post-Variscan extension (Pożaryski et al., 1992; Antonowicz et al., 1994). Above, a broad cover of lavas and pyroclastics of the Lower Rotliegend occurs. The Saalian movements in the mid-Permian caused the rejuvenation of the Variscan relief and development of a stratigraphic gap between the Lower and Upper Rotliegend. The Wolsztyn Ridge was formed during this phase (Zawierucha, 2011). Three sedimentary environments – aeolian, fluvial and playa – prevailed during the sedimentation of the Upper Rotliegend. The facies development, and especially the thickness, were related to paleomorphology and synsedimentary fault activity (Kiersnowski and Buniak, 2006). These facies are covered by marine sediments of four Zechstein cyclothemes. In terms of hydrocarbon prospectivity, the most important is the Main Dolomite horizon in the second cyclothem, built of basin, platform-slope and shallow-marine platform carbonates (Wagner, 1994; Dadlez et al., 1998; Jaworowski and Mikołajewski, 2007). According to Kiersnowski et al. (2017), the Main Dolomite paleogeography were an effect of the relief inherited after the deposition of the Upper Anhydrite of the first cyclothem, when the anhydrite platforms and their slopes developed.

The Triassic succession in the Wielkopolska is complete and includes carbonate-clastic marginal-marine deposits of the lower series, carbonate-evaporitic and clastic marine sediments of the middle series, and continental siliciclastics with evaporitic intercalations of the Upper Triassic (Szyperko-Śliwczyńska, 1977; Kulikowski, 1977, 1979; Gajewska, 1977, 1979; Gajewska and Szyperko-Teller, 1979). Rhaetian is absent only in the western part. The thickness of the Triassic succession is from 1400 to 1500 m. The complete Jurassic of about 200–400 m in thickness occurs only in the western part. The succession is built of alternating complexes of continental and marginal-marine sandstones and fine-grained clastics (Pieńkowski, 2004). Lack of the Lower Jurassic Hettangian, Sinemurian and Toarcian sediments occurs in the eastern part, where, in extreme cases, only about 20 m of Pliensbachian sandstones appears. The Middle Jurassic rocks occur in the N, NE and E part, in the Szczecin and Mogilno-Łódź depressions. The Bajocian-Callovian succession is represented by marine siliciclastics of thickness up to 200 m (Dayczak-Calikowska, 1977, 1979). Stratigraphic condensation and gaps occur in the lower part. The distribution of the Upper Jurassic sediments is even narrower within the Szczecin and Mogilno-Łódź depressions, as an effect of the later erosional events (Dembowska, 1977, 1979a, b). The Oxfordian and Lower Kim-meridgian is built of open-marine clastic (claystones, siltstones, sandstones) and carbonate (limestones) sediments. The uppermost part of the Upper Jurassic is built of marls and silt-stones. The total thickness of the Upper Jurassic is up to 700 m. The complete Lower Cretaceous succession appears only in the depresssions flanked the Mid-Polish Antyclinorium, and only Bar-remian-Albian sediments have wider distribution (Marek, 1977; Raczyńska, 1979). The Lower Cretaceous is composed of marine siliciclastics with limestones and evaporites in the lower part. Its total thickness is up to 300 m. The Upper Cretaceous is widely distributed and represented by limestones and marly limestones, marls, "opokas" and gaizes (Jaskowiak-Schoeneichowa, 1979, 1987). The thickness is over 2000 m in the central part of the Mogilno Depression.

Petroleum systems.

1. Carboniferous-Permian Petroleum System:
   Source rocks – Carboniferous claystones and mudstones; Ordovician claystones.
   Reservoir rocks – Lower Carboniferous carbonates and clastics, Upper Carboniferous

clastics, Rotliegend sandstones, Zechstein Limestone carbonates.

Traps – paleogeomorphological, structural, mixed.

Seal – Zechstein evaporites.

Hydrocarbon deposits – 84 gas deposits in the Carboniferous, Rotliegend and Zechstein Limestone and 1 oil deposit in the Zechstein Limestone.

Natural gas

Prospecting horizons	Number of deposits as of 31.12.2017	Anticipated economic resources as of 31.12.2017	Economic resources in place as part of anticipated economic resources as of 31.12.2017	Production in 2017
		[mln m^3]		
Carboniferous	4	1692.16	359.83	63.01
Carboniferous and Rotliegend (undivided)	2	636.93	31.63	11.08
Rotliegend	62	22865.6	8438.59	1088.49
Rotliegend and Zechstein Limestone (undivided)	5	18013.3	15286.2	948.96
Zechstein Limestone	7	1750.88	974.49	124.17
Rotliegend and Main Dolomite (undivided)	4	2392.01	695.84	28.13
Main Dolomite	59	28862.04	11067.92	1341.66

According to the Balance of Mineral Resources Deposits in Poland as of 2017.

Crude oil

Prospecting horizons	Number of deposits as of 31.12.2017	Anticipated economic resources as of 31.12.2017	Economic resources in place as part of anticipated economic resources as of 31.12.2017	Production in 2017
		[kt]		
Zechstein Limestone	1	472.83	254.31	8.04
Main Dolomite	36	15041.85	7967.12	682.99

According to the Balance of Mineral Resources Deposits in Poland as of 2017.

2. Permian/Zechstein petroleum system:

Source rocks – Main Dolomite organic-rich interbeds.

Reservoir rocks – Main Dolomite carbonates (shallow-marine carbonate platform of ooid and oolite facies; packstones, wackstones and mudstones of the carbonate platform slopes with secondary porosity; see: Depowski and Peryt, 1985; Protas and Wojtkowiak, 2000; Jaworowski and Mikołajewski, 2007; Słowakiewicz and Mikołajewski, 2009; Czekański et al., 2010). Secondary porosity is related to multi-stage diagenetic processes. In the extreme cases, the highest porosity is related to dolomitization and recrystallization of limestones (Czekański et al., 2010).

Traps – stratigraphic-structural.

Seal – Zechstein evaporites.

Generation, migration and accumulation of hydrocarbons – oil and gas in the Main Dolomite are syngenetic, generated from deeper basin and barrier facies (Pikulski, 1998). III-type kerogen predominates, and organic matter is mature (oil window). Migration and accumulation of hydrocarbons occurred during two phases. The first took place before the Cimmerian movements, when most of stratigraphic traps were formed. The second phase of migration was related to the formation of structural traps after the Cimmerian tectonic reorganization. However, the older traps were probably preserved (Pikulski, 1998).

Hydrocarbon deposits – 63 gas deposits (including 4 deposits producing simultaneously from the Rotliegend and Main Dolomite) and 36 oil deposits.

3. Mesozoic petroleum system:

Source rocks – lower Keuper, Lower Jurassic (Zagaje and Łobez formations), Middle Jurassic (Aalenian, Bajocian and Bathonian black shales), Upper Jurassic (Łyna and Pałuki formations) (Bachleda-Curuś et al., 1992). The Upper Jurassic contains oil-and-gas-prone type II/III kerogen, while the other horizons – the gas-prone type III kerogen.

Reservoir rocks – Lower Jurassic sandstones (aluvial sandstones of the Zagaje and Borucice formations, near-shore sandstones of the Ostrowiec Formation), Middle Jurassic sandstones (near-shore Bajocian and Bathonian sandstones), Lower Cretaceous sandstones (near-shore sandstones of the Włocławek and Mogilno formations). The biohermal, organodetritic and oolitic Oxfordian limestones and Lower Kimmeridgian, Lower Berriasian and Upper Tithonian limestones can play a role of reservoir rocks, as well.

Generation, migration and accumulation of hydrocarbons – effective hydrocarbon generation occured in the Kujawy Anticlinorium and in the SE part of the Pomerania Anticlinorium and Pomerania Synclinorium, and in this fragment of the Szczecin Synclinorium, which is close to the Pomerania and Mogilno-Łódź synclinoria (Burzewski i in., 1990; Bachleda-Curuś and in., 1992). The hydrocarbon accumulations are expected in deeply buried Jurassic and Cretaceous rocks located close to the major faults, which supported migration paths (Karnkowski, 1993, 1999). The traps can occur in the antyclines related to the salt pillows and salt diapirs, as well as in the Oxfrodian bioherms, and anticlines developed in the Tithonian limestones.

The main phase of generation occurred during the Late Cretaceous and Neogene, while the beginning of the migration took place in the Neogene. The traps could have been destroyed during the Laramide tectonic movements in the Neogene. The best chance for hydrocarbon accumulations occur in the flanks of synclinoria, where lithological traps could be preserved (Bachleda-Curuś et al., 1992).

Hydrocarbon deposits – none.

Wells. 3501 deep wells (> 500 m), in which 156 wells were drilled in the last 10 years (beginning from 2009).

Hydrocarbon concessions. 33 concessions of total acreage ~24336 km^2 (Ad. 1).

Petroleum subprovinces and regions. Two subprovinces, in which petroleum systems occur, and one region with unconfirmed prospectivity have been distinguished in the Western Petroleum Province (Ad. 1–2).

Wielkopolska-Silesian Subprovince

The Wielkopolska-Silesian Subprovince is bordered by the Variscan Deformation Front to the north, Odra Fault Zone to the south, and northern edge of the Łódź Depression to the east (Nawrocki and Becker, 2017). The Carboniferous-Permian and Permian/ Zachstein petroleum systems work in the area, while the Mesozoic system is still not confirmed.

Western Pomerania Subprovince

The Western Pomerania Subprovince is bordered by the TTZ to the north, and maximal range of the Variscan Deformation Front to the south (Nawrocki and Becker, 2017; Ad. 1–2). The Carboniferous-Permian and Permian/ Zachstein petroleum systems are confirmed, while the Mesozoic system is still under investigations.

Łódź Region

The Łódź Region includes the eastern part of the province, outside of the oil- and gas-bearing areas. The Carboniferous-Permian, Permian/Zachstein and Mesozoic petroleum systems are supposed to work in the region.

Prospectincg areas. Gorzów (acreage 1015.063 km^2).

4.2. PROSPECTING AREAS

4.2.1. GORZÓW

(Hubert Kiersnowski, Krzysztof Waśkiewicz, Anna Feldman-Olszewska, Tadeusz Peryt, Ewelina Krzyżak)

Fig. 4.1

Coordinates:

Border points	PL 1992	
	X	Y
1	231 703.41	578 050.68
2	298 543.71	574 775.40
3	297 853.03	556 156.87
4	256 367.92	558 082.24

Acreage: **1015.063 km^2**

Geology and petroleum systems:

a) geological location: Gorzów Block, Lipiany and Drezdenko tectonic units;
b) basement: Variscan Externides;
c) tectonic-structural stages of sedimentary cover: Carboniferous, Permian-Mesozoic, Cenozoic;
d) petroleum location: Western Petroleum Province, Wielkopolska-Silesian Subprovince;
e) type of expected deposits: conventional for oil and gas;
f) petroleum systems: Carboniferous-Permian;
g) potential reservoir rocks: carbonates of the Main Dolomite isolated platforms and their slopes;
h) potential source rocks: Main Dolomite stromatolitic mudstones and wackstones developed in lagoon and tidal-flat environments;
i) seal rocks: Zechstein evaporites;
j) thickness of the overburden: ~3800 m;
k) expected traps: lithological.

