



**Polish Geological Institute
National Research Institute**
Polish Geological Survey

HYDROCARBON PROSPECTIVE OF POLAND

**NFEP&WM agreement No. 307/2021/Wn-07/FG-sm-dn/D of 21-04-2021
PGI–NRI project No. 22.5004.2101.00.1**

GOSTYŃ

TENDER AREA

GEOLOGICAL PACKAGE ENGLISH ABSTRACT

VII LICENSING ROUND

**FOR CONCESSIONS FOR PROSPECTION AND EXPLORATION
OF HYDROCARBON FIELDS AND PRODUCTION OF HYDROCARBONS FROM FIELDS
IN POLAND**

Team leader:
Krystian WÓJCIK



**NATIONAL FUND
FOR ENVIRONMENTAL PROTECTION
AND WATER MANAGEMENT**

**Dariusz BRZEZIŃSKI, Joanna FABIAŃCZYK, Anna GRYCZKO-GOSTYŃSKA,
Marzena JARMUŁOWICZ-SIEKIERA, Marek JASIONOWSKI,
Anna KALINOWSKA, Hubert KIERSNOWSKI, Sylwia KIJEWSKA,
Aleksandra KŁOS, Przemysław KOWALSKI, Olimpia KOZŁOWSKA,
Marcin ŁOJEK, Barbara MASSALSKA, Wojciech MIŚKIEWICZ,
Tomasz OLSZAK, Elżbieta PRZYTUŁA, Olga ROSOWIECKA,
Joanna ROSZKOWSKA-REMIN, Leszek SKOWROŃSKI, Marcin TYMIŃSKI,
Dorota WĘGLARZ, Michał WOROSZKIEWICZ**

Warsaw, 2024

Table of contents

1. GENERAL INFORMATION	3
1.1. LOCATION	3
1.2. ENVIRONMENTAL CONDITIONS.....	8
2. GEOLOGY	12
2.1. GENERAL GEOLOGY AND TECTONICS	12
2.2. STRATIGRAPHY	17
2.2.1. CARBONIFEROUS	17
2.2.2. PERMIAN – ROTLIEGEND	18
2.2.3. PERMIAN – ZECHSTEIN	21
2.2.4. TRIASSIC	40
2.2.5. JURASSIC	41
2.2.6. CENOZOIC	41
2.3. HYDROGEOLOGY	42
3. PETROLEUM PLAY	46
3.1. GENERAL CHARACTERISTICS.....	46
3.2. SOURCE ROCKS.....	47
3.3. RESERVOIR ROCKS	50
3.4. SEAL AND OVERBURDEN ROCKS	56
3.5. GENERATION, MIGRATION, ACUMULATION, AND HYDROCARBON TRAPS	56
4. HYDROCARBON FIELDS	58
4.1. KAŁOLEWO NATURAL GAS FIELD	60
4.2. ŻAKOWO NATURAL GAS FIELD	63
5. WELLS	67
6. SEISMIC SURVEYS.....	71
7. GRAVIMETRY, MAGNETOMETRY AND MAGNETOTELLURICS.....	77
7.1. GRAVIMETRY	77
7.2. MAGNETOMETRY.....	77
7.3. MAGNETOTELLURICS	77
8. SUMMARY.....	81
9. REFERENCES.....	83

1. GENERAL INFORMATION

1.1. LOCATION

The Gostyń tender area of 916.92 km² is located onshore in western Poland (concession blocks 245, 246, and 247; Fig. 1.1). The precise location is defined by geographic coordinates listed below.

Border points	1992 coordinate system	
	X	Y
1	458612.86	329000.37
2	449098.43	390925.24
3	434350.20	388236.63
4	435825.17	379052.82
5	436042.65	379058.04
6	436084.28	377442.15
7	444253.75	327199.72

Tab. 1.1. Border points' coordinates of the Gostyń tender area (Fig. 1.2).

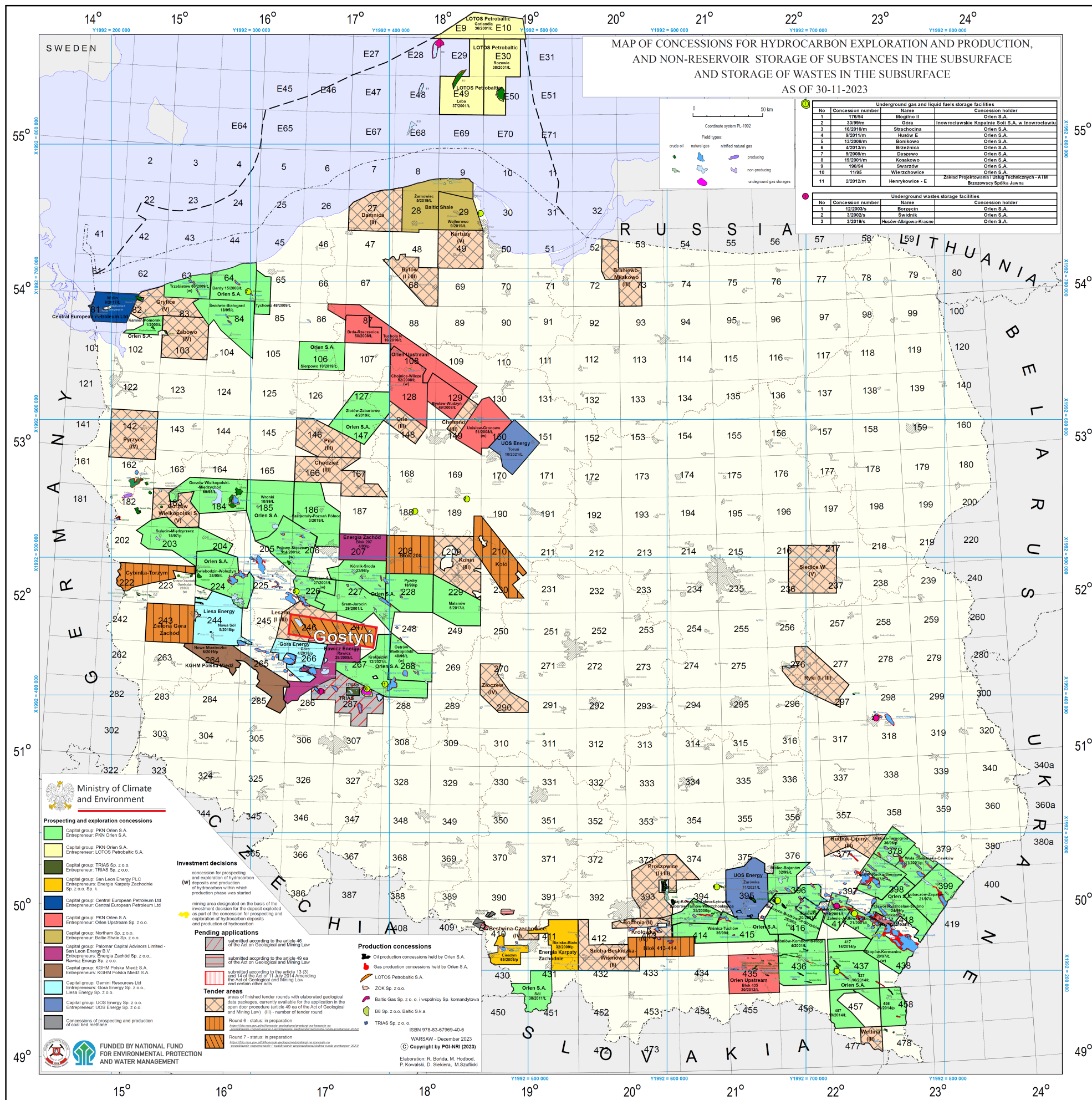
To the end of November, 2014, the western part of the Gostyń tender area (blocks 245 and 246) was subjected to hydrocarbon prospecting and exploration concession Leszno No. 65/2008/p (FX Energy Poland). Later, the same side was a part of the Leszno tender area dedicated to the 1st and 3rd tender rounds for hydrocarbon concessions in Poland.

To the end of August, 2015, the eastern part of the tender area (block 247) was subjected to hydrocarbon prospecting and exploration concessions Jarczewo-Pogorzela No. 28/2001/p, Czatkowice No. 9/2008/p, and Pakosław-Krotoszyn No. 42/98/p, operated by PGNiG S.A.

Currently, the Gostyń tender area is adjacent to the south to the Rawicz concession No. 39/2009/Ł, operated by Rawicz Energy Sp. z o.o. (Fig. 1.1). In the vicinity there area also Śrem-Jarocin No. 29/2001/Ł and Krotoszyn No. 12/2021/Ł concessions, operated by ORLEN S.A., although they do not directly border the Gostyń tender area.

The Gostyń tender area is prospective for exploration of conventional oil and gas fields in the Permian/Zechstein Main Dolomite, Zechstein Limestone, and in the Permian/Rotliegend, as well as conventional and unconventional oil and gas fields in the Lower Carboniferous. The Gostyń tender area is also dedicated to exploration of two gas fields discovered in the Main Dolomite – Żakowo and Kąkolewo.

→**Fig. 1.1.** Location of the Gostyń tender area in 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 30-11-2023.



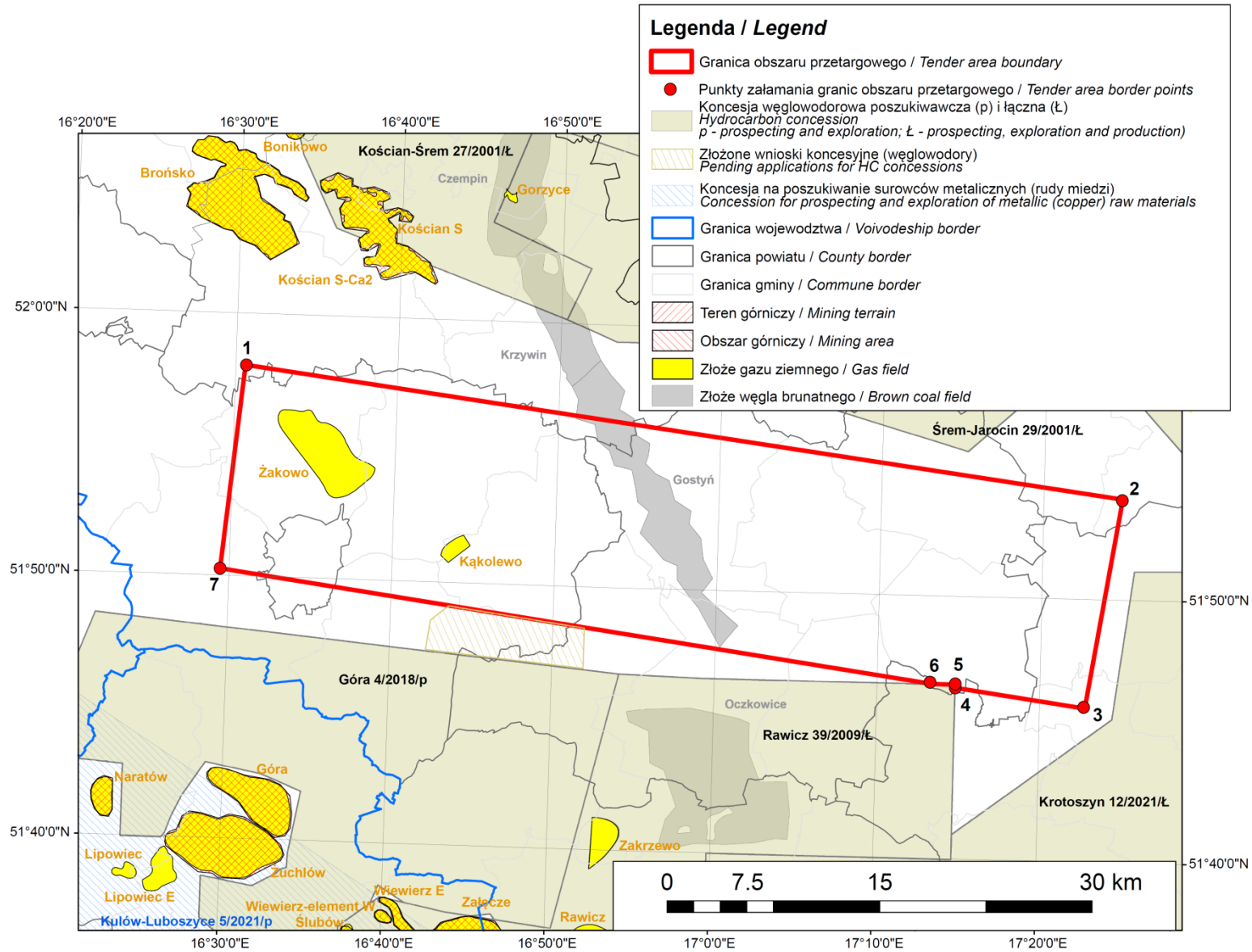


Fig. 1.2. Border points of the Gostyń tender area and location of the hydrocarbon concessions and fields of mineral resources in the neighborhood, as of 30-11-2023 (CGDB, 2023).

1.2. ENVIRONMENTAL CONDITIONS

THE ENVIRONMENTAL CONDITIONS DATASHEET FOR TENDER AREA GOSTYŃ				
1.	LOCATION OF THE TENDER AREA ON THE MAP	1 : 50 000 geological map sheet	578 Świąciechowa (Bukowiec Górny), 579 Leszno, 580 Krzywiń, 581 Gostyń, 582 Jaraczewo, 615 Wschowa, 616 Góra, 617 Poniec, 618 Kobylin, 619 Krotoszyn	
2.	ADMINISTRATIVE LOCATION	Voivodeship	Wielkopolskie	
		County	Kościan	
		The commune and % of the area within the tendering area	Śmigiel (0.26%), Krzywiń (1.10%)	
		County	Jarocin	
		Commune	Jaraczewo (1.25%), Jarocin (0.39%)	
		County	Leszno	
		Commune	Lipno (9.96%), Osieczna (12.80%), Krzemieniewo (11.25%), Świąciechowa (1.47%), Rydzyna (2.19%),	
		County	Leszno City	
		Commune	Leszno (2.47%)	
		County	Gostyń	
		Commune	Gostyń (12.28%), Piaski (10.70%), Borek Wielkopolski (7.77%), Poniec (3.84%), Krobia (3.04%), Pępowo (2.38%), Pogorzela (9.73%)	
		County	Krotoszyn	
Commune	Koźmin Wielkopolski (6.13%), Krotoszyn (0.65%), Kobylin (0.34%)			
3.	PHYSIOGRAPHIC REGIONALIZATION (after KONDRACKI, 2013 and SOLON et al., 2018)	Macroregion	Pojezierze Leszczyńskie (315.8)	
		Mesoregion	Pojezierze Krzywińskie (315.82)	
		Macroregion	Nizina Południowowielkopolska (318.1-2)	
		Mesoregion	Wysoczyzna Leszczyńska (318.11) Wysoczyzna Kaliska (318.12)	
4.	COORDINATES OF THE TENDER AREA BORDER POINTS	PL-1992 [X; Y]	458612.86	329000.37
			449098.43	390925.24
			434350.20	388236.63
			435825.17	379052.82
			436042.65	379058.04
			436084.28	377442.15
			444253.75	327199.72
5.	SURFACE OF THE TENDER AREA	[km ²]	916.92	
6.	CONCESSION TYPE		prospecting, exploration and production of hydrocarbons	
7.	AGE OF HYDROCARBON FORMATION		Permian (Main Dolomite, Zechstein Limestone, Rotliegend), Lower Carboniferous	
8.	PROTECTED NATURAL AREAS	[yes/ no] if “yes”: the name of the tender area and its % within the total area		
	National Parks		no	
	Natural Reserves		Pępowo (0.01%), Czerwona Róża (0.006%), Ostoja żółwia błotnego (0.004%), Torfowisko Źródłiskowe w Gostyniu Starym (0.004%), Boddzewko (0.001%), Dolinka (0.002%)	
	Landscape Parks		no	
	Protected landscape areas		Kompleks leśny Śmigiel-Świąciechowa (4.09%), Krzywińsko-Osiecki wraz z zadrzewieniami	

THE ENVIRONMENTAL CONDITIONS DATASHEET FOR TENDER AREA GOSTYŃ			
			generała Dezyderego Chłapowskiego i kompleksem leśnym Osieczna-Góra (26.03 %)
	Natura 2000, (Special Area of Conservation, SAC)		PLH300014 Zachodnie Pojezierze Krzywińskie (5.71%)
	Natura 2000, (Special Bird Protection, SPA)		PLB300005 Zbiornik Wonieść (1.05 %)
	Nature and landscape complexes		no
	Ecological area		2
	Nature monuments	[yes (quantity) / no]	73 (including 199 objects)
	Documentation positions		no
9.	PROTECTED SOIL	[yes / no]	yes
10.	FOREST COMPLEXES	[yes / no]	yes
11.	PROTECTIVE FORESTS	[yes (% of the total area / no)]	126.5 km ² (13.8 %)
		[yes (quantity) / no]	
12.	CULTURAL HERITAGE FACILITIES Archaeological monuments		
		Hillfort	16
		Hamlet	13
		Cemetery	4
		others	2
13.	MAJOR GROUNDWATER RESERVOIRS	[yes (number, name and age of the aquifer) / no]	305 Zbiornik międzymorenowy Leszno, Q ; 307 Sandr Leszno, Q; 308 Zbiornik międzymorenowy rzeki Kani, Q
14.	PROTECTIVE ZONES OF WATER INTAKE	[yes / no]	yes
15.	SPA PROTECTION ZONES	[yes / no]	no
16.	FLOOD HAZARD AREA	[yes / no]	no
17.	POROVEN MINERAL DEPOSITS	[yes (type of mineral deposit)/ no]	yes (natural aggregates, brown coals, natural gas, clays, chalk, gyttjas)
18.	PROGNOSTIC AND PERSPECTIVE AREAS OF OCCURRENCE OF MINERAL RESOURCES (excluding hydrocarbons)	[yes (type of mineral deposit)/ no]	yes (sands, sands and gravels, peats, rock salts, brown coal, gold, tilts)
19.	NATURAL GAS PIPELINES	[yes / no]	yes
20.	UNDERGROUND GAS STORAGE	[yes / no]	no
21.	DATE OF THE DATASHEET COMPLETION		07.03.2023
22.	DATA COLLECTION		Aleksandra Kłos

Tab. 1.3. The environmental conditions datasheet for the Gostyń tender area.

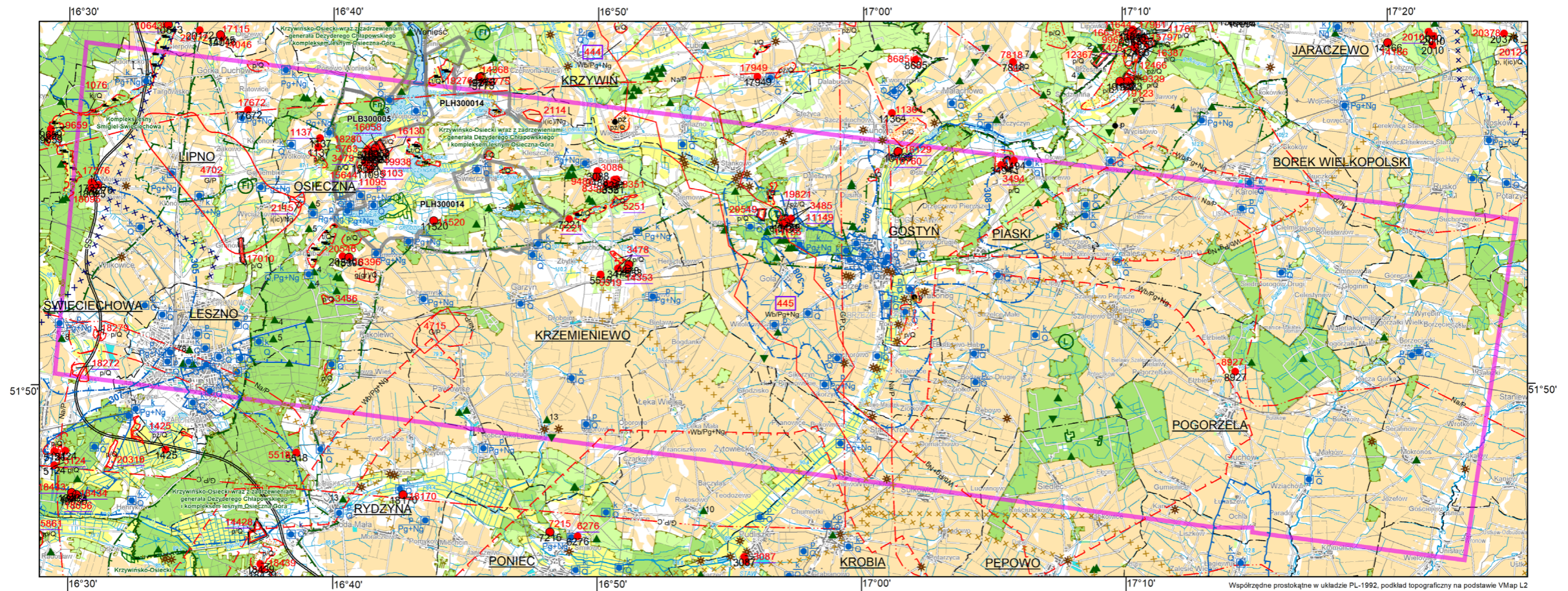
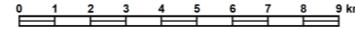
→**Fig. 1.3.** Environmental Map of the Gostyń area.

Mapa środowiskowa obszaru GOSTYŃ

Environmental Map of the GOSTYŃ area

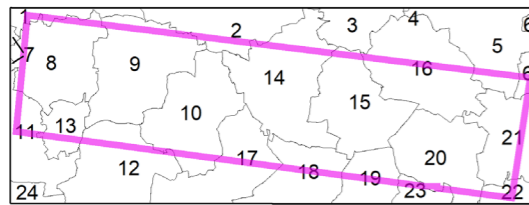


skala 1:125 000
scale 1:125 000



Współrzędne prostokątne w układzie PL-1992, podkład topograficzny na podstawie VMap L2

Położenie obszaru przetargowego Gostyń na tle podziału administracyjnego
Location of tender area on administrative division map



Copyright by PIG-PIB, Warszawa 2022

woj. WIELKOPOLSKIE
powiat Kościański
1 - gm. Smigiel
2 - gm. Krzymień
powiat Sremski
3 - gm. Dołsk
4 - gm. Książ Wielkopolski
powiat Jaraczewski
5 - gm. Jaraczewo
6 - gm. Jarocin
powiat Leszczyński
7 - gm. Włoszakowice
8 - gm. Lipno
9 - gm. Osieczna
10 - gm. Krzemieniewo
11 - gm. Święciechowa
12 - gm. Rydzyna

powiat Leszno
13 - m. Leszno
powiat Gostyński
14 - gm. Gostyń
15 - gm. Piaski
16 - gm. Borek Wielkopolski
17 - gm. Poniec
18 - gm. Pępowo
19 - gm. Pępowo
20 - gm. Pogorzela
powiat Krotoszyński
21 - gm. Koźmin Wielkopolski
22 - gm. Krotoszyn
23 - gm. Kobylin
woj. DOLNOŚLĄSKIE
powiat Górski
24 - gm. Góra

Położenie obszaru przetargowego na arkuszach 1:50 000
Location of tender area on maps with a scale of 1:50 000

578	579	580	581	582
Święciechowa (Bukowiec Góry)	Leszno	Krzywiń	Gostyń	Jaraczewo
615	616	617	618	619
Wschowa	Góra	Poniec	Kobylin	Krotoszyn

Zestawienie danych oraz redakcja komputerowa mapy: **Aleksandra Kłos**
Data compilation and map edition:

Weryfikacja: **Olimpia Kozłowska**
Verification:

Objaśnienia do Mapy środowiskowej obszaru
GOSTYŃ

Legend of the Environmental Map of the GOSTYŃ area
(opracowano na podstawie bazy MGŚP z zasobów PIG-PIB*)
(based on MGŚP database*)

ZŁOŻA KOPALIN ORAZ
PERSPEKTYWY I PROGNOZY ICH WYSTĘPOWANIA

MINERAL DEPOSIT AND
PERSPECTIVE AREA'S, PROGNOSTIC AREA'S FOR DOCUMENTING DEPOSITS

	kreda jeziorna i gytja lacustrine chalk and gyttja		piaski i żwiry sands and gravels
	ity i łupki ilaste raw materials		piaski sands
	gliny tills		torfy peat

3088 identyfikator z bazy MIDAS złóż mało konfliktowego
ID from the MIDAS database of the small environmental conflict

1076 identyfikator z bazy MIDAS złóż konfliktowego
ID from the MIDAS database of the environmental conflict

445 GOSTYŃ identyfikator z bazy Midas oraz nazwa złoża bardzo konfliktowego
ID from the MIDAS database of the very environmental conflict

— granica złoża
deposit boundary

- - - granica obszaru prognostycznego
prognostic area boundary

- · - granica obszaru perspektywicznego
perspective area boundary

● złożo o powierzchni ≤ 5 ha
deposit with area ≤ 5 ha

GÓRNICZTWO I PRZETWÓRSTWO KOPALIN

MINING AND MINERAL PROCESSING

— granica obszaru górniczego
boundary of the mining area

- - - granica terenu górniczego
boundary of the mining terrain

○ obszar i teren górniczy złoża o powierzchni ≤ 5 ha
area and terrain of the deposit with area ≤ 5 ha

● p punkt niekoncesjonowanej eksploatacji kopaliny (pc - rodzaj kopaliny)
point of unlicensed exploitation of a mineral (p - type of mineral)

Symbol kopaliny:

Mineral symbol.

Wb - węgiel brunatny
coal

G - gaz ziemny
natural gas

ī(c) - ity i łupki ilaste ceramiki budowlanej
building ceramics raw materials

g(gc) - gliny ceramiki budowlanej
building ceramic clay

Na - sól kamienna
rock salt

Au - złoto
gold

kj - kreda jeziorna
lacustrine chalk and gyttja

pż - piaski i żwiry
sands and gravels

p - piaski
sands

t - torfy
peat

Symbol jednostki stratygraficznej:

Symbol of the stratigraphic unit.

Q - Czwartorzęd
Quaternary

Ng - Neogen
Neogene

Pg - Paleogen
Paleogene

P - Perm
Permian

C - Karbon
Carboniferous

OCHRONA PRZYRODY, KRAJOBRAZU
I DZIEDZICTWA KULTUROWEGO

PROTECTION OF NATURE, LANDSCAPE AND CULTURAL HERITAGE

grunty orne (klasy I-IVa użytków rolnych)
arable land (class I-IVa)

łąki na glebach pochodzenia organicznego
meadows on organic soils

lasy
forests

lasy ochronne
protected forests

zielenie urządzone
urban greenery

— granice terenów zarządzanych przez Dyрекcję Generalną Lasów Państwowych
boundary of areas managed by General Directorate of the State Forests

— granica obszaru chronionego krajobrazu; nazwa obszaru
boundary of protected landscape area; area name

— L — granica rezerwatu przyrody (L - lasy)
boundary of natural reserve (L - forests)

Obszary Europejskiej Sieci Ekologicznej Natura 2000; kod obszaru
Natura 2000 ecological network; area code

Fn rezerwat przyrody o powierzchni ≤ 5 ha
(Fn - faunistyczny, Fl - florystyczny, T - torfowiskowy, L - lasy)
boundary of natural reserve with area ≤ 5 ha (Fn - faunistic, Fl - floristic, T - peatland, L - forest)

n pomnik przyrody żywej (n - liczba obiektów)
animate nature monument (n - number of objects)

▼ pomnik przyrody nieożywionej
inanimate nature monument

użytek ekologiczny
ecological area

geostanowisko o znaczeniu regionalnym
geosite of regional importance

* stanowisko archeologiczne
archaeological site

INFORMACJE DODATKOWE

ADDITIONAL INFORMATIONS

— granica powiatu
district boundary

— granica gminy, miasta
commune or town boundary

== S5 == oś autostrady lub drogi szybkiego ruchu
highway or express route

ŚWIECIECHOWA siedziba urzędu gminy, miasta
commune or town office headquarter

× × × × × sieć gazociągów przesyłowych
natural gas pipeline network

× × × × × sieć elektroenergetyczna najwyższych napięć
high-voltage power network

granica obszaru przetargowego
boundary of tender area

WODY POWIERZCHNIOWE I PODZIEMNE

— granica działu wodnego drugiego rzędu
water divide of second rank

— granica działu wodnego trzeciego rzędu
water divide of third rank

— granica działu wodnego czwartego rzędu
water divide of fourth rank

308 granica głównego zbiornika wód podziemnych wraz z jego numerem
principle boundary aquifer with ID number

— granica strefy ochrony ujęcia wód
water intake protected area boundary

Zb. Wronoski zbiornik retencyjny wraz z jego nazwą
water reservoir with its name

ujęcia wód podziemnych o wydajności ≥ 50 m³/h
(k - komunalne, p - przemysłowe, Q - wiek ujmowanych utworów)
underground water intake with capacity ≥ 50 m³/h
(k - municipal, p - industrial, Q - age of exploited rocks)

* tylko ujęcia posiadające ustanowioną strefę ochrony
* applies to intakes with an established protection zone

* Wykorzystano informacje udostępniane przez: RZGW, GDOŚ, GDLP, IMGW-PIB, NID, PSE, GAZ-SYSTEM, urzędy morskie oraz z baz danych PŚG i PSH w PIG-PIB
* Data source: RZGW, GDOŚ, GDLP, IMGW-PIB, NID, PSE, GAZ-SYSTEM, maritime offices and from database of PŚG and PSH

2. GEOLOGY

2.1. GENERAL GEOLOGY AND TECTONICS

The Gostyń tender area is located within the Western European platform (Żelaźniewicz et al., 2011). It consists of the Variscan basement and the Permian-Mesozoic and Cenozoic sedimentary covers (Nawrocki and Becker, 2017; Figs 2.1–2.2). The Variscan basement is formed by folded and partially metamorphosed Devonian and Carboniferous rocks, which belong to the Variscan Externides: the Wielkopolska Fold Belt (Fig. 2.1B). The Devonian phyllites crop out directly under the Permian-Mesozoic cover in the western part of the tender area: this metamorphic belt continues NW on the southern side of the Dolsk Fault, forming the so-called Wolsztyn-Leszno High (Żelaźniewicz et al., 2011). In the central and eastern parts of the Gostyń area, metamorphic rocks are covered by the Upper Devonian and Carboniferous flysch series and molasses. Above them, the Upper Carboniferous and Lower Permian volcanic rocks occur in places.

The Permian-Mesozoic sedimentary cover begins with the (Lower and Upper) Rotliegend deposits. Their range is limited only to the south-western part of the tender area. The remaining part of the Gostyń area (without Rotliegend sediment cover) belongs to the so-called Wolsztyn High. In this report, the Wolsztyn High (opposed to the Wolsztyn-Leszno High defined above) will be understood as a structure in which Carboniferous-Lower Permian volcanogenic or older rocks crop out directly under the Zechstein. The Carboniferous and Lower Permian volcanogenic rocks do not form a continuous cover in the Gostyń area, but occur only in its central part. To the east of them, the Carboniferous deposits form the so-called Pogorzela High – the eastern closure of the Wolsztyn High (Kwolek and Mikołajewski, 2007).

The palaeotopography of the Wolsztyn High influenced the sedimentation of the Zechstein deposits, at least during the sedimentation of its first two cyclothems, which are clearly stratigraphically reduced on the Pogorzela High. Above the Zechstein, there are clastic-carbonate succession of the Triassic and the partially preserved Jurassic. In the Old-Alpine structural plan (Fig. 2.1), the Gostyń tender

area is located within the Fore-Sudetic Monocline.

The youngest structural stage in the Gostyń tender area is formed by flat-lying Cenozoic sediments. They are represented by Oligocene, Miocene, Pliocene and Quaternary clastic deposits. It is worth to note that the tender area is crossed by a NNW-SSE tectonic trench, which cuts through the Mesozoic and Oligocene strata and it is filled with Miocene brown-coals and clastic sediments. However, younger Pliocene and Quaternary strata completely level out this relief.

In the next sections, lithological and stratigraphic characteristics of the stratigraphic succession in the Gostyń tender area are presented. These descriptions are derived from geological reports from 23 wells drilled within the tender area: Bułaków 1, Bułaków-2, Frankowo 1, Kąkolewo 1, Kąkolewo 2, Kąkolewo 4, Kobylin-1, Pogorzela 1, Pogorzela 2, Pogorzela 4, Pogorzela 7, Rusko-1, Siedmiorogów-1, Świąciechowa 1, Świąciechowa 2, Żakowo 1, Żakowo 2, Żakowo 3, Żakowo 4, Żakowo 5, Żakowo 6, Żakowo 7, and Żakowo 9. Location of these wells can be found in Fig. 2.3.

Tectonics

Tectonically, the Gostyń tender area is located within the so-called the Southern Wielkopolska Block, between the Middle Odra and Dolsk Fault Zones (the latter cuts the north-eastern part of the tender area, separating the Variscan Externides and the Variscan Fore-deep; Fig. 2.4). The Variscan basement was formed in the Variscan orogeny, during which fold-and-thrust deformations caused the Carboniferous and older rocks formed a number of compression structures which are still not mapped/investigated in details. The largest one is the Pogorzela High. In the Variscan basement the Carboniferous and older rocks dips up to 90°.

In the Gostyń area, the Permian basement top surface lies at a depths of about 2000–2500 m b.s.l., and dips more or less monoclinaly towards the north-east, except for the eastern part of the area, where, on the Pogorzela High, the Permian basement occurs at a

depth of approximately 1,700 m b.s.l. (Fig. 2.5). The Zechstein basement surface more or less follows the trend of the sub-Permian surface and is located at a depths of approximately 1,800–2,400 m b.s.l., but the Pogorzela High with an amplitude of approximately 300 m is still visible (Kudrewicz, 2007).

The Fore-Sudetic Monocline succession (Zechstein, Triassic, Jurassic) dips gently at an angle of several degrees, generally towards the north-east. The only exceptions are zones of tectonic trenches, where the occurrence of

faults and flexures causes disturbances in the regional dip. Two large fault zones in the form of tectonic trenches run through the Gostyń area: (1) NNW-SSE Poznań-Oleśnica Fault Zone located in the central part and (2) Chruściny-Nowa Wieś Zone branching off in the SW direction. These zones are visible not only on the sub-Cenozoic structural surface, but are also visible in the Zechstein, and even correlate with faults identified in the Variscan basement. They are also visible on magnetic anomaly maps (Fig. 2.6).

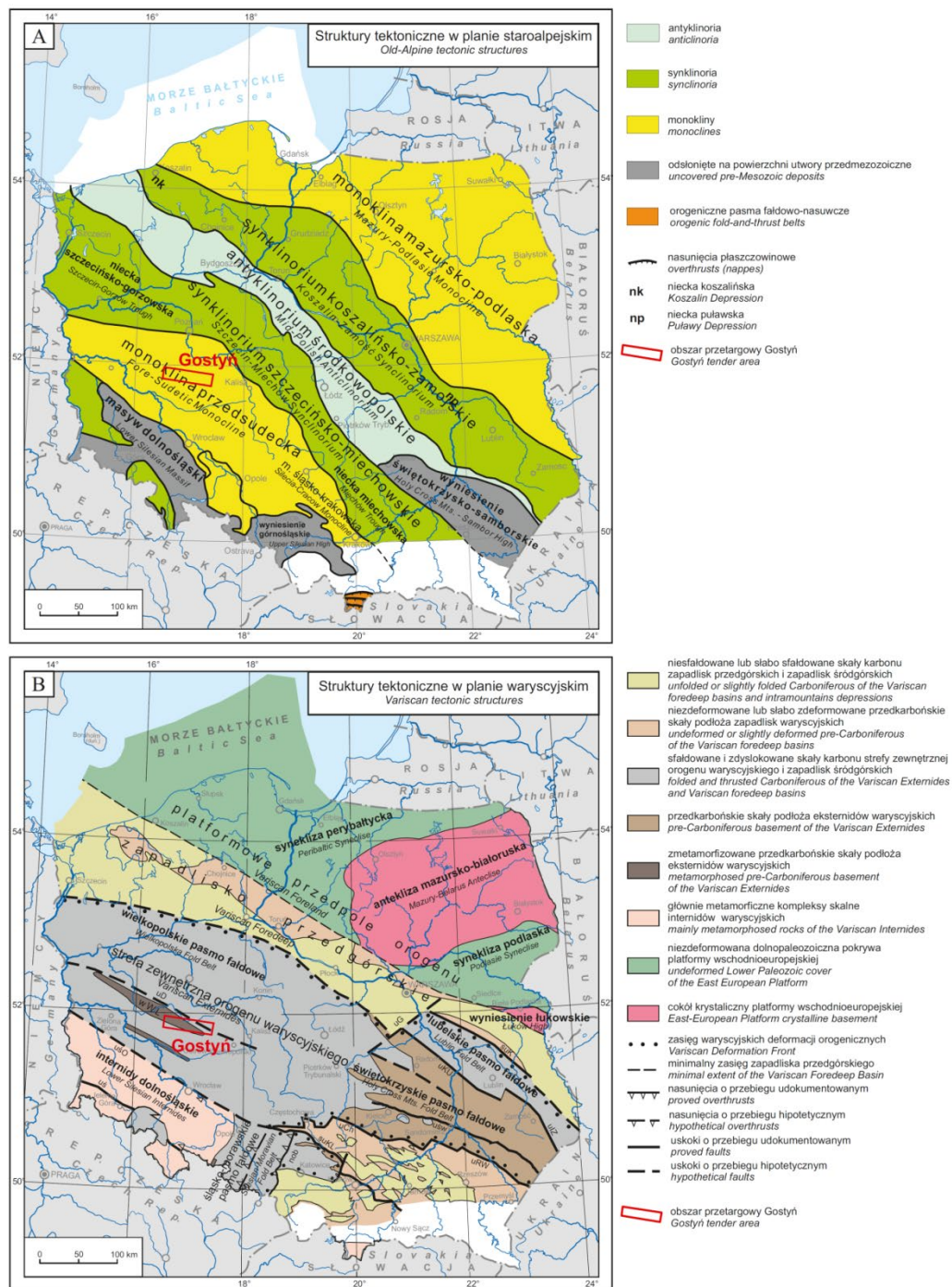


Fig. 2.1. A. Location of the Gostyń tender area in relation to the Old-Alpine tectonic structures (Nawrocki and Becker, 2017; modified). B. Location of the Gostyń area in relation to the Variscan tectonic structures (Nawrocki and Becker, 2017; modified).

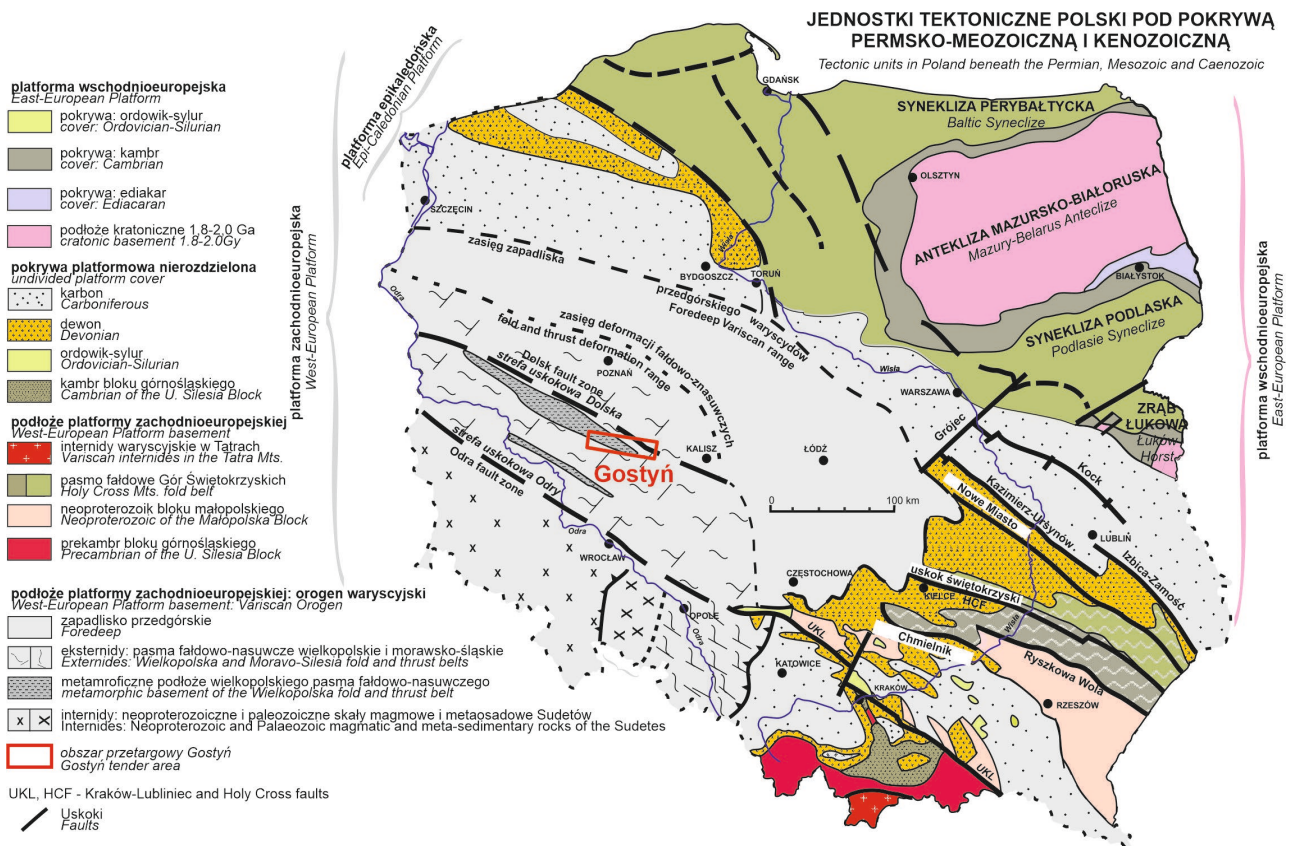


Fig. 2.2. Location of the Gostyń tender area in relation to the main tectonic units in Poland beneath the Permian, Mesozoic and Cenozoic (Żelaźniewicz et al., 2011; modified).

