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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

ZIELONA GÓRA WEST

TENDER AREA

GEOLOGICAL PACKAGE ENGLISH ABSTRACT

VI LICENSING ROUND
FOR CONCESSIONS FOR PROSPECTION AND EXPLORATION
OF HYDROCARBON FIELDS AND PRODUCTION OF HYDROCARBONS FROM FIELDS
IN POLAND

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NATIONAL FUND
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1. GENERAL INFORMATION
1.1. LOCATION

The Zielona Góra West tender area of 954.57 km^2 is located onshore in western Poland (concession block 243; Fig. 1.1). The precise location is defined by geographic coordinates listed below.

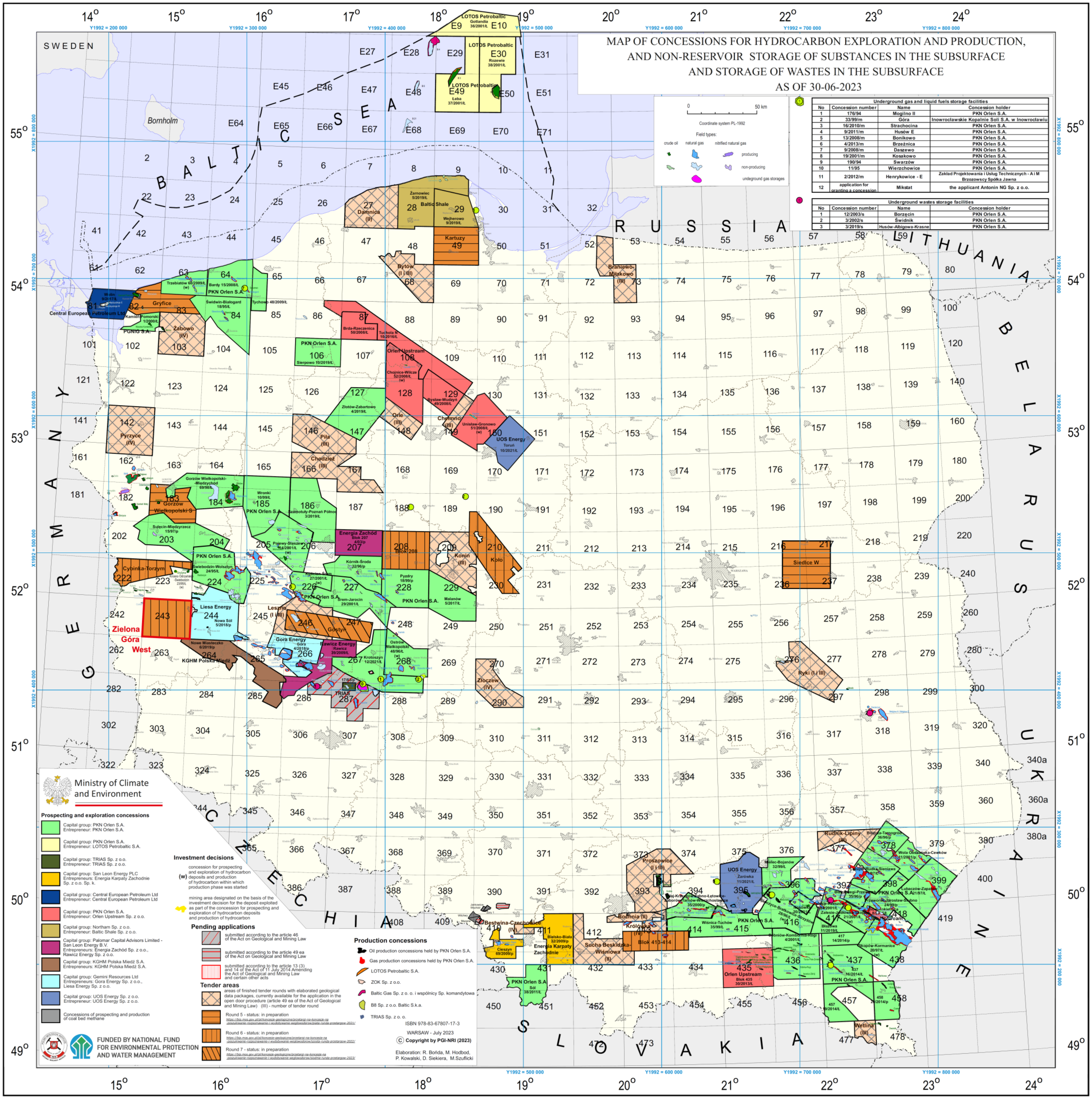
Border points	1992 coordinate system	
	X	Y
1	466864.29	225534.14
2	465099.30	259706.65
3	460854.86	259501.20
4	455090.39	259224.01
5	437314.83	258369.88
6	439083.64	224005.94

Tab. 1.1. Border points' coordinates of the Zielona Góra West tender area (Fig. 1.2).

The Zielona Góra West tender area was previously subjected to hydrocarbon prospection and exploration concession No. 14/2007/p Blok 243 (Celtique Energie Poland/Bobr Energia). Currently, in the neighborhood of the tender area, there are two active concessions No. 5/2018/p Nowa Sól (Liesa Energy Sp. z o.o.) and No. 6/2019/p Nowe Miasteczko (KGHM Polska Miedź S.A.; Figs 1.1–1.2).

The Zielona Góra West area is prospective for exploration of conventional oil and gas fields in the Permian Rotliegend and Main Dolomite horizons.

→**Fig. 1.1.** Location of the Zielona Góra West 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 30-06-2023.


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 30-06-2023
Underground gas and liquid fuels storage facilities
No | Concession number | Name | Concession holder
1 | 176/94 | Mogilno II | PKN Orlen S.A.
2 | 33/99/m | Góra | Inowrocławskie Kopalnie Soli S.A. w Inowrocławiu
3 | 16/2010/m | Strachocina | PKN Orlen S.A.
4 | 9/2011/m | Husów E | PKN Orlen S.A.
5 | 13/2008/m | Bonikowo | PKN Orlen S.A.
6 | 4/2013/m | Brzeźnica | PKN Orlen S.A.
7 | 9/2008/m | Daszewo | PKN Orlen S.A.
8 | 19/2001/m | Kosakowo | PKN Orlen S.A.
9 | 190/94 | Swarzów | PKN Orlen S.A.
10 | 11/95 | Wierzchowice | PKN Orlen S.A.
11 | 2/2012/m | Henrykowice - E | Zakład Projektowania i Usług Technicznych - A i M Brzozowscy Spółka Jawna
12 | application for granting a concession | Mikstat | the applicant Antonin NG Sp. z o.o.
Underground wastes storage facilities
No | Concession number | Name | Concession holder
1 | 12/2003/s | Borzęcin | PKN Orlen S.A.
2 | 3/2002/s | Świdnik | PKN Orlen S.A.
3 | 3/2019/s | Husów-Albigowa-Krasne | PKN Orlen S.A.
SWEDEN
BALTIC SEA
RUSSIA
LITHUANIA
BELARUS
UKRAINE
SLOVAKIA
CZECHIA
GERMANY
Zielona Góra West
Ministry of Climate and Environment
Prospecting and exploration concessions
Capital group: PKN Orlen S.A. Entrepreneur: PKN Orlen S.A.
Capital group: PKN Orlen S.A. Entrepreneur: LOTOS Petrobaltic S.A.
Capital group: TRIAS Sp. z o.o. Entrepreneur: TRIAS Sp. z o.o.
Capital group: San Leon Energy PLC Entrepreneurs: Energia Karpaty Zachodnie Sp. z o.o. Sp. k.
Capital group: Central European Petroleum Ltd Entrepreneur: Central European Petroleum Ltd
Capital group: PKN Orlen S.A. Entrepreneur: Orlen Upstream Sp. z o.o.
Capital group: Northam Sp. z o.o. Entrepreneur: Baltic Shale Sp. z o.o.
Capital group: Palomar Capital Advisors Limited - San Leon Energy B.V. Entrepreneurs: Energia Zachód Sp. z o.o., Rawicz Energy Sp. z o.o.
Capital group: KGHM Polska Miedź S.A. Entrepreneurs: KGHM Polska Miedź S.A.
Capital group: Gemini Resources Ltd Entrepreneurs: Gora Energy Sp. z o.o., Liesa Energy Sp. z o.o.
Capital group: UOS Energy Sp. z o.o. Entrepreneur: UOS Energy Sp. z o.o.
Concessions of prospecting and production of coal bed methane
Investment decisions
(w) concession for prospecting and exploration of hydrocarbon deposits and production of hydrocarbon within which production phase was started
mining area designated on the basis of the investment decision for the deposit exploited as part of the concession for prospecting and exploration of hydrocarbon deposits and production of hydrocarbon
Pending applications
submitted according to the article 46 of the Act on Geological and Mining Law
submitted according to the article 49 ea of the Act on Geological and Mining Law
submitted according to the article 13 (3) and 14 of the Act of 11 July 2014 Amending the Act of Geological and Mining Law and certain other acts
Tender areas
areas of finished tender rounds with elaborated geological data packages, currently available for the application in the open door procedure (article 49 ea of the Act of Geological and Mining Law) (III) - number of tender round
Round 5 - status: in preparation
Round 6 - status: in preparation
Round 7 - status: in preparation
Production concessions
Oil production concessions held by PKN Orlen S.A.
Gas production concessions held by PKN Orlen S.A.
LOTOS Petrobaltic S.A.
ZOK Sp. z o.o.
Baltic Gas Sp. z o. o. i wspólnicy Sp. komandytowa
B8 Sp. z o.o. Baltic S.k.a.
TRIAS Sp. z o. o.
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Elaboration: R. Bońda, M. Hodbod, P. Kowalski, D. Siekiera, M.Szuflicki
FUNDED BY NATIONAL FUND FOR ENVIRONMENTAL PROTECTION AND WATER MANAGEMENT

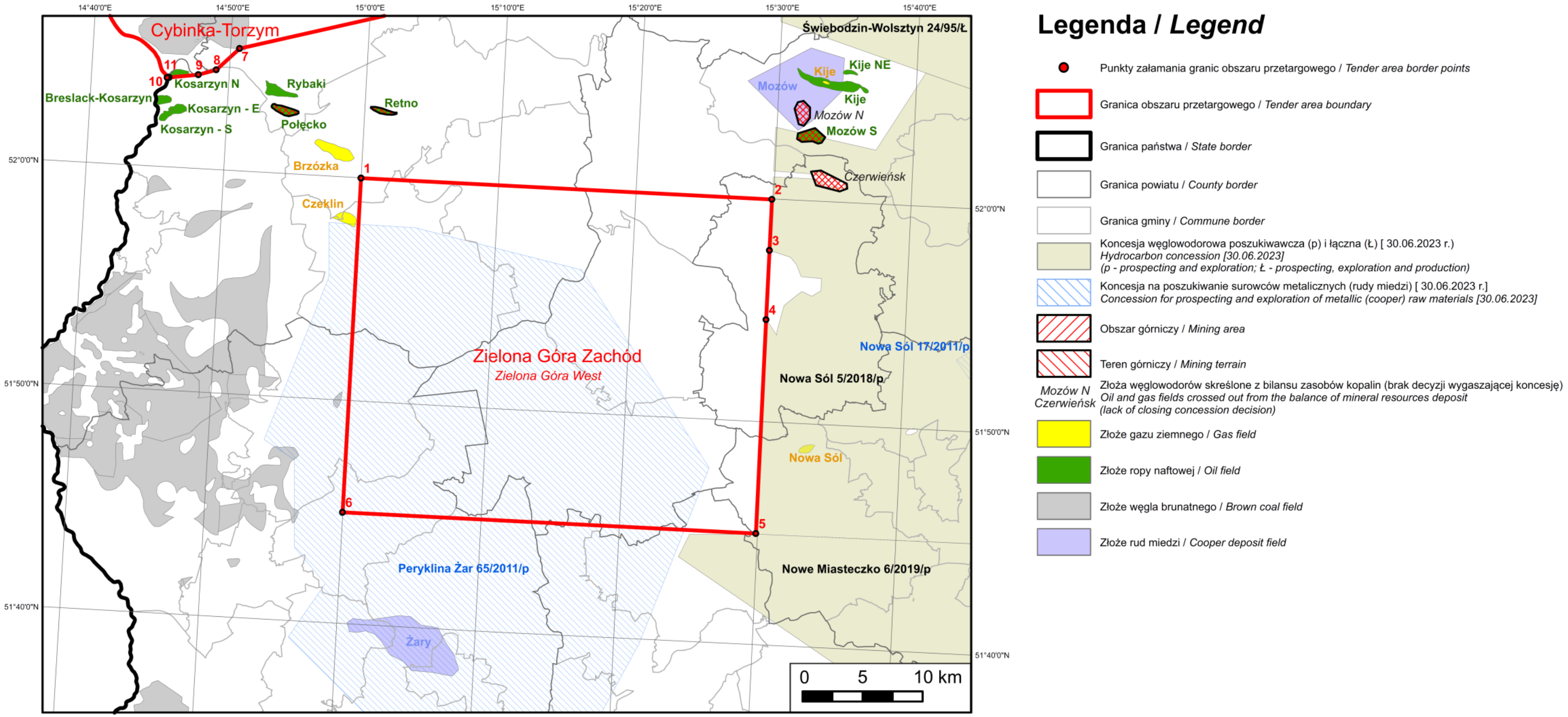


Fig. 1.2. Border points of the Zielona Góra West tender area and location of the hydrocarbon concessions in the neighborhood, as of 30-06-2023 (CGDB, 2023).

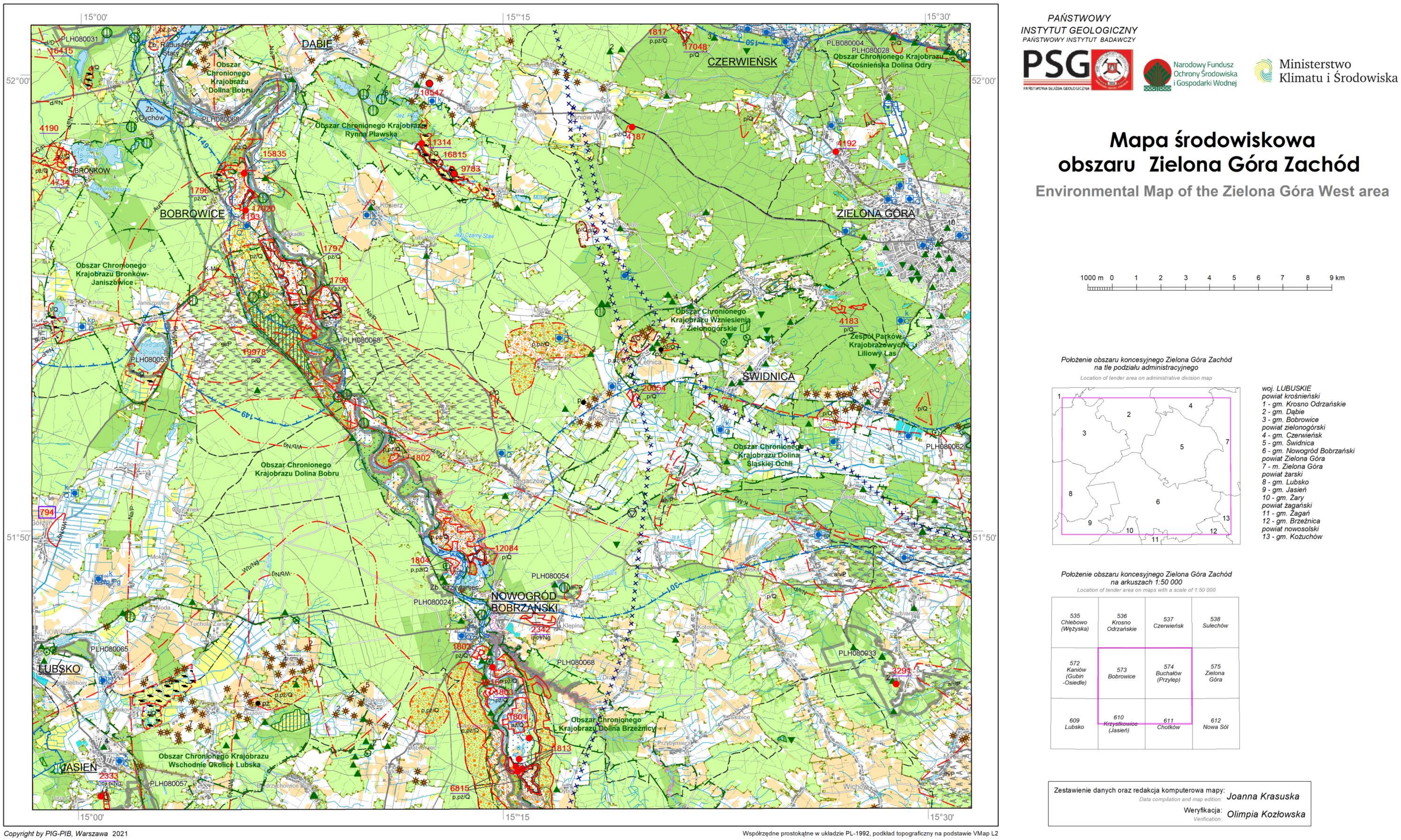
1.2. ENVIRONMENTAL CONDITIONS

THE ENVIRONMENTAL CONDITIONS DATASHEET FOR TENDER AREA ZIELONA GÓRA WEST				
1.	LOCATION OF THE TENDER AREA ON THE MAP	1 : 50 000 geological map sheet	Czerwińsk 537, Bobrowice 573, Przylep 574, Jasień 610, Chotków 611	
2.	POŁOŻENIE ADMINISTRACYJNE	Voivodeship	Lubuskie	
		County	Krosno Odrzańskie	
		The commune and % of the area within the tendering area	Bobrowice (14.76%), Dąbie (10.05%), Krosno Odrzańskie (0.44%)	
		County	Nowa Sól	
		Commune	Kożuchów (2.04%)	
		County	Zielona Góra City	
		Commune	Zielona Góra (8.70%)	
		County	Zielona Góra	
		Commune	Czerwieńsk (4.16%), Nowogród Bobrzański (26.57%), Świdnica (16.86%)	
		County	Żagań	
		Commune	Brzeźnica (1.57%), Żagań (0.25%)	
		County	Żary	
		Commune	Żary (1.13%), Lubsko (6.98%), Jasień (6.49%)	
3.	PHYSIOGRAPHIC REGIONALIZATION (after KONDRACKI, 2013 and SOLON et al., 2018)	Macroregion	Pradolina Warciańsko-Odrzańska (315.6)	
		Mesoregion	Dolina Środkowej Odry (315.61)	
		Macroregion	Wzniesienia Zielonogórskie (315.7)	
		Mesoregion	Wzniesienia Gubińskie (315.71), Dolina Dolnego Bobru (315.72), Wysoczyzna Czerwieńska (315.73), Wał Zielonogórski (315.74)	
		Macroregion	Obniżenie Dolnołużyckie (317.2)	
		Mesoregion	Kotlina Zasiecka (317.23)	
		Macroregion	Obniżenie Milicko-Głogowskie (318.3)	
		Mesoregion	Obniżenie Nowosolskie (318.31)	
		Macroregion	Wał Trzebnicki (318.4)	
		Mesoregion	Wzniesienia Żarskie (318.41), Wzgórza Dalkowskie (318.42), Dolina Środkowego Bobru (318.47)	
4.	COORDINATES OF THE TENDER AREA BORDER POINTS	PL-1992 [X; Y]	466864.29	225534.14
			465099.30	259706.65
			460854.86	259501.20
			455090.39	259224.01
			437314.83	258369.88
			439083.64	224005.94
5.	SURFACE OF THE TENDER AREA	[km^2]	954.57	
6.	CONCESSION TYPE		prospecting, exploration and production of hydrocarbons	
7.	AGE OF HYDROCARBON FORMATION		Permian – Rotliegend, Main Dolomite	
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		no	
	Landscape Parks		no	
	Protected landscape areas		OChK Rynna Pławska (3%), OChK Dolina Bobru (6%), OChK Dolina Śląskiej Ochli (5%), OChK Wzniesienia Zielonogórskie (2%), OChK Bronków-Janiszowice (3%), OChK Dolina Brzeźnicy (1%), OChK Wschodnie Okolice Lubska (6%)	

THE ENVIRONMENTAL CONDITIONS DATASHEET FOR TENDER AREA ZIELONA GÓRA WEST			
	Natura 2000, (Special Area of Conservation, SAC)		PLH080068 Dolina Dolnego Bobru (1%), PLH080024 Mopkowy tunel koło Krzystkowic (<1%), PLH080053 Jezioro Janiszowice (<1%), PLH080065 Lubski Łęg Śnieżycowy (<1%), PLH080033 Broniszów (1%), PLH080054 Nowogrodzkie Przygiełkowisko (<1%)
	Natura 2000, (Special Bird Protection, SPA)		no
	Nature and landscape complexes		Liliowy Las (<1%)
	Ecological area	[yes (quantity) / no]	19
	Nature monuments		115 (including 187 objects)
	Documentation positions		0
9.	PROTECTED SOIL	[yes / no]	yes
10.	FOREST COMPLEXES	[yes / no]	yes
11.	PROTECTIVE FORESTS	[yes (% of the total area / no]	200.3 km^2 (21.0%)
12.	CULTURAL HERITAGE FACILITIES Archaeological monuments	[yes (quantity) / no]	yes
		Hillfort	2
		Hamlet	97
		Cemetery	12
		others	2
13.	MAJOR GROUNDWATER RESERVOIRS	[yes (number, name and age of the aquifer) / no]	301, Pradolina Zasieki-Nowa Sól, Q; 149, Sandr Krosno-Gubin, Q
14.	PROTECTIVE ZONES OF WATER INTAKE	[yes / no]	yes
15.	SPA PROTECTION ZONES	[yes / no]	nie
16.	FLOOD HAZARD AREA	[yes / no]	yes
17.	POROVEN MINERAL DEPOSITS	[yes (type of mineral deposit)/ no]	yes (natural aggregates, clays, peat)
18.	PROGNOSTIC AND PROSPECTIVE AREAS OF OCCURRENCE OF MINERAL RESOURCES (excluding hydrocarbons)	[yes (type of mineral deposit)/ no]	yes (sand, sand and gravels, peat, brown coal, potassium salts, salt, anhydrites, gypsum, gold)
19.	NATURAL GAS PIPELINES	[yes / no]	no
20.	UNDERGROUND GAS STORAGE	[yes / no]	no
21.	DATE OF THE DATASHEET COMPLETION	17.11.2021	
22.	*DATA COLLECTION AND ELABORATION*	Paulina Kostrz-Sikora, Joanna Krasuska	

Tab. 1.3. The environmental conditions datasheet for the Zielona Góra West tender area.

→**Fig. 1.3.** Environmental Map of the Zielona Góra West area.


PAŃSTWOWY INSTYTUT GEOLOGICZNY
PAŃSTWOWY INSTYTUT BADAWCZY
Narodowy Fundusz Ochrony Środowiska i Gospodarki Wodnej
Ministerstwo Klimatu i Środowiska
Mapa środowiskowa obszaru Zielona Góra Zachód
Environmental Map of the Zielona Góra West area
Położenie obszaru koncesyjnego Zielona Góra Zachód na tle podziału administracyjnego
Location of tender area on administrative division map
woj. LUBUSKIE
powiat krośnieński
1 - gm. Krosno Odrzańskie
2 - gm. Dąbie
3 - gm. Bobrowice
powiat zielonogórski
4 - gm. Czerwieńsk
5 - gm. Świdnica
6 - gm. Nowogród Bobrzański
powiat Zielona Góra
7 - m. Zielona Góra
powiat żarski
8 - gm. Lubsko
9 - gm. Jasień
10 - gm. Żary
powiat żagański
11 - gm. Żagań
12 - gm. Brzeźnica
powiat nowosolski
13 - gm. Kożuchów
Położenie obszaru koncesyjnego Zielona Góra Zachód na arkuszach 1:50 000
Location of tender area on maps with a scale of 1:50 000
535 Chlebowo (Wężyska)
536 Krosno Odrzańskie
537 Czerwieńsk
538 Sulechów
572 Kaniów (Gubin -Osiedle)
573 Bobrowice
574 Buchałów (Przylep)
575 Zielona Góra
609 Lubsko
610 Krzystkowice (Jasień)
611 Chotków
612 Nowa Sól
Zestawienie danych oraz redakcja komputerowa mapy: Joanna Krasuska
Data compilation and map edition
Weryfikacja: Olimpia Kozłowska
Verification
DĄBIE
CZERWIEŃSK
BOBROWICE
ZIELONA GÓRA
ŚWIDNICA
NOWOGRÓD BOBRZAŃSKI
LUBSKO
JASIEŃ
Obszar Chronionego Krajobrazu Dolina Bobru
Obszar Chronionego Krajobrazu Rynna Pławska
Obszar Chronionego Krajobrazu Krośnieńska Dolina Odry
Obszar Chronionego Krajobrazu Bronków-Janiszowice
Obszar Chronionego Krajobrazu Wzniesienia Zielonogórskie
Zespół Parkowo-Krajobrazowy Liliowy Las
Obszar Chronionego Krajobrazu Dolina Śląskiej Ochli
Obszar Chronionego Krajobrazu Dolina Brzeźnicy
Obszar Chronionego Krajobrazu Wschodnie Okolice Lubska
15°00'
15°15'
15°30'
52°00'
51°50'
Copyright by PIG-PIB, Warszawa 2021
Współrzędne prostokątne w układzie PL-1992, podkład topograficzny na podstawie VMap L2

Objaśnienia do Mapy środowiskowej obszaru ZIELONA GÓRA ZACHÓD

Legend of the Environmental Map of the Zielona Góra West 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

- piaski i żwiry – sands and gravels
- iły i łupki ilaste – raw materials
- piaski – sands
- torfy – peats
- gipsy – gypsum
- anhydryty – anhydrite
- 4187 – identyfikator z bazy MIDAS złoża małokonfliktowego – ID from the MIDAS database of the small environmental conflict
- 9783 – identyfikator z bazy MIDAS złoża konfliktowego – ID from the MIDAS database of the environmental conflict
- 794 – identyfikator z bazy MIDAS złoża bardzo konfliktowego – ID from the MIDAS database of the very environmental conflict
- granica złoża – deposit boundary
- granica obszaru prognostycznego – prognostic area boundary
- granica zweryfikowanego obszaru prognostycznego – verified prognostic area boundary
- granica obszaru perspektywicznego – perspective area boundary
- złoże o powierzchni ≤ 5 ha – deposit with area ≤ 5 ha

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

Symbol kopaliny: / Mineral symbol:

- K-Mg - sole potasowo-magnezowe – potassium-magnesium salts
- G - gaz ziemny – natural gas
- Wb - węgiel brunatny – brown coal
- Na - sole kamienne – rock salts
- Au - rudy złota – gold ores
- p - piachy – sands
- pż - piaski i żwiry – sands and gravels
- t - torfy – peats
- i(ic) - iły i łupki ilaste ceramiki budowlanej – building ceramics raw materials
- gi - gipsy – gypsum
- ah - anhydryty – anhhydrite

Symbol jednostki stratygraficznej: / Symbol of the stratigraphic unit:

- Q - Czwartorzęd – Quaternary
- Ng - Neogen – Neogene
- P - Perm – Permian

WODY POWIERZCHNIOWE I PODZIEMNE

SURFACE AND UNDERGROUNG WATERS

- obszary dolinne zagrożone podtopieniami – valley flood hazard area
- 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
- 301 – granica głównego zbiornika wód podziemnych wraz z jego numerem – principle boundary aquifer with ID number
- granica strefy ochrony pośredniej ujęcia wód – water intake protected area boundary
- Zb. Dychów – zbiornik retencyjny wraz z jego nazwą – water reservoir with its name
- ujęcie wód podziemnych o wydajności 25 - 50 m³/h (k - komunalne, p - przemysłowe, Q - wiek ujmowanych utworów) – underground water intake with capacity 25 - 50 m³/h (k - municipal, p - industrial, Q - age of exploited rocks)
- ujęcie wód podziemnych o wydajności ≥ 50 m³/h – underground water intake with capacity ≥ 50 m³/h

WARUNKI PODŁOŻA BUDOWLANEGO

BUILDING SUBSTRATE CONDITIONS

- tereny osuwiskowe i zagrożone ruchami masowymi – landslides and mass movements hazard area
- obszary (dawnych i obecnych) negatywnych oddziaływań górnictwa – areas (past and present) of negative impact of mining

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
- granice terenów zarządzanych przez Dyrekcję 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
- Fl – granica rezerwatu przyrody (Fl - florystyczny) – boundary of natural reserve (Fl - floristic)
- Obszary Europejskiej Sieci Ekologicznej Natura 2000; kod obszaru – Natura 2000 ecological network; area code
- aleja drzew pomnikowych – avenue of monumental trees
- n – pomnik przyrody żywej (n - liczba obiektów) – animate nature monument (n - numer of objects)
- pomnik przyrody nieożywionej – inanimate nature monument
- użytek ekologiczny – ecological area
- n – użytek ekologiczny o powierzchni ≤ 5 ha (n - liczba obiektów) – ecological area with area ≤ 5 ha (n - numer of objects)
- geostanowisko o znaczeniu lokalnym – geosite of local importance
- n – stanowisko archeologiczne (n - liczba objektów) – archeological site (n - numer of objects)

INFORMACJE DODATKOWE

ADDITIONAL INFORMATIONS

- granica powiatu – disitrct boundary
- granica gminy, miasta – commune or town boundary
- S7 – oś autostrady lub drogi szybkiego ruchu – highway or express route
- ŚWIDNICA – siedziba urzędu gminy, miasta – commune or town office headquarter
- sieć energetyczna najwyższych napięć – high-voltage power network
- granica obszaru przetargowego – boundary of tender area

* *Wykorzystano informacje udostępniane przez: RZGW, GDOŚ, GDLP, IMGW-PIB, NID, PSE, GAZ-SYSTEM, urzędy morskie oraz z baz danych PSG i PSH w PIG-PIB*

* *Data source: RZGW, GDOŚ, GDLP, IMGW-PIB, NID, PSE, GAZ-SYSTEM, maritime offices and from database of PSG and PSH*

2. GEOLOGY
2.1. GENERAL GEOLOGY AND TECTONICS

The Zielona Góra West tender area is located on the Western European Platform, also known as the Paleozoic platform (Nawrocki and Becker, 2017; Żelaźniewicz et al., 2011). Its geological structure consists of three structural units: the Neoproterozoic-Paleozoic basement and the Permian-Mesozoic and Cenozoic sedimentary covers (Figs 2.1–2.2). The basement is divided into two larger structural units. First of them is the Variscan Internides (=Fore-Sudetic Block), occurring in the south-eastern part of the discussed area (Figs 2.1–2.2). They consist of Neoproterozoic-Paleozoic crystalline rocks and strongly metamorphosed sedimentary rocks. The Middle Odra Fault Zone separates the Internides from the second structural unit of the basement – the Variscan Externides. The Externides consist of strongly folded Carboniferous flysch formations of the Wielkopolska fold-and-thrust belt. The sedimentary cover of the Fore-Sudetic Monocline lies discordantly on the basement (Fig. 2.1). It consists of clastic formations of the uppermost Carboniferous, clastic-volcanic sediments of the Rotliegend, Zechstein carbonate-sulphate-evaporite succession and Triassic clastic-carbonate rocks. An important role in the structural evolution of the Permian-Mesozoic cover of the Fore-Sudetic Monocline was played by tectonic movements taking place during the Cimmerian and Laramian orogeny.

The last structural unit in the Zielona Góra West tender area is the Cenozoic cover. It lies flat on the Permian-Mesozoic formations of the Fore-Sudetic Monocline. The Cenozoic stage is represented by the Paleogene-Neogene-Quaternary succession.

In the further part of the study, the characteristics of stratigraphic divisions are presented. Data from wells located in the tender area were used to describe them: Broniszów, Bronków M-27, Chojnowo 1, Dachów 1, Dachów M-24, Dęby 1, Drzonów 1, Drzonów 2, Dychów M-26, Górzyn P-3, Jarogniewice IG-1, Jasień P4, Jeleniów-1, Klępinka, Kosierz 1, Kosierz M-25, Lubiatów 1, Lubiatów M-20, Niwiska 1, Nowa Sól 16, Nowa Sól 18, Nowa Sól 7, Nowa Sól 9, Nowa Wieś P-1, Pajęczno 1, Piaski 1, Stary Zagór 1, Strużka 1, Świdnica-1, Tarnawa M-21, Trzebule 1, Urzuta, Wysoka 1, Wysoka 2, Żarków 1, Żarków 2, Żarków 3, Żarków 4. Their location can be found in Fig. 2.3.

The basement was identified in 3 wells in the southern and south-western parts of the tender area (see section 2.2.1. Formations older than Carboniferous). They consist of Neoproterozoic-Lower Paleozoic crystalline rocks and metamorphic sedimentary rocks. In the Variscan structural plan (Fig. 2.1), the area of occurrence of crystalline and metamorphosed rocks is limited by the Middle Odra Zone (Kiersnowski and Petecki, 2017). This boundary consists of a series of faults with a course similar to the NW-SE direction and separates the area of the Internides from the Variscan Externides. In addition, the Variscan Internides themselves have a blocky internal structure. The tectonic blocks are separated by numerous faults in the NW-SE and NE-SW directions. In the sub-Permian plan, the depth of the basement varies from about 500 to 1500 m.

The Neoproterozoic-Lower Palaeozoic basement is overlain by strongly inclined (up to 90°) Lower Carboniferous, cut by a network of numerous faults, in some cases having the nature of thrusts (Pożaryski and Dembowski, 1983; Kudrewicz, 2007). They emphasize the block structure of the basement. These faults were formed in the Late Carboniferous during Variscan deformations. The post-Variscan structural deformations affected the clastic-volcanic formations of the Rotliegend. To the north of the Middle Odra Fault Zone, there is a zone of Middle Odra Rifts (Fig. 2.4). It is associated with the thinning of the Earth's crust (Oberc, 1990), as well as with an extensive system of deeply rooted steep faults, probably of a shifting nature (Kiersnowski and Petecki, 2017). The Middle Oder Rift Zone played an important role during the sedimentation of the Carboniferous and Permian. Their deposition took place in a series of tectonic trenches (often interconnected) located along the rift zone. The formation of the trenches and their tectonic activity was probably related to the shifting regime (Aleksandrowski 1995; Aleksandrowski et al., 1997). According to Kiersnowski and Petecki (2017, after Aleksandrowski – unpublished information, 2016), the southern part of the area of the Wielkopolska fold-and-thrust belt can be divided into northern internides and southern externides, the border of which is the range of the Middle Odra Rift Zone (Fig. 2.4). In the light of the above division, the south-western part of the Zielona Góra West tender area belongs to the Variscan Internides, and the remaining part to the northern internides. Throughout the tender area, the formations of the Laramie structural stage lie discordantly on the older rocks. The reduction in the profile of Mesozoic rocks was related with Cimmerian and Laramian tectonic movements. In the sub-Cenozoic structural plan (Fig. 2.1), the Laramian structural stage is characterized by a banded system of outcrops with a general inclination not exceeding 5° towards the north-east (Deczkowski and Gajewska, 1977). This surface is cut by numerous faults running NW-SE, N-S and NE-SE. Some of these faults form a system of tectonic trenches of compression nature (Sokołowski, 1967; Podemski, 1973; Deczkowski and Gajewska, 1977, 1980). They have older tectonic assumptions (Deczkowski and Gajewska, 1977, 1980), the beginning of which is dated to the Keuper-Rhaetian breakthrough (Deczkowski and Gajewska, 1977, 1980), and even to the Early Triassic (Grocholski, 1991; Kwolek, 2000). The final reconstruction of the system of Triassic trenches and the remaining sub-Cenozoic surface occurred as a result of tectonic movements of the Laramie orogeny.

The last one identified in the Zielona Góra West tender area is the Cenozoic structural unit. It lies horizontally. The deposits are represented by Paleogene-Neogene-Quaternary clastics. Large-scale glacitectonic disturbances were observed in the Quaternary sediments (Markiewicz, 2010). Their formation is related to the neotectonic reactivation during the Pleistocene glaciations (Markiewicz and Litwin, 2002; Markiewicz and Winnicki, 2005, 2007a, b; Markiewicz, 2007).