Wells: **4 deep wells > 500 m**

Well	Depth [m TVD]	Stratigraphy at the bottom
DRAWINY 1	1904.8	Carnian
STRZ. KRAJEŃSKIE IG-1	4700.0	Permian
ŻABICKO GEO-1	1030.4	Lower Toarcian
OSTROWIEC 1	3807.0	Lower Triassic

Seismic survey (owner):*

1977 – 2 lines Sulęcin-Świebodzin 2D (ST)
1979 – 4 lines Myślibórz-Krzyż 2D (PGNiG S.A.)
1979 – 1 line Piła-Bydgoszcz 2D (ST)
1984–1986 – 7 lines Chociwel-Czaplinek 2D (ST)
1987–1988 – 3 lines PGSS PAN (ST)
1992 – 1 line PGSS PAN (ST)
1995 – 3 lines Dzieduszyce 2D (PGNiG S.A.)
1997 – 1 line Polonaise'97 (ST)
2000 – 1 line Międzyrzec 2D (PGNiG S.A.)
2008–2012 – 6 lines N. Szczec. 2D (PGNiG S.A.)
29 lines 2D of total length 167.037 km
* State Treasury

Oil and gas deposits discovered on the area and in its neighborhood: **7 deposits**

NAME	DEPOSITS
Grotów	OIL
Krobielewko	GAS
Lubiatów	OIL
Międzychód	GAS
Różańsko	GAS
Sieraków	OIL
Stanowice	GAS

Prospectivity:

Numerous oil and gas deposits discovered in the neighborhood indicate high prospectivity of the Gorzów area. The main risk is related to poor data on deep geological structure.

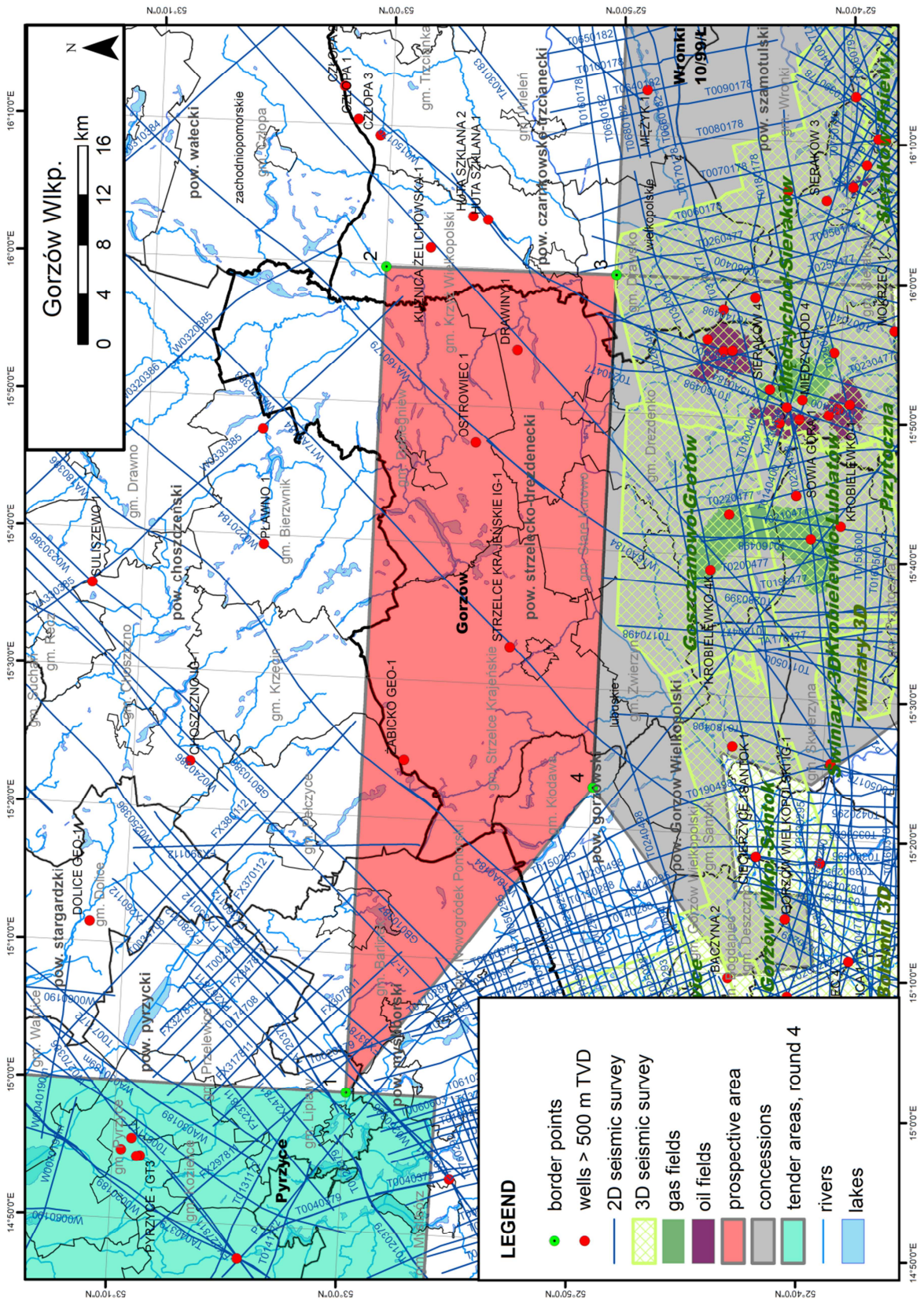

Fig. 4.1. Border points, seismic surveys, wells, hydrocarbon deposits and hydrocarbon concessions on the Gorzów area and in its neighborhood as of 28.02.2019 (CBDG, 2019).

5. NORTHERN PETROLEUM PROVINCE
5.1. DESCRIPTION

Boundaries. Distribution of the Lower Paleozoic rocks in the northern Poland is limited to the Peribaltic Syneclise (Ad. 2). The province extends from the Teisseyre-Tornquist Zone (TTZ) in the west, to the Mazury-Belarus Anteclise to the east and south-east and Baltic Shield to the north (Ad. 1–2). The extent of Carboniferous deposits of the Variscan foreland basin limits the province to the south (Ad. 2).

Acreage. ~57 900 km^2

Geology. The Precambrian crystalline basement of the Peribaltic Syneclise is covered by Ediacaran to Upper Silurian sedimentary succession divided into four depositional sequences (Jaworowski, 2002):

- sequence I (Ediacaran – Lower Cambrian);
- sequence II (Middle Cambrian – Lower Ordovician);
- sequence III (Middle and Upper Ordovician);
- sequence IV (Silurian).

This succession was partly eroded during the Caledonian movements – the stratigraphic gap includes at least part of the Pridoli. The thin succession of the Devonian is present only in the eastern part of the syneclise. The Lower Paleozoic and Devonian is cut by the Variscan unconformity, and covered by the Permian to Cenozoic deposits of the Mazury-Podlasie Monocline and Koszalin-Zamość Sunclinorium (Ad. 3).

Petroleum systems.

1. Lower Paleozoic petroleum system:

Source rocks – Cambrian, Ordovician and Silurian claystones and mudstones.

Reservoir rocks – Lower to Middle Cambrian sandstones and hypothetically Silurian carbonates in the eastern part of the Syneclize (Kętrzyn area) for conventional oil and gas deposits; Lower to Middle Cambrian sandstones for unconventional tight oil and tight gas deposits; Cambrian, Ordovician and Silurian claystones and mudstones for unconventional shale oil and shale gas deposits.

Traps – lithological, structural and mixed for conventional oil and gas deposits; mixed for unconventional tight oil and tight gas deposits; continuous for unconventional shale oil and shale gas deposits. Hydrocarbon accumulations in Cambrian, Ordovician and Silurian shales are formed *in situ* in fine-grained clastic rocks, which play a roles of source, reservoir and seal rocks at the same time. These accumulations have continuous character – opposite to the conventional traps. Current geological studies indicate the Piaśnica (Cambrian), Sasino (Ordovician) and Jantar (Silurian) formations of the Łeba High and its neighborhood as the most prospective for unconventional shale gas and shale oil accumulations (Podhalańska, 2018).

Seal – impermeable sandstones in the upper part of Middle Cambrian and Upper Cambrian, Ordovician and Silurian clasytones and mudstones.

Oil and gas deposits – the Lower Paleozoic petroleum system is proved by numerous oil and gas deposits and hydrocarbon shows in the Lower and Middle Cambrian of the Peribaltic Syneclise in Poland, Kaliningrad Oblast (Russia), Lithuania, Latvia and Sweden. In Poland, the hydrocarbon deposits in the Middle Cambrian occur in the Łeba High onshore (Białogóra E, Żarnowiec W, Żarnowiec, Dębki) and offshore (B3, B4, B6, B8, B16, B21, B34). In the Ordovician and Silurian carbonates, the hydrocarbon deposits occur in Sweden, Latvia, Lithuania and Kaliningrad Oblast, while in Poland only in the Kętrzyn IG-1 well an oil was observed in Lower Silurian nodular limestones of the Barciany Formation. The occurrence of unconventional tight oil and tight gas deposits in the Middle Cambrian, as well as shale oil and shale gas accumulations in the Lower Paleozoic are also possible. This should be taken into consideration especially, if to remember the recent discovery of the tight gas accumulation in the Opalino structure in the Middle Cambrian sandstones and initial production tests from the shale formations.

Gas

Prospecting horizons	Number of deposits as of 31.12.2017	Anticipated economic resources as of 31.12.2017	Economic resources in place as part of anticipated economic resources as of 31.12.2017	Production in 2017
		[mln m^3]		
Cambrian	8	4605.63	4475.61	26.46

According to the Balance of Mineral Resources Deposits in Poland as of 2017.

Crude oil

Prospecting horizons	Number of deposits as of 31.12.2017	Anticipated economic resources as of 31.12.2017	Economic resources in place as part of anticipated economic resources as of 31.12.2017	Production in 2017
		[kt]		
Cambrian	6	6833.21	6043.42	209.41

According to the Balance of Mineral Resources Deposits in Poland as of 2017.

Wells. 372 deep wells (> 500 m), in which 54 wells were drilled in the last 10 years (from the beginning of 2009).

Hydrocarbon concessions. 12 prospecting and exploration concessions of total acreage ~9307 km^2 (Ad. 1).

Petroleum subprovinces and regions. One subprovince, in which a petroleum system occurs, and one region with unconfirmed prospectivity have been distinguished in the northern petroleum province (Ad. 1–2).

Baltic Subprovince

The Baltic Subprovince includes the Middle Cambrian deposits of confirmed prospectivity for conventional oil and gas accumulations. The Lower Paleozoic petroleum system occurs in the subprovince.

Słupsk-Grudziądz Region

The region is located along the edge of the East European Platform, outside to the Baltic Subprovince. The Lower Paleozoic petroleum system is supposed to work within the region.

Prospecting areas. Hel, Jastarnia, Kartuzy, Łeba S, Nowa Karczma, Rozewie S, Sierakowice and Władysławowo (total acreage 8257.585 km^2).