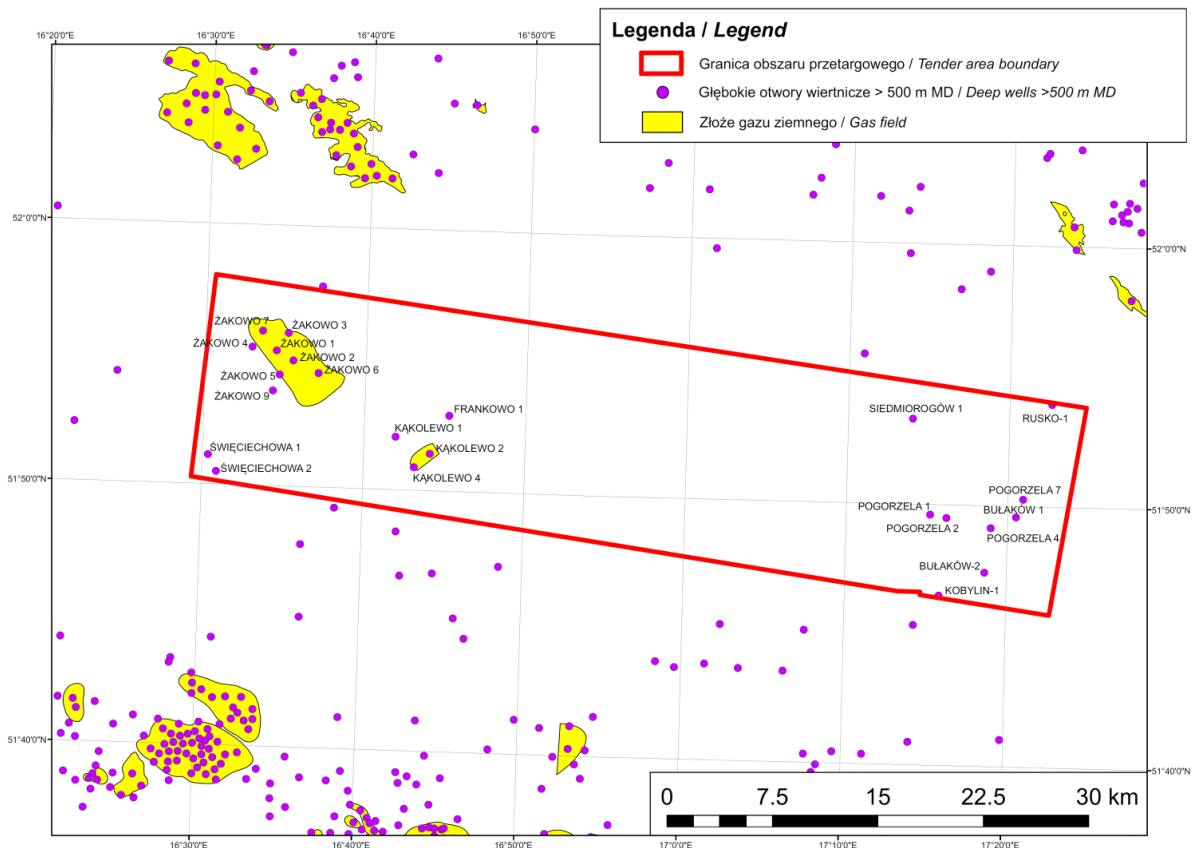


Fig. 2.3. Location of deep wells within the Gostyń tender area as crucial for geological characteristics of the area in relation to oil and gas fields.

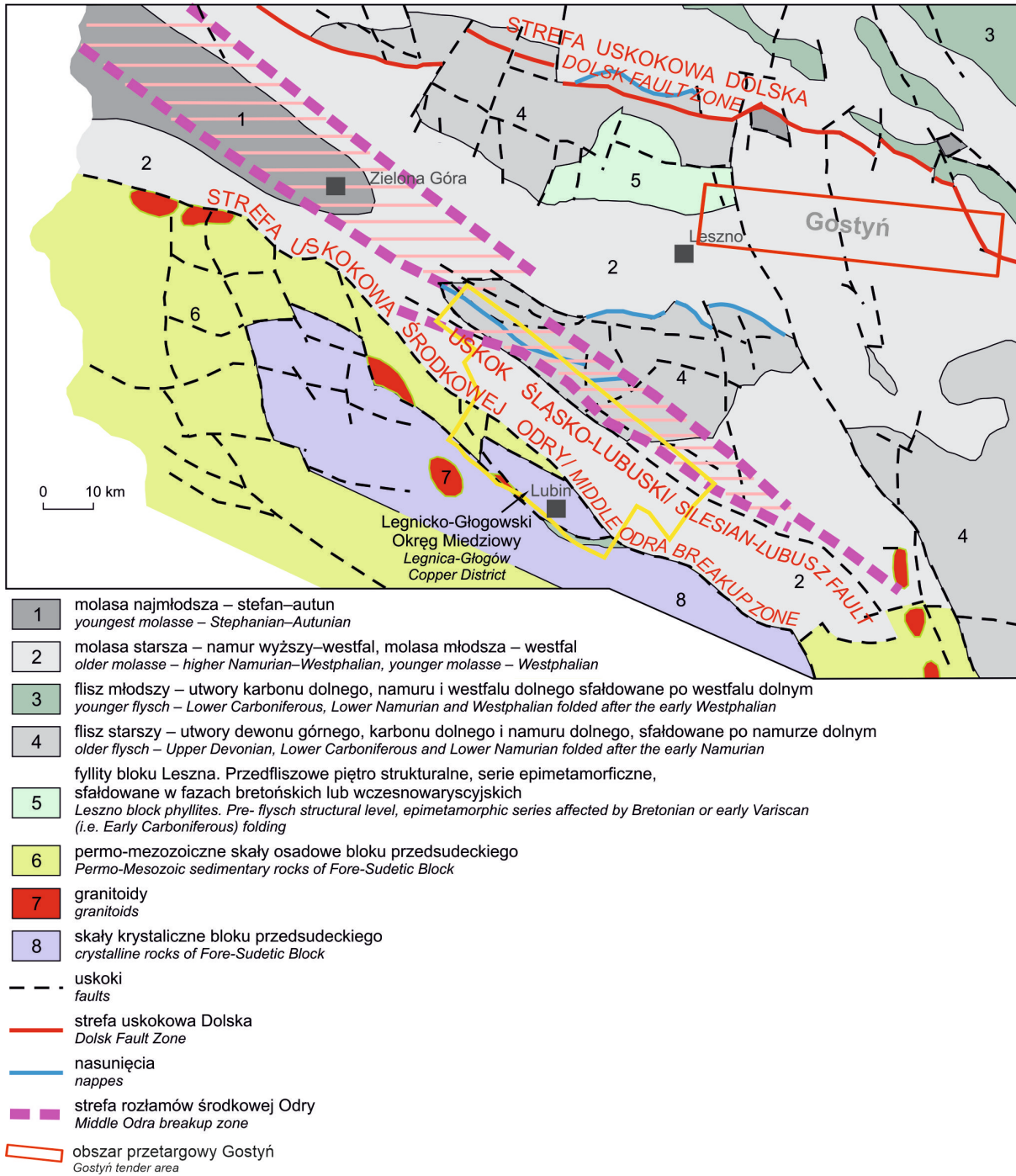


Fig. 2.4. Location of the Gostyń tender area on the geological sketch map of the sub-Permian basement of the Variscan foreland and fold-and-thrust belt (Kiersnowski and Petecki, 2017).

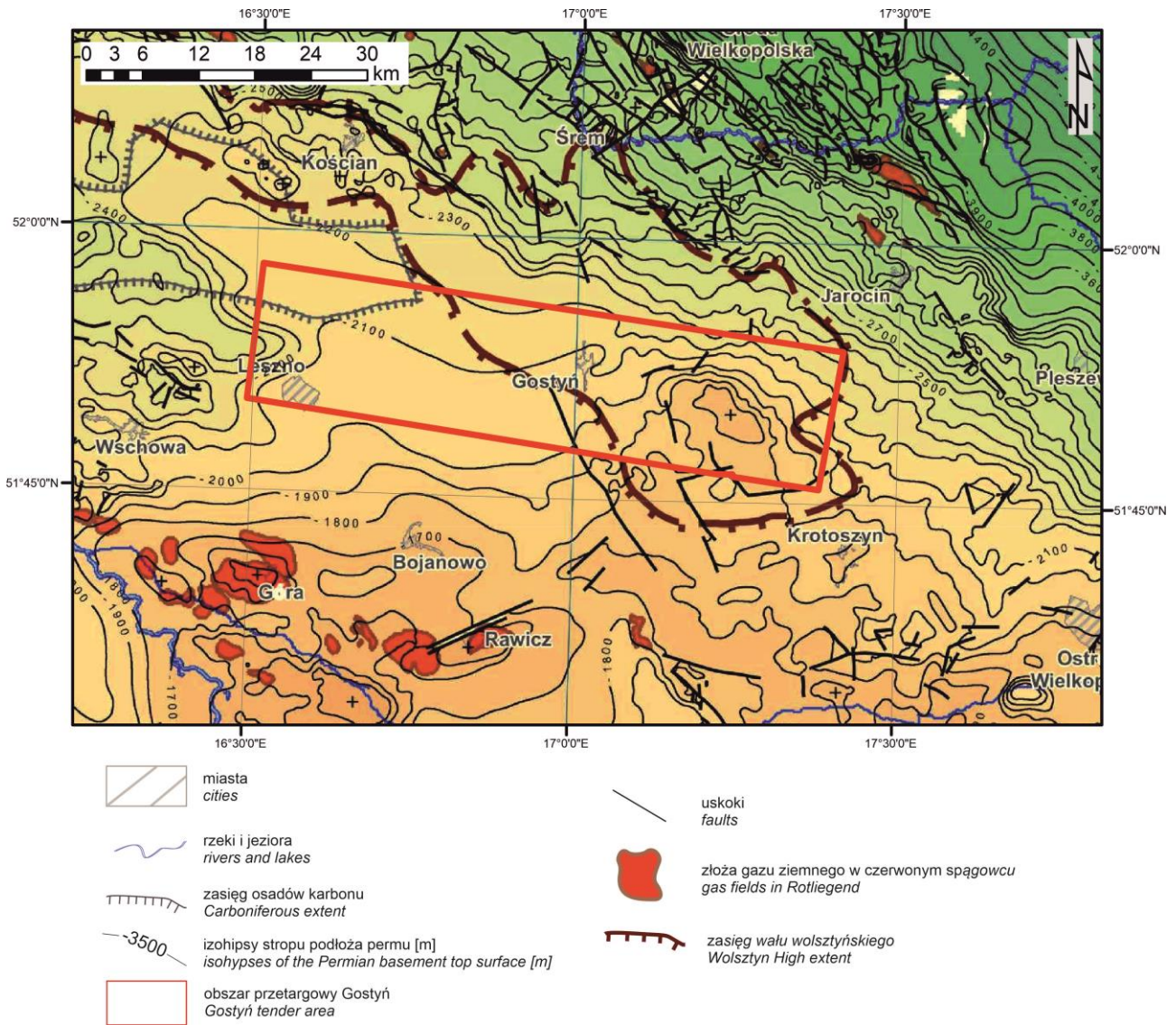


Fig. 2.5. Location of the Gostyń tender area on the map of the Permian basement top surface (Kudrewicz, 2007).

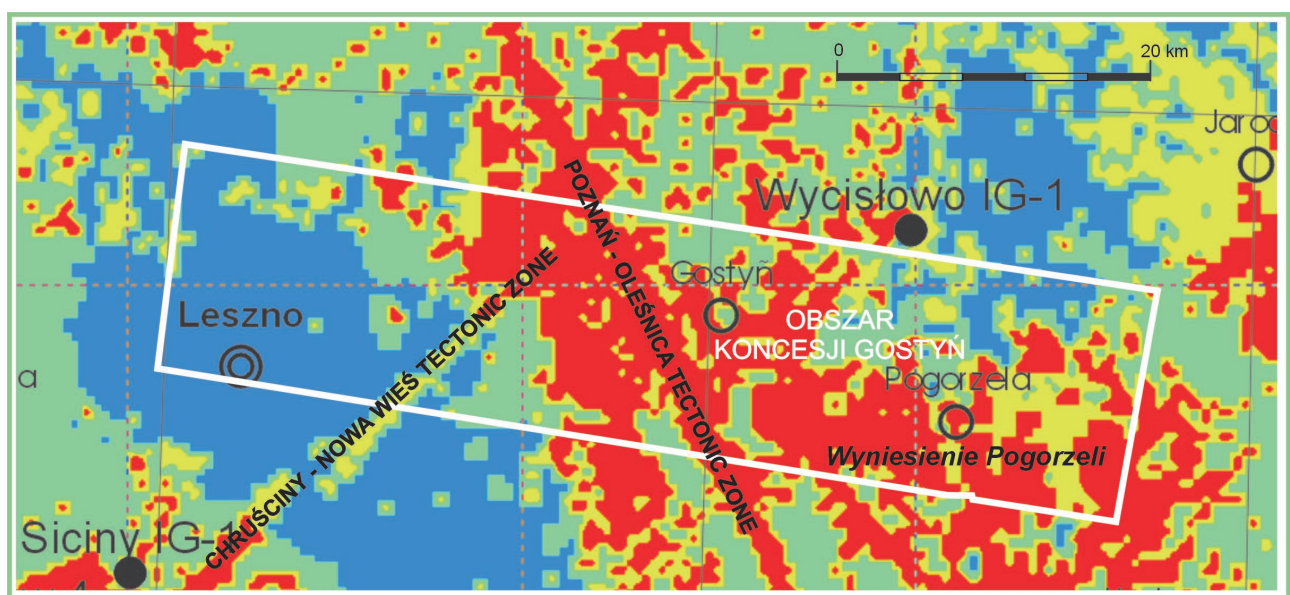


Fig. 2.6. Location of the Gostyń tender area on the magnetic anomaly map (Pepeł and Żuk, unpublished). See linear anomalies as the boundaries of the Neogene tectonic trenches.

2.2. STRATIGRAPHY

2.2.1. CARBONIFEROUS

Distribution and thickness

The Carboniferous was drilled in the following wells located within the Gostyń tender area:

- Bułaków 1: 2137,0–2225,0 m,
- Bułaków-2: 1853,5–1888,5 m,
- Kobylin-1: 1921,0–2861,0 m,
- Pogorzela 1: 1770,0–1797,7 m,
- Pogorzela 2: 1749,5–1767,0 m,
- Pogorzela 4: 2007,0–2060,2 m,
- Pogorzela 7: 2191,0–2207,3 m,
- Siedmiorogów-1,
- Święciechowa 1: 2595,5–2652,5 m,
- Święciechowa 2: 2173,5–2200,0 m,
- Żakowo 1: 2227,0–2374,8 m,
- Żakowo 3: 2236,0–2298,5 m,
- Żakowo 4: 2226,0–2232,5 m,
- Żakowo 6: 2190,0–2216,0 m.

The thickness of the Carboniferous in the Gostyń tender area is unknown. Only in the Święciechowa 1, the 57 m thick Carboniferous succession was pierced, and the Devonian metamorphic rocks were drilled below.

Lithology and stratigraphy

The oldest rocks in the Gostyń area were drilled in its western and central parts. These are metamorphosed siliceous-mica schists and chlorite schists belonging to the phyllites of the Wielkopolska Fold Belt/Wolsztyn-Leszno High (Żelaźniewicz et al., 2011, Figs 2.1–2.2). These shales are highly fractured, and the Upper Devonian/Lower Carboniferous sediments are considered as the protolith rocks (Żelaźniewicz et al., 2003, 2011; Mazur et al., 2006). Metamorphosed shales were drilled in the Żakowo 3, Żakowo 4 wells and in the bottom part of the Święciechowa 1 well. The Carboniferous in the remaining part of the tender area is represented by siliciclas-

tic formations, but their chronostratigraphy is undefined. In the Święciechowa 1 well, the so-called basement conglomerates lie directly on the metamorphosed older Paleozoic rocks. According to Kłapciński (after: Bojanowski et al., 1975), these conglomerates are characteristic for the entire Fore-Sudetic Monocline and belong to the Lower Carboniferous. In the Dąbcze 2 well, located approximately 3 km south of the tender area, shales, red-grey sandstones and mudstones were drilled and palynologically dated as the Upper Carboniferous (Westphalian–Stephanian). Most often, however, similar deposits are classified as Carboniferous without a more detailed stratigraphic diagnosis. For example, claystones drilled in the Żakowo 6 well do not contain any fossils and were classified only as the Carboniferous (after Bojanowski et al., 1975).

The petrographic characteristics of siliciclastic sediments are described in details in the Leszno geological data package (Kiersnowski et al., 2017). This report was prepared on the basis of scientific studies of Krzemiński (2005), report on tight gas prepared by the Polish Geological Service (Wójcicki et al., 2014) and final geological reports from the Święciechowa 1, Święciechowa 2, Żakowo 6, Jezierzyce 1, Dąbcze 2, and Śmiłowo 1 wells.

According to Wierzchowska-Kicułowa (2007; see also Kiersnowski and Petecki, 2017), within the Gostyń tender area the Carboniferous sediments belong to the older and younger molasses (Namurian–Upper Westphalian and Westphalian, respectively; Fig. 2.4). This is consistent with regional stratigraphic studies of Górecka-Nowak (2007, 2008), who confirmed that the Fore-Sudetic Monocline in this part is composed of Namurian A/B and Westphalian B, C and D rocks.

2.2.2. PERMIAN – ROTLIEGEND

Distribution and thickness

The Rotliegend was drilled in 12 wells in the Gostyń tender area (MD intervals):

- Frankowo-1: 2050.0–2200.0 m,
- Kąkolewo 1: 2053.0–2170.0 m,
- Kąkolewo 2: 2000–2084.0 m,
- Kąkolewo 4: 1979.0–2087.5 m,
- Rusko-1*: 2396.1–2599.5 m,
- Święciechowa 1: 2095.0–2595.5 m,
- Święciechowa 2: 2044.5–2173.5 m,
- Żakowo 1: 2195.5–2227.0 m,
- Żakowo 3: 2210.0–2236.0 m,
- Żakowo 4: 2199.5–2226.0 m,
- Żakowo 6: 2154.0–2190.0 m,
- Żakowo 9: 2169.0–2300.0 m.

Those wells, in which the Lower and Upper Rotliegend were drilled, are emphasized. In the Rusko-1 well only the Lower Rotliegend occurs. In the remaining wells only the Upper Rotliegend was drilled. The thickness of the investigated strata ranges from 0 to 500.5 m.

Lithology and stratigraphy

The Rotliegend basement in the Gostyń area is complicated and not fully recognized: there occur strongly tectonically arranged Lower Carboniferous rocks of the Culm facies, as well as carbonate-clayey rocks. Additionally, quartz-sericite phyllites occur directly under the Permian sediments in some places (Figs 2.4 and 2.7). In the western part of the Gostyń area, there are metamorphic rocks interpreted as phyllites (Kiersnowski and Petecki, 2017; Fig. 2.4). Their occurrence is related to the so-called Mid Crystalline Ridge Zone, which runs in the south-western Poland (Franke, 2014). There are also the Lower Rotliegend sedimentary rocks preserved there in tectonic trenches (Fig. 2.7). In the eastern part of the Gostyń area, directly under the Zechstein deposits, there are the Rotliegend volcanic rocks and Carboniferous sedimentary rocks on the Pogorzela High (Kwolek and Mikołajewski, 2007; Kiersnowski et al., 2010; Fig. 2.7). Kiersnowski (oral information) interprets the origin of this elevation as related to the overthrust of the Sub-Carboniferous phyllites.

The Rotliegend sedimentary basin in Poland was fulfilled by claystones, siltstones, sandstones, and conglomerates originated in the playa, playa-lake, aeolian, fluvial, and alluvial environments. The Gostyń area is located in the northern part of the Silesian Rotliegend sub-basin, located south of the Wolsztyn High (the Wolsztyn High is devoid of the Rotliegend deposits and is composed of the Lower Carboniferous rocks partly of volcanic origin). Here, the Upper Rotliegend sedimentary rocks are composed of aeolian and fluvial sandstones up to several dozen meters thick, and coarse-clastic alluvial deposits (Figs 2.7–2.8). Locally, clastic sediments of the Lower Rotliegend with a thickness exceeding 100 m and Lower Permian volcanic rocks were found (Fig. 2.7).

Hydrocarbon prospective of the Rotliegend and Carboniferous strata

In the Gostyń tender area, the Rotliegend exploration target is related to sandstones occurred in the topmost part of the succession. These sandstones dominate in the south-western part of the area. This horizon is sealed by Zechstein evaporites. However, the distribution of individual sedimentary lithofacies is not obvious and partially interpreted (Fig. 2.8). The ranges of sandstones, especially aeolian ones, are essential for the searching of zones with good reservoir properties. The best properties of the aeolian sandstones seem to occur in the western part of the Gostyń area. Their average porosity ranges from several to several percent (Fig. 2.9).

In the Gostyń area the existence of Rotliegend structural highs is postulated in the central part of the area. Unrecognized structural traps could be related to the high tectonic engagement of this region (Figs 2.7–2.8 and 2.10). The following prospective areas for oil and gas exploration in the Rotliegend occur (Fig. 2.10):

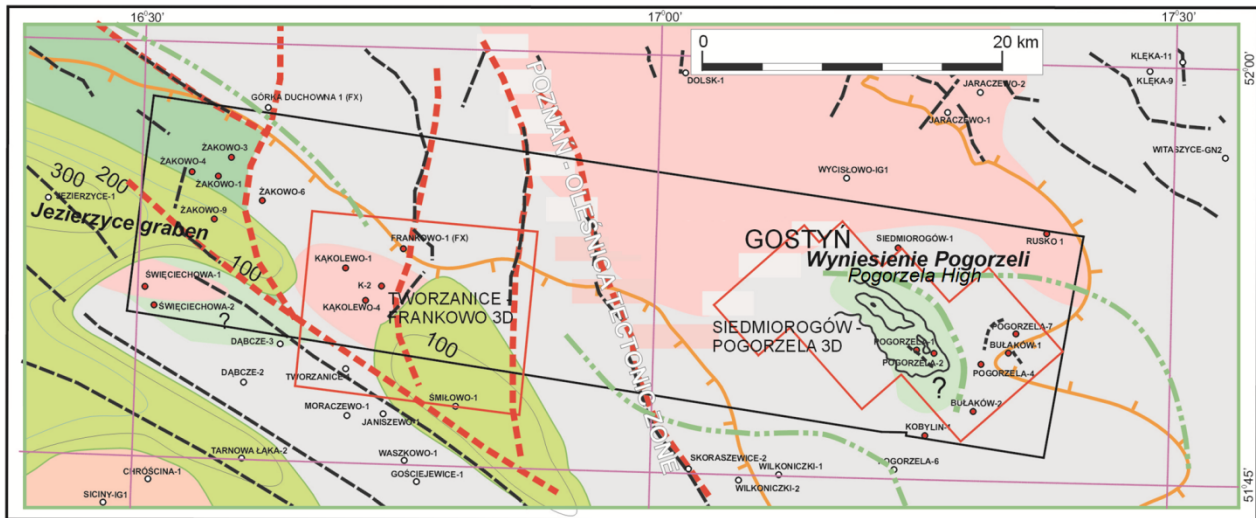
1. Southern part of the Frankowo-Tworzanice 3D seismic survey. The occurrence of geomorphological traps in the Upper Rotliegend aeolian sediments is postulated here. The seal is composed of Zechstein evaporites.

2. Poznań-Olesnica tectonic zone. Possible structural traps occur in the Upper Rotliegend and Carboniferous sediments. The seal is composed of Zechstein evaporites.

3. Pogorzela High. The Pogorzela 1 and 2 wells are located outside the Pogorzela culmination. However, according to Kiersnowski (oral information), at the central part of the High, within strongly frac-

tured Carboniferous strata, the accumulations of gas may occur.

In addition to possible tectonic (structural) traps, the geomorphological traps may also occur in the Gostyń area in the form of preserved dune paleofields in the topmost part of the Rotliegend. This possibility could be true only in the south-western part of the tender area.



- 100** Zasięg występowania i miąższość skał skał osadowych dolnego czerwonego spągowca
Lower Rotliegend sedimentary rocks extent and thickness
- Górnokarbońsko - dolnopermskie skały wulkaniczne (lawy i tufy)
Upper Carboniferous-Lower Permian volcanic rocks
- Skały osadowe (morskie) karbonu dolnego
Lower Carboniferous sedimentary (marine) rocks
- Górnodewońskie-dolnokarbońskie skały metamorficzne (fyllity) pod przykryciem osadów dolnego czerwonego spągowca i/lub cechsztynu
Upper Devonian-Lower Carboniferous metamorphic rocks (phyllites) under Lower Rotliegend and/or Zechstein sedimentary cover
- Górnodewońskie - dolnokarbońskie skały metamorficzne (fyllity) pod przykryciem osadów karbonu
Upper Devonian-Lower Carboniferous metamorphic rocks (phyllites) under the Carboniferous sedimentary cover

Uskoki i bloki tektoniczne interpretowane z map anomalii grawimetrycznych, map anomalii magnetycznych oraz danych sejsmicznych

Faults and tectonic blocks interpreted basing on gravimetric, magnetic and seismic data






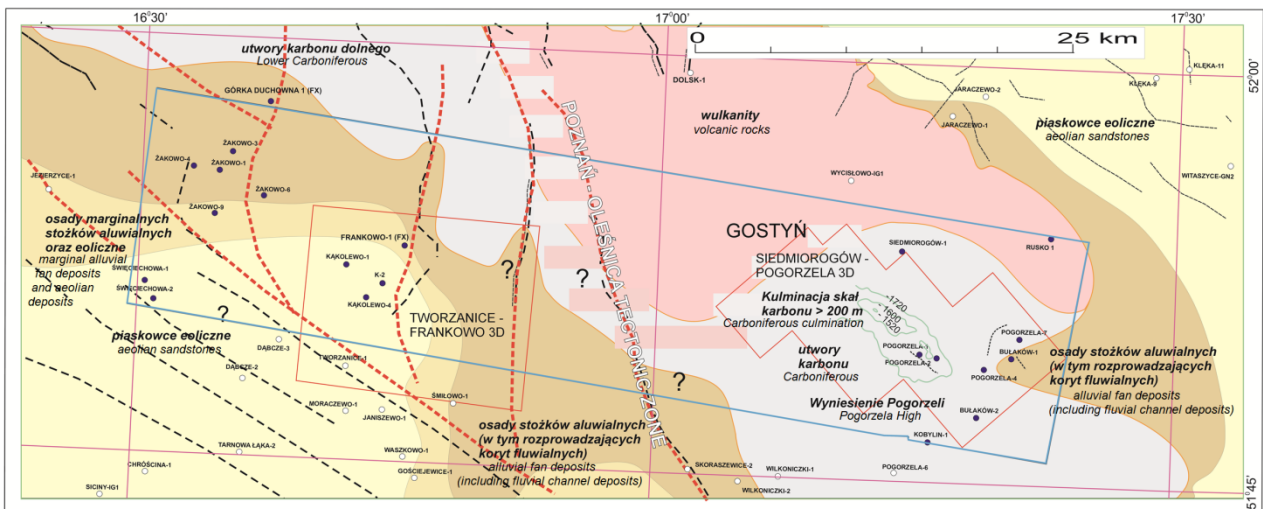
-  Strefy głównych uskoków tektonicznych
Main tectonic zones
-  Uskoki tektoniczne interpretowane z map miąższości osadów czerwonego spągowca oraz map strukturalnych podłoża cechsztynu
Faults interpreted basing on Rotliegend thickness maps and Zechstein basement structural maps
-  Interpretowane granice nasunięć tektonicznych
Interpreted overthrusts
-  Granice zasięgu występowania skał osadowych górnego czerwonego spągowca
Upper Rotliegend sedimentary rocks extent
-  KAKOLEWO 1 Otwory wiertnicze przewiercające osady karbonu i/lub czerwonego spągowca i cechsztynu
Wells pierced Carboniferous and/or Rotliegend and Zechstein deposits

Fig. 2.7. Geological map of the Upper Rotliegend and Zechstein basement (Kiersnowski, original materials basing on the CGDB 2023 data).



Litofacie w stropie osadów czerwonego spągowca
Lithofacies in the topmost part of the Rotliegend

- Piaskowce eoliczne
Aeolian sandstones
- Piaskowce eoliczne i aluwialne
Aeolian and alluvial sandstones
- Piaskowce i żwiry aluwialne
Alluvial sandstones and gravels

- Zasięg występowania i miąższość skał osadowych dolnego czerwonego spągowca
Lower Rotliegend sedimentary rocks extent and thickness

- Górnokarbońsko-dolnopermskie skały wulkaniczne (lawy i tufy)
Upper Carboniferous-Lower Permian volcanic rocks

Uskoki i bloki tektoniczne interpretowane z z map anomalii grawimetrycznych, map anomalii magnetycznych oraz danych sejsmicznych

Faults and tectonic blocks interpreted basing on gravimetric, magnetic and seismic data

- Strefy głównych uskoków tektonicznych
Main tectonic zones

- Uskoki tektoniczne interpretowane z map miąższości osadów czerwonego spągowca oraz map strukturalnych podłoża cechsztynu
Faults interpreted basing on Rotliegend thickness maps and Zechstein basement structural maps

- KĄKOLEWO 1
Otwory wiertnicze przewiercające osady karbon i/lub czerwonego spągowca i cechsztynu
Wells pierced Carboniferous and/or Rotliegend and Zechstein deposits

Fig. 2.8. Upper Rotliegend lithofacies in the Gostyń tender area and its vicinity (Kiersnowski, original materials basing on the CGDB 2023 data).

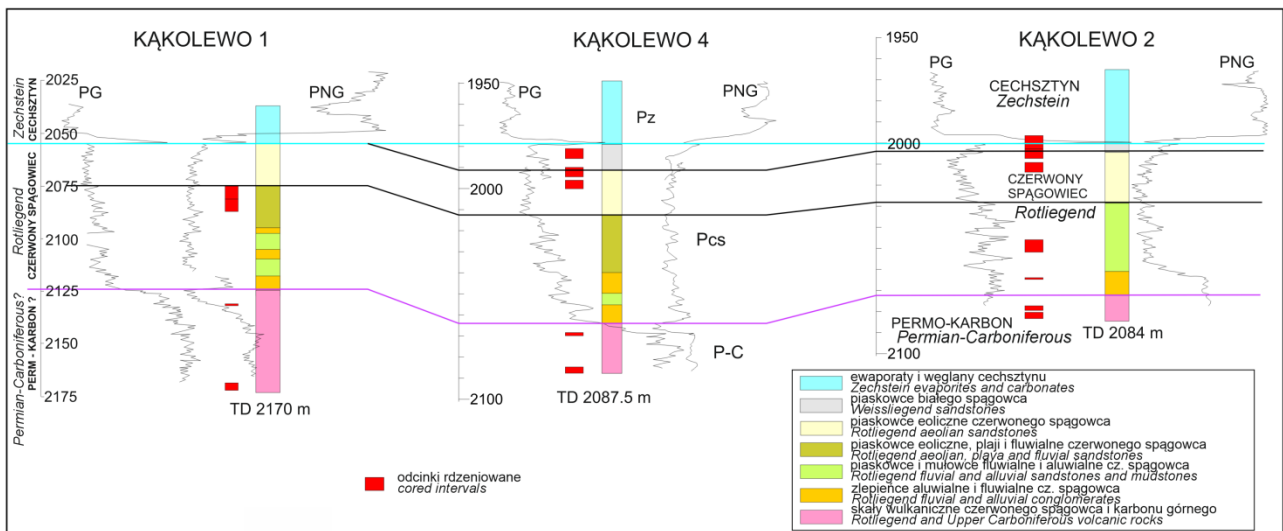


Fig. 2.9. Stratigraphic correlation of the Rotliegend deposits in the Gostyń tender area. The Zechstein basement surface is the reference level. See the presence of continuous horizon of the aeolian sandstones in the topmost part of the Rotliegend succession – possible traps for gas accumulations may occur therein. (Kiersnowski, original materials basing on the CGDB 2023 data).

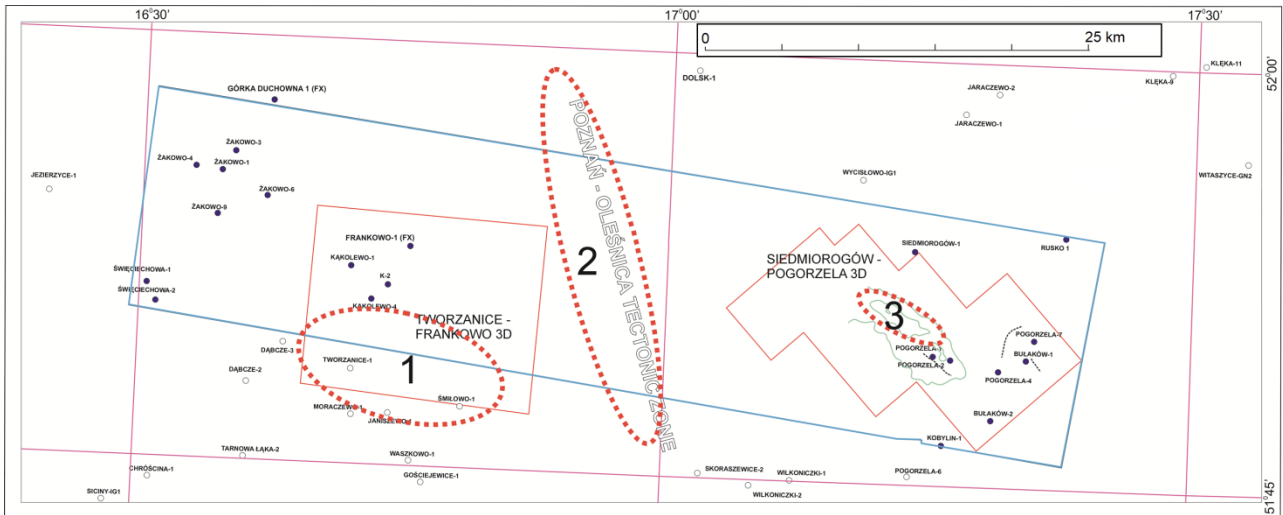


Fig. 2.10. Areas prospective for gas accumulations in the Carboniferous and Rotliegend deposits in the Gostyń tender area. (Kiersnowski, original materials basing on the CGDB 2023 data).

2.2.3. PERMIAN – ZECHSTEIN

Distribution and thickness

The Zechstein was drilled in all 23 deep wells located within the Gostyń tender area. These are (MD intervals):

- Bułaków 1: 1803.0–2137.0 m,
- Bułaków-2: 1636.5–1853.5 m,
- Frankowo 1: 1492.5–2050.0 m,
- Kąkolewo 1: 1555.0–2053.0 m,
- Kąkolewo 2: 1502.5–2000.0 m
- Kąkolewo 4: 1519.0–1979.0 m,
- Kobylin-1: 1608.0–1921.0 m,
- Pogorzela 1: 1636.0–1770.0 m,
- Pogorzela 2: 1650.0–1749.5 m,
- Pogorzela 4: 1735.0–2007.0 m,
- Pogorzela 7: 1850.0–2191.0 m,
- Rusko-1: 2094.0–2396.1 m,
- Siedmiorogów-1,
- Świąciechowa 1: 1571.5–2095.0 m,
- Świąciechowa 2: 1565.0–2044.5 m,
- Żakowo 1: 1677.5–2195.5 m,
- Żakowo 2: 1635.0–1830.2 m,
- Żakowo 3: 1663.0–2210.0 m,
- Żakowo 4: 1663.5–2199.5 m,
- Żakowo 5: 1628.5–1830.7 m,
- Żakowo 6: 1646.0–2154.0 m,
- Żakowo 7: 1653.0–1836.0 m,
- Żakowo 9: 1657.5–2169.0 m.

The listed wells are located in the western and eastern parts of the area, while the centre is devoid of drillings (Fig. 2.3). The Zechstein base runs at depths of approximately 1,800 to over 2,300 m b.s.l. (Fig. 2.11). The Zechstein deposits also vary in thickness (Fig. 2.12). In the eastern part of the area (Pogorzela High) it is strongly reduced to below 100 m (Pogorzela 2 well; Tab. 2.1), in many cases an incomplete lithostratigraphic succession is observed therein (see below). The maximum thickness was found in the Pogorzela 7 well (341.0 m). In the western part of the Gostyń area, the thickness of the Zechstein is much greater and usually exceeds ~500 m – from 427.0 m in the Kąkolewo 1 well to 557.5 m in the Frankowo 1 well (Tab. 2.2).

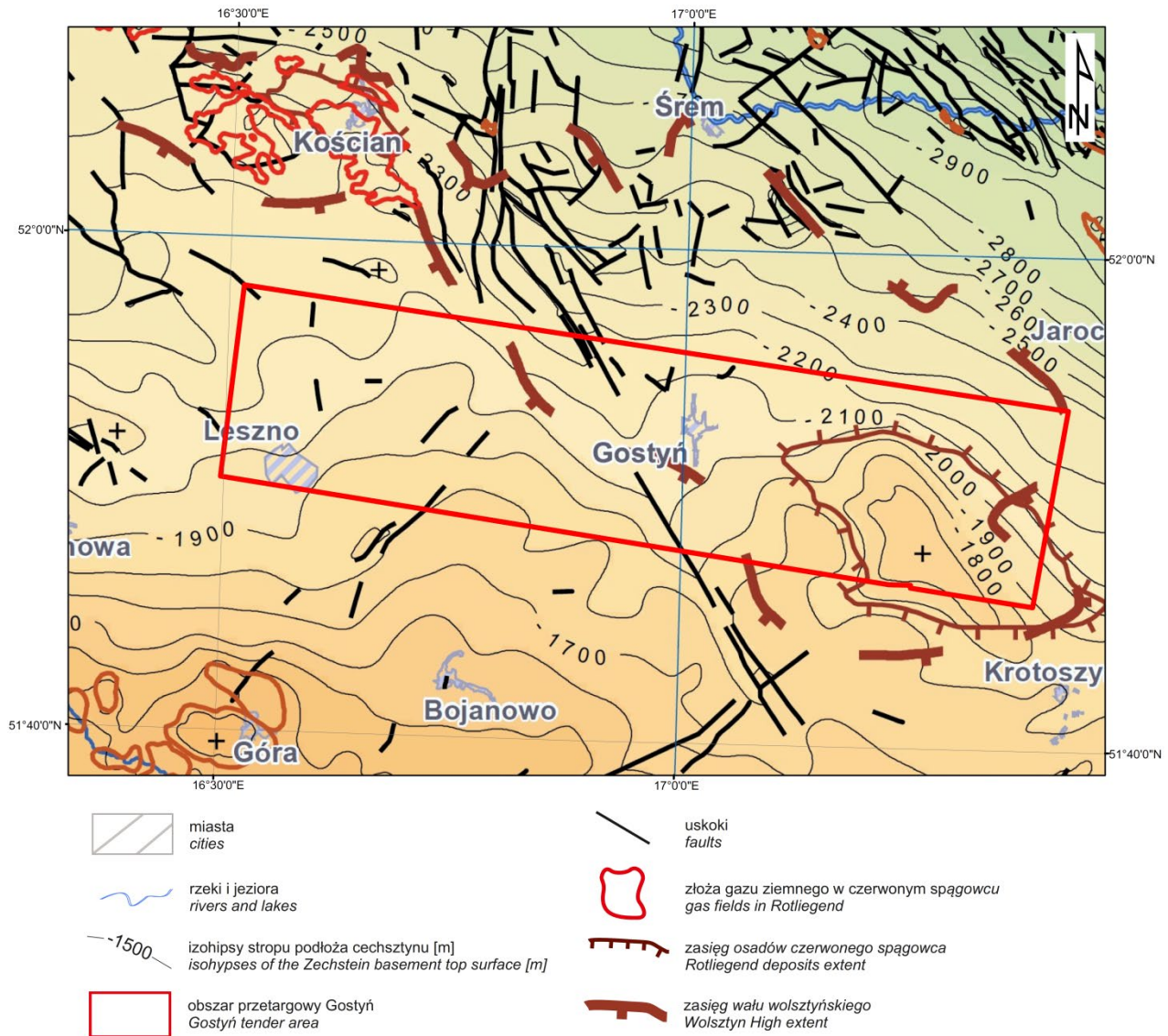


Fig. 2.11. Location of the Gostyń tender area on the structural map of the Zechstein basement top surface (Kudrewicz, 2007).

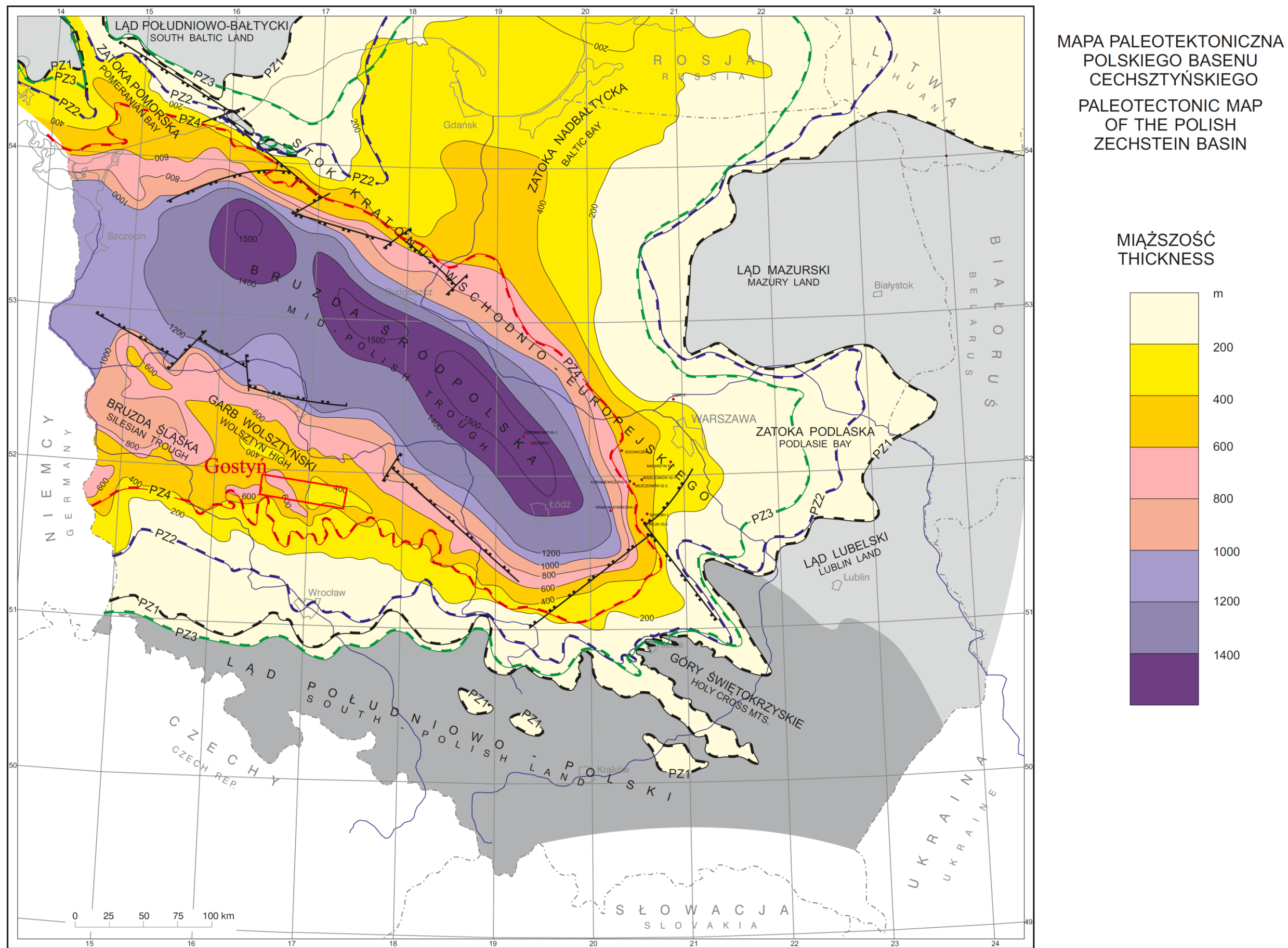


Fig. 2.12. Location of the Gostyn tender area on the palaeotectonic map of the Polish Zechstein Basin (Wagner, 1998). Other explanations in Fig. 2.14.