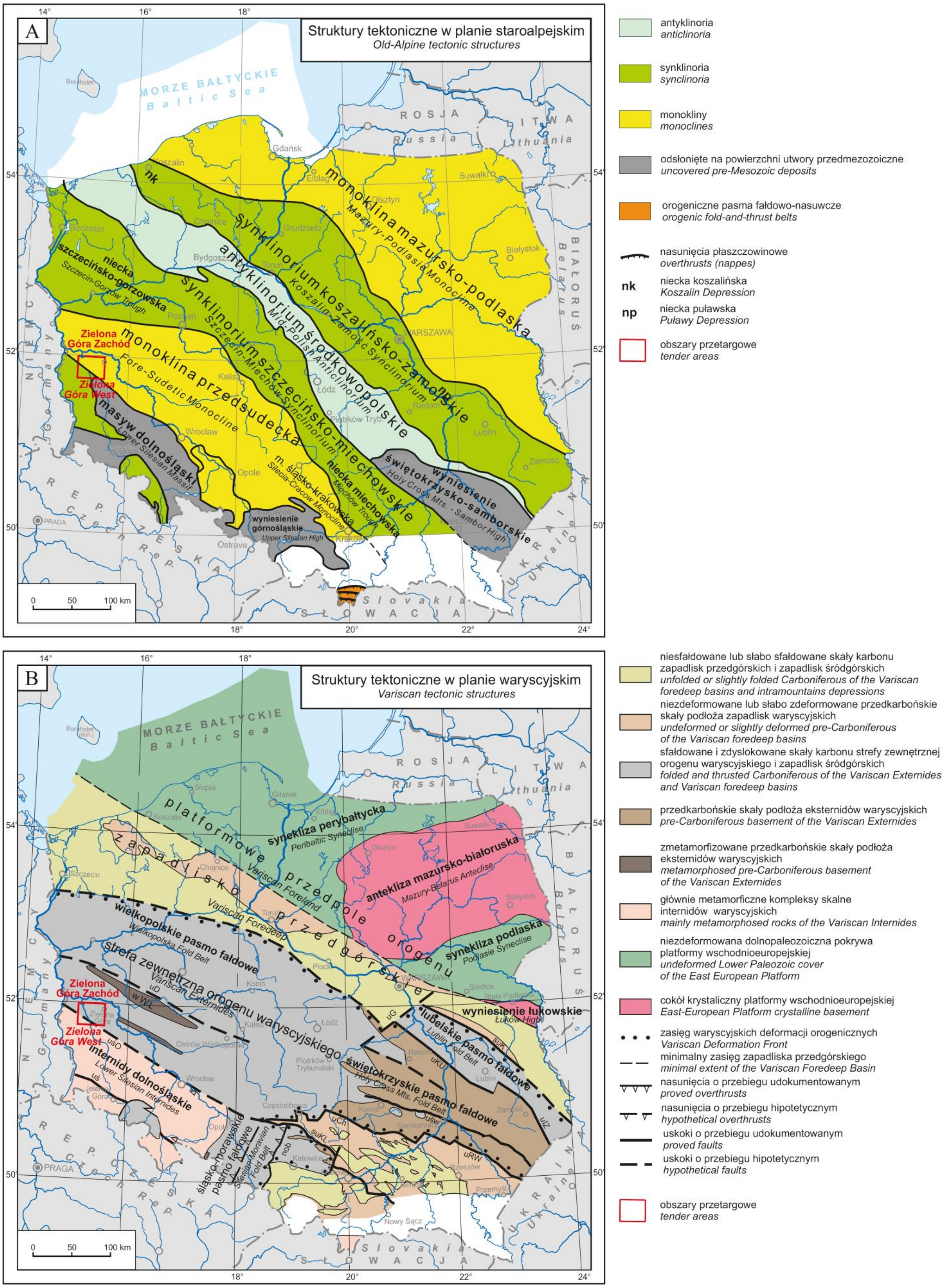


Fig. 2.1. A. Location of the Zielona Góra West tender area in relation to the Old-Apline tectonic structures (Nawrocki and Becker, 2017; modified). **B.** Location of the Zielona Góra West area in relation to the Variscan tectonic structures (Nawrocki and Becker, 2017; modified).

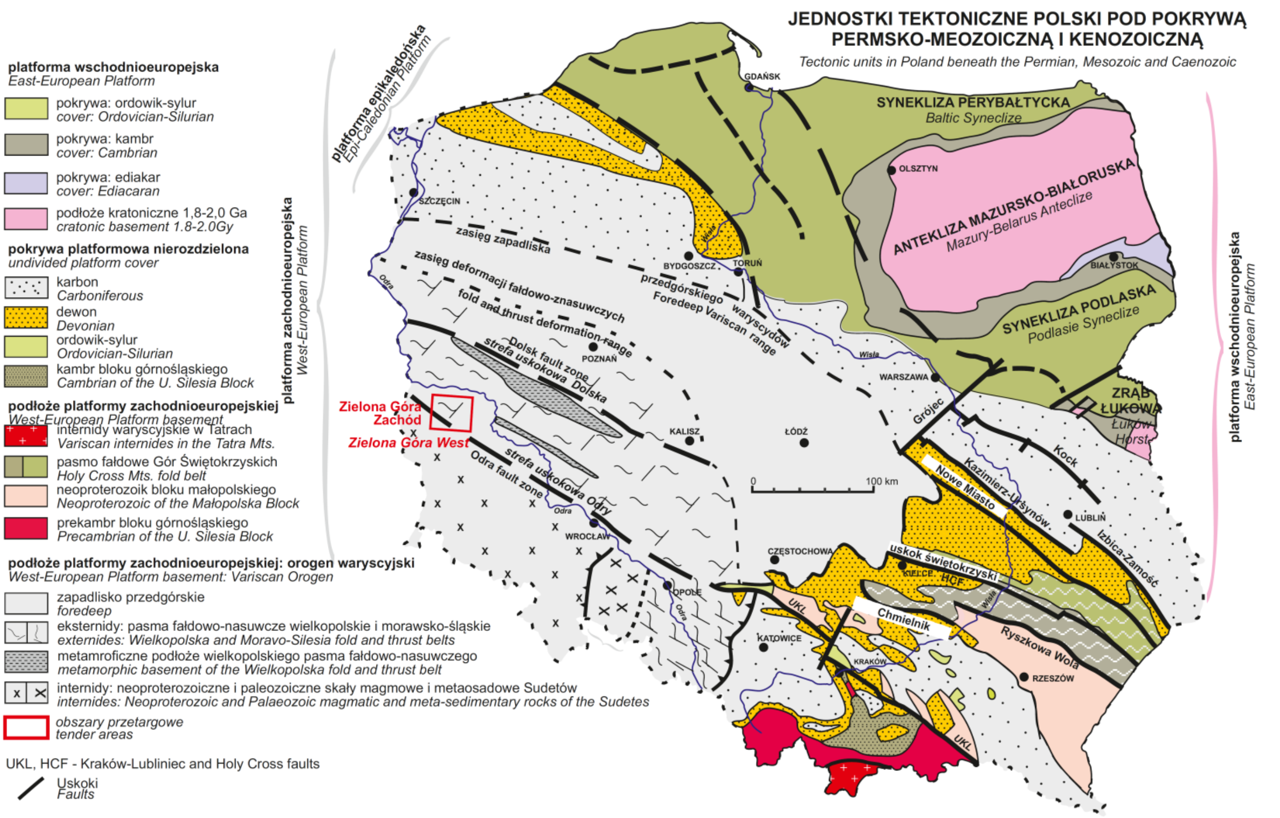


Fig. 2.2. Location of the Zielona Góra West tender area in relation to the main tectonic units in Poland beneath the Permian, Mesozoic and Cenozoic (Żelaźniewicz et al., 2011; modified).

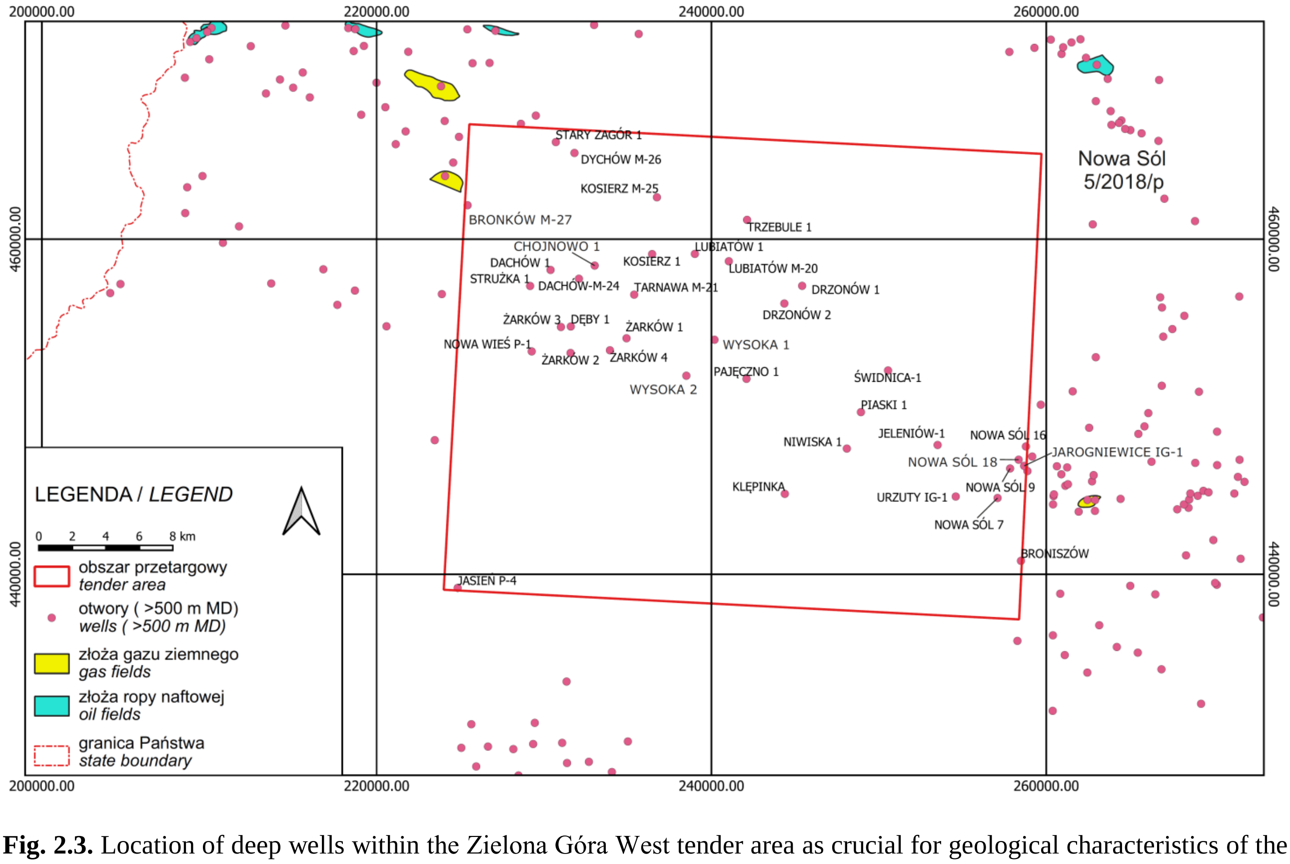


Fig. 2.3. Location of deep wells within the Zielona Góra West tender area as crucial for geological characteristics of the area in relation to oil and gas fields.

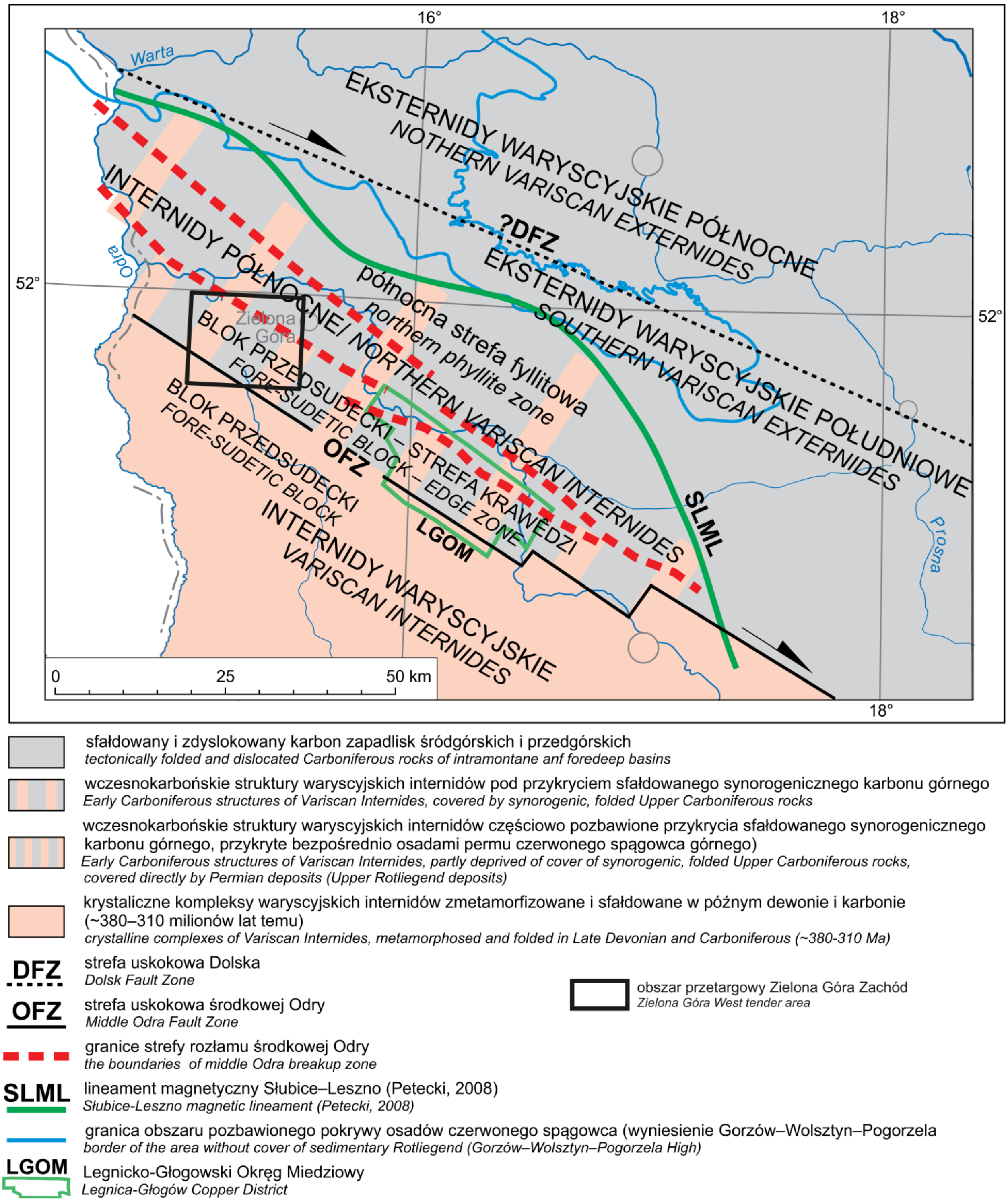


Fig. 2.4. Proposed change of the Variscan Internides and Externides ranges (Kiersnowski and Petecki, 2017).

2.2. STRATIGRAPHY
2.2.1. FORMATIONS OLDER THAN CARBONIFEROUS

Distribution and thickness

In the tender area of Zielona Góra West, in three wells, formations older than the Carboniferous were found. These are (the depths of occurrence of rocks older than the Carboniferous are given according to the geophysical measure):

- Klępinka: 457.4–708.2 m,
- Żarków 2: 929.4–994.1 m,
- Żarków 4: 1041.5–1059.7 m.

Formations older than the Carboniferous occur in the south-western and southern parts of the tender area (Figs 2.5–2.6). The depth of their burial varies significantly. The shallowest deposits are located in the southern part (Fig. 2.7). Towards the north-west a gradual increase in dip is observed. In regional terms, this area is the northern part of the Fore-Sudetic Block. The second zone of formations older than the Carboniferous is located north of the Middle Oder Fault Zone (Devonian; Figs 2.5–2.6). These rocks are characterized by a significant dip towards the NE (Fig. 2.7), consistent with the regional trend.

Lithology and stratigraphy

The oldest identified rocks in the Zielona Góra West tender area are grey and grey-brown feldspar-mica schists, quartzites, amphibolites and gneisses. They are a part of the Proterozoic Middle Odra Metamorphic (Oberc, 1972). The Klępinka well contains siliceous shales, mudstones and limestones. Originally, these deposits were considered to be Cambrian (Milewicz and Koraś, 1971), later analyses indicated that they are Upper Devonian (Upper Frasnian-Lower Famennian). In the Żarków 2 and Żarków 4 wells, granitoids lie directly under the Permian, being associated with magmatism during the Variscan orogeny (Sokołowski, 1967, Milewicz and Wroński, 1975; Górecka et al., 1977).

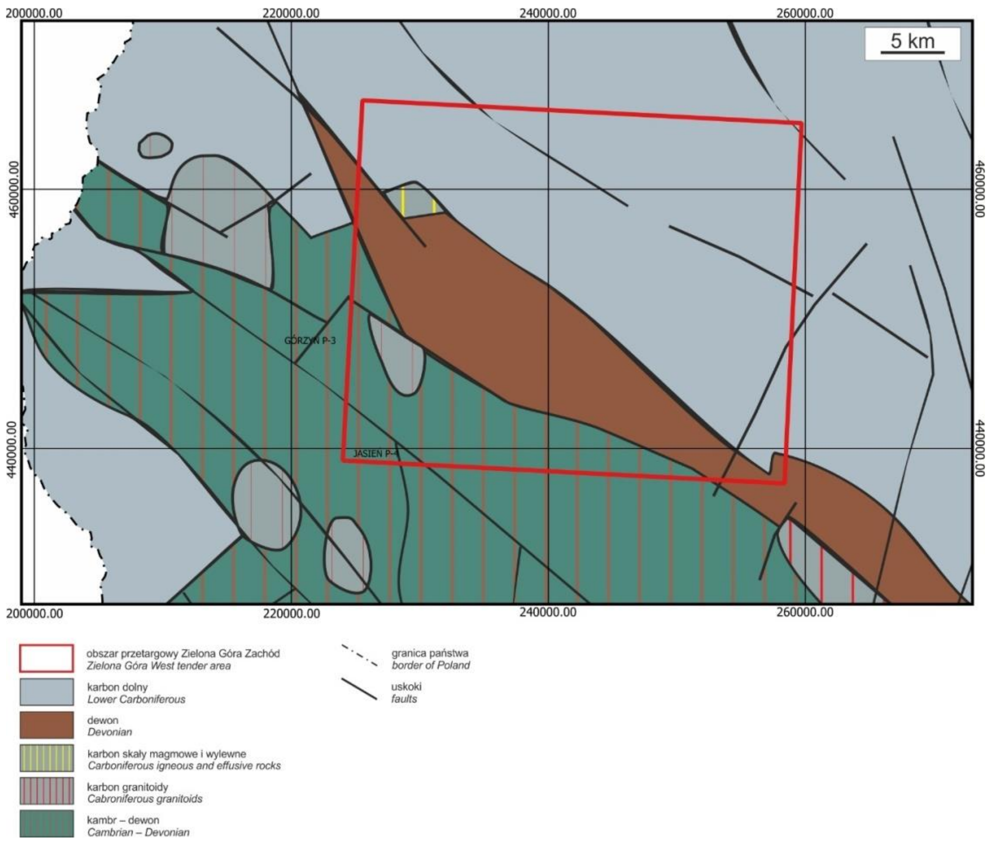


Fig. 2.5. Sub-Variscan surface geological map in the Zielona Góra West tender area and its vicinity (Waksmundzka and Buła, 2017).

2.2.2. CARBONIFEROUS

Distribution and thickness

The Carboniferous was drilled in five wells located in the Zielona Góra West tender area. They are located in its western and south-eastern parts (Fig. 2.3). These are (the depths of Carboniferous are given according to the geophysical measure):

- Dachów 1: 1432.5–1508.0 m,
- Dęby 1: 1049.0–1370.5 m,
- Niwiska 1: 1645.0–1700.0 m,
- Piaski 1: 1870.0–2021.8 m,
- Strużka 1: 1445.0–1492.4 m.

The range of Carboniferous deposits in the tender area is limited. They occur in the north-eastern, northern and extreme north-western parts (Figs 2.5–2.6). The Carboniferous is characterized by a varied burial depth. The shallowest strata occur in the southern part, where the top surface runs at a depth of about 1000 m (Fig. 2.7). In the remaining part of the area, the Carboniferous top surface dips to the north-east (Fig. 2.7). It decreases only in its extreme, north-eastern part, where the (most likely?) Carboniferous formations reach a burial depth of over 3000 m (Fig. 2.7).

Lithology and stratigraphy

In the Dęby 1 well, the Carboniferous consists of highly inclined sandstones, mudstones and claystones. Despite the lack of paleontological research, the deposits have been classified as Lower Carboniferous (Krawczyńska-Grocholska and Grocholski, 1976). The Carboniferous in the remaining wells is represented by brown-red and grey claystones, mudstones with inserts of fine- and medium-grained sandstones. These rocks are characterized by the presence of numerous cracks, tectonic mirror surfaces, as well as a high angle of dip of the laminae/layers, reaching up to 90°. According to Żelichowski (in: Wierzchowska-Kicułowa, 1984, 1987), the Carboniferous deposits occurring in e.g. Dachów 1, Niwiska 1, Piaski 1 and Strużka 1 wells should be treated as the Upper Westphalian-Stephanian molasses (Fig. 2.6). In addition, on the basis of the lithological variability of these sediments, two informal lithostratigraphic units were distinguished: arkose-greywacke (lower unit) and quartz sandstone (upper unit). In the wells mentioned above, the Carboniferous rocks represent the arkose-greywacke series (Żelichowski; in: Wierzchowska-Kicułowa, 1984, 1987).

Petrography

The petrographic characteristics is based on the information from 5 final well documentations in which Carboniferous was drilled (see above).

Claystones are cherry, dark brown, grey in color, sometimes with a violet or greenish tint. They are characterized by a pelitic-aleuritic-psamitic structure and a unorganized or directional texture, emphasized by the laminae rich in or devoid of iron oxides, mica, or the presence of finer and coarser grained material. The shale fissility of the rock is characteristic. Claystones are mainly composed of illite, kaolinite, pelitic quartz, muscovite, biotite, chlorite, and hematite. Among the clastic material, quartz dominates, with sharp-edged grains ranging in size from 0.01 to 0.08 mm. In addition, there are albite, volcanic rock fragments and biotite, as well as accessory minerals (zircon, rutile, apatite and epidote). Hematite occurs in a dispersed form or forms streaks, giving the rock a brick color. The green color of the rock is associated with the presence of chlorites. The veins crossing the claystones are filled with carbonates (including calcite), quartz and iron oxides, locally with anhydrite.

Mudstones are red-brown, grey-brown, grey-purple and green. They are characterized by an aleuritic structure and an unorganized or directional texture, emphasized by the muscovite or biotite plaques. The main components of the rock are quartz grains (with an average size of 0.01–0.05 mm) and feldspar (including acid plagioclase). The content of these minerals in the rock is similar. Feldspars are often sericitized, rarely carbonated. In addition, there are significant amounts of muscovite and biotite plaques, most of which are transformed into chlorites. Some of the muscovite may have been recrystallized. The chlorites dispersed in the rock are responsible for the green color. Few, very fine grains of zircon are present as the accessory minerals. The grains in the rock interact with each other, and the lamellar minerals in places indicate advanced recrystallization, which may indicate diagenetic or even metamorphic changes. The matrix is made of quartz, illite/muscovite and chlorites. Small, irregular concentrations of opaque minerals, iron oxides, are common. Two generations of veins cutting through the rock were distinguished: the older – filled with quartz and the younger – quartz-carbonate. The carbonate probably represents ankerite or siderite. In thicker veins, quartz crystallizes from the edges to the inside, forming automorphic pillars ending in pyramids.

Heteroliths are composed of alternating packages of claystones and mudstones, arranged parallel to each other. The sandstones are grey in color, pink and grey-brown in places. They are compacted, characterized by a grained structure, from very fine-grained to coarse-grained, conglomerated. The texture of the rock is chaotic or directional, emphasized by the linear arrangement of grains. The rocks are represented by arkose arenites (Strużka 1) and wackes, probably sub-arkose ones (Dachów 1, Niwiska 1, Piaski 1). The granular material is poorly rounded, sharp-edged, poorly sorted. The main component of sandstones is quartz with the most common grain size of 0.06–0.4 mm, in some places >1 mm, and feldspars (potassium feldspars and plagioclases). In feldspars, the effects of sericitization are visible, less often carbonation. The micas, whose content is variable, include muscovite and biotite, which is often transformed into chlorites. Rock fragments are quartzites, phyllites, granites and fragments of volcanic rocks (melaphyre type), claystones and mudstones. The matrix of the sandstones is composed of fine clay-hydroscale mass and quartz pelite, carbonate cement (dolomite?) and opaque minerals (hematite), which bring brown color of the rock.

Volcanic rocks – heavily altered melaphyres – were identified at a depth of about 1052.7 m in the Dęby 1 well. The color of the rock is cherry red with irregular cracks filled with carbonates. The rock matrix is built of microliths of highly sericitized albite and a substance rich in iron oxides and carbonates. The phenocrystals are composed of sericitized albite and quartz. Moreover, there are chlorite-calcite pseudomorphs, sometimes containing quartz and quartz fragments (cracked, corroded grains). Phenocrystals and xenoliths are surrounded by coatings of iron oxides.

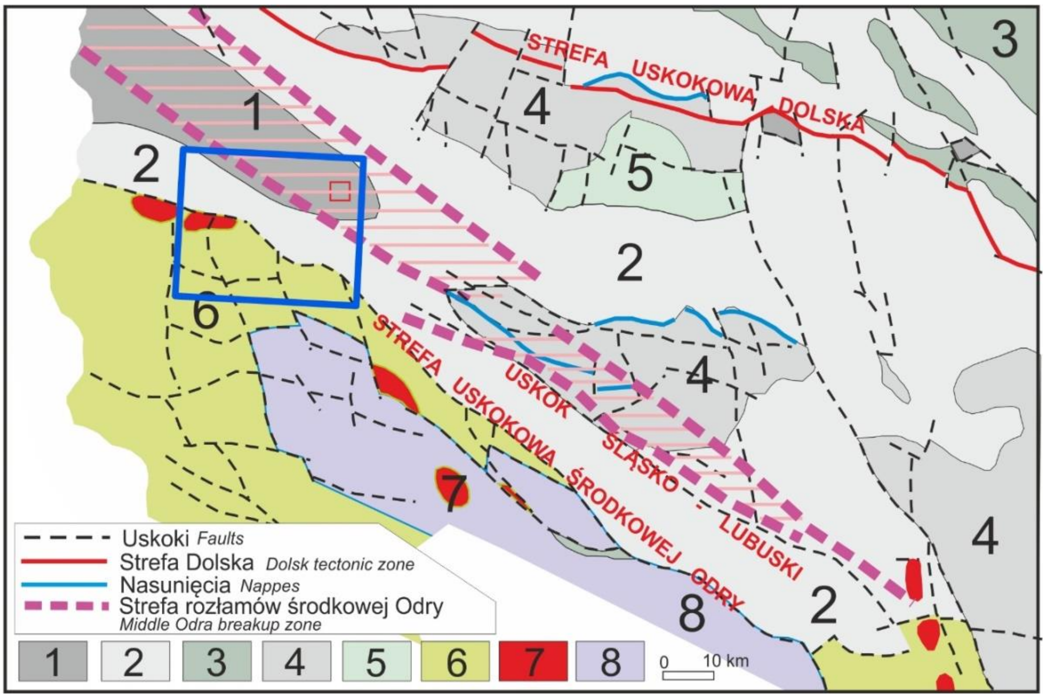


Fig. 2.6. The Zielona Góra West tender area (blue line) on the geological sketch map of the sub-Permian basement of the Variscan foreland and fold-and-thrust belt (according to Wierzchowska-Kicułowa, 2007; Kiersnowski and Petecki, 2017). Explanation of colors and their numbers: 1 – youngest molasses – Stephanian-Autunian, 2 – older molasses – upper Namurian-Westphalian, younger molasses – Westphalian, 3 – younger flysch – Lower Carboniferous, Namurian and Lower Westphalian deposits folded in early Westphalian, 4 – older flysch – Upper Devonian, Lower Carboniferous and Lower Namurian, folded in the Lower Namurian, 5 – phyllites of the Leszno Block – pre-flysch structural stage, epimetamorphic series folded in the Bretonian or Early Variscan phases, 6 – Permian-Mesozoic sedimentary rocks of the Fore-Sudetic Block, 7 – granitoids, 8 – crystalline rocks of the Fore-Sudetic Block.

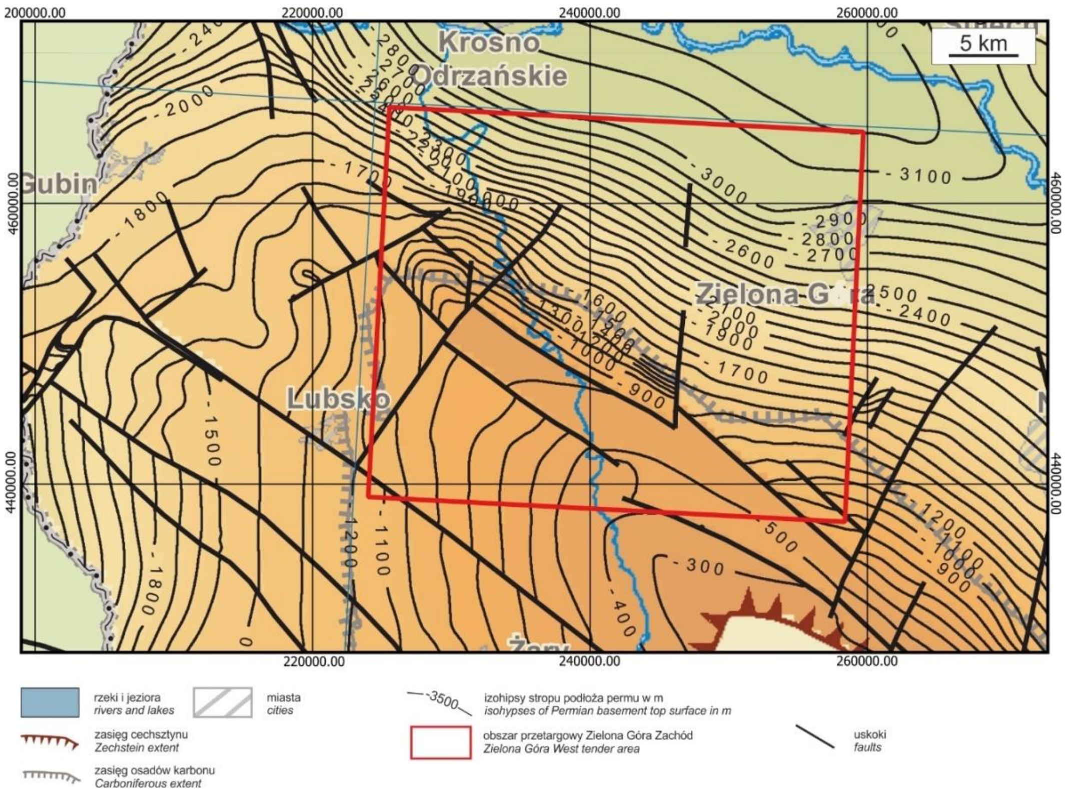


Fig. 2.7. Location of the Zielona Góra West tender area on the map of the Permian basement top surface (Kudrewicz, 2007).

2.2.3. PERMIAN – ROTLIEGEND

Distribution and thickness

The Rotliegend deposits in the Zielona Góra West tender area were drilled in 27 wells (Fig. 2.3). Most of them only reached the Rotliegend rocks, only 7 of them drilled through to the Carboniferous or pre-Carboniferous. These are (the depths of the Rotliegend are given according to the geophysical measure):

- Broniszów: 785.5–791.5 m,
- Bronków M-27: 1508.3–1564.0 m,
- Chojnowo 1: 1505.0–1530.1 m,
- Dachów 1: 1375.0–1432.5 m,
- Dachów M-24: 1482.3–1538.4 m,
- Dęby 1: 1040.0–1049.0 m,
- Dychów M-26: 1911.6–1930.0 m,
- Jasień P-4,
- Jeleniów 1: 1449.5–1492.3 m,
- Klępinka: 418.8–457.4 m,
- Kosierz M-25: 1784.8–1810.0 m,
- Lubiatów 1: 1350.0–1451.4 m,
- Lubiatów M-20: 1638.7–1662.0 m,
- Niwiska 1: 1282.0–1645.0 m,
- Nowa Wieś P-1: 970.3–1012.0 m,
- Piaski 1: 1414.0–1870.0 m,
- Stary Zagór 1: 1962.5–1984.6 m,
- Strużka 1: 1299.7–1445.0 m,
- Tarnawa M-21: 1450.0–1466.0 m,
- Trzebule 1:1847.5–2666.7 m,
- Urzuty IG-1: 1248.6–1250.0 m,
- Wysoka 1: 1420.0–1440.7 m,
- Wysoka 2: 1285.0–1305.0 m,
- Żarków 1: 1363.5–1363.6 m,
- Żarków 2: 923.7–929.4 m,
- Żarków 3: 1162.0–1214.6 m,
- Żarków 4: 1039.5–1041.5 m.

The Rotliegend rocks are widely distributed within the tender area; the exception is the south-western and southern parts, where these rocks are absent (Fig. 2.8). The depth of the Rotliegend top surface varies from about 600 m to over 1900 m (Fig. 2.9). This surface dips gradually towards the north. If to consider the facies development of the Lower and Upper Rotliegend Basin, it could be concluded that the tender area was located in the marginal western part of the Silesian Basin. Its location has a direct impact on the occurrence of individual lithostratigraphic units and their thickness. The southern part of the Zielona Góra West area is characterized by a reduced thickness of the Rotliegend, not exceeding a few meters (Żarków 2 and Żarków 4 wells). Towards the center part of the basin, the thickness of Rotliegend rocks increases. This is confirmed by the Niwiska 1 (363.0 m) and Piaski 1 (456.0 m) wells.

Lithology and stratigraphy

Two lithostratigraphic subdivisions of the Rotliegend are in use. The first, formal (Wagner et al., 2008), was developed by Karnkowski (1987; Fig. 2.10) and is based on generalized lithological variability in the Rotliegend Basin. The second lithostratigraphic subdivision, informal, proposed by Pokorski (1981, 1988, 1997; Fig. 2.10) has features of allostratigraphy and tectonostratigraphy, which enables its correlation with sediments of the North German Basin (Hoffmann et al., 1997). An informal subdivision, as having more international character, was used to analyse and describe the Rotliegend deposits in this paper.

Lower Rotliegend

In the Zielona Góra West tender area, the occurrence of the Lower Rotliegend deposits was documented in 7 wells. They consist mainly of brown, brown-grey or dark violet trachybasalts and trachyandesites, with numerous green and grey patches (Juroszek et al., 1981). In addition, in some wells there are brown trachybasalatic or trachyandesitic tuffs and conglomerates consisting of boulders of extrusive rocks, turning into brown-red shales. The succession of the Lower Rotliegend in the tender area begins with conglomerates of the Świniec Formation (Fig. 2.10). In the light of the informal lithostratigraphic scheme of volcanic clastic sediments proposed by Kiersnowski (2008), the above-mentioned conglomerates represent a series of sub-volcanic sedimentary rocks. They were drilled in the Klępinka well, and their thickness is 2.4 m. According to Deczkowski et al. (1993), the Świniec Formation reaches its maximum thickness in the Zielona Góra Basin, exceeding 300 m (Hryniewiecka, 1988).

The Świniec Formation/sub-volcanic sedimentary rocks are overlain by volcanic formations classified as the Wielkopolska Volcanogenic Formation (Fig. 2.10). These rocks occur in a large part of the tender area, excluding its south-western marigin (Fig. 2.11). The top surface of the Wielkopolska Vulcanogenic Formation decreases towards the south. The shallowest volcanic rocks were drilled in the Klępinka well, where the top lies at depth of 432.9 m. The deepest volcanic rocks were documented in the Trzebule 1 well, at a depth of 2618.0 m. The thickness of the Wielkopolska Volcanogenic Formation also decreases towards the edge of the basin, and finally the formation wedges out (Fig. 2.10). In a large part of the tender area, the maximum thickness of the Wielkopolska Volcanogenic Formation reaches 100 m (Fig. 2.11). Only near the edges, their thickness increases to over 100 m (Fig. 2.11). The sediments of the formation may be separated in some places by complexes of sedimentary rocks of various thicknesses. In the Niwiska 1 well, on the tuffs of the lower part of the formations, conglomerates with pebbles of extrusive rocks are deposited first, which turn into brown-red shales. The above sediments, in the light of the informal lithostratigraphic scheme (Kiersnowski, 2008), represent intra-volcanic sedimentary rocks. In the north-western part of the tender area, rocks of the Supervolcanic sedimentary series are deposited above the Wielkopolska Volcanogenic Formation (Kiersnowski, 2008; Fig. 2.12). They were formed in alluvial fans and fluvial floodplain environments (Kiersnowski, 2003). They include wet alluvial fans, fluvial channel and river-plain sediments, and sometimes lacustrine deposits (including thin layers of limestones), and complexes identified as alluvial-pyroclastic (Kiersnowski, 2003). The deposition of Supervolcanic series took place in the western part of the Zielona Góra Basin (Kiersnowski, 2008). The thickness of these rocks is varied and ranges from 0 m in the marginal part to over 500 m in the central part of the basin (Fig. 2.12).

Upper Rotliegend

Between the Lower and Upper Rotliegend there is a time gap of at least 10 million years (Nawrocki, 1995) or even 20 million years (personal information: H. Kiersnowski, 2021), during which erosion and peneplenisation of the volcanic cover occurred.

The Upper Rotliegend (Saxonian) rocks consist mainly of fine and medium grained sandstones, as well as conglomerates, coarse-grained sandstones, mudstones and claystones. They are developed in aeolian and alluvial environments (alluvial fans) and fluvial channels (Fig. 2.8). The main source of clastic material was previously deposited sediments, which were repeatedly processed. It also came from outcrops of the pre-Permian rocks, located e.g. in the south-western part of the tender area (Fig. 2.8). The Upper Rotliegend deposits are deposited on volcanites and sediments of the Lower Rotliegend, as well as on the pre-Permian rocks. The Zielona Góra West tender area in the western part consists of conglomerates and alluvial sandstones facies (Fig. 2.8). The remaining part is dominated by fine- and medium-grained aeolian sandstones, while in the north-eastern part there is probably a thinning of the aeolian cover, under which fluvial deposits appear.

The Upper Rotliegend in the Zielona Góra West tender area monoclinally dips to a north-northwest direction (Fig. 2.9). The Upper Rotliegend top surface dips gradually. The burial depth varies from 783,0 m (Broniszów) to about 2000 m (Stary Zagór 1). Tectonically, the Rotliegend top surface is characterized by a non-complex tectonic structure (Fig. 2.9). The faults of the NW-SE direction have older tectonic assumptions, and cut mainly formations older than the Permian. Only in a few places the Upper Rotliegend rocks are cut by younger faults of the NNE-SSW trend (Fig. 2.9).

The thickness of the Upper Rotliegend varies in the tender area. The lowest values occur in the south-western part, where they reach a maximum of a few meters (Fig. 2.13). In the remaining part of the discussed area, the thickness increases towards the centre (Fig. 2.13). Generally, the thickness of Upper Rotliegend ranges from 2.5 to over 400 m. Its greatest value (over 300 m) in the Zielona Góra West tender area was documented in the Trzebule 1 well.