5.2. PROSPECTIVE AREAS

5.2.1. HEL

(Marcin Janas, Teresa Podhalańska, Joanna Roszkowska-Remin)

Fig. 5.1

Coordinates:

Border points	PL 1992	
	X	Y
1	774 588.93	521 368.50
2	756 267.53	520 183.94
3	743 956.47	532 324.66
4	744 586.66	498 099.45
5	760 779.19	482 224.42
6	774 536.10	467 893.14

Acreage: **1196.982 km^2**

Geology and petroleum system:

a) geological location: offshore, Gdańsk Depression, Gdańsk Block (Pokorski, 2010);
b) basement: East European Platform;
c) sedimentary cover: Ediacaran-Quaternary with numerous stratigraphic gaps;
d) petroleum location: Northern Petroleum Province, Baltic Subprovince;
e) type of expected deposits: conventional for oil and gas in Cambrian sandstones; unconventional for tight oil and tight gas in Cambrian sandstones;
f) petroleum systems: Lower Paleozoic petroleum system;
g) potential reservoir rocks: Lower and Middle Cambrian sandstones;
h) potential source rocks: Lower and Middle Cambrian claystones and mudstones interbeds and Upper Cambrian, Ordovician and Silurian claystones and mudstones;
i) seal rocks: Lower Paleozoic claystones and mudstones;
j) thickness of the overburden: 2000 m;
k) expected traps: structural, lithological and mixed.

Wells: **none**

Oil and gas deposits discovered on the area and in its neighborhood: **none**

Prospectivity:

Although there are no deep wells in the Hel area and the knowledge of deep geological structures are rather poor, the prospectivity of the Cambrian deposits can be deducted from oil and gas fields recognized in the farther neighborhood in Poland (onshore: Dębki, Żarnowiec, Żarnowiec W, Białogóra and Opalino structure), and in Kaliningrad Oblast (offshore: C-9). Also numerous tectonic structures related to the Sambia Tectonic Zone – regional barrier for hydrocarbon migration – have been mapped (Dadlez, 1998; Domżalski et al., 2004; Kotarba, 2010).

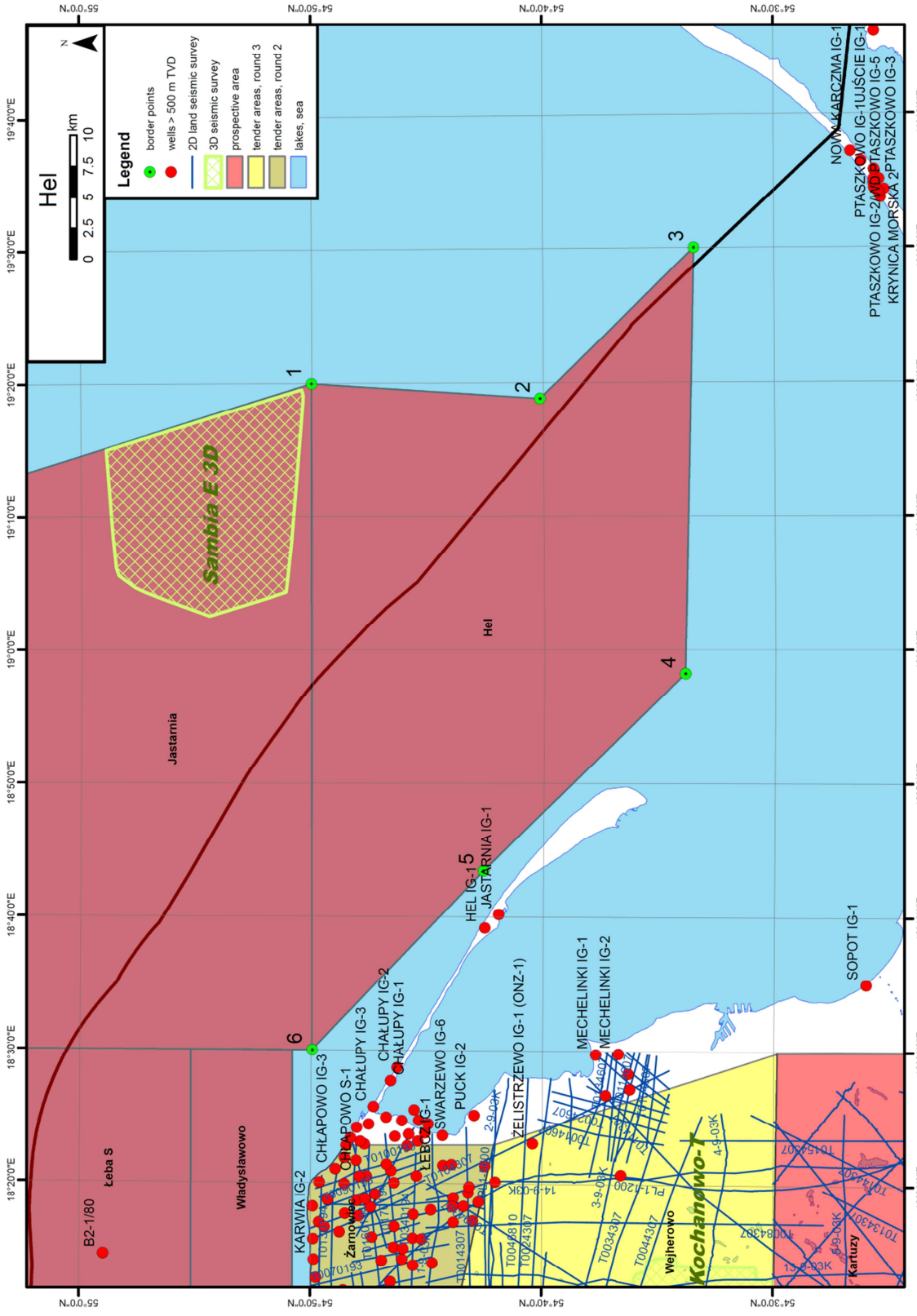

Fig. 5.1. Border points, seismic surveys, wells, hydrocarbon deposits and hydrocarbon concessions on the Hel area and in its neighborhood as of 28.02.2019 (CBDG, 2019).

5.2.2. JASTARNIA

(Marcin Janas, Teresa Podhalańska, Joanna Roszkowska-Remin)

Fig. 5.2

Coordinates:

Border points	PL 1992	
	X	Y
1	774 588.93	521 368.50
2	774 536.10	467 893.14
3	784 245.44	467 962.51
4	797 561.64	468 057.76
5	797 604.00	500 000.00
6	797 622.74	514 122.38

Acreage: **1146.388 km^2**

Geology and petroleum systems:

a) geological location: offshore, Gdańsk Depression, parts of Gdańsk, Kurlandia, Żarnowiec and Rozewie tectonic blocks (Pokorski, 2010);
b) basement: East European Platform at depth 2000–2500 m, 5150 m;
c) sedimentary cover: Ediacaran-Quaternary with numerous stratigraphic gaps;
d) petroleum location: Northern Petroleum Province, Baltic Subprovince;
e) type of expected deposits: conventional for oil and gas in Cambrian sandstones; unconventional for tight oil and tight gas in Cambrian sandstones;
f) petroleum systems: Lower Paleozoic petroleum system;
g) potential reservoir rocks: Lower and Middle Cambrian sandstones;
h) potential source rocks: interbeds of claystones and mudstones in Lower and Middle Cambrian and claystones and mudstones of Upper Cambrian, Ordovician and Silurian; Ordovician and Silurian claystones and mudstones;
i) seal rocks: Lower Paleozoic claystones and mudstones;
j) thickness of the overburden: ~2000 m;
k) expected traps: structural, lithological and mixed.

Wells: **none**

Oil and gas deposits discovered on the area and in its neighborhood: **none**

Prospectivity:

In the Jastarnia area, there are no deep wells and regional geology is poorly recognized. The prospectivity of the Cambrian deposits can be deducted only from oil and gas fields recognized in the neighborhood (see the description of the Hel area).

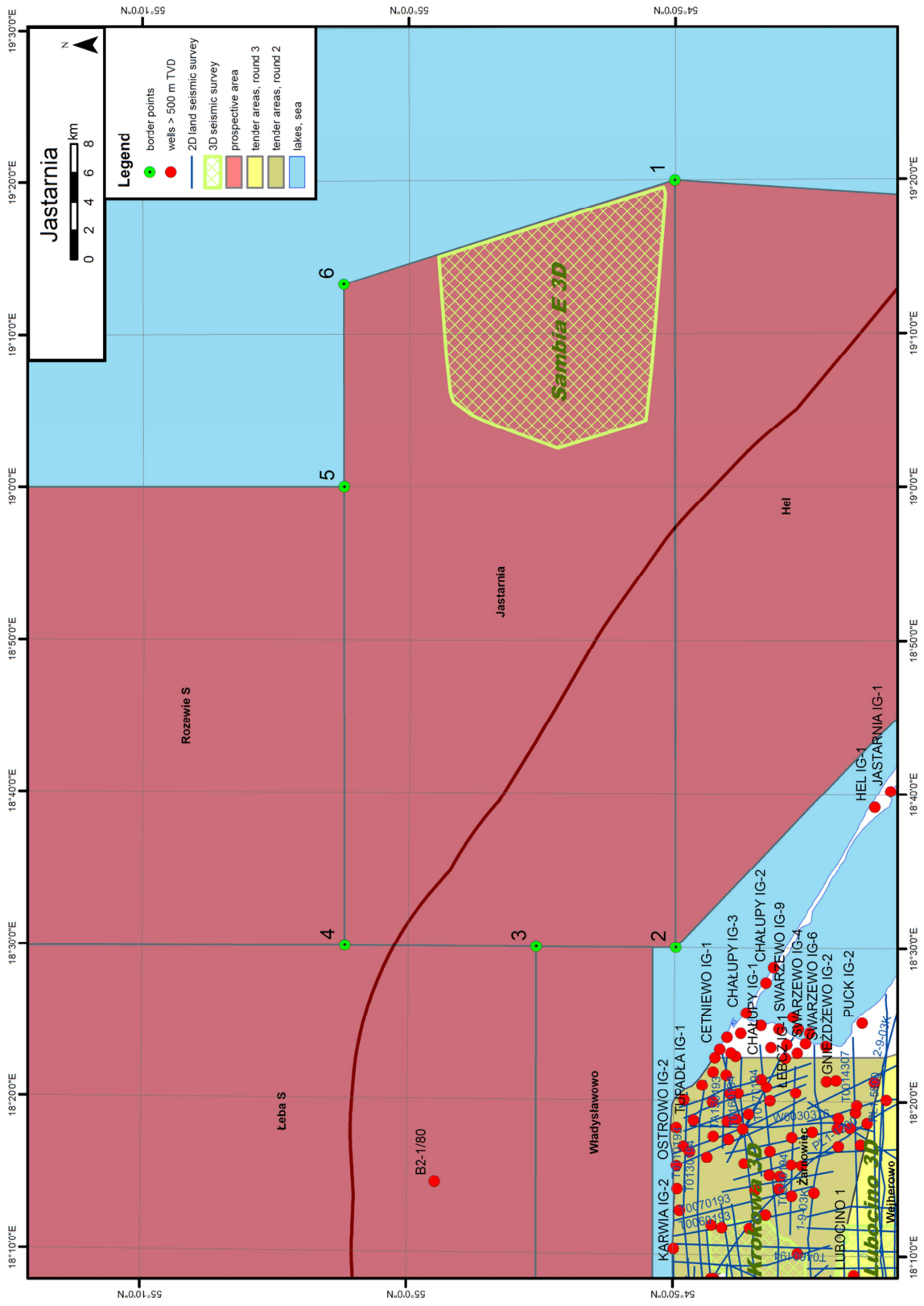

Fig. 5.2. Border points, seismic surveys, wells, hydrocarbon deposits and hydrocarbon concessions on the Jastarnia area and in its neighborhood as of 28.02.2019 (CBDG, 2019).