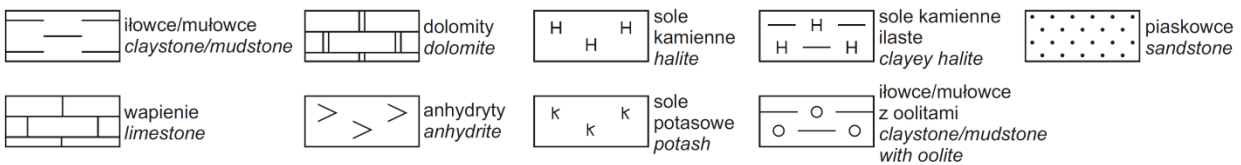
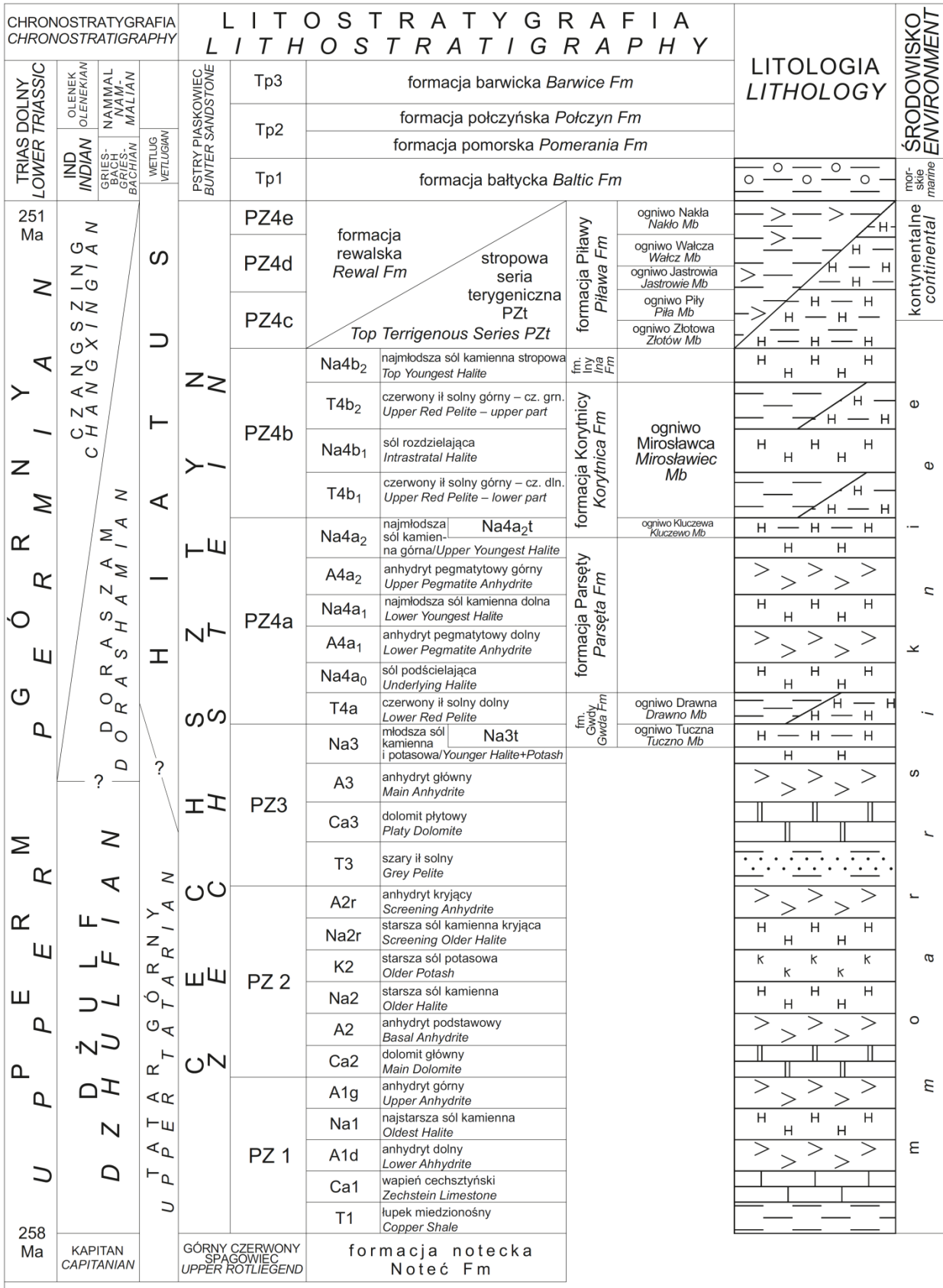


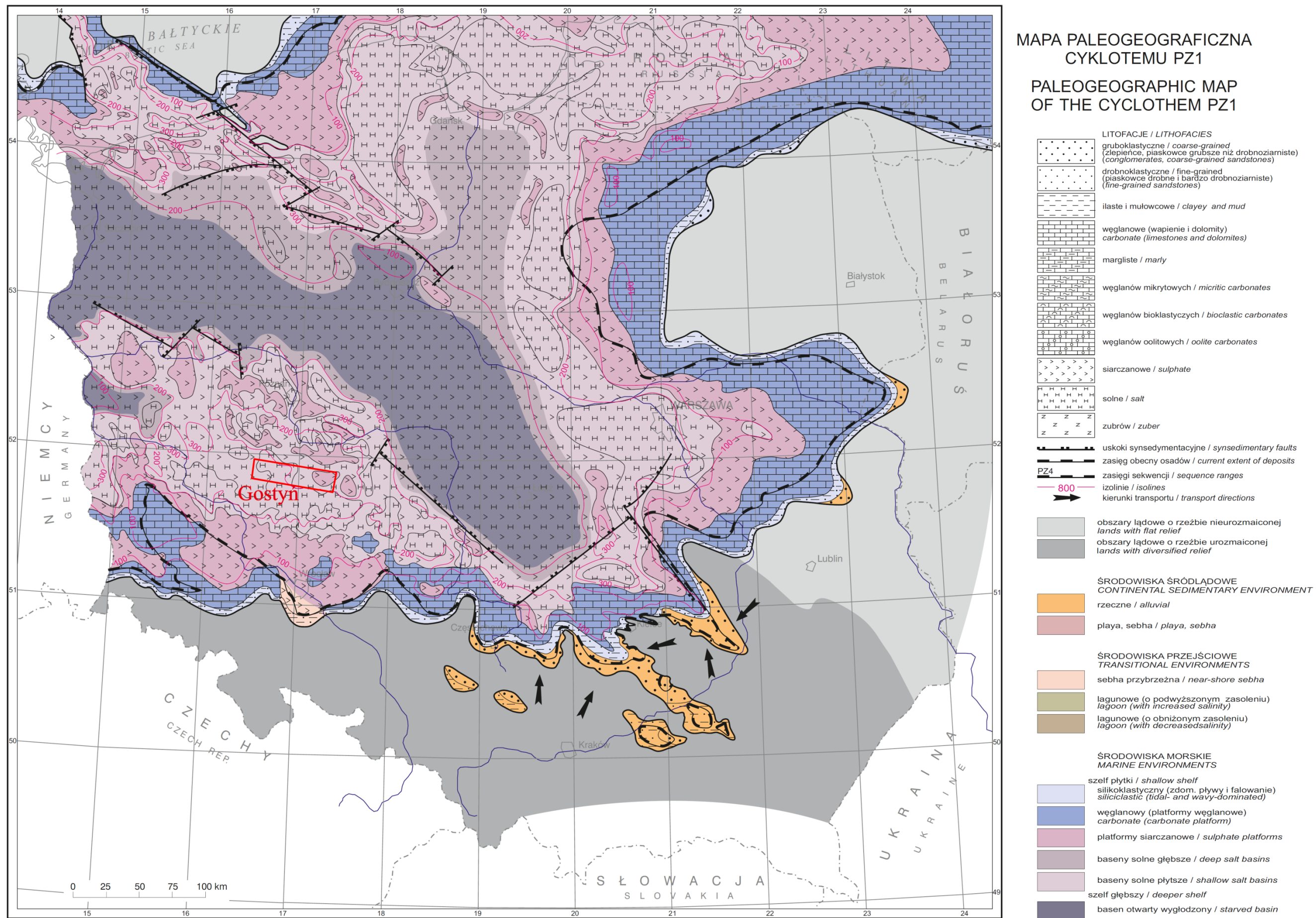
Fig. 2.13. Zechstein stratigraphy in Poland (Wagner and Peryt, 1997).

Lithostratigraphy		Depth (thickness) [m]										
		Rusko 1	Siedmiogów-1	Pogorzela 1	Pogorzela 2	Pogorzela 4	Pogorzela 7	Bulaków 1	Bulaków-2	Kobylin-1		
PZ4		66.0		54,0	19,5	11,5	16,5	10,0	9,0	26,5		
PZt	Top Terrigenous Series	2094.0–2107 (13.0)		1636.0–1652.0 (16.0)	1650.0–1669.5 (19.5)	1735.0–1746.5 (11.5)	1850.0–1866.5 (16.5)	1803.0–1813.0 (10.0)		1608.0–1624.5 (16.5)		
Na4b2	Top Younger Halite											
T4b2	Upper Red Pelite – upper part											
Na4b1	Intrastratal Halite											
T4b1	Upper Red Pelite – lower part											
A4a2	Upper Pegmatite Anhydrite											
Na4a	Youngest Halite	2107.0–2116.5 (9.5)							1636.5–1643.0 (6.5)	1624.5–1631.5 (7.0)		
A4a1	Lower Pegmatite Anhydrite	2116.5–2117.5 (1.0)							1643.0–1644.5 (1.5)	1631.5–1632.5 (1.0)		
T4a	Lower Red Pelite	2117.5–2119.5 (2.0)							1644.5–1645.5 (1.0)	1632.5–1634.5 (2.0)		
PZ3		131.8				143.0	153.0	149.0	85.5	82.5		
A3r	Top Anhydrite	2119.5–2120.0 (0.5)										
Na3	Younger Halite	2120.0–2137.5 (17.5)		1700.0–1705.0 (5.0)		1746.5–1857.5.0 (111.0)	1866.5–1993.0 (126.5)	1813.0–1930.0 (117.0)	1645.5–1705.0 (59.5)	1634.5–1669.5 (35.0)		
A3	Main Anhydrite	2137.5–2249.0 (111.5)				1857.5–1888.0 (30.5)	1993.0–2017.0 (24.0)	1930.0–1960.0 (30.0)	1705.0–1729.5 (24.5)	1669.5–1715.0 (45.5)		
T3	Grey Pelite	2949.0–2251.3 (2.3)				1888.0–1889.5 (1.5)	2017.0–2019.5 (2.5)	1960.0–1962.0 (2.0)	1729.5–1731.0 (1.5)	1715.0–1717.0 (2.0)		
PZ2		76.9				50.5	72.0	61.0	55.5	54.5		
A2r	Screening Anhydrite	2251.3–2253.0 (1.7)					2019.5–2023.5 (4.0)	1962.0–1966.0 (4.0)	1731.0–1734.0 (3.0)			
Na2r	Screening Older Halite			1705.90–1751.0 (46.0)	1669.5–1729.0 (59.5)							
K2	Older Potash											
Na2	Older Halite	2253.0–2271.7 (18.7)					2023.5–2036.0 (12.5)	1966.0–1995.0 (29.0)	1734.0–1742.0 (8.0)			
A2	Basal Anhydrite	2271.7–2295.2 (23.5)				1889.5–1905.0 (15.5)	2036.0–2051.0 (15.0)	1995.0–2001.0 (6.0)	1742.0–1746.0 (4.0)	1717.0–1723.0 (6.0)		
Ca2	Main Dolomite	2295.2–2328.2 (33.0)				1751.0–1770.0 (19.0)	1729.0–1749.5-0 (20.5)	1905.0–1940.0 (35.0)	2051.0–2091.5 (40.5)	2001.0–2023.0 (22.0)	1746.0–1781.5 (35.5)	1723.0–1771.5 (48.5)
PZ1		67.9				brak	brak	67.0	99.5	127.0	72.0	150.0
A1g	Upper Anhydrite										1771.5–1798.5 (27.0)	
Na1	Oldest Halite	2328.2–2356.0 (27.8)				1940.0–1975.0 (35.0)		2023.0–2071.0 (48.0)			1798.5–1834.0 (35.5)	
A1d	Lower Anhydrite							2091.5–2154.0 (62.5)		1781.5–1823.5 (42.0)	1834.0–1918.0 (84.0)	
Ca1 + T1	Zechstein Limestone and Kupferschiefer	2356.0–2396.1 (40.1)				1975.00–2007.0 (32.0)	2154.0–2191.0 (37.0)	2071.0–2137.0 (66.0)	1823.5–1853.5 (30.0)	1918.0–1921.0 (3.0)		
Zechstein total thickness		302.1				134.0	99.5	272.0	341.0	334.0	253.5	313.0

Tab. 2.1. Zechstein stratigraphy and thickness in the eastern part of the Gostyń tender area (CGDB, 2023; Pogorzela 1 and Pogorzela 2 wells according to Kwolek and Mikołajewski, 2007).

Lithostratigraphy		Depth (thickness) [m]													
		Frankowo 1	Kąkolewo 1	Kąkolewo 2	Kąkolewo 4	Święciechowa 1	Święciechowa 2	Żakowo 1	Żakowo 2	Żakowo 3	Żakowo 4	Żakowo 5	Żakowo 6	Żakowo 7	Żakowo 9
Cyklotem PZ4		16.0	31.0	35.0	14.5	28.5	40.0	31.5	30.0	31.0	28.5	48.0	32.5	40.0	34.5
PZt	Top Terrigenous Series	1492.5–1507.0 (14.5)	1555.0–1567.5 (12.5)	1502.5–1517.5 (15.0)	1519.0–1534.0 (15.0)	1571.5–1587.5 (16.0)	1565.0–1581.5 (16.5)	1677.5–1687.5 (10.0)	1635.0–1650.0 (15.0)	1663.0–1677.0 (14.0)	1663.5–1678.0 (14.5)	1628.5–1644.5 (16.0)	1646.0–1662.5 (16.5)	1653.0–1677.5 (24.5)	1657.5–1676.0 (18.5)
Na4b2	Top Younger Halite														
T4b2	Upper Red Pelite – upper part														
Na4b1	Intrastratal Halite														
T4b1	Upper Red Pelite – lower part														
A4a2	Upper Pegmatite Anhydrite	1507.0–1508.5 (1.5)													
Na4a	Youngest Halite		1567.5–1582.5 (15.0)	1517.5–1532.0 (14.5)	1534.0–1552.0 (18.0)	1587.5–1596.5 (9.0)	1581.5–1601.5 (20.0)	1687.5–1707.5 (20.0)	1650.0–1661.0 (11.0)	1677.0–1689.0 (12.0)	1678.0–1688.5 (10.5)	1644.5–1671.0 (26.5)	1662.5–1675.0 (12.5)	1677.5–1688.0 (10.5)	1676.0–1690.5 (14.5)
A4a1	Lower Pegmatite Anhydrite					1596.5–1597.0 (0.5)									
T4a	Lower Red Pelite		1582.5–1586.0 (3.5)	1532.0–1537.5 (5.5)	1552.0–1555.0 (3.0)	1597.0–1600.0 (3.0)	1601.5–1605.0 (3.5)	1707.5–1709.0 (1.5)	1661.0–1665.0 (4.0)	1689.0–1694.0 (5.0)	1688.5–1692.0 (3.5)	1671.0–1676.5 (5.5)	1675.0–1678.5 (3.5)	1688.0–1693.0 (5.0)	1690.5–1692.5 (2.5)
Cyklotem PZ3		26.5	142.0	55.5	84.0	87.5	116.0	88.5	102.0	116.0	116.0	101.5	98.5	113.5	83.5
A3r	Top Anhydrite						1605.0–1607.0 (2.0)								
Na3	Younger Halite	1508.5–1534.4 (25.9)	1586.0–1697.0 (113.0)	1537.5–1567.0 (29.5)	1555.0–1620.0 (65.0)	1600.0–1609.5 (9.5)	1607.0–1686.0 (79.0)	1709.0–1731.0 (22.0)	1665.0–1738.0 (73.0)	1694.0–1786.0 (92.0)	1692.0–1787.0 (95.0)	1676.5–1761.0 (84.5)	1678.5–1750.0 (72.5)	1693.0–1778.0 (85.0)	1692.5–1710.5 (18.0)
A3	Main Anhydrite	1534.4–1534.9 (0.4)	1697.0–1714.0 (17.0)	1567.0–1591.0 (24.0)	1620.0–1637.0 (17.0)	1609.5–1686.5 (77.0)	1686.0–1719.0 (33.0)	1731.0–1785.5 (44.5)	1738.0–1765.0 (28.0)	1786.0–1807.0 (21.0)	1787.0–1805.5 (18.5)	1761.0–1776.5 (15.5)	1750.0–1771.0 (21.0)	1778.0–1804.0 (26.0)	1710.5–1774.0 (63.5)
T3	Grey Pelite	1534.9–1535.1 (0.2)	1714.0–1716.0 (2.0)	1591.0–1593.0 (2.0)	1637.0–1639.0 (2.0)	1686.5–1687.5 (1.0)	1719.0–1721.0 (2.0)	1785.5–1787.5 (2.0)	1765.0–1767.0 (2.0)	1807.0–1810.0 (3.0)	1805.5–1808.0 (2.5)	1776.5–1778.0 (1.5)	1771.0–1773.5 (2.5)	1804.0–1806.5 (2.5)	1774.0–1776.0 (2.0)
Cyklotem PZ2		46.9	109.0	76.5	98.0	100.0	85.5	98.5	>63.2	100.0	99.0	>52.8	99.0	>29.5	91.0
A2r	Screening Anhydrite		1716.0–1721.0 (5.0)	1593.0–1597.5 (4.5)	1639.0–1642.5 (3.5)	1687.5–1690.0 (2.5)	1721.0–1723.0 (2.0)	1787.5–1791.0 (3.5)	1767.0–1770.0 (3.0)	1810.0–1813.0 (3.0)	1808.0–1811.5 (3.5)	1778.0–1780.5 (2.5)	1773.5–1776.0 (2.5)	1806.5–1810.0 (3.5)	1776.0–1779.0 (3.0)
Na2r	Screening Older Halite		–		–					–					
K2	Older Potash		–		–		–			–					
Na2	Older Halite		1721.0–1738.0 (17.0)	1597.5–1618.0 (20.5)	1642.5–1665.0 (22.5)	1690.0–1720.0 (30.0)	1723.0–1740.0 (17.0)	1791.0–1810.0 (19.0)	1770.0–1795.0 (25.0)	1813.0–1842.0 (29.0)	1811.5–1831.0 (19.5)	1780.5–1797.5 (17.0)	1776.0–1805.0 (29.0)	1810.0–1830.0 (20.0)	1779.0–1797.0 (18.0)
A2	Basal Anhydrite	1535.1–1539.0 (3.9)	1738.0–1745.0 (12.0)	1618.0–1626.5 (8.5)	1665.0–1672.5 (7.5)	1720.0–1725.0 (5.0)	1740.0–1745.5 (5.5)	1810.0–1818.0 (8.0)	1795.0–1805.0 (10.0)	1842.0–1849.0 (7.0)	1831.0–1840.0 (9.0)	1797.5–1804.5 (7.0)	1805.0–1813.5 (8.5)	1830.0–1836.0 (6.0)	1797.0–1804.0 (7.0)
Ca2	Main Dolomite	1539.0–1582.0 (43.0)	1745.0–1820.0 (75.0)	1626.5–1669.5 (43.0)	1672.5–1737.0 (64.5)	1725.0–1787.5 (62.5)	1745.5–1806.5 (61.5)	1818.0–1886.0 (68.0)	1805.0–1830.2 (>25.2)	1849.0–1910.0 (61.0)	1840.0–1907.0 (67.0)	1804.5–1830.7 (>26.2)	1813.5–1872.5 (59.0)	–	1804.0–1867.0 (63.0)
Cyklotem PZ1		468.5	233.0	330.5	242	307.5	238.0	309.5	–	300.0	292.7	–	281.5	–	302
A1g	Upper Anhydrite	1582.0–1646.0 (64.0)	1820.0–1838.0 (18.0)	1669.5–1724.0 (24.5)	1737.0–1824.0 (87.0)	1787.5–1822.0 (34.5)	1806.5–1841.0 (34.5)	1886.0–1906.0 (20.0)	–	1910.0–1935.0 (25.0)	1907.0–1929.0 (22.0)	–	1872.5–1896.5 (14.0)	–	1867.0–1892.0 (25.0)
Na1	Oldest Halite	1646.0–2028.0 (382.5)	1838.0–1953.0 (115.0)	1724.0–1971.5 (247.5)	1824.0–1910.0 (86.0)	1822.0–1875.0 (52.5)	1841.0–1882.0 (41.0)	1906.0–2134.0 (128.0)	–	1935.0–2155.0 (220.0)*	1929.0–2150.0 (221.0)*	–	1896.5–2106.5 (109.0)*	–	1892.0–2134.0 (242.0)*
A1d	Lower Anhydrite	2028.0–2046.5 (18.5)	1953.0–2050.0 (97.0)	1971.5–1996.0 (24.5)	1910.0–1976.0 (66.0)	1875.0–2080.5 (205.5)	1882.0–2041.0 (69.0)	2134.0–2189.0 (55.0)	–	2155.0–2207.0 (52.0)	2150.0–2175.5 (25.5)	–	2106.5–2149.0 (42.5)	–	2134.0–2164.5 (30.5)
Ca1 + T1	Zechstein Limestone and Kupferschiefer	2046.5–2050.0 (3.5)	2050.0–2053.0 (3.0)	1996.0–2000.0 (4.0)	1976.0–1979.0 (3.0)	2080.5–2095.0 (15.0)	2041.0–2044.5 (3.5)	2189.0–2195.5 (6.5)	–	2207.0–2210.0 (3.0)	2175.5–2199.5 (24.0)	–	2149.0–2154.0 (5.0)	–	2164.5–2169.0 (4.5)
Zechstein total thickness		557.5	427.0	497.5	460.0	523.5	479.5	518.0	>195.2	547.0	536.0	>167.2	508.0	>183.0	511.5

Tab. 2.2. Zechstein stratigraphy and thickness in the western part of the Gostyń tender area (CGDB, 2023).



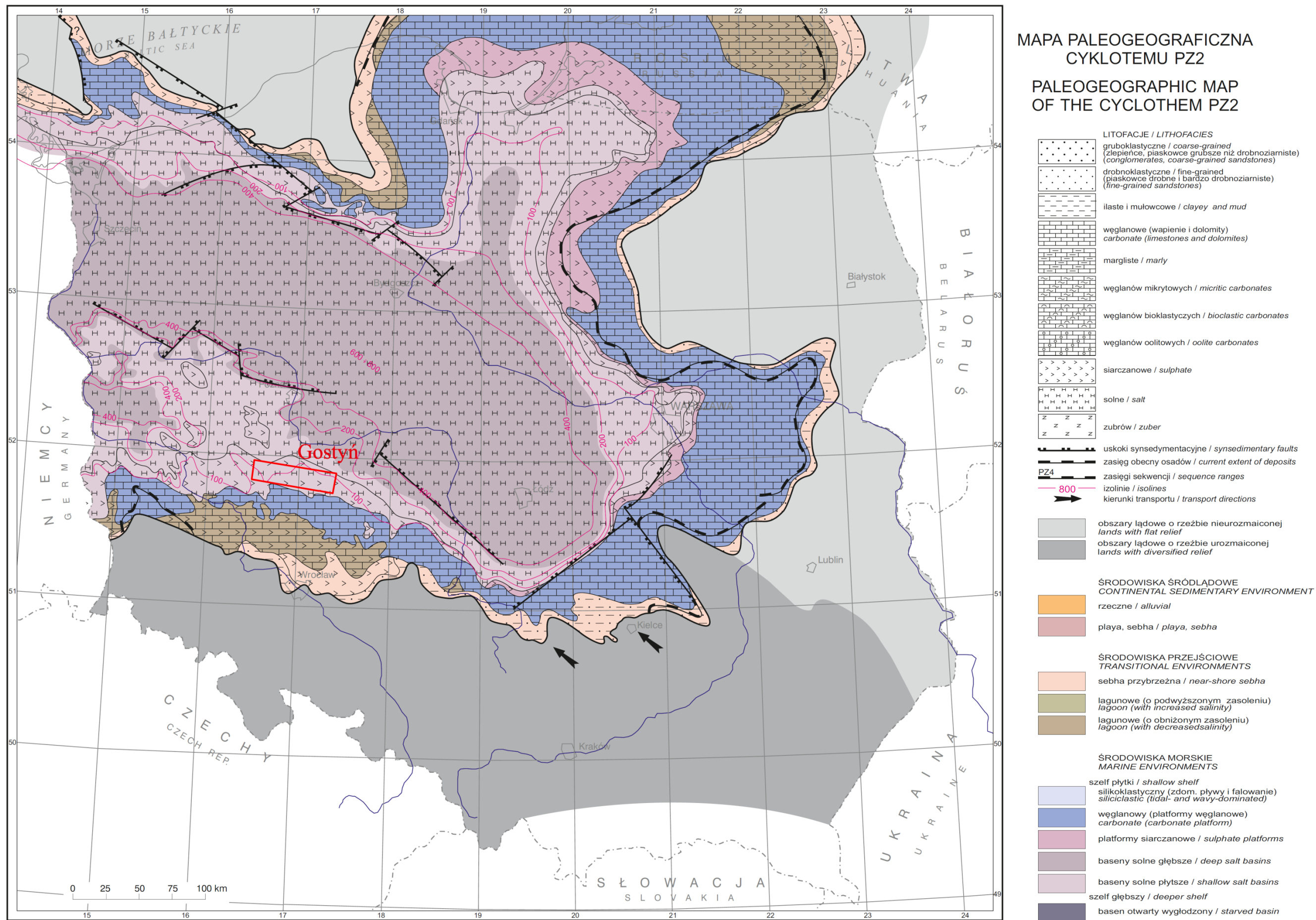


Fig. 2.15. Location of the Gostyń tender area on the palaeogeographic map of the PZ2 cyclothem (Wagner, 1998).

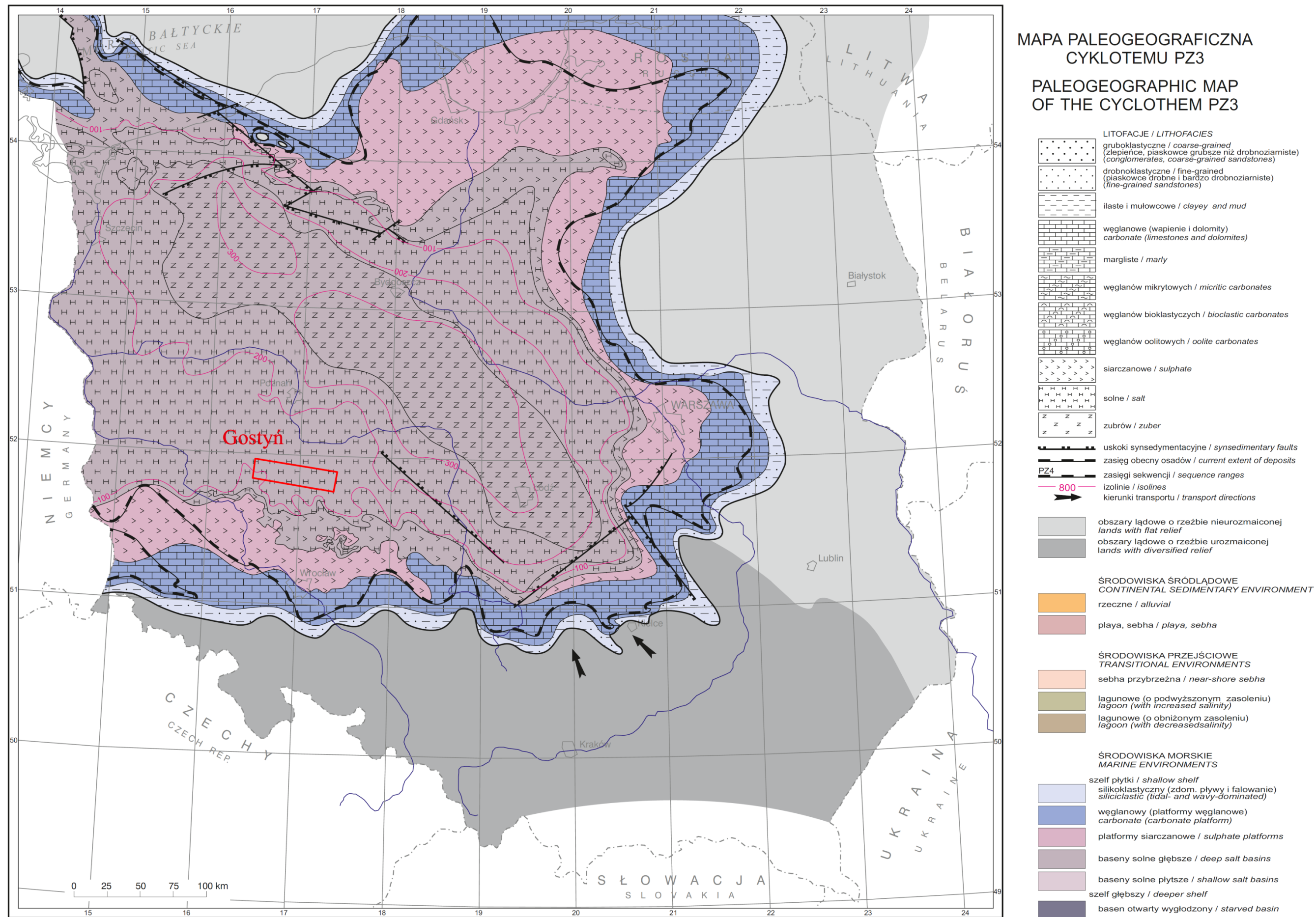


Fig. 2.16. Location of the Gostyn tender area on the palaeogeographic map of the PZ3 cyclothem (Wagner, 1998).

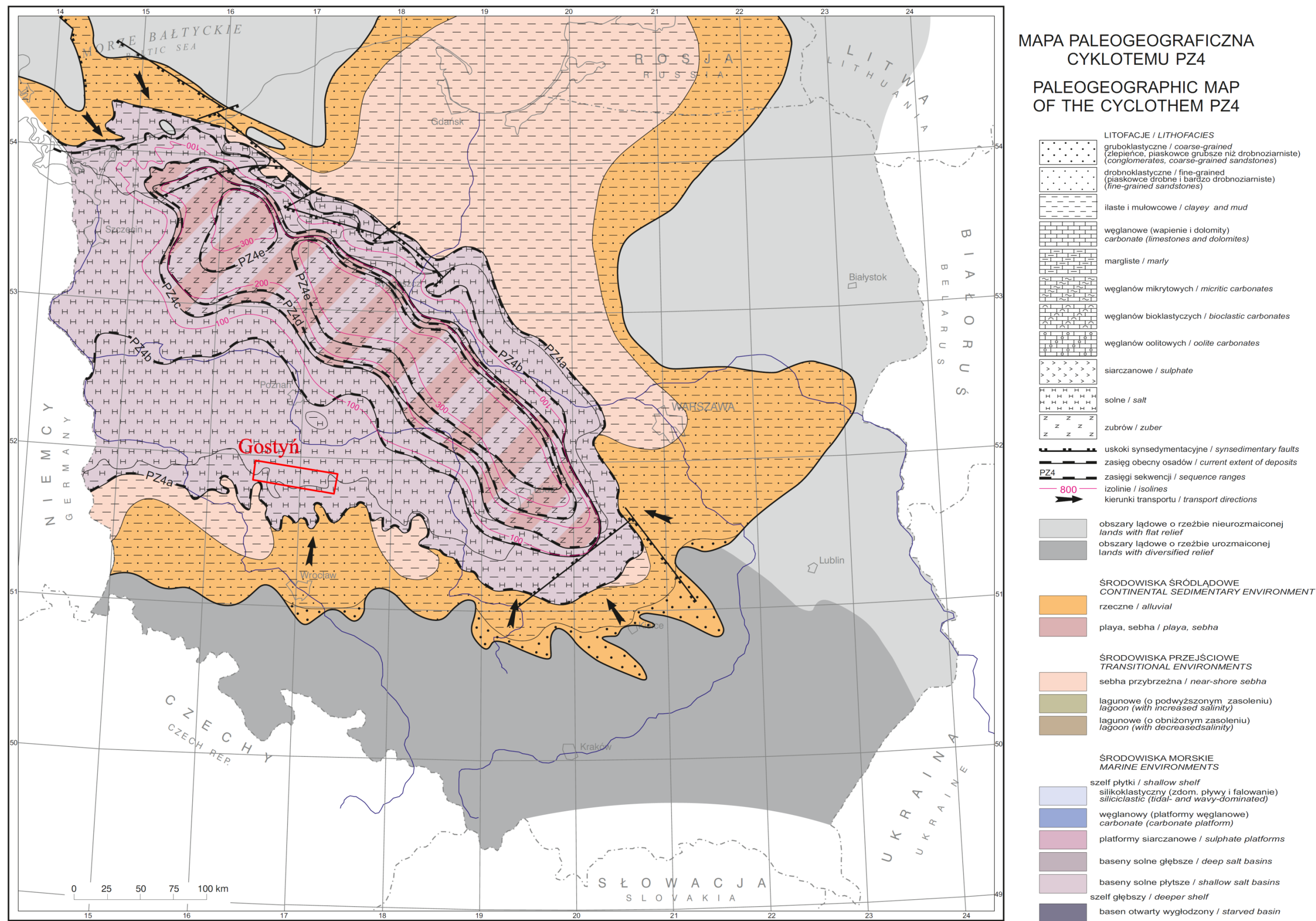


Fig. 2.17. Location of the Gostyń tender area on the palaeogeographic map of the PZ4 cyclothem (Wagner, 1998).

Lithology and stratigraphy

Within the Zechstein evaporite succession of the Polish Lowland, four cyclothems – PZ1 to PZ4 – can be distinguished (Wagner, 1994; Wagner and Peryt, 1997; Figs 2.13–2.19) corresponding to the Werra, Stassfurt, Leine and Aller cyclothems from the German basin (e.g. Richter-Bernburg, 1955). A significant part of the Zechstein succession was formed during transgressive-regressive carbonate-evaporite sedimentary cycles (PZ1 to PZ3 cyclothems), and only the uppermost part of the succession (PZ4a to PZ4e cyclothems) during terrigenous-carbonate cycles associated with the climate fluctuations from humid to dry (Wagner and Peryt, 1997). During carbonate sedimentation episodes, which began the first three cyclothems (PZ1–PZ3), three horizons of carbonate rocks were formed: Zechstein Limestone Ca1, Main Dolomite Ca2 and Platy Dolomite Ca3 (Fig. 2.13). In the Gostyń area, which is located in the marginal part of the basin, only the continuous Main Dolomite horizon was found, while the Zechstein Limestone is absent in some wells on the Pogorzela High (see below) and there is also a complete lack of the Ca3 Platy Dolomite. Carbonate horizons are separated by evaporite successions developed mainly in sulphate (anhydrite) and chloride (rock salt – halite) facies. In the tender area, evaporite intervals are often incompletely developed and have reduced thickness, especially in the eastern part of the region.

The PZ1 (Werra) cyclothem in the Gostyń tender area vary in thickness and lithostratigraphy. In the western part of the area, the thickness ranges from 233.0 m (Kąkolewo 1) to 468.5 m (Frankowo 1) and the PZ1 cyclothem has a typical and complete succession (Tab. 2.2). The Zechstein Limestone (including Kupferschiefer) is developed here in the basin facies and its thickness is usually small, from 3 to 6.5 m (Fig. 2.20); only in the Świąciechowa 1 and Żakowo 4 wells greater thicknesses from 15.0 m to 24.0 m respectively, were found. Above, there are anhydrites (Lower and Upper Anhydrite) separated by rock salts (Oldest Halite Na1 of maximum thickness 382.5 m in the Frankowo 1 well).

In the eastern part of the area, the thickness of PZ1 deposits found in wells is smaller – from several dozen to a maximum 150.0 m in the Kobylin-1 well, and in two wells located in the axial part of the Pogorzela High, the PZ1 deposits are completely absent (Pogorzela 1 and Pogorzela 2 wells). The Zechstein Limestone deposits occurring around the High are very thick (probably up to over 60 m), forming an isolated carbonate platform (Fig. 2.20). The thickness of the Zechstein Limestone, which was drilled here in several wells, is several dozen meters (Tab. 2.1). The Lower Anhydrite (A1d) thickness rises up to 100 m outside the Pogorzela High. The Oldest Halite (Na1) is almost completely missing, it occurs only in the Kobylin-1 well, located in the basin zone outside the Pogorzela High.

The stratigraphy of the Zechstein deposits on the Pogorzela High is a matter of long debate (see e.g. Kwolek and Protas, 2001; Filo et al., 2005; Kwolek and Mikołajewski, 2007). The Pogorzela High forms the southeasternmost part of the Wolsztyn High (Brandenburg-Wolsztyn Ridge), built mainly by Carboniferous rocks of Variscan consolidation (Kiersnowskin et al., 2010). The Wolsztyn High is an intrabasinal horst whose formation was caused by extensional movements in the Variscan domain. In the Pogorzela 1 and Pogorzela 2 wells (Tab. 2.1), a significant reductions in the thickness of the Zechstein deposits were found in relation to the neighboring regions (Kwolek and Protas, 2001). In the Zechstein succession, only one carbonate interval was identified there (Pogorzela 1 – 19 m thick; Pogorzela 2 – 20.5 m thick), located directly on the uplifted Carboniferous. This horizon was classified originally as the Zechstein Limestone Ca1 (see Peryt and Protas, 1978; Kwolek and Protas, 2001). The results of subsequent seismic works (Siedmiorogów-Pogorzela 3D seismic survey) conducted on a large part of the Pogorzela High in 2004 (Filo et al., 2005) brought new interpretation of the Zechstein stratigraphy in the region (Kwolek and Mikołajewski, 2007). They indicate that PZ1 deposits do not occur in a large part of the Pogorzela High. The initial phases of the Zechstein transgression did not cover the most uplifted part of the High, which is why the Main Dolomite rocks lie directly on the

Carboniferous (Kowlek and Mikołajewski, 2007; Figs 2.20–2.23). The lack of the Ca1 on the Pogorzela High brings new ideas for exploration: in the succession bordering the High from the south and north-east, numerous structures related to the wedging out of the Ca1 sediments on the slopes of the Pogorzela High were interpreted (Figs 2.20–2.23). The

Ca1 deposits are very thick and in places they reach significant porosity (Fig. 2.22). However, in the Bułaków 2 well drilled in 2007 on the Bułaków structure, no gas flow was obtained. This structure was compared (Kwolek and Mikołajewski, 2007) to Ca1 reefs analogous to those known from the Kościan area.

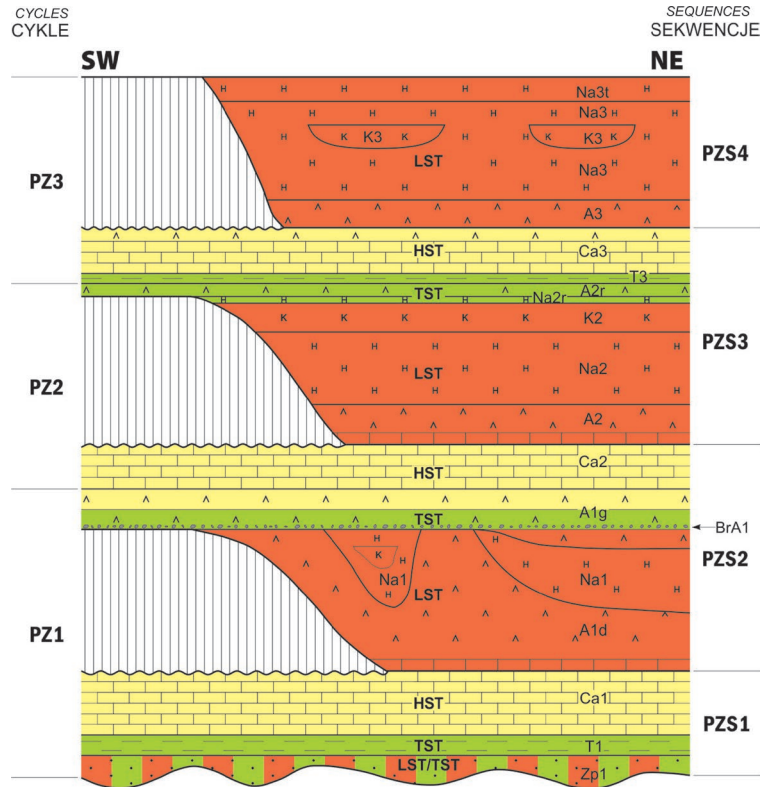


Fig. 2.18. Zechstein stratigraphy and depositional sequences – PZ1–PZ3 cyclothem (Wagner and Peryt, 1997).

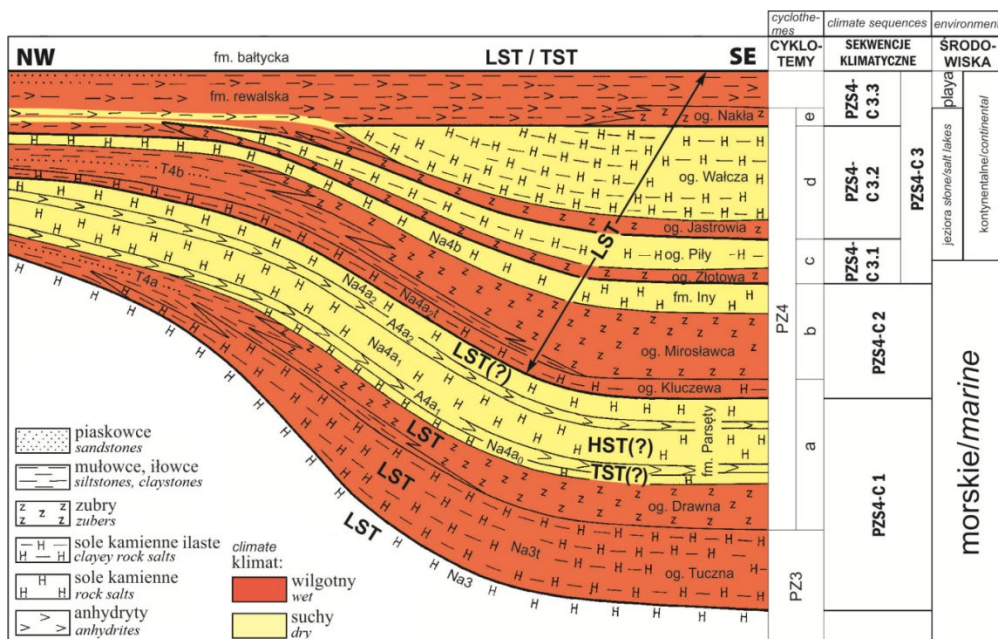


Fig. 2.19. Zechstein PZ4 climatic depositional sequences (Wagner and Peryt, 1997).