Rotliegend exploration perspectives

Exploration work carried out in the Zielona Góra West tender area so far, generally did not focus on the hydrocarbon potential of the Upper Rotliegend deposits. If to consider the burial depth and the presence of aeolian facies in a large part of the tender area, the Upper Rotliegend sediments seem to be an attractive prospecting horizon. The petrophysical properties of these rocks are good and very good. Fluid flows were obtained in many wells during sampling of the Upper Rotliegend. The main problem would be potentially low content of methane. The natural gas fields located to the east and north-east of the area (Grochowice, Kulów and Wilcze) are characterized by methane content of up to 50%. The regional trend for gas content in the Upper Rotliegend indicates that the amount of methane decreases in favor of nitrogen (Fig. 2.14). Nevertheless, despite the dominance of nitrogen over methane, to the west of the state border, in Germany, in the Birkholz and Reudnitz wells, there is natural gas with a methane content of about 20% and nitrogen 80%, and these places are considered prospective.

The Rotliegend is weakly recognized in the north-eastern part of the tender area. There are no wells, and the number of seismic lines is small. The regional trend of gas content indicates that this part should have the highest methane content compared to the rest of the area.

Rotliegend petrography

The petrographic research of the Rotliegend deposits in the Zielona Góra West tender area can be obtained e.g. from scientific publications (Kuberska and Kozłowska, 2011; Maliszewska and Kuberska, 2008; Maliszewska et al., 2016) and from the final well reports (Chojnowo 1, Dachów 1, Kosierz M-25, Lubiatów 1, M-20, Niwiska 1, Piaski 1, Stary Zagór 1, Wysoka 1, 2). The following lithofacies were distinguished: conglomerates, sandstones and mudstone-claystones.

Conglomerates are fine- and medium-grained, grey-brown and brown-cherry. They contain about 60% psephitic fraction composed mainly of volcanic rock fragments, with smaller amounts of sedimentary, metamorphic and magmatic rocks. Among the fragments of volcanic rocks (including fragments of extrusive, subvolcanic and pyroclastic rocks), the most numerous are those with alkaline chemistry, rhyolites or dacites with a porphyric or aphyric structure occurring in some places. Among the sedimentary rocks, single fragments of very fine-grained sandstones, mudstones and claystones were distinguished. Metamorphic rocks are represented by quartz fragments, characteristic of cataclasites, while fragments of magmatic rocks are mainly quartz-feldspar fragments. The matrix of the conglomerates corresponds to the composition of medium- and coarse-grained sandstone, and its composition consists of sharp-edged (spindle-shaped) grains of mono- and polycrystalline quartz, feldspars (mainly albite), lithoclasts, similar to those described in the psephitic fraction. The detritic material of the conglomerates is cemented with a clay-ferruginous, carbonate or quartz matrix. The matrix components are distributed unevenly.

Sandstones are characterized by grey, rose-seledine and grey-red colors, often with a visible spotted color. They are fine-grained or multi-grained rocks (poorly sorted). Due to the mineral composition of the sandstones and the type of matrix, sublithic, lithic and subarcosic arenites and wackes were distinguished (nomenclature according to the classification of Pettijohn et al., 1972). The main component of the detritic material is monocrystalline quartz, rarely polycrystalline. Feldspars (microcline, orthoclase, plagioclases of a albite-oligoclase series) occur in the form of sharp-edged or semi-rounded grains. The feldspar grains are partially sericitized. Among the lithoclasts, the most numerous are fragments of volcanic rocks with a similar composition to those described in conglomerates. In addition to the main components listed above, the sandstones contain micas (muscovite, biotite – often chloritized) and, accessorily, zircon. Among the main components of matrix, the following were distinguished: iron oxides and hydroxides, allo- and authigenic clay minerals, carbonates, quartz, occasionally sulphates. Iron oxides and hydroxides are common in the described sandstones, giving them a characteristic reddish color. In the group of authigenic clay minerals, as in the Stypułów 17 well (Kuberska and Kozłowska, 2011), located near the tender area, illite and chlorites were distinguished in grey-seledine sandstones. The most common carbonate mineral is calcite; the presence of dolomite is not excluded. Comparing with the results of a detailed analysis of carbonates in sandstones from the nearby Stypułów 17 wells (Kuberska and Kozłowska, 2011), the Mn-calcite, the most common (yellow or yellow-orange luminescence in CL), and Mn/Fe-calcite (luminescence in orange-red colors) could be distinguished. Autogenic quartz occurs in the form or as single individuals crystallized in pore spaces. In some places, the expanding quartz rims completely closed the free pore spaces.

Sulphates are represented by barite.

Mudstones and claystones are sediments with an aleurite, pelite, and aleurite-pelite structure. They occur in the form of interbeds or inserts within sandstones or conglomerates. Parallel lamination is observed in these rocks. The directional texture is usually marked by the presence of mica and clay minerals.

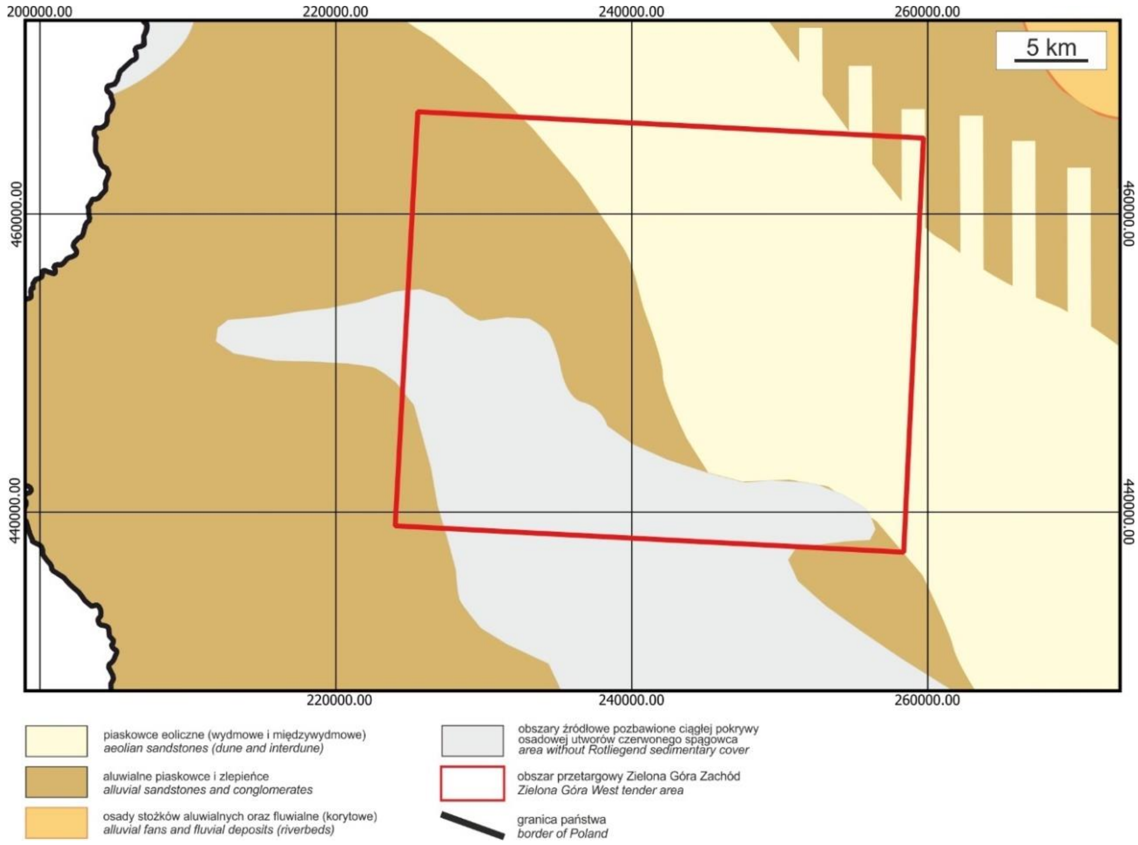


Fig. 2.8. Lithofacies and palaeogeographic map of the topmost part of the Upper Rotliegend in the Zielona Góra West tender area just before the transgression of the Zechstein sea (Kiersnowski et al., 2020).

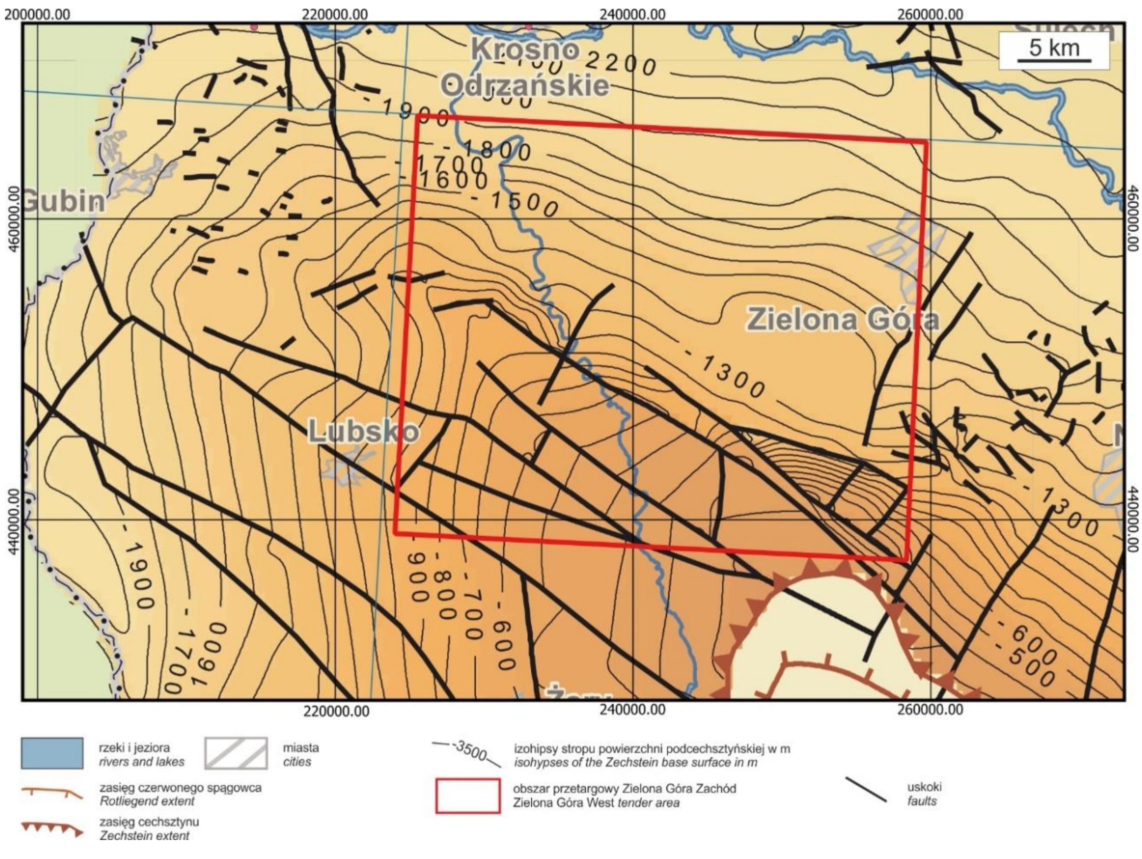


Fig. 2.9. Location of the Zielona Góra West tender area on the map of the Zechstein base surface (Kudrewicz, 2007).

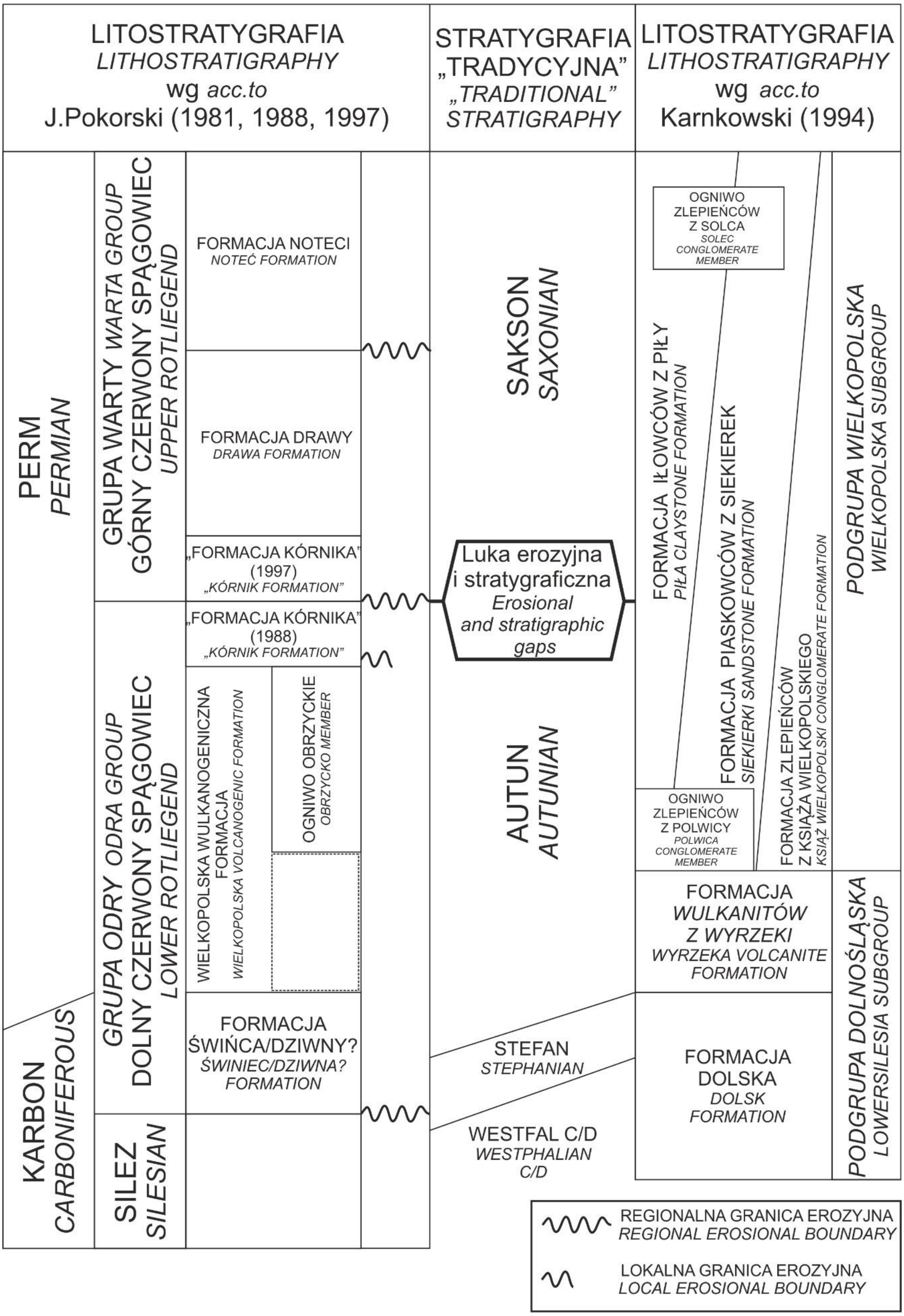


Fig. 2.10. Stratigraphic subdivision of the Rotliegend of the Polish part of the South Permian Basin (Kiersnowski, in: Maliszewska et al., 2003).

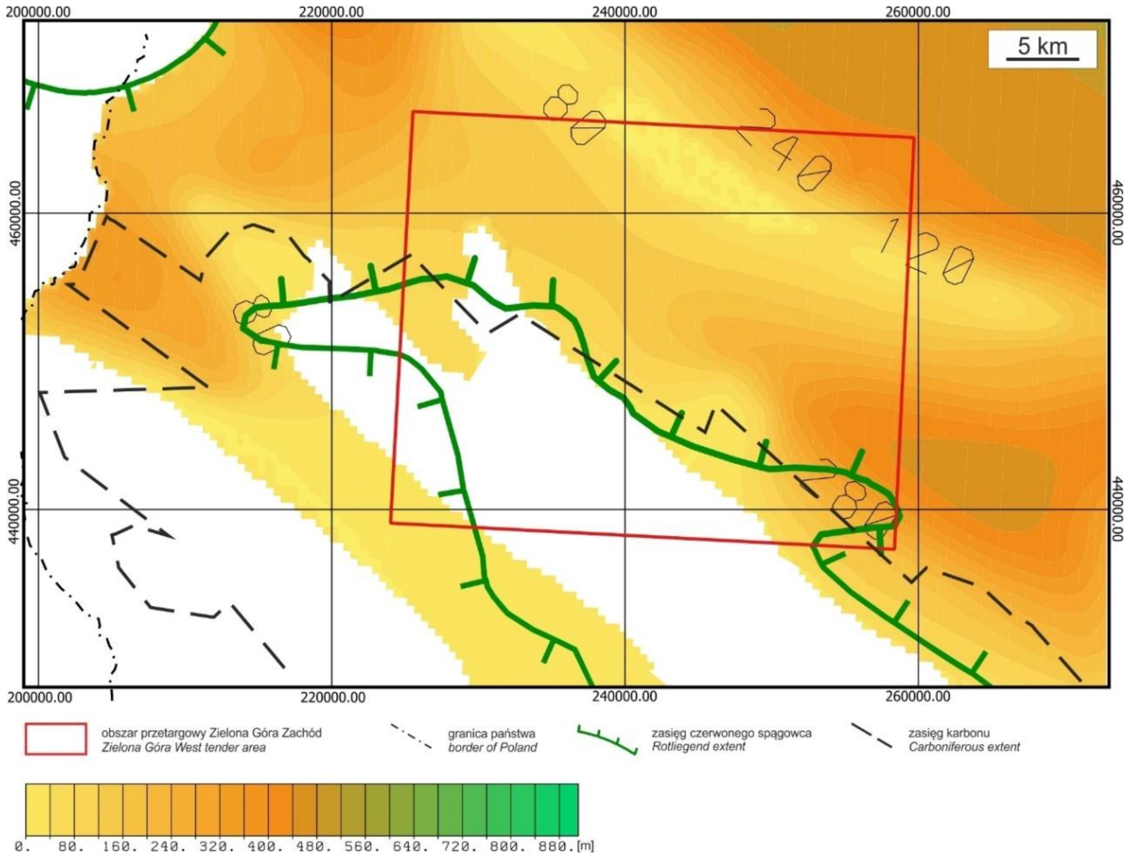


Fig. 2.11. Thickness of the Rotliegend volcanogenic series in the Zielona Góra West and neighboring areas (Wagner et al., 2008).

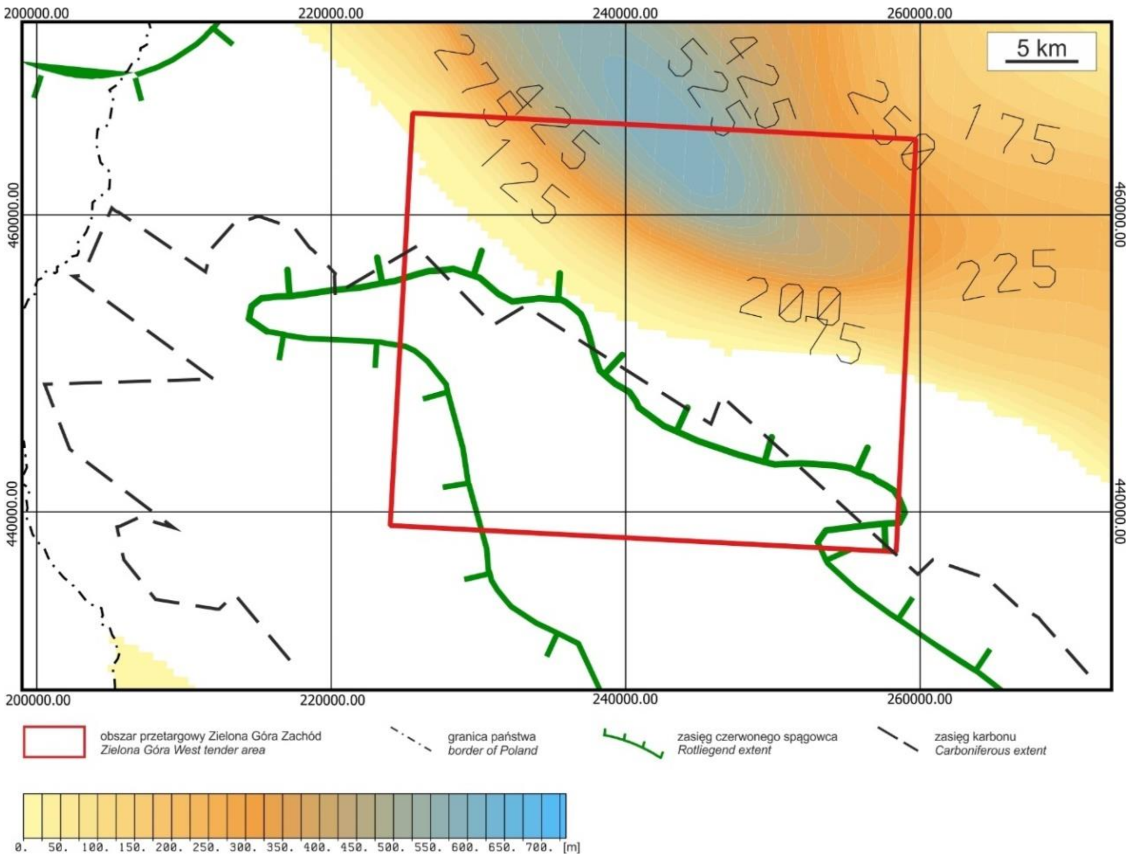


Fig. 2.12. Thickness of the Rotliegend Supervolcanic series in the Zielona Góra West and neighboring areas (Wagner et al., 2008).

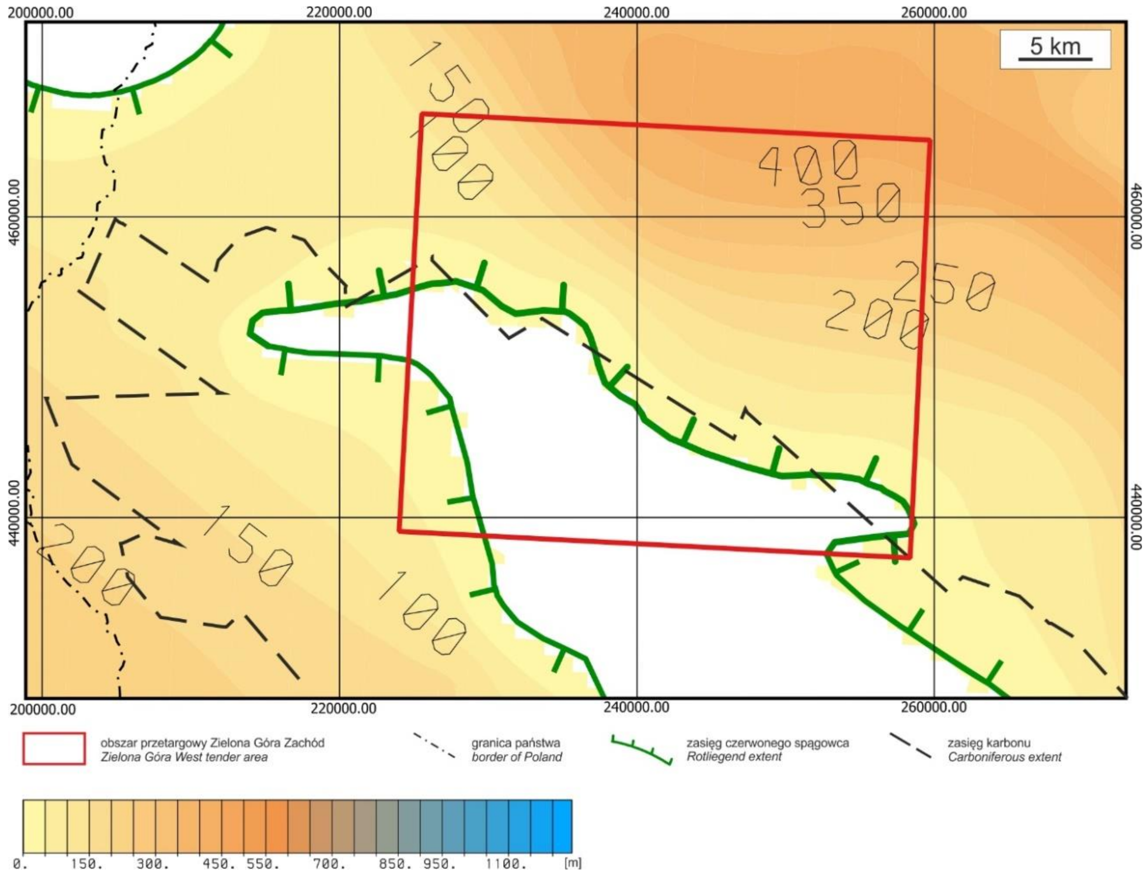


Fig. 2.13. Thickness of the Upper Rotliegend in the Zielona Góra West and neighboring areas (Wagner et al., 2008).

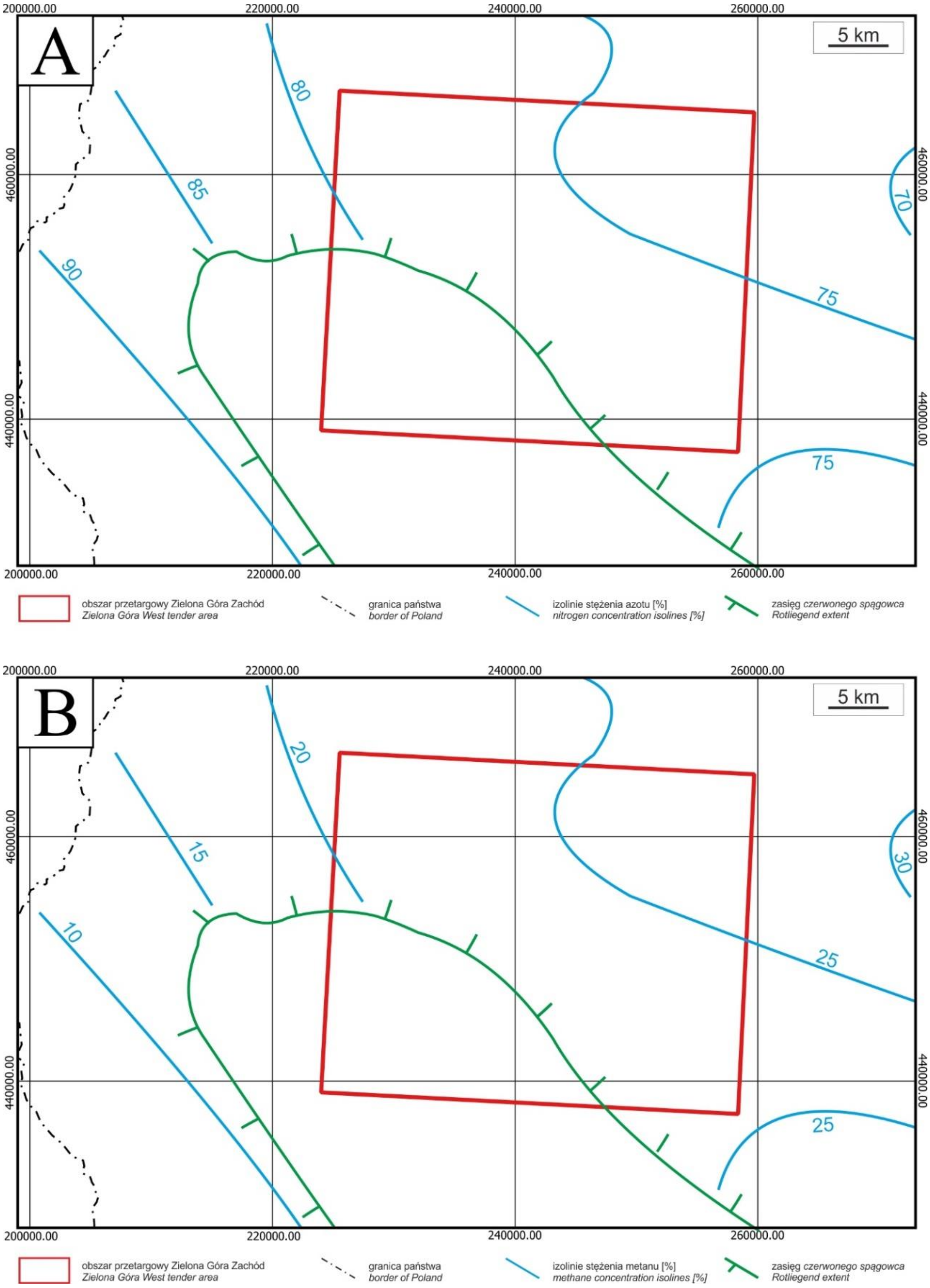


Fig. 2.14. Map of nitrogen (A) and methane (B) content in the Zielona Góra West and neighboring areas (Wagner et al., 2008).

2.2.4. PERMIAN – ZECHSTEIN

Distribution and thickness

In the Zielona Góra West tender area, all wells (except Jarogniewice IG-1) drilled the Zechstein. These are (the depths of the Zechstein occurrence are given according to the geophysical measure):

- Broniszów: 582.0–783.0 m,
- Bronków M-27: 1009.0–1508.3 m,
- Chojnowo 1: 992.0 –1505.0 m,
- Dachów 1: 922.5–1375.0 m,
- Dachów M-24: 953.2–1482.3 m,
- Dęby 1: 737.5–1040.0 m,
- Drzonów 1: 1152.0–1303.0 m,
- Drzonów 2: 1109.0–1434.0 m,
- Dychów M-26: 1354.7 –1911.6 m,
- Jasień P-4,
- Jeleniów 1: 944.5–1449.5 m,
- Klępinka: 278.4–418.8 m,
- Kosierz 1: 1093.0–1415.0 m,
- Kosierz M-26: 1252.3–1784.8 m,
- Lubiatów 1: 907.0–1350.0 m,
- Lubiatów M-20: 1134.2–1638.7 m,
- Niwiska 1: 768.0–1282.0 m,
- Nowa Sól 7: 800.0–1113.2 m,
- Nowa Sól 9: 928.5–1137.3 m,
- Nowa Sól 16: 1041.0 –1299.0 m,
- Nowa Sól 18: 970.5 –1241.6 m,
- Nowa Wieś P-1: 687.0–970.3 m,
- Pajęczno 1: 888.0 –1203.0 m,
- Piaski 1: 907.0–1414.0 m,
- Stary Zagór 1: 1415.5–1962.5 m,
- Strużka 1: 723.0–1299.7 m,
- Świdnica 1: 1070.0–1391.0 m,
- Tarnawa M-21: 971.7–1450.0 m,
- Trzebule 1: 1259.0–1847.5 m,
- Urzuty IG-1: 683.7–1248.6 m,
- Wysoka 1: 953.5–1420.0 m,
- Wysoka 2: 815.0–1285.0 m,
- Żarków 1: 851.5–1363.5 m,
- Żarków 2: 605.0–923.7 m,
- Żarków 3: 800.0–1162.0 m,
- Żarków 4: 746.0–1039.5 m.

The Zechstein succession in the Zielona Góra West tender area is almost complete stratigraphically. The occurrence of all PZ1, PZ2 and PZ3 cyclothems has been documented in the wells, separated in some cases by locally occurring informal levels (central A1s anhydrite, Werra A1 anhydrite, etc.). Only the PZ4 cyclothem is reduced in the tender area. Its range is limited to its central and northern part.

The Zielona Góra West tender area was located in the marginal southern part of the Zechstein Basin. This location determined the accommodation space that the Zechstein sediments had to fill. The Zechstein thickness is the smallest in the southern part of the area (Fig. 2.15).

Lithology and stratigraphy

The Zechstein stratigraphic subdivision developed by Richter-Bernburg (1955) was adopted by Tokarski (1958) and Poborski (1960) for the Polish part of the Permian Basin. In This scheme was modified several times (Wagner et al., 1978; Wagner, 1987, 1988, 1994).

The Upper Permian deposits consist of four cyclothems: PZ1–PZ2–PZ3–PZ4 (Fig. 2.16). The PZ1–PZ3 cyclothems are represented by carbonate-evaporite rocks. Their deposition took place as a result of successive transgressive-regressive cycles (Wagner, 1994; Wagner and Peryt, 1997, 1998). In the case of the last PZ4 cyclothem, the factors controlling precipitation and sediment transport, as well as sedimentary environments, have changed. The previously occurring carbonate-evaporite succession, with the beginning of the sedimentation of the PZ4 cyclothem was replaced by the terrigenous-evaporite sedimentation, associated with climatic fluctuations, depending on the cyclical nature of dry and wet periods (Wagner, 1994). The lower boundary of the Zechstein lies at the base of the Kupferschiefer (T1; Fig. 2.16), or, in the case of absence, at the base of the Zechstein Limestone (Ca1; Fig. 2.12; Peryt and Piątkowski, 1976; Wagner et al., 1978). The top of the Zechstein corresponds to the top surface of the Top Terrigenous Series (PZt; Fig. 2.16).

PZ1

In the Zielona Góra West tender area, the Zechstein begins with the Kupferschiefer (T1; Fig. 2.12). It is represented by grey-black limestones, horizontally laminated, and bituminous shales with fish remains (Wagner, 1994). Their deposition occurred below the storm wave-base in anaerobic conditions (Oszczepalski and Rydzewski, 1987). The thickness of the Kupferschiefer is usually from a few to several dozen centimeters, up to 1 m. The Zechstein Limestone (Ca1) lies above (T1). It consists of grey, dark grey and less often red limestones, which in some cases are replaced by dolomites in the upper part of succession. The Zechstein Limestone deposits were deposited in the shallow basin plain (Fig. 2.17). The thickness of the formations is small, reaching maximum 10 m (Fig. 2.17). At the end of the Ca1 deposition, the water depth in the basin decreased. The consequence was the emergence of areas of the previous carbonate platform and basin plain sedimentation, and the sediments deposited in these zones underwent intensive diagenetic changes (Peryt and Piątkowski, 1976, 1977; Peryt, 1984). Next transgression started the evaporitic phase of sedimentation. In an extremely dry climate, deposition of the Lower Anhydrite occurred (A1d; Wagner, 1994). Nodular anhydrites of extreme shallow environments occur in the lower part of the A1d profile, passing upwards into more deep-water, irregularly layered, laminated anhydrites (Kłapciński, 1991). The thickness of A1d in the tender area is varied and ranges from almost 50 m to over 150 m. Then, the Oldest Halite (Na1) was deposited on the A1d formations. In the shallower zones, salts filled depressions created as a result of A1d sedimentation (Wagner, 1994). The anhydrite barriers limiting them acted as chemical traps that prevented the outflow of heavy, saturated brines. As a consequence, a system of isolated lagoons and salt pans was created (Czapowski, 1983; Czapowski and Tomassi-Morawiec, 1985). The Na1 deposits have been identified in most of wells. Their thickness is varied and ranges from a few meters (Wysoka 2) to over 180 m (Stary Zagór 1). The Na1 in two wells (Kosierz M-25 and Wysoka 2) is divided by Middle Anhydrite (A1s; Fig. 2.18). A similar case was recognized by Dyjaczyński and Peryt (2014) in the northern part of the Wolsztyn embankment. The thickness of A1s is small, reaching a maximum of 12.5 m. In the case of separated Na1 formations, their lower part is distinguished as the Lower Oldest Halite (Na1d; Fig. 2.18), and the upper one as the Upper Oldest Halite (Na1g; Fig. 2.18), reaching a thickness of up to 40 m and 20 m, respectively. The upper part of the PZ1 cyclothem is represented by the Upper Anhydrite (A1g). Its sedimentation was associated with the reintrusion of waters into the Permian Basin. The range of A1g was most likely slightly greater than that of A1d and has the character of a transgressive sequence (Peryt, 1990). Most of wells located in the tender area drill through the A1g rocks. Their smallest thickness was documented in the area of Nowa Sól, where it does not exceed 10 m. In the case of the remaining part of the area, the thickness of A1g is similar and ranges from 20 m to 50 m. In four wells (Broniszów, Lubiatów M-20, Urzuty IG-1 and Żarków 2) the anhydrite succession was not separated by salts. The continuous anhydrite level probably includes the A1d and A1g. In the existing, formal lithostratigraphic scheme of the Zechstein, there is no unit containing a continuous anhydrite profile in the PZ1 cyclothem, although it is distinguished in some studies and databases as the Werra Anhydrite (A1). The A1 deposits may be the facies and temporal equivalent of the succession of two sulphate and one chloride precipitates that were deposited in the marginal part of the evaporite basin (Czapowski et al., 2018). At the end of the carbonate-sulphate-evaporite PZ1 sedimentation, the greater part of the Ca1 carbonate platforms was exposed, which was directly related to their erosion and diagenetic transformations. In the remaining area, sedimentation of the Upper Anhydrite continued, under which the Lower Anhydrite platforms and numerous marginal isolated salt basins, as well as shallow-water open salt basins were hidden (Wagner, 1994). In a large part of the tender area, the thickness of the PZ1 cyclothem ranges from 100 m to over 200 m (Fig. 2.19). Only in the southern part its values do not exceed 100 m. In the north-western part, the thickness of the PZ1 cyclothem exceeds 200 m (Fig. 2.18).

PZ2

Significant ingression of the open-marine waters into the Permian Basin led to the interruption of evaporite-sulphate sedimentation and its replacement by carbonate sedimentation. Therefore, the PZ2 cyclothem begins with the

Main Dolomite (Ca2; Fig. 2.16). This horizon has a transgressive-regressive character (Wagner, 1994). The palaeogeography of the Ca2 was strictly dependent on the palaeomorphology of the A1g. The development of the A1g platform had a direct impact on the width and slope angle of the Ca2 carbonate platforms, as well as on the development of the platform and basin parts. There are three main facies zones in the Ca2 palaeogeography (Wagner, 1994, 1998, 2012), which correspond to separate depositional systems (Jaworowski and Mikołajewski, 2007; Wagner, 2012):

- basin plains,
- slope of carbonate platforms,
- carbonate platforms.

The Zielona Góra West tender area is located in the south-western part of the Polish Zechstein Basin. All three main facies zones occur in its area (Fig. 2.20).