5.2.3. KARTUZY

(Marcin Janas, Teresa Podhalańska, Joanna Roszkowska-Remin)

Fig. 5.3.

Coordinates:

Border points	PL 1992	
	X	Y
1	709 648.50	467 438.93
2	709 994.91	434 842.34
3	737 770.93	435 133.01
4	737 259.22	467 502.29
5	720 361.13	467 514.79

Acreage: **898.424 km^2**

Geology and petroleum systems:

a) geological location: onshore, Łeba High (Pokorski, 2010);
b) basement: East European Platform at depth 4500;
c) sedimentary cover: Ediacaran-Quaternary with numerous stratigraphic gaps;
d) petroleum location: Northern Petroleum Province, Baltic Subprovince;
e) type of expected deposits: conventional for oil and gas in Cambrian sandstones; unconventional for tight oil and tight gas in Cambrian sandstones; unconventional for shale oil and shale gas in the Lower Paleozoic (Ordovician, Silurian);
f) petroleum systems: Lower Paleozoic petroleum system;
g) potential reservoir rocks: Lower and Middle Cambrian sandstones; Ordovician and Silurian shales;
h) potential source rocks: interbeds of claystones and mudstones in Lower and Middle Cambrian and claystones and mudstones of Upper Cambrian, Ordovician and Silurian; Ordovician and Silurian claystones and mudstones;
i) seal rocks: Lower Paleozoic claystones and mudstones;
j) thickness of the overburden: 3900–4300 m;
k) expected traps: structural, lithological, mixed, and unconventional – continuous for shale oil and shale gas.

Wells: **5 deep wells > 500 m**

Well name	Depth [m TVD]	Stratigraphy at the bottom
Borcz 1	3759.0	Middle Cambrian
Kartuzy GEO-1	805.5	Jurassic
Lewino-1G2	3600.4	Cambrian
Miłoszewo ONZ-1	1558.0	Prodoli
Niestępowo 1	3632.9	Middle Cambrian

Seismic survey (owner):*

1997 – 1 line Polonaise'97 (ST)
2003–2007 – 17 lines Gd. 2D (PGNiG S.A.)
2010 – 13 lines Balt. Bas. Gdańsk-W 2D (ST)
2011–2012 – 16 lines Som.-Przywidz 2D (ST)
2012 – 1 line PolandSPAN 2D (ION, ST)
48 lines 2D of total length 667.018 km
* ST – State Treasury

Oil and gas deposits discovered on the area:

none

Prospectivity:

The results of the recent research by PGI on the Lower Paleozoic shales (Podhalańska, 2018) indicate the unconventional accumulations occurrences in the Sasino and Jantar formations. The investigations of PGNiG S.A. (Makos, 2014) and BNK Petroleum (BNK, 2014) proved the occurrence of gas and oil/condensate accumulations in the Lower Paleozoic shales, although the production tests were not commercial at the time (Wysin 2H/3H and Gapowo B-1 horizontal wells).

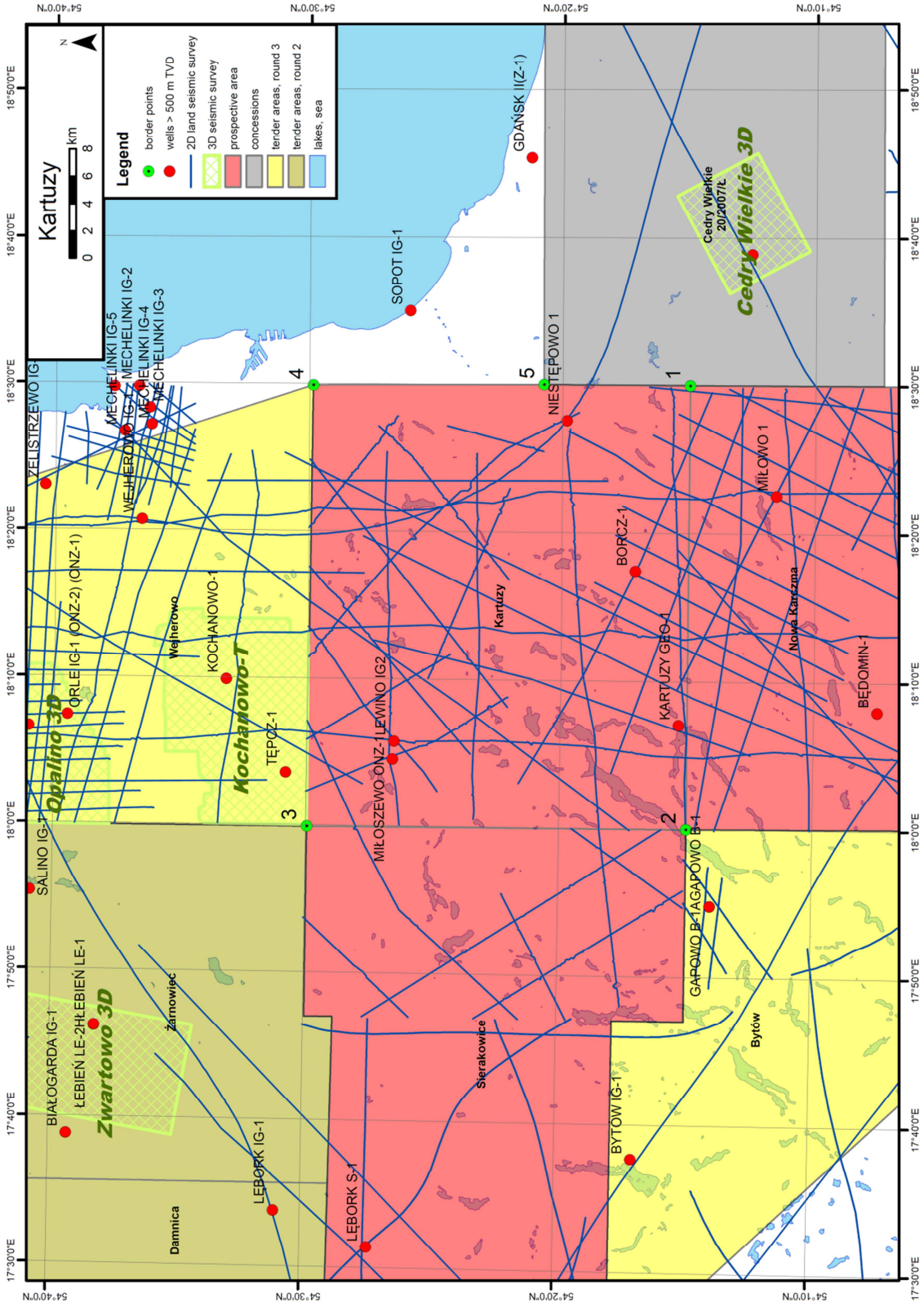

Fig. 5.3. Border points, seismic surveys, wells, hydrocarbon deposits and hydrocarbon concessions on the Kartuzy area and in its neighborhood as of 28.02.2019 (CBDG, 2019).

5.2.4. ŁEBA S

(Marcin Janas, Teresa Podhalańska, Joanna Roszkowska-Remin)

Fig. 5.4

Coordinates:

Border points	PL 1992	
	X	Y
1	797 561.64	468 057.76
2	784 245.44	467 962.51
3	784 298.35	435 921.59
4	821 201.40	436 324.10
5	820 859.70	468 098.90

Acreage: **1172.924 km^2**

Geology and petroleum systems:

a) geological location: offshore, Łeba High, Łeba and Żarnowiec tectonic blocks (Pokorski, 2010);
b) basement: East European Platform;
c) sedimentary cover: Ediacaran-Quaternary with numerous stratigraphic gaps;
d) petroleum location: Northern Petroleum Province, Baltic Subprovince;
e) type of expected deposits: conventional for oil and gas in Cambrian sandstones; unconventional for tight oil and tight gas in Cambrian sandstones; unconventional for shale oil in Lower Paleozoic (Cambrian, Ordovician and Silurian);
f) petroleum systems: Lower Paleozoic petroleum system;
g) potential reservoir rocks: Lower and Middle Cambrian sandstones; Cambrian, Ordovician and Silurian shales;
h) potential source rocks: interbeds of claystones and mudstones in Lower and Middle Cambrian and claystones and mudstones of the Upper Cambrian, Ordovician and Silurian;
i) seal rocks: Lower Paleozoic claystones and mudstones;
j) thickness of the overburden: 2000–2200 m;
k) expected traps: structural, lithological, mixed, and unconventional – continuous for shale oil and shale gas.

Wells: **1 deep wells > 500 m**

Well name	Depth [m TVD]	Stratigraphy at the bottom
B2-1/80	2944.0	Precambrian

Oil and gas deposits discovered on the area and in its neighborhood: **7 fields**

Field name	Type
B 21	GAS
B 3	OIL
B 8	OIL
Białogóra-E	OIL
Dębki	OIL
Żarnowiec	OIL
Żarnowiec W	OIL

Prospectivity:

Numerous oil and gas fields were discovered onshore and offshore in the neighborhood of the Łeba S (B3, Dębki, Żarnowiec, Żarnowiec-W, Białogóra). The results of geochemical and acoustic study of the bottom sediments (Domżalski et al., 2004; PIG–PIB et al., 2008; Jaśniewicz et al., 2019), as well as identification of potential traps (Dadlez, 1998; Domżalski et al., 2004, Kotarba, 2010) and faults – barriers for hydrocarbon migration (Dadlez, 1998) indicate good perspectives for new projects. Also, the results of new research on the Lower Paleozoic shales (Podhalańska, 2018) indicate the unconventional accumulations potential in the Sasino and Jantar formations.