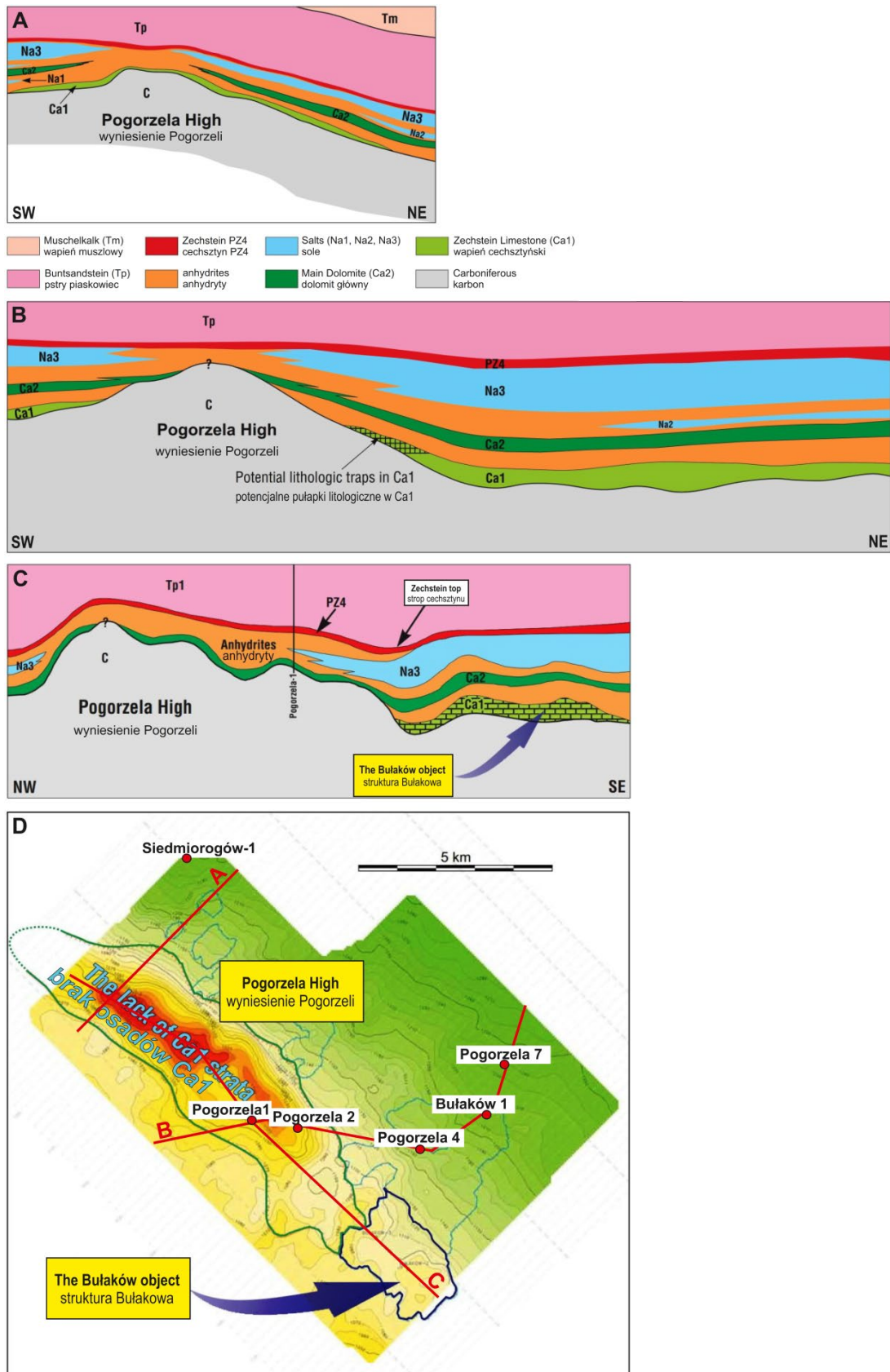


Fig. 2.21. Geology and distribution of the Zechstein deposits in and around the Pogorzela High. **A.** According to Kwolek and Protas (2001). **B.** According to Kwolek and Mikołajewski (2007) – potential lithological traps related to the Ca1 wedging out were marked. **C.** Geological cross-section through the Bulaków structure (Kwolek and Mikołajewski, 2007). **D.** Location of the Bulaków structure and other traps (green areas) around the Pogorzela High in relation to the Z1'–Tp2 seismic complex thickness (Zechstein basement surface–Middle Bunter Sandstone top surface; Kwolek and Mikołajewski, 2007).

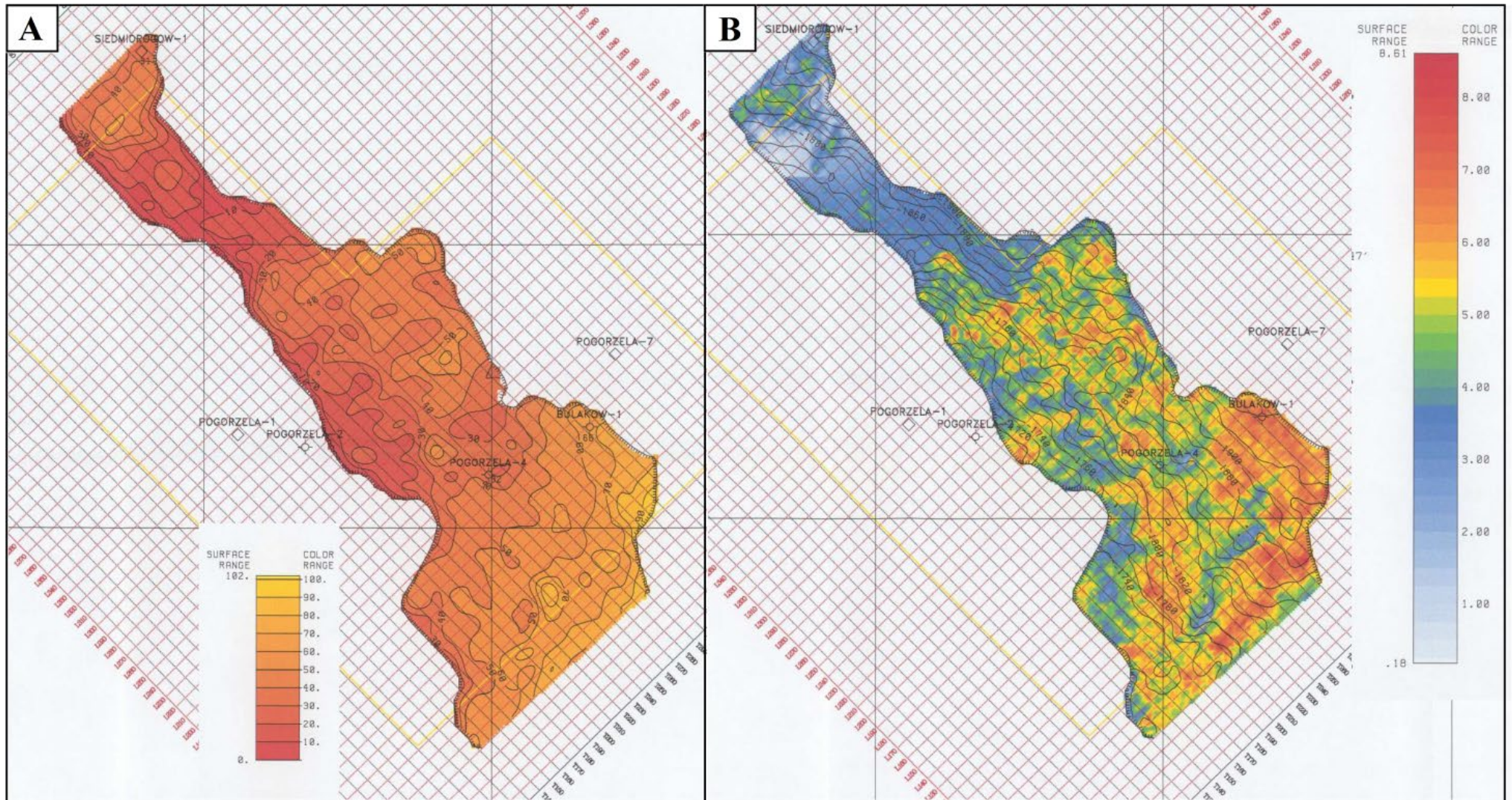


Fig. 2.22. Thickness (A) and porosity (B) of the Zechstein Limestone Ca1 deposits in the eastern part of the Gostyń area (Filo et al., 2005).

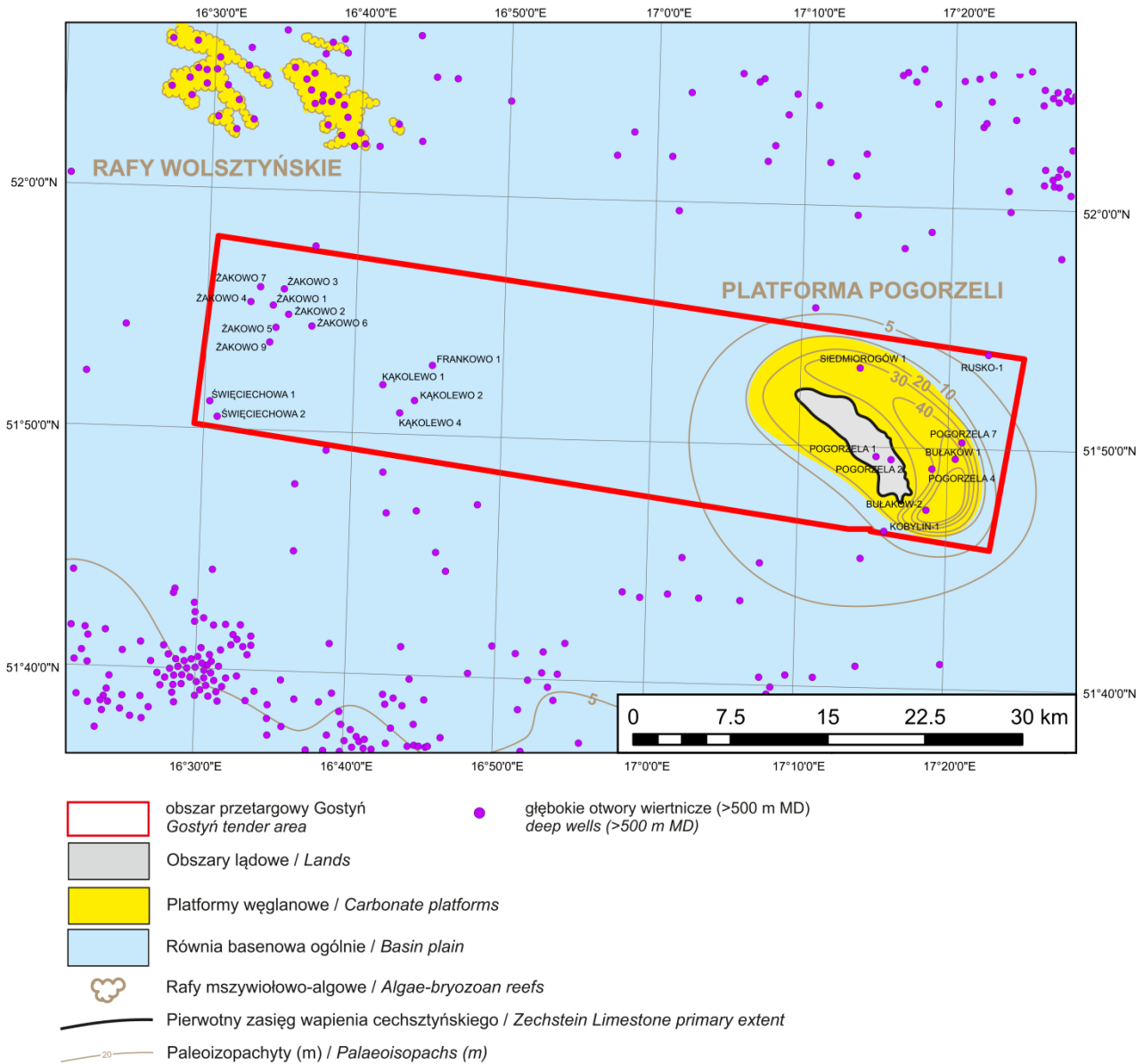


Fig. 2.23. Location of the Gostyń tender area on the palaeogeographic-facies map of the Zechstein Limestone Ca1 (Buniak et al., 2013).

The thickness of the PZ2 cyclothem (Stassfurt) in the Gostyń tender area ranges from approximately 50 m (46.9 m in the Frankowo 1 well) to over 100 m (109 m in the Kąkolewo 1 well; Tabl. 2.1–2.2). The lower part of the PZ2 succession is formed by the Main Dolomite Ca₂, reaching a thickness from 19.0–20.5 m in the Pogorzela High to 75 m in the Kąkolewo 1 well (Fig. 2.24). Three main palaeogeographic zones can be distinguished in the Main Dolomite (Wagner, 2012), which correspond to separate depositional systems (Jaworowski and Mikołajewski, 2007): carbonate platforms, their slopes, and basin plain (Fig. 2.24). The Gostyń tender area is located

entirely within the Ca₂ carbonate platform zone, generally within an extensive platform plain with high-energy sedimentation, including shoal and oncolite-oid barrier deposits (Fig. 2.24). Such sediments were found, for example, in the Bułaków-2 and Siedmiorogów-1 wells (Fig. 2.25). The higher part of the Ca₂ succession in the Bułaków-2 well is composed of high-energy platform plain deposits (sublittoral carbonate sands – grainstones and carbonate mud sands – packstones and wackstones; Strzelecka and Rostkowski, 2016). In the lower part of the succession in the same well there are low-energy carbonate ramp deposits, developed as rhythmites

formed by sublittoral carbonate muds with intercalations of carbonate sandy silts.

The Main Dolomite is characterized by diverse, generally poor reservoir properties. Only locally they may be good – e.g. in the Siedmiorogów-1 well (Figs 2.25–2.27), in which 30 m thick succession of oncolithic sediments was found, representing a barrier sedimentation environment, characterized by very good reservoir properties (Kwolek and Protas, 2001).

The Basal Anhydrite A2 lies on the Main Dolomite (Tab. 2.1–2.2) and it is usually several to several meters thick. Only in the Rusko 1 (23.5 m) and Pogorzela 2 (35 m) wells it clearly exceed the values. In the Pogorzela High (Pogorzela 1 well), the Basal Anhydrite is absent. In most cases, the Basal Anhydrite is covered by the Older Halite Na₂, reaching a thickness of several to 30 m (Święciechowa 1). However, in several wells in the area of the Pogorzela High (Pogorzela 1, 2, 4, Siedmiorogów-1, Kobylin-1), and in the western part of the tender area – Frankowo 1 well – the Na₂ is also absent. The topmost part of the Stassfurt cyclothem is composed by the Screening Anhydrite with a thickness not exceeding several meters.

The thickness of the PZ3 (Leine) cyclothem in the Gostyń tender area ranges from approximately 20 m to 150 m (Tab. 2.1–2.2). The largest values (153 m in the Pogorzela 7 well), but also the greatest differences in thickness between individual wells, were found in the eastern part of the tender area. On the Pogorzela High (Pogorzela 1 and 2 wells), a large reduction in thickness is observed (26.5 m in the Pogorzela 2 well). In the western part of the Gostyń tender area, the thickness of the PZ3 is usually approximately 100 m except of the Frankowo 1 (26.5 m) and Kąkolewo 1 (142.0 m) wells. The PZ3 sedimentation begins with Grey Pelite T3 of up to 2.5 m thick. Above, there is the Main Anhydrite A3 with a thickness ranging from about 10 m (Pogorzela 2) to almost 77 m (Święciechowa 1). Only in the Rusko 1 well the anhydrite horizon is separated by a layer of rock salt, moreover in the Frankowo 1 well the A3 is only 0.4 m thick. The topmost part of the PZ3 cyclothem is composed of the

Younger Halite Na₃, ranging in thickness from 5 m (Pogorzela 1) to 126.5 m (Pogorzela 7). Moreover, in the Święciechowa 2 well, the Top Anhydrite A3r of 2 m thick was found.

The thickness of the PZ4 (Aller) cyclothem ranges from 9.0 m in the Bułaków 2 well to 66.0 m in the Rusko 1 well (Tab. 2.1–2.2). The lower part of the succession in almost all wells is composed by the Lower Red Pelite T4a, usually 1–2 m thick. Above, in some wells, the Lower Pegmatite Anhydrite A4a1 was found, but in most cases the Youngest Halite Na_{4a} occurs. The succession is completed by the Top Terrigenous Series with a thickness ranging from 10 m (Bułaków 1) to 24.5 m (Żakowo 7).

Hydrocarbon prospective

In the Zechstein Basin in Poland, there are two carbonate horizons in which hydrocarbons may occur. These are the Zechstein Limestone (Ca1), which is a reservoir rock for gas generated from the underlying Carboniferous strata, and the Main Dolomite (Ca2), which is closed petroleum play containing both – source and reservoir rocks (Wagner, 1994; Kotarba et al., 2020).

The Zechstein Limestone may be prospective for hydrocarbon exploration in the Gostyń area in its most eastern part – in the area of the Pogorzela High. These deposits have large thickness (probably over 60 m) and originated in the carbonate platform environments (Fig. 2.23). In the remaining part of the Gostyń area, the Zechstein Limestone is formed in basin facies of a few meters thick and therefore does not provide any prospects for hydrocarbon exploration.

In the case of the Main Dolomite, two gas fields occur in the western part of the tender area – Żakowo and Kąkolewo and both should be explored, although they have relatively low methane content (15–20%). The eastern part of the tender area is also quite well explored. Despite often good reservoir parameters of the Main Dolomite therein, no industrial gas flows were obtained. Therefore, this area does not seem to be promising. It should be emphasized, however, that in many wells a higher methane content was found in relation to the western part of the tender area.

The methane content here is approximately 50% (e.g. Pogorzela-7 well). Promising for the exploration of the Ca2 horizon seems to be the central part of the Gostyń tender area, which is, however, completely devoid of deep wells. The available data show that favorable reservoir parameters may occur there in the Main Dolomite, together with its relatively high thickness (50–60 m) and grained car-

bonate facies (Fig. 2.24). According to the 3D seismic survey, the Ca2 porosity is the highest in the western part of the tender area, where it reaches several percent. However, previous seismic surveys has not revealed the presence of traps in the Ca2 horizon, therefore, a detailed reinterpretation of the available seismic data is needed.

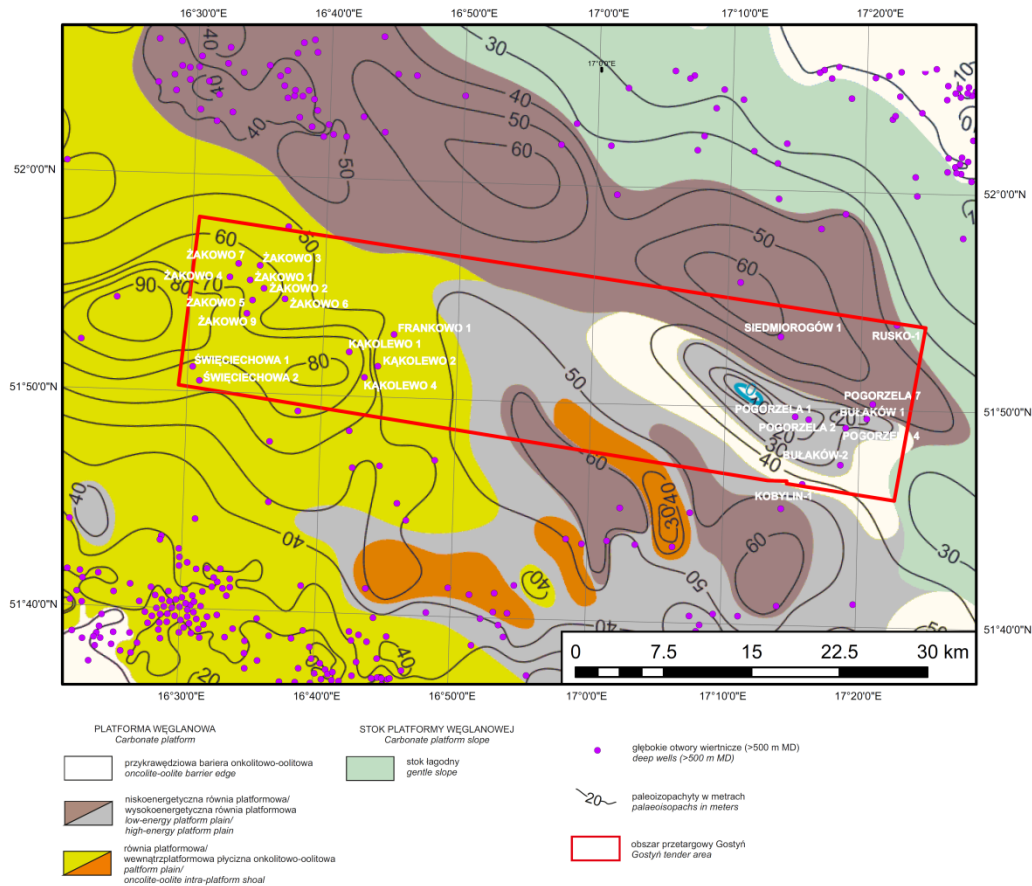


Fig. 2.24. Main Dolomite palaeogeography and thickness in the Gostyń tender area and its vicinity (Wagner, 2012).

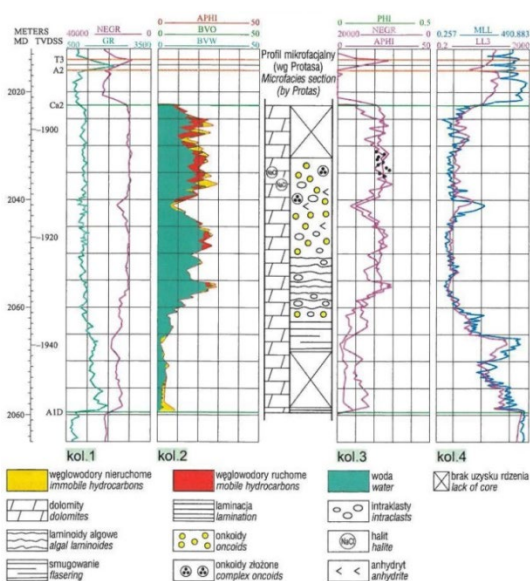


Fig. 2.25. Siedmiogów-1 well geology, microfacies and geophysics (Kwolek and Protas, 2001).

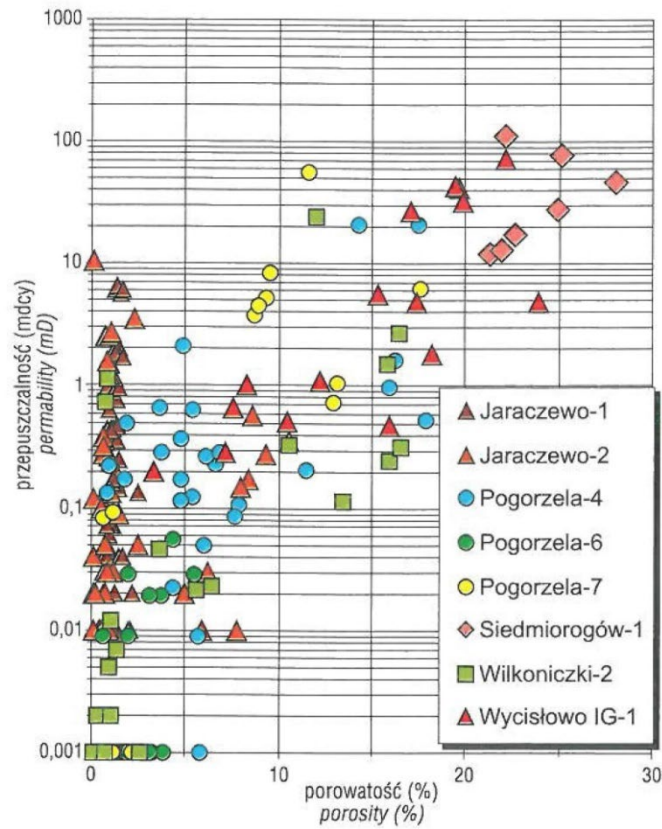


Fig. 2.26. The relationship between porosity and permeability in the Main Dolomite in the Siedmiorogów-1 well compared to other wells from the Pogorzela High (Kwolek and Protas, 2001).

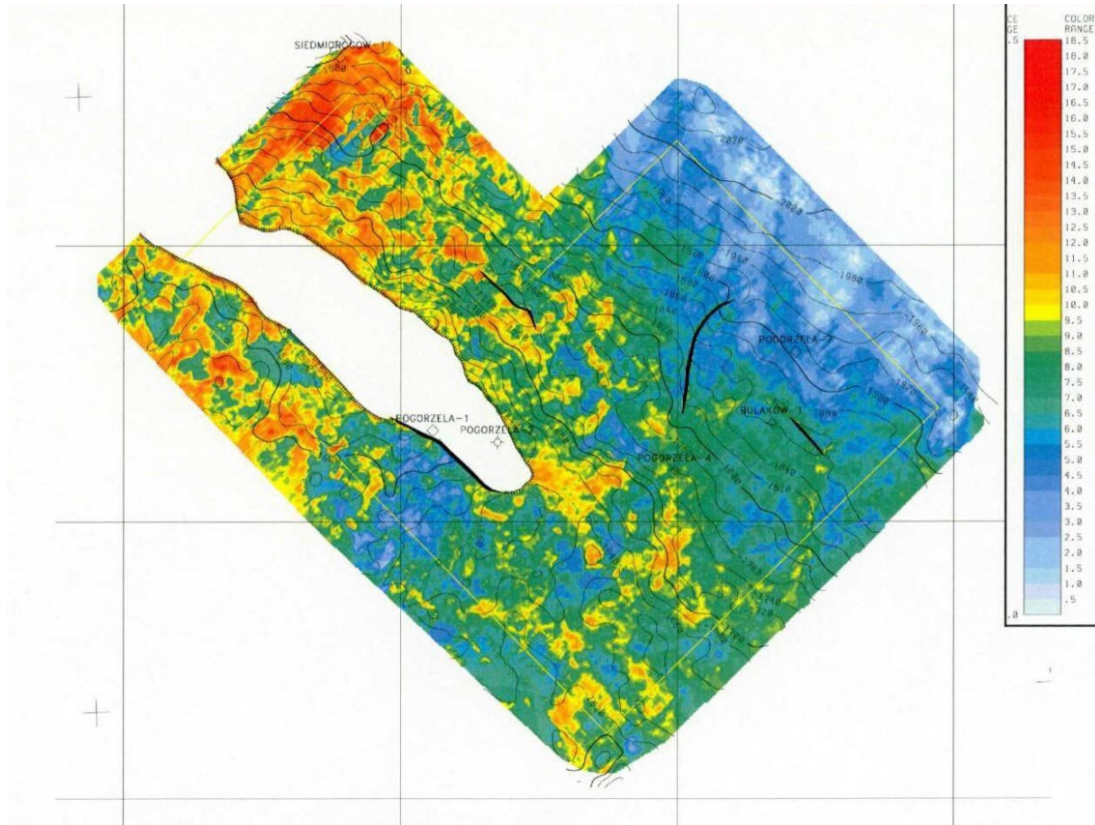


Fig. 2.27. Main Dolomite porosity in the eastern part of the Gostyń tender area (Pogorzela High) as a result of the 3D Siedmiorogów-Pogorzela seismic survey (Filo et al., 2005).

2.2.4. TRIASSIC

Distribution and thickness

The Triassic occurs in the Gostyń tender area below the Cenozoic cover (Dadlez et al., 2000; Fig. 2.28). Its top surface runs at depths 206.0–327.0 m b.g.l., and base surface at depths 1492.5–2094.0 m b.g.l. The thickness is 1231.5–2065.5 m. The Triassic was drilled in the following wells (MD intervals):

- Bułaków 1: 215.0–1803.0 m,
- Bułaków-2: 207.5–1636.5 m,
- Frankowo 1: 261.0–1492.5 m,
- Kąkolewo 1: 250.0–1555.0 m,
- Kąkolewo 2: 270.5–1502.5 m,
- Kąkolewo 4: 270.0–1519.0 m,
- Kobylin-1: 206.0–1608.0 m,
- Pogorzela 1: 222.0–1636.0 m,
- Pogorzela 2: 245.0–1650.0 m,
- Pogorzela 4: 225.0–1735.0 m,
- Pogorzela 7: 208.0–1850.0 m,
- Rusko-1: 289.5–2094.0 m,
- Siedmiorogów-1,
- Święciechowa 1: 327.0–1571.5 m,
- Święciechowa 2: 270.0–1565.0 m,
- Żakowo 1: 276.0–1677.5 m,
- Żakowo 2: 267.5–1635.0 m,
- Żakowo 3: 270.0–1663.0 m,
- Żakowo 4: 273.0–1663.50 m,
- Żakowo 5: 265.0–1628.5 m,
- Żakowo 6: 255.0–1646.0 m,
- Żakowo 7: 269.5–1653.0 m,
- Żakowo 9: 269.0–1657.5 m.

In the Gostyń tender area the Triassic is represented by the Lower, Middle and Upper (Carnian, Norian, Rhaetian) series. The boundary with the Zechstein Top Terrigenous Series (PZt) is not clearly defined.

Lower Triassic

The thickness of the Lower Triassic in the tender area is generally constant and oscillates around 600 m. The exception are the Żakowo 1 and Żakowo 3 wells, where the thickness of the Lower Triassic is 344 m and 467 m, respectively. According to regional subdivision, the Lower, Middle and Upper Bunter Sandstone are distinguished. The beginning of the Early Triassic sedimentation is a record of the transition from a marine (Zechstein) to conti-

ental environments. The Lower Bunter Sandstone is represented by clastic rocks: brown-red, brown and cherry claystones, mudstones and fine-grained sandstones with carbonate, anhydrite and gypsum intercalations (this part of succession still has some features of transitional environments and a slight influence of the marine sedimentation is visible). The Middle Bunter Sandstone is a sandstone-claystone complex. Red claystones, as well as fine-grained pink and pink-grey sandstones predominate. The Upper Bunter Sandstone reflects a marine transgression, as the intercalations of limestones, anhydrites and marls appear again in the succession.

Middle Triassic

The Middle Triassic is represented by shallow shelf sediments divided into the Muschelkalk and Lower Keuper. Their thickness is between 217 m in the Rusko-1 well and 360 m in the Święciechowa 1 well. The lower part of the Middle Triassic succession is represented by the Lower and Middle Muschelkalk, dominated by grey limestones with subordinate shear of marls and dark grey and grey-green claystones. The Upper Muschelkalk and Lower Keuper are dominated by claystones and siltstones ranging in color from grey (Upper Muschelkalk) to brown and variegated (Lower Keuper). In the wells located in the more central part of the tender area (Kąkolewo 1, 2, 4), the Middle Triassic was investigated in details by Bojanowski et al. (1975).

Upper Triassic

The Upper Triassic deposits (Carnian, Norian and Rhaetian) belong to the Middle and Upper Keuper. They are characterized by a various thickness: from 218 m in the Święciechowa 1 well to 958 m in the Rusko-1 well. The succession is composed mostly of grey, brown-red and red claystones with intercalations of gypsum and anhydrites (Lower and Upper Gypsum Beds), separated by an interval of fine-grained brown, grey and brown sandstones with plant and fish remains

and intercalated with siltstones and calcareous

claystones (Reed Sandstone).

2.2.5. JURASSIC

The Jurassic deposits were drilled only in the north-eastern part of the Gostyń tender area, in the Rusko-1 well (depth 213.0–289.5 m). It is a 76.5-m thick interval containing medium- and coarse-grained quartz sands, and grey and blue-grey clays with plant remains (Strzelecka and Rostkowski, 2016). In the vicinity of the tender area, in the Wycisłowo IG-1 well (Kuhn,

1979), the Lower Hetangian (Zagaje Formation) was investigated at depths 224–251 m, composed of fine-grained sandstones, and grey clayey mudstones. The higher part of the Jurassic succession was eroded as a result of the tectonic inversion of the Fore-Sudetic Monocline at the turn of the Cretaceous and Paleogene (Marek and Pajchłowa, 1997; Fig. 2.28).

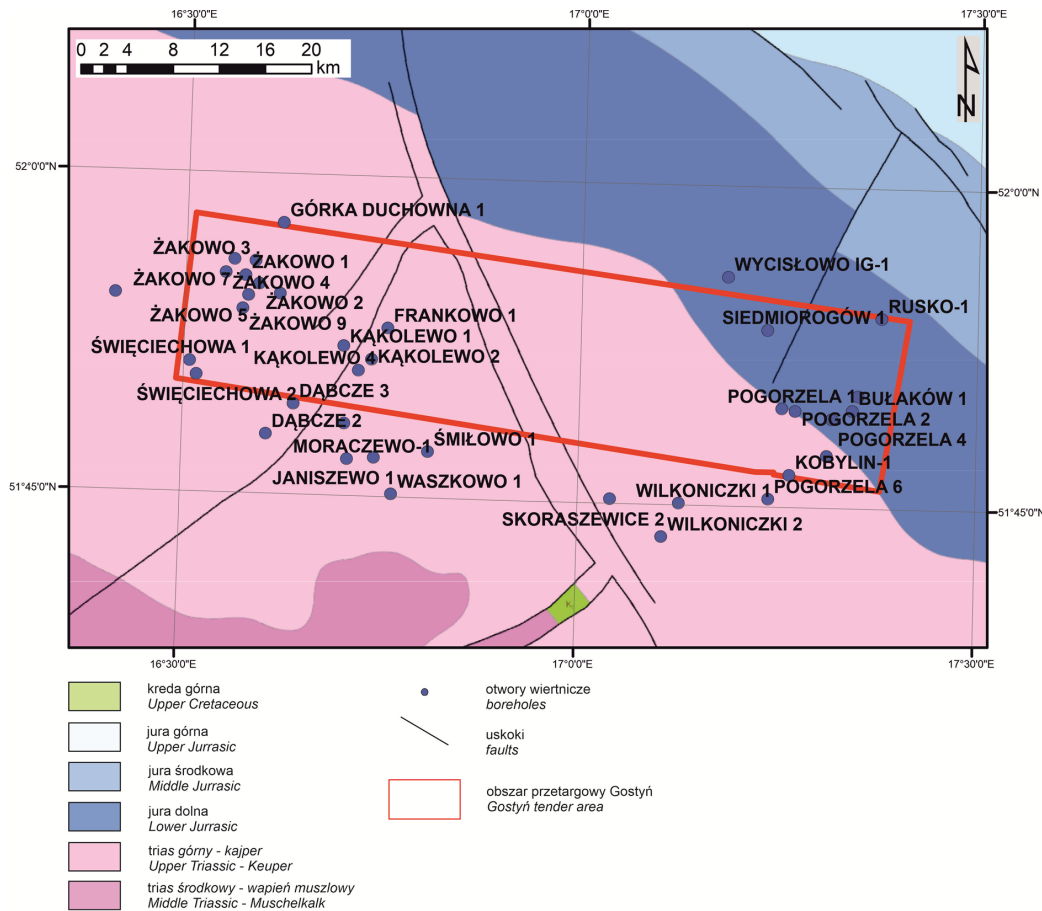


Fig. 2.28. Location of the Gostyń tender area on the Geological map of Poland without Cenozoic deposits (Dadlez et al., 2000; modified).

2.2.6. CENOZOIC

The total thickness of the Cenozoic deposits in the Gostyń tender area ranges from 200 to 270 m, only in the Świączechowa 1 well is 327 m thick (CGDB, 2023). The Paleogene sediments – locally Eocene, and more often Oligocene, cover the Mesozoic basement. The Paleogene is composed of shallow-marine glauconitic sands, terrestrial sands, silts and

brown coals, belonging to the Leszno Formation (Piwocki, 1997). The Neogene deposits include in its lower part (Lower to Middle Miocene) silts, clays, sands and brown coals (Rawicz, Ścinawa, Pawłowice and Adamów Formations). The upper part is composed of variegated clays of the Poznań Formation (Upper Miocene). In the Gostyń tender area,

the Miocene deposits, especially brown coals, reach the greatest thickness in the Gostyń tectonic trench, which could be related to the Szamotuły-Poznań-Oleśnica tectonic zone. The Gostyń lignite deposit (Fig. 1.2) has two brown coals horizons of industrial importance (Kasiński et al., 2019).

Detailed stratigraphic and lithological descriptions of Cenozoic sediments, including

2.3. HYDROGEOLOGY

The Gostyń tender area is located in the Middle Odra water region. It is located at the border of the P-XIII – Obra, W-II Barycz, W-I Obrzyca and Krzycki Rów regions. Three groundwater body units (JCWPd) – No. 69, 70 and 79 occur within.

The flat moraine plateaus built of clays and fluvioglacial deposits form the surface morphology in the whole tender area. There are numerous lakes in its western part. The main aquifer used as water supply is related to the Quaternary deposits, while the Neogene-Paleogene horizon is used locally. The Quaternary water-bearing horizons are associated with the Pleistocene and Holocene sands. They occur as: the near-surface water-bearing horizon, the intertill water-bearing horizon, and the subsoil water-bearing horizon. They are in direct hydraulic contact. The mineralization of groundwaters is up to 1 g/l to the depths of 200–270 m.

The near-surface water-bearing horizon and the intertill water-bearing horizon are commonly exploited for various purposes, including industrial, agricultural, and drinking water supply. The near-surface water-bearing horizon most often occurs in river valleys and locally on the highlands, being developed in sands and gravels. The thickness of the aquifer is from 10 to over 40 meters (locally 60 m). The water table is unconfined, locally confined and lies at a depth of 0.5–5 m in river valleys, up to 10–15 m on highlands.

Within the intertill water-bearing horizon there are several intertill aquifers which are in hydraulic contact. These aquifers are related to sands and gravels occurring between clay

the Quaternary, can be found in the explanations to the Detailed Geological Map of Poland 1 : 50 000: sheets Leszno (Gizler, 2001), Krzywiń (Winnicki, 2003), Gostyń (Szałajdewicz, 2002), Jaraczewo (Szałamacha, 2001), Góra (Multan, 2002), Poniec (Nowak, 2002), Kobylin (Król, 2003), and Krotoszyn (Błaszczak, 1997).

deposits. The water table is confined (locally unconfined) and is found at different depths. The thickness of this horizon varies from 5 m to 40 m.

The subsoil water-bearing horizon occurs in depressions of the Quaternary basement. It is found at a depth of more than 60 m b.g.l. The thickness of this horizon is about 5–30 m.

In the central part of the tender area, no main aquifer was distinguished because of very high chloride content (2500 mg/dm³ in Gostyń).

Apart from Quaternary water bearing horizons, water is also found in the Oligocene and Miocene fine and medium grained sands. They can be locally connected with the Quaternary deposits. The Miocene aquifer occurs at depth from 110 to 170 m b.g.l. (locally up to 260 m b.g.l.) and its average thickness is from 10 to 40 meters. The Oligocene aquifer (50 meters thick) is not a useful aquifer because of poor hydrogeological parameters. Locally, in the south-eastern part of the tender area, the Jurassic aquifer (without any usable significance) could be also distinguished.

Within the Gostyń tender area, three Major Groundwater Basins (MGB) are documented in the Quaternary deposits: No. 305, 307 and 308 (Fig. 2.29). The degree of groundwater vulnerability has been described as very low to medium, however, in the area of Gostyń and Leszno cities, it rises up to high (Fig. 2.30). There are several dozens of groundwater supplies within the tender area. They exploit the Quaternary, locally Neogene-

Palaeogene aquifers. The majority of them are in the area of Leszno and Gostyń cities. Six protection zones for groundwater supplies have been defined in the Gostyń tender area.

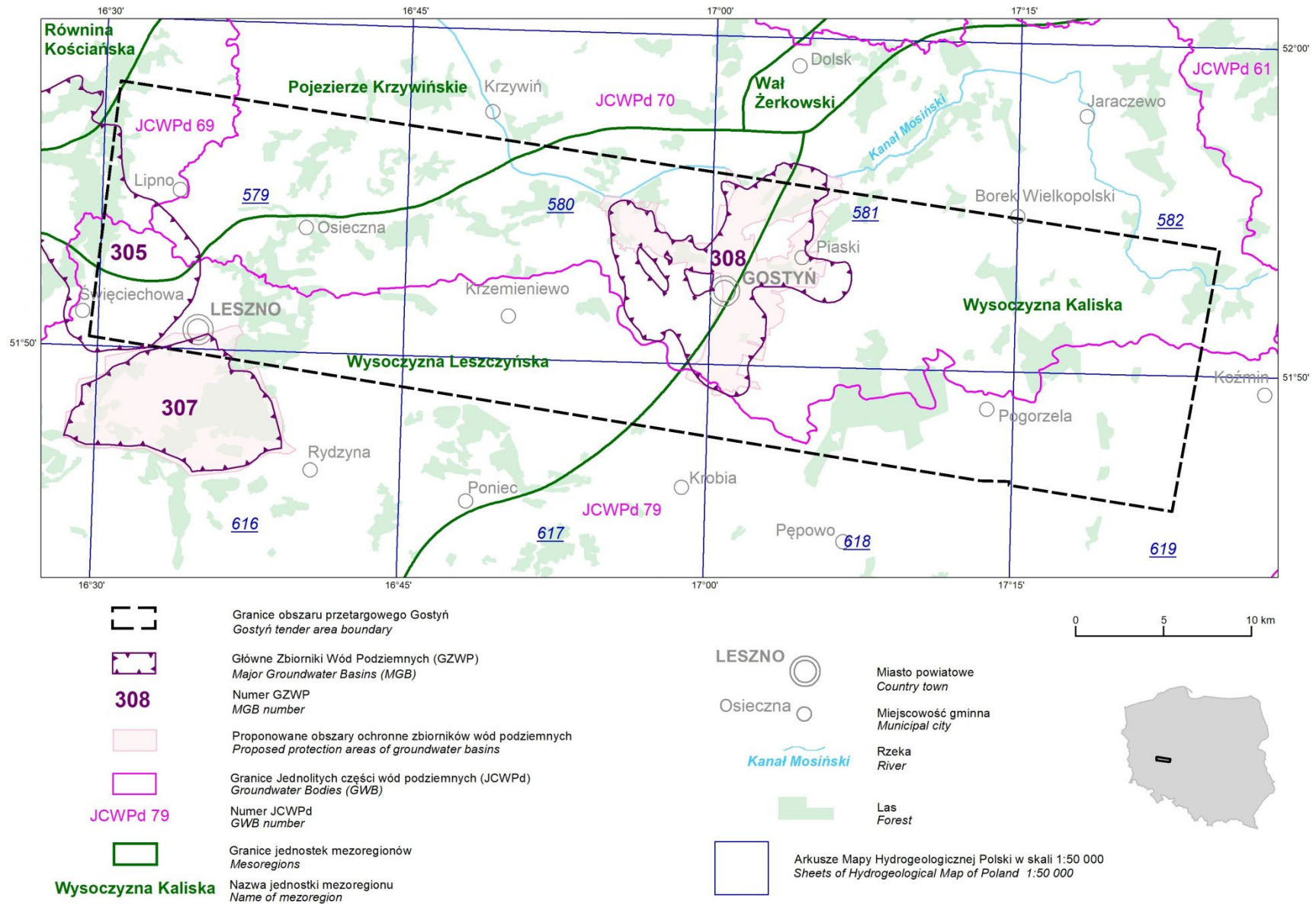


Fig. 2.29. Location of the Gostyń tender area in relations to physio-geographic units, MGB and GWB.