Depositional system of basin plains. In the tender area, the shallower basin plain facies were identified in its north-eastern part. In the paleogeographic reconstruction, this area was a bay deeply intruding into the carbonate platform, which was called the Zielona Góra Bay (Wagner, 1994, 2012). According to Buniak et al. (2013) the extent of the Zielona Góra Bay is smaller. It covers only the northernmost part of the tender area (Fig. 2.21). Differences are the result of lack of wells in the crucial part.

The Ca2 sediments of the shallower part of the basin plain consist of dolomites interbedded with layered mudstones (Jaworowski and Mikołajewski, 2007). There are also thin inserts of wackstones, less often of packstones, the formation of which was associated with the activity of bottom traction currents or suspension currents. The carbonate muds present in the succession were stabilized in some places by microbial activity. In the tender area, the thickness of sediments of the shallower part of the basin plain does not exceed 20 m (Fig. 2.20).

Depositional system of the carbonate platform slopes. Distribution, thickness and type of deposited sediment belonging to the slope facies depended on the palaeomorphology of the A1g platform, the angle of its slope, as well as mechanism of redeposition. In the Main Dolomite deposits, two types of slopes were identified: gentle and steep.

Deposits of a carbonate platform gentle slope were identified in the tender area (Figs 2.20–2.21). In the light of Wagner's interpretation (2012), the gentle slope of the carbonate platform surrounds the Zielona Góra Bay and the Silesian-Sudetic carbonate platform, which are located in the north-eastern part of the tender area (Fig. 2.20). According to Buniak et al. (2013) deposits of a gentle slope occur only in extreme northern part of the area (Fig. 2.21). Differences in interpretation may suggest the need to reanalyse the seismic materials and drill cores, as the extent of the slope is of key importance for oil exploration. For the purposes of this study, the Ca2 palaeogeography was adopted after Wagner (2012; Fig. 2.20). The gentle slope deposits are represented by laminated limestones and dolomites, which in some cases are enriched with fine, subtle streaks of clayey or bituminous laminae. Despite the low angle of the slope, sediments are also deposited as a result of gravity flows (Jaworowski and Mikołajewski, 2007).

The thickness of the Ca2 slope sediments varies from about 20 to over 40 m (Fig. 2.20). In some cases, its significant increase is observed. The large thickness of almost 200 m may be associated with the presence of a more varied shoreline.

Carbonate platform depositional system. The tender area was located in the western part of the Silesian-Sudetic carbonate platform (Wagner, 1994, 2012). Interpretations of the extent of this zone are consistent (Wagner, 1994, 2012; Buniak et al., 2013). In the north-western and eastern part, Wagner (1994, 2012) recognized deposits of a low-energy and high-energy platform plain, respectively (Fig. 2.20). In the western part, south-east of the Kaniów 1 well, Buniak et al. (2013) determined the marginal part of the intra-platform oolite shoal (high-energy platform plain after Wagner, 1994, 2012; Fig. 2.21).

The Zielona Góra West tender area covers the western part of the Silesian-Sudetic platform, there is one facies zone – the platform plain. This zone is separated from the basin plain by a carbonate barrier. In terms of its extent, it is the largest palaeogeographic zone found on the platform area. In addition, it is also characterized by microfacies and bathymetric diversity. Despite slight differences in the bottom palaeomorphology, even small changes in the shallow water environment result in changes in sedimentary regimes. Thanks to them, two zones can be distinguished within the carbonate platform:

- high-energy plain with intra-platform ooid-oncoid shoals,
- low-energy flat zone.

The high-energy zone of the platform plain was formed on local palaeomorphological elevations at the backs of the carbonate barriers. It consists mainly of horizontally and diagonally layered ooid-oncoid and peloid grainstones and packstones (Jaworowski and Mikołajewski, 2007). The high-energy zone of the platform plain has been identified with numerous wells in the south-eastern part of the tender area. Sediments identified in this zone are up to 50 m thick (Fig. 2.20).

The low-energy platform plain occurs in the north-western part of the tender area (Fig. 2.20). The sediments of the low-energy plain consist mainly of dark-grey sublittoral carbonate muds and sands, also carbonate mudsands and microbial mats forming wackstones, mudstones, less often packstones and boundstones (Jaworowski and Mikołajewski, 2007).

Main Dolomite exploration prospective

In the Zielona Góra West tender area, the hydrocarbon exploration of the Ca2 was carried out from the 1960s to the end of the 1980s. Later, between 2007 and 2015 several 2D seismic surveys, as well as 3D seismic acquisition were performed.

Well name	Top Ca2 [m]	Base Ca2 [m]
Broniszów	651.4	705.2
Bronków M-27	1205.3	1276.4
Chojnowo 1	1215.0	1291.5
Dachów 1	1107.0	1170.0
Dachów M-24	1187.2	1247.2
Dęby 1	789.5	855.5
Drzonów 2	1396.5	-
Dychów M-26	1581.9	1664.6
Jasień P-4	Data belong to the Private Investor	
Jeleniów 1	1170.0	1224.0
Klępinka	306.1	330.7
Kosierz 1	1339.5	1411.5
Kosierz M-26	1522.7	1599.6
Lubiatów 1	1099.5	1174.0
Lubiatów M-20	1395.4	1449.0
Niwiska 1	1020.0	1065.0
Nowa Sól 16	1251.5	1296.5
Nowa Sól 18	1198.0	1243.5
Nowa Sól 7	1060.0	1108.0
Nowa Sól 9	1086.5	1133.0
Nowa Wieś P-1	738.6	801.7
Pajęczno 1	1130.0	1195.5
Piaski 1	1132.0	1177.0
Stary Zagór 1	1628.0	1685.0
Strużka 1	1033.0	1092.0
Świdnica 1	1359.5	1387.5
Tarnawa M-21	1180.8	1260.1
Trzebule 1	1619.0	1645.0
Urzuty IG-1	1016.1	1065.8
Wysoka 1	1170.0	1237.5
Wysoka 2	1035.5	1115.0
Żarków 1	1091.5	1160.0
Żarków 2	700.0	751.0
Żarków 3	865.2	938.0
Żarków 4	773.5	821.0

Tab. 2.1. Wells drilled the Main Dolomite in the Zielona Góra West tender area. Blue color indicates the Main Dolomite is not pierced.

The Ca2 top surface lies consistent with the regional structural trend of the Fore-Sudetic Monocline. The most shallow Main Dolomite deposits occur in the southern part of the tender area, where the top surface is at depth of about 650 (Broniszów and Żarków 2 wells; Tab. 2.1). Its central part is characterized by burial ranging from 1000 m to 1500 m (Piaski 1 and Drzonów 2 wells; Tab. 2.1). The deepest Ca2 top surface is in the northern part of the tender area, reaching over 1500 m (Kosierz M-26 and Trzebule 1 wells; Tab. 2.1)

The Ca2 deposits in the tender area have hydrocarbon potential. This is evidenced by the natural gas deposits discovered in its vicinity. The Czeklin field is located just beyond the north-western edge. The trap is structural, and the reservoir rocks are strongly fractured. The formation of the trap was associated with the activity of halotectonic processes. Behind the south-eastern edge of the tender area, there is the Nowa Sól natural gas field discovered in the 1960s. Trap and reservoir rocks are similar in nature to the case of the Czeklin field and was also formed as a result of halotectonic processes.

Individual core sections from the Ca2 interval, coming from wells located within the tender area, are saturated with hydrocarbons.

Sampling of Ca2 deposits in some wells resulted in non-industrial oil flows and weak natural gas flows.

All the factors mentioned above confirm hydrocarbon prospective of the Zielona Góra West tender area. Analysis and interpretation of the Nowa Sól 3D seismic survey led to the mapping of a new prospects. Further analysis, especially in the north-eastern and south-eastern parts of the area, may bring interesting research results. Also, the north-western part of the area, where gas flows were obtained from some wells, seems to be very attractive in terms of hydrocarbon prospecting.

Main Dolomite petrography

The entire Zielona Góra West tender area is located within the Ca2 carbonate platform (Figs 2.20–2.21). Two microfacies can be distinguished (Peryt, 1978): micrites (mudstones), sometimes laminated with terrigenous material, and oncoid microfacies (grainstones/packstones). Single foraminifers, ostracods and bivalves are found in mudstones (Peryt, 1978). For example, in the Lubiatów 1 well, located in the central part of the area, micritic deposits (mudstones), usually clay-filled, predominate. Oncoid facies occur in the bottom part of the Ca2 succession, however, in the Czeklin 1 well, they were also found in the top of the profile.

The geological documentations of wells located within the tender area contains no information on microfacies and petrography. As in other parts of the Fore-Sudetic Monocline, the Ca2 deposits are mostly dolomitized (see Peryt, 1978). In the Kosierz M-26 well, they are described as grey fine-crystalline dolomites with anhydrite and numerous stylolites – from the above cursory description it can be concluded that these are probably mainly mudstones. Similar descriptions of the Ca2 deposits can be found in other wells in this area (e.g. Dychów M-26). On the other hand in the Jeleniów 1 well (eastern part of the area), in the Ca2, mainly “monolithic” dolomites are described, massive, compact, fine-grained with vertical cracks. From such a description, it is difficult to conclude anything about their microfacies characteristics, petrography or diagenesis.

The Ca2 deposits in the tender area are overlain by the Basal Anhydrite (A2). The boundary between these lithostratigraphic units is continuous, although there are cases in which there is a sharp, erosive boundary (Wagner, 1994). The A2 deposits consist of laminated and layered anhydrites (Kłapciński, 1991). Their thickness varies from 2 m to 25 m. Only in the Drzonów 2 well, a significant thickness of the A2 was documented, which is 41.0 m.

In the vertical succession of the PZ2 cyclothem, the A2 is replaced by the Older Halite (Na2). In the tender area, the Na2 usually reaches a thickness of about 50 m. In the south-western part, a significant reduction in the Na2 thickness is observed, and in the Świdnica 2 and Trzebule 1 wells, its suddenly increases, reaching over 130 m. The upper part of the PZ2 cyclothem in the Zielona Góra West area is reduced. The Older Potash (K2) and Screening Older Halite (Na2r) have not been documented in wells. The above-mentioned lithostratigraphic units were found only in the Dachów 1 well. The thickness of the K2 there is 3.0 m, and Na2r – 4.5 m. The A2r deposits reach a small thickness, reaching a maximum of several meters.

According to Wagner (1994): *“In the final stage of development of the PZ2 cyclothem, extremely shallow-water conditions prevailed. The central sedimentary basin was filled with deposits of potassium salts. The coastal parts of the carbonate platforms were exposed and not very intense terrigenous sedimentation continued here, slightly stronger in the southern part of the basin. Erosion and sedimentation of the clastics were not strong because the climate was extremely dry at that time.”*

In the tender area, there is an increase in the total thickness of the PZ2 towards the north (Fig. 2.22). Its lowest values were documented in the southern and south-western part. In the Jasień P-4, Żarków 2, Żarków 4 and Nowa Wieś P-1 wells, the total thickness of PZ2 ranges from 41.2 m to 73.7 m (Fig. 2.22). Only in the extreme northern and south-eastern parts of the discussed area, in the Trzebule 1 and Urzuty IG-1 wells, the thickness of the PZ2 cyclothem reaches 229.5 m and 282.4 m, respectively.

PZ3

Sedimentation of the evaporite-sulphate succession of the PZ2 cyclothem flattened denivelations that occurred in the Polish Zechstein Basin (Wagner, 1994). As a result, another transgression, which initiated the deposition of the third cyclothem, entered the area of a levelled, shallow saline basin. The formations of the PZ3 cyclothem in the Zielona Góra West tender area begin with the Grey Pelite (T3; Fig. 2.16). It is characterized by a small thickness, in most cases not exceeding 5 m. Then, in the vertical succession, the Platy Dolomite (Ca3) appears, which due to their very small thickness (less than 1 m) and the type of rock (anhydrites and dolomites) are included into the Main Anhydrite (A3; Podemski, 1973). Only in the Jasień P-4 and Urzuty IG-1 wells, the Ca3 horizon was distinguished as a separate lithostratigraphic unit. The thickness of the A3 (including Ca3) ranges from 10.0 m (Dachów 1) to 61.0 m (Nowa Sól 7). Rocks of the Younger Halite (Na3) are deposited on the A3. Their thickness ranges from 63.5 m (Wysoka 1) to 178.0 m (Strużka 1). The smallest total thickness of the PZ3 cyclothem was documented in wells located in the southern part of the tender area (Fig. 2.23); it does not exceed 100 m. The PZ3 cyclothem is absent in Broniszów well. For the remaining part of the tender area, the total thickness of PZ3 is above 100 m (Fig. 2.23). Its highest value occurs in the Niwiska 1 well – 156.0 m.

PZ4

With the start of the sedimentation of the PZ4 cyclothem, the factor controlling the deposition in the basin changed. The influence of transgressive-regressive cycles decreased, disappearing completely during the subcyclothem PZ4c, in favor of climatic fluctuations (humid and dry periods; Wagner, 1994). The subcyclothem PZ4a (Fig. 2.16) occurs in practically all wells and is represented by the Red Pelite (T4a), Lower Pegmatite Anhydrite (A4ad), Youngest Halite (Na4a) and Top Anhydrite (A4ar). The top of the PZ4 cyclothem is represented by the Top Terrigenous Series (PZt).

In the south-western part of the tender area, the PZ4 has not been identified in any well (except PZt sediments). The lack of the PZ4 was most likely related to later erosion processes that may have occurred in the marginal part of the basin, as well as to the limited deposition. The remaining part of the Zielona Góra West tender area is characterized by the total thickness of the PZ4 cyclothem from 12 m to 33 m (Fig. 2.24).

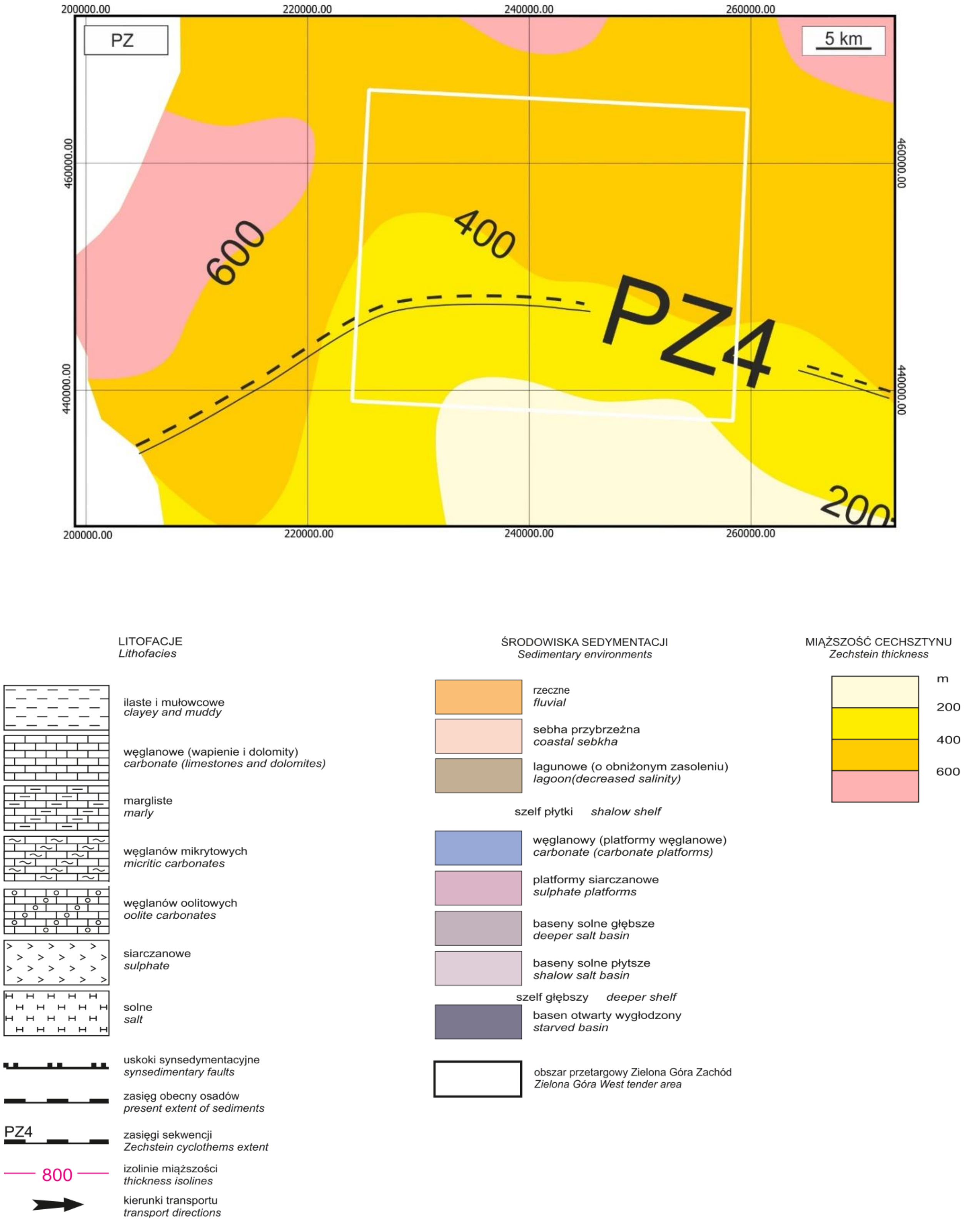


Fig. 2.15. The thickness of the Zechstein in the Zielona Góra West tender area (Wagner, 1998).

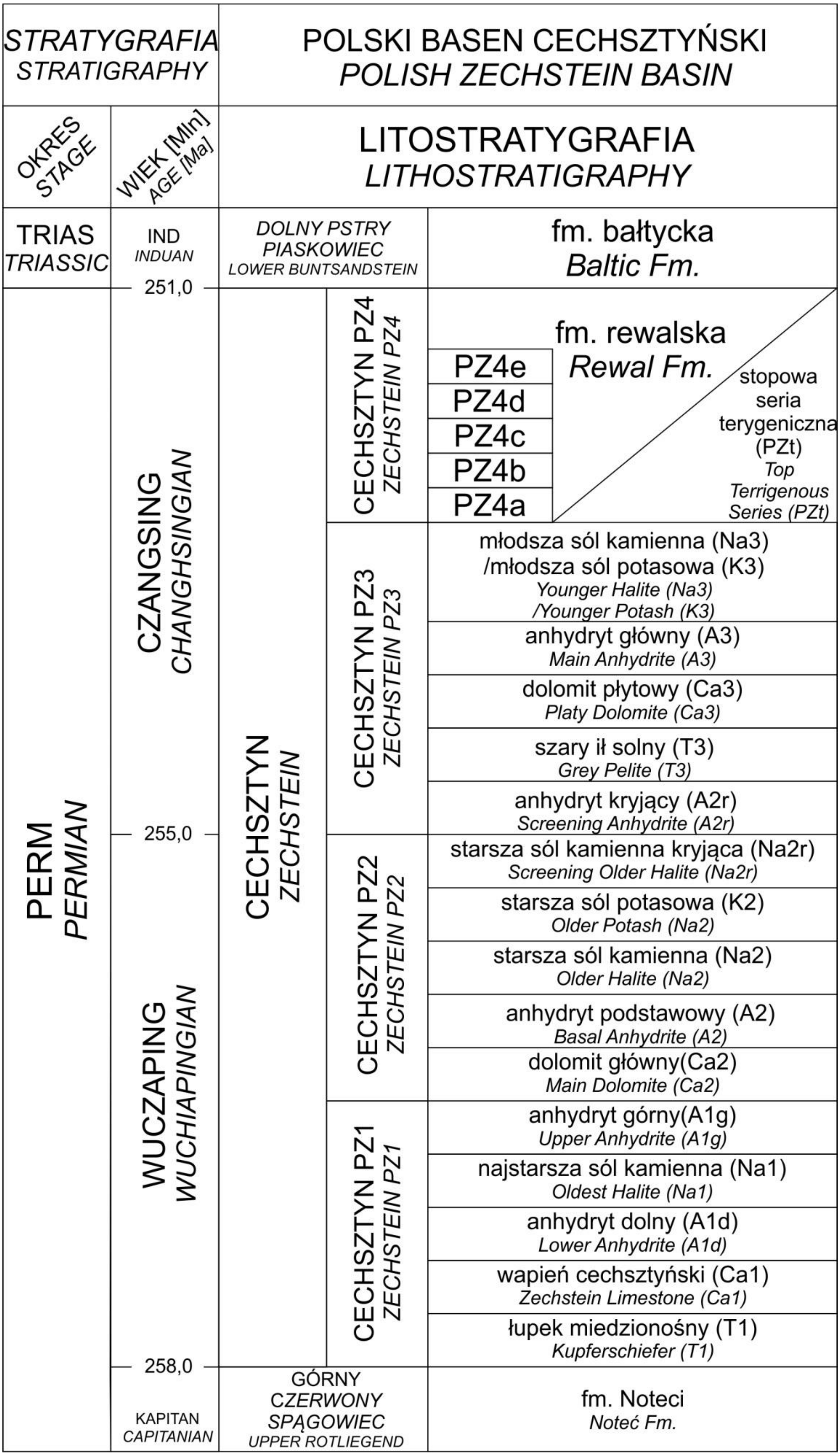


Fig. 2.16. Zechstein stratigraphy in Poland (Wagner and Peryt, 1997, 1998).

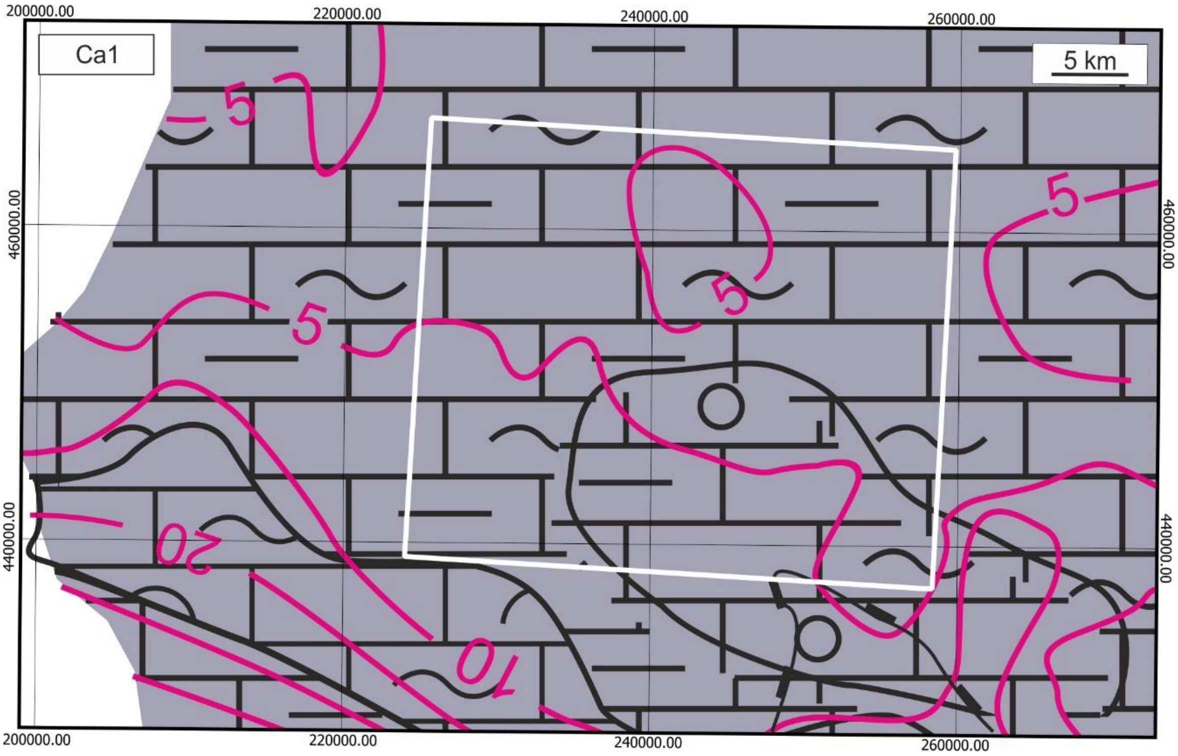


Fig. 2.17. Paleogeography and thickness of the Zechstein Limestone in the Zielona Góra West tender area (Wagner, 1998). Abbreviations – see Fig. 2.15.

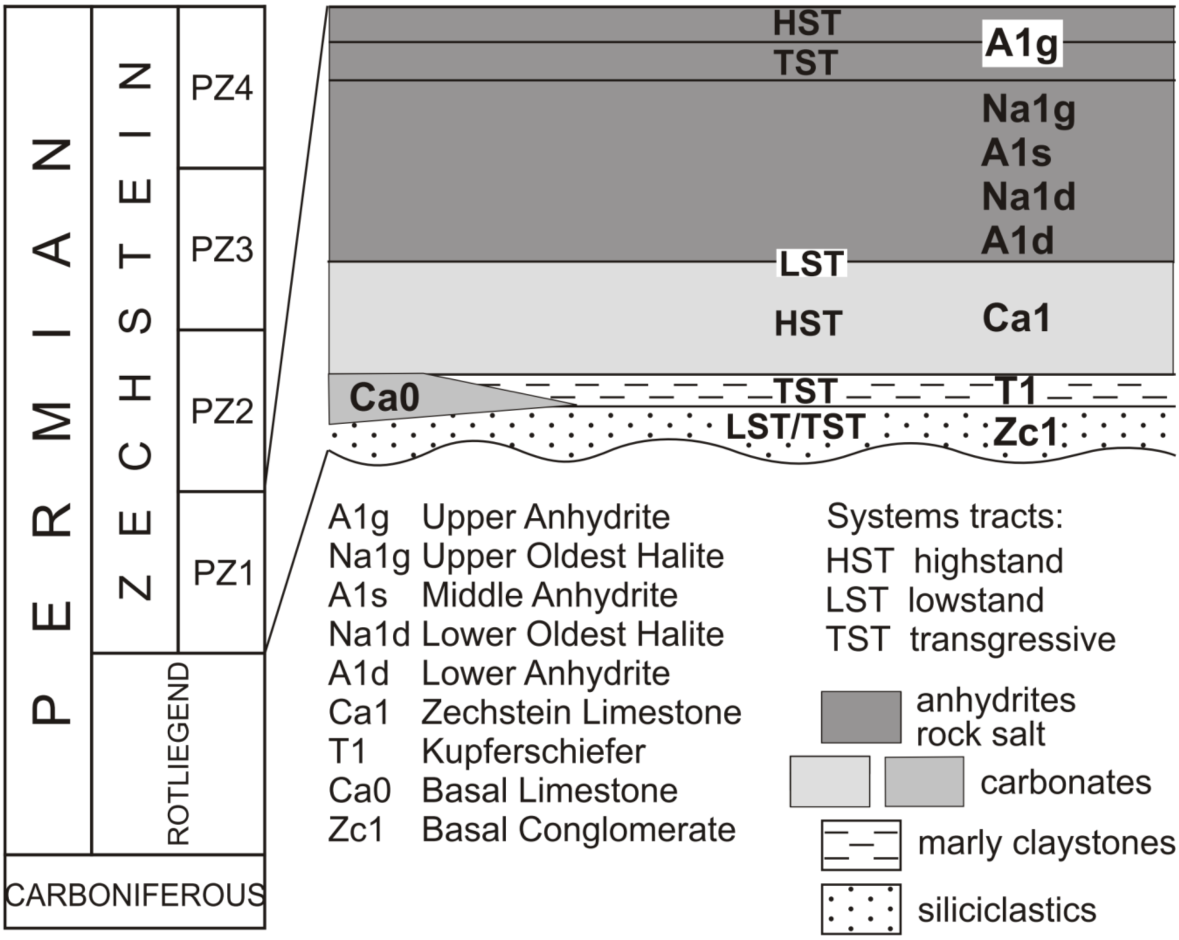


Fig. 2.18. PZ1 stratigraphy in the Branderburg-Wolsztyn-Pogorzela High (Dyjaczyński and Peryt, 2014).

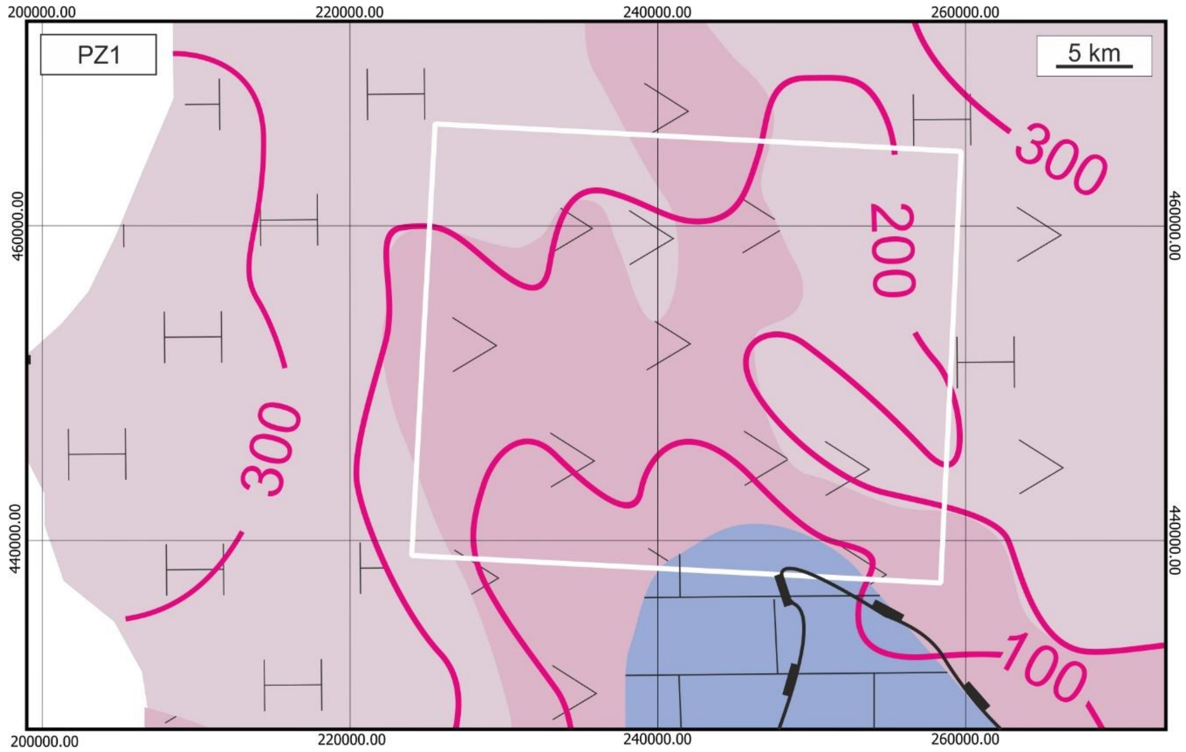


Fig. 2.19. Paleogeography and thickness of the PZ1 in the Zielona Góra West tender area (Wagner, 1998). Abbreviations – see Fig. 2.15.

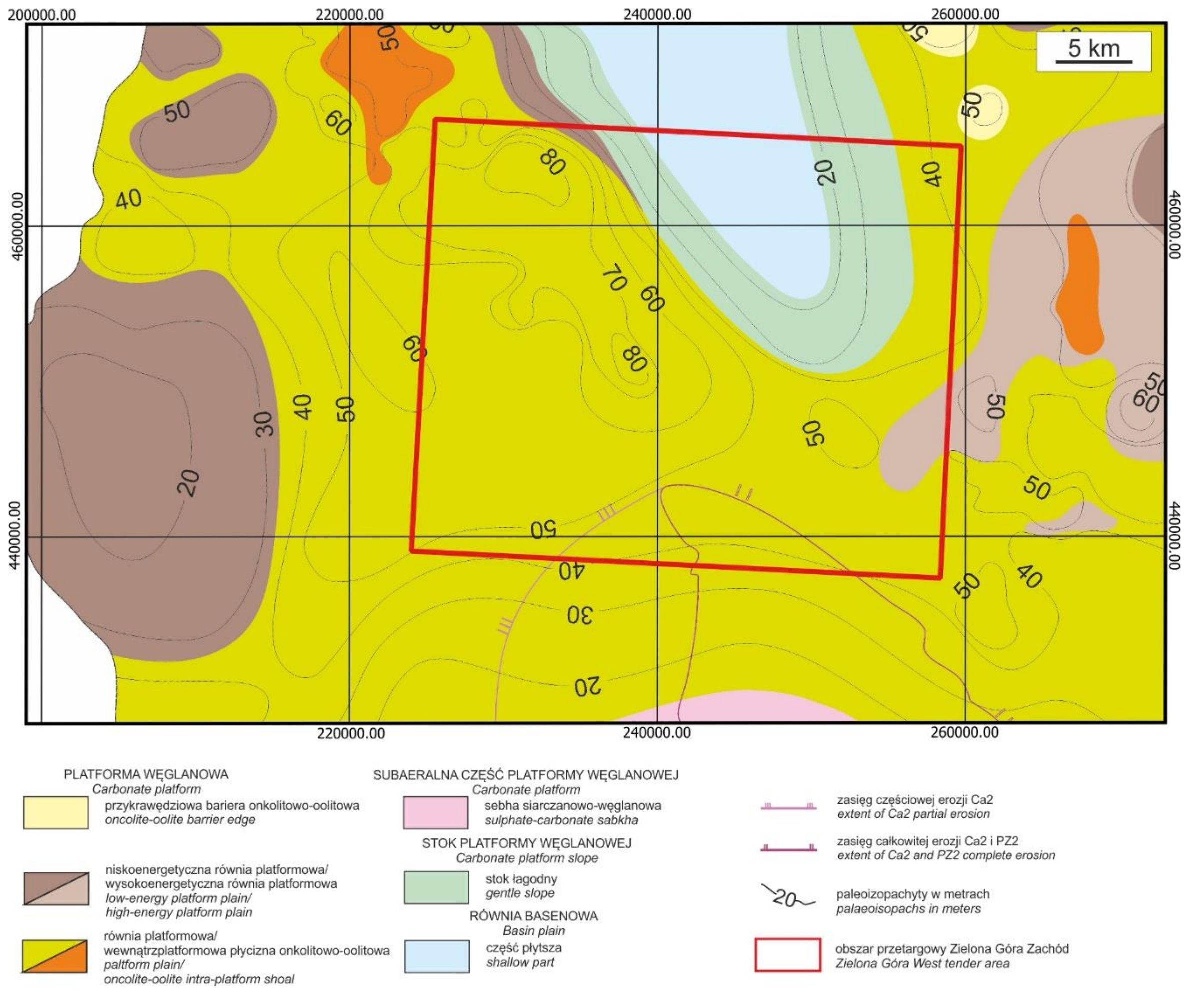


Fig. 2.20. Paleogeography and thickness of the Main Dolomite (Ca2) in the Zielona Góra West tender area (Wagner, 2012).

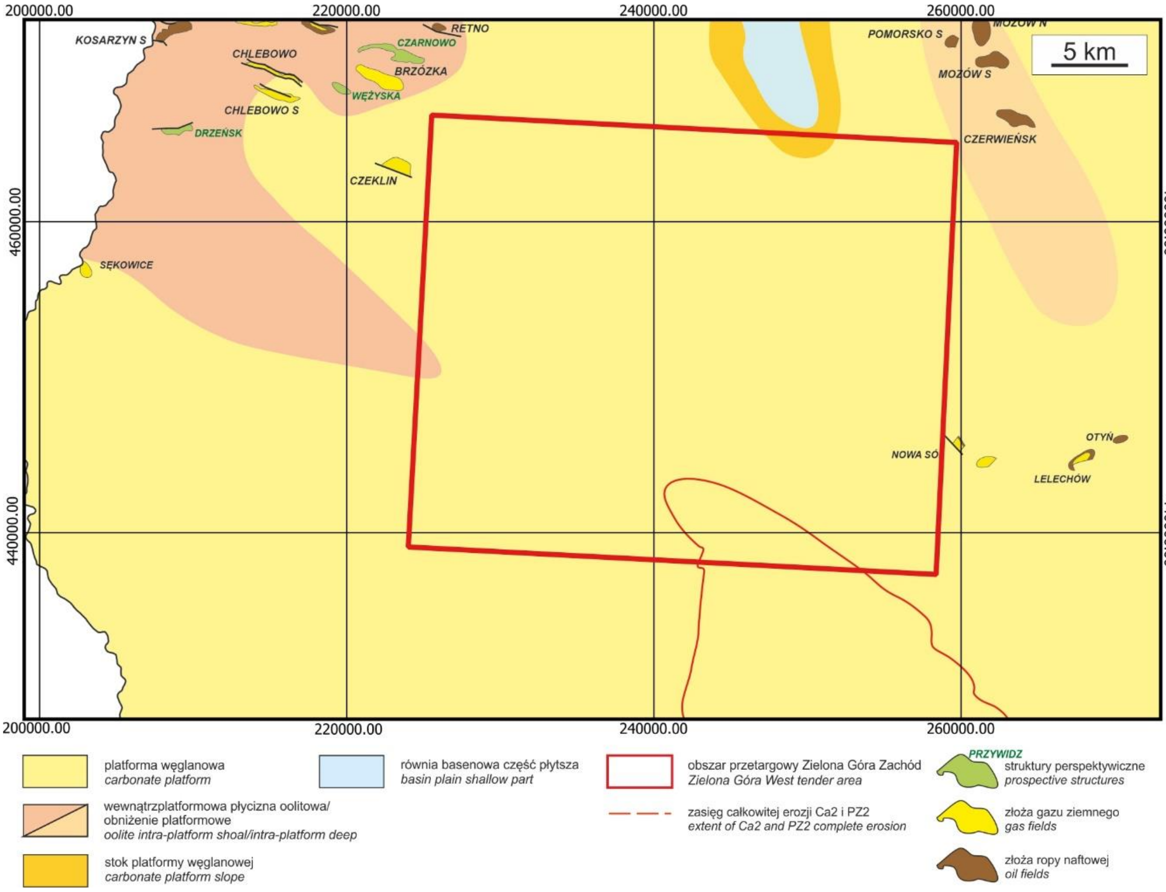


Fig. 2.21. Paleogeography and thickness of the Main Dolomite (Ca2) in the Zielona Góra West tender area (Buniak et al., 2013).