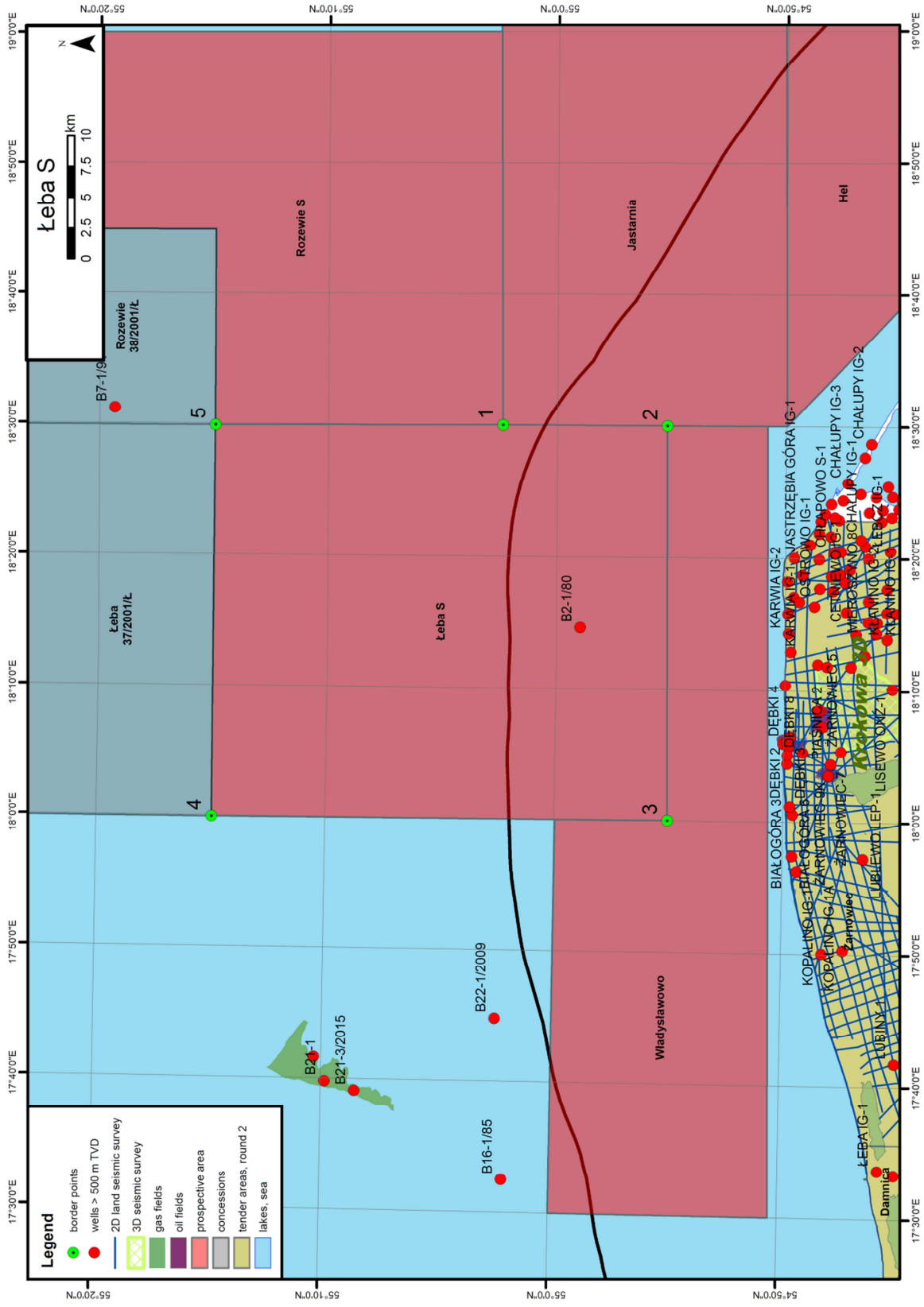

Fig. 5.4. Border points, seismic surveys, wells, hydrocarbon deposits and hydrocarbon concessions on the Łeba S area and in its neighborhood as of 28.02.2019 (CBDG, 2019).

5.2.5. NOWA KARCZMA

(Marcin Janas, Teresa Podhalańska, Joanna Roszkowska-Remin)

Fig. 5.5

Coordinates:

Border points	PL 1992	
	X	Y
1	709 648.50	467 438.93
2	695 454.92	467 338.43
3	681 841.49	467 242.03
4	682 184.52	434 676.55
5	709 994.91	434 842.34

Acreage: **906.099 km^2**

Geology and petroleum systems:

a) geological location: onshore, Łeba High, Żarnowiec tectonic block (Pokorski, 2010);
b) basement: East European Platform at depth 4500–5200 m, 5150 m in Kościerzyna IG-1 well (Ryka, 1982);
c) sedimentary cover: Ediacaran-Quaternary with numerous stratigraphic gaps;
d) petroleum location: Northern Petroleum Province, Baltic Subprovince;
e) type of expected deposits: conventional for oil and gas in Cambrian sandstones; unconventional for tight oil and tight gas in Cambrian sandstones; unconventional for shale oil and shale gas in Lower Paleozoic (Ordovician, Silurian);
f) petroleum systems: Lower Paleozoic petroleum system;
g) potential reservoir rocks: Lower and Middle Cambrian sandstones; Ordovician and Silurian shales;
h) potential source rocks: interbeds of claystones and mudstones in Lower and Middle Cambrian and claystones and mudstones of Upper Cambrian, Ordovician and Silurian; Ordovician and Silurian claystones and mudstones;
i) seal rocks: Lower Paleozoic claystones and mudstones;
j) thickness of the overburden: 3900–4300 m;
k) expected traps: structural and lithological, unconventional – continuous for shale oil and shale gas.

Wells: **7 deep wells > 500 m**

Well name	Depth [m TVD]	Stratigraphy at the bottom
Będomin-1	4100.0	Middle Cambrian
Kościerzyna IG-1	5202.0	Precambrian
Miłowo 1	3855.0	Middle Cambrian
Wysin-1	4040.5	Middle Cambrian
Wysin-2	5058.0	Silurian
Wysin-2hbis	5333.0	Silurian
Wysin-3h	5540.0	Lower Silurian

Seismic surveys (owner):*

1975 – 1 line Koszalin-Bydgoszcz 2D (ST)
1976 – 1 line Chojnice-Kościerzyna 2D (ST)
1997 – 1 line Polonaise'97 (ST)
2003–2007 – 15 lines K-Gd. 2D (PGNiG S.A)
2012 – 2 lines PolandSPAN 2D (ION, ST)
2011–2012 – 22 lines Przywidz 2D (ST)
42 lines 2D of total length 834.251 km
*ST – State Treasury

Oil and gas deposits discovered on the area and in its neighborhood: **none**

Prospectivity:

The results of the new research on the Lower Paleozoic shales (Podhalańska, 2018) indicate the unconventional accumulations in the Sasino and Jantar formations. Also, the results of the previous works provided by the PGNiG S.A. (Makos, 2014) and BNK Petroleum (BNK, 2014) in the neighborhood of the Nowa Karczma area proved the presence of gas and oil accumulations in the Lower Paleozoic shales.

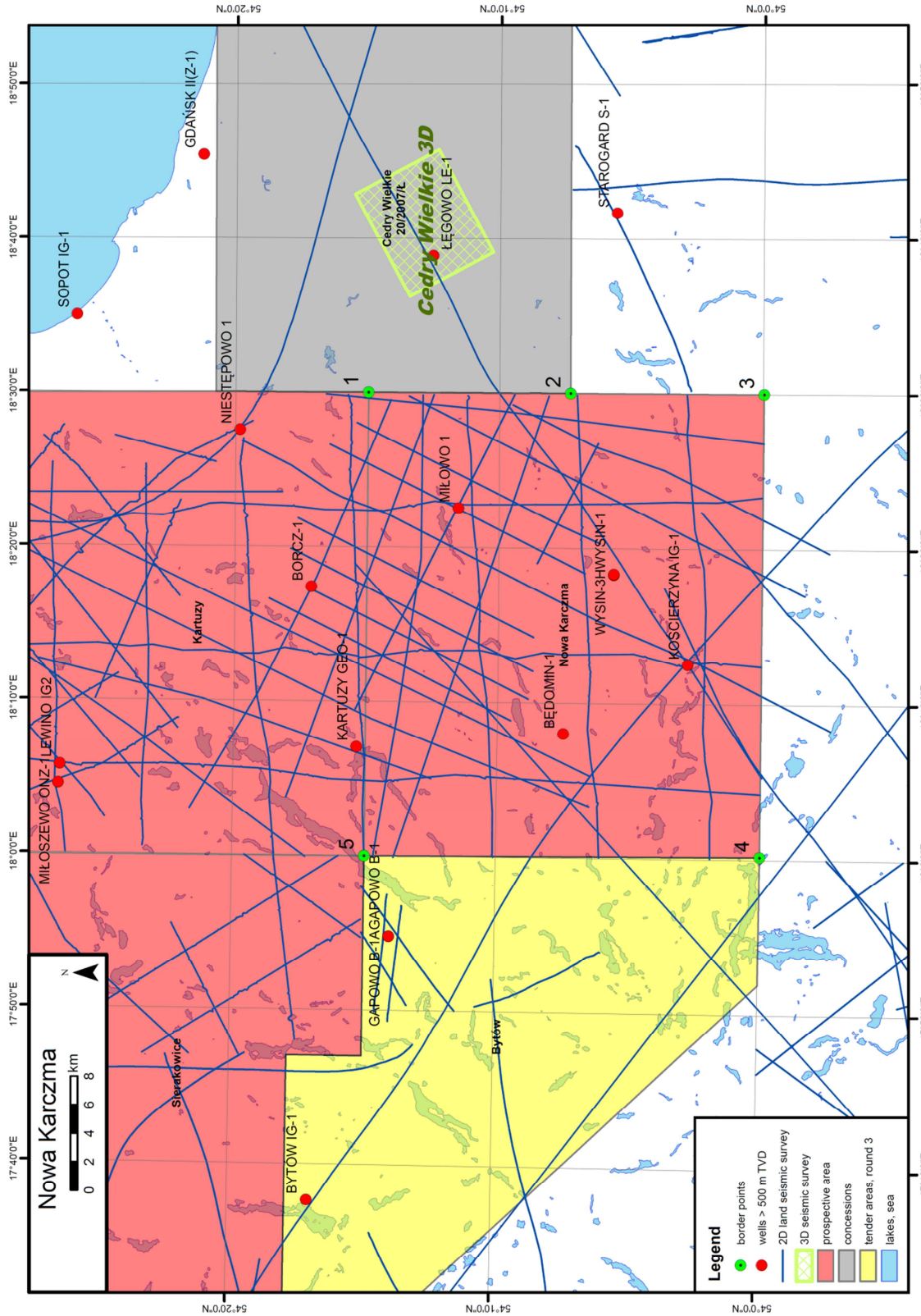

Fig. 5.5. Border points, seismic surveys, wells, hydrocarbon deposits and hydrocarbon concessions on the Nowa Karczma area and in its neighborhood as of 28.02.2019 (CBDG, 2019).

5.2.6. ROZEWIE S

(Marcin Janas, Teresa Podhalańska, Joanna Roszkowska-Remin)

Fig. 5.6

Coordinates:

Border points	PL 1992	
	X	Y
1	848 587.35	500 000.00
2	797 604.00	500 000.00
3	797 561.64	468 057.76
4	820 859.70	468 098.90
5	820 774.10	483 986.60
6	848 587.40	484 086.60
7	848 562.20	494 611.90

Acreage: **1187.822 km^2**

Geology and petroleum systems:

a) geological location: offshore, Łeba High, Rozewie and Kurlandia tectonic block (Pokorski, 2010);
b) basement: East European Platform at depth ~2500 m;
c) sedimentary cover: Ediacaran-Quaternary with numerous stratigraphic gaps;
d) petroleum location: Northern Petroleum Province, Baltic Subprovince;
e) type of expected deposits: conventional for oil and gas in Cambrian sandstones; unconventional for tight oil and tight gas in Cambrian sandstones; unconventional for shale oil in Lower Paleozoic (Ordovician Sasino Formation, Silurian Jantar Formation);
f) petroleum systems: Lower Paleozoic petroleum system;
g) potential reservoir rocks: Lower and Middle Cambrian sandstones; Ordovician and Silurian shales
h) potential source rocks: interbeds of claystones and mudstones in Lower and Middle Cambrian; Ordovician and Silurian claystones and mudstones;
i) seal rocks: Lower Paleozoic claystones and mudstones;
j) thickness of the overburden: ~2100 m;
k) expected traps: structural and lithological, unconventional – continuous for shale oil.