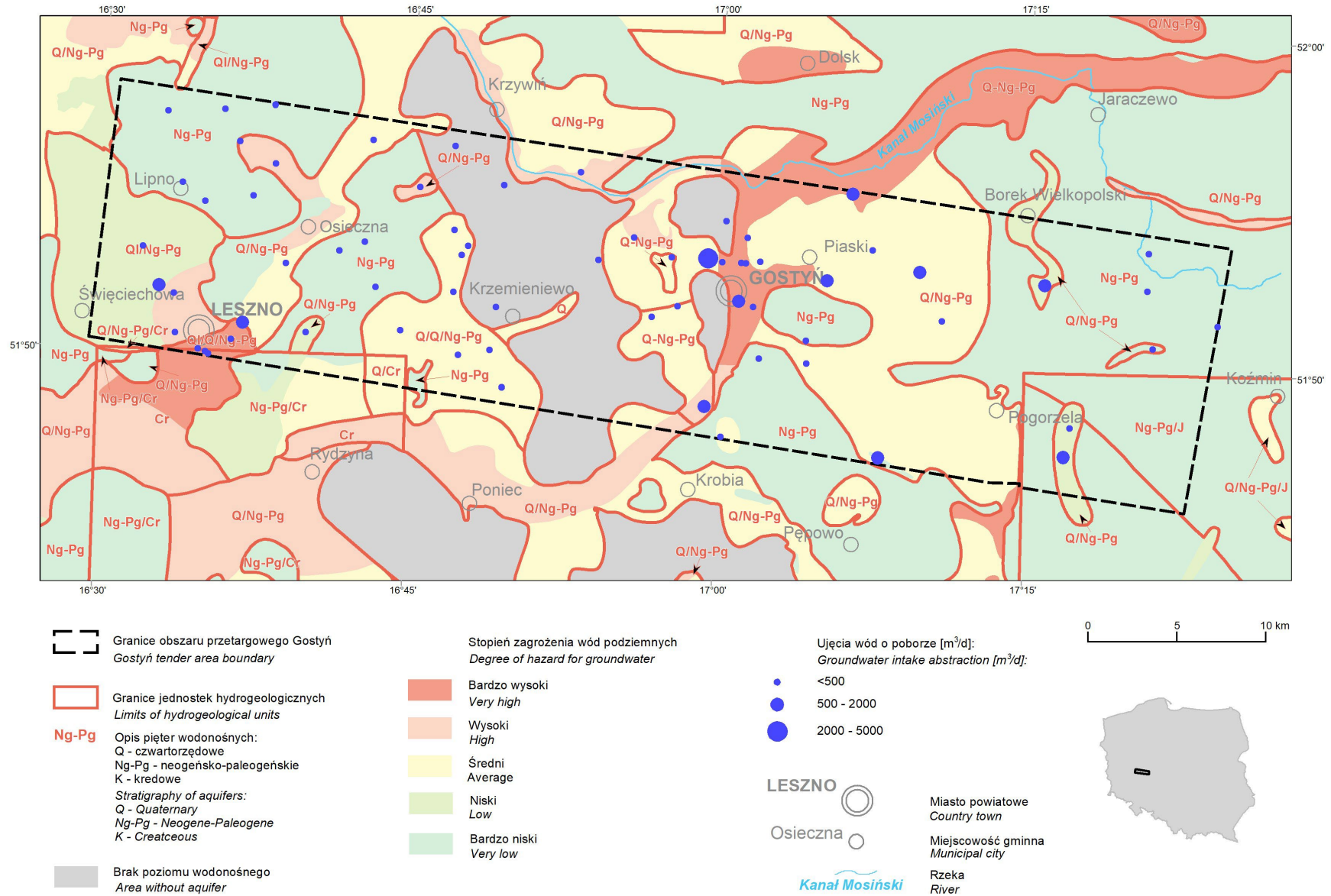


Fig. 2.30. Location of the Gostyń tender area in relations to hydrogeological units.

3. PETROLEUM PLAY

3.1. GENERAL CHARACTERISTICS

The petroleum play is defined as the set of geological and petroleum processes leading to the formation of a hydrocarbon field. The petroleum play includes source rocks, reservoir rocks, and seal rocks. In addition, an essential element of the petroleum play in conventional accumulations is a trap, which, due to its structural, stratigraphic, lithological and tectonic features, creates a place of accumulation of hydrocarbons. The existence of a petroleum play and the formation of a hydrocarbon reservoir require a set of processes located in space, as well as in geological time, consisting of generation, expulsion, migration and accumulation of hydrocarbons and formation of a reservoir trap. The temporal interrelationships between the mentioned elements and processes of the petroleum play allow the formation of oil and gas fields.

The geology and tectonic, as well as hydrocarbon characteristics of the Gostyń tender area enable to distinguish three petroleum plays. They are developed in:

- Permian/Zechstein – Main Dolomite (conventional),
- Carboniferous–Lower Permian (conventional),
- Lower Carboniferous (unconventional).

The Main Dolomite petroleum play is hydrodynamically isolated from the top and bottom by Zechstein evaporite rocks. Therefore, the Main Dolomite horizon acts both as the source and reservoir rock, with oil and gas fields located within structural and structural-tectonic traps. Source rocks developed in low-energy facies of the carbonate platform and its slope, in the form of bacterial-microalgal builds and biolaminites. Minor contribution is also attributed to laminites deposited in the basinal facies of the Main Dolomite. The basic reservoir rocks of the discussed petroleum system are dolomitized packstones and grainstones developed in certain areas of carbonate platform and microplatform zones (Kotarba and Wagner, 2007; Słowakiewicz and Mikołajewski, 2011; Słowakiewicz and Gąsiewicz, 2013; Kosakowski and Krajewski, 2015). To date, two natural gas fields –

Kąkolewo and Żakowo – were discovered and documented within the Main Dolomite petroleum play in the Gostyń tender area.

Gaseous hydrocarbons deposited in the Carboniferous–Lower Permian petroleum play in Poland are genetically associated with the Upper and Lower Carboniferous shales, claystones and siltstones rich in organic matter. Hydrocarbons generated from the source rocks migrated to areas displaying lower hydrostatic pressure, which were the porous and permeable sandstones of the Upper Carboniferous and Upper Rotliegend, and locally the Zechstein Limestone, as well. Migration could have been local – along tectonic discontinuities – or regional, short- and long-distance – through permeable pores and fractures. Gas fields in the conventional Carboniferous–Lower Permian petroleum play are found in structural and structural-tectonic traps, sealed from the top by Zechstein anhydrites and salts (Kotarba et al., 1992, 1999, 2002; Karnkowski, 2007; Botor et al., 2013). So far, no gas fields of the Carboniferous–Lower Permian petroleum play have been discovered within the Gostyń tender area, however, numerous gas fields are known from the neighboring concessions, i.e.: Bonikowo, Brońsko, Góra, Kościan, Sztychlingowa, Wilków or Żuchłów fields.

The tender area is located within the zone of the potential occurrence of unconventional gas accumulations within the claystone-siltstone-sandstone series of the Lower Carboniferous (Poprawa and Kiersnowski, 2008; Poprawa, 2010). The main characteristic of unconventional petroleum systems is that the reservoir rocks simultaneously act as sealing rocks. The source rocks in the unconventional petroleum system of the Lower Carboniferous are organic-matter rich shales, claystones and siltstones, which represent sediments of deep sea turbidity currents (Poprawa and Kiersnowski, 2008, and references therein). The rock complex could potentially accumulate natural gas within the claystone and siltstone source rocks (Poprawa and Kiersnowski, 2008), as well as within the

sandstone interbeds (Kozłowska and Kuberska, 2015). The search for unconventional hydrocarbon accumulations in Poland is currently in the stage of prospecting and exploration. There are prerequisites to suspect the existence of significant unconventional gas accumulations within the Lower Carbonifer-

ous of the Fore-Sudetic Monocline (Poprawa and Kiersnowski, 2008; Poprawa, 2010). This is exemplified by positive results obtained in the Siciny 2 well (Wójcicki et al., 2014; Kozłowska and Kuberska, 2015), located to the south of the Gostyń tender area.

3.2. SOURCE ROCKS

Carboniferous

Lithology: claystones, siltstones

TOC: 0.02–3.94%wt.

Kerogen type: II?

The presence of natural gas accumulations in Carboniferous and Lower Permian reservoir rocks of the Polish Lowland is genetically associated with organic matter-rich fine-grained clastic beds within carbonate-terrigenous complexes of the Upper and Lower Carboniferous (Kotarba et al., 1992, 1999, 2002; Karnkowski, 2007; Botor et al., 2013). In the Western Europe, the main source rocks of natural gas are the Upper Carboniferous coal-bearing terrigenous molasses. Although this succession is poorly recognized in the Polish Lowland, the presence of the coal beds in the Variscian Externides is possible (Śliwiński et al., 2006; Malinowski et al., 2007).

The total organic carbon content in Carboniferous rocks in Poland rarely exceeds 2%wt. The estimated hydrocarbon potential of source rocks is between fine and excellent. They typically constitute of gas-prone type III kerogen, however mixed, type II/III kerogen is also observed (Botor et al., 2013 and reference therein). On the Fore-Sudetic Monocline, where Carboniferous rocks are composed of complexes of interbedded claystones and sandstones (Żelichowski, 1964), the observed TOC values oscillate between 0.5 and 2%wt. and are typically lower than in other parts of the basin (Nowak, 2003, 2007; Papiernik et al., 2008; Botor et al., 2013). This is most likely caused by the high degree of thermal alteration, and consequently, a considerably exhausted generation potential of the rock. Elevated values of Tmax (440–520°C) and %Ro (1.0–5.0%) are attributed to

the significant depth, hydrothermal activity and Permian volcanism (Poprawa, 2010; Botor et al., 2013).

Studies of Carboniferous organic matter in the Gostyń tender area were provided in the following wells: Bułaków-2, Kobylin-1, Pogorzela 1, Pogorzela 2, Pogorzela 4, Pogorzela 7, Siedmiorogów-1, and Święciechowa 2. Except the Bułaków-2 and Kobylin-1 wells, the analysis was limited to the determination of extractable bitumen content (Tab. 3.2). Furthermore, these wells only drilled only top-most parts (16.3–89.5 m) of the Carboniferous rocks, not reaching into the main source rocks horizons. Similarly, the Bułaków-2 well drilled only through the top of the succession (36.5 m), however, the organic matter was tested to evaluate TOC content. The Kobylin-1 well, in which 940 m of the Carboniferous succession was recognized, is the only well, in which extensive geochemical and petrological study of the preserved organic matter was provided (Tab. 3.1).

The bitumen content in the investigated part of the Carboniferous succession varies from trace amounts up to 0.064%wt. (Tab. 3.2). These are low values, which do not qualify the intervals as potential source rocks. Three of four Carboniferous samples tested for TOC content (TOC = 0.39–1.73%wt.) in the Bułaków-2 well can be initially qualified as good potential source rocks. Analysis conducted on samples from the Kobylin-1 well show TOC values ranging from 0.02 to 3.94%wt. (Tab. 3.1), whereby, the majority of the samples show values between 0.5 and 2.5%wt. The top layers are relatively depleted in organic carbon. Among 124 samples, only

few did not match the minimal criteria for potential source rocks ($\text{TOC} > 0.5\%$ wt.; Dembicki, 2017). High thermal maturity and largely depleted generation potential of the rocks is reflected in low S2 values (0.0–0.6 mg HC/gRock) and vitrinite reflectance values within the range of 2.21–3.35% (Tab. 3.1). The degree of thermal alteration of the rocks is indicative of the dry gas stage (metagene-

sis). Reduced HI and unreliable Tmax values prevent kerogen typing based on Rock-Eval parameters. Chromatographic analysis also did not produce conclusive results. The authors of the report suggest the presence of type II kerogen with the potential to generate gaseous hydrocarbons (Chruścińska et al., 2016).

	TOC _{LECO}	TOC _{RE}	S1	S2	S3	PI	HI	OI	MinC	%Ro
N	30	94								19
Min.	0.25	0.02	0.00	0.00	0.00	0.01	0	0	0.01	2.21
Max.	3.00	3.94	0.06	0.61	1.09	0.90	85	300	25.00	3.35
Average	1.86	1.34	0.02	0.13	0.22	0.18	13	37	0.75	2.56

Tab. 3.1. Selected results of geochemical and petrological analysis of organic matter in the Kobylin-1 well (Chruścińska et al., 2016). N – number of samples; TOC_{LECO} – total organic carbon determined with the LECO apparatus (%wt.);

TOCRE – Rock-Eval total organic carbon (%wt.); S1 – free hydrocarbons (mg HC/gRock); S2 – hydrocarbons generated during kerogen cracking (mg HC/g Rock); S3 – organic CO₂ (mg CO₂/gRock); PI – production index; HI – hydrogen index (mg HC/gTOC); OI – oxygen index (mg CO₂/g TOC); MinC – mineral carbon (%wt.); %Ro – vitrinite reflectance (%).

Well	Thickness [m]	Number of samples	Bitumen content [%wt.]		
			Min.	Max.	Average
Pogorzela 1	27.7	2	trace	trace	trace
Pogorzela 2	17.5	2	0.011	0.019	0.015
Pogorzela 4	53.2	8	trace	trace	trace
Pogorzela 7	16.3	7	0.007	0.064	0.017
Święciechowa 2	26.5	2	0.021	0.044	0.032

Tab. 3.2. Bitumen content in the Carboniferous rocks (according to final well geological reports).

Main Dolomite

Lithology: mudstones, wackstones

TOC: 0.01–1.35%wt.

Kerogen type: II

The Main Dolomite is one of the principal exploration targets on the Polish Lowland. The horizon forms a closed petroleum system, and contains both the source and reservoir rocks, isolated from the top and bottom by impermeable evaporite rocks. Main source rocks in the Main Dolomite are lithofacies of microbial and algal origin, including: stromatolites, trombolites and biolaminites occurring within carbonate platform planes and slopes, tidal flats, and oolite barriers. Minor contribution can also be attributed to laminites deposited in the basin facies (Kotarba and Wagner, 2007; Słowakiewicz and Mikołajewski, 2011; Słowakiewicz and

Gąsiewicz, 2013; Kosakowski and Krajewski, 2015).

Total organic carbon (TOC) values in the Main Dolomite source rocks typically do not exceed 1%wt., although occasionally they can reach up to 6%wt. Hydrocarbon potential of these rocks varies from fair to very good. Marine bacteria and algae are recognized in the source organic matter preserved in the Main Dolomite (Kotarba and Wagner, 2007; Słowakiewicz and Mikołajewski, 2011; Kosakowski and Krajewski, 2014, 2015). However, detailed geochemical studies show a predominantly microbial origin of extracted hydrocarbons (Słowakiewicz and Mikołajewski, 2011). Diagenetic processes transform this type of organic matter into oil-prone type II kerogen. Local admixtures of terrestrial organic material (type I or III) is suggested by

both petrological and geochemical observations (Kotarba and Wagner, 2007; Słowakiewicz and Mikołajewski, 2011; Kosakowski and Krajewski, 2015).

The Gostyń tender area is located in the marginal part of the Main Dolomite basin, in the area of occurrence of the shallow carbonate platform zone. Potential source rocks may have developed in low-energy facies – in the extensive depressions of the carbonate platform plane, located in the western part of the tender area, as well as the backshoals of oolite-oncolite barriers found in its eastern part (Wagner, 2012). Potential source rocks are represented here by biolaminated mudstones and wackestones. The analysis of organic matter in the Main Dolomite was performed on samples from the following wells: Bułaków-2, Frankowo 1, Kąkolewo 1, Kąkolewo 2, Kąkolewo 4, Pogorzela 4, Pogorzela 7, Siedmiorogów-1, Święcichowa 1, Święcichowa 2, Żakowo 1, Żakowo 2, Żakowo 3, Żakowo 4, Żakowo 5, Żakowo 6, and Żakowo 9. In most of the listed wells, the study of organic material in the Main Dolomite was limited to the determination of the extractable bitumen content (Tab. 3.3). An exception is the Frankowo-1 well, in which total organic carbon content was determined,

and the Bułaków-2 well, in which extensive geochemical and petrological studies were performed. The average bitumen content in the Main Dolomite of the analyzed wells is low and oscillates between 0.007 and 0.033%wt. The highest values of this parameter are observed in the wells drilled in the Żakowo structure (Tab. 3.3). The TOC results from the Frankowo-1 well are between 0.11 and 0.26%wt. (5 samples), and such values are indicative of a poor quality source rock. The Main Dolomite samples from the Bułaków-2 well show TOC values from 0.01 to 1.35%wt. It was estimated that there is ca. 10 m of potential source rock in the entire 35.5 m profile. Vitrinite and solid bitumen reflectance measurements (9 samples) showed that the level of thermal maturity of the rocks is high and reflects the wet gas stage of catagenesis. The amount of hydrocarbons generated from the rock during pyrolysis (S2) is low (0.12–0.35 mgHC/gRock), which likely results from the exhaustion of the original hydrocarbon potential of the rock. The composition of saturated and aromatic hydrocarbon fractions (10 samples) showed signs of vertical migration of low molecular weight hydrocarbons and mild biodegradation. The kerogen was classified as oil-prone, type II (Strzelecka and Rostkowski, 2016).

Well	Thickness [m]	Number of samples	Bitumen content [%wt.]		
			Min.	Max.	Average
Bułaków-2	35.5	10	0.018	0.037	0.023
Kąkolewo 1	75.0	30	0.008	0.064	0.023
Kąkolewo 2	43.0	122	0.003	0.180	0.026
Kąkolewo 4	64.5	27	0.002	0.021	0.011
Pogorzela 4	35.0	48	trace	0.011	0.008 (9)*
Pogorzela 7	17.0	18	0.001	0.202	0.007
Święcichowa 1	40.5	30	trace	0.550	0.034 (16)*
Święcichowa 2	62.5	12	0.020	0.045	0.030
Żakowo 1	10.0	8	0.003	0.087	0.015
Żakowo 2	25.2	4	0.004	0.017	0.009
Żakowo 3	61.0	25	0.011	0.071	0.030
Żakowo 4	67.0	28	0.006	0.154	0.032
Żakowo 5	26.2	109	0.002	0.104	0.023
Żakowo 6	59.0	39	0.005	0.082	0.033
Żakowo 9	63.0	175	0.006	0.853	0.029

Tab. 3.3. Results of bitumen content measurements in the Main Dolomite rocks (according to final well geological reports). * – values in the brackets represents the number of samples used to calculate the average.

3.3. RESERVOIR ROCKS

*Lower Carboniferous
and Carboniferous–Lower Permian*

In the unconventional Lower Carboniferous petroleum play, the reservoir rocks are related to the fine-grained clastic rocks intercalated with sandstones. The unconventional occurrences of gas in the Carboniferous horizons were discussed by Wójcicki et al. (2014) and Kiersnowski et al. (2017). In the case of the conventional Carboniferous–Lower Permian play, the reservoir rocks are related to the Upper Carboniferous and Upper Rotliegend sandstones and Zechstein Limestone horizons.

The Carboniferous rocks have generally poor reservoir properties. Especially in the western part of the Gostyń area – on the Pogorzela High, porosities do not exceed 2.55%, and permeability ranges from very low to 0.423 mD. These properties are slightly better in the vicinity of the High, on its northern and southern sides, where an increase in porosity and permeability were observed in the Bułaków 1, Pogorzela 7 and Kobylin-1 wells (Tab. 3.4). The reservoir properties of the Carboniferous rocks seem to be better in the western part of the area, in the Święciechowa

2 well, where the porosity reaches 9.27%, and permeability 1.63 mD.

The Rotliegend deposits have good reservoir properties in the central and western part of the Gostyń area – near the Żakowo and Kąkolewo fields (Tab. 3.5). The Zechstein Limestone in the Gostyń tender area has the best reservoir properties in the Frankowo 1 well, near the Kąkolewo field, and in the Święcie-chowa 1 well. Its reservoir properties deteriorate towards the east: in the area of the Pogorzela High the occurrence of the Zechstein Limestone is questioned (Kwolek and Mikołajewski, 2007). Nevertheless, it seems that the Zechstein Limestone occurs in the northern and southern vicinity of the Pogorzela High, where its reservoir properties are better, e.g. in the Rusko-1 well (Tab. 3.6).

The Results of production tests conducted in the Carboniferous, Rotliegend, and Zechstein Limestone horizons are summarized in Tab. 3.7. Although they did not bring any economic flows, it is worth paying attention to its type and efficiency.

Well	Depth [m]	Number of samples	Porosity Min.–Max. (Average)	Permeability Min.–Max. (Average)
			[%]	[mD]
CARBONIFEROUS				
BUŁAKÓW 1	2137.0–2225.0	36	0.48–7.15 (2.63)	0–0.292 (0.03)
BUŁAKÓW-2	1853.5–1888.5	1	3.8	<0.001
KOBYLIN-1*	1920.35–2858.3	43	0.0–6.05	
POGORZELA 1	1796.55–1797.0	2	0.77–0.92	very low
POGORZELA 2	1764.35–1764.65	2	0.17–0.74	0.0223
POGORZELA 4*	2002.05–2020.35	14	0.07–2.55 (0.97)	very low–0.423 (0.083)
POGORZELA 7	2191.75–2206.55	3	0.38–9.58	0.022–0.562
ŚWIĘCIECHOWA 2	20194.5–2196.15	3	1.41–9.27	0.1545–1.6311

*with the Zechstein Limestone base

Tab. 3.4. Reservoir characteristics of the Carboniferous rocks in the Gostyń tender area (according to the final well geological reports).

Well	Depth [m]	Number of samples	Porosity Min.–Max. (Average)	Permeability Min.–Max. (Average)
			[%]	[mDcy]
PERMIAN – ROTLIEGEND				
KĄKOLEWO 1	2053.0–2122.5	10	7.54–17.35 (12.35)	0.6855–5.6963 (3.0792)
KĄKOLEWO 2	2000.0–2072.0	33	5.13–30.43 (13.47)	0.10–8.39 (2.83)
KĄKOLEWO 4	1979.0–2066.0	33	4.73–14.98 (9.04)	0.20–8.19 (2.07)
RUSKO-1*	2396.1–2599.5	2	0.9–1.0	<0.001–0.001
ŚWIĘCIECHOWA 1	2095.85–2163.55	15	3.23–18.29 (9.94)	0.201–48.314 (17.058)
ŚWIĘCIECHOWA 2	2044.9–2159.75	39	0.79–19.5 (12.07)	0.0334–20.872 (4.2504)
ŻAKOWO 3**	2209.25–2222.75	10	0.96–7.45 (4.35)	0.1213–2.4412 (0.09376)
ŻAKOWO 4**	2196.45–2217.95	17	4.84–19.7 (9.11)	0.0203–19.132 (2.9645)
ŻAKOWO 6	2165.05–2187.05	44	3.27–29.77 (8.74)	0–52.610 (3.212)
ŻAKOWO 9	2170.55–2296.1	28	0–6.47 (2.48)	0–0.280 (0.025)

*Lower Rotliegend

**together with Zechstein Limestone and Kupferschiefer base

Tab. 3.5. Reservoir characteristics of the Rotliegend rocks in the Gostyń tender area (according to the final well geological reports).

Well	Depth [m]	Number of samples	Porosity Min.–Max. (Average)	Permeability Min.–Max. (Average)
			[%]	[mDcy]
PERMIAN/ZECHSTEIN – ZECHSTEIN LIMESTONE				
BUŁAKÓW 1	2121.25–2135.55	4	0.70–1.95 (1.24)	0.0–0.081 (0.02)
BUŁAKÓW -2	1823.5–1853.5	56	0.1–18.0 (4.10)	<0.001–21.11 (0.59)
FRANKOWO 1	2046.5–2050.0	9	7.9–25.4 (17.8)	0.086–7.691 (1.632)
KĄKOLEWO 2	1996.0–2000.0	2	2.32–5.37	0.0
RUSKO-1	2356.0 2396.1	37	0.6–18.1 (7.0%)	<0.001–52.6 (2.9)
ŚWIĘCIECHOWA 1	2083.45–2093.45	11	0.25–17.51 (8.98)	0.146–56.962 (21.154)
ŚWIĘCIECHOWA 2	2041.9–2044.2	4	0.97–2.78 (2.15)	0.0250–0.1029 (0.0516)
ŻAKOWO 9	2165.15–2166.55	1	0.15	0

Tab. 3.6. Reservoir characteristics of the Zechstein Limestone (with Kupferschiefer) rocks in the Gostyń tender area (according to the final well geological reports).

Well	Depth [m]	Method	Flow type	Efficiency
ZECHSTEIN LIMESTONE				
BUŁAKÓW 1	2073.0–2129.0	formation tester KII-95	brine with gas shows	5.2 m ³ /42 min.
	2071.0–2074.0	perforation, formation tester KII-95	fluid with no hydrocarbons from outside casing pipes	
	2071.0–2074.0	perforation, injection 10125 l of fluid	formation fluid	0.9 m ³ /121 min.
	2071.0–2074.0	injection 32500 l of fluid		P _{head.} = 0 atn P _{siph.} = 0 atn
POGORZELA 7	2156.0–2182.0	formation tester KII-95	gasified brine	P _{formation initial} = 232.2 atn
RUSKO-1*	2354.5–2393.0	formation tester Halliburton 5" depth 2349.0 m	12.1 m ³ fluid	P _{formation} = 25.03 MPa
ŚWIĘCIECHOWA 1	1899.0?	formation tester	fluid	
ZECHSTEIN LIMESTONE + ROTLIEGEND				
FRANKOWO 1	2049.0–2077.0	formation tester, depth 2020.0 m	~320 l fluid	
KĄKOLEWO 2*	1990.0–2015.2	formation tester	gasified brine	P _{formation} = 216 atm depth 2011 m V _{pot.} = 1.94 m ³ /d V _{true} = 1.03 m ³ /d
KĄKOLEWO 4*	1952.0–1996.0	formation tester	gasified brine	P _{formation} = 206 atm V = 1 m ³ /h V _{true} = 0.19 m ³ /h
	1952.0–1996.0	formation tester	1580 l gasified fluid	V = 1.1 m ³ /h
ŚWIĘCIECHOWA 2*	2035.5–2056.0	formation tester KJJ-II-146	600 l gasified fluid	not determined
	2034.0–2068.0	formation tester KJJ-II-146	800 l mud	not determined
ŻAKOWO 1*	2183.3–2195.5	formation tester KII-2-146	6.1 m ³ brine	Temp. = 73°C P _{formation} = 222 atn Q _{pot.} = 472.5 m ³ /d
ŻAKOWO 3*	2201.4–2228.3	formation tester	930 l brine	
ŻAKOWO 4	2190.3–2214.5	formation tester	brine with no hydrocarbons	Q = 4.8 m ³
ŻAKOWO 6*	2145.0–2171.0	formation tester KII-95	gasified brine	V = 1,9 m ³ /h P _{formation} = 238 atm
ROTLIEGEND				
KĄKOLEWO 1	2067.0–2087.0	formation tester, depth 2067.0 m	water	0.61 m ³ /h P _{formation initial} = 227 atn.
ŚWIĘCIECHOWA 2	2070.5–2085.0	formation tester KJJ-II-146	200 l mud	not determined
CARBONIFEROUS + ZECHSTEIN LIMESTONE				
BUŁAKÓW-2*	1820.0–1854.0	formation tester	400 l brine	P _{formation} = 19,028 MPa depth 1817.0 m;
POGORZELA 4*	1970.0–2012.0	formation tester KII-95	formation water	P _{formation initial} = 210 atn
CARBONIFEROUS				
BUŁAKÓW 1	2152.0–2225.0	formation tester KII-95	no flow	

*together with Lower Anhydrite

Tab. 3.7. Results of the production tests in the Carboniferous and Lower Permian in the Gostyń tender area (according to the final well geological reports).

Main Dolomite

The Main Dolomite carbonates – limestones and dolomites – constitute the main exploration horizon in the Gostyń tender area. Their facies characteristics can be found in Chapter 2 of this study, here we limits only to show their reservoir parameters.

Two natural gas fields were documented in the Main Dolomite in the Gostyń tender area – Żakowo field (23.5 m average effective thickness, 4.87% average porosity, 1.368 mD average permeability, absolute efficiency up to 446 Nm³/min) and Kąkolewo field (24.75 m average effective thickness, 5–8.6% average porosity, 1.368 mD average permeability, absolute efficiency up to 410 Nm³/min). Un-

fortunately, these deposits have high nitrogen content, while the methane reaches from 10.3% to 15.1%, respectively. An industrial gas flow with a similar composition was also obtained from the Main Dolomite in the Frankowo 1 well. This proves the high petroleum prospectives of the Main Dolomite in the western part of the Gostyń area. The Main Dolomite in the eastern part of the area has worse reservoir properties: formation tests carried out on the Pogorzela High and in its vicinity did not yield hydrocarbon flows. The reservoir properties of the Main Dolomite in the Gostyń area together with the results of the formation tests are summarized in Tabs 3.8–3.9.

Well	Depth [m]	Number of samples	Porosity	Permeability
			Min.–Max. (Average) [%]	Min.–Max. (Average) [mdcy]
MAIN DOLOMITE				
BULAKÓW-2	1746.0–1781.5	55	0.1–11.1 (2.74)	<0.001–21.992 (1.269)
FRANKOWO 1	1539.0–1582.0	2	2.7–21.3 (12.0)	0–3.28 (1.64)
KĄKOLEWO 1	1749.05–1819.75	30	0.18–6.14 (1.60)	0.0268–0.2561 (0.0886)
KĄKOLEWO 2	1626.5–1669.5	132	0.0–33.81 (8.41)	0.0–20.15 (0.9587)
KĄKOLEWO 4	1672.5–1737.0	28	0.46–16.27 (7.21)	0.0–6.46 (0.44)
POGORZELA 1	1760.55–1767.55	13	1.17–6.43	very low–0.663
POGORZELA 2	1729.55–1747.55	12	0.18–4.61	0.0149–2.2228
POGORZELA 4	1905.05–1935.45	48	0.27–18.52 (5.88)	very low–20.764 (1.51)
POGORZELA 7	2052.25–2091.05	14	0.07–17.57 (7.93)	very low–242.06 (6.175)
RUSKO-1	2295.2–2328.2	18	0.2–27.0	<0.001–182
ŚWIĘCIECHOWA 1	1731.25–1784.65	30	0.45–9.81 (3.66)	0.109–1.092 (0.390)
ŚWIĘCIECHOWA 2	1746.5–1773.25	12	0.26–3.98 (1.31)	0.0129–0.2402 (0.0629)
ŻAKOWO 1	1842.0–1851.5	8	0.18–15.66 (6.15)	0–4.262 (1.07)
ŻAKOWO 2	1806.65–1825.05	4	1.22–10.81 (6.39)	very low–0.6307 (0.2724)
ŻAKOWO 3	1854.95–1906.55	26	0.21–12.09 (2.69)	000044–0.4006 (0.1194)
ŻAKOWO 4	1840.55–1903.65	28	0.44–33.87 (5.89)	0.012–1.94 (0.40)
ŻAKOWO 5	1804.55–1827.85	113	0.08–8.08 (2.17)	0–0.700 (0.096)
ŻAKOWO 6	1817.45–1870.75	56	0–11.6 (2.06)	0–2.153 (0.224)
ŻAKOWO 9	1805.05–1866.75	166	0–32.99 (4.75)	0–14.53 (0.87)

Tab. 3.8. Reservoir characteristics of the Main Dolomite rocks in the Gostyń tender area (according to the final well geological reports).

Well	Depth [m]	Method	Flow type	Efficiency
MAIN DOLOMITE				
BULAKÓW 1	1817.0–2045.2	formation tester KII-95	brine with no hydrocarbons	4.9 m ³ /54 min
	1817.0–2045.2	formation tester KII-95	brine with no hydrocarbons	5.8 m ³ /180 min
	2001.0–2004.0	perforation, fluid injection	no flow	P _{head} = 0 atn P _{siph.} = 0 atn
FRANKOWO 1	1543.4	cable tester	gas with H ₂ S	P = 2300 PSI

	1560.93	cable tester	no flow	
	1568.05	cable tester	no flow	
	1539.05	cable tester	gas with H ₂ S	
	1566.0–1571.0	perforation, formation tester, depth 1535.0 m	gas	P _i = 186.35 bar S = 23.9 kh = 18.5 mD*m
	1542.0–1547.0	perforation, formation tester, depth 1518.0 m	gas with H ₂ S	P _i = 185.56 bar S = 25.8 kh = 674 mD*m
KĄKOLEWO 1	1738.4–1762.4	formation tester, depth 1738.4 m	no flow	
	1763.0–1823.0	formation tester, depth 1763.0 m	water with no hydrocarbons	0.338 m ³ /h P _{formation initial} = 206 atn
KĄKOLEWO 2	1623.0–1639.3	formation tester	gas with H ₂ S	P _{formation} = 185 atn
	1644.0–1664.0	formation tester	gas and fluid	P _{formation} = 191 atn
	1629.0–1655.0	liquidation to the depth 1655.0 m, exploitation head, siphoning	gas	P _{static head} = 161.5 atn P _{static bottom} = 199.42 ata V _{abs.} = 46.91 Nm ³ /min
	1629.0–1655.0	siphoning, acidizing	gas	P _{static head} = 161.5 atn P _{static bottom} = 199.38 ata V _{abs.} = 445.6 Nm ³ /min
KĄKOLEWO 4	1644.7–1682.0	formation tester	no flow	
	1683.0–1713.0	formation tester	no flow	
POGORZELA 1	1746.6–1764.0	formation tester KII-146	fluid	0.51 m ³ /h P _{formation initial} = 183.5 atn
POGORZELA 2	1683.0–1735.0	formation tester KII-2-95	fluid with no hydrocarbons	0.5 m ³ /61 min
	1725.8–1757.0	formation tester KII-2-95	fluid with no hydrocarbons	3.8 m ³ /29 min
	1698.0–1767.0	formation tester KII-2-95	26,3 m ³ fluid	not determined
POGORZELA 4	1904.0–1922.7	formation tester KII-95	formation water with no hydrocarbons	2.7 m ³ /46,5 min P _{formation initial} = 202 atn
ŚWIĘCIECHOWA 1	1725.0–1740.0	perforation, formation tester depth 1690.0 m	fluid with no hydrocarbons	not determined
ŚWIĘCIECHOWA 2	1745.5–1757.0	formation tester KJJ-II-146	unsuccessful test	
ŻAKOWO 1	1765.1–1854.5	formation tester KII-2-146	non-inflammable gas, 1.46 m ³ brine with hydrocarbons	Temp. = 64.5°C P _{formation initial} = 219 atn Q _{pot} = 930 m ³ /d
	1818.0–1829.0 1840.0–1863.0	siphoning, acidizing	gas eruption	Temp. = 65°C P _{static head} = 175 atn P _{static bottom} = 213 atn V _{abs.} = 128 Nm ³ /min
	1818.0–1830.0	reperforation (2010), acidizing	gas	Temp. = 343K P _{static head} = 17 MPa P _{static bottom} = 21 MPa

				$V_{abs} = 173 \text{ Nm}^3/\text{min}$
ŻAKOWO 2	1804.7–1829.7	perforation, acidizing, siphoning	gas	Temp. = 338K $P_{static\ head} = 181 \text{ atm}$ $P_{static\ bottom} = 223 \text{ ata}$ $V_{abs} = 109 \text{ Nm}^3/\text{min}$
ŻAKOWO 3	1846.5–1864.2	formation tester	air with gas, 0.32 m ³ brine	Temp. = 71°C $P_{formation} = 237 \text{ atm}$ $Q_{pot} = 0.216 \text{ m}^3/\text{d}$
	1866.6–1886.0	formation tester	brine	$P_{formation} = 196 \text{ atm}$
	1853.5–1862.0	siphoning		$P_{static\ head} = 171.4 \text{ atn}$ $P_{static\ bottom} = 212 \text{ atn}$ $V_{abs} = 11.5 \text{ Nm}^3/\text{min}$
ŻAKOWO 4	1840.0–1860.0	acidizing, siphoning	2 m ³ brine	$P_{max} = 60 \text{ atn}$
	1832.4–1907.1 1827.5–1907.2 1828.0–1907.2	3 formation testers	fluid and non- inflammable gas	$P_{formation} = 204.5 \text{ atn}$
	1837.0–1875.0	siphoning	gasified fluid	$P_{max} = 5 \text{ atn}$ $Q = 8.5 \text{ m}^3$
ŻAKOWO 5	1804.5–1825.5	siphoning, formation tester	no flow	
	1804.5–1830.7	siphoning, I acidizing		
	1804.5–1830.7	II acidizing		
	1804.5–1830.7	siphoning, III acidizing	gas, water with gas, formation water	
	1804.5–1830.7	siphoning	gas and water	$V = <5 \text{ Nm}^3/\text{min}$
ŻAKOWO 6	1808.0–1835.0	siphoning	gas and water	$V = 183 \text{ Nm}^3/\text{min}$ $P_{head} = 177.9 \text{ atm}$ $P_{bottom} = 218.1 \text{ atm}$
	1838.0–1845.0	formation tester KII-95	0.4 m ³ gasified mud	$P_{formation} = 232.6 \text{ atm}$ at depth 1843.0 m
	1844.0–1863.0	formation tester KII-95	fluid with H ₂ S	$V = 2.5 \text{ m}^3/\text{h}$ $P_{formation} \sim 225\text{--}235 \text{ atm}$
	1823.2–1830.0	siphoning, acidizing	gas, water and fluid	$V_{abs.} = 410 \text{ Nm}^3/\text{min}$ $P_{static\ head} = 179,5 \text{ atm}$ $P_{static\ bottom} = 219,76 \text{ atm}$
ŻAKOWO 9	1803.0–1849.5	formation tester KII-95, depth 1774.0 m	no flow	not determined
	1803.0–1849.5	formation tester depth 1783.0 m	gas and 200 l mud	not determined
	1848.0–1855.5	formation tester KII-95, depth 1848.0 m	no flow	not determined

*together with Carboniferous basement

Tab. 3.9. Results of the production tests in the Main Dolomite horizon and its surroundings in the Gostyń tender area (according to the final well geological reports).

3.4. SEAL AND OVERBURDEN ROCKS

The conventional Carboniferous–Lower Permian petroleum play is sealed from the top by the PZ1 cyclothem evaporite succession (67.0–468.0 m thick), with the exception of the Pogorzela High, where the system is in hydraulic contact with the Zechstein/Main Dolomite horizon, sealed by the evaporites of the second cyclothem PZ2. The thickness of the overburden, i.e. younger Zechstein, Meso-

zoic and Cenozoic deposits, is from 1582.0 to 2328.2 m.

The Main Dolomite is sealed from the bottom and top by the evaporites of the PZ1 and PZ2+PZ3 cyclothem, respectively. The thickness of the seal is 30.5–188.0 m, while the thickness of the overburden is 1537.5–2119.5 m.

3.5. GENERATION, MIGRATION, ACUMULATION, AND HYDROCARBON TRAPS

Main Dolomite

Source rocks: Main Dolomite wackstones and mudstones.

Reservoir rocks: Main Dolomite dolomitized grainstones and packstones..

Seal rocks: Zechstein evaporites.

Trap type: structural and structural-stratigraphic.

Age and mechanisms of hydrocarbon trap formation: in the Gostyń tender area hydrocarbon traps are synsedimentary (Kotarba et al., 2000; Kwolek and Mikołajewski, 2010). Typical is distribution of reservoir rocks in relation to palaeogeographic zones. Reservoir rocks developed primarily in the areas of occurrence of oolite-onkolite barrier and organogenic buildup facies of the carbonate platform. For example, the Żakowo field developed within biohermal facies. Later halotectonic processes and faulting were also key factors in the formation of hydrocarbon traps. The presence of bacteriogenic methane in the Main Dolomite of the western part of the Fore-Sudetic Monocline suggests that the hydrocarbon traps likely were already formed during the early stages of organic matter diagenesis (Kotarba et al., 2000).

Age and mechanisms of hydrocarbon generation, expulsion, migration and accumulation: regional studies of the Fore-Sudetic Monocline suggest that the generation of hydrocarbons from the Main Dolomite occurred during two stages. The first stage took place during the diagenesis, as a result of bacterial activity. The second stage was related to the processes of thermal alteration (Kotarba et al.,

2000; Kosakowski and Wróbel, 2010; Pletsch et al., 2010). Thermal maturity of the Main Dolomite rocks in the Gostyń tender area is related to the wet gas stage of catagenesis (Strzelecka and Rostkowski, 2016). The heat flow was the highest in the Late Permian and Early Triassic. Increased subsidence began in the Permian and continued uninterrupted till the Late Triassic. Both of these factors contributed to the transformation of organic matter and subsequent generation of hydrocarbons. The beginning of expulsion of hydrocarbons is dated to the Early Triassic. The biggest depth of burial of the Main Dolomite was achieved in the Jurassic. This period also coincides with the main stage of hydrocarbon generation. The highest temperature conditions (gas window) and substantial exhaustion of the generation potential of the source rocks took place in the Middle Jurassic (Kosakowski and Wróbel, 2010; Pletsch et al., 2010). The kerogen transformation ratio calculated for the area of the Wielkopolska Platform is over 98% (Kosakowski and Wróbel, 2010).

Migration began simultaneously with expulsion – in the Early Triassic. 2D modeling results show the continuation of migration processes to the Late Jurassic and Cretaceous. The end of expulsion and migration was marked by a tectonic inversion which occurred at the end of the Cretaceous period (Kosakowski and Wróbel, 2010). Migration within the Main Dolomite took place over short distances of up to several kilometers. Oil accumulated in traps between the Triassic and Jurassic period, while saturation with

gaseous hydrocarbons occurred in the Late Jurassic (Kotarba and Wagner, 2007).

*Lower Carboniferous
and Carboniferous–Lower Permian*

Source rocks: organic matter-rich Carboniferous claystones and siltstones.

Reservoir rocks: in the case of the conventional Carboniferous–Lower Permian petroleum play, the Upper Carboniferous and Upper Rotliegend sandstones, as well as the Zechstein Limestone carbonates are reservoir rocks. While, in the unconventional Lower Carboniferous petroleum play, the role of reservoir rocks is assumed by the claystone-siltstone source rocks and the sandstone intercalations.

Seal rocks: PZ1 evaporite rocks seal the reservoir rocks of the Carboniferous–Lower Permian petroleum play from the top. In the unconventional Lower Carboniferous petroleum play, the reservoir rocks simultaneously act as seal rocks.

Size and shape of hydrocarbon traps: the traps in the conventional Carboniferous–Lower Permian petroleum play are structural or structural-tectonic of small and medium size. The size of reservoirs within the unconventional Lower Carboniferous petroleum play has not been recognized.

Age and mechanisms of hydrocarbon trap formation: hydrocarbon traps in the Zechstein Limestone and the top of the Rotliegend are syndimentary. The presence of mixed type, structural-tectonic traps is recognized, and such traps have likely formed as a result of Cimmerian and/or Laramian tectonic events.

Age and mechanisms of hydrocarbon generation, expulsion, migration and accumulation: results of basin modeling for the Siciny 2 (located to the south of the Gostyń tender area) and Wycisłowo IG-1 (located to the west of the area) wells enable the characterization of generation, expulsion, migration and accumulation processes in the vicinity of

the tender area. The thermal maturity of kerogen in the Carboniferous source rocks of this area ranges between the wet gas stage (late catagenesis; Wójcicki et al., 2014) and the dry gas stage (metagenesis; Chruścińska et al., 2016). Therefore, thermal conditions necessary for the generation of gaseous hydrocarbons has been achieved in the geological history of the rocks. Modeling results show that catagenesis began in the Early Triassic, whilst the main stage of natural gas generation (wet gas window) took place at the end of the Triassic period. Maturation processes ceased as a result of the tectonic inversion and intensive erosion in Upper Cretaceous (Wójcicki et al., 2014). The generated natural gas was partially trapped within its source rocks, while the unconventional traps interbedding the source rocks could have accumulated hydrocarbons even in the early stages of their generation. The model of migration, accumulation and sealing processes in the Lower Carboniferous petroleum play (Wójcicki et al., 2014 after H. Kiersnowski) assumes very short distance migration, which took place between the layers of the Lower Carboniferous siltstone-sandstone complex.

Hydrocarbon traps within the conventional Carboniferous–Lower Permian petroleum play could only have been saturated with hydrocarbons after the development of the regional sealing system in the form of the Zechstein evaporite layers. The main phase of migration began in the Lower Jurassic and continued up to the end of the Jurassic period. Volcanic rocks present at the bottom of the Rotliegend have limited large-scale movement of hydrocarbons. Migration took place on short distances below the surface of Permian volcanic rocks. Vertical movement of hydrocarbons transpired along dislocation zones intersecting the volcanic layers. A second migration pulse may have occurred in the Upper Cretaceous in conjunction with the increasing depth of burial (Górecki et al., 2009).