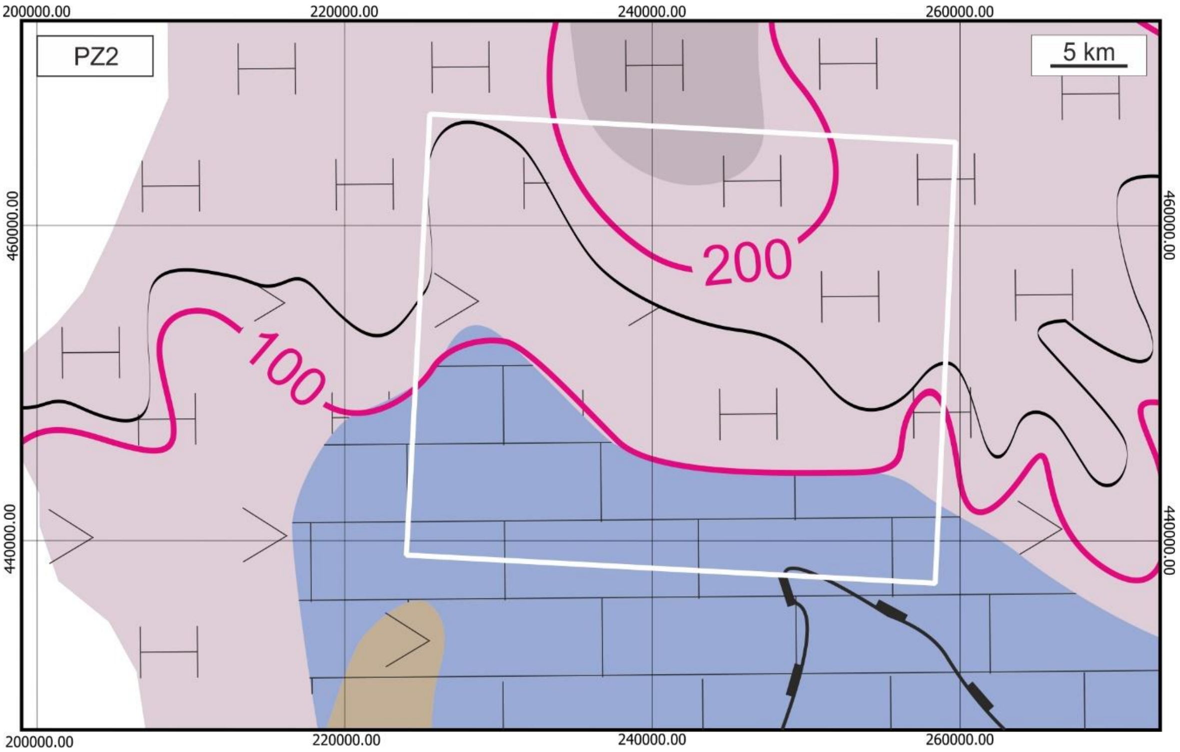


Fig. 2.22. Paleogeography and thickness of the PZ2 in the Zielona Góra West tender area (Wagner, 1998). Abbreviations – see Fig. 2.13.

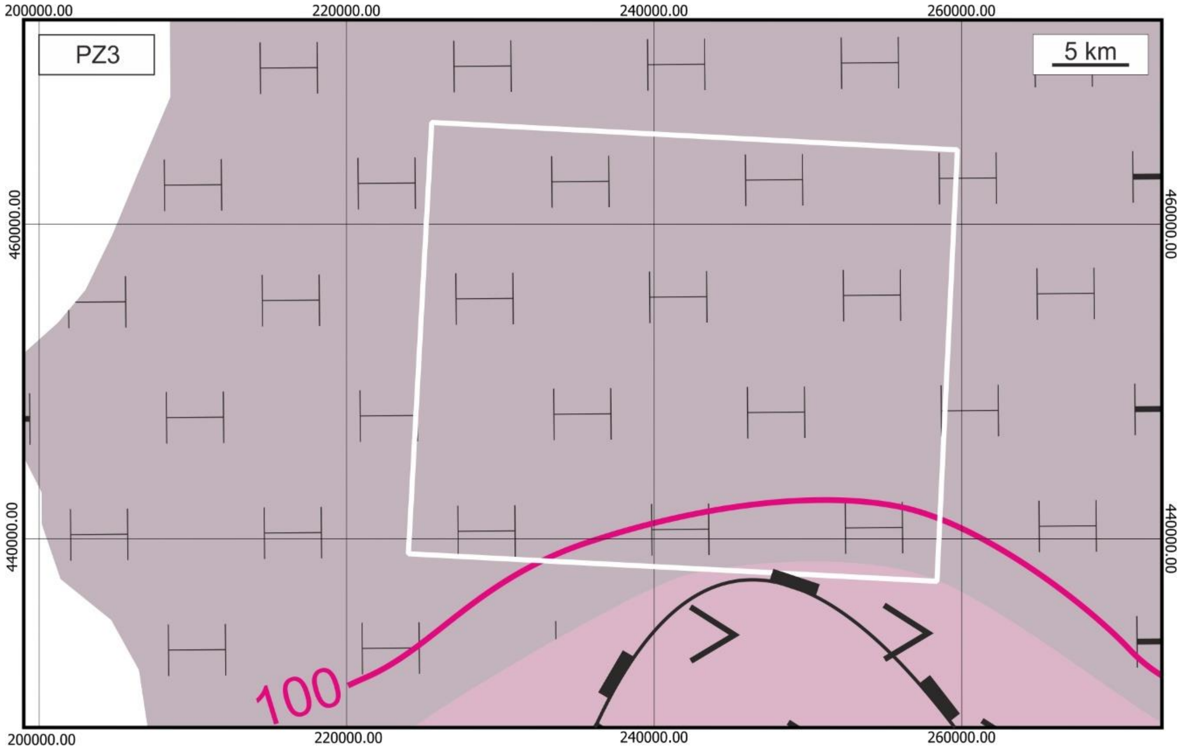


Fig. 2.23. Paleogeography and thickness of the PZ3 in the Zielona Góra West tender area (Wagner, 1998). Abbreviations – see Fig. 2.15.

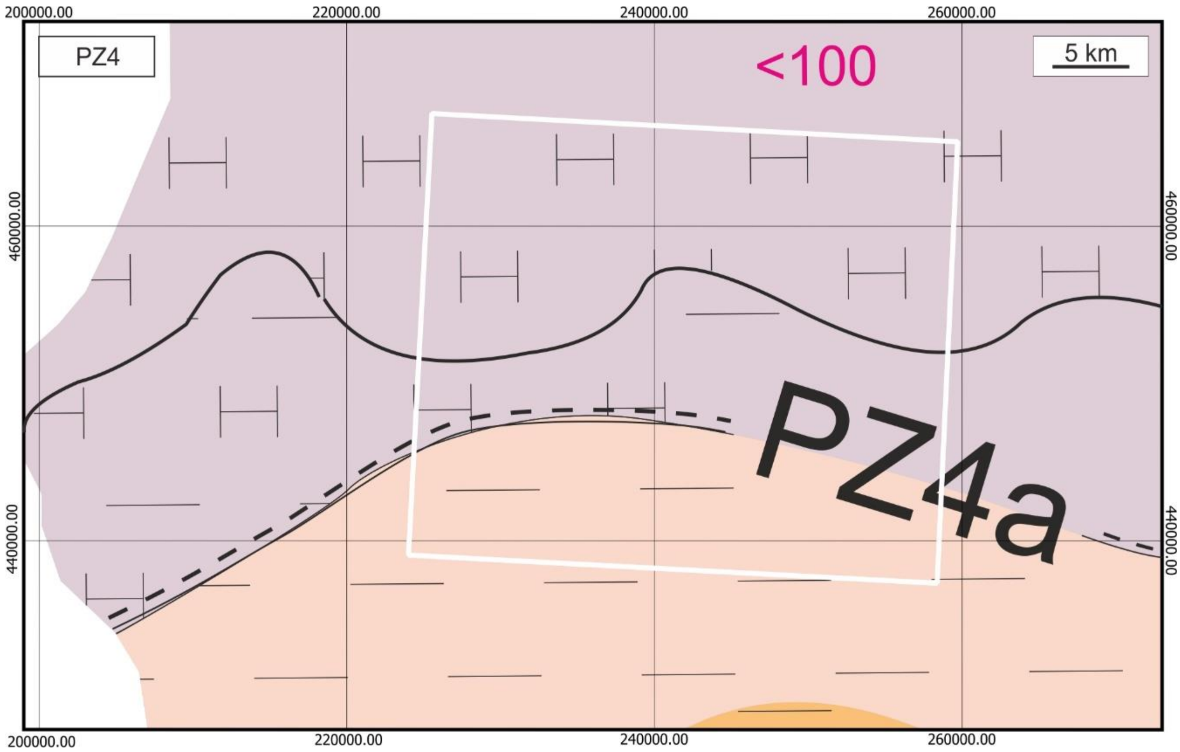


Fig. 2.24. Paleogeography and thickness of the PZ4 in the Zielona Góra West tender area (Wagner, 1998). Abbreviations – see Fig. 2.15.

2.2.5. TRIASSIC

Distribution and thickness

In the Zielona Góra West tender area 36 wells drilled the Triassic. These are (the depths are given according to the geophysical measure):

- Broniszów: 332.3–582.0 m,
- Bronków M-27: 226.8–1009.0 m,
- Chojnowo 1: 230.0–992.0 m,
- Dachów 1: 250.0–922.5 m,
- Dachów M-24: 230.8–953.2 m,
- Dęby 1: 285.0–737.5 m,
- Drzonów 1: 262.5–1152.0 m,
- Drzonów 2: 271.0–1109.0 m,
- Dychów M-26: 231.0–1354.7 m,
- Jarogniewice IG-1: 280.4–551.6 m,
- Jasień P-4,
- Jeleniów 1: 275.0–944.5 m,
- Kosierz 1: 247.5–1093.0 m,
- Kosierz M-26: 265.2 –1252.3 m,
- Lubiatów 1: 284.0–907.0 m,
- Lubiatów M-20: 268.3–1134.2 m,
- Niwiska 1: 275.0–768.0 m,
- Nowa Sól 7: 320.0–800.0 m,
- Nowa Sól 9: 286.0–928.5 m,
- Nowa Sól 16: 275.0–1041.0 m,
- Nowa Sól 18: 380.0–970.5 m,
- Nowa Wieś P-1: 400–687.0 m,
- Pajęczno 1: 350.5–888.0 m,
- Piaski 1: 265.0–907.0 m,
- Stary Zagór 1: 230.0–1415.5 m,
- Strużka 1: 318.0–723.0 m,
- Świdnica 1: 270.0–1070.0 m,
- Tarnawa M-21: 228.3–971.7 m,
- Trzebule 1: 262.5–1259.0 m,
- Urzuty IG-1: 344.5–683.7 m,
- Wysoka 1: 256.5–953.5 m,
- Wysoka 2: 295.0–815.0 m,
- Żarków 1: 245.0–851.5 m,
- Żarków 2: 292.0–605.0 m,
- Żarków 3: 305.0–800.0 m,
- Żarków 4: 288.0–746.0 m.

The succession of the Triassic in the Zielona Góra West tender area is diversified. In its southern and south-eastern parts, directly under the Paleogene and Neogene, there are Permian rocks (Fig. 2.25). The remaining southern and central parts are characterized by a reduced Triassic lithological profile – to the south there is only the Bunter Sandstone, and in the centre – the Muschelkalk (Fig. 2.25). The most complete Triassic succession is expected in the northern part of the tender area.

Lithology and stratigraphy

The Lower Bunter Sandstone consist of sandstone lithofacies (Szyperko-Teller, 1997). In its vertical succession, there is some variation in ratio of sandstones to claystones and mudstones, the presence or absence of conglomerates and grain gradation. The Middle Bunter Sandstone is represented by the clastic-carbonate succession (Szyperko-Teller, 1997). Depending on the location within the area of the Fore-Sudetic Monocline, the range of one of these two lithological types changes – towards the north, the percentage of carbonates in the succession increases, and towards the south – clastics predominate (Szyperko-Teller, 1997). The Lower Triassic ends with the Röt. They consist mainly of sulphate and carbonates and claystones.

The Middle Triassic in the major part of the succession consist of carbonate rocks (limestones and dolomites), among which there are also marls, claystones, and anhydrite intercalations (Muschelkalk; Gajewska, 1997a). Only in the highest part there is a clear lithological change. The carbonate succession is replaced by the clastic-carbonates. They are represented by grey, red and variegated claystones, among which there are intercalations of mudstones, sandstones, limestones, dolomites and marls (Sulechów Beds; Gajewska, 1997b). Plant remains often appear among these rocks, forming thin layers of brown coals.

In the lower part of the Upper Triassic, there are two thick complexes of red claystones, in the lower one sulphate-evaporite intercalations appear (Lower Gypsum Beds; Gajewska, 1997b), while in the upper part the content of anhydrite-dolomite-sandstone beds is minimal (Upper Gypsum Beds; Gajewska, 1997b). These two complexes are separated by a sandstone succession, with very few traces of flora remains, or claystone succession, characterized by numerous plant remains (Reed Sandstone, Gajewska, 1997b). Next, gray, grey-green, cherry and brown-red claystones appear higher in the succession. Among these rocks there are intercalations of dolomites, mudstones, dolomitic claystones, nodular claystones, as well as interbeds of conglomerates (Jarkowo and Zbąszynek Beds; Deczkowski, 1997).

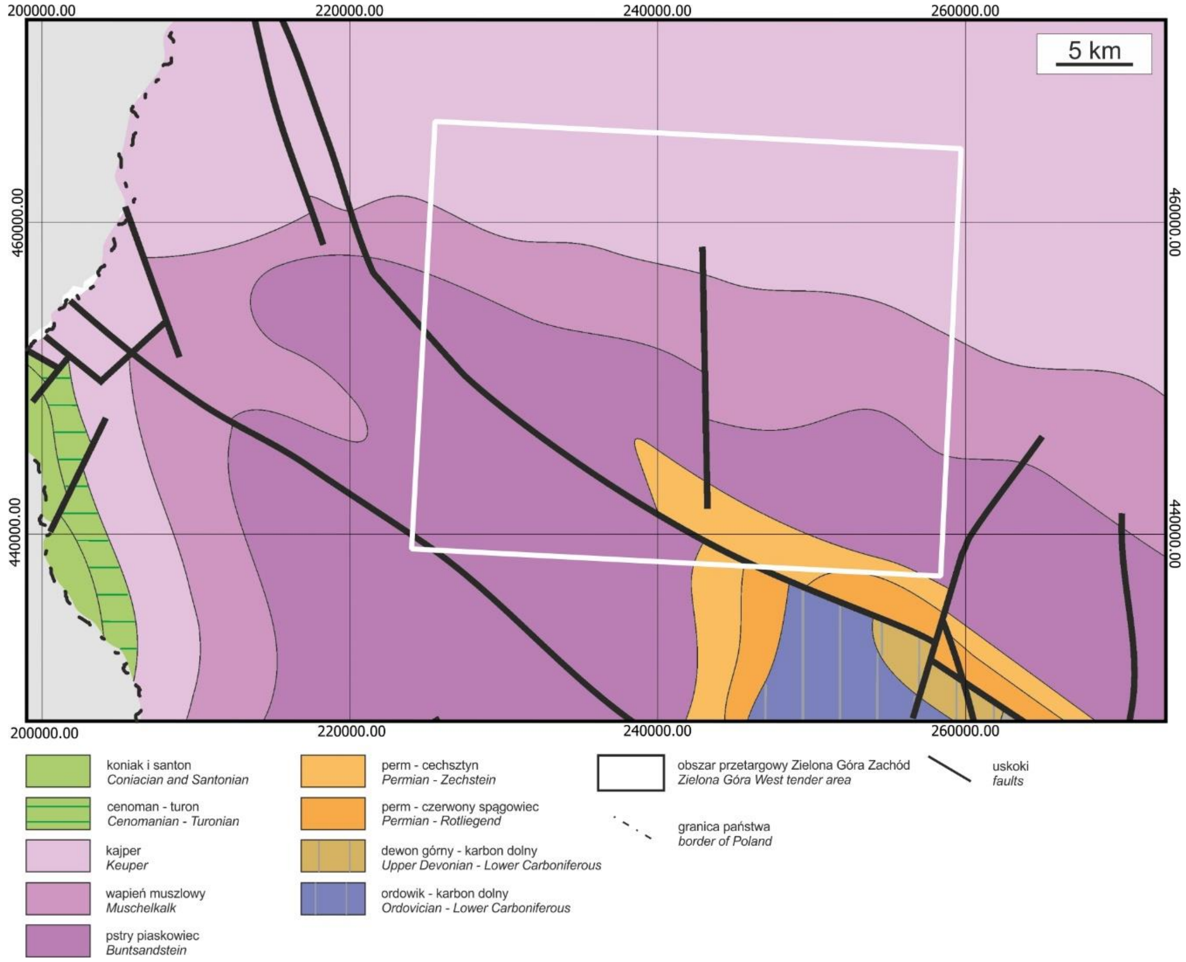


Fig. 2.25. Location of the Zielona Góra West tender area on the Geological map of Poland without Cenozoic deposits (Dadlez et al., 2000).

2.2.6. CENOZOIC

Distribution and thickness

Sedimentation of the Paleogene deposits begins when the Mesozoic basemen was strongly denudated. The thickness of the Paleogene is varied and depends on the morphology of the Mesozoic top surface (Bartczak, 2002; Chmal, 2002; Badura and Przybylski, 2002; Urbański, 2002). The oldest glaciation caused intense glacitectonic disturbances of the Paleogene and Neogene sediments. Nevertheless, outcrops of the Middle and Upper Miocene and Pliocene rocks can be found within the tender area, as well.

The Pleistocene deposits thickness depends on the intense of galcitectonic processes and the erosive activity of successive glaciations (Bartczak, 2002; Chmal, 2002; Badura and Przybylski, 2002; Urbański, 2002).

Lithology and stratigraphy

The oldest Paleogene deposits are represented by the Eocene, documented in Sieciejów, located slightly south of the south-western border of the tender area; these are silts, clays and sands lying directly on the Triassic (Bartczak, 2002).

In the south-eastern part of the area, the Upper Eocene and Lower Oligocene deposits have been identified, including silts, sandstones, conglomerates and limestones (Badura and Przybylski, 2002). The entire tender area is covered with the Oligocene (Bartczak, 2002; Chmal, 2002; Badura and Przybylski, 2002; Urbański, 2002). In the northern and south-western part, the Oligocene is formed by sands, sands with glauconite, clay silts, sands with accumulations of micas and brown coals (Bartczak, 2002; Chmal, 2002; Urbański, 2002). The Oligocene succession of the south-eastern part of the tender area is represented by sands, silts and gravels included to the Leszno Formation (Badura and Przybylski, 2002).

In the Zielona Góra West area, the Neogene deposits are represented by the Lower, Middle and Upper Miocene (Bartczak, 2002; Chmal, 2002; Badura and Przybylski, 2002; Urbański, 2002), and in the southern and north-eastern part also by the Pliocene (Urbański, 2002). Generally, during the Early and Middle Miocene, the deposition of sands, clays, silts, brown coals, gravels, kaoline clays, conglomerates, and silty sands took place. The Poznań Formation is the youngest Miocene lithostratigraphic unit in the tender area. It is formed by clays, silts and sands (Bartczak, 2002; Chmal, 2002; Badura and Przybylski, 2002; Urbański, 2002). The Pliocene occurs throughout almost the entire tender area. It is missing only in the north-western part (Chmal, 2002). The Pliocene does not form a continuous cover, and its greatest distribution is documented in the south-western part. These are sands and gravels, sometimes with silts, clays, kaoline clays and conglomerates (Bartczak, 2002).

The Pleistocene consists of boulder clays, sands and gravels, and silts. The Cenozoic succession in the tender area ends with the Holocene. It consists of peats, silts, sands, gravels and gyttjas, as well as deluvial clays (Bartczak, 2002; Chmal, 2002; Badura and Przybylski, 2002; Urbański, 2002).

2.3. HYDROGEOLOGY

The Zielona Góra West tender area is located in the Middle Oder water region. It is characterized by very diverse hydrogeological conditions. Groundwater occurs in several different hydrogeological structures with different abundance and different hydrogeological parameters. In addition, aquifers of little importance in sense of usability have also been identified in the area. The main usable aquifer is the Quaternary horizon, while the Neogene-Paleogene horizon is of secondary importance. The Quaternary aquifers occur primarily within the current and buried river valleys and geological troughs. They are also associated with sander areas and related to the façade reservoirs of the Zielona Góra Embankment. The Bóbr river valley, buried valleys and troughs are of fundamental importance within the tender area. The Main Groundwater Aquifer Pradolina Zasieki – Nowa Sól (MGB No. 301) is built of two water bearing horizons (upper and lower), composed of postglacial sands and gravels, with a thickness of several to several dozen meters, with irregular layers of poorly permeable clays, silts and tills. Within the Bóbr valley and pre-valley, the usable aquifer usually forms one water bearing horizon, which occurs most often at depths below 5 m and its thickness ranges from a few to over 40 m. Sandstone levels occur in the north-western part of the tender area and are formed in the form of gravels and sands of various grains, with variable lithology and thickness. They form the Major Groundwater Aquifer Sandr Krosno-Gubin (MGB No. 149). On the other hand, aquifers located in the highland areas are formed of interlinear sandy-gravel layers with a subartesian water level. Often, on the upland, the Quaternary aquifer is associated with the presence of narrow, fragmented troughs with a course similar to latitudinal. In the central and southern parts of the tender area, extensive areas with no usable aquifers were found.

The Neogene-Paleogene aquifer is of less importance. It does not form uniform aquifer, but a complex of multi-layer systems, wedging and making lenses, that in some areas are in contact with Quaternary waters. Below this, in the Triassic, the groundwater is of increased mineralization and temperatures.

In the tender area, the risk to the main usable aquifer is considered to be medium. A high and very high degree of risk occurs mainly in the Bóbr valley and in the area of Zielona Góra City.

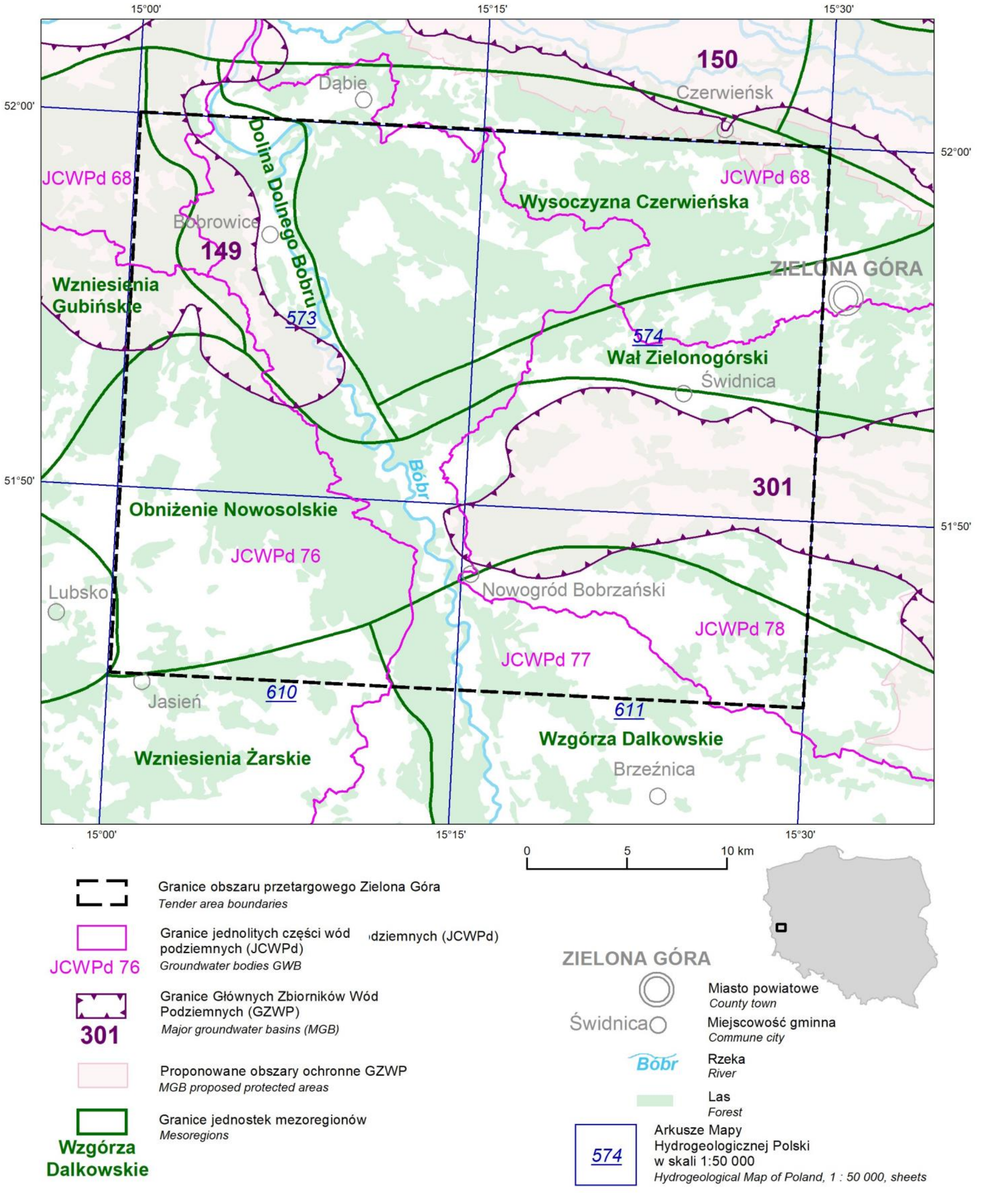


Fig. 2.26. Location of the Zielona Góra West tender area on the background of physico-geographic units, Major Groundwater Basins (MGB) and Groundwater Bodies (GBW).

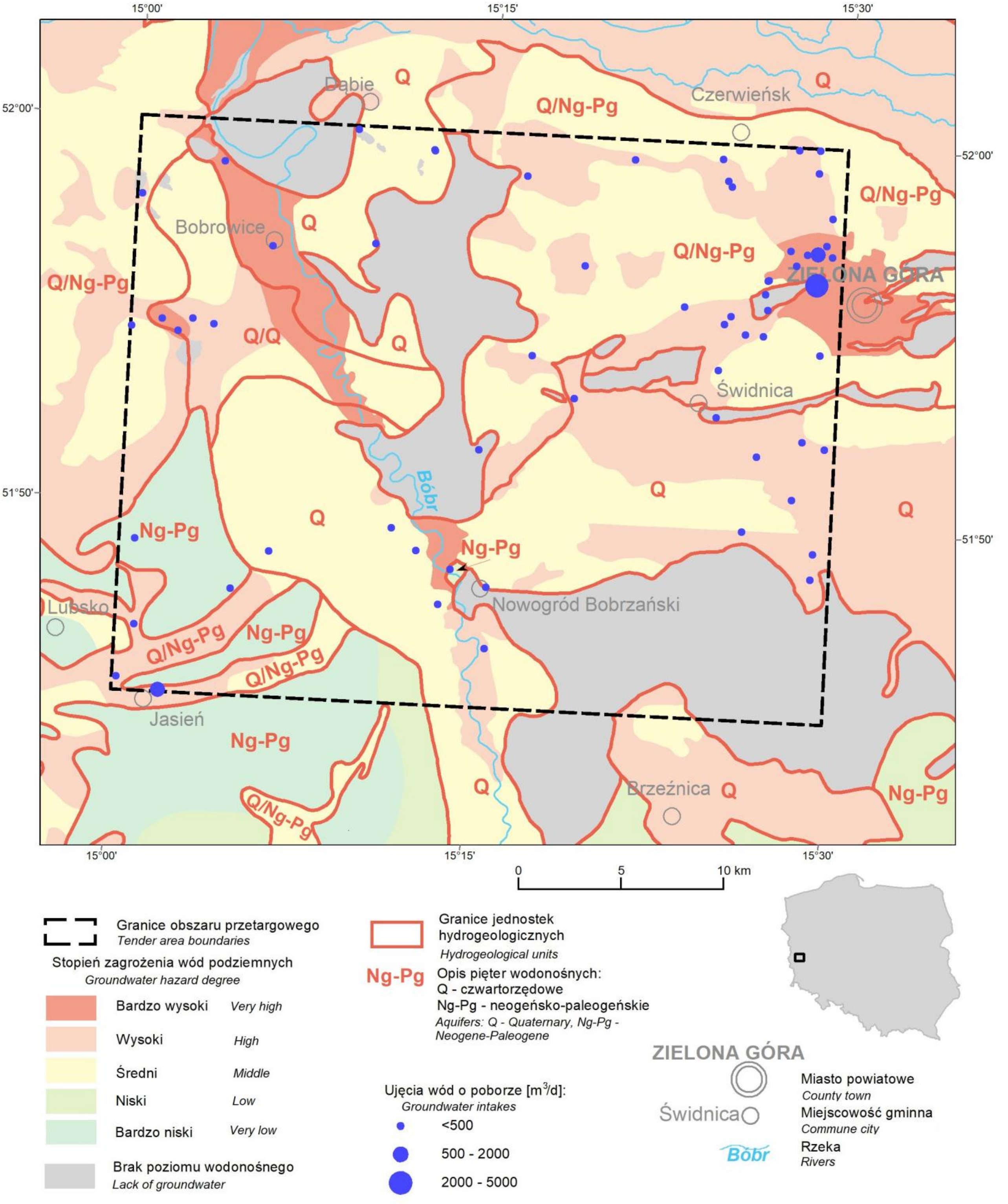


Fig. 2.27. Location of the Zielona Góra West tender area on the background of hydrogeological units

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 of the Zielona Góra West tender area, as well as geochemical parameters, and results of petrophysical studies in individual lithostratigraphic units, allow to distinguish two conventional petroleum plays, developed in the Zechstein Main Dolomite and Carboniferous-Permian/Rotliegend, respectively.

The Zechstein/Main Dolomite petroleum play is a closed hydrodynamic system. This means that the system is completely sealed from the surrounding rocks, and the Main Dolomite (Ca2) acts both as the host rock and the reservoir rock (Fig. 3.1). The source rocks are of microbial (cyanobacteria) and algal origin (Kotarba and Wagner, 2007), and occur in two varieties: 1) compact – microbialites and mudstones, 2) dispersed – laminae of microbilatites, stabilizing the granular sediment (Słowakiewicz and Gąsiewicz, 2013; Słowakiewicz et al., 2016). The reservoir rock consists most often of limestones and dolomites represented by grainstones and packstones. Among them, numerous pol and gas shows in drilling cores are noted, as well as numerous oil and natural gas fields have been documented in the neighbourhood of the tender area. The Main Dolomite petroleum play has a double, highly effective seal. From the base and top it is sealed with thick evaporites of PZ1 and PZ2 cyclothems (Fig. 3.1). In the vicinity of the Zielona Góra West tender area, in the Ca2, the occurrence of natural gas and crude oil have been documented in Czeklin, Nowa Sól, and Lelechów fields.

The Carboniferous-Lower Permian petroleum play may also work in the tender area. The source rocks are considered to be the Lower Carboniferous (Fig. 3.1). In some cases, the Upper Carboniferous (Fig. 3.1), which occurrence is limited to local tectonic rifts, could also play a role of source rocks. The reservoir rock is the Upper Rotliegend sandstones (Fig. 3.1). The best properties occur in aeolian sediments, however, accumulations of hydrocarbons in river channels or alluvial and fluvial facies are also possible. The Carboniferous-Lower Permian petroleum play have a seal formed by the Zechstein evaporites of the PZ1 cyclothem (Fig. 3.1). In the tender area and its vicinity, no natural gas fields have been discovered in the Upper Rotliegend, although there are shows of hydrocarbons in wells and drillcores. Numerous natural gas fields have been documented to the east of the area, e.g. in Grochowice, Kulów and Dębina.

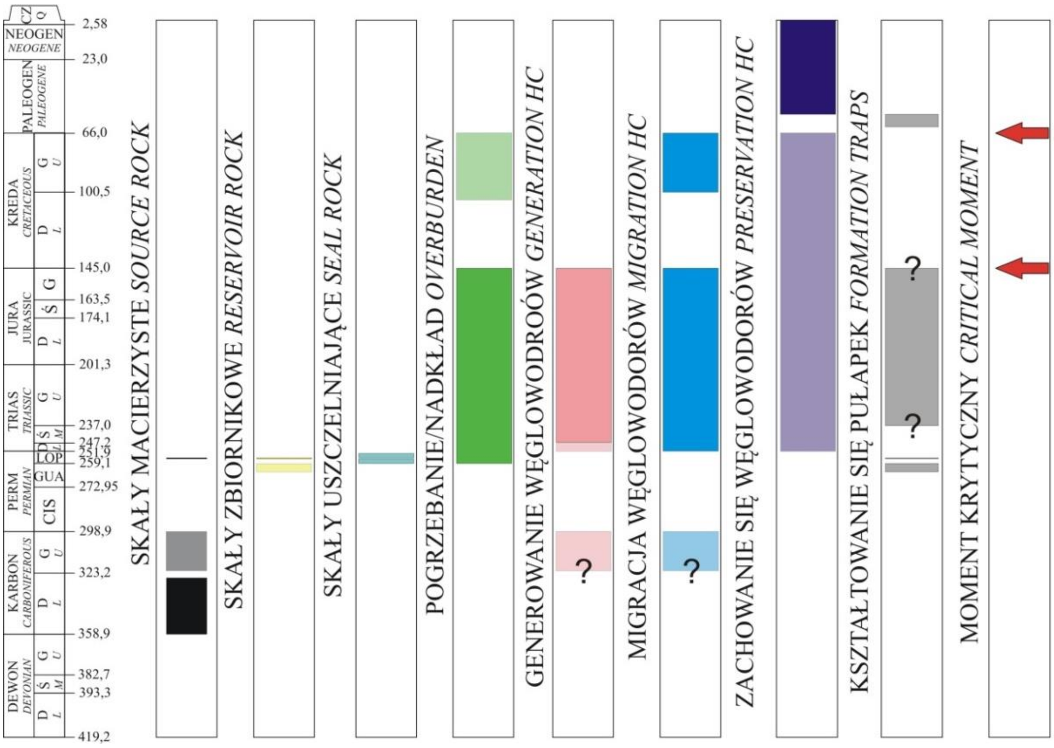


Fig. 3.1. Petroleum plays in the Zielona Góra West tender area. Lighter color indicates hypothetical petroleum play elements.

3.2. SOURCE ROCKS

Carboniferous
Lithology: claystones and siltstones

Thickness: not pierced
~ 47.4 m in the Strużka 1 well,
~ 321.5 m in the Dęby 1 well.
Depth:
Dachów: 1432.5–1508.0 m,
Dęby 1: 1049.0–370.5 m,
Niwiska 1: 1645.0–1700.0 m,
Strużka 1: 1445.0–1492.4 m,
Piaski 1: 1870.0–2021.8 m.

In the Zielona Góra West tender area there is no direct data about hydrocarbon potential of the Carboniferous rocks. Detailed studies on dispersed organic matter in the Carboniferous were carried out by Podhalańska et al. (2016), Nowak (2016) and Roman (2016). They studied selected wells located mainly in the central part of the Variscan Externides. The wells located close to the tender area that were subjects of investigations were Siciny IG-1 and Paproć 29. The organic matter occurs there in the form of macerals of mainly two basic groups – vitrinite and inertinite, which are humic components. In the Carboniferous rocks, two generations of vitrinite were observed: autochthonous (primary) and allochthonous (secondary) – redeposited; they differ in color, reflectivity and form of occurrence. Primary vitrinite usually occurs in the form of fine and thin streaks and small fragments (vitrodetrinite). Inertinite is the second group of organic components commonly found in the Carboniferous rocks of the Fore-Sudetic Monocline (Nowak, 2003). The macerals from the inertinite group are represented primarily by inertdetrinite, and sometimes in the case of larger fragments of inertinite, it is possible to recognize fusinite, semifusinite, secretinite or funginite.

Taking into account that the organic matter found in the Carboniferous is characterized by the predominance of humic components of terrestrial origin with a large admixture of redeposited vitrinite (up to 18%), the studied rocks were classified as source rocks of type III kerogen (Nowak, 2016).

In older studies (Wagner et al., 2008) it was indicated that thermogenic gases were most likely formed from a single source rock containing kerogen III or mixed III/II.

The most abundant in the Carboniferous is vitrinite together with humic detritus (66–100%) and inertinite (up to 22%). Such a composition of organic matter dispersed in the Carboniferous rocks is typical of marine turbidite sediments (Nowak, 2003).

So far, studies of the Carboniferous rocks have not led to identification of horizons with significant (large) accumulations of organic matter. It was usually concluded (e.g. Wagner et al., 2008) that it was impossible to isolate specific horizons basing only on the geochemical criteria. An unequivocal distinction of host rock complexes is difficult due to the lithology of the Carboniferous, as well as due to the limited research material – in most cases only the top parts of the Carboniferous were drilled. Therefore, in petroleum analyses, the presence of source rock horizons was most often assumed to occur in the whole Carboniferous succession.

In the vicinity of the Zielona Góra West tender area, only in the Siciny IG-1 well source rocks horizons were identified as a result of geophysical interpretation calibrated with geochemical tests of rock samples (Fig. 3.2). The succession shows two complexes with a thickness of about 250 and 80 m, in which the average TOC content is greater than 2%. (Roman, 2016). In general, the degree of thermal maturity, i.e. the transformation of organic matter in the Carboniferous rocks is high. Values of vitrinite reflectance vary within wide limits, ranging from less than 1.5% to more than 5.5%. (Nowak, 2003). Typically, the obtained values of Ro vitrinite correspond to the stages from the generation of gases to the phase of hydrocarbon destruction. Earlier publications (Nowak, 1999) indicate that the main phase of gas generation is observed in the Carboniferous of the northwestern and western parts of the Fore-Sudetic Monocline, while in the south-eastern direction there is a significant increase in the degree of metamorphism and transformations.