Wells: **no deep wells in the area**

Oil and gas deposits discovered on the area and in its neighborhood: **1 field**

Field name	Type
B 8	OIL

Prospectivity:

The area is located close to the B8 oil field, in which the trap is developed in the Middle Cambrian sandstones. The results of geochemical and acoustic study of the bottom sediments (Domżalski et al., 2004; PIG–PIB et al., 2008; Jaśniewicz et al., 2019), as well as identification of potential traps (Dadlez, 1998; Domżalski et al., 2004, Kotarba, 2010) and faults – barriers for hydrocarbon migration (Dadlez, 1998) indicate good perspectives for new projects. Also, the results of the new research on the Lower Paleozoic shales (Podhalańska , 2018) indicate the unconventional accumulations potential in the Sasino and Jantar formations.

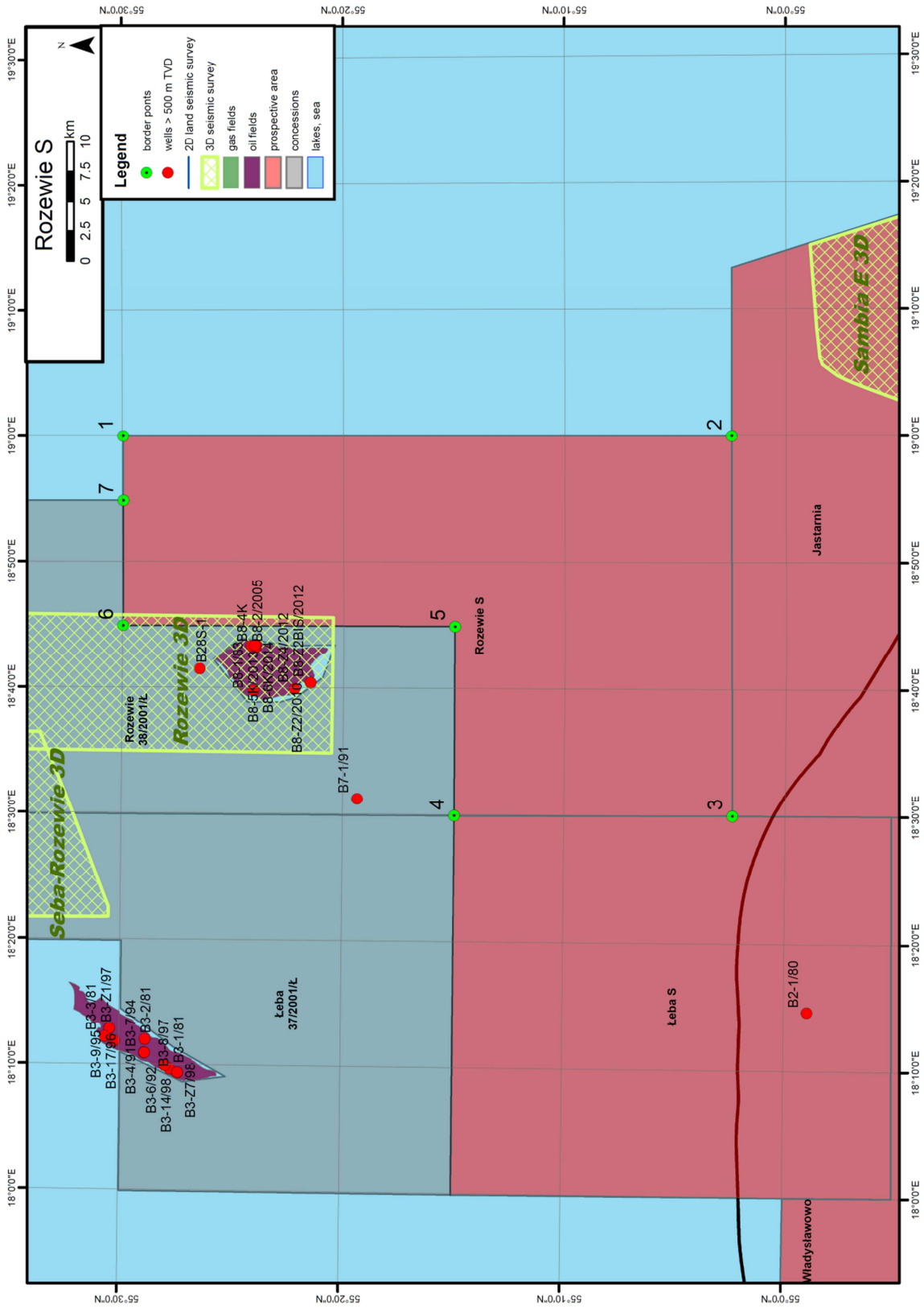

Fig. 5.6. Border points, seismic surveys, wells, hydrocarbon deposits and hydrocarbon concessions on the Rozewie S area and in its neighborhood as of 28.02.2019 (CBDG, 2019).

5.2.7. SIERAKOWICE

(Marcin Janas, Teresa Podhalańska, Joanna Roszkowska-Remin)

Fig. 5.7

Coordinates:

Border points	PL 1992	
	X	Y
1	715 916.10	395 018.18
2	736 654.49	394 914.17
3	736 415.47	403 325.65
4	735 907.85	421 189.09
5	737 990.19	421 224.49
6	737 770.93	435 133.01
7	709 994.91	434 842.34
8	710 216.13	420 752.34
9	715 477.11	420 841.77

Acreage: **926.732 km^2**

Geology and petroleum systems:

a) geological location: onshore, Łeba High;
b) basement: East European Platform at depth about 5000 m (Znosko, 1998);
c) tectonic-structural stages of sedimentary cover: Ediacaran-Quaternary with numerous stratigraphic gaps;
d) petroleum location: Northern Petroleum Province, Baltic Subprovince;
e) type of expected deposits: unconventional for tight oil and tight gas in Cambrian sandstones; unconventional for shale gas and shale oil in Lower Paleozoic;
f) petroleum systems: Lower Paleozoic petroleum system;
g) potential reservoir rocks: Lower and Middle Cambrian sandstones; Lower Paleozoic shales
h) potential source rocks: interbeds of claystones and mudstones in Lower and Middle Cambrian; Upper Cambrian, Ordovician and Silurian claystones and mudstones;
i) seal rocks: claystones and mudstones of the Upper Cambrian, Ordovician and Silurian;
j) thickness of the overburden: ~3500 m;
k) expected traps: structural and lithological, unconventional - continuous for shale gas and shale oil.

Wells: **1 deep well > 500 m**

Well name	Depth [m TVD]	Stratigraphy at the bottom
Lębork S-1	3590.0	kambr

Seismic survey (owner):*

1987 – 2 lines GBS (ST)
1992 – 1 line PGSS PAN (ST)
2007 – 1 line Gdańsk 2D (PGNiG S.A.)
2010 – 7 lines Peribaltic Syneclise 2D (ST)
2012 – 1 line PolandSPAN (ION, ST)
12 lines 2D of total length 162.507 km
*ST – State Treasury

Oil and gas deposits discovered on the area and in its neighborhood: **none**

Prospectivity:

The Sierakowice area is prospective for unconventional oil and gas accumulations in shales of the Sasino and Jantar formations (Podhalańska, 2018). The results of the previous works provided by PGNiG S.A. (Makos, 2014) and BNK Petroleum (BNK, 2014) in the neighborhood proved the presence of gas and oil in the Lower Paleozoic shales. Podhalańska (2018) showed also prospectivity of the area related to the unconventional tight type hydrocarbon accumulations in the Middle Cambrian sandstones.

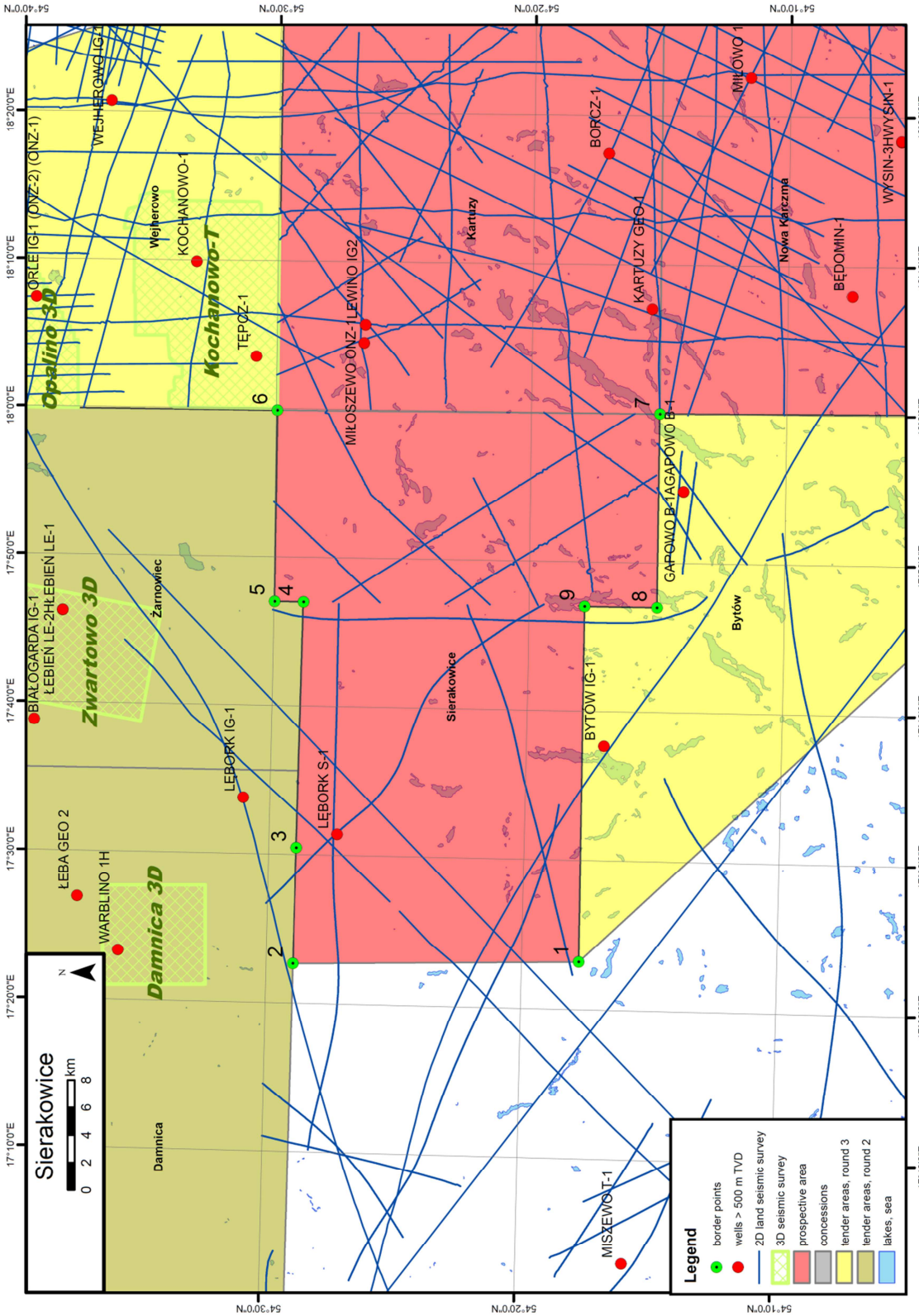

Fig. 5.7. Border points, seismic surveys, wells, hydrocarbon deposits and hydrocarbon concessions on the Sierakowice area and in its neighborhood as of 28.02.2019 (CBDG, 2019).