4. HYDROCARBON FIELDS

There are two hydrocarbon fields documented within the Gostyń tender area (Fig. 4.1). These are:

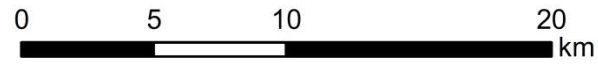
- Kąkolewo natural gas field (GZ 4715; Fig. 4.2);
- Żakowo natural gas field (GZ 4702; Fig. 4.3).

→ **Fig. 4.1.** Hydrocarbon fields within and in the neighborhood of the Gostyń tender area. Exploited fields are framed with red contour of mining areas.

Obszary wytypowane do postępowania przetargowego na koncesje na poszukiwanie i rozpoznawanie złóż węglowodorów oraz wydobywanie węglowodorów ze złóż (7. runda przetargowa)






Areas selected to the tender procedure for concessions for prospection and exploration of hydrocarbon fields and production of hydrocarbons from fields (7th tender round)

Gostyń



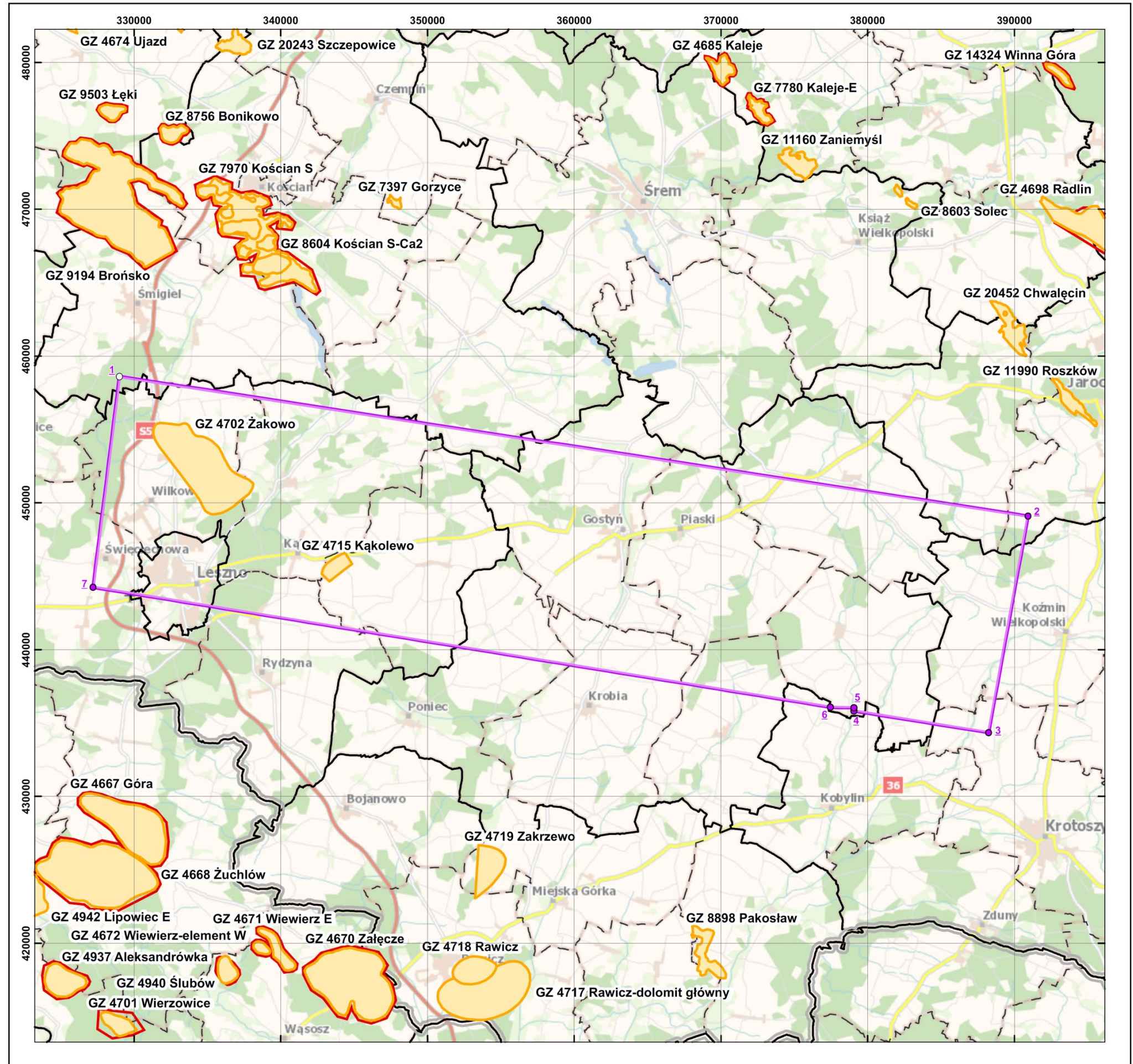
Układ współrzędnych / Coordinate system: PL-1992

Objaśnienia / Legend

-  obszar przetargowy tender area
-  złoża węglowodorów hydrocarbon fields
-  obszary górnicze wyznaczone dla złóż węglowodorów mining areas assigned for hydrocarbon fields
-  granice gmin commune borders
-  granice powiatów county borders

Współrzędne punktów wyznaczających granice obszaru przetargowego, uki. wsp. PL-1992
Coordinates determining the borders of tender area, coordinate system PL-1992

Nr punktu / Point No	X	Y
1	458612,86	329000,37
2	449098,43	390925,24
3	434350,20	388236,63
4	435825,17	379052,82
5	436042,65	379058,04
6	436084,28	377442,15
7	444253,75	327199,72



Udokumentowane złoża kopalin oraz obszary górnicze:
Państwowy Instytut Geologiczny - Państwowy Instytut Badawczy
System Gospodarki i Ochrony Bogactw Mineralnych Polski MIDAS
Podkład topograficzny: Główny Urząd Geodezji i Kartografii
Mapa podkładowa BDOO i BDOT10k (usługa WMTS)

Documented fields and mining areas:
Polish Geological Institute - National Research Institute
System of Management and Protection of Mineral Resources
in Poland MIDAS
Topographic background: Head Office of Geodesy and Cartography
Background maps of BDOO and BDOT10k (WMTS service)

Copyright by PGI-NRI
Warsaw 2023

4.1. KĄKOLEWO NATURAL GAS FIELD

Administrative location:

voivodeship – Wielkopolskie
 county – Leszche
 communes – Krzemieniewo, Osieczna

Acreage: 205.00 ha

Depth: 1,626.50–1,669.50 m

Stratigraphy: Permian/Zechstein – Main Dolomite

Field not exploited

MIDAS System no: 4715

Geological documentations in National Geological Archive (NGA) of the PGI-NRI:

1. Bojanowski M., Błaszowska V., Kalbarczyk R., Stolarczyk J., Stolarczyk F., 1975. Kąkolewo gas field geological documentation. Inv. 5919/ 2022, CAG PIG, Warsaw.

Resources:

Primary exploitable anticipated economic resources: not determined
 Exploitable anticipated economic resources as of 31.12.2022:
 240.00 MCM of natural gas in cat. C
 Economic resources in place as of 31.12.2022: lack of resources
 Production in 2022: no production

Geology:

First geophysical surveys in the area of Kąkolewo were conducted already from 1935, however their resolution did not allow to field structures detection within the Permian-Mesozoic complex. In 1970 the Kąkolewo-1 well was drilled and then liquidated due to negative results. The Kąkolewo structure was

explored in 1971 as a result of seismic investigations, and the gas accumulation (Fig. 4.2) was discovered in 1973 in the Kąkolewo 2 well – drilled in the central part of the structure. The preliminary geological documentation was elaborated in 1973, mainly on a basis of seismic works from 1971 and data from Kąkolewo 1 and Kąkolewo 2 wells. Then, after drilling another well – Kąkolewo 4, the documentation was supplemented and the field resources reassessed.

The Kąkolewo field is located on a slope of the Wolsztyn swell. The field structure is slightly extended, in a form of small brachyanticline with amplitude of 70 m. Gas-bearing horizon occurs in the Main Dolomite (Fig. 4.2). The field is limited by tectonic zones (from SE, probably also from NE and SW), the NW border is formed by a contour line -1,543 m. From the top, the field is sealed by impermeable Zechstein evaporites.

Wells: (Fig. 4.2; as of 2023 r.)

Well name	Depth [m]	Stratigraphy at the bottom	Field interval [m]
KĄKOLEWO 2	2,084.0	Permian	1,629–1,655

Field parameters and gas quality: data presented in Tab. 4.1.

Production history:

In a geological documentation (Błaszowska et al., 1975) there were not specified gas and liquid volumes in the field exploited during sampling and formation tests. Reasons for not starting the field exploitation was related to a high content of nitrogen.

Parameter	Minimum value	Maximum value	Average value	Unit	Comments
depth of underlying water	-----	-----	-----	m	underlying water not determined, the whole Main Dolomite level saturated with gas
depth of reservoir location	1,626.500	1,669.500	-----	m	Kąkolewo 2 borehole
effective reservoir thickness	-----	43.000	24.750	m	
porosity	-----	-----	8.620	%	according to laboratory tests
porosity	-----	-----	8.690	%	weighted average
porosity	-----	-----	5.500	%	according to geophysical researches

porosity	-----	-----	5.000	%	accepted to calculations
field acreage	-----	-----	2.050	km ²	
permeability	-----	-----	1.368	mD	
hydrocarbons saturation factor	-----	-----	0.800	.	
production factor	-----	-----	0.700	.	
absolute efficiency V_{abs}	-----	-----	446.000	Nm ³ /min	Kąkolewo 2 well
permitted efficiency V_{dozw}	-----	-----	60.000	Nm ³ /min	Kąkolewo 2 well
quality parameters of natural gas (main raw material)					
Parameter	Minimum value	Maximum value	Average value	Unit	Comments
calorific value	2,712.700	2,971.400	-----	Kcal/Nm ³	
C ₂ H ₆	-----	-----	5.250	% v/v	
CH ₄	-----	-----	10.295	% v/v	
CO	-----	-----	1.410	% v/v	
CO ₂	-----	-----	3.220	% v/v	
H ₂	-----	-----	0.007	% v/v	
He	-----	-----	0.038	% v/v	
N ₂	-----	-----	75.120	% v/v	
H ₂ S	-----	-----	1.250	% v/v	
hydrocarbons	-----	-----	18.955	% v/v	including propane and higher hydrocarbons 89.741 g/Nm ³

Tab. 4.1. Parameters of the Kąkolewo natural gas field and quality parameters of gas (MIDAS, 2023 according to Błaszowska et al., 1975).

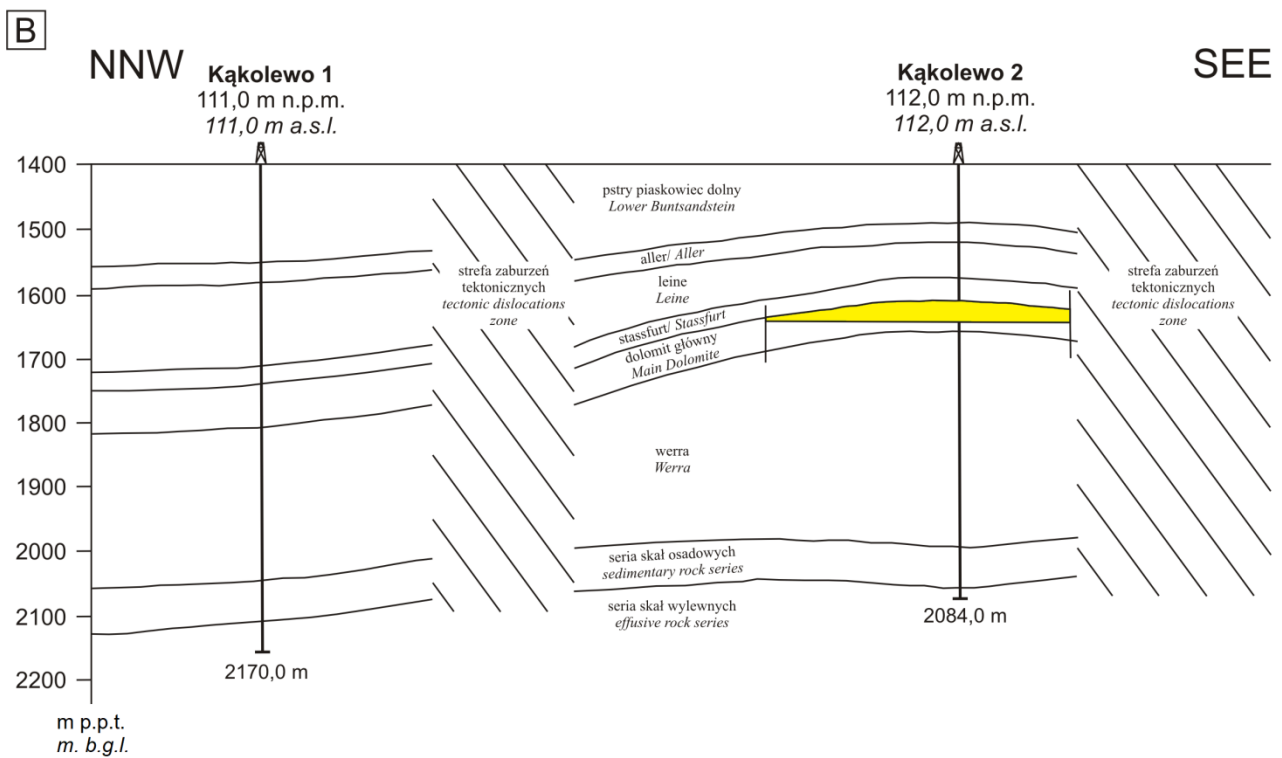
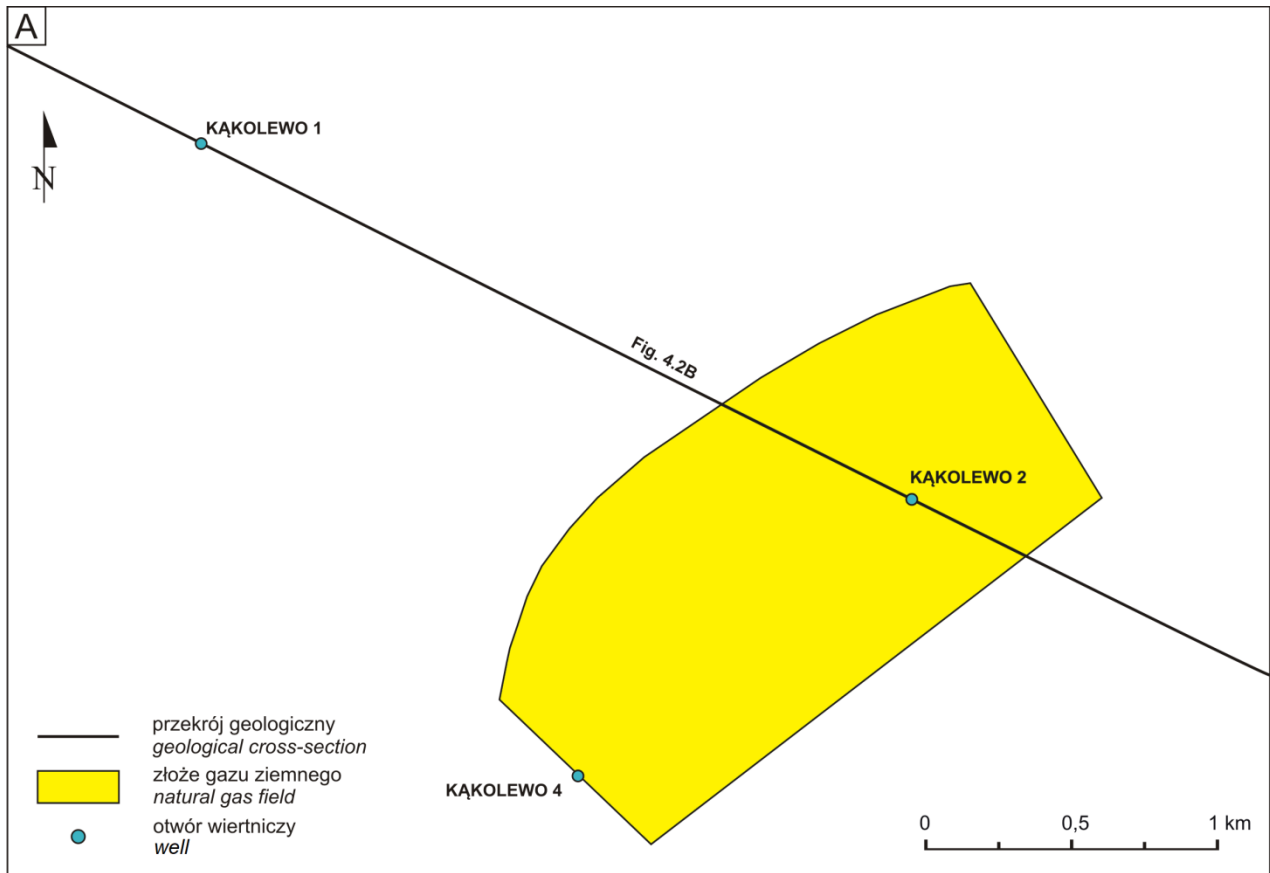


Fig. 4.2. A. Location of wells within the Kąkolewo natural gas field and its neighborhood (CGDB, 2023). B. Geological cross-section through the Kąkolewo natural gas field (Błaszowska et. al., 1975).

4.2. ŻAKOWO NATURAL GAS FIELD

Administrative location:

voivodeship – Wielkopolskie
county – Leszno
communes – Lipno, Osieczna

Acreage: 2,057.50 ha

Depth: from -1,697.1 to -1,740.0 m a.s.l.

Stratigraphy: Permian/Zechstein – Main Dolomite

Field not exploited

MIDAS System no: 4702

Geological documentations in National Geological Archive (NGA) of the PGI-NRI:

1. Krzyżanowski S., Piela J., 1972. Żakowo gas field geological documentation. Inv. 5918/2022, CAG PIG, Warsaw.
2. Stolarczyk F., Stolarczyk J., Kalbarczyk R., 1975. Żakowo gas field geological documentation, suppl. 1. Inv. 5920/2022, CAG PIG, Warsaw.

Resources:

Primary exploitable anticipated economic resources: not determined

Exploitable anticipated economic resources as of 31.12.2022:

1,680.00 MCM of natural gas in cat. B

470.00 MCM of natural gas in cat. C

Economic resources in place as of

31.12.2021: lack of resources

Production in 2021: field not exploited

Geology:

The most important for the Żakowo field exploration were seismic surveys conducting in the vicinity of Leszno since 1956. On a basis of these works, the first structural map for Buntsandstein was prepared, on which the Żakowo structure was presented in a form of structural “nose” at a culminating zone – the so called Klonowiec structure. In 1966-67 there were further seismic researches conducted aiming a preliminary exploration of signalized elements within the Mesozoic, Permian and Pre-Permian. In 1971, there were detailed seismic surveys conducted that allow to continuous and clear tracing of the Buntsandstein, Main Dolomite and a top of Rotliegend horizons and thus to more cer-

tain defining the shape and size of the Żakowo structure. Drilling works in the vicinity of the Żakowo structure started in 1966 – there were two parametric wells drilled: Świąciechowa 1 and Żakowo 1. In the Żakowo 1 well (drilled in 1967) there a natural gas flow was obtained. Further, the Żakowo 2 and Żakowo 3 wells were drilled (in 1969-70) confirmed the existence of the accumulation of gas discovered in the Żakowo 1 well, which allowed to determine its resources together with the type and quality of natural gas (Fig. 4.3). The Żakowo 4 well, conducted in 1971, despite gas with brine inflow, was liquidated as negative. Geological documentation of the Żakowo gas field was prepared in 1972 and then, after drilling further wells in 1973-74 (Żakowo 5 and Żakowo 6, Żakowo 7, and Żakowo 9), the resources were recalculated and summarized in a supplement no 1 – prepared in 1975. Only from the Żakowo 6 well there was an economic gas inflow obtained, whereas the remaining wells did not give positive results (in the Żakowo 5 and Żakowo 9 wells gas production was not induced, whereas in the Żakowo 7 there were technical problems). In addition, weak recognition of the reservoir parameters, did not allow to qualification of resources to category B.

The Żakowo field is located in the central part of the Fore-Sudetic Monocline within the carbonate horizon of the Zechstein Main Dolomite (Fig. 4.3). The field is irregular in shape, of bioherm type. Reservoir rocks are characterized by a large horizontal and vertical variety of microfacies, and thus a great diversity of the reservoir parameters. Accumulation of hydrocarbons occurred in brachyanticline of an acreage about 30 km². The structure amplitude reaches 45 m and its limbs are of a dip about 1–2.5°. This structure is fully filled by gas. Maximum thickness of a gaseous cap is 37 m, whereas the thickness of a zone filled with crude oil – 5 m. In the middle part of the Żakowo structure, between the Żakowo 5 and Żakowo 9 wells, there is a lateral dislocation zone occurring on the NW-SE direction, lowering the southern part of the bioherm by 8–10 m. From the top,

the field is sealed directly by the Basal Anhydrite and younger evaporites. The bottom boundary of the field is a level of underlying water delineated at a depth of 1,740 m b.s.l.

Wells: (Fig. 4.3A; as of 2022)

Well name	Depth [m]	Stratigraphy at the bottom	Field interval [m]
ŻAKOWO 1	2,374.8	Carboniferous	1,818.0–1,853.4
ŻAKOWO 2	1,830.2	Upper Permian	1,805.0–1,830.2
ŻAKOWO 3	2,298.5	Carboniferous	1,849.0–1,854.6
ŻAKOWO 5	1,830.7	Upper Permian	1,788.9–1,830.7
ŻAKOWO 6	2,216.0	Carboniferous	1,813.5–1,839.7
ŻAKOWO 7	1,836.0	Upper Permian	–

Field parameters and gas quality: data presented in Tab. 4.2.

Production history:

In a geological documentation of the Żakowo field (Krzyżanowski and Piela, 1972) and in the Suppl. No 1 to the geological documentation (Stolarczyk et al., 1975) there were not specified gas and liquid volumes obtained during sampling and formation tests. Due to high nitrogen and H₂S contents the field was not exploited.

Parameter	Minimum value	Maximum value	Average value	Unit	Comments
bottom pressure P_{ds}	-----	-----	219.760	ata	Żakowo 6 well
bottom pressure P_{ds}	-----	-----	220.850	ata	Żakowo 1 well
bottom pressure P_{ds}	-----	-----	218.700	ata	for the whole field
bottom pressure P_{ds}	-----	-----	222.580	ata	Żakowo 2 well
bottom pressure P_{ds}	-----	-----	211.620	ata	Żakowo 3 well
primary reservoir pressure	-----	-----	218.700	ata	
depth of underlying water	-----	-----	-1,740.00	m	
depth of reservoir location	-1,697.10	-1,740.00	-----	m	
effective reservoir thickness	-----	40.000	23.500	m	
porosity	-----	-----	4.870	%	according to laboratory tests
field acreage	-----	-----	10.935	km ²	in cat. C
field acreage	-----	-----	9.640	km ²	in cat. B
reservoir temperature	-----	-----	338.000	°K	Żakowo 2 well
reservoir temperature	-----	-----	338.250	°K	for the whole field
reservoir temperature	-----	-----	338.000	°K	Żakowo 6 well
reservoir temperature	-----	-----	339.000	°K	Żakowo 3 well
reservoir temperature	-----	-----	338.000	°K	Żakowo 1 well
chemical type of reservoir water	-----	-----	-----	.	Cl-Na brines
hydrocarbons saturation factor	-----	-----	0.800	.	
production factor	-----	-----	0.850	.	for a port in cat. B
production factor	-----	-----	0.600	.	for a port in cat. C
absolute efficiency V_{abs}	-----	-----	108.890	Nm ³ /min	Żakowo 2 well
absolute efficiency V_{abs}	-----	-----	410.000	Nm ³ /min	Żakowo 6 well
absolute efficiency V_{abs}	-----	-----	11.460	Nm ³ /min	Żakowo 3 well
absolute efficiency V_{abs}	-----	-----	62.450	Nm ³ /min	Żakowo 1 well
permitted efficiency V_{dozw}	-----	-----	19.000	Nm ³ /min	Żakowo 2 well
permitted efficiency V_{dozw}	-----	-----	7.000	Nm ³ /min	Żakowo 1 well
permitted efficiency V_{dozw}	-----	-----	-----	Nm ³ /min	Żakowo 6 well – lack of data
permitted efficiency V_{dozw}	-----	-----	2.000	Nm ³ /min	Żakowo 3 well

quality parameters of natural gas (main raw material)					
Parameter	Minimum value	Maximum value	Average value	Unit	Comments
calorific value	2,963.600	3,254.100	-----	Kcal/Nm ³	
C ₂ H ₆	-----	-----	3.900	% v/v	
CH ₄	-----	-----	15.080	% v/v	
CO	-----	-----	1.320	% v/v	
CO ₂	-----	-----	1.730	% v/v	
H ₂	-----	-----	0.180	% v/v	
He	-----	-----	0.020	% v/v	
N ₂	-----	-----	74.450	% v/v	
H ₂ S	-----	-----	0.890	% v/v	
hydrocarbons content	-----	-----	22.710	% v/v	including propane and higher hydrocarbons 92.01 g/Nm ³
heavy hydrocarbons C ₃₊ content	-----	-----	95.010	g/Nm ³	

Tab. 4.2. Parameters of the Żakowo natural gas field and quality parameters of gas (MIDAS, 2023 according to Stolarczyk et al., 1975).

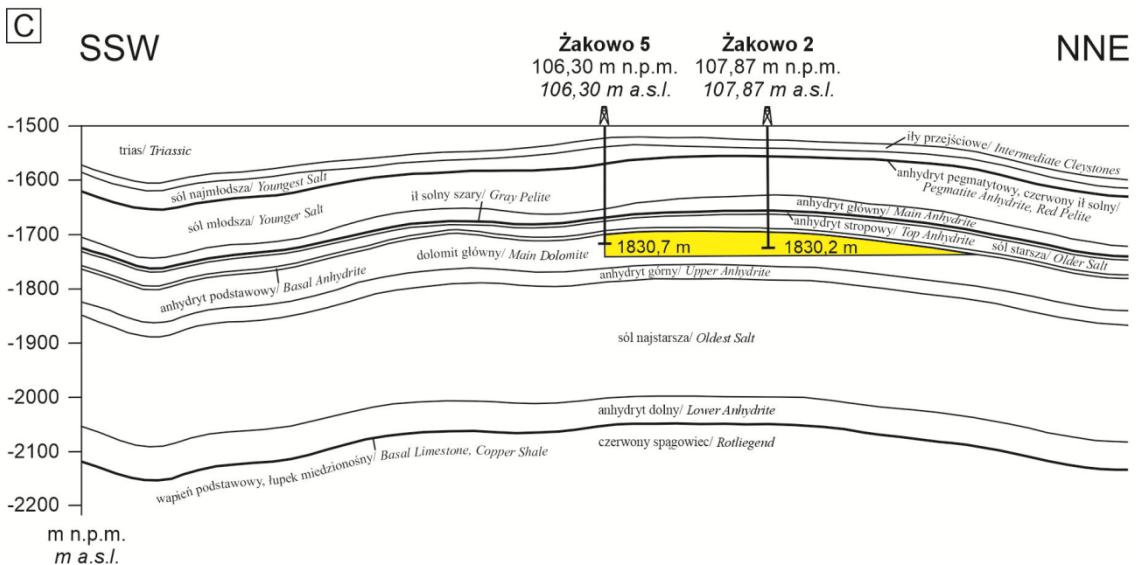
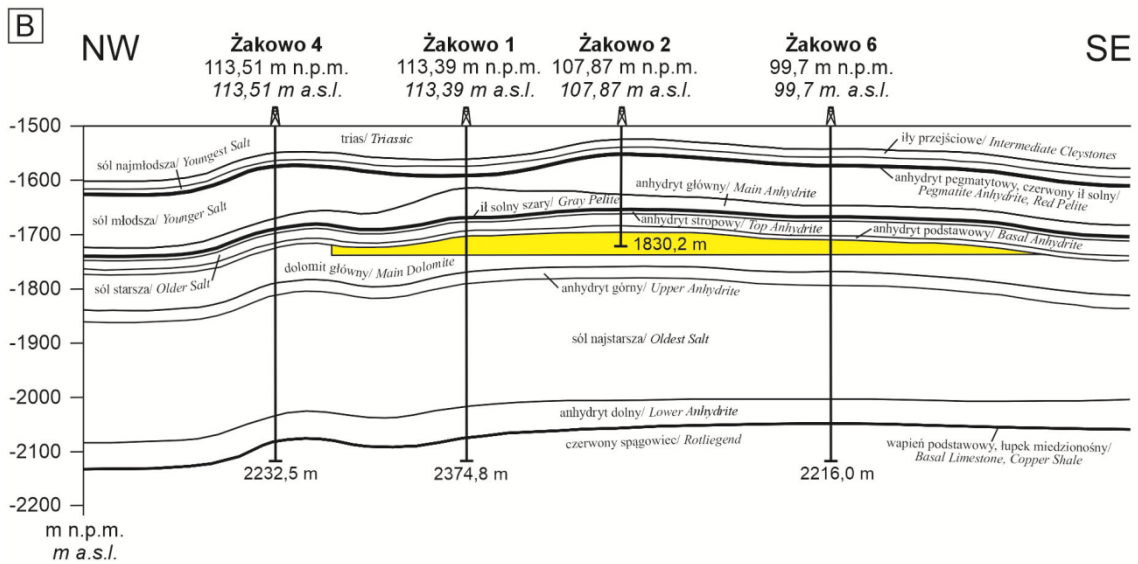
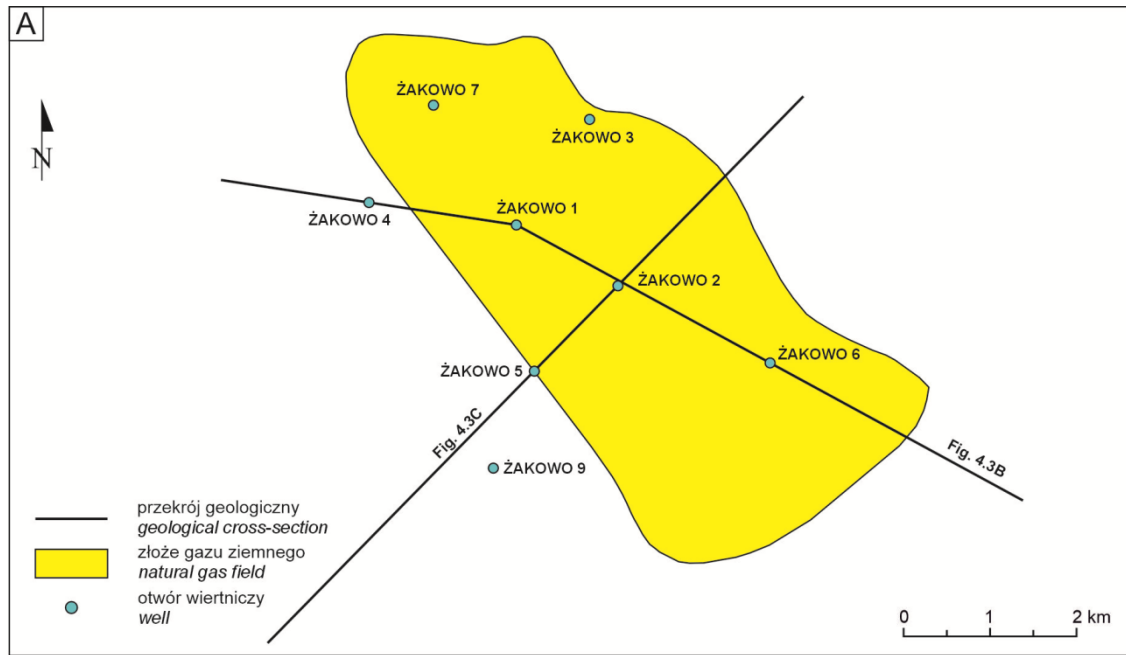


Fig. 4.3. A. Location of wells within the Żakowo natural gas field and its neighborhood (CGDB, 2023). B–C. Geological cross-section through the Żakowo natural gas field (Stolarczyk et al., 1975).

5. WELLS

The following wells deeper than 500 m MD were drilled in the Gostyń tender area:

Well name	Year	Geological concessions (after 1994)	Owner	Depth [m]	Stratigraphy at the bottom:
BUŁAKÓW 1	1973		State Treasury	2225.0	Carboniferous
BUŁAKÓW-2	2007	Jarczewo-Pogorzela 28/2001/p	State Treasury	1890.0	Carboniferous
FRANKOWO 1	2012	Leszno 65/2008/p	State Treasury	2200.0	Permian/Rotliegend
KĄKOLEWO 1	1970		State Treasury	2170.0	Permian/Rotliegend
KĄKOLEWO 2	1973		State Treasury	2084.0	Permian/Rotliegend
KĄKOLEWO 4	1974		State Treasury	2087.5	Permian/Rotliegend
KOBYLIN-1	2015	Czatkowice 9/2008/p	State Treasury	2861.0	Carboniferous
POGORZELA 1	1973		State Treasury	1797.5	Carboniferous
POGORZELA 2	1975		State Treasury	1767.0	Carboniferous
POGORZELA 4	1974		State Treasury	2060.2	Carboniferous
POGORZELA 7	1974		State Treasury	2207.3	Carboniferous
RUSKO-1	2015	Jarczewo-Pogorzela 28/2001/p	State Treasury	2600.0	Permian/Rotliegend
SIEDMIOROGÓW-1	1992		ORLEN S.A.	2246.0	Carboniferous
ŚWIĘCIECHOWA 1	1967		State Treasury	2776.8	Devonian
ŚWIĘCIECHOWA 2	1975		State Treasury	2200.0	Carboniferous
ŻAKOWO 1	1968		State Treasury	2374.8	Carboniferous
ŻAKOWO 2	1969		State Treasury	1830.2	Permian/Main Dolomite
ŻAKOWO 3	1970		State Treasury	2298.5	Carboniferous
ŻAKOWO 4	1969		State Treasury	2232.5	Carboniferous
ŻAKOWO 5	1973		State Treasury	1830.7	Permian/Main Dolomite
ŻAKOWO 6	1973		State Treasury	2216.0	Carboniferous
ŻAKOWO 7	1974		State Treasury	1836.0	Permian/Basal Anhydrite
ŻAKOWO 9	1974		State Treasury	2300.0	Permian/Rotliegend

Location of the above-mentioned wells is presented in Fig. 5.1. Their general characteristics are shortly summarized in Tab. 5.1. The Żakowo 6 well is illustrated in Fig 5.2 as an example.

The original data from the wells belonging to the State Treasury are collected in the DATA ROOM and will be available at the Polish Geological Institute – National Research Institute in Warsaw during the 7th tender round.

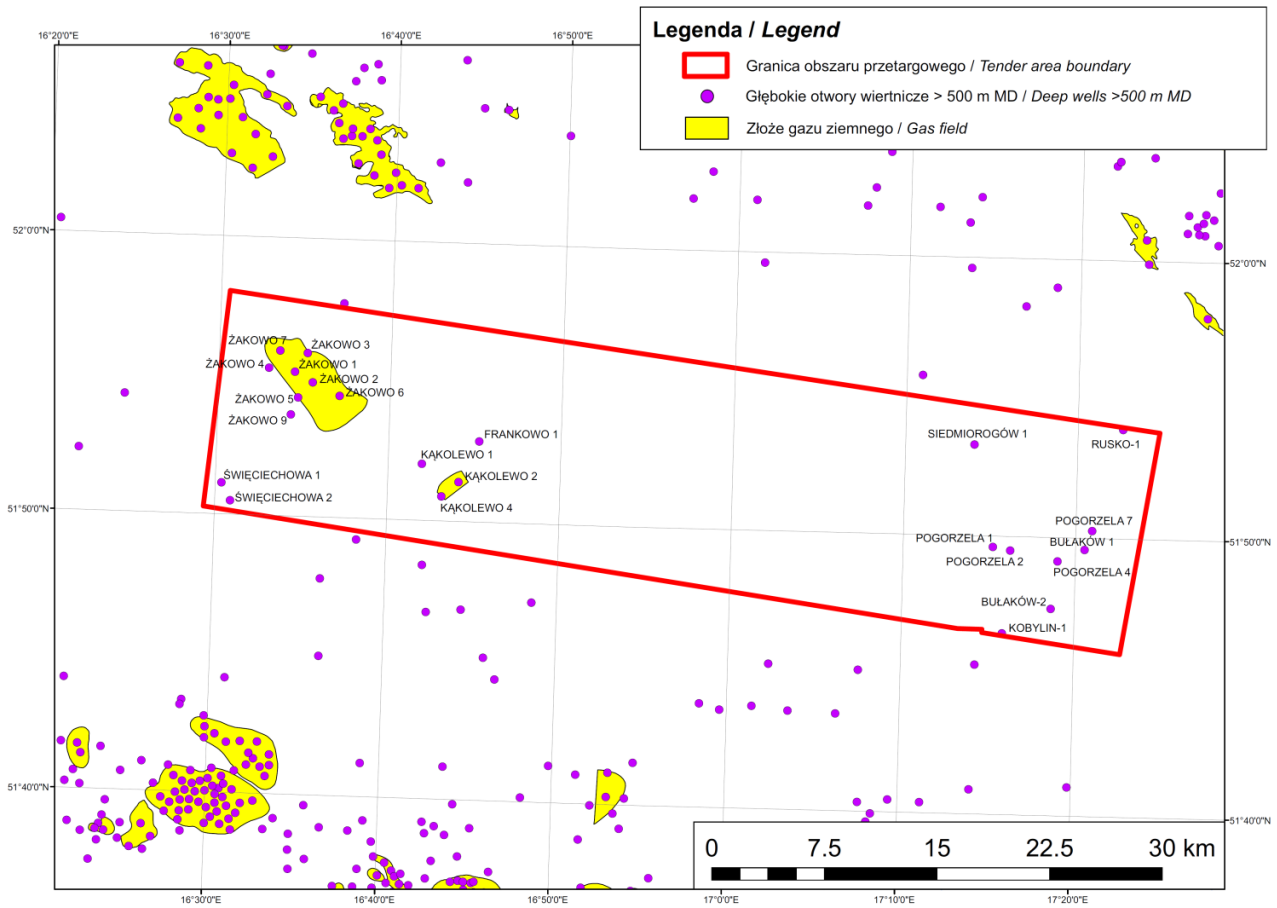


Fig. 5.1. Deep wells (>500 m MD) located within the Gostyń tender area and in its close neighborhood (CGDB, 2023).