It is also worth to mention the work of Poprawa (2010), who drew the maps showing the level of maturity of organic matter expressed by the vitrinite reflectance at 1.4–2.5% in the Zielona Góra West tender area (Fig. 3.3) and the average content of organic matter (TOC) estimated at 1.2–1.6% (Fig. 3.4). In the work of Botor et al. (2013) the determined maturity of the Carboniferous organic matter was 1.5–2.0% (Figs 3.5–3.6). Both of the mentioned ranges are sufficient for the generation of natural gas

Summary. In the Zielona Góra West tender area, there is a high chance that the Carboniferous rocks contain dispersed organic matter, which could generate hydrocarbons (mainly gaseous) in commercial quantities.

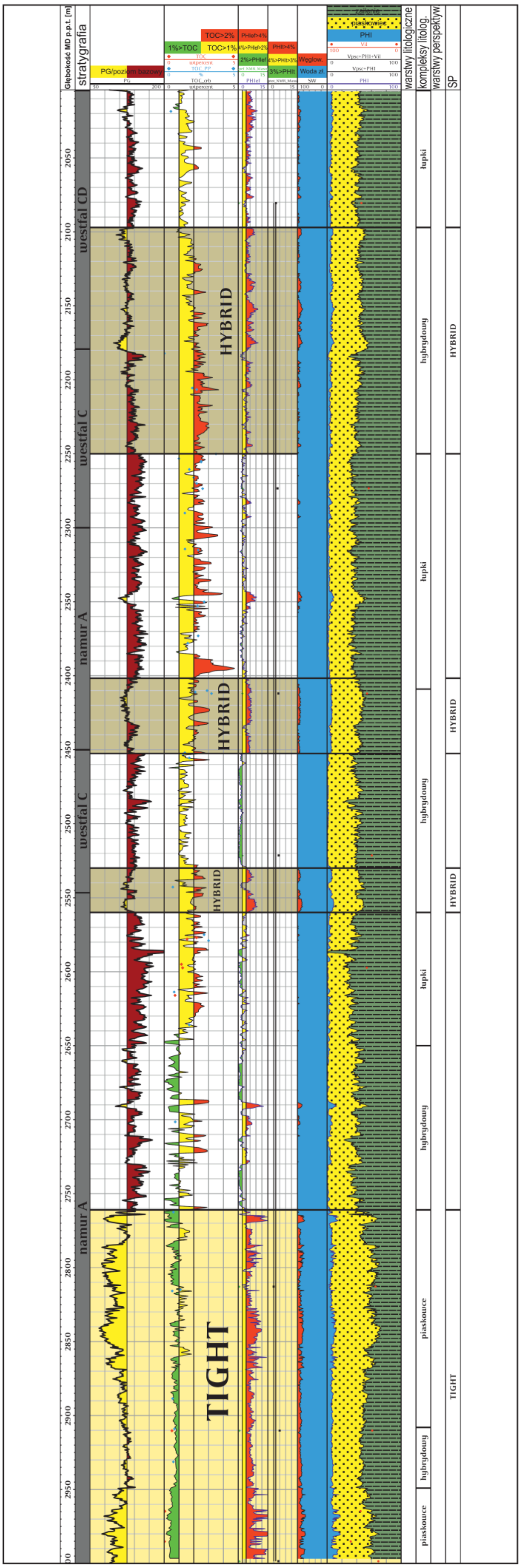


Fig. 3.2. Geophysics and prospective horizons for hydrocarbon occurrences in the Siciny IG-1 well (Roman, 2016).

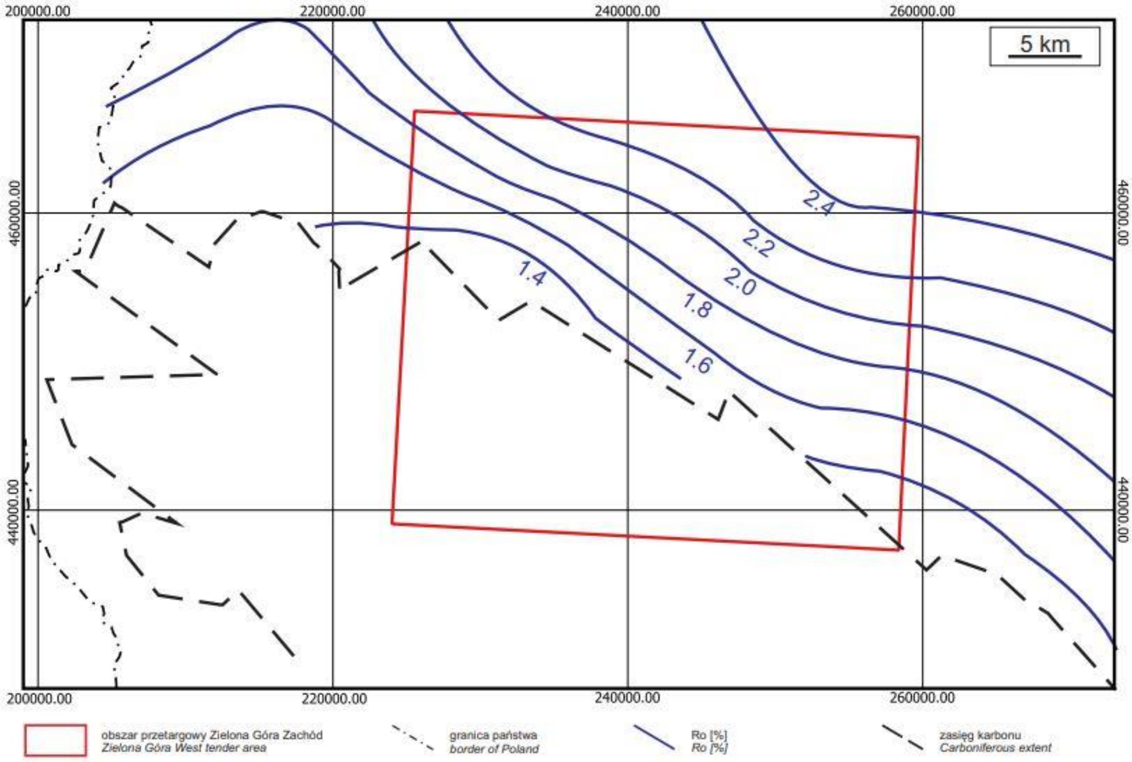


Fig. 3.3. Vitrinite reflectance map of the Carboniferous deposits in the Zielona Góra West tender area and its vicinity (Poprawa, 2010).

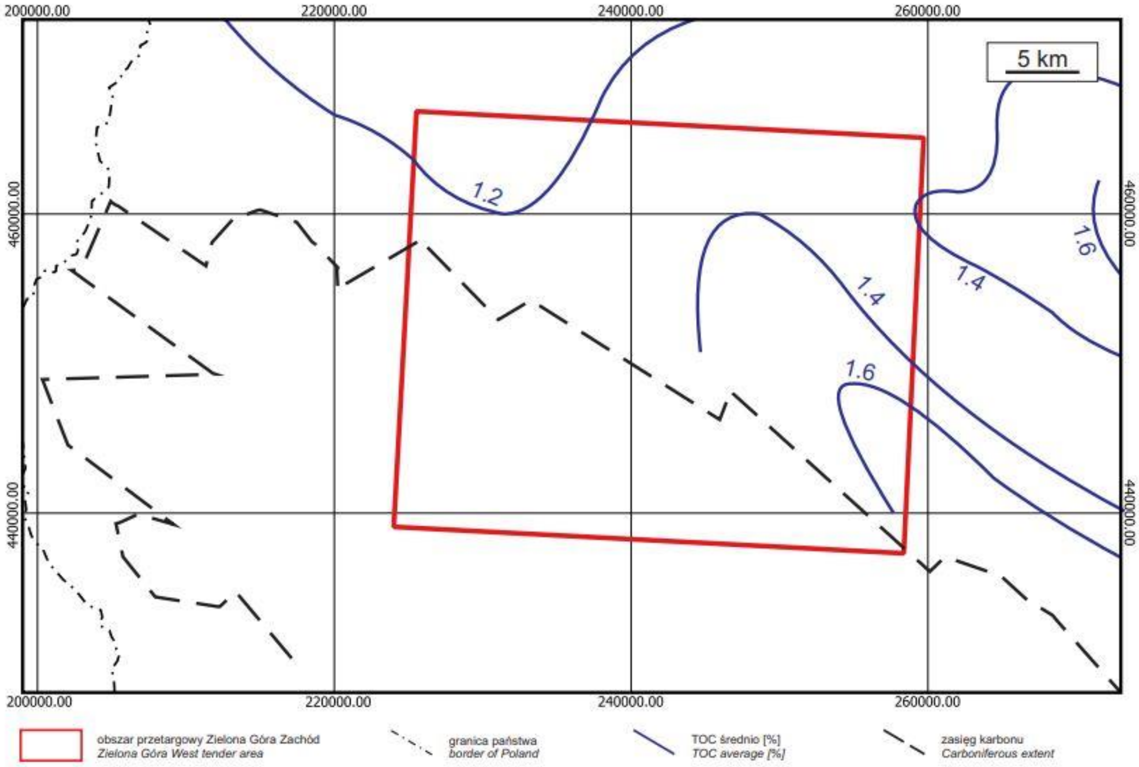


Fig. 3.4. Total organic carbon content (TOC) in the Carboniferous deposits in the Zielona Góra West tender area and its vicinity (Poprawa, 2010).

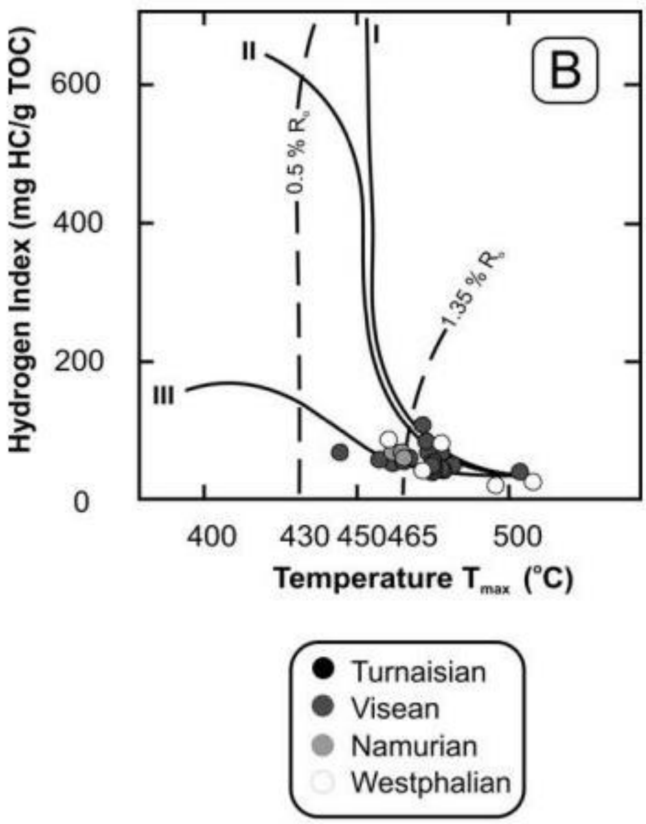


Fig. 3.5. Hydrocarbon potential of the Carboniferous rocks in southern and south-western Poland (Variscan Externides; Botor et al., 2013).

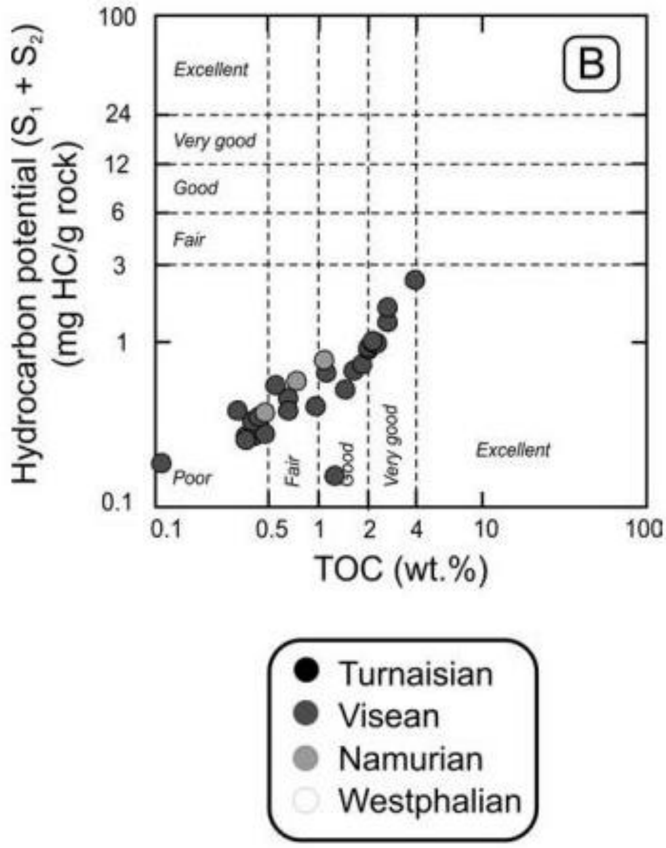


Fig. 3.6. HI vs. Tmax of the Carboniferous rocks in southern and south-western Poland (Variscan Externides; Botor et al., 2013).

Main Dolomite
Lithology: dolomites and limestones, mudstones, boundstones, packstones and grainstones

Thickness: 24.6–82.7 m.
Depth (see Tab. 2.1).
The main source rocks in the Main Dolomite horizon are related the carbonate platform facies. Geochemical studies of the Main Dolomite of the Wielkopolska carbonate platform were published by Kosakowski and Wróbel (2010) and Kosakowski and Krajewski (2014). Despite the lack of research on wells located in the Zielona Góra West tender area, the Main Dolomite sediments belong to the same facies zones and were characterized by a similar geological history (similar depths, overburden thickness, heat, etc.).

Kosakowski and Wróbel (2010) investigated 39 wells. More than half of these wells are located in the north-western and northern parts of the Silesian-Sudetic carbonate platform. The organic matter consists mainly of macerals of the liptinite group, indicating type II kerogen (Fig. 3.7). An increase of the thermal maturity is observed from the carbonate platform towards the basin plain. The vitrinite reflectance of the northern part of the Silesian-Sudetic carbonate platform (Wielkopolska platform) ranges from 0.5 to 1.35% Ro, which corresponds to the so-called oil window.

Detailed sedimentological and geochemical studies of the Main Dolomite source rocks were presented by Kosakowski and Krajewski (2014). The best parameters in terms of hydrocarbon content (HI) and total organic matter content (TOC) are found in carbonate platform sediments (Fig. 3.8). However, in the vertical geochemical succession, the Main Dolomite shows greater diversity. High contents of TOC and HI seem not to occur in the whole profile, but only in its shallowest parts (Fig. 3.8; Kotarba and Wagner, 2007).

In the light of geochemical studies (Kosakowski and Krajewski, 2014; Tab. 3.1–3.3; Figs 3.8–3.9), the carbonate platform slope sediments have a weak or good hydrocarbon potential (average bitumen content 1430 ppm), carbonate platform sediments have a good hydrocarbon potential (average bitumen content 4930 ppm), while the deposits near the edge of the barrier have the highest potential (average bitumen content 9560 ppm).

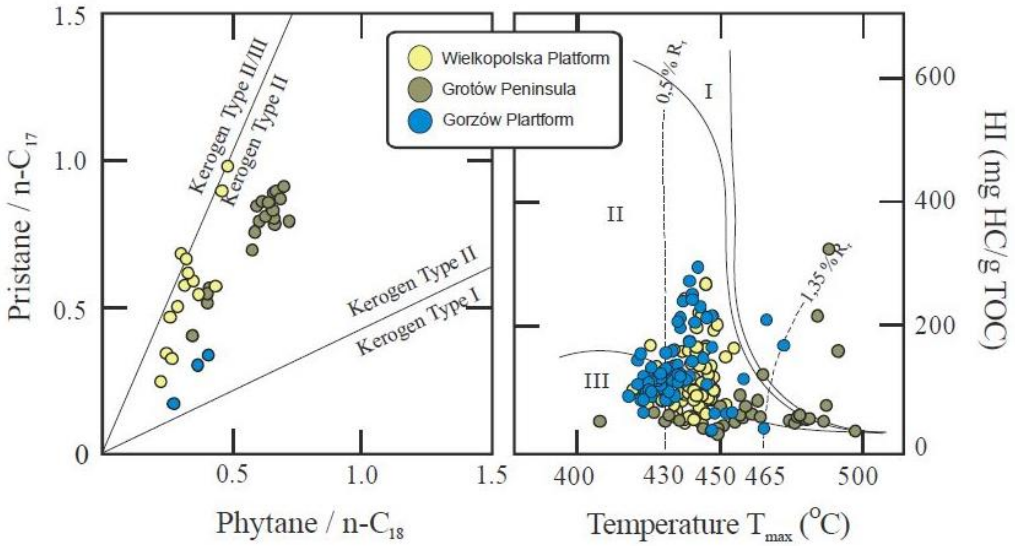


Fig. 3.7. Main Dolomite as a source rock in the south western part of Poland (Kosakowski and Wróbel, 2010).

Index	II		III		IV		V		VII		IX		XI		XIII	
Total organic carbon	0.01 to 3.36	(183)	0.00 to 3.87	(34)	0.00 to 0.77	(30)	0.04 to 0.11	(10)	0.01 to 0.04	((10)	0.01 to 0.83	(20)	0.01 to 0.77	(7)	0.01 to 0.11	(5)
(TOC) (wt. %)	0.21	(13)	0. 83	(8)	0.19	(7)	0.08	-(2)	0.02	-(1)	0.19	(3)	0.27	(1)	0.03	(1)-
$S_1 + S_2$ (mg HC/g rock)	0.18 to 3.12	(38)	0.08 to 10.71	(8)	0.11 to 0.98	(8)	–		–		0.51 to 2.51	(5)	0.33 to 2.26	(4)	–	
	0.86	(5)	2.01	(4)	0.65	(5)					1.24	(1)	1.25	(1)		
Hydrogen index (HI)	25 to 225	(38)	67 to 166	(8)	56 to 10	(8)	–		–		52 to 170	(5)	90 to 145	(4)	–	
(mg HC/g TOC)	75	(5)	116	(4)	83	(5)					109	(1)	119	(1)		
Oxygen index (OI)	6 to 219	(38)	5 to 180	(8)	8 to 204	(8)	–		–		93 to 604	(5)	69 to 223	(4)	–	
(mg CO_2/g TOC)	103	(5)	74	(4)	113	(2)					280	(1)	159	(1)		
T_{max} (°C)	434 to 510	(31)	435 to 462	(6)	420 to 456	(8)	–		–		433	(1)	433 to 442	(2)	–	
	454	(5)	449	(3)	436	(5)							–	(1)	–	
Production index (PI)	0.30 to 0.89	(38)	0.22 to 0.53	(8)	0.36 to 0.56	(8)	–		–		0.38 to 0.69	(5)	0.33 to 0.87	(4)	–	
	0.50	(5)	0.31	(4)	0.45	(5)					0.58	(1)	0.56	(1)	–	
Bitumens (ppm)	210 to 2800	(19)	190 to 2370	(8)	440 to 1070	(3)	–		–		100 to 5380	(3)	1880	(1)	–	
	1000	(5)	1068	(4)	653	(3)					2303	(1)				
Aromatics HC (%)	13 to 46	(10)	29 and 39	(2)	36		–		–		–				–	
	33	(5)	–	(2)									22			
Saturated HC (%)	10 to 37	(10)	28 and 32	(2)	16		–		–		–				–	
	22	(5)	–	(2)									19			
Resins (%)	3 to 22	(10)	20 and 21	(2)	12		–		–		–				–	
	14	(5)	–	(2)									16			
Asphaltenes (%)	14 to 49	(10)	9 and 22	(2)	36		–		–		–				–	
	31	(5)	–	(2)									43			

TOC – total organic carbon; Tmax – temperature of maximum of S_2 peak; S_2 – residual petroleum potential; S_1 – oil and gas yield (mg HC/g rock); PI – production index; HI – hydrogen index; OI – oxygen index. Range of geochemical parameters is given as numerator; median values in denominator, in parentheses: number of samples from wells (numerator) and number of sampled wells (denominator).

Tab. 3.1. The results of the Rock-Eval pyrolysis analysis and the group composition of bitumens in different microfacies in the Main Dolomite (Kosakowski and Krajewski, 2014). Explanation of parameters: TOC – total organic carbon; Tmax – temperature of maximum of S2 peak; S2 – residual petroleum potential; S1 – oil and gas yield (mg HC/g rock); PI – production index; HI – hydrogen index; OI – oxygen index. Range of geochemical parameters is given as numerator; median values in denominator, in parentheses: number of samples from wells (numerator) and number of sampled wells (denominator).

Microfacies: II – Microbioclastic-peloid calcisilte, dolopackstone and dolomudstones; III – Microbreccia, lithoclastic dolopackstone, grainstone, dolofloatstone, dolomudstone; IV – Laminated peloidal dolopackstone, dolobindstone, dolomudstone; V – ooid dolograinstones and dolopackstones; VII – Microbial dolobindstones and microframestones, dolopackstones; IX – Algal dolopackstones and grainstones with aggregate grains, dolobindstones; XI – Fenestral, microbial dolobindstones, dolomudstones and dolopackstones; XIII – Lithoclastic dolorudstones and floatstones, dolopackstones.

Index	Facies			
	V		XII/V	
Total organic carbon	0.09 to 1.92	(3)	0.37 to 1.13	(5)
(TOC) (wt. %)	0.83	(1)	0.75	(1)
$S_1 + S_2$ (mg HC/g rock)	4.50 and 9.87	(2)	4.07 to 11.75	(5)
	–	(1)	6.62	(1)
Hydrogen index (HI)	147 and 164	(2)	147 to 207	(5)
(mg HC/g TOC)	–	(1)	156	(1)
Oxygen index (OI)	24 and 94	(2)	24 to 153	(5)
(mg CO_2/g TOC)	–	(1)	156	(1)
T_{max} (°C)	434	(1)	–	
Production index (PI)	0.68 and 0.84	(2)	0.79 to 0.86	(5)
	–	(1)	0.83	(1)
Bitumens (ppm)	12440	(1)	7540 to 12800	(3)
			9560	(1)
Aromatics HC (%)	21	(1)	–	
Saturated HC (%)	45	(1)	–	
Resins (%)	7	(1)	–	
Asphaltenes (%)	27	(1)	–	

Tab. 3.2. The results of Rock-Eval and bitumens analyses in the marginal platform barrier (Kosakowski and Krajewski, 2014). Explanations for geochemical parameters and microfacies – Tab. 3.1.

Index	II		IX		X		XI		XIV	
Total organic carbon (TOC) (wt. %)	0.03 to 2.95	(30)	0.01 to 1.32	(86)	0.03 to 1.33	(19)	0.03 to 0.71	(6)	0.07 to 0.84	(8)
	0.35	(3)	0.23	(7)	0.23	(3)	0.27	(4)	0.27	(1)
$S_1 + S_2$ (mg HC/g rock)	0.58 to 5.16	(13)	0.23 to 11.8	(30)	0.52 to 3.20	(5)	0.22 to 2.21	(4)	0.28 to 1.90	(5)
	2.32	(3)	2.32	(6)	1.62	(2)	0.74	(3)	0.70	(1)
Hydrogen index (HI) (mg HC/g TOC)	70 to 106	(13)	70 to 106	(30)	60 to 116	(5)	63 to 180	(4)	72 to 152	(5)
	88	(3)	88	(6)	101	(2)	106	(3)	103	(1)
Oxygen index (OI) (mg CO_2/g TOC)	17 to 233	(13)	69 to 336	(30)	16 to 153	(5)	45 to 261	(4)	43 to 95	(5)
	101	(3)	172	(6)	88	(2)	153	(3)	80	(1)
T_{max} (°C)	437 to 448	(7)	438 to 457	(11)	437 to 446	(4)	429 to 444	(3)	429 to 441	(5)
	445	(2)	445	(4)	442	(2)	434	(2)	437	(1)
Production index (PI)	0.44 to 0.94	(13)	0.27 to 0.83	(30)	0.46 to 0.77	(5)	0.19 to 0.85	(4)	0.33 to 0.47	(5)
	0.67	(3)	0.59	(6)	0.60	(2)	0.56	(2)	0.43	(1)
Bitumens (ppm)	870 to 5360	(11)	510 to 15760	(15)	1950 to 4440	(3)	660 and 1010	(2)	660 and 1320	(1)
	2500	(2)	2500	(5)	2950	(2)	–	(2)	–	(1)
Aromatics HC (%)	24 and 29	(2)	19 to 34	(8)	20		20 and 28	(2)	–	
	–	(2)	26	(4)			–	(2)		
Saturated HC (%)	39 and 40	(2)	9 to 69	(8)	14		14 and 40	(2)	–	
	–	(2)	40	(4)			–	(2)		
Resins (%)	17 and 17	(2)	7 to 24	(8)	17		9 and 29	(2)	–	
	–	(2)	14	(4)			–	(2)		
Asphaltenes (%)	14 and 22	(2)	3 to 56	(8)	21		23 and 37	(2)	–	
	–	(2)	20	(4)			–	(2)		

TOC – total organic carbon; Tmax – temperature of maximum of S_2 peak; S_2 – residual petroleum potential; S_1 – oil and gas yield (mg HC/g rock); PI – production index; HI – hydrogen index; OI – oxygen index. Range of geochemical parameters is given as numerator; median values in denominator, in parentheses: number of samples from wells (numerator) and number of sampled wells (denominator).

Tab. 3.3. The results of Rock-Eval and bitumens analyses in the inner platform flat (Kosakowski and Krajewski, 2014). Explanations for geochemical parameters and microfacies – Tab. 3.1.

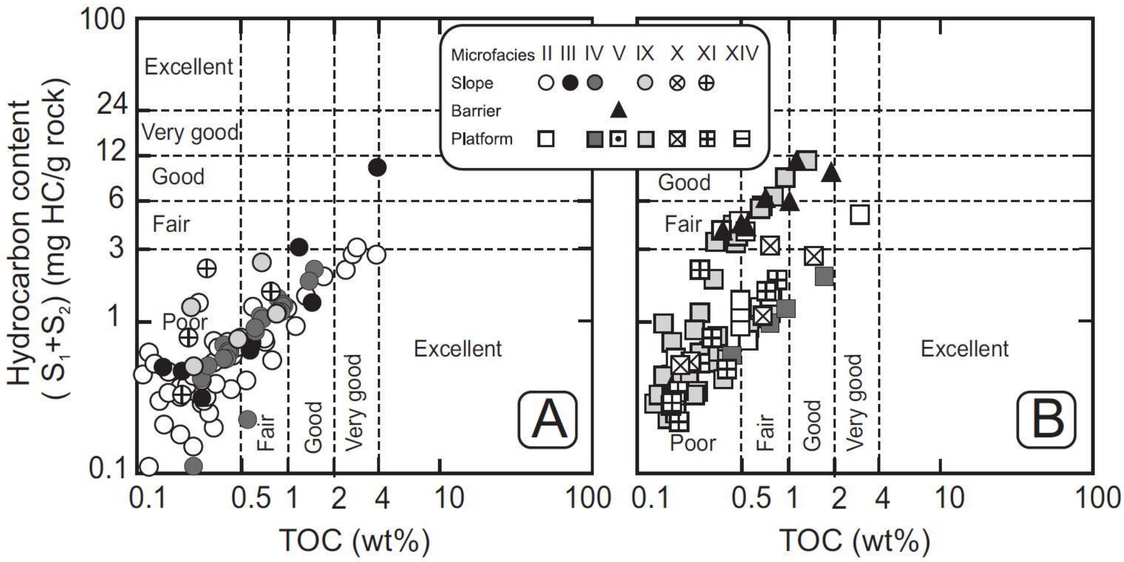


Fig. 3.8. Petroleum source quality diagram for organic matter from Zechstein Main Dolomite in western part of the Wielkopolska Platform (Kosakowski and Krajewski, 2014). Circle – slope sediments, triangle – barrier sediments, square – platform sediments. A – classification according to Hunt (1996). B – classification according to Peters and Cass (1994).

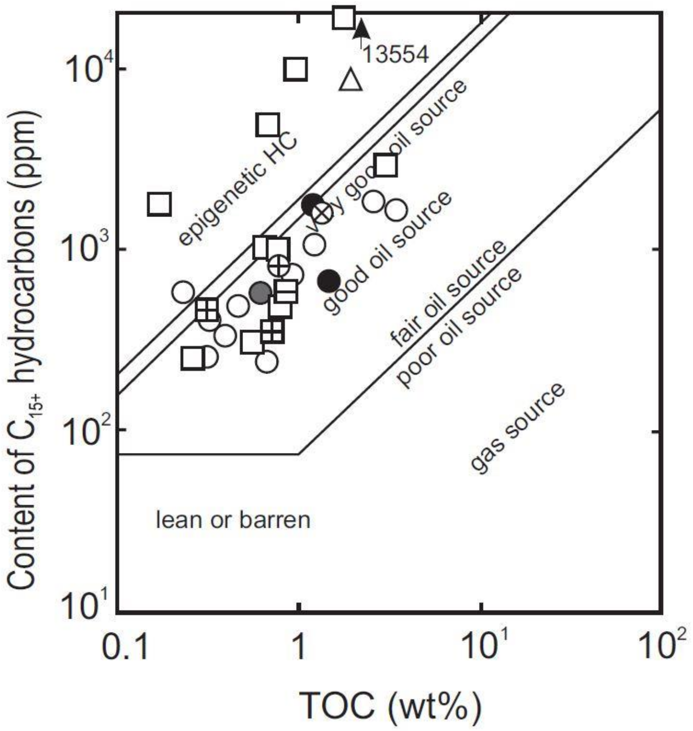


Fig. 3.9. Petroleum source quality diagram for organic matter of Zechstein Main Dolomite in the analysed part of the Wielkopolska Platform. Circle – slope sediments, triangle – barrier sediments, square – platform sediments. Classification by Hunt (1979) and Leenher (1984; after Kosakowski and Krajewski, 2014).

3.3. RESERVOIR ROCKS

Main Dolomite
Lithology: dolomites and limestones, grainstones and packstones

Thickness: 24.6–82.7 m.
Depth (see Tab. 2.1)
The Main Dolomite in the Zielona Góra West area consists of several ten meters thick grainstones/packstones (often oncoid), mudstones/wackstones and sometimes boundstones succession. The above-mentioned microfacies could locally be characterized by good porosity and permeability, but during diagenesis their petrophysical properties are usually lowered, mainly due to the cementation of the pore space and chemical compaction.

The diagenetic processes include dolomitisation, calcitization (dedolomitisation), anhydritization, early- and late-diagenetic cementation (mainly dolomite, calcite, anhydrite, halite), recrystallization, dissolution (e.g. some mineralogically unstable skeletons of organisms/bioclasts), compaction, and stylolitization (Peryt, 1978). Diagenetic processes had various, usually destructive effects on reservoir properties. Only dolomitisation could theoretically contribute to the increase of intergranular microporosity, and dissolution processes to the development of macroporosity. Fracturing is also observed, which has a very large effect on porosity and permeability (unless the fractures are refilled with cements). Other diagenetic phenomena (in particular cementation and dissolution under pressure/stylolitization) led to a reduction in porosity and permeability. Semyrka et al. (2015) investigated the porosity and permeability of the Ca2 sediments on the Grotów platform located north of the tender area (Tab. 3.4). They distinguished three basic microfacies: grain-compact (packstones, grainstones, floatstones and rudstones), mud-compact (mudstones and wackstones) and microbial (boundstones – microbial mats). These microfacies are characterized not only by different lithological development, but also by different petrophysical parameters (Table 3.4). It was found that the grain-compact microfacies are characterized by the best reservoir properties (Tab. 3.4). High average effective porosity and high average dynamic porosity, as well as high permeability for gas and oil were found for these sediments (Tab. 3.4).

The Ca2 reservoir parameters from wells located within the tender area are presented in Tab. 3.5. The porosity in individual samples is very low and ranges from nearly 0 to a maximum of 7% in a few cases. The permeability is also very low – no permeability was found in most of the wells. Just in several cases, higher permeability values were measured – from about 0.5 to over 3 mD, and in two cases over 30 and 50 mD (Nowa Sól 7 and Żarków 3 wells, respectively; Tab. 3.5).

In the Ca2 drillcores hydrocarbon saturation was observed in some places (Tab. 3.6). In some wells, the tested Ca2 intervals brought no hydrocarbon flow (Table 3.6). In the others, during the Ca2 testing, an inflow of brine, gasified brine, brine with crude oil or non-industrial natural gas flows were obtained (e.g. Bronków M-27; Tab. 3.6).

Petrophysical properties	Boundstones	Packstones	Grainstones
Skeletal density [g/cm^3]	2.79	2.75	2.76
Volume density [g/cm^3]	2.47	2.51	2.37
Effective porosity [%]	12.09	8.92	14.16
Capillar diameter [µm]	0.49	0.82	1.65
Specific surface [m^2/g]	0.62	0.64	0.49
Threshold diameter [µm]	9.67	6.08	9.43
Oil dynamic porosity [%]	5.79	5.67	8.45
Gas dynamic porosity [%]	10.80	7.92	13.64

Tab. 3.4. Petrophysical properties of the different microfacies types in the Main Dolomite of the Grotów Peninsula, northern part of the Wielkopolska carbonate platform and the eastern part of the Gorzów carbonate platform (based on Semyrka, 2013; from Waśkiewicz and Kiersnowski, 2020).

Well name:	Depth [m] (numer of samples)	Permeability [mD] (mean)	Porosity [%] (mean)	Bitumen content [%] (mean)
Chojnowo 1	1215.0–1291.5 (63)	0.042–0.286	0.12–6.21	0–0.15
Dachów 1	1106.5–1173.2 (46)	v.l.–2.124	0.13–3.89	0.0185–0.0698
Dęby 1	787.6–859.7 (42)	0.041–0.0427	0.15–5.14	0.0138–0.0758
Drzonów 2	1400.9–1434.0 (32)	v.l.–0.202	0.13–0.74	0.02–0.0958
Jeleniów 1	1164.0–1226.0 (37)	0.074–0.0935 (0.229)	0.13–0.58 (0.302)	0.0195–0.0783 (0.0321)
Kosierz 1	1339.5–1411.5 (56)	b.s.–0.663	0.14–2.16	0.012–0.1633
Niwiska 1	1014.7–1059.3 (43)	<0.01–0.0768 (0.0186)	0.14–0.67 (0.21)	0.0023–0.0913 (0.0303)
Nowa Sól 7	1606.0–1108.0 (18)	<0.01–31.16	n.p.–0.77	0.0090–0.0760
Nowa Sól 9	1087.4–1135.2 (30)	n.p.	n.p.–4.73	0.0075–0.1460
Nowa Sól 16	1269.5–1300.0 (19)	0.042–0.136	0.12–0.66	0.022–0.161
Nowa Sól 18	1194.0 – 1204.4 (15)	0.061–1.994	0.13–0.22	0.0205–0.1485
	1204.3–1241.6 (37)	0.12–071	0.048–0.348	0.0083–0.0675
Pajęczno 1	1129.0–1193.0	<0.01–0.0616	0.16–1.15	0–0.1018

	(60)	(0.0272)	(0.43)	(0.0249)
Piaski 1	1132.0–1177.0 (30)	0.351–20.836	0.15–0.73	0.0153–0.148
Stary Zagór 1	1628.0–1685.0 (73)	0.057–0.359	0.12–3.68	0.0108–0.094
Strużka 1	1033.0–1092.0 (31)	b.s.–0.364	0.13–21.26	0.0123–0.0318
Świdnica 1	1359.5–1387.5 (52)	0.074–0.229	0.12–0.68	0.014–0.1593
Trzebule 1	1619.0–1645.0 (19)	0.099–0.211	0.14–3.56	0.029–0.1073
Wysoka 1	1168.0–1200.6 (30)	0.084–0.872	0.14–4.75	0.018–10.0425
Wysoka 2	1039.6–1116.2 (57)	0.054–3.366	0.14–0.99	0.005–0.0375
Żarków 1	1129.8–1158.2 (47)	0.049–0.29	0.25–1.13	0.012–0.1135
Żarków 2	727.0–753.1 (22)	0.077–0.911	0.13–1.91	0.025–1.413
Żarków 3	863.0–938.0 (23)	0.071–50.442	0.14–5.45	0.012–0.274
Żarków 4	768.9–820.0 (22)	0.106–0.361	0.19–7.26	0.0195–0.3425

v.l. – very low permeability; n.p. – no porosity/permeability

Tab. 3.5. Reservoir parameters of the Main Dolomite (and its overlying and underlying deposits) in the Zielona Góra West tender area according to the well final reports.