5.2.8. WŁADYSŁAWOWO

(Marcin Janas, Teresa Podhalańska, Joanna Roszkowska-Remin)

Fig. 5.8

Coordinates:

Border points	PL 1992	
	X	Y
1	793 990.87	404 079.74
2	793 419.95	436 021.08
3	784 298.35	435 921.59
4	784 245.44	467 962.51
5	776 119.74	467 904.45
6	776 205.60	403 698.83

Acreage: **822.213 km^2**

Geology and petroleum systems:

a) geological location: offshore, Łeba High, Żarnowiec tectonic block (Pokorski, 2010);
b) basement: East European Platform at depth 3000–3500 m;
c) sedimentary cover: Ediacaran-Quaternary with numerous stratigraphic gaps;
d) petroleum location: Northern Petroleum Province, Baltic Subprovince;
e) type of expected deposits: conventional for oil and gas in Cambrian sandstones; unconventional for tight oil and tight gas in Cambrian sandstones; unconventional for shale oil in Lower Paleozoic (Cambrian Piaśnica Formation, Ordovician Sasino Formation, Silurian Jantar Formation);
f) petroleum systems: Lower Paleozoic petroleum system;
g) potential reservoir rocks: Lower and Middle Cambrian sandstones; Lower Paleozoic shales
h) potential source rocks: interbeds of claystones and mudstones in Lower and Middle Cambrian; Upper Cambrian, Ordovician and Silurian claystones and mudstones;
i) seal rocks: Lower Paleozoic claystones and mudstones;
j) thickness of the overburden: 2700 m for Middle Cambrian conventional traps;
k) expected traps: structural and lithological, unconventional – continuous for shale gas and shale oil.

Wells: **none**

Oil and gas deposits discovered on the area and in its neighborhood: **5 fields**

Field name	Type
Żarnowiec W	OIL
B 21	GAS
Dębki	OIL
Białogóra-E	OIL
Żarnowiec	OIL

Prospectivity:

Numerous oil and gas fields have been discovered onshore and offshore in the neighborhood of the Władysławowo area (B16 structure; Dębki, Żarnowiec, Żarnowiec-W, Białogóra, B21 fields). The results of geochemical and acoustic study of the bottom sediments (Domżalski et al., 2004; PIG–PIB et al., 2008; Jaśniewicz et al., 2019), as well as identification of potential traps (Dadlez, 1998; Domżalski et al., 2004, Kotarba, 2010) and faults – barriers for hydrocarbon migration (Dadlez, 1998) indicate good perspectives for new projects. Also, the results of the new research on the Lower Paleozoic shales (Podhalańska, 2018) indicate the unconventional accumulations potential in the Piaśnica, Sasino and Jantar formations.

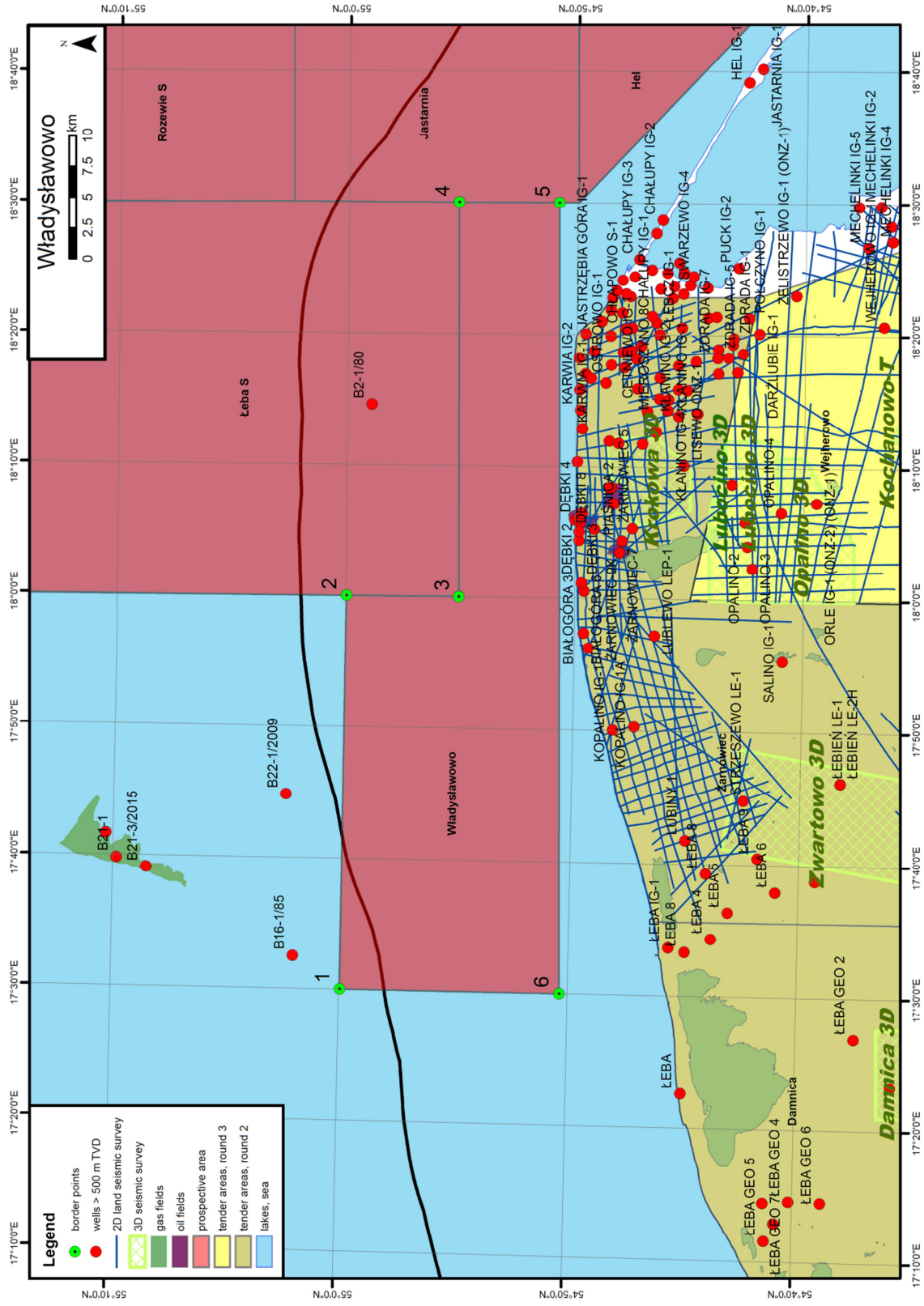

Fig. 5.8. Border points, seismic surveys, wells, hydrocarbon deposits and hydrocarbon concessions on the Władysławowo area and in its neighborhood as of 28.02.2019 (CBDG, 2019).

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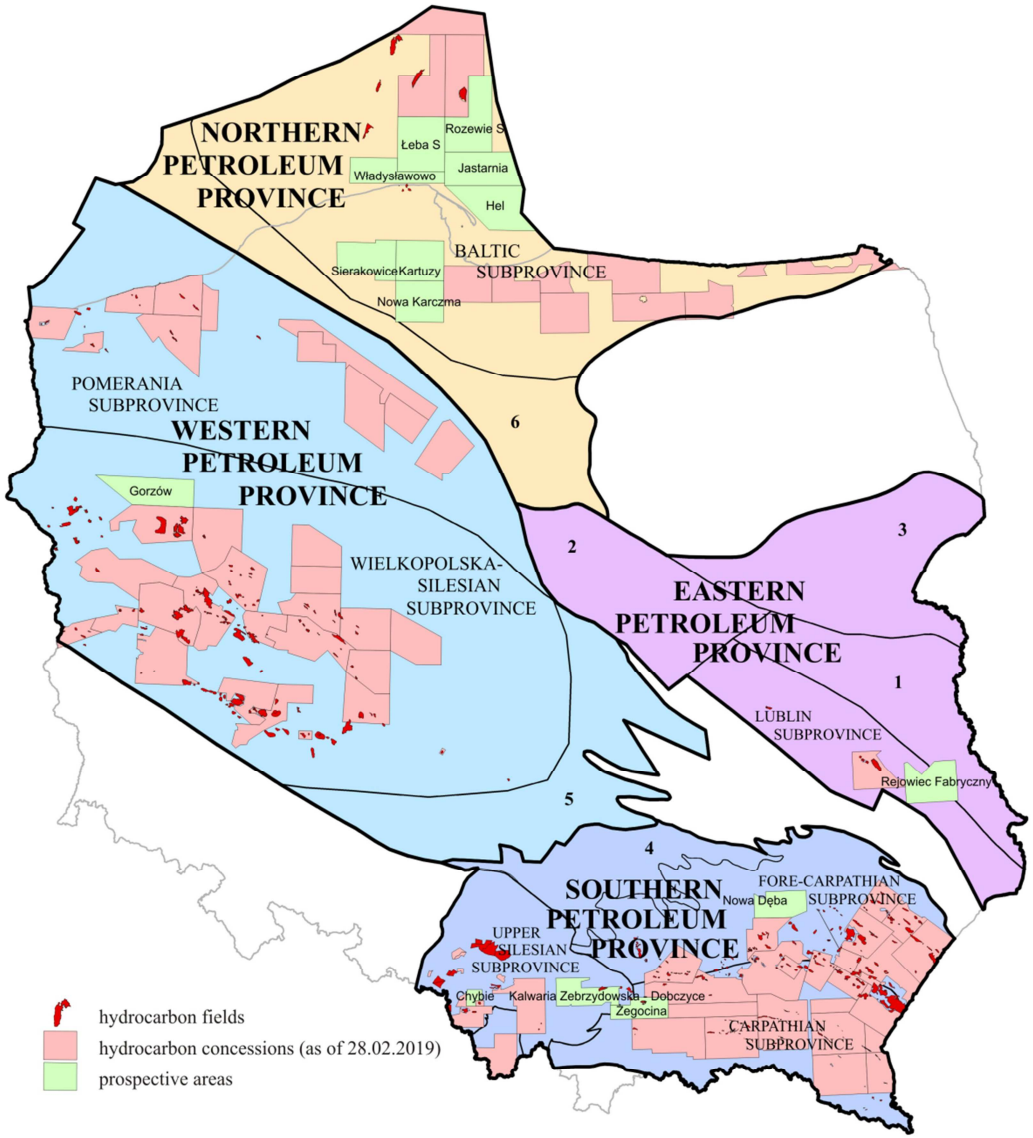
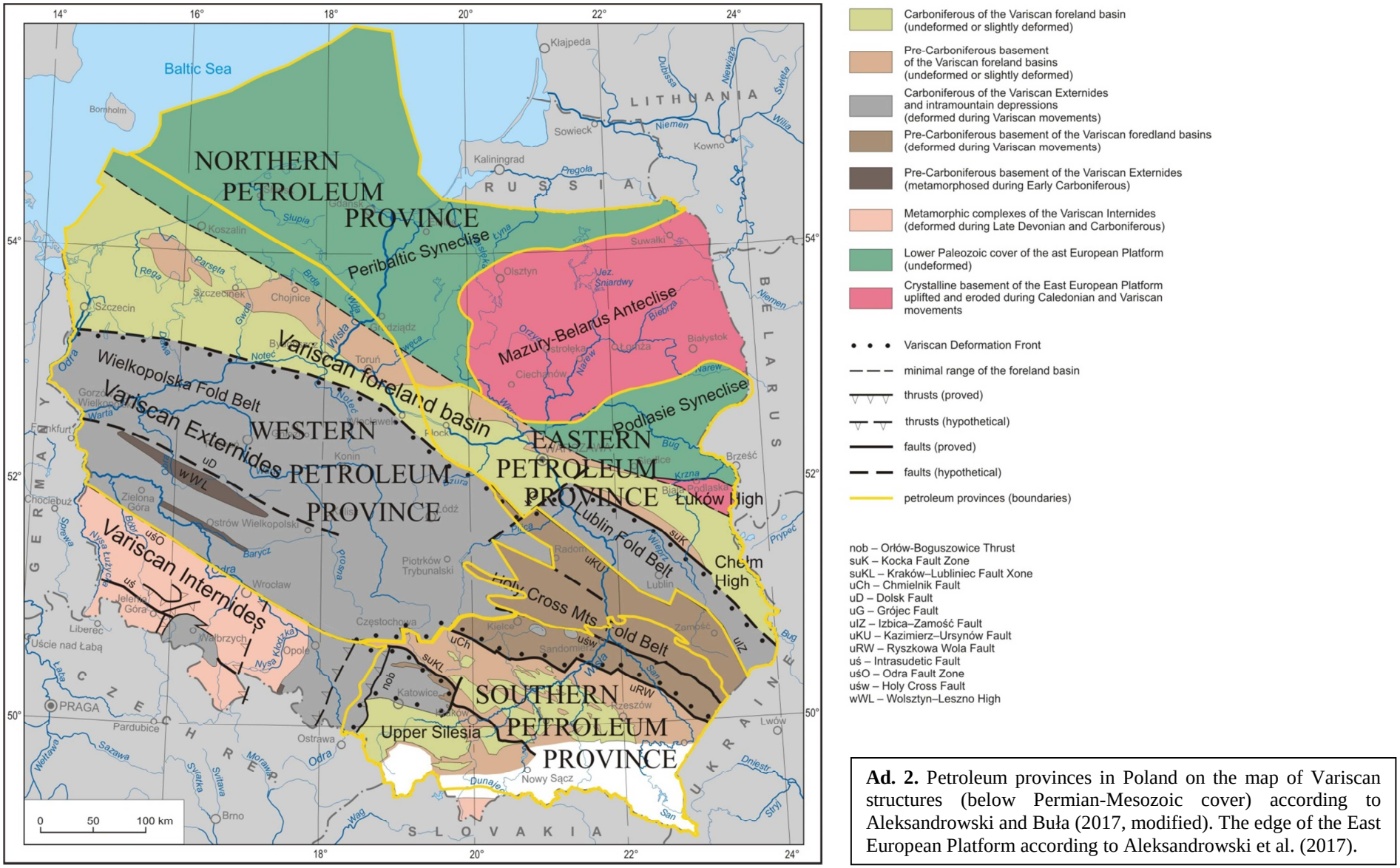
7. ADDITIONS