STRATIGRAPHY	BULAKÓW 1		BULAKÓW-2		FRANKOWO 1		KAKOLEWO 1		KAKOLEWO 2		KAKOLEWO 4		KOBYLIN-1		POGORZE-LA 1		POGORZE-LA 2		POGORZE-LA 4		POGORZE-LA 7		RUSKO-1		ŚWIĘCIECHOWA 1		ŚWIĘCIECHOWA 2		ŻAKOWO 1		ŻAKOWO 2		ŻAKOWO 3		ŻAKOWO 4		ŻAKOWO 5		ŻAKOWO 6		ŻAKOWO 7		ŻAKOWO 9							
	Depth [m]		Depth [m]		Depth [m]		Depth [m]		Depth [m]		Depth [m]		Depth [m]		Depth [m]		Depth [m]		Depth [m]		Depth [m]		Depth [m]		Depth [m]		Depth [m]		Depth [m]		Depth [m]		Depth [m]		Depth [m]		Depth [m]		Depth [m]		Depth [m]		Depth [m]							
	from	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to	to					
Cenozoic	0.0	215.0	0.0	207.5	0.0	261.0	0.0	250.0	0.0	270.5	0.0	270.0	0.0	206.0	0.0	222.0	0.0	245.0	0.0	225.0	0.0	208.0	0.0	213.0	0.0	327.0	0.0	270.0	0.0	276.0	0.0	267.5	0.0	270.0	0.0	273.0	0.0	265.0	0.0	255.0	0.0	269.5	0.0	269.0						
Jurassic																							213.0	289.5																										
Triassic	215.0	1803.0	207.5	1636.5	261.0	1492.5	250.0	1555.0	270.5	1502.5	270.0	1519.0	206.0	1608.0	222.0	1636.0	245.0	1650.0	225.0	1735.0	208.0	1850.0	289.5	2094.0	327.0	1571.5	270.0	1565.0	276.0	1677.5	267.5	1635.0	270.0	1663.0	273.0	1663.5	265.0	1628.5	255.0	1646.0	269.5	1653.0	269.0	1657.5						
PPermian	1803.0	2137.0	1636.5	1853.5	1492.5	2200.0	1555.0	2170.0	1502.5	2084.0	1519.0	2087.5	1608.0	1921.0	1636.0	1770.0	1650.0	1749.5	1735.0	2007.0	1850.0	2191.0	2094.0	2599.5	1571.5	2595.5	1565.0	2173.5	1677.5	2227.0	1635.0	1830.2	1663.0	2236.0	1663.5	2226.0	1628.5	1830.7	1646.0	2190.0	1653.0	1836.0	1657.5	2300.0						
Top Terrigenous Series PZt	1803.0	1813.0					1555.0	1567.5	1502.5	1517.5	1519.0	1534.0			1636.0	1652.0	1650.0	1669.5	1735.0	1746.5	1850	1866.5			1571.5	1587.5	1565.0	1581.5	1677.5	1687.5	1635.0	1650.0	1663.0	1677.0	1663.5	1678.0	1628.5	1644.5	1646.0	1662.5	1653.0	1677.5	1657.5	1676.0						
Transitional Clays T4r					1492.5	1507.0							1608.0	1624.5									2094.0	2107.0																										
Upper Pegmatite Anhydrite A4a2					1507.0	1508.5																																												
Youngest Halite Na4a			1636.5	1643.0				1567.5	1582.5	1517.5	1532.0	1534.0	1552.0	1624.5	1631.5	1652.0	1700.0							2107.0	2116.5	1587.5	1596.5	1581.5	1601.5	1687.5	1707.5	1650.0	1661.0	1677.0	1689.0	1678.0	1688.5	1644.5	1671.0	1662.5	1675.0	1677.5	1688.0	1676.0	1690.5					
Pegmatite Anhydrite A4a1			1643.0	1644.5									1631.5	1632.5									2116.5	2117.5	1596.5	1597.0									1688.5	1692.0														
Red Pelite T4			1644.5	1645.5				1582.5	1586.0	1532.0	1537.5	1552.0	1555.0	1632.5	1634.5								2117.5	2119.5	1597.0	1600.0	1601.5	1605.0	1707.5	1709.0	1661.0	1665.0	1689.0	1694.0			1671.0	1676.5	1675.0	1678.5	1688.0	1693.0	1690.5	1692.5						
Top Anhydrite A3r			1645.5	1646.0																			2119.5	2120.0			1605.0	1607.0																						
Younger Halite Na3	1813.0	1930.0	1646.0	1705.0	1508.5	1534.4	1586.0	1697.0	1537.5	1567.0	1555.0	1620.0	1634.5	1669.5	1700.0	1705.0							1746.5	1857.5	1866.5	1993.0	2120.0	2137.5	1600.0	1609.5	1607.0	1686.0	1709.0	1731.0	1665.0	1738.0	1694.0	1786.0	1692.0	1787.0	1676.5	1761.0	1678.5	1750.0	1693.0	1778.0	1692.5	1710.5		
Main Anhydrite A3	1930.0	1960.0	1705.0	1729.5	1534.4	1534.9	1697.0	1714.0	1567.0	1591.0	1620.0	1637.0	1669.5	1715.0									1857.5	1888.0	1993.0	2017.5	2137.5	2249.0	1609.5	1686.5	1686.0	1719.0	1731.0	1785.5	1738.0	1765.0	1786.0	1807.0	1787.0	1805.5	1761.0	1776.5	1750.0	1771.0	1778.0	1804.0	1710.5	1774.0		
Grey Pelite T3	1960.0	1962.0	1729.5	1731.0	1534.9	1535.1	1714.0	1716.0	1591.0	1593.0	1637.0	1639.0	1715.0	1717.0									1888.0	1889.5	2017.5	2019.5	2249.0	2251.3	1686.5	1687.5	1719.0	1721.0	1785.5	1787.5	1765.0	1767.0	1807.0	1810.0	1805.5	1808.0	1776.5	1778.5	1771.0	1773.5	1804.0	1806.5	1774.0	1776.0		
Screening Anhydrite A2r	1962.0	1966.0	1731.0	1734.0			1716.0	1721.0	1593.0	1597.5	1639.0	1642.5			1705.0	1751.0										2019.5	2023.5	2251.3	2253.0	1687.5	1690.0	1721.0	1723.0	1787.5	1791.0	1767.0	1770.0	1810.0	1813.0	1808.0	1811.5	1778.5	1780.5	1773.5	1776.0	1806.5	1810.0	1776.0	1779.0	
Older Halite Na2	1966.0	1995.0	1734.0	1742.0			1721.0	1738.0	1597.5	1618.0	1642.5	1665.0														2023.5	2036.0	2253.0	2271.7	1690.0	1720.0	1723.0	1740.0	1791.0	1810.0	1770.0	1795.0	1813.0	1842.0	1811.5	1831.0	1780.5	1797.5	1776.0	1805.0	1810.0	1830.0	1779.0	1797.0	
Basal Anhydrite A2	1995.0	2001.0	1742.0	1746.0	1535.1	1539.0	1738.0	1745.0	1618.0	1626.5	1665.0	1672.5	1717.0	1723.0									1889.5	1905.0	2036.0	2051.0	2271.7	2295.2	1720.0	1725.0	1740.0	1745.5	1810.0	1818.0	1795.0	1805.0	1842.0	1849.0	1831.0	1840.0	1797.5	1804.5	1805.0	1813.5	1830.0	1836.0	1797.0	1804.0		
Main Dolomite Ca2	2001.0	2023.0	1746.0	1781.5	1539.0	1582.0	1745.0	1820.0	1626.5	1669.5	1672.5	1737.0	1723.0	1771.5	1751.0	1770.0	1729.0	1749.5	1905.0	1940.0	2051.0	2091.5	2295.2	2328.2	1725.0	1787.5	1745.5	1806.5	1818.0	1886.0	1805.0	1830.2	1849.0	1910.0	1840.0	1907.0	1804.5	1830.7	1813.5	1872.5			1804.0	1867.0						
Upper Anhydrite A1g			1781.5	1823.5	1582.0	1646.0	1820.0	1838.0	1669.5	1724.0	1737.0	1824.0	1771.5	1798.5												1787.5	1822.0	1806.5	1841.5	1886.0	1906.0			1910.0	1935.0	1907.0	1929.0			1872.5	1896.5			1867.0	1892.0					
Upper Oldest Halite Na1g																																																		
Middle Anhydrite A1s	2023.0	2071.0			1646.0	2028.0	1838.0	1953.0	1724.0	1971.5	1824.0	1910.0	1798.5	1834.0											2328.2	2356.0	1822.0	1875.0	1841.5	1882.0	1906.0	2134.0			2137.0	2147.0	2137.0	2145.0			2082.5	2101.0			2108.5	2128.0				
Lower Oldest Halite Na1d																																																		
Lower Anhydrite A1d					2028.0	2046.5	1953.0	2050.0	1971.5	1996.0	1910.0	1976.0	1834.0	1918.0											1940.0	1975.0	2091.5	2154.0	1875.0	2080.5	1882.0	2041.0	2134.0	2189.0			2155.0	2207.0	2150.0	2175.5			2106.5	2149.0			2134.0	2164.5		
Zechstein Limestone Ca1	2071.0	20137.0	1823.5	1853.5	2046.5	2050.0	2050.0	2053.0	1996.0	2000.0	1976.0	1979.0	1918.0	1921.0											1975.0	2007.0	2154.0	2191	2356.0	2396.1	2080.5	2094.0	2041.0	2044.5	2189.0	2195.5			2207.0	2210.0	2175.5	2197.0			2149.0	2154.0			2164.5	2169.0
Kupferschiefer T1																																																		
Upper Rotliegend					2050.0	2200.0	2053.0	2122.5	2000.0	2072.0	1979.0	2066.0																																						
Lower Rotliegend							2122.5	2170.0	2072.0	2084	2066.0	2087.5																																						
Carboniferous	2137.0	2225.0	1853.5	1888.5									1921.0	2																																				

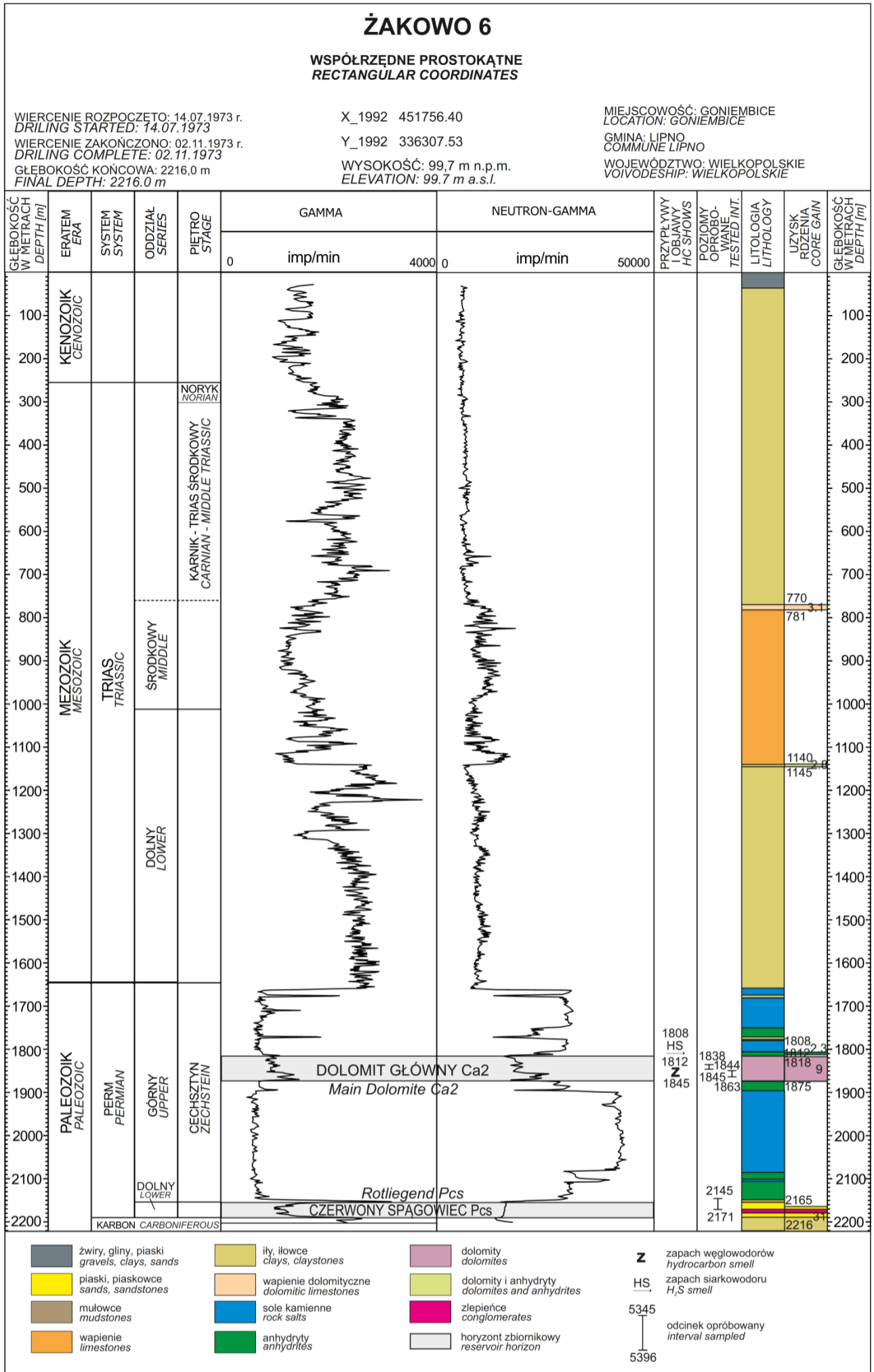


Fig. 5.2. Stratigraphy and geophysics in the Żakowo 6 well according to final well geological documentation (Kalbarczyk and Haase, 1974).

6. SEISMIC SURVEYS

Complete list of 2D and 3D seismic surveys conducted within the Gostyń tender area can be found in Figs 6.1–6.2 and in Tabs 6.1–6.2. The most important are three 3D seismic sur-

veys conducted after 2001. These data belong to the State Treasury.

LINE NAME	YEAR	PROJECT	REGION	CON- CESSIONS (after 2001)	OWNER	LENGTH [km]
10-4-75K	1975	Jarocin-Kalisz			State Treasury	8.81
11-4-75K	1975	Jarocin-Kalisz				4.44
45A-4-75K	1975	Jarocin-Kalisz	Jaraczewo			8.12
54-9-75K	1975	Wschowa-Gostyń-Milicz				6.48
55-9-75K	1975	Wschowa-Gostyń-Milicz				8.1
7-4-75K	1975	Jarocin-Kalisz	Jaraczewo			8.17
T0380375	1975	Kościan-Gostyń	Tarnowa-Morownica- Donatowo			11.09
T0390375	1975	Kościan-Gostyń				13.18
T0400375	1975	Kościan-Gostyń				13.71
W00C0375	1975	Profile Regionalne	Wschowa-Leszno- Śrem			17.25
10-4-76K	1976	Pyzdry-Krotoszyn-Kalisz	Domachowo			6.39
11-4-76K	1976	Pyzdry-Krotoszyn-Kalisz	Pogorzela			12.38
12-4-76K	1976	Pyzdry-Krotoszyn-Kalisz				8.54
15-4-76K	1976	Pyzdry-Krotoszyn-Kalisz	Skoraszewice- Pogorzela			14.13
15X-1-76K	1976	Jarocin-Kalisz	Pyzdry-Jarocin-Konin			8.16
4-4-76K	1976	Pyzdry-Krotoszyn-Kalisz	Pogorzela			13.16
5-4-76K	1976	Pyzdry-Krotoszyn-Kalisz	Pogorzela-Krotoszyn			21.9
6-4-76K	1976	Pyzdry-Krotoszyn-Kalisz	Pogorzela-Orpiszew			12.74
7-4-76K	1976	Gostyń-Krotoszyn				15.67
8-4-76K	1976	Pyzdry-Krotoszyn-Kalisz	Domachowo			11.69
9-4-76K	1976	Pyzdry-Krotoszyn-Kalisz	Pogorzela			3.63
T0050376	1976	Kościan-Gostyń	Tarnowa-Morownica- Donatowo			6.29
T0060376	1976	Kościan-Gostyń				7.66
T0070376	1976	Kościan-Gostyń				12.48
T0110376	1976	Kościan-Gostyń				21.72
T0120376	1976	Kościan-Gostyń				9.38
T0340376	1976	Kościan-Gostyń				27.3
WB050176	1976	Monoklina Przedsudecka				
WC050176	1976	Monoklina Przedsudecka				5.16
T0520377	1977	Kościan-Gostyń	Tarnowa-Morownica- Donatowo			7.56
T0560377	1977	Kościan-Gostyń				10.36
T0570377	1977	Kościan-Gostyń				11.72
T0590377	1977	Kościan-Gostyń				3.78
T0600377	1977	Kościan-Gostyń				4.28
T0610377	1977	Kościan-Gostyń				7.11
T0620377	1977	Kościan-Gostyń				5.13
T0630377	1977	Kościan-Gostyń				6.34
T0800377	1977	Kościan-Gostyń				9.29
3A-5-78K	1978	Nowa Sól-Góra-Milicz				
17-1-80K	1980	Góra-Rawicz				5.32
18-1-80K	1980	Góra-Rawicz				8.54
10-9-86K	1986	Pogorzela-Krotoszyn	Jaraczewo-Koźmin			2.04
11-9-86K	1986	Pogorzela-Krotoszyn	Gostyń-Koźmin- Orpiszew		2.56	
12-9-86K	1986	Pogorzela-Krotoszyn			3.13	

14-9-86K	1986	Pogorzela-Krotoszyn			5.27
15-9-86K	1986	Pogorzela-Krotoszyn			7.58
16-9-86K	1986	Pogorzela-Krotoszyn			6.61
17-9-86K	1986	Pogorzela-Krotoszyn			8.22
1-9-86K	1986	Pogorzela-Krotoszyn	Jaraczewo-Koźmin		5.56
19-9-86K	1986	Pogorzela-Krotoszyn	Gostyń-Koźmin-Orpiszew		3.13
20-9-86K	1986	Pogorzela-Krotoszyn	Gostyń-Koźmin-Krotoszyn		6.32
28-4-86K	1986	Leszno-Rawicz			3.31
3-9-86/87K	1986	Pogorzela-Krotoszyn	Jaraczewo-Koźmin		5.59
39-9-86K	1986	Pogorzela-Krotoszyn			7.92
40-9-86K	1986	Pogorzela-Krotoszyn	Gostyń-Koźmin-Orpiszew		8.73
4-9-86K	1986	Pogorzela-Krotoszyn	Jaraczewo-Koźmin		2.85
8-9-86K	1986	Pogorzela-Krotoszyn			5.44
9-9-86K	1986	Pogorzela-Krotoszyn	Gostyń-Koźmin-Orpiszew		7.65
15-9-87K	1987	Pogorzela-Krotoszyn	Jarocin-Orpiszew		12.9
18-9-87K	1987	Pogorzela-Krotoszyn			11.85
36-4-87K	1987	Leszno-Rawicz			3.93
37-4-87K	1987	Leszno-Rawicz			6.84
38-4-87K	1987	Leszno-Rawicz			3.69
41-4-87K	1987	Leszno-Rawicz			5.57
41-9-87K	1987	Pogorzela-Krotoszyn	Jaraczewo-Koźmin		17.5
42-4-87K	1987	Leszno-Rawicz			2.52
42-9-87K	1987	Pogorzela-Krotoszyn	Jarocin-Orpiszew		5.16
43-4-87K	1987	Leszno-Rawicz			4.73
45-9-87K	1987	Pogorzela-Krotoszyn	Jarocin-Orpiszew		10.42
47-9-87K	1987	Pogorzela-Krotoszyn			12.15
48-9-87K	1987	Pogorzela-Krotoszyn			4.79
107-9-88K	1988	Śrem-Gostyń	Książ-Gostyń		8.32
10-9-88K	1988	Pogorzela-Krotoszyn	Gostyń-Koźmin-Orpiszew		18.75
109-9-88K	1988	Śrem-Gostyń	Książ-Gostyń		4.54
110-9-88K	1988	Śrem-Gostyń			3.56
111-9-88K	1988	Śrem-Gostyń			2.81
113-4-88K	1988	Leszno-Rawicz			7.4
12-9-88K	1988	Pogorzela-Krotoszyn	Jarocin-Orpiszew		18.24
134-4-88K	1988	Leszno-Rawicz			9.32
15-9-88K	1988	Pogorzela-Krotoszyn	Pogorzela-Gostyń		3.1
3-9-88K	1988	Pogorzela-Krotoszyn			17.06
47-9-88K	1988	Pogorzela-Krotoszyn			15.39
49-9-88K	1988	Pogorzela-Krotoszyn			4.6
49A-9-88K	1988	Pogorzela-Krotoszyn			20.16
51-9-88K	1988	Pogorzela-Krotoszyn			17.99
54-9-88K	1988	Pogorzela-Krotoszyn			13.09
7-9-88K	1988	Pogorzela-Krotoszyn			19.22
104-4-89K	1989	Leszno-Rawicz			2.11
106-9-89K	1989	Śrem-Gostyń	Książ-Gostyń		5.13
108-9-88/89K	1989	Śrem-Gostyń			5.01
125-9-89K	1989	Śrem-Gostyń			8.48
126-9-89K	1989	Śrem-Gostyń			6.69
127-9-89K	1989	Śrem-Gostyń			11.11
128-9-89K	1989	Śrem-Gostyń			8.84
133-4-89K	1989	Leszno-Rawicz	Gostkowo		10.22
45-9-88K	1989	Pogorzela-Krotoszyn	Pogorzela-Gostyń		13.84
83-4-89K	1989	Leszno-Rawicz	Gostkowo		5.7
T0070789	1989	Nowy Tomyśl-Wolsztyn-Leszno	Wielichowo-Leszno	ORLEN S.A.	2.51

T0080789	1989	Nowy Tomyśl-Wolsztyn-Leszno			5.35
TA070789	1989	Nowy Tomyśl-Wolsztyn-Leszno			5.48
T0520790	1990	Nowy Tomyśl-Wolsztyn-Leszno			8.52
T0860197	1997	Kościan-Krobia	Kościan-Krobia	Kościan-Krobia 7/97/p	15.83
T0930197	1997	Kościan-Krobia			39.52
T0940197	1997	Kościan-Krobia			38.13
11-9-98K	1998	Jaraczewo-Pogorzela		Jaraczewo-Pogorzela 49/96/p Kościan-Śrem 31/95/p Solec-Jarocin 24/96/p	24.75
12-9-98K	1998	Jaraczewo-Pogorzela			12.02
13-9-98K	1998	Jaraczewo-Pogorzela			22.12
15-9-98K	1998	Jaraczewo-Pogorzela			23.58
16-9-98K	1998	Jaraczewo-Pogorzela			18.08
19-9-98K	1998	Jaraczewo-Pogorzela			22.86
21-9-98K	1998	Jaraczewo-Pogorzela			18.58
23-9-98K	1998	Jaraczewo-Pogorzela			15.09
25-9-98K	1998	Jaraczewo-Pogorzela			6.42
32-9-98K	1998	Jaraczewo-Pogorzela			9.84
36-9-98K	1998	Jaraczewo-Pogorzela			6.79
42-9-98K	1998	Jaraczewo-Pogorzela			8.65
44-9-98K	1998	Jaraczewo-Pogorzela			2.17
46-9-98K	1998	Jaraczewo-Pogorzela			2.06
48-9-98K	1998	Jaraczewo-Pogorzela			4.54
9-9-98K	1998	Jaraczewo-Pogorzela			15.21
T0720198	1998	Kościan-Krobia	Kościan-Krobia		Kościan-Krobia 7/97/p
T0730198	1998	Kościan-Krobia		9.83	
T0740198	1998	Kościan-Krobia		15.73	
T0750198	1998	Kościan-Krobia		14.47	
T0760198	1998	Kościan-Krobia		14.95	
T0770198	1998	Kościan-Krobia		14.98	
T0780198	1998	Kościan-Krobia		14.95	
T0790198	1998	Kościan-Krobia		14.55	
T0800198	1998	Kościan-Krobia		16.14	
T0810198	1998	Kościan-Krobia		16.78	
T0820198	1998	Kościan-Krobia		17.36	
T0830198	1998	Kościan-Krobia		18.26	
T0840198	1998	Kościan-Krobia		18.64	
T0850198	1998	Kościan-Krobia		14.23	
T0870198	1998	Kościan-Krobia		4.86	
T0880198	1998	Kościan-Krobia		2.1	
T0890198	1998	Kościan-Krobia		9.04	
T0900198	1998	Kościan-Krobia		14.55	
T0910198	1998	Kościan-Krobia		26.91	
T0920198	1998	Kościan-Krobia		34.96	
T0950198	1998	Kościan-Krobia	32.9		
T0960198	1998	Kościan-Krobia	28.4		
T0970198	1998	Kościan-Krobia	20.65		
T0980198	1998	Kościan-Krobia	5.15		
10-9-98K	1999	Jaraczewo-Pogorzela		Jaraczewo-Pogorzela 49/96/p Kościan-Śrem 31/95/p Solec-Jarocin 24/96/p	9.79
14-9-98K	1999	Jaraczewo-Pogorzela			14.12
18-9-98K	1999	Jaraczewo-Pogorzela			18.58
20-9-98K	1999	Jaraczewo-Pogorzela			18.18
22-9-98K	1999	Jaraczewo-Pogorzela			18.97
26-9-98K	1999	Jaraczewo-Pogorzela			19.65
27-9-98K	1999	Jaraczewo-Pogorzela			4.73
28-9-98K	1999	Jaraczewo-Pogorzela			19.27
30-9-98K	1999	Jaraczewo-Pogorzela			19.58
3-9-98K	1999	Jaraczewo-Pogorzela			6.8
5-9-98K	1999	Jaraczewo-Pogorzela			12.39

7-9-98K	1999	Jaraczewo-Pogorzela				16.12	
T0110499	1999	Kościan-Krobia	Kościan-Krobia	Kościan-Krobia 7/97/p		12.53	
T0120499	1999	Kościan-Krobia				10.36	
T0130499	1999	Kościan-Krobia				22.32	
T0140499	1999	Kościan-Krobia				14.13	
T0150499	1999	Kościan-Krobia				11.27	
T0160499	1999	Kościan-Krobia				15.39	
T0170499	1999	Kościan-Krobia				6.61	
T0180499	1999	Kościan-Krobia				16.47	
T0190499	1999	Kościan-Krobia				13.8	
T0200499	1999	Kościan-Krobia				15.24	
T0210499	1999	Kościan-Krobia				11.09	
T0220499	1999	Kościan-Krobia				11.78	
T0230499	1999	Kościan-Krobia				7.42	
T0240499	1999	Kościan-Krobia				9.17	
T0250499	1999	Kościan-Krobia				12.32	
T0260499	1999	Kościan-Krobia				5.92	
T0280499	1999	Kościan-Krobia				3.17	
T0290499	1999	Kościan-Krobia				3.12	
T0310499	1999	Kościan-Krobia				14.58	
T0320499	1999	Kościan-Krobia				12.39	
T0330499	1999	Kościan-Krobia				10.73	
T0340499	1999	Kościan-Krobia	10.85				
T0360499	1999	Kościan-Krobia	6.38				
T0390499	1999	Kościan-Krobia	10.41				
T0011504	2004	Jarocin-Jaraczewo		Jarczewo- Pogorzela 28/2001/p	State Treasury	5.07	
T0021504	2004	Jarocin-Jaraczewo				8.87	
T0031504	2004	Jarocin-Jaraczewo				7.48	
T0041504	2004	Jarocin-Jaraczewo				5.79	
T0051504	2004	Jarocin-Jaraczewo				2.34	
T0101504	2004	Jarocin-Jaraczewo				2.73	
FX059512	2012	Kościan-Żakowo 2D		Leszno 65/2008/p	State Treasury	7.91	
FX059512 E	2012	Kościan-Żakowo 2D				7.82	
FX059512 W	2012	Kościan-Żakowo 2D				7.96	
						State Treasury	849.57
						ORLEN S.A.	1246.23

Tab. 6.1. 2D seismic surveys (lines longer than 2 km) within the Gostyń tender area.

NAME	YEAR	OWNER	CONCESSIONS (after 2001)	ACREAGE [km ²]	
Kościan-Krzywin	1998	ORLEN S.A.	Kościan-Krobia 7/97/p	5.65	
Siedmiorogów-Pogorzela-3D	2004	State Treasury	Jarczewo-Pogorzela 28/2001/p	166.49	
Frankowo-3D	2012	State Treasury	Leszno 65/2008/p	27.8	
Tworzаницe-3D	2013	State Treasury		133.29	
				State Treasury	327.58
				ORLEN S.A.	5.65

Tab. 6.2. 3D seismic surveys within the Gostyń tender area.

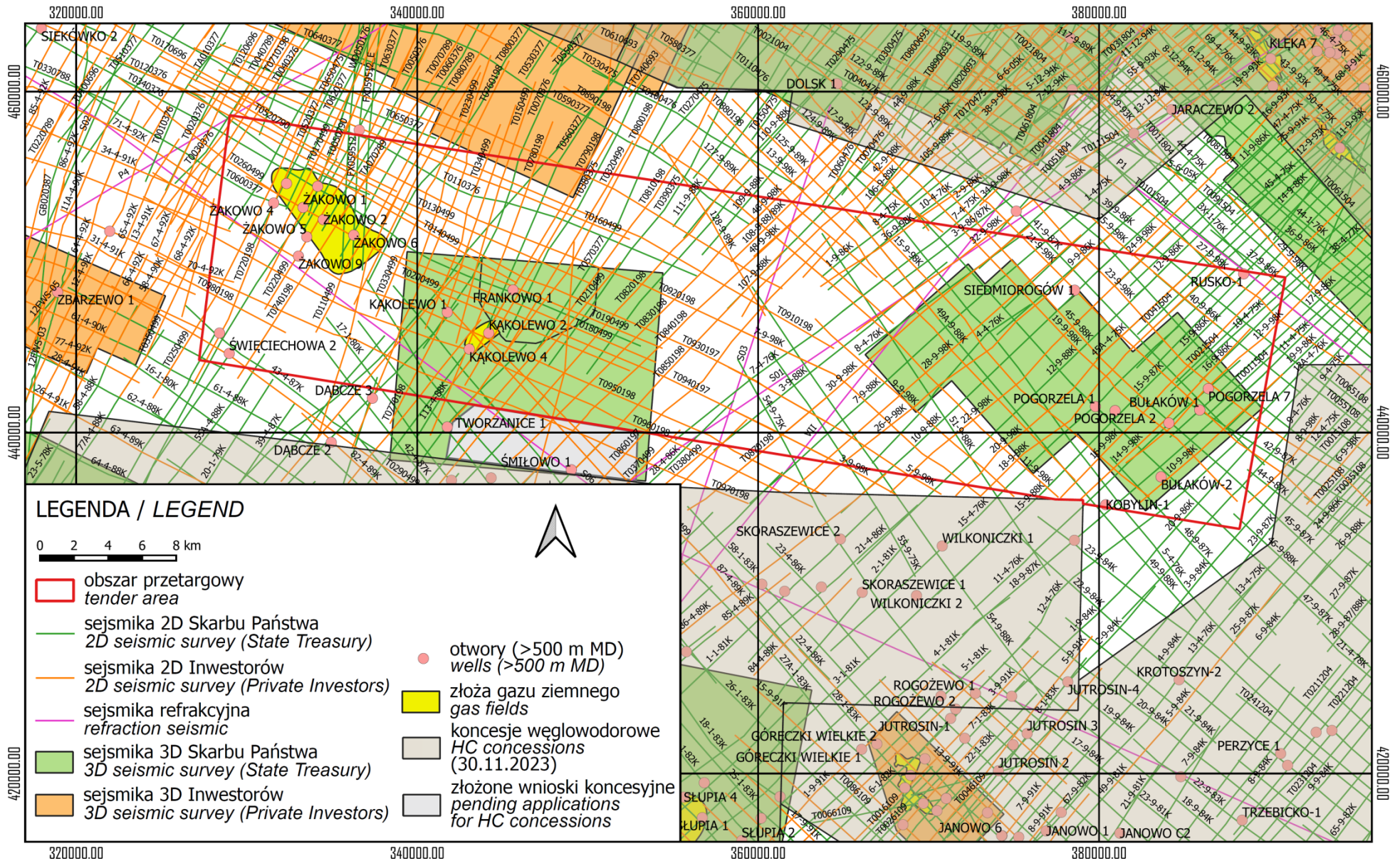


Fig. 6.1. Seismic survey within and in the neighborhood of the Gostyń tender area (CGDB, 2023).

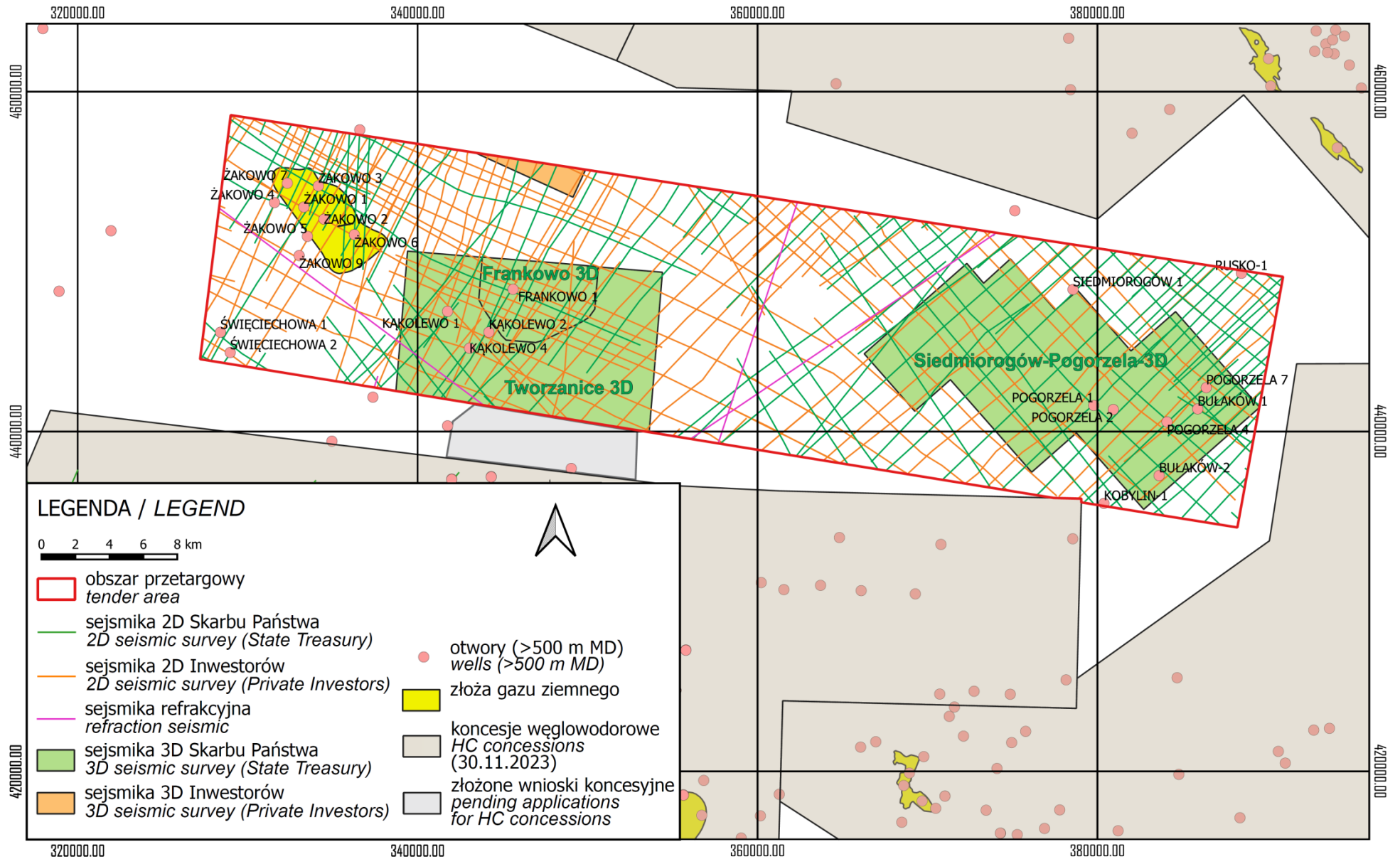


Fig. 6.2. Seismic survey within the Gostyń tender area (CGDB, 2023).

7. GRAVIMETRY, MAGNETOMETRY AND MAGNETOTELLURICS

7.1. GRAVIMETRY

Semidetailed gravimetric surveys in the Gostyń tender area and in its close neighborhood were collected with a point density in the range of 1.5–2.0 stations/km² (Fig. 7.1). All data are available in the CGDB (2023). There are 1395 data points within the tender area (Fig. 7.1) coming from the Leszno-Ostrzeszów (Duda, 1964) and from the Leszno-Rawicz (Duda and Bochnia, 1961) surveys, as well as 245 data points from the Gorzów-Jarocin (Bochnia and Duda, 1965) and 79 data points from the Mogilno-Konin-Uniejów (Reczek, 1967) surveys. There are 487 data points of detailed survey, collected along 2 profiles with the 100 m step along the profile. First profile was focused on brown coal exploration (Łaszczyńska et al., 1982). The other one (Kleszcz, 1976) crossed Fore-Sudetic Monocline. Królikowski and Petecki (1995) proposed a division of Poland into several gravity regions. Thus, the Gostyń tender area is placed within north-west end of Szczecin-Mogilno-Miechów Low (Fig. 7.2), witch source is defined indefinitely. Most researchers assume the dominant role of the crystalline basement in its formation. The influence of the Variscan orogen is also not excluded.

7.2. MAGNETOMETRY

A ground, semidetailed survey of the total magnetic field intensity was conducted in the Gostyń tender area (Pasik, 1974 and Kosobudzka, 1990). The survey has an average density of 1 station/km². All data are available in the CGDB (2023). There are 1516 data points within the Gostyń tender area (Fig. 7.3).

An image of magnetic anomalies presented on the Fig. 7.4 is taken from magnetic map of Poland (Petecki and Rosowiecka, 2017). The map is divided into several regions with different magnetic characteristic. The Gostyń tender area is located within the Central and Western Poland domain (CWPd). This domain is a vast magnetic low in which there are no strong anomalies of regional importance. The absence of magnetic anomalies in this domain suggests either consistently lower magnetization of the basement rocks in comparison to the neighbouring magnetic domains, or a smooth top of the basement at a great depth.

7.3. MAGNETOTELLURICS

The Gostyń tender area is located on the route of the regional magnetotelluric Zgorzelec-Wizajny profile completed in 2007 (Ostrowski et al., 2007; Fig. 7.5 **Błąd! Nie można odnaleźć źródła odwołania.**). The aim of the survey was to identify the contact zone of the Precambrian East European Platform with the Palaeozoic Platform of Central and Western Europe (TTZ), to determine the thickness of the sedimentary cover, to locate the main tectonic zones within the sedimentary cover and the deep crystalline basement, to separate individual lithostratigraphic complexes within the sedimentary cover, to define prospective zones for oil prospection within the sedimentary cover and recognition of potential areas of ore deposits in the north-eastern and south-western part of the profile.

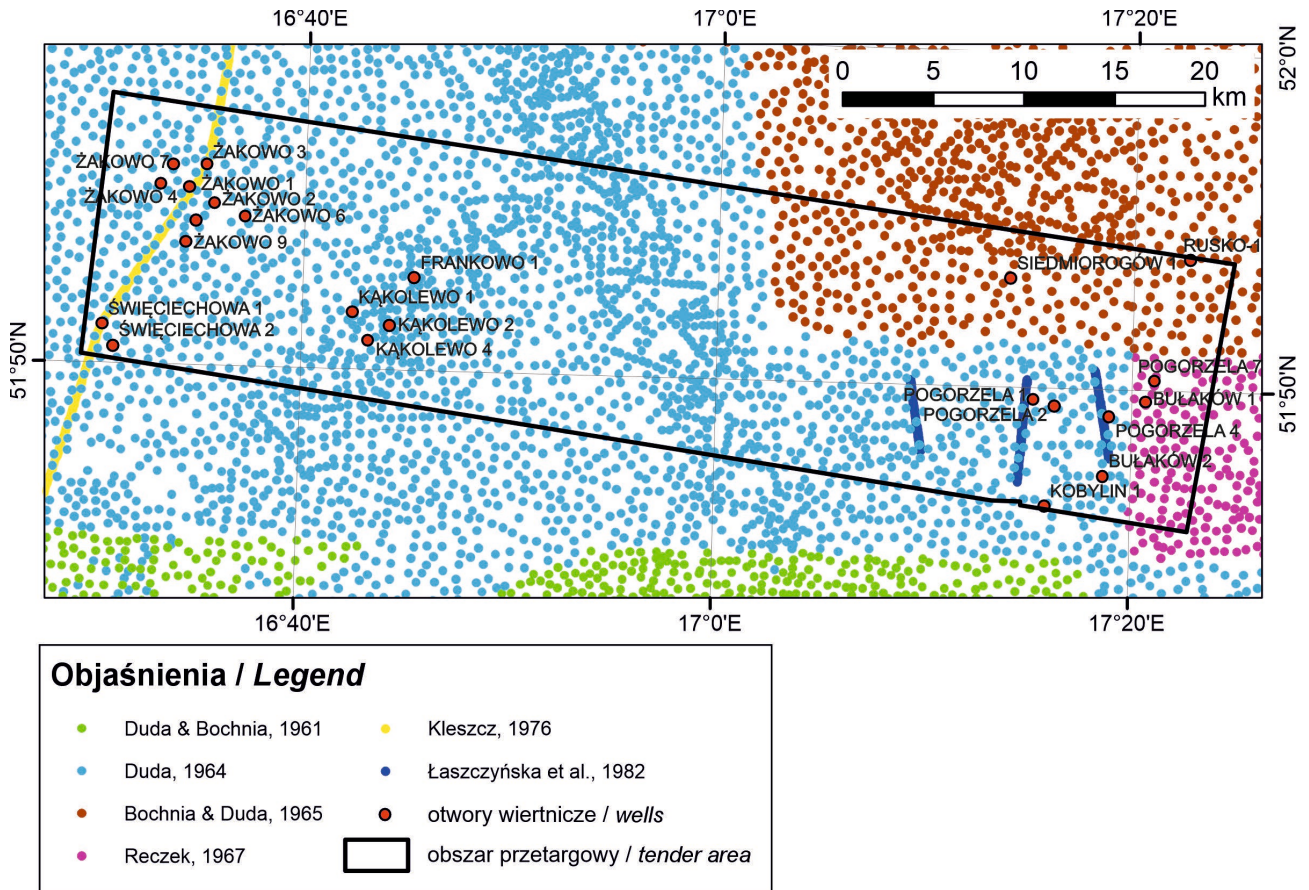


Fig. 7.1. Distribution of gravimetric measurements in the Gostyń tender area (CGDB, 2023).

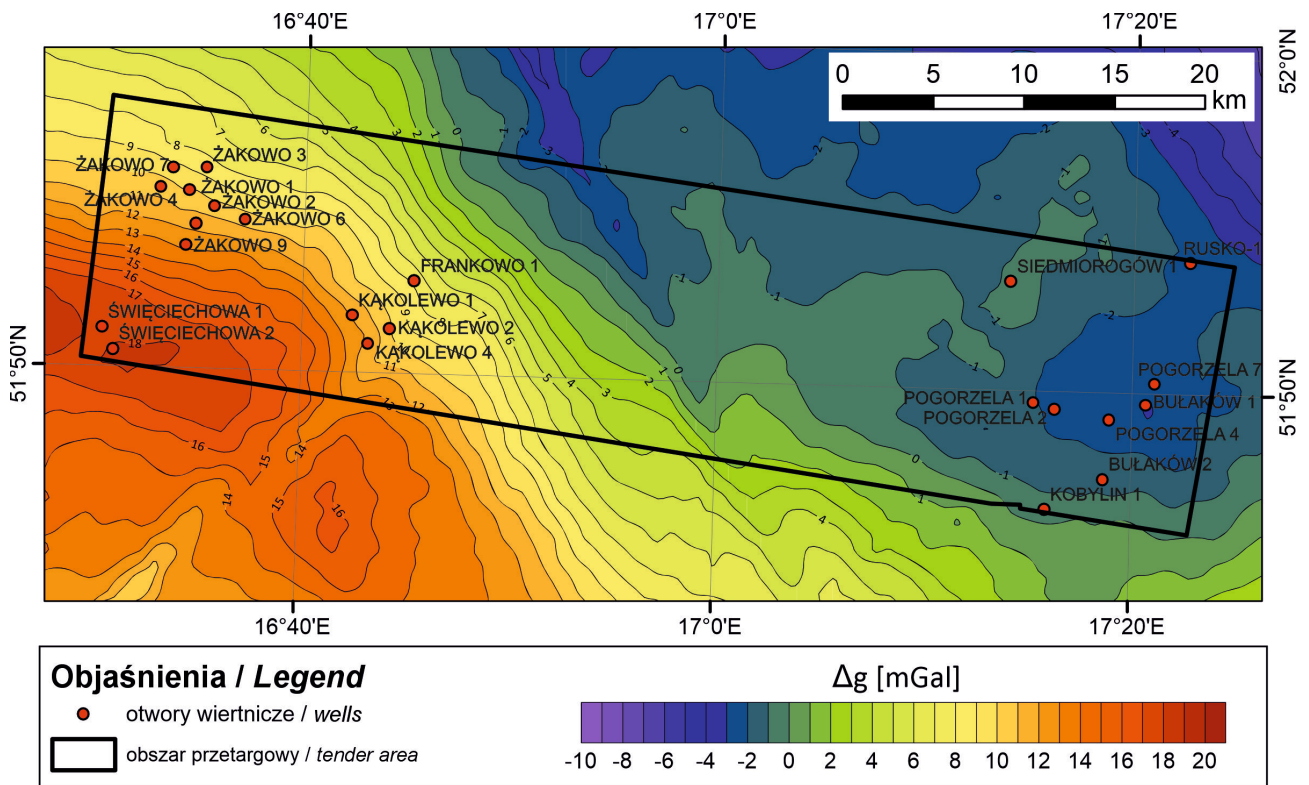


Fig. 7.2. Location of the Gostyń tender area on the Bouguer gravity anomaly map of Poland (Królikowski and Petecki, 1995).

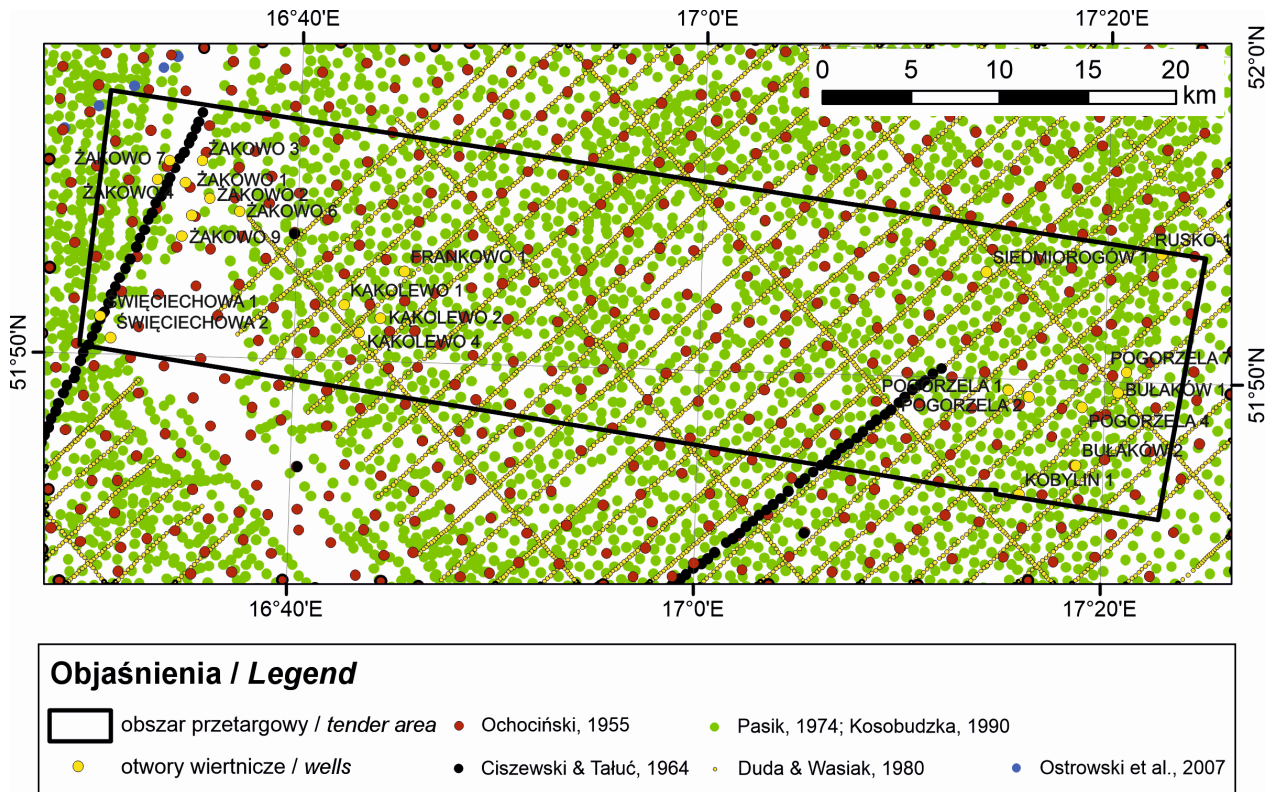


Fig. 7.3. Distribution of magnetic stations in the Gostyń tender area (CGDB, 2023).