Well name:	HC shows (core)	Tested intervals [m]:	Results	Content Brine [g/l] Gas [%]
Bronków M-27	+	1205.0–1223.0	no inflow	–
		1205.0–1277.0	gas	CH_4: 22.0047 C_2H_6: 13.2125 C_4H_{10}: 4.2753 N2: 59.7132 Ar: 0.7943
		1202.0–1282.0	5.4 m^3 brine with gas	Cl^-: 242.2 HCO_3^-: 0.12 SO_4^{3-}: 0.83 Fe^{3+}: 0.22 Ca^{2+}: 46.37 Mg^{2+}: 0.92 Na^+: 50.38 Br^-: 4.37
Chojnowo 1	+	1220.0–1242.7*	no inflow	–
Dachów 1	+	1105.8–1172.0*	brine	Cl^- + Br^-: 195.7392 HCO_3^-: 0.5002 CO_3^{2-}: 0.1440 SO_4^{3-}: 0.7449 Ca^{2+}: 17.0889 Mg^{2+}: 6.8099 Na^+: 6.8099
		1105.8–1172.0*		Cl^- + Br^-: 195.7392 HCO_3^-: 0.5002 CO_3^{2-}: 0.1440 SO_4^{3-}: 0.7449 Ca^{2+}: 17.0889 Mg^{2+}: 6.8099 Na^+: 6.8099 Br^-: 195.7392

Dęby 1	+	795.3–837.0*. **	2.5 m^3/h brine with gas	Cl^-: 108.8622 HCO_3^-: 1.1102 SO_4^{2-}: 2.8479 Fe^{3+}: 1.2547 Ca^{2+}: 7.1088 Mg^{2+}: 7.7772 Na^+: 47.4498
Dychów M-26	?	1584.0–1619.0	minimum inflow	no data
Jeleniów 1	+	1163.3–1189.1	no inflow	–
		1163.3–1189.1**	brine	Cl^-: 227.1186 SiO^-: 0.1063 HCO_3^-: 1.2810 SO_4^{2-}: 0.5391 Fe^{3+}: 0.5651 Ca^{2+} : 24.7150 Mg^{2+}: 47.3117 Na^+: 28.7710 Br^-: 1.5984
Kosierz 1	+	–	–	–
Kosierz M-25	?	1514.0–1545.0	no inflow	–
		1513.5–1581.0	0.3 m^3/h brine	
Lubiatów M-20	+	1401.0–1450.8	0.011 m^3/h brine with oil	–
Niwiska 1	+	1020.0–1050.4	no inflow	–
Nowa Sól 7	+	1060.0–1113.2*. **	40 l/h brine	Cl^-: 227.6532 SiO^-: 0.1064 HCO_3^-: 0.5612 SO_4^{2-}: 0.4897 Fe^{3+}: 2.0926 Ca^{2+} : 20.1062 Mg^{2+}: 26.1901 Na^+: 72.9567
Nowa Sól 16	+	1251.5–1296.5**	15 l/h brine	Cl^-: 146.0952 SiO^-: 0.1392 HCO_3^-: 0.7685 SO_4^{2-}: 1.0206 Fe^{3+}: 6.5240 Ca^{2+}: 21.6300 Mg^{2+}: 12.7419 Na^+: 38.6327
Nowa Sól 18	+	1194.0–1214.0*.**	100 l/d brine, 6 l oil	–
		1194.0–1214.0**. ***	120 l/d brine with gas	Cl^-: 169.1442 SiO^-: 0.1368 HCO_3^-: 0.4758 SO_4^{2-}: 0.5185 Fe^{3+}: 2.0003 Ca^{2+}: 23.5475 Mg^{2+}: 24.9155 Na^+:33.3899
Nowa Wieś P-9	?	752.0–756.3	2.4 m^3/h brine with gas	Cl^-: 1.03 E5 HCO_3^-: 3.29 E2 SO_4^{2-}: 4.28E3 Fe^{3+}: 3.95 Ca^{2+}: 1.73E2 Mg^{2+}: 5.71 E2 Na^+: 6.93 E4
Piaski 1	+	1135.0–1150.0**	no inflow	–

		1156.0–1160.0**	100l brine with gas	Cl^-: 220.0414 SiO^-: 3.4494 HCO_3^-: 0.5978 SO_4^{2-}: 0.4115 Fe^{3+}: 2.3262 Ca^{2+}: 20.2284 Mg^{2+}: 37.3564 Na^+: 49.1007 Br^-: 3.3566
Pajęczno 1	+	1130.0–1183.0	no inflow	–
Stary Zagór 1	+	1620.0–1644.2*	no inflow	–
		1620.0–1685.0*	no inflow	
Strużka 1	+	1031.0–1080.0*	no inflow	–
		1031–1080**	9 m^3 brine	
Tarnawa M-21	+	1181.0–1195.0	no inflow	–
		1181.0–1210.0	no inflow	
		1220.0–1270.0	no inflow	
		1180.0–1215.0**	no inflow	–
Trzebule 1	+	1619.0–1633.0*. **	no inflow	–
Wysoka 1	+	1170.5–1237.5**	brine	Cl^-: 239.6243 SiO^-: 4.7992 HCO_3^-: 0.8784 SO_4^{2-}: 0.1275 Fe^{3+}: 2.1835 Ca^{2+}: 27.4959 Mg^{2+}: 42.0476 Na^+: 45.8680 Br^-: 3.2767
Wysoka 2	+	1034–1039**	brine	Cl^-: 201.9332 SiO^-: 2.1324 HCO_3^-: 0.5734 SO_4^{2-}: 1.4369 Fe^{3+}: 1.9569 Ca^{2+}: 18.3467 Mg^{2+}: 24.0175 Na^+: 64.6221 Br^-: 1.2520
Żarków 1	+	1087.7–1129.8*.**	160 l/d brine and 270 l oil	Cl^-: 227.6532 SiO^-: 3.4899 HCO_3^-: 1.1468 SO_4^{2-}: 0.5144 Fe^{3+}: 2.2674 Ca^{2+}: 33.2159 Mg^{2+}: 23.9007 Na^+: 64.3112
Żarków 2	+	–	–	–
Żarków 3	+	865.2–938.0		Cl^-: 176.2362 SiO^-: 0.2861 HCO_3^-: 1.1224 SO_4^{2-}: 0.4197 Fe^{3+}: 1.5666 Ca^{2+}: 12.2113 Mg^{2+}: 1.7983 Na^+: 95.7481

Żarków 4	+	764.4–774.5**.***	no inflow	–

*spoon, **acid treating, ***hydroperforation

Tab. 3.6. Hydrocarbon shows and test results in the Main Dolomite of the Zielona Góra West tender area according to final well reports.

Upper Rotliegend
Lithology: fine- and medium-grained aeolian sandstones

The petrophysical properties of the Upper Rotliegend were tested in 8 wells in the Zielona Góra West tender area (Tab. 3.7). These properties were greatly influenced by diagenetic processes affecting the rocks, as well as sedimentary environment in which deposition took place. The porosity ranges from 2.61 to 26.53%, and the permeability is from 0.806 to 240.01 mD (Tab. 3.7).

In the drilled and tested horizons, brine flows were obtained in most cases (Table 3.8). Some of them were gasified (Tab. 3.8). In the Tarnawa M-21 well an industrial gas flow were obtained, although dominated by nitrogen (Tab. 3.8).

Well name:	Depth [m] (samples)	Permeability [mD] (mean)	Porosity [%] (mean)	Bitumin content [%] (mean)
Chojnowo 1	1505.0–1530.1 (4)	1.792–102.410	6.67–21.44	traces
Dachów 1	1372.0–1396.0 (11)	0.543–210.585	2.61–26.17	traces
Dęby 1	1042.9–1053.7 (6)	8.795–117.266	1.09–15.19	traces
Niwiska 1	1289.0–1362.6 (11)	0.1379–36.3707 (15.6738)	3.96–19.1 (12.04)	traces –0.0343 (0.0057)
Piaski 1	(3)	0.554–161.047	8.42–24.03	traces
Stary Zagór 1	1965.0–1984.6 (14)	97.848–240.0173	13.71–26.53	traces
Wysoka 2	1285.0–1305.0 (13)	8.672–185.823	4.21–16.76	traces
Żarków 3	1034.2–1040.2 (1)	0.806	3.41	traces

Tab. 3.7. Reservoir parameters of the Upper Rotliegend (and its overlying and underlying deposits) of the Zielona Góra West tender area according to well final reports.

Well name:	HC shows (core)	Tested intervals [m]:	Results	Content Brine [g/l] Gas [%]
Bronków M-27	–	1504.2–1517.0	1.64 m^3/h brine	Cl^- – 161.91 SiO^- – 0.4 HCO_3^- – 1.59 SO_4^{2-} – 0.51 Fe^{3+} – 0.41 Ca^{2+} – 36.54 Mg^{2+} – 46.51 Na^+ – 20.18 Br^- – 0.63
Chojnowo 1	+	1505–1530.1*	no inflow	–
Dachów 1	–	1374.6–1508	brine and mud	–
Jeleniów 1	–	1443.7–1492.3	7 m^3/h brine	–
Kosierz M-25	–	1772.0–1810.0	16.2 m^3/h brine with mud	–

Lubiatów M-20	–	1625.0–1662.0	16.2 m^3/h brine	Cl^- – 168.742 HCO_3^- – 0.20867 SO_4^{2-} – 0.44944 Fe^{3+} – 0.01841 Ca^{2+} – 45.622 Mg^{2+} – 1.252 Na^+ – 55.227 J^- – 0.02328 K^+ – 1.461 Mn^{2+} – 0.13135
Niwiska 1	–	1281.5–1303.0	3.3 m^3/h brine	Cl^- – 117.0180 HCO_3^- – 0.1220 SO_4^{2-} – 1.6626 Fe^{3+} – 0.0909 Ca^{2+} – 5.3690 Mg^{2+} – 3.6277 Na^+ – 63.6013
Nowa Wieś P-9	–	939.0–1012.0	0.14 m^3/h brine with gas	CH_4: 20.3% C_2H_6: 0.11% N_2: 79.09% H_2: 0.49%
Piaski 1	–	1633.0–1650.0*	100 l/h brine	Cl^- – 49.9986 SiO^- – 0.2353 CO_3^{2-} – 0.1200 SO_4^{2-} – 2.0412 Ca^{2+} – 12.1866 Mg^{2+} – 0.0598 Na^+ – 19.5404
		1414.0–1420.0	brine	Cl^- – 2.8368 SiO^- – 0.1874 CO_3^{2-} – 0.1440 SO_4^{2-} – 1.5227 Ca^{2+} – 0.8960 Mg^{2+} – 0.238 Na^+ – 1.7261
Stary Zagór 1	–	1962.5–1984.6	300 l/h brine	Cl^- – 217.0152 SiO^- – 0.8914 HCO_3^- – 0.1647 SO_4^{2-} – 0.5350 Fe^{3+} – 0.6518 Ca^{2+} – 66.3450 Mg^{2+} – 1.1843 Na^+ – 62.4246 J^- – 0.0181
Strużka 1	–	1031.0–1306.0*	brine	–
Tarnawa M-21	–	1443.0–1466.0	gas Vabs.=46 m^3/min	CH_4: 10.61% C_2H_6: 0.68% N_2: 88.85% CO_2: 0.03% He: 0.41%
Wysoka 1	–	1420.0–1440.7*	brine	Cl^- – 164.8107 SiO^- – 3.1606 HCO_3^- – 0.0732 SO_4^{2-} – 0.4609 Fe^{3+} – 1.5848 Ca^{2+} – 20.3935 Mg^{2+} – 4.5051 Na^+ – 75.2929

				Br^- – 0.4329
Wysoka 2	–	1287.3–1303.0	brine	Cl^- – 154.1242 SiO^- – 3.3600 HCO_3^- – 0.0488 SO_4^{2-} – 0.4033 Fe^{3+} – 0.8113 Ca^{2+} – 18.3542 Mg^{2+} – 1. 8020 Na^+ – 82.1299 Br^- – 0.4102
Żarków 1	–	1360.0–1363.0	120/h brine	Cl^- – 184.0374 SiO^- – 0.1975 HCO_3^- – 0.2318 SO_4^{2-} – 1.1688 Fe^{3+} – 0.2266 Ca^{2+} – 22.6717 Mg^{2+} – 4.6388 Na^+ – 85.0478
Żarków 4	–	1034.0–1034.0***	no inflow	–

*spoon, **acidification, ***hydroperforation

Tab. 3.8. Hydrocarbon shows and test results in the Upper Rotliegend of the Zielona Góra West tender area according to final well reports.

3.4. SEAL ROCKS

The evaporite-sulphate succession of the PZ1 and PZ2 cyclothems from the bottom and top seal for the Main Dolomite horizon, respectively. The remaining Zechstein succession (PZ3 and PZ4), as well as the Mesozoic (in this case only the Triassic) and Cenozoic rocks form the overburden (Fig. 3.1).

In the case of the Carboniferous-Lower Permian petroleum play, the PZ1 (evaporites overlying the Rotliegend) forms the seal. In addition, in the case of the south-eastern part of the tender area, impermeable complexes of the Rotliegend alluvial conglomerates and sandstones may be potential seal rocks. In the Carboniferous-Lower Permian petroleum system, a part of the Zechstein profile (PZ2, PZ3 and PZ4 cyclothem), as well as the Mesozoic (Triassic) and Cenozoic rocks form the overburden (Fig. 3.1).

3.5. GENERATION, MIGRATION, ACCUMULATION AND TRAPPING

Main Dolomite

Source rocks: mudstones, boundstones, packstones and grainstones.
Reservoir rocks: dolomitized grainstones and packstones.
Seal rocks: PZ1 and PZ2 evaporites.
Overburden: Permian-Mesozoic (PZ3, PZ4 and Triassic) and Cenzozoic sedimentary rocks with a thickness of about 650.0 to about 1350.0 m.
Shape and size of the traps: small and medium-sized structural or structural-tectonic traps.
Age and mechanism of trap formation: primary synsedimentary traps (Kotarba et al., 2000) associated with the edge zone of the Ca2 carbonate platform, as well as basin

highs (shallow water, carbonate granular facies). The second type is related with subsequent halotectonic processes (salt uplift and A1g, Ca2 and A2 uplift).

Age and mechanism of generation, expulsion, migration and accumulation of hydrocarbons. The first stage of hydrocarbon generation from the Main Dolomite began during the Late Permian. At this stage, autochthonous gas dominated by methane was generated. The formation of autochthonous gas is associated with the microbial activity of bacteria transforming the organic matter (Kotarba et al., 2000). The main stage of hydrocarbon generation in the Zielona Góra West tender area was associated with the entry of the Ca2 rocks into the so-called oil window. Increased subsidence and high heat flux were very important factors influencing the generation of hydrocarbons. According to Dadlez et al. (1995), the heat flux was highest in the Late Permian and Early Triassic. Intensified subsidence started in the Permian and continued in the Early, Middle and Late Triassic. As a result, the Main Dolomite, buried to a depth of more than 1500 m, were heated with a temperature exceeding 80°C, entering the initial stage of the oil window (Kosakowski and Wróbel, 2010). However, it should be noted the entrance of the source rocks of the basin facies into the oil window occurred in the Triassic period (Pletsch et al., 2010). The greatest burial of the Main Dolomite occurred in the Jurassic. This period also coincides with the main stage of hydrocarbon generation. Due to the high thermal flux that occurred in this part of the basin, the rocks of the basin plain exhausted their generation potential already in the Late Triassic, and in the case of the carbonate platform facies – in the Middle Jurassic (Pletsch et al., 2010). The expulsion of hydrocarbons began in the Early Triassic in the area covering, among the others, the Zielona Góra West tender area and lasted until the end of the Late Jurassic or beginning of the Early Cretaceous, when the expulsion was interrupted by Cimmerian orogenic movements. According to 1D modelling, the kerogen transformation coefficient for the area of e.g. Silesian-Sudetic carbonate platform is above 98% (Kosakowski and Wróbel, 2010). According to 2D modelling (Kosakowski and Wróbel, 2010), the migration of hydrocarbons took place already in the Early Triassic, and continued into the Late Jurassic/Early Cretaceous.

According to Kotarba and Wagner (2007), the hydrocarbon generation process took place in two ways. In the case of the first path, the generation process has one-stage. It was associated with a continuous and progressive phase of transformation of organic matter, whose hydrocarbon potential was exhausted at the end of the Triassic. The second path is characterized by two stages of hydrocarbon generation. The first one, during which 80 to 90% of the hydrocarbons were generated from kerogen, lasted until the end of the Late Jurassic. For the remaining part of the hydrocarbons, generation took place already in the post-Cretaceous period. As a consequence, the accumulation of oil in the traps occurred at the turn of the Triassic and Jurassic, the gas saturation of oil deposits took place at the end of the Late Jurassic, and the final generation of gas occurred in the Paleogene and Neogene. Geological and geochemical studies indicate that the migration of hydrocarbons from the source rock to the reservoir rock took place within a range of only a dozen or so kilometres (Kotarba and Wagner, 2007).

Carboniferous-Lower Permian

Source rocks: Lower and Upper Carboniferous claystones and mudstones.

Reservoir rocks: Upper Rotliegend fine- and medium-grained aeolian sandstones.

Seal rocks: evaporites of the PZ1 cyclothem.

Overburden rocks: Permian-Mesozoic (PZ2, PZ3, PZ4 and Triassic) and Cenozoic sedimentary rocks with a thickness of about 750.0 to about 1700.0 m.

Shape and size of the traps: small and medium-sized stratigraphic or structural-stratigraphic types.

Age mechanism of trap formation: synsedimentary traps occur at the top of the aeolian sediments. It is also assumed that the traps of a mixed type, structural and stratigraphic, may have formed as a result of the Cimmerian and/or Laramian movements.

Age and mechanism of generation, expulsion, migration and accumulation of hydrocarbons. The analysis presented below is based on numerical modelling of the Carboniferous-Lower Permian petroleum play, which was performed for the entire Polish part of the Permian Basin (Botor et al., 2013). In the Zielona Góra West tender area, a significant part of the Lower Carboniferous source rocks (partly Upper Carboniferous, as well) reaches vitrinite reflectance in the range of 1.5–2.0% Ro (Fig. 3.10). Only in its north-western part, vitrinite reflectance is in the range of 1.0–1.5% Ro. This means that the source rocks are in the main phase of thermogenic gas generation. After Botor et al. (2013), the Variscan heat flux and the degree of kerogen transformation of the source rocks for the end of the Carboniferous period, show that the generation potential for hydrocarbons has not been consumed (Fig. 3.11). This is crucial information; it means that the main process of generation and migration of hydrocarbons took place later, thanks to which the hydrocarbons were not destroyed during the Variscan Orogeny. Increased subsidence during the Zechstein and Triassic occurred in the Polish Basin. Also in its marginal parts (e.g. tender area), the 1D modeling of burial history (e.g. Siciny 2 well; Wójcicki et al., 2014) indicates a significant burial of the top of the Carboniferous, which may reach about 3000 m. Studies of the Carboniferous-Lower Permian petroleum play indicate that the kerogen transformation coefficient of the Carboniferous source rocks ranged from 40 to 60% at the end of the Triassic (Fig. 3.12). Increased subsidence reached its maximum at the end of the Late Jurassic, and was interrupted by the Cimmerian movements. Despite repeated subsidence during the Cretaceous, the Carboniferous source rocks most likely did not reach a greater degree of kerogen transformation. Two factors could have contributed to this: 1) the burial of the top of the Carboniferous succession was shallower, and 2) the heat flux decreased over time, reaching values close to today's values at the end of the Cretaceous. The above information may suggest that some of the synsedimentary traps in the Upper Rotliegend could have been destroyed, and hydrocarbons could have migrated to other zones or to mixed, structural-stratigraphic traps. According to Botor et al. (2013), at the end of the Cretaceous, the degree of kerogen transformation of the Carboniferous source rocks of the Zielona Góra West area reached about 90% (Fig. 3.13). The migration of hydrocarbons was probably only vertical due to the volcanic rocks separate the reservoir and source rocks (Fig. 3.14). However, it should be note that numerous faults, especially the Middle Odra Fault Zone (Kiersnowski and Petecki, 2017), which were renewed during the Cimmerian or Laramian movements, could be a potential migration path for hydrocarbons.

According to Burzewski et al. (2009), the Carboniferous source rocks within the Zielona Góra West tender area were characterized by a genetic potential of 200–600 kg HC/m^2 (Fig. 3.15).

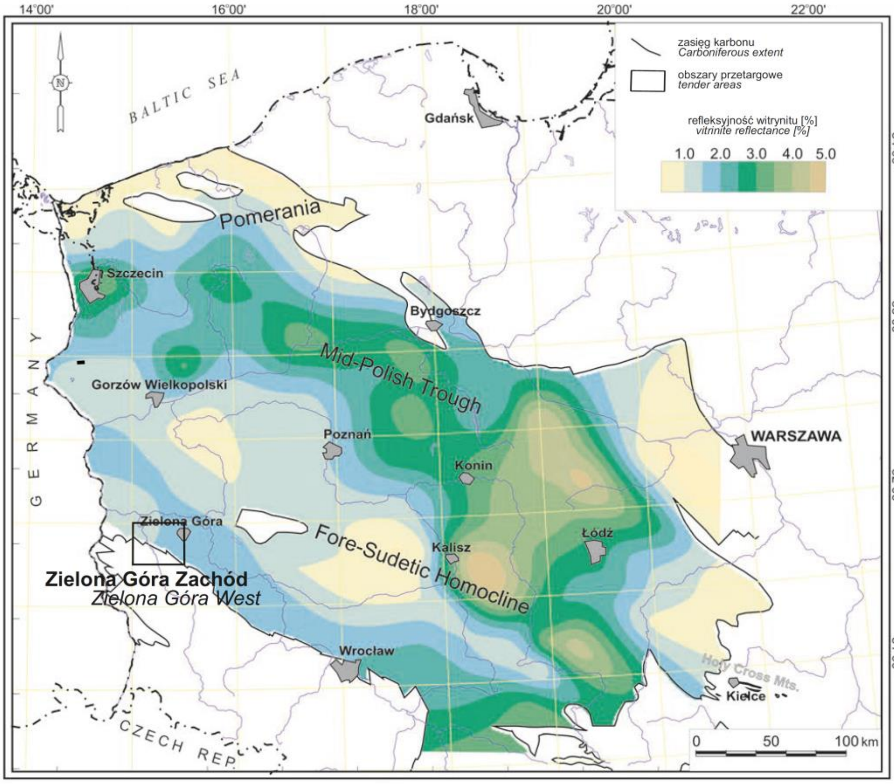


Fig. 3.10. Vitrinite reflectance of the Carboniferous source rocks in Poland (Botor et al., 2013; modified).

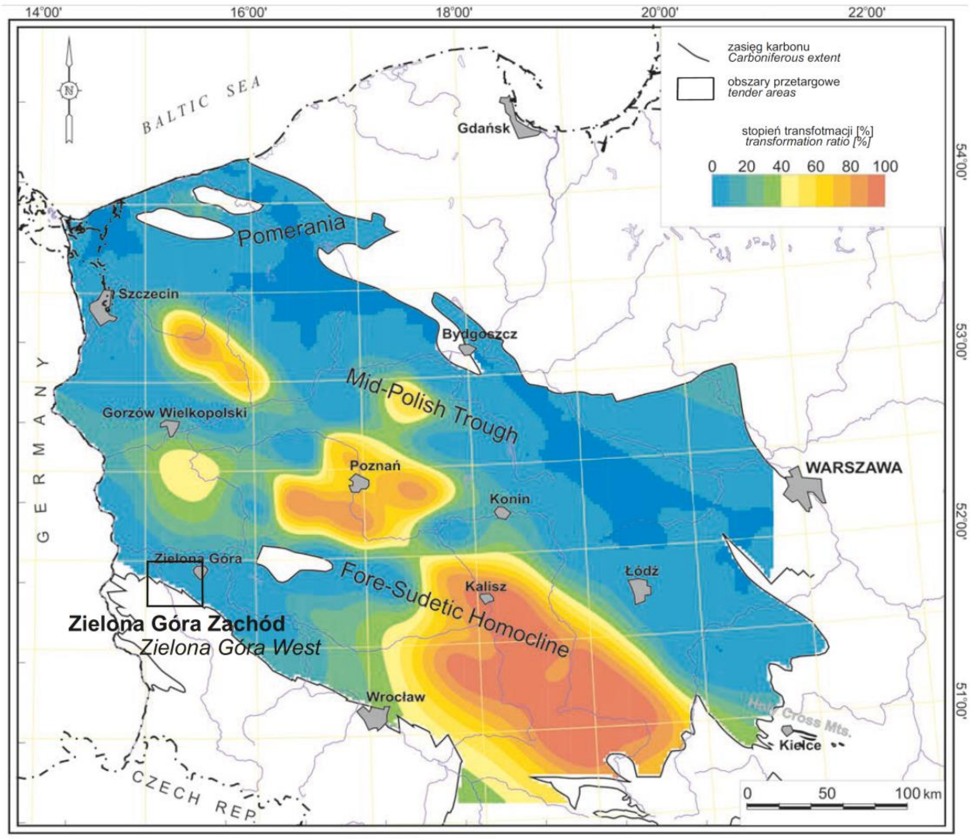


Fig. 3.11. Kerogen transformation ratio of the Carboniferous source rocks in Poland at the end of the Carboniferous (Botor et al., 2013; modified).

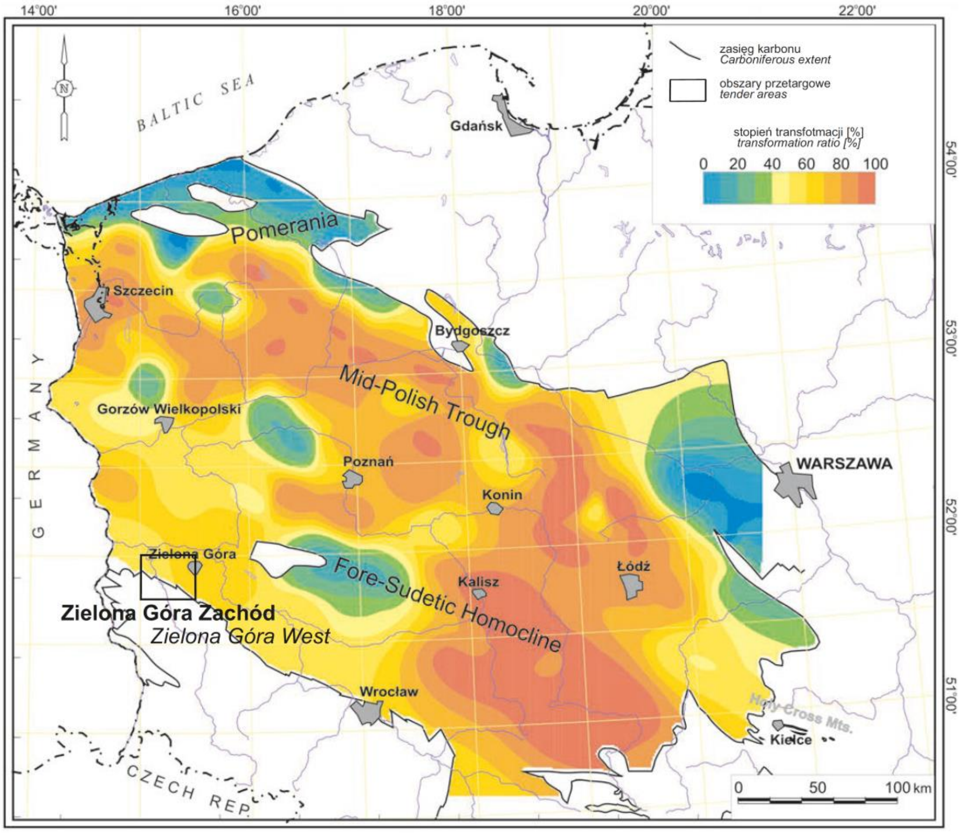


Fig. 3.12. Kerogen transformation ratio of the Carboniferous source rocks in Poland at the end of the Triassic (Botor et al., 2013; modified).

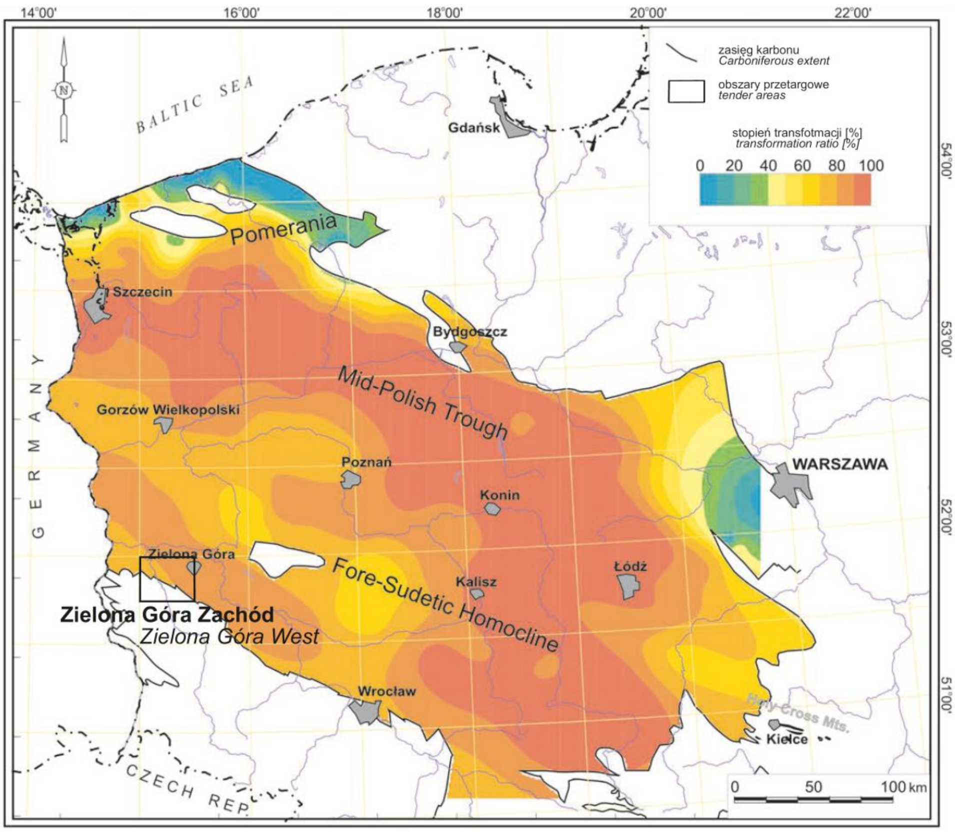


Fig. 3.13. Kerogen transformation ratio of the Carboniferous source rocks in Poland at the end of the Cretaceous (Botor et al., 2013; modified).

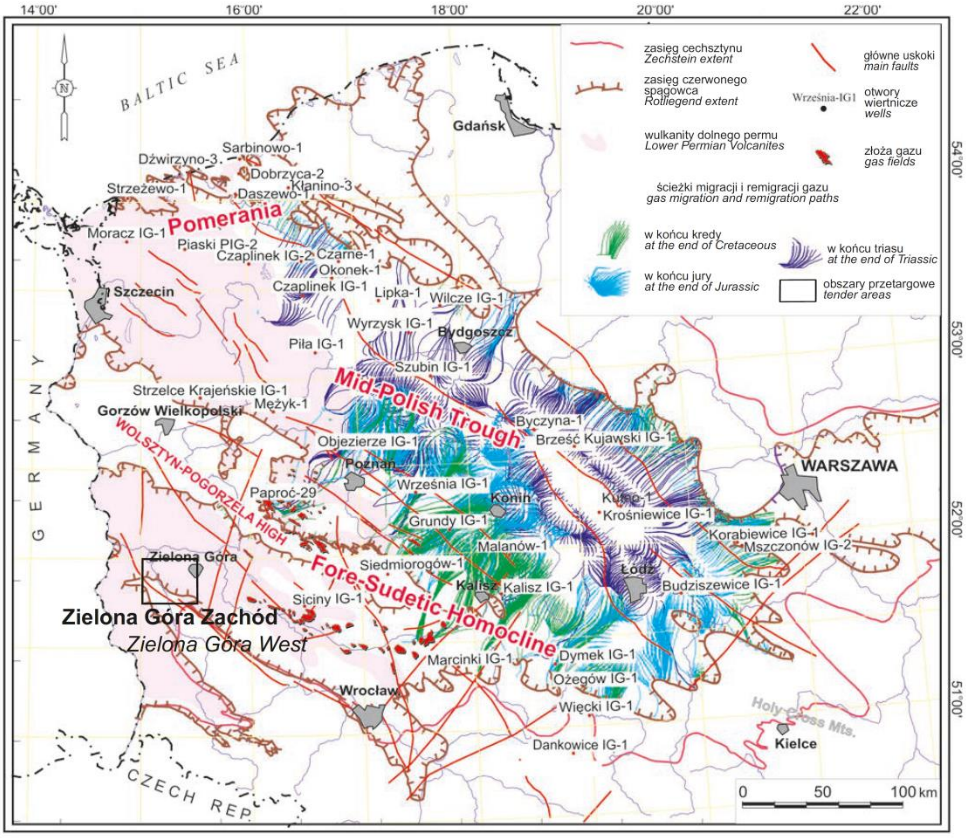


Fig. 3.14. Gas migration pathways from the Carboniferous source rocks to the Upper Rotliegend in Poland (Botor et al., 2013; modified).

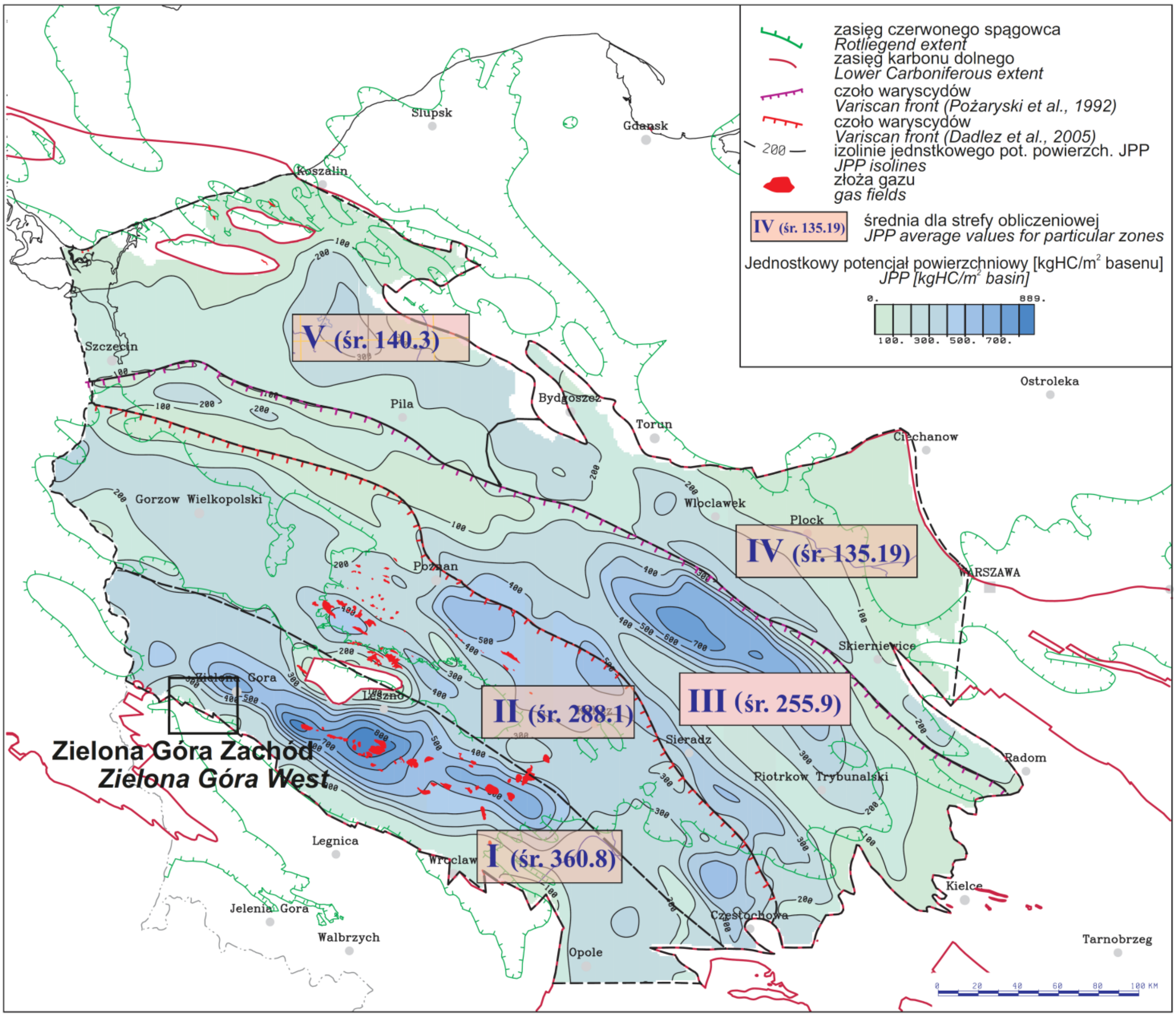


Fig. 3.15. Surface generation potential (JPP) for the Carboniferous source rocks in Poland (Burzewski et al., 2009; modified).

4. HYDROCARBON FIELDS

There have been seven hydrocarbon fields documented within the close neighborhood of the Zielona Góra West tender area (Fig. 4.1). These are:

- Brzózka natural gas field (GZ 16415; Fig. 4.2, Tab. 4.1);
- Czeklin natural gas field (GZ 4734; Fig. 4.3, Tab. 4.2);
- Czerwieńsk crude oil field crossed out from national register (NR 4807; Figs 4.4–4.6, Tab. 4.3);
- Lelechów crude oil field crossed out from national register (NR 4808; Figs 4.7–4.9, Tab. 4.4);
- Mozów N crude oil field crossed out from national register (NR 5326; Figs 4.10–4.12, Tab. 4.5);
- Mozów S crude oil field (NR 5511; Figs 4.13–4.15, Tab. 4.6);
- Nowa Sól natural gas field (GZ 6724; Fig. 4.16, Tab. 4.7).

→ **Fig. 4.1.** Hydrocarbon fields in the neighborhood of the Zielona Góra West tender area.