Ad. 1. Petroleum provinces in Poland – petroleum subdivision on the map of the hydrocarbon concessions in Poland as of 28.02.2019. 1–6 – petroleum regions (of unconfirmed/hypothetical prospectivity): 1 – Chełm Region, 2 – Płock-Warszawa Region, 3 – Podlasie Region, 4 – Małopolska Region, 5 – Łódź-Wieluń Region, 6 – Słupsk-



Carboniferous of the Variscan foreland basin (undeformed or slightly deformed)

Pre-Carboniferous basement of the Variscan foreland basins (undeformed or slightly deformed)

Carboniferous of the Variscan Externides and intramountain depressions (deformed during Variscan movements)

Pre-Carboniferous basement of the Variscan foredland basins (deformed during Variscan movements)

Pre-Carboniferous basement of the Variscan Externides (metamorphosed during Early Carboniferous)

Metamorphic complexes of the Variscan Internides (deformed during Late Devonian and Carboniferous)

Lower Paleozoic cover of the ast European Platform (undeformed)

Crystalline basement of the East European Platform uplifted and eroded during Caledonian and Variscan movements

Variscan Deformation Front

minimal range of the foreland basin

thrusts (proved)

thrusts (hypothetical)

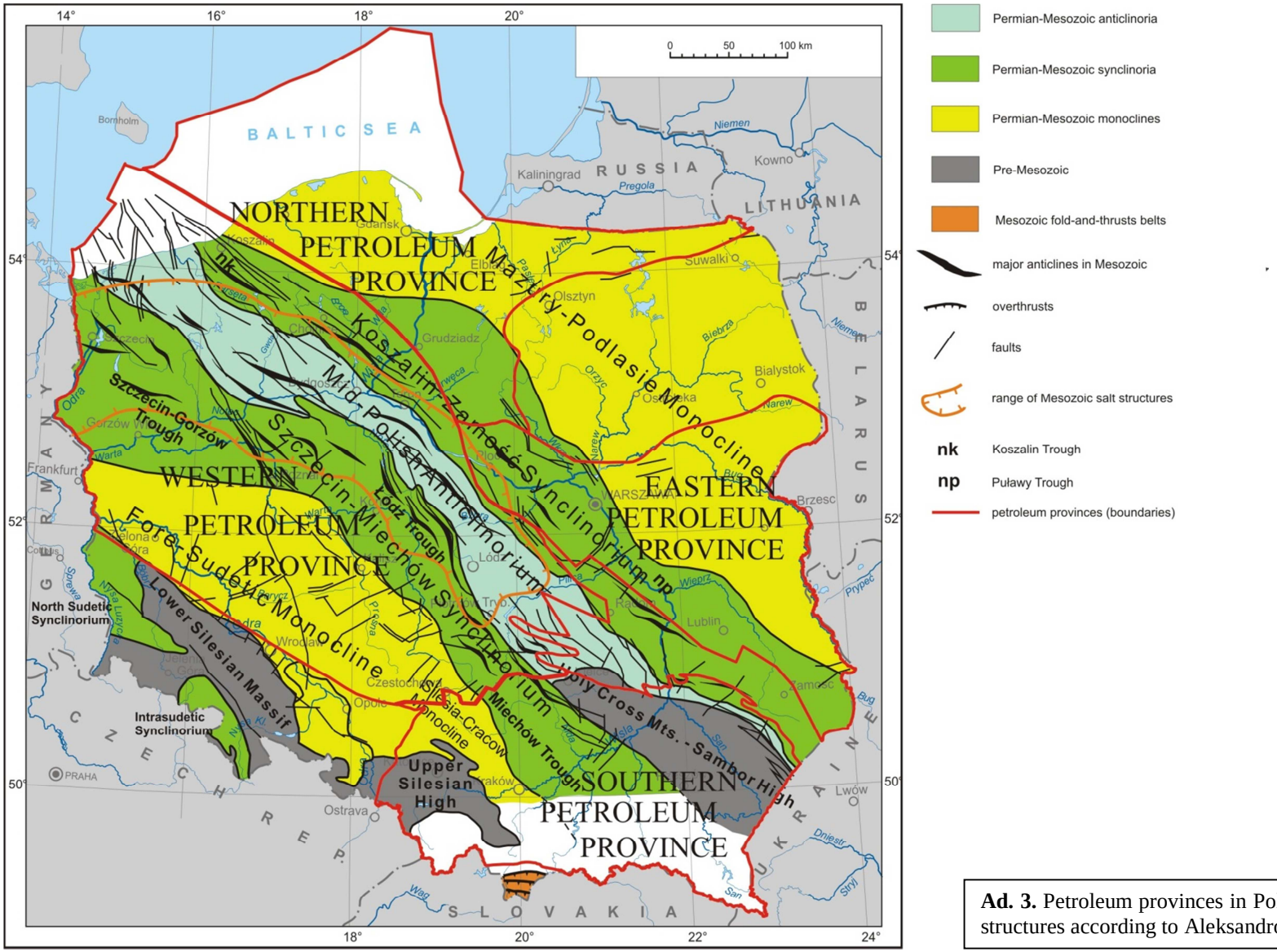
faults (proved)

faults (hypothetical)

petroleum provinces (boundaries)

nob – Orłów-Boguszowice Thrust
suK – Kocka Fault Zone
suKL – Kraków–Lubliniec Fault Xone
uCh – Chmielnik Fault
uD – Dolsk Fault
uG – Grójec Fault
uIZ – Izbica–Zamość Fault
uKU – Kazimierz–Ursynów Fault
uRW – Ryszkowa Wola Fault
uś – Intrasudetic Fault
uśO – Odra Fault Zone
uśw – Holy Cross Fault
wWL – Wolsztyn–Leszno High

Ad. 2. Petroleum provinces in Poland on the map of Variscan structures (below Permian-Mesozoic cover) according to Aleksandrowski and Buła (2017, modified). The edge of the East European Platform according to Aleksandrowski et al. (2017).



Permian-Mesozoic anticlinoria

Permian-Mesozoic synclinoria

Permian-Mesozoic monoclines

Pre-Mesozoic

Mesozoic fold-and-thrusts belts

major anticlines in Mesozoic

overthrusts

faults

range of Mesozoic salt structures

nk Koszalin Trough

np Puławy Trough

petroleum provinces (boundaries)

Ad. 3. Petroleum provinces in Poland on the map of Old-Alpine structures according to Aleksandrowski (2017a).

Ad. 4. Table of prospective areas.

No.	Name	Acreage [km^2]	Petroleum province	Target
1	Rejowiec Fabryczny	896.328	EASTERN PP	unconventional for shale gas and shale oil in Lower Silurian shales
2	Chybie	100.697	SOUTHERN PP	conventional and unconventional for gas in Middle and Upper Devonian and Lower Carboniferous carbonates, Lower Devonian and Upper Carboniferous sandstones, siltstones and sandstones of Miocene Skawina Formation, sandstones of Istebna, Ciężkowice and Krosno beds
3	Kalwaria Zebrz. - Dobczyce	615.816		conventional and unconventional for oil and gas in Precambrian sandstones (hypothetically), Middle and Upper Devonian, Lower Carboniferous and Upper Jurassic carbonates, Cretaceous sandstones, Badenian and Sarmatian siltstones and sandstones of Carpathian Foredeep, Carpathian Istebna and Ciężkowice sandstones
4	Żegocina	480.493		
5	Nowa Dęba	584.168		conventional and unconventional for gas in Ediacaran and Cambrian sandstones (hypothetically), Badenian and Sarmatian siltstones and sandstones of Carpathian Foredeep
6	Gorzów	1015.063	WESTERN PP	conventional for oil and gas in Main Dolomite carbonates (isolated platforms and their slopes)
7	Hel	1196.982	NORTHERN PP	conventional for oil and gas in Cambrian sandstones; unconventional for tight oil and tight gas in Cambrian sandstones
8	Jastarnia	1146.388		
9	Kartuzy	898.424		conventional for oil and gas in Cambrian sandstones; unconventional for tight oil and tight gas in Cambrian sandstones; unconventional for shale oil and shale gas in Lower Paleozoic
10	Łeba S	1172.924		
11	Nowa Karczma	906.099		
12	Rozewie S	1187.822		
13	Sierakowice	926.732		unconventional for tight/shale oil and tight/shale gas in Cambrian sandstones; unconventional for shale gas and shale oil in Lower Paleozoic
14	Władysła-wowo	822.213		conventional for oil and gas in Cambrian sandstones; unconventional for tight oil and tight gas in Cambrian sandstones; unconventional for shale oil and shale gas in Lower Paleozoic