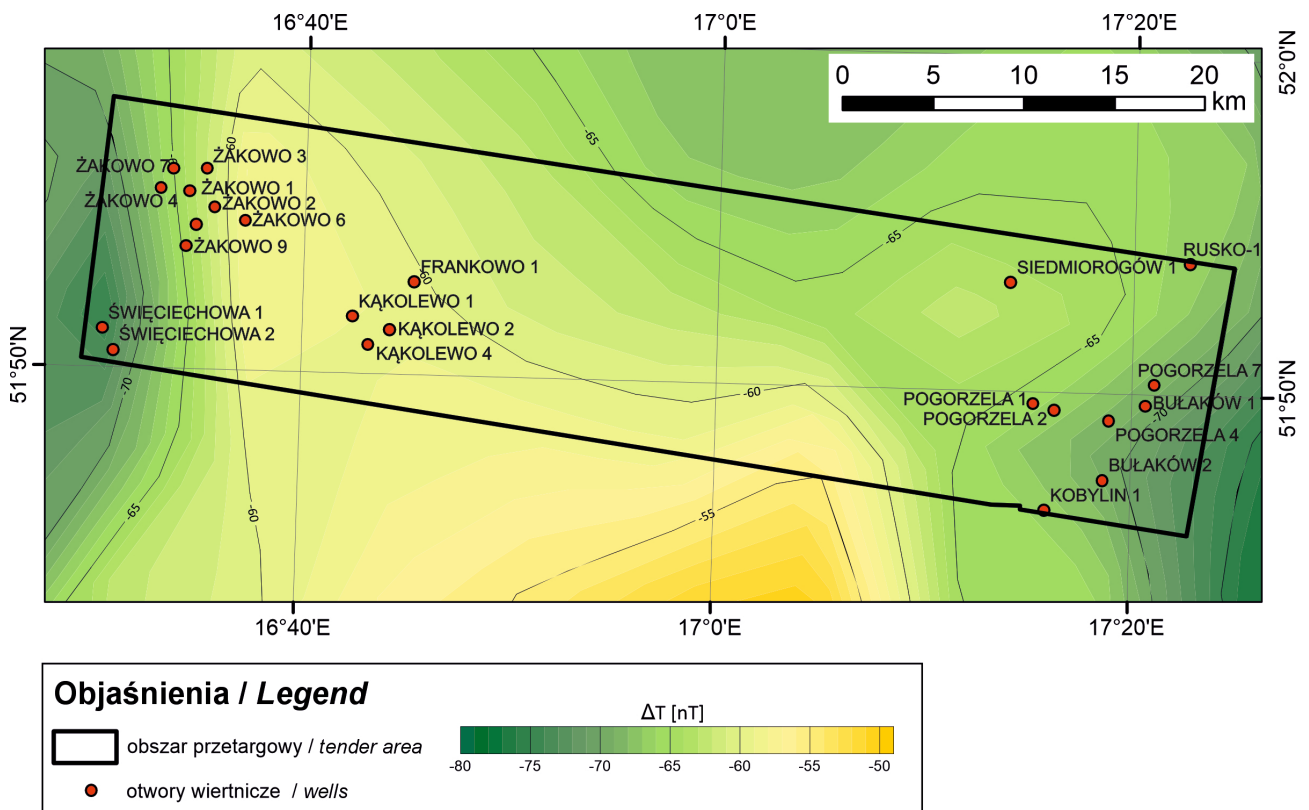


Fig. 7.4. Location of the Gostyń tender area on the magnetic anomaly map of Poland (Petecki and Rosowiecka, 2017).

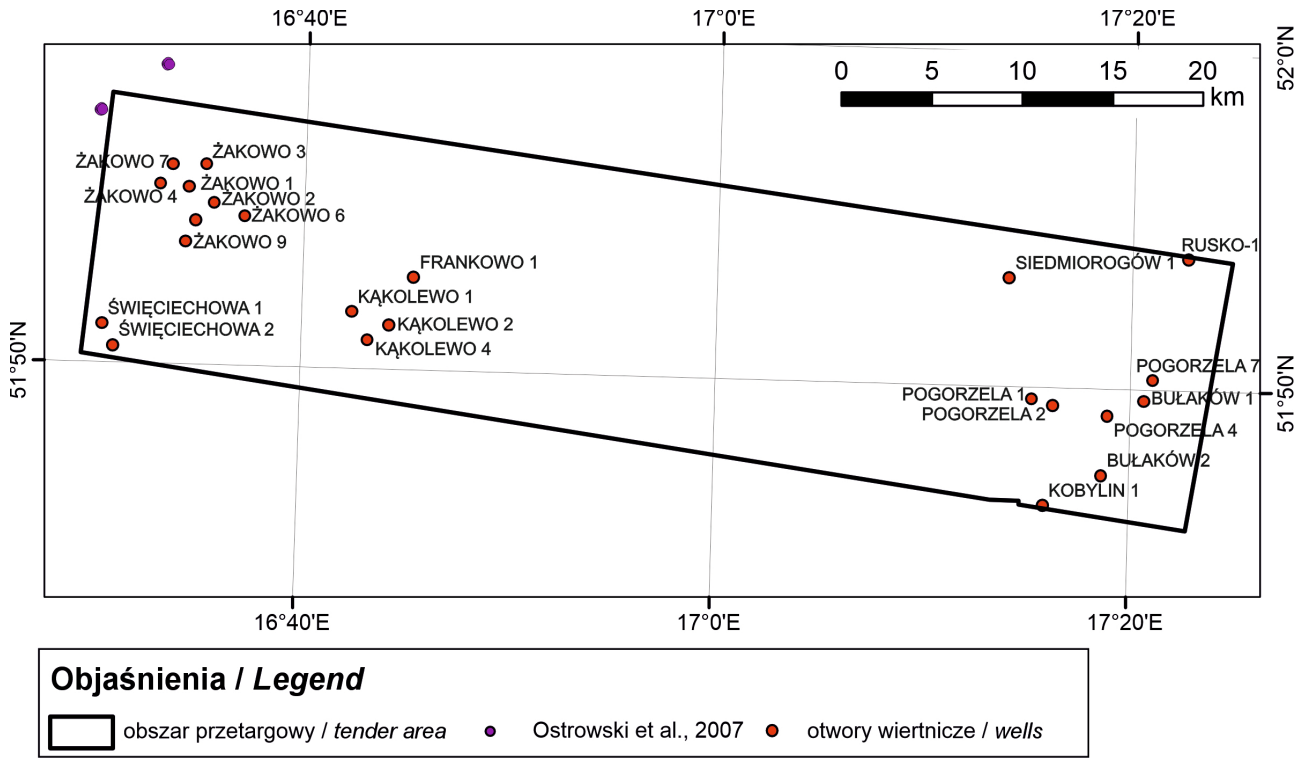


Fig. 7.5. Magnetotelluric surveys in the neighborhood of the Gostyń tender area (CGDB, 2023).

8. SUMMARY

Tender area:		GOSTYŃ
General information:	Location:	<p>Onshore Hydrocarbon concession blocks: 245, 246 i 247 Administrative location: Wielopolskie voivodeship, Kościan county, communes: Śmigiel (0.26%), Krzywiń (1.10%); Jarocin county, communes: Jaraczewo (1.25%), Jarocin (0.39%); Leszno county, communes: Lipno (9.96%), Osieczna (12.80%), Krzemieniewo (11.25%), Święciechowa (1.47%), Rydzyna (2.19%); Leszno City country, commune: Leszno (2.47%); Gostyń county, communes: Gostyń (12.28%), Piaski (10.70%), Borek Wielkopolski (7.77%), Poniec (3.84%), Krobia (3.04%), Pępowo (2.38%), Pogorzela (9.73%); Krotoszyn county, communes: Koźmin Wielkopolski (6.13%), Krotoszyn (0.65%), Kobylin (0.34%).</p>
	Concession type:	prospection and exploration of hydrocarbon deposits and production of hydrocarbons from a deposit
	Time:	concession for 30 years, including: prospection and exploration phase (5 years), production phase – after investment decision
Participation:		winner of the tender 100%
Acreage [km ²]:		916.92
Accumulation type:		Conventional oil and gas fields in the Permian (Main Dolomite, Zechstein Limestone, Rotliegend) and Carboniferous unconventional tight gas fields in the Lower Carboniferous
Structural stages:		Cenozoic, Permian-Mesozoic, Variscan
Petroleum plays:		(I) Conventional – Permian/Main Dolomite (II) Conventional – Carboniferous and Lower Permian (Carboniferous, Rotliegend, Zechstein Limestone) (III) unconventional – Lower Carboniferous
Reservoir rocks:		(I) Main Dolomite carbonate rocks (gainstones and packstones) (II) Carboniferous and Rotliegend sandstones and Zechstein Limestone carbonates (III) Lower Carboniferous sandstones
Source rocks:		(I) Main Dolomite carbonate rocks (mudstones and wackstones) (II) Carboniferous fine-grained clastic rocks (III) Lower Carboniferous fine-grained clastic rocks
Seal rocks:		(I) PZ2+PZ3 Zechstein evaporites (II) PZ1 Zechstein evaporites (III) Carboniferous fine-grained clastic rocks, also Zechstein evaporites
Trap type:		(I) structural (II) structural, geomorphological (III) unconventional/continuous
Oil and gas fields within the tender area:		Żakowo, Kąkolewo
Seismic surveys (owner):		<p>1975 Wschowa-Gostyń-Milicz 2D, 2 profile (Skarb Państwa) 1975–1976 Jarocin-Kalisz 2D, 5 profili (Skarb Państwa) 1975 Profile Regionalne, 1 profil (Skarb Państwa) 1975–1977 Kościan-Gostyń 2D, 18 profili (Skarb Państwa) 1976 Gostyń-Krotoszyn 2D, 1 profil (Skarb Państwa) 1976 Monoklina Przedsudecka, 2 profile (Skarb Państwa) 1976 Pyzdry-Krotoszyn-Kalisz, 9 profili (Skarb Państwa) 1978 Nowa Sól-Góra-Milicz 2D, 1 profil (Skarb Państwa) 1980 Góra-Rawicz 2 D, 2 profile (Skarb Państwa) 1986–1989 Pogorzela-Krotoszyn 2D, 34 profile (Skarb Państwa, ORLEN S.A.) 1986–1989 Leszno-Rawicz 2D, 12 profili (Skarb Państwa, ORLEN S.A.) 1988–1989 Śrem-Gostyń 2D, 10 profili (Skarb Państwa, ORLEN S.A.) 1989 Nowy Tomyśl-Wolsztyn-Leszno 2D, 4 profile (ORLEN S.A.) 1997–1999, Kościan-Krobia 2D, 51 profili (ORLEN S.A.) 1998–1999 Jaraczewo-Pogorzela 2D, 28 profili 2D (ORLEN S.A.) 2004 Jarocin-Jaraczewo 2D, 6 profili (Skarb Państwa) 2012 Kościan-Żakowo 2D, 3 profile (Skarb Państwa) 1998 Kościan-Krzywiń 3D, 5,65 km² (ORLEN S.A.) 2004 Siedmiorogów-Pogorzela 3D, 166,49 km² (Skarb Państwa) 2012 Frankowo 3D, 27,8 km² (Skarb Państwa) 2013 Tworzаницe 3D, 133,29 km² (Skarb Państwa)</p>

Wells (depth):	BUŁAKÓW 1 (2225.0 m) BUŁAKÓW-2 (1890.0 m) FRANKOWO 1 (2200.0 m) KAŃKOLEWO 1 (2170.0 m) KAŃKOLEWO 2 (2084.0 m) KAŃKOLEWO 4 (2087.5 m) KOBYLIN-1 (2861.0 m) POGORZELA 1 (1797.5 m) POGORZELA 2 (1767.0 m) POGORZELA 4 (2060.2 m) POGORZELA 7 (2207.3 m) RUSKO-1 (2600.0 m) SIEDMIOROGÓW-1 (2246.0 m) ŚWIĘCIECHOWA 1 (2776.8 m) ŚWIĘCIECHOWA 2 (2200.0 m) ŻAKOWO 1 (2374.8 m) ŻAKOWO 2 (1830.2 m) ŻAKOWO 3 (2298.5 m) ŻAKOWO 4 (2232.5 m) ŻAKOWO 5 (1830.7 m) ŻAKOWO 6 (2216.0 m) ŻAKOWO 7 (1836.0 m) ŻAKOWO 9 (2300.0 m)
---------------------------	--

Possible minimum work program for the prospection and exploration phase

- Archival data reinterpretation and analysis
 - Reconstruction of one well

or
- Drilling of a well to the maximal depth 5000 m TVD with obligatory coring of prospective intervals

9. REFERENCES

- **Błaszczak J. 1997.** Objasnienia do szczegółowej mapy geologicznej Polski w skali 1 : 50 000, arkusz Kobylin (619). [Detailed Geological Map of Poland 1 : 50 000. Kobylin Sheet (619)]. Description. Polish Geological Institute, Warsaw. [in Polish]
- **Bochnia N., Duda W. 1965.** Dokumentacja poszczegółowych badań grawimetrycznych. Temat: Gorzów-Jarocin. [Semidetailed gravimetric survey report. Gorzów-Jarocin area]. Inv. 1237, Cat. 3923/43, CAG PIG, Warsaw. [in Polish]
- **Bojanowski M., Błaszczowska V., Kalbarczyk R., Stolarczyk J., Stolarczyk F. 1975.** Dokumentacja geologiczna złoża gazu ziemnego Kąkolewo. [Kąkolewo gas field geological documentation]. Inv. 5919/2022, CAG PIG, Warsaw. [in Polish]
- **Botor D., Papiernik B., Maćkowski T., Reicher B., Kosakowski P., Machowski G., Górecki W. 2013.** Gas generation in Carboniferous source rocks of the Variscan foreland basin: implications for a charge history of Rotliegend deposits with natural gases. *Annales Societatis Geologorum Poloniae*, **83**, 353–383.
- **Buniak A., Mikołajewski Z., Wagner R. 2013.** Mapa paleogeograficzna wapienia cechsztyńskiego (Ca1), 1 : 500 000. [Palaeogeographic Map of the Zechstein Limestone (Ca1) in Poland, 1 : 500 000]. PGNiG, Departament Poszukiwania Złóż, Ośrodek Północ w Pile; Polish Geological Institute – National Research Institute, Warsaw. [in Polish]
- **CGDB 2023.** Central Geological Database. <http://otworywiertnicze.pgi.gov.pl>
- **Chruścińska J., Wojtysiak B., Rostkowski R. 2016.** Dokumentacja prac geologicznych niekończących się udokumentowaniem zasobów złoża kopaliny wykonanych na obszarze koncesji na poszukiwanie i rozpoznawanie złóż ropy naftowej i gazu ziemnego Czatkowice 9/2008/p. [Documentation of geological works performed within the Concession No. 9/2008/p Czatkowice]. Inv. 7782/2020, CAG PIG, Warsaw. [in Polish]
- **Dadlez R., Marek S., Pokorski J. 2000.** Mapa geologiczna Polski bez utworów kenozoiku 1 : 1 000 000. [Geological Map of Poland without Cenozoic deposits, 1 : 1 000 000]. Polish Geological Institute, Warsaw. [in Polish]
- **Dembicki H. 2017.** Practical Petroleum Geochemistry for Exploration and Production. Elsevier, Amsterdam, 331.
- **Duda W. 1964.** Opracowanie półszczełowych badań grawimetrycznych: monoklina przedsudecka (Leszno-Ostrzeszów), 1963. [Semidetailed gravimetric survey report, Fore-Sudetic Monocline (Leszno-Ostrzeszów area), 1963]. Inv. 1044; Kat. 4123/34, CAG PIG, Warsaw. [in Polish]
- **Duda W., Bochnia N. 1961.** Szczegółowe badania grawimetryczne: Leszno-Rawicz, 1960. [Detailed gravimetric survey report, Leszno-Rawicz area, 1960]. Inv. 14379/62, Kat. 4123/32, CAG PIG, Warsaw. [in Polish]
- **Filo M. et al. 2005.** Opracowanie wyników badań sejsmicznych dla tematu: Polowe prace sejsmiczne, przetwarzanie i prace interpretacyjno-dokumentacyjne /Etap I/ Siedmiorogów-Pogorzela 3D, rok: 2004. [Seismic survey report: Field seismic conduction, reprocessing and interpretation /Stage I/, Siedmiorogów-Pogorzela 3D, 2004. Inv. 1966/2006, CAG PIG, Warsaw. [in Polish]
- **Franke F. 2014.** Topography of the Variscan orogen in Europe: failed–not collapsed. *International Journal of Earth Sciences*, **103**, 1471–1499.
- **Gizler H. 2001.** Objasnienia do szczegółowej mapy geologicznej Polski w skali 1 : 50 000, arkusz Leszno (579). [Detailed Geological Map of Poland 1 : 50 000. Leszno Sheet (579). Description]. Polish Geological Institute, Warsaw. [in Polish]
- **Górecka-Nowak A. 2007.** Palynological constraints on the age of the Carboniferous clastic succession of SW Poland (Fore-Sudetic area) based on miospore data. *Geological Quarterly*, **51**, 39–56.
- **Górecka-Nowak A. 2008.** New interpretations of the Carboniferous stratigraphy of

- SW Poland based on miospore data. *Bulletin of Geosciences*, **83**, 101–116.
- **Górecki W., Maćkowski T., Papiernik B., Reicher B. 2009.** Dwuwymiarowe modelowania historii termicznej i generowania/ekspulsji węglowodorów oraz modelowanie migracji węglowodorów. [2-dimensional modelling of the thermal history and generation/expulsion and migration of hydrocarbons]. (W): Historia oraz geneza zdarzeń termicznych w basenie polskim i jego osadowym podłożu – ich znaczenie dla rekonstrukcji procesów generowania węglowodorów. [History and genesis of thermal events in the Polish Basin and its sedimentary basement as a key for reconstruction of the hydrocarbon generation processes]. (Ed.): Poprawa P. Inv. 5568/2011, CAG PIG, Warsaw. [in Polish]
 - **Jaworowski K., Mikołajewski Z. 2007.** Oil- and gas-bearing sediments of the Main Dolomite (Ca₂) in the Międzychód region: a depositional model and the problem of the boundary between the second and third depositional sequences in the Polish Zechstein Basin. *Przegląd Geologiczny*, **55**, 1017–124.
 - **Kalbarczyk R., Haase J. 1974.** Dokumentacja wynikowa otworu Żakowo 6. [Żakowo 6 well final geological documentation]. Inv. 118978, CAG PIG, Warsaw. [in Polish]
 - **Karnkowski P. 2007.** Petroleum provinces in Poland. *Przegląd Geologiczny*, **55**, 1061–1067.
 - **Kasiński J., Saternus A., Urbański P. 2019.** Atlas geologiczny wybranych złóż węgla brunatnego w Polsce. Tom I. Rejon zachodni i rejon wielkopolski. [Geological atlas of selected brown coal deposits in Poland. Vol. I. Western Poland and Wielkopolska Region]. Polish Geological Institute – National Research Institute, Warsaw. [in Polish]
 - **Kiersnowski H., Becker A., Brzeziński D., Czapigo-Czapla M., Dymowski W., Dyrka I., Fabiańczyk J., Feldman-Olszewska A., Gryczko-Gostyńska A., Głuszyński A., Grudzień T., Janas M., Jasionowski M., Kafara D., Kijewska S., Klimuszko E., Kostrz-Sikora P., Kozłowska A., Kozłowska O., Krzemiński L., Kuberska M., Laskowicz R., Leszczyński K., Roman M., Rosowiecka O., Sikorska-Maykowska M., Skowroński L., Sokołowski J., Wagner R., Wołkiewicz K., Wójcik K. 2017.** Pakiet danych geologicznych do postępowania przetargowego na poszukiwanie złóż węglowodorów. Obszar przetargowy „LESZNO”. Ocena perspektywiczności geologicznej zasobów złóż węglowodorów oraz przygotowanie materiałów na potrzeby przeprowadzenia postępowania przetargowego w celu udzielenia koncesji na poszukiwanie i rozpoznawanie lub wydobywanie złóż węglowodorów – etap II. [Leszno geological data package. Hydrocarbon prospective of Poland]. PSG Project No. 22.5004.1502.08.0. Polish Geological Institute – National Research Institute, Warsaw. [in Polish]
 - **Kiersnowski H., Peryt T.M., Buniak A., Mikołajewski Z. 2010.** From the intradesert ridges to the marine carbonate island chain: middle to late Permian (Upper Rotliegend – Lower Zechstein) of the Wolsztyn-Pogorzela high, west Poland. *Geological Journal*, **45**, 319–335.
 - **Kiersnowski H., Petecki Z. 2017.** Budowa geologiczna podcechsztyńskiego podłoża Legnicko-Głogowskiego Okręgu Miedziowego (LGOM) i jego otoczenia: spojrzenie krytyczne. [Geology of the Zechstein basement of the Legnica-Głogów Copper District (LGOM) and its surroundings: a critical overview]. *Biuletyn Państwowego Instytutu Geologicznego*, **468**, 175–198. [in Polish with English summary]
 - **Kleszcz T. 1976.** Dokumentacja szczególnych badań profilowych. Temat monoklina przedsudecka, 1975. [Detailed gravimetric survey report, Fore-Sudetic Monocline, 1975]. Inv. 18995, cat.53/139, CAG PIG, Warsaw. [In Polish]
 - **Kochan B., Burbulis H. 1973.** Dokumentacja wynikowa otworu poszukiwawczego Pogorzela 1. [Pogorzela 1 well final geological documentation]. Inv. 117877, CAG PIG, Warsaw. [In Polish]
 - **Kondracki J. 2013.** Geografia regionalna Polski. [Regional Geography of Poland].

- Wydawnictwa Naukowe PWN, Warsaw. [In Polish]
- **Kosakowski P., Wróbel M. 2010.** Source rock evaluation and basin modelling in the Western Part of the Fore-Sudetic Monocline – SW Poland (P343). 72nd EAGE Conference and Exhibition incorporating SPE EUROPEC 2010 Barcelona, Spain, 14-17 June, 1-5.
 - **Kosakowski P., Krajewski M. 2014.** Hydrocarbon potential of the Zechstein Main Dolomite in the western part of the Wielkopolska platform, SW Poland: New sedimentological and geochemical data. *Marine and Petroleum Geology*, **49**, 99–120.
 - **Kosakowski P., Krajewski M. 2015.** Hydrocarbon potential of the Zechstein Main Dolomite (Upper Permian) in western Poland: Relation to organic matter and facies characteristics. *Marine and Petroleum Geology*, **68**, 675–694.
 - **Kosobudzka I. 1990.** Dokumentacja półszczełowych badań magnetycznych T. Temat: niecka szczecińska i monoklina przedsudecka rok 1981–1989, rejon: Sulęcín-Myślíbórz oraz Kościan-Krzyż, Zbąszyn-Międzychód, Choszczno-Ińsko, Cedynia-Pyrzyce. [Semidetailed magnetic survey report, Szczecin Trough and Fore-Sudetic Monocline 1981–1989, Sulęcín-Myślíbórz, Kościan-Krzyż, Zbąszyn-Międzychód, Choszczno-Ińsko, and Cedynia-Pyrzyce areas]. Inv. 1259/91, CAG PIG, Warsaw. [In Polish]
 - **Kotarba M., Wagner R. 2007.** Generation potential of the Zechstein Main Dolomite (Ca₂) carbonates in the Gorzów Wielkopolski–Międzychód–Lubiatów area: geological and geochemical approach to microbial-algal source rock. *Przegląd Geologiczny*, **55**, 1025–1036.
 - **Kotarba M.J., Clayton J.L., Rice D.D., Wagner M. 2002.** Assessment of hydrocarbon source rock potential of Polish bituminous coals and carbonaceous shales. *Chemical Geology*, **184**, 11–35.
 - **Kotarba M.J., Grelowski C., Kosakowski P., Więclaw D., Kowalski A., Sikorski B. 1999.** Potencjał węglowodorowy skał macierzystych i geneza gazu ziemnego akumulowanego w utworach czerwonego spągowca i karbonu w północnej części Pomorza Zachodniego. [Hydrocarbon potential of the source rocks and origin of gas accumulated in the Rotliegend and Carboniferous deposits in the northern part of the Western Pomerania region]. *Przegląd Geologiczny*, **47**, 480. [in Polish]
 - **Kotarba M.J., Piela J., Żolnierczuk T. 1992.** Geneza gazu ziemnego akumulowanego w permsko-karbońskich pułapkach litologicznych złoża "Paproc" w świetle badań izotopowych. [Origin of natural gas in Permo–Carboniferous lithological traps of Paproc field (western Poland) in light of isotope studies]. *Przegląd Geologiczny*, **40**, 260–263. [in Polish with English summary]
 - **Kotarba M.J., Więclaw W., Stecko Z. 2000.** Skład, geneza i środowisko generowania gazu ziemnego w utworach dolomitu głównego zachodniej części obszaru przedsudeckiego. [Composition, origin and habitat of natural gases in the Zechstein Main Dolomite strata of the western part of the Fore-Sudetic area (SW Poland)]. *Przegląd Geologiczny*, **48**, 429–435. [in Polish with English summary]
 - **Kozłowska A., Kuberska M. 2015.** Piaszkowce dolnego karbonu strefy wielkopolsko-śląskiej jako utwory perspektywiczne pod względem poszukiwań złóż gazu zamkniętego (badania wstępne). [The Lower Carboniferous sandstones in the Wielkopolska-Silesia zone prospective for tight gas exploration (preliminary studies)]. *Biuletyn Państwowego Instytutu Geologicznego*, **464**, 49–59. [in Polish with English summary]
 - **Król J. 2003.** Objasnienia do szczegółowej mapy geologicznej Polski w skali 1 : 50 000, arkusz Kobylin (618). [Detailed Geological Map of Poland 1 : 50 000. Kobylin Sheet (618). Description]. Polish Geological Institute, Warsaw. [in Polish]
 - **Królikowski C., Petecki Z. 1995.** Atlas grawimetryczny Polski. [Gravimetric Atlas of Poland]. Polish Geological Institute, Warsaw. [In Polish]
 - **Krzemiński L. 2005.** Proweniencja materiału okruchowego piaszkowców karbońskich z waryscyjskich basenów przedpola w południowo-zachodniej Polsce i na Mo-

- rawach. [Provenance of Carboniferous sandstones from the Variscan foreland basins in southwestern Poland and Moravia]. *Biuletyn Państwowego Instytutu Geologicznego*, **417**, 27–108. [in Polish with English summary]
- **Krzyżanowski S., Piela J. 1972.** Dokumentacja geologiczna złoża gazu ziemnego Żakowo. [Żakowo gas field geological documentation]. Inv. 5918/2022, CAG PIG, Warsaw. [in Polish]
 - **Kudrewicz R. 2007.** Mapy strukturalne powierzchni podcechsztyńskiej i podpermskiej, 1 : 500 000. [Structural maps of the Zechstein basement top surface and Permian basement top surface, 1 : 500 000]. (In: Wagner et al., 2008 (Eds). Inv. 2293/2009, CAG PIG, Warsaw. [In Polish]
 - **Kuhn D. 1979.** Dokumentacja wyników otworu badawczego Wycisłowo IG-1. [Wycisłowo IG-1 well final geological documentation]. Inv. 25086, CAG PIG, Warsaw. [in Polish]
 - **Kwolek K., Mikołajewski Z. 2007.** New stratigraphic scheme for Zechstein rocks in the Pogorzela High (Foresudetic Monocline) and its significance for hydrocarbon exploration. *Przegląd Geologiczny*, **55**, 1037–1047.
 - **Kwolek K., Mikołajewski Z. 2010.** Kryteria identyfikacji obiektów litofacjalnych jako potencjalnych pułapek złożowych w utworach dolomitu głównego (Ca₂) u podnóża platform i mikroplatform węglanowych w środkowo-zachodniej Polsce. [Criteria of identification of lithofacies objects as potential hydrocarbon traps in the Main Dolomite (Ca₂) strata at the toe-of-slope of carbonate platforms and microplatforms in the central-western Poland]. *Przegląd Geologiczny*, **58**, 426–435. [in Polish with English summary]
 - **Kwolek K., Protas A. 2001.** Nowe aspekty poszukiwań węglowodorów w utworach dolomitu głównego w rejonie wyniesienia Pogorzeli, monoklina przedsudecka. [New aspects of hydrocarbons prospecting within the Main Dolomite in the Pogorzela High area, Fore-Sudetic Monocline (SW Poland)]. *Przegląd Geologiczny*, **49**, 229–236. [in Polish with English summary]
 - **Łaszczyńska B., Okulus H., Wojaś A. 1982.** Dokumentacja badań geofizycznych; temat: Poszukiwania złóż węgla brunatnego w obrębie anomalii grawimetrycznych (obszary: Oborniki, KłECKO, Pogorzela, Świebodzin-Boryszyn, Studzieniec, Bobrowice), 1981. [Geophysical documentation; topic: Searching of brown coal fields gravimetric anomalies (Oborniki, KłECKO, Pogorzela, Świebodzin-Boryszyn, Studzieniec, Bobrowice regions), 1981]. Inv. 2189, CAG PIG, Warsaw. [In Polish]
 - **Malinowski M., Grad M., Guterch A., Takács E., Sliwinski Z.J., Antonowicz L., Iwanowska E., Keller G.R., Hegedűs E. 2007.** Effective sub-Zechstein salt imaging using low-frequency seismics — Results of the GRUNDY 2003 experiment across the Variscan front in the Polish Basin. *Tectonophysics*, **439**, 89–106.
 - **Marek S., Pajchłowa M. 1997.** Epikontynentalny perm i mezozoik w Polsce. [The epicontinental Permian and Mesozoic in Poland]. *Prace Instytutu Geologicznego*, **153**. [in Polish with English summary]
 - **Mazur S., Dunlap W.J., Turniak K., Oberc-Dziedzic T. 2006.** Age constraints for the thermal evolution and erosional history of the central European Variscan belt: new data from sediments and basement of the Carboniferous foreland basin in western Poland. *Journal of Geological Society of London*, **163**, 1011–1024.
 - **Multan M. 2002.** Objaśnienia do szczegółowej mapy geologicznej Polski w skali 1 : 50 000, arkusz Góra (616). [Detailed Geological Map of Poland 1 : 50 000. Góra Sheet (616). Description]. Polish Geological Institute, Warsaw. [in Polish]
 - **Nawrocki J., Becker A. 2017.** Geological Atlas of Poland. Polish Geological Institute – National Research Institute, Warsaw.
 - **Nowak J. 2002.** Objaśnienia do szczegółowej mapy geologicznej Polski w skali 1 : 50 000, arkusz Poniec (617). [Detailed Geological Map of Poland 1 : 50 000. Poniec Sheet (617). Description]. Polish Geological Institute, Warsaw. [in Polish]
 - **Nowak G. 2003.** Petrologia materii organicznej rozproszonej w późnopaleozoicznych skałach osadowych południowo-zachodniej Polski. [Petrology of organic

- matter dispersed in Late Palaeozoic sedimentary rocks of southwestern Poland]. *Cuprum*, **4**, 3–209. [in Polish with English summary]
- **Nowak G. 2007.** Comparative studies of organic matter petrography of the Late Palaeozoic black shales from south western Poland. *International Journal of Coal Petrology*, **71**, 568–585.
 - **Ostrowski C., Stefaniuk M., Wojdyła M., Kosobudzka I. 2007.** Dokumentacja badań geofizycznych, Temat: Pomiary polowe magnetotelluryczne, magnetyczne i grawimetryczne wzdłuż profilu Zgorzelec-Wiżajny wraz z ich przetworzeniem i interpretacją. 2005–2007. [Geophysical survey report; Magnetotelluric, magnetic and gravimetric field measurements along Zgorzelec-Wiżajny line with interpretation and reprocessing, 2005–2007]. Inv. 3093/2014, CAG PIG, Warsaw. [in Polish]
 - **Papiernik B., Kosakowski P., Machowski G., Słupczyński K., Semyrka R., Kowalski A., Capik M. 2008.** Conditions of occurrence of hydrocarbon deposits in Zechstein Main Dolomite (Ca2) petroleum system, exemplified by the Grotów Peninsula area (Fore-Sudetic Monocline, SW Poland). 33rd International Geological Congress, Oslo, Norway, 2008, August 6–14.
 - **Pasik J. 1974.** Dokumentacja półszczełowych badań magnetycznych. Temat: monoklina przedsudecka, 1974. [Semi-detailed magnetic survey report, Fore-Sudetic Monocline, 1974]. Cat. M-164 PBG, CAG PIG, Warsaw. [in Polish]
 - **Petecki Z., Rosowiecka O. 2017.** A new magnetic anomaly map of Poland and its contribution to the recognition of crystal line basement rocks. *Geological Quarterly*, **61**, 934–945.
 - **Piwocki M. 1997.** Geologia trzeciorzędowych złóż węgla brunatnego w rowach tektonicznych Wielkopolski. [Geology of the Tertiary brown coal deposits in the tectonic fault troughs of the Wielkopolska region]. Conference materials of the 62. Meeting of the Polish Geological Society, Poznań. [in Polish]
 - **Pletsch T., Appel J., Botor D., Clayton C.J., Duin E.J.T., Faber E., Górecki W., Kombrink H., Kosakowski P., Kuper G., Kus J., Lutz R., Mathiesen A., Ostertag C., Papiernik B., Van Bergen F. 2010.** Petroleum generation and migration. [W]: Petroleum Geological Atlas of the Southern Permian Basin Area; [Red.:] Doornenbal, J.G., Stevenson, A.G. EAGE Publications b. v., Hout, 225–253.
 - **Poprawa P. 2010.** Rozpoznanie basenów węglowodorowych Polski pod kątem możliwości występowania i zasobów oraz możliwości koncesjonowania poszukiwań niekonwencjonalnych złóż gazu ziemnego - etap I. [Recognition of petroleum basins in Poland in terms of the occurrence, resources and licensing of unconventional natural gas deposits – stage I]. Inv. 2439/2011, CAG PIG, Warsaw. [in Polish]
 - **Poprawa P., Kiersnowski H. 2008.** Perspektywy poszukiwań gazu ziemnego w skałach ilastych (shale gas) oraz gazu ziemnego zamkniętego (tight gas) w Polsce. [Potential for shale gas and tight gas exploration in Poland]. *Biuletyn Państwowego Instytutu Geologicznego*, **429**, 145–152. [in Polish with English summary]
 - **Reczek J. 1967.** Dokumentacja półszczełowych badań grawimetrycznych, temat: Mogilno-Konin-Uniejów, 1965/66. [Semi-detailed gravimetric survey report, Mogilno-Konin-Uniejów area, 1965/1966]. Kat. G-215 PBG, CAG PIG, Warsaw. [in Polish]
 - **Richter Bernburg G. 1955.** Stratigraphische Gliederung des deutschen Zechsteins. *Zeitschrift der Deutschen Gesellschaft für Geowissenschaften*, **105**, 843–854.
 - **Rosowiecka O. 2011.** Opracowanie modelu rozkładu gęstości głównych jednostek geologicznych kraju. [Density modelling of the main geological units of Poland]. Inv. 3604/2014, CAG PIG, Warsaw. [in Polish]
 - **Słowakiewicz M., Gąsiewicz A. 2013.** Palaeoclimatic imprint, distribution and genesis of Zechstein Main Dolomite (Upper Permian) petroleum source rocks in Poland: Sedimentological and geochemical rationales. *Geological Society of London, Special Publications*, **376**, 523–538.

- **Słowakiewicz M., Mikołajewski Z. 2011.** Upper Permian Main Dolomite microbial carbonates as potential source rocks for hydrocarbons (W Poland). *Marine and Petroleum Geology*, **28**, 1572–1591.
- **Solon J., Borzyszkowski J., Bidlasik M., Richling A., Badora K., Balon J., Brzezińska-Wójcik T., Chabudziński Ł., Dobrowolski R., Grzegorzczak I., Jodłowski M., Kistowski M., Kot R., Kraż P., Lechnio J., Macias A., Majchrowska A., Malinowska E., Migoń P., Myga-Piątek U., Nita J., Papińska E., Rodzik J., Strzyż M., Terpiłowski S., Ziaja W. 2018.** Physicogeographical mesoregions of Poland – verification and adjustment of boundaries on the basis of contemporary spatial data. *Geographia Polonica*, **91**.
- **Stolarczyk F., Stolarczyk J., Kalbarczyk R. 1975.** Dodatek nr 1 do dokumentacji geologicznej złoża gazu ziemnego Żakowo. [Żakowo gas field geological documentation, Suppl. 1]. Inv. 5920/2022, CAG PIG, Warsaw. [in Polish]
- **Strzelecka D., Rostkowski R., 2016.** Dokumentacja prac geologicznych niekończących się udokumentowaniem zasobów złoża kopaliny wykonanych na obszarze koncesji na poszukiwanie i rozpoznawanie złóż ropy naftowej i gazu ziemnego Jarczewo-Pogorzela nr 28/2001/p. [Documentation of geological works performed within the Concession No. 28/2001/p Jarczewo-Pogorzela]. Inv. 5152/2018, CAG PIG, Warsaw. [in Polish]
- **Szałajdewicz J. 2002.** Objasnienia do szczegółowej mapy geologicznej Polski w skali 1 : 50 000, arkusz Gostyń (581). [Detailed Geological Map of Poland 1 : 50 000. Gostyń Sheet (581). Description]. Polish Geological Institute, Warsaw. [in Polish]
- **Szalamacha B. 2001.** Objasnienia do szczegółowej mapy geologicznej Polski w skali 1 : 50 000, arkusz Jarczewo (582). [Detailed Geological Map of Poland 1 : 50 000. Jarczewo Sheet (582). Description]. Polish Geological Institute, Warsaw. [in Polish]
- **Śliwiński Z., Antonowicz L., Iwanowska E., Malinowski M., Grad M., Guterch A., Keller R., Takács E. 2006.** Interpretacja zasięgu eksternidów waryscyjskich na eksperymentalnym profilu sejsmicznym GRUNDY 2003. [Extent of the Variscan externides interpreted along the experimental seismic profile GRUNDY 2003]. *Przegląd Geologiczny*, **54**, 45–50. [in Polish with English summary]
- **Wagner R. 1994.** Stratygrafia osadów i rozwój basenu cechsztyńskiego na Niżu Polskim. [Stratigraphy and evolution of the Zechstein Basin in the Polish Lowland]. *Prace Państwowego Instytutu Geologicznego*, **146**, 1–71. [In Polish with English summary]
- **Wagner R. 1998.** Mapy paleogeograficzne cechsztynu. [Palaeogeographic map of the Zechstein]. (In): Palaeogeographic Atlas of the Epicontinental Permian and Mesozoic in Poland, 1 : 2 500 000; (Eds): Dadlez et al. Inv. 3417/98, 4610/2015, CAG PIG, Warsaw. [in Polish]
- **Wagner R. 2012.** Mapa paleogeograficzna dolomitu głównego (Ca₂) w Polsce. [Palaeogeographic map of the Main Dolomite (Ca₂) in Poland]. Polish Geological Institute – National Research Institute, Warsaw. [in Polish]
- **Wagner R., Peryt T.M. 1997.** Possibility of sequence stratigraphic subdivision of the Zechstein in the Polish Basin. *Geological Quarterly*, **41**, 457–474.
- **Wierzchowska-Kicułowa K. 2007.** Podłoże monokliny. [Fore-Sudetic Monocline basement]. KGHM Polska Miedź S.A. Monography (Second edition): 90–92, Lubin. [In Polish]
- **Winnicki J. 2003.** Objasnienia do szczegółowej mapy geologicznej Polski w skali 1 : 50 000, arkusz Krzywiń (580). [Detailed Geological Map of Poland 1 : 50 000. Krzywiń Sheet (580). Description]. Polish Geological Institute, Warsaw. [in Polish]
- **Wójcicki, A., Kiersnowski, H., Dyrka, I., Adamczak-Biały, T., Becker, A., Głuszyński, A., Janas, M., Kozłowska, A., Krzemiński, L., Kuberska, M., Paczeńska, J., Podhalańska, T., Roman, M., Skowroński, L., Waksmundzka, M.I., 2014.** Prognostyczne zasoby gazu ziemnego w wybranych zwięzłych skałach zbiornikowych Polski. Szacowanie zasobów

- złóż węglowodorów – zadanie ciągłe PSG (etap I, 2014-2017 r.). [Prognostic resources of tight gas in Poland]. Polish Geological Institute – National Research Institute, Warsaw, 1–65. [in Polish]
- **Ziółkowski M. 2002.** Mapa hydrogeologiczna Polski w skali 1 : 50 000, ark. Święciechowa (0578). [Hydrogeological Map of Poland 1 : 50 000, Święciechowa sheet (0578)]. Polish Geological Institute, Warsaw. [in Polish]
 - **Kotarba M.J., Bilkiewicz E., Kosakowski P. 2020.** Origin of hydrocarbon and non-hydrocarbon (H₂S, CO₂ and N₂) components of natural gas accumulated in the Zechstein Main Dolomite carbonate reservoir of the western part of the Polish sector of the Southern Permian Basin. *Chemical Geology*, **554**, 119807.
 - **Żelaźniewicz A., Marheine D., Oberc-Dziedzic T. 2003.** A Late Tournaisian synmetamorphic folding and thrusting event in the eastern Variscan foreland: 40Ar/39Ar evidence from the phyllites of the Wolsztyn-Leszno High, western Poland. *International Journal of Earth Sciences*, **92**, 185–194.
 - **Żelaźniewicz A., Aleksandrowski P., Buła Z., Karnkowski P.H., Konon A., Oszczytko N., Ślęczka A., Żaba J., Żytko K. 2011.** Regionalizacja tektoniczna Polski. [Tectonic subdivision of Poland]. Komitet Nauk Geologicznych PAN, Wrocław. [in Polish]
 - **Żelichowski A.M. 1964.** Utwory karbonu w podłożu monokliny przedsudeckiej. [Carboniferous deposits in the basement of the Fore-Sudetic Monocline]. *Przegląd Geologiczny*, **12**, 224–228. [in Polish with English summary]