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

Areas selected to the tender procedure for concessions for hydrocarbons fields prospection and exploration and for hydrocarbons production from fields (6th tender round)

Zielona Góra Zachód

0 2,5 5 10 km

Układ współrzędnych / *Coordinate system: PL-1992*

Objaśnienia / Legend

- obszary wytypowane do przetargu / *areas selected to the tender procedure*
- złoża węglowodorów / *hydrocarbon fields*
- złoża węglowodorów skreślone z bilansu zasobów / *hydrocarbon fields crossed out from the balance of mineral resources deposits in Poland*
- 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, ukł. wsp. PL-1992
Coordinates determining the borders of tender area, coordinate system PL-1992

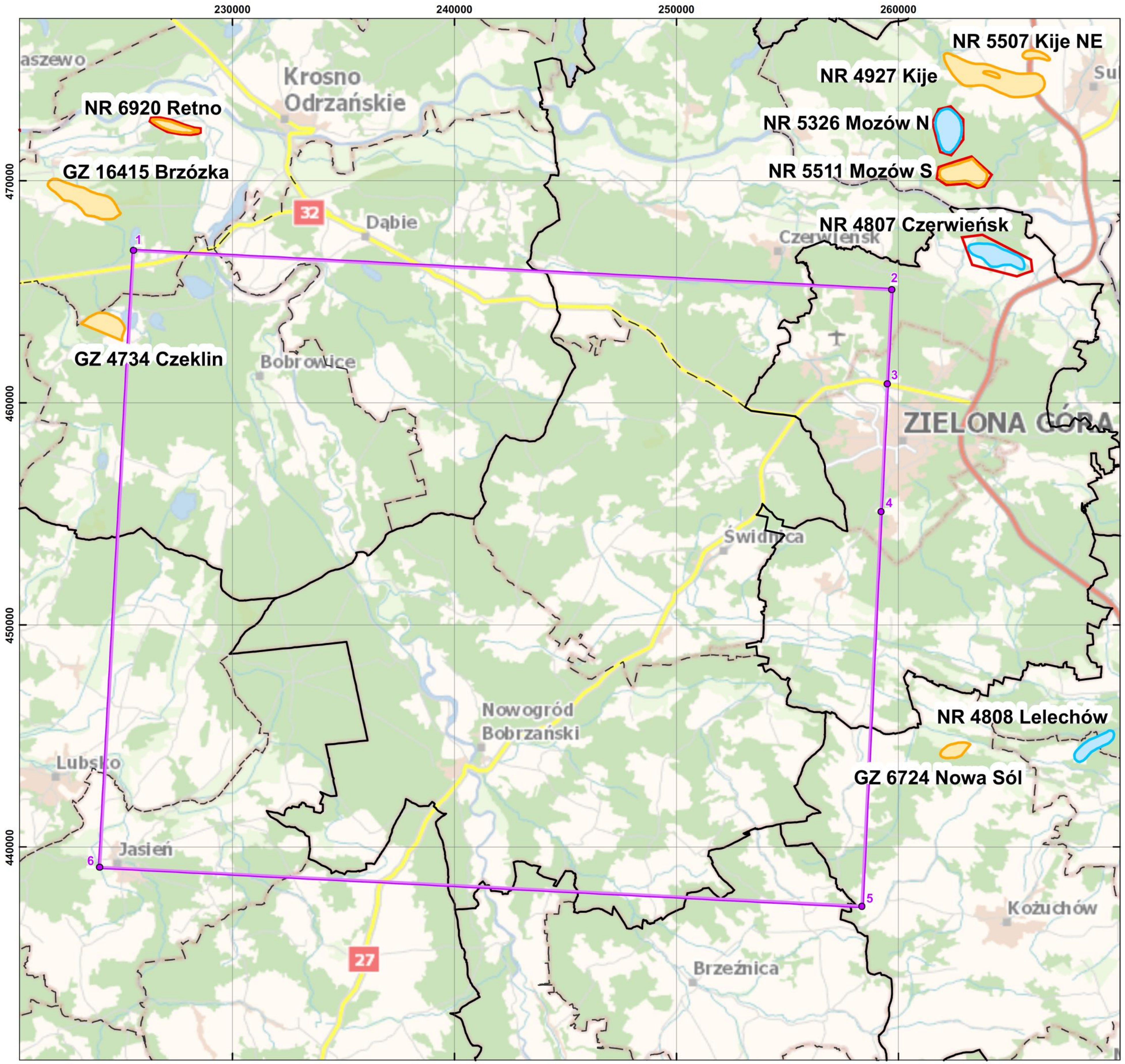
Nr punktu / *Point No*	X	Y
1	466864,29	225534,14
2	465099,30	259706,65
3	460854,86	259501,20
4	455090,39	259224,01
5	437314,83	258369,88
6	439083,64	224005,94

Udokumentowane złoża kopalin, obszary i tereny 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 field, mining areas and mining counties: 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)



Brzózka natural gas field

Total field acreage: 274.00 ha
Depth: from 1,613.00 to 1,666.50 m
Stratigraphy: Permian – Zechstein (Stassfurt cyclothem, Main Dolomite)
Resources:
The primary exploitable anticipated economic resources (as of 2011):
75.60 Mm^3 of natural gas in cat. C

The exploitable anticipated economic resources as of 31 XII 2022:
75.40 Mm^3 of natural gas in cat. C
The economic resources in place as of 31 XII 2022:
lack of resources
The production in 2022:
lack of production

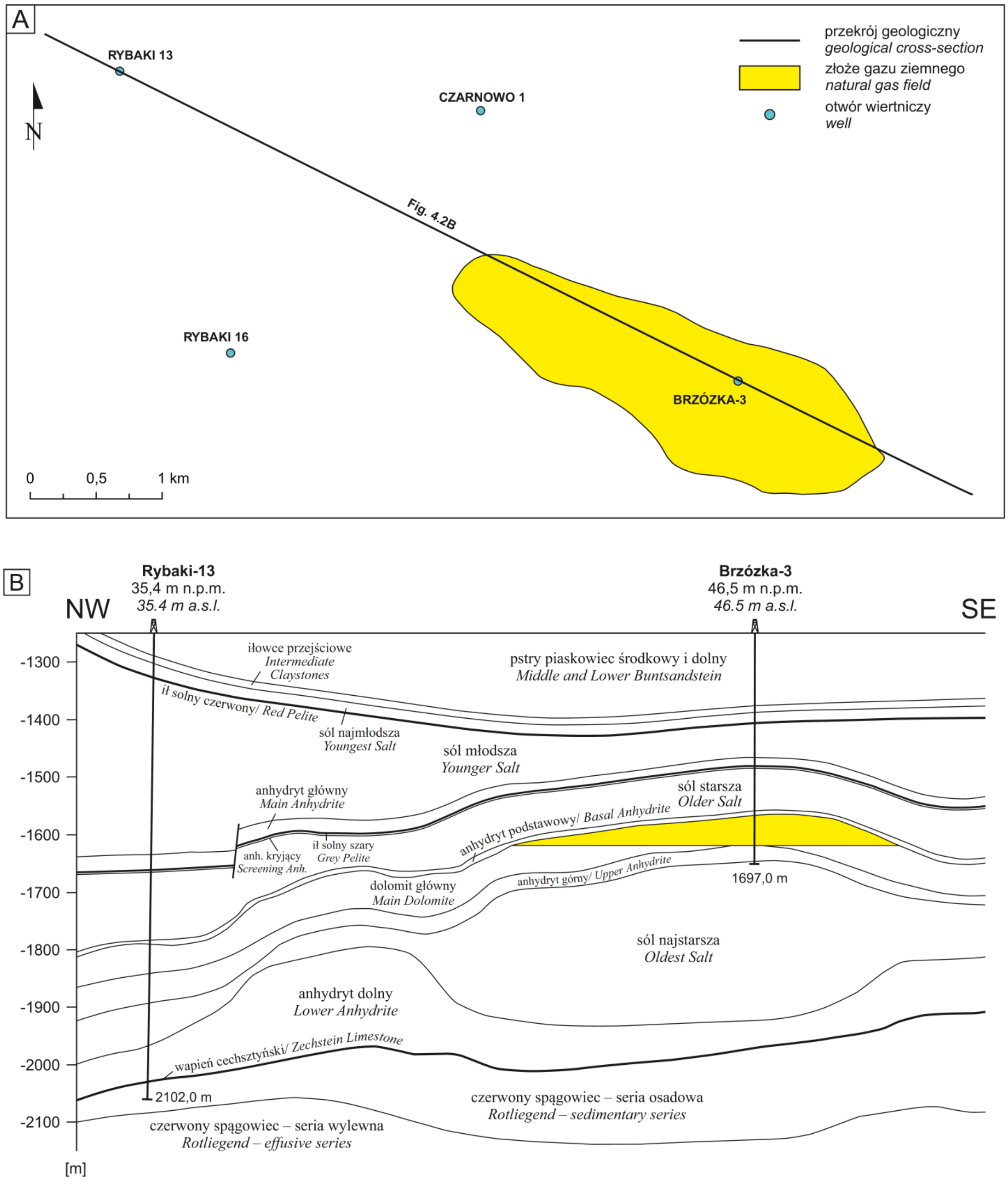


Fig. 4.2. A. Location of wells within Brzózka natural gas field and its neighborhood (on the basis of the Central Geological Database, 2022). **B.** Geological cross-section through Brzózka natural gas field (on the basis of Wolańska, 2012).

Parameter	Minimum value	Maximum value	Average value	Unit	Comments
bottom pressure P_{ds}	---------	---------	19.820	MPa	at the depth of 1,649.7 m
wellhead pressure P_{gs}	---------	---------	16.620	MPa	
primary reservoir pressure	---------	---------	19.820	MPa	
depth of underlying water	---------	---------	---------	m	not applicable
effective reservoir thickness	---------	---------	6.740	m	average value from the map of effective thickness
porosity	0.400	9.100	2.230	%	for the whole Main Dolomite horizon
effective porosity	---------	---------	7.050	%	average value from the map of effective thickness
permeability	---------	---------	0.490	mD	average value covering a top spinal part of Main Dolomite
reservoir temperature	---------	---------	65.750	°C	
production conditions	---------	---------	---------	–	volumetric
hydrocarbons saturation factor	---------	---------	0.633	–	
production factor	---------	---------	0.600	–	
absolute efficiency V_{abs}	---------	---------	290.000	m^3/min	
permitted efficiency V_{dozw}	---------	---------	60.000	m^3/min	
quality parameters of natural gas (main raw material)					
Parameter	**Minimum value**	**Maximum value**	**Average value**	**Unit**	**Comments**
combustion heat	---------	---------	10.097	MJ/m^3	
density	---------	---------	0.939	–	
Wobbe index	---------	---------	10.420	MJ/m^3	
calorific value	8.790	9.820	9.193	MJ/m^3	
C_2H_6 content	1.905	1.985	1.953	% v/v	
CH_4 content	13.090	14.220	13.517	% v/v	
carbon dioxide content	0.000	0.109	0.052	% v/v	
H_2 content	---------	---------	0.002	% v/v	
He content	0.035	0.036	0.035	% v/v	
Hg content	1.521	1.616	1.559	µg/m^3	
N_2 content	80,820	82,120	81.810	% v/v	
hydrogen sulfide content	0.000	0.000	0.000	% v/v	
hydrocarbons content	---------	---------	18.106	% v/v	
heavy hydrocarbons C_{3+} content	2.492	2.849	2.636	% v/v	

Tab. 4.1. Parameters of Brzózka natural gas field and quality parameters of the raw material (the MIDAS Database, 2022 according to Wolańska, 2012).

Czeklin natural gas field

Total field acreage: 136 ha
Depth: from 1,250.00 m to 1,351.00 m
Stratigraphy: Permian – Zechstein (Stassfurt cyclothem, Main Dolomite)
Resources:
The primary exploitable anticipated economic resources:
not determined

The exploitable anticipated economic resources as of 31 XII 2022:
95.00 Mm^3 of natural gas in cat. C
The economic resources in place as of 31 XII 2022:
lack of resources
The production in 2022:
lack of production

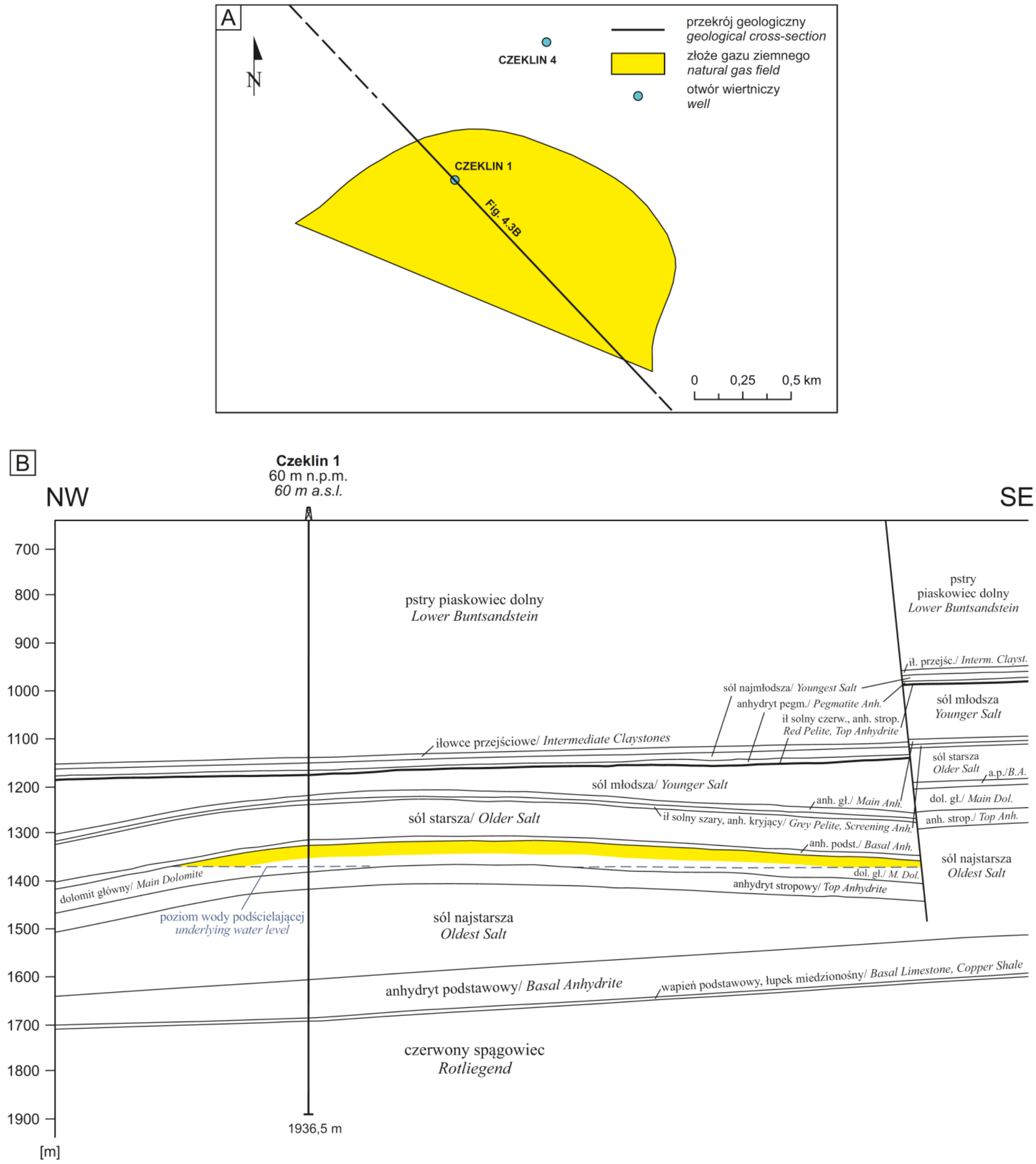


Fig. 4.3. A. Location of wells within Czeklin natural gas field and its neighborhood (on the basis of the Central Geological Database, 2022). **B.** Geological cross-section through Czeklin natural gas field (on the basis of Urbański et. al., 1975).

Parameter	Minimum value	Maximum value	Average value	Unit	Comments
bottom pressure P_{ds}	---------	---------	163.440	ata	Czeklin 1 well
wellhead pressure P_{gs}	---------	---------	140.800	atn	Czeklin 1 well
primary reservoir pressure	---------	---------	163.440	ata	
depth of underlying water	---------	---------	1,351.000	m	
effective reservoir thickness	---------	---------	13.400	m	„b" field
effective reservoir thickness	---------	---------	26.800	m	„a" field
effective reservoir thickness	---------	27.000	21.000	m	
porosity	---------	---------	3.280	%	for the whole complex
porosity	---------	---------	0.790	%	lower complex
porosity	---------	---------	5.120	%	upper complex
effective porosity	---------	---------	5.120	%	
permeability	---------	---------	0.764	mD	upper complex
permeability	---------	---------	0.296	mD	lower complex
mineralization degree of formation water	---------	---------	342.000	g/l	
reservoir temperature	---------	---------	337.000	°K	
production conditions	---------	---------	---------	–	volumetric
hydrocarbons saturation factor	---------	---------	0.700	–	
production factor	---------	---------	0.700	–	
absolute efficiency V_{abs}	---------	---------	900.000	Nm^3/min	Czeklin 1 well
permitted efficiency V_{dozw}	---------	---------	50.000	Nm^3/min	
quality parameters of natural gas					
Parameter	**Minimum value**	**Maximum value**	**Average value**	**Unit**	**Comments**
density	0.922	0.969	0.938	–	in relation to air
calorific value	---------	---------	1,678.000	$Kcal/Nm^3$	lower value calculated
calorific value	---------	---------	1,854.000	$Kcal/Nm^3$	upper value calculated
C_2H_6 content	1.140	1.570	1.370	% v/v	
CH_4 content	11.800	14.050	13.260	% v/v	
carbon dioxide content	0.000	3.333	0.060	% v/v	
N_2 content	80.000	85.500	84.000	% v/v	
hydrogen sulfide content	---------	---------	---------	% v/v	not stated
heavy hydrocarbons C_{3+} content	30.500	31.800	31.000	g/Nm^3	

Tab. 4.2. Parameters of Czeklin natural gas field and quality parameters of raw materials (the MIDAS Database, 2022 according to Urbański et. al., 1975).

Czerwieńsk crude oil field

Total field acreage: 172.3 ha
Depth: from -1,831.45 to -1,860.0 m
Stratigraphy: Permian – Zechstein (Stassfurt cyclothem, Main Dolomite)
Resources:

Resources crossed out from the national register in 2009.

The primary exploitable anticipated economic resources (as of 2008):
35.00 kt of crude oil in cat. A
7.70 Mm^3 of natural gas in cat. A

The exploitable anticipated economic resources as of 31 XII 2008:
2.31 Mm^3 of natural gas in cat. A

The exploitable anticipated sub-economic resources as of 31 XII 2008:
0.37 kt of crude oil in cat. A

The economic resources in place as of 31 XII 2008:
0.37 kt of the crude oil economic resources in place in cat. A
62.00 kt of the crude oil sub-economic resources in place in cat. A
4.31 Mm^3 of the natural gas sub-economic resources in place in cat. A

The production in 2022:
lack of production

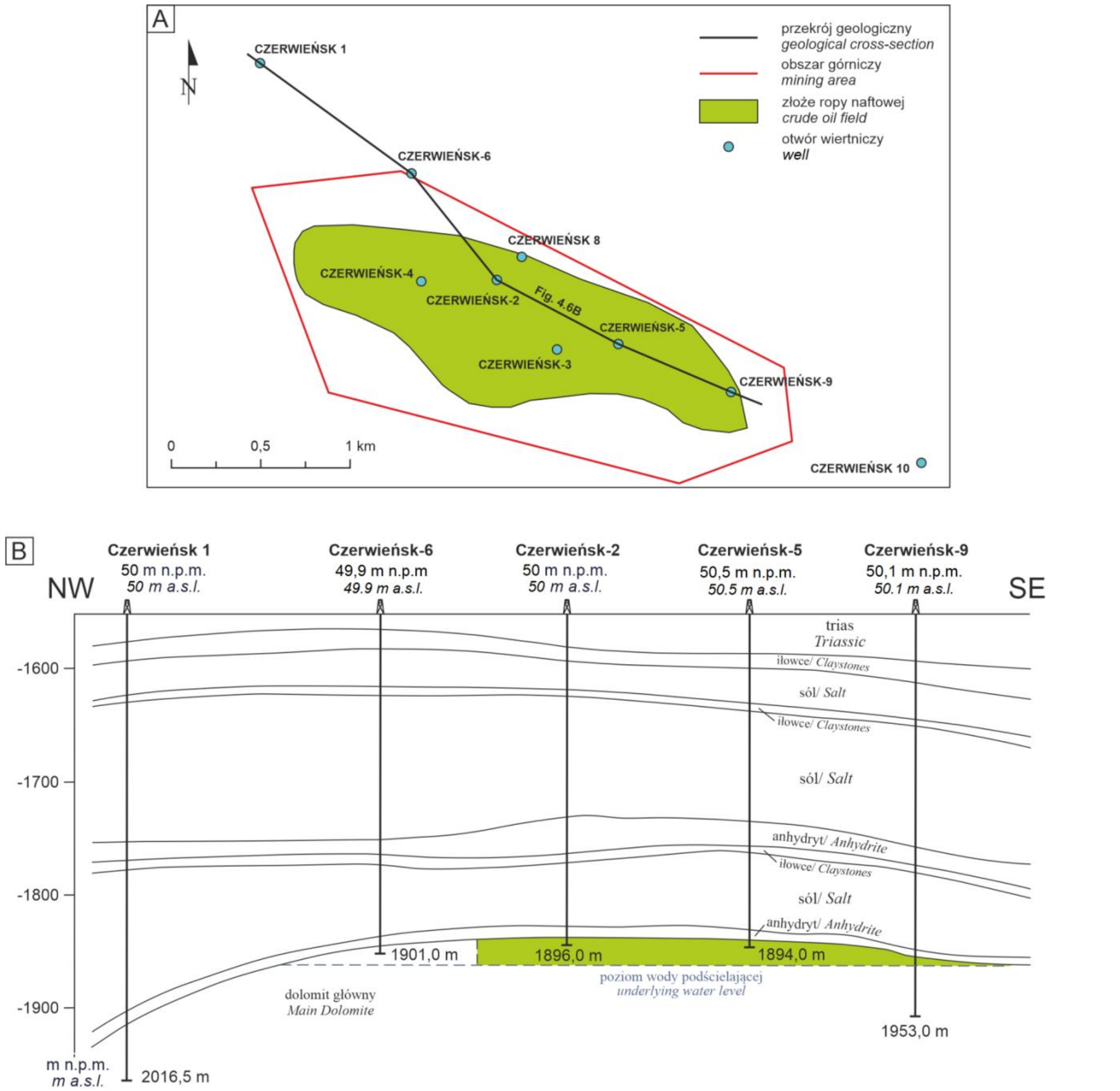


Fig. 4.4. A. Location of wells within Czerwieńsk crude oil field and its neighborhood (on the basis of the Central Geological Database, 2022). **B.** Geological cross-section through Czerwieńsk crude oil field (on the basis of Burdzy, 2009).

Parameter	Minimum value	Maximum value	Average value	Unit	Comments
current pressure	---------	---------	13.310	MPa	as of 14 X 2000
primary reservoir pressure	---------	---------	23.320	MPa	
depth of underlying water	---------	---------	-1,860.00	m	
effective reservoir thickness	---------	---------	14.400	m	
oil saturation	---------	---------	60.000	%	
porosity	---------	---------	1.000	%	
reservoir temperature	---------	---------	345.000	°K	
chemical type of formation water	---------	---------	---------	–	Cl-Na-Ca brine
production conditions	---------	---------	---------	–	production ended
production factor	---------	---------	0.350	–	
permitted efficiency V_{dozw}	---------	---------	45.000	t/month	3 t/cycle (15 cycles per month)
gas exponent	---------	---------	50.000	m^3/t	December 2006
water exponent	---------	---------	0.500	m^3/t	December 2006
sand encroachment	---------	---------	---------	%	not measured
quality parameters of crude oil (main raw material)					
Parameter	**Minimum value**	**Maximum value**	**Average value**	**Unit**	**Comments**
oil specific gravity	---------	---------	0.842	g/cm^3	
paraffin content	---------	---------	3.570	% w/v	
sulfur content	---------	---------	1.270	% w/v	
quality parameters of natural gas (accompanying material)					
Parameter	**Minimum value**	**Maximum value**	**Average value**	**Unit**	**Comments**
calorific value	---------	---------	52.400	MJ/Nm^3	
C_2H_6 content	---------	---------	19.990	% v/v	
CH_4 content	---------	---------	42.880	% v/v	
carbon dioxide content	---------	---------	0.200	% v/v	
He content	---------	---------	0.040	% v/v	
N_2 content	---------	---------	0.380	% v/v	
hydrogen sulfide content	---------	---------	0.380	% v/v	
heavy hydrocarbons C_{3+} content	---------	---------	21.830	% v/v	

Tab. 4.3. Parameters of Czerwieńsk crude oil field and quality parameters of raw materials (the MIDAS Database, 2022 according to Brudzy, 2009).

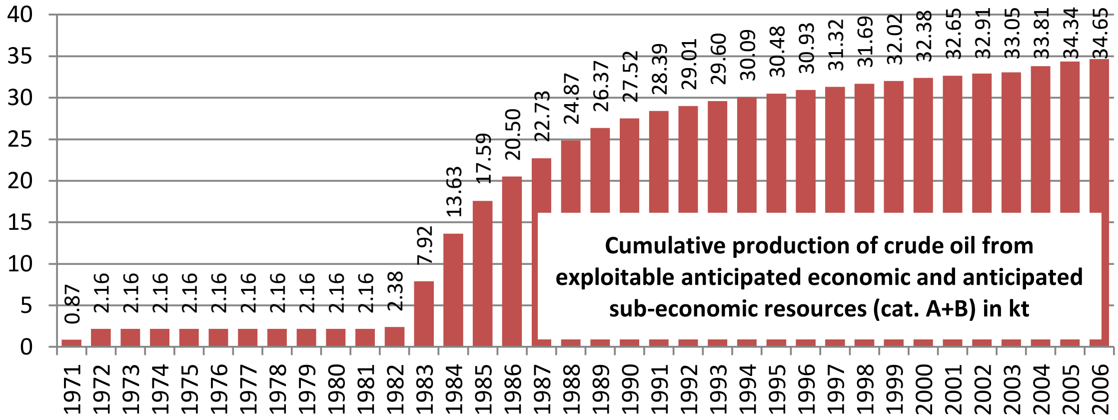


Fig. 4.5. Graph of crude oil (main raw material) production from Czerwieńsk field (according to Annex 3 to geological documentation of the field – Burdzy, 2009).

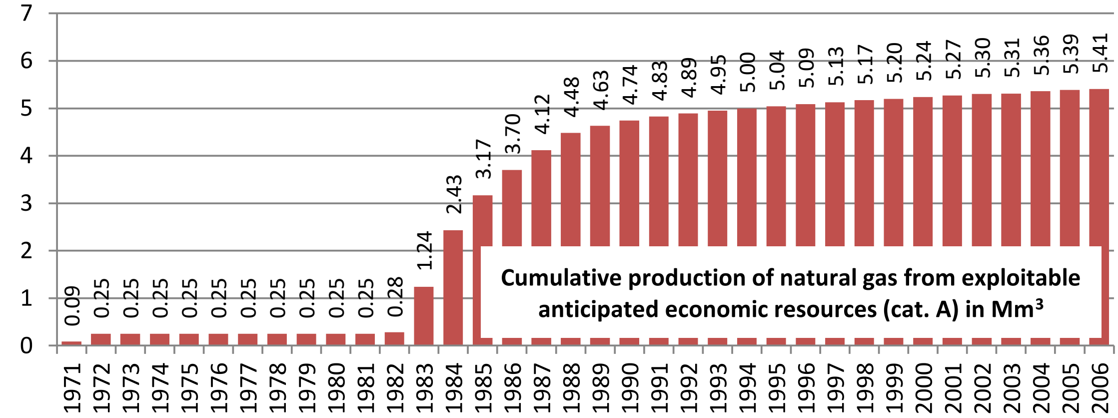


Fig. 4.6. Graph of natural gas (accompanying raw material) production from Czerwieńsk field (according to Annex 3 to geological documentation of the field – Burdzy, 2009).

Lelechów crude oil field

Total field acreage: 98.00 ha
Depth: from -1,000.00 m to -1,055.00 m
Stratigraphy: Zechstein (Stassfurt cyclothem, Main Dolomite)
Resources:
Resources crossed out from the national register in 2000.
The primary exploitable anticipated economic resources (as of 1999):
lack of resources
The exploitable anticipated economic resources as of 31 XII 1999:
lack of resources
The economic resources in place as of 31 XII 1999:
lack of resources
The production in 2022:
lack of production

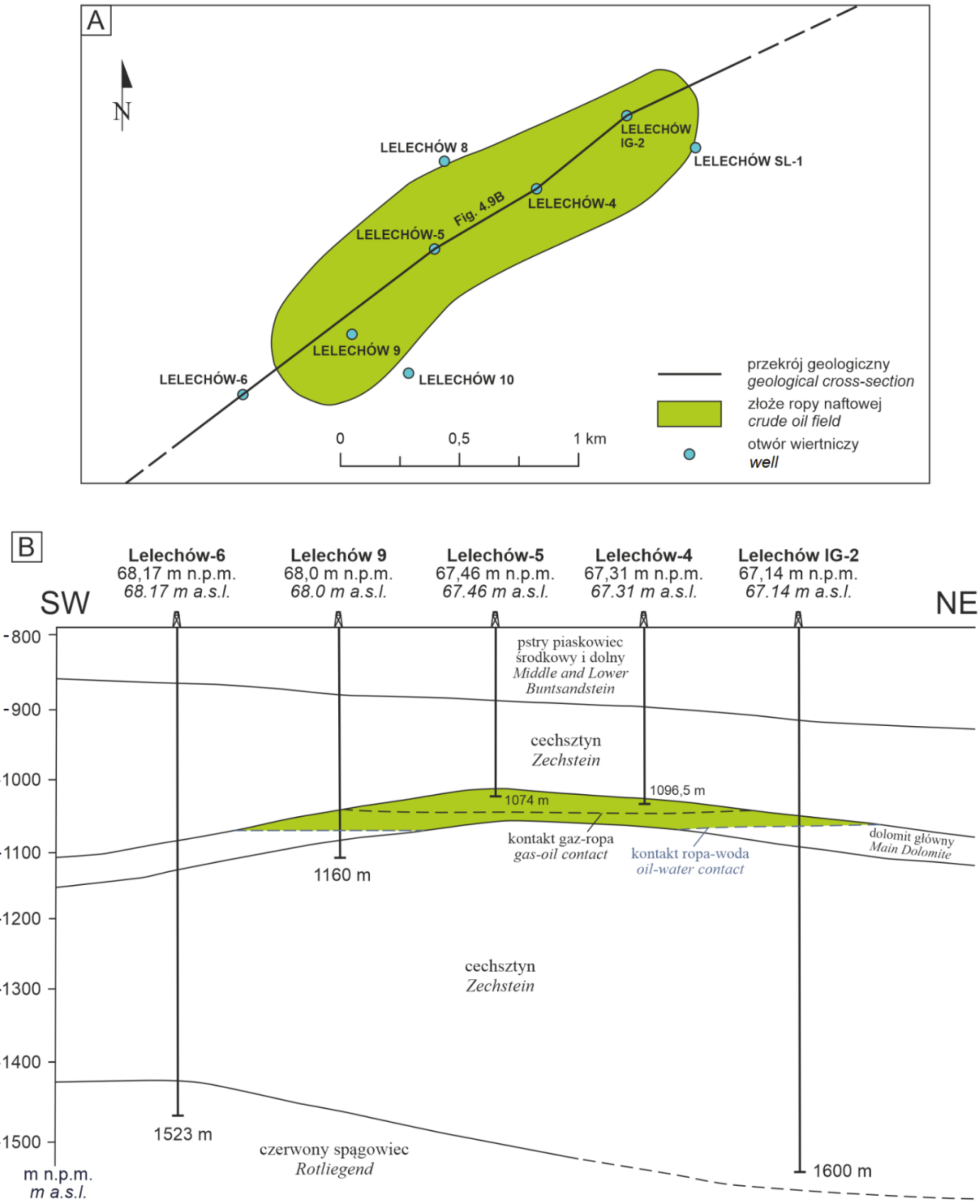


Fig. 4.7. A. Location of wells within Lelechów crude oil field and its neighborhood (on the basis of the Central Geological Database, 2022). **B.** Geological cross-section through Lelechów crude oil field (on the basis of Pawłowski and Zoła, 2000).

Parameter	Minimum value	Maximum value	Average value	Unit	Comments
current pressure	---------	---------	6.420	MPa	24 X 1997 at the depth of 1,060 m, Lelechów-5 well
saturation pressure	---------	---------	---------	MPa	not stated from PVT tests
primary reservoir pressure	---------	---------	12.260	MPa	at the depth of 1,085 m
depth of underlying water	---------	---------	-1,055.00	m	water contour
depth of underlying water	---------	---------	-1,035.00	m	oil-gas boundary
effective reservoir thickness	---------	---------	22.390	m	
oil saturation	---------	---------	70.000	%	
porosity	2.500	4.500	3.640	%	according to geo-physical tests
porosity	0.170	1.820	0.430	%	according to laboratory tests
permeability	0.001	0.179	0.043	mD	
mineralization degree of formation water	345.700	384.780	---------	g/l	
reservoir temperature	---------	---------	315.650	°K	
reservoir temperature	---------	---------	42.500	°C	
production conditions	---------	---------	---------	–	gas cap and gas dissolved in oil
hydrocarbons saturation factor	---------	---------	70.000	%	gas saturation in cap
production factor	---------	---------	0.150	–	for crude oil
well efficiency	6.000	20.000	12.000	t/d	for crude oil
production factor	---------	---------	0.900	–	for natural gas from gas cap
production factor	---------	---------	0.150	–	for natural gas dissolved in oil
well efficiency	12.000	45.000	23.000	m^3/min	for natural gas from gas cap
quality parameters of crude oil (main raw material)					
Parameter	**Minimum value**	**Maximum value**	**Average value**	**Unit**	**Comments**
oil specific gravity	---------	---------	0.803	g/cm^3	
paraffin content	---------	---------	0.920	% w/v	
sulfur content	0.080	2.250	---------	% w/v	
quality parameters of natural gas (accompanying material)					
Parameter	**Minimum value**	**Maximum value**	**Average value**	**Unit**	**Comments**
calorific value	---------	---------	14.910	MJ/m^3	Hs
calorific value	---------	---------	13.540	MJ/m^3	Hi
C_2H_6 content	---------	---------	4.054	% v/v	
CH_4 content	---------	---------	20.401	% v/v	
carbon dioxide content	---------	---------	0.079	% v/v	
Hg content	---------	---------	0.052	% v/v	
N_2 content	---------	---------	71.198	% v/v	
hydrogen sulfide content	---------	---------	0.001	% v/v	
heavy hydrocarbons content	---------	---------	74.100	g/m^3	
heavy hydrocarbons C_{3+} content	---------	---------	3.063	% v/v	

Tab. 4.4. Parameters of Lelechów crude oil field and quality parameters of raw materials (the MIDAS Database, 2022 according to Pawłowski and Zoła, 2000).

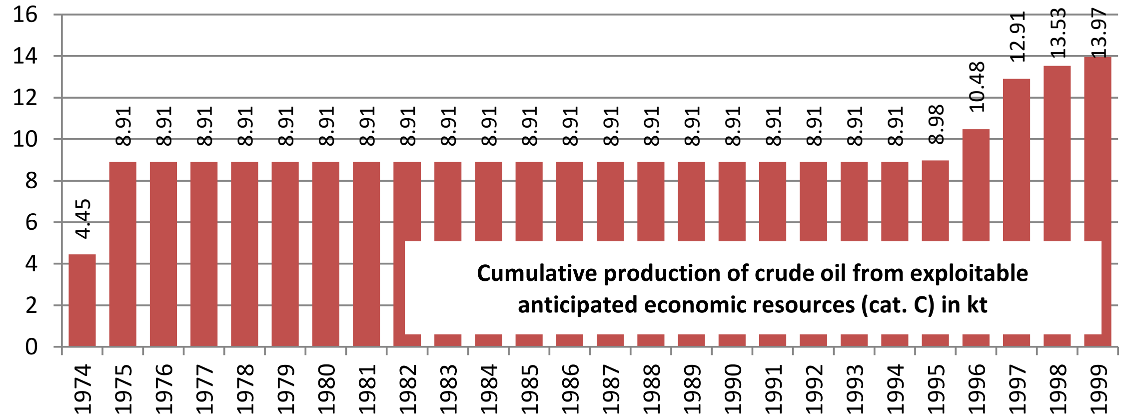


Fig. 4.8. Graph of crude oil production from Lelechów field (on the basis of annual forms of fields resources changes sent to PGI-NRI by concession holders; 1995-1999 period according to the MIDAS Database, 2022; previous years according to "The balance of mineral resources deposits in Poland – paper editions).

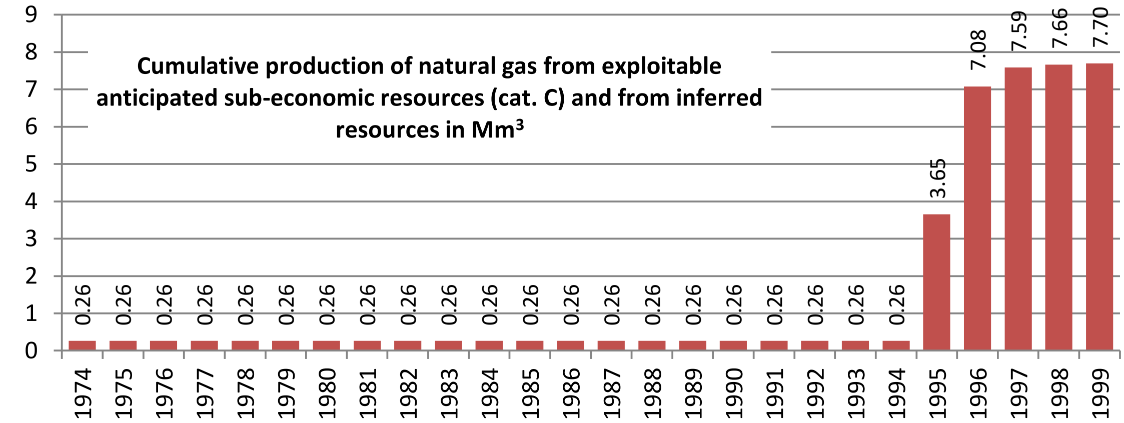


Fig. 4.9. Graph of natural gas production from Lelechów field (on the basis of annual forms of fields resources changes sent to PGI-NRI by concession holders; 1995-1999 period according to the MIDAS Database, 2022; previous years according to "The balance of mineral resources deposits in Poland – paper editions).

Mozów N crude oil field

Total field acreage: 177.00 ha
Depth: -1,935.00 m (field bottom)
Stratigraphy: Permian – Zechstein (Stassfurt cyclothem, Main Dolomite)
Resources:
Field crossed out from the national register in 2001.
The primary exploitable anticipated economic resources (as of 2000):
5.2 kt of crude oil in cat. B
0.8 Mm^3 of natural gas in cat. B
The exploitable anticipated economic resources as of 31 XII 2000:
0.908 kt of crude oil in cat. B
0.1701 Mm^3 of natural gas in cat. B
The economic resources in place as of 31 XII 2000:
lack of resources
The production in 2022:
lack of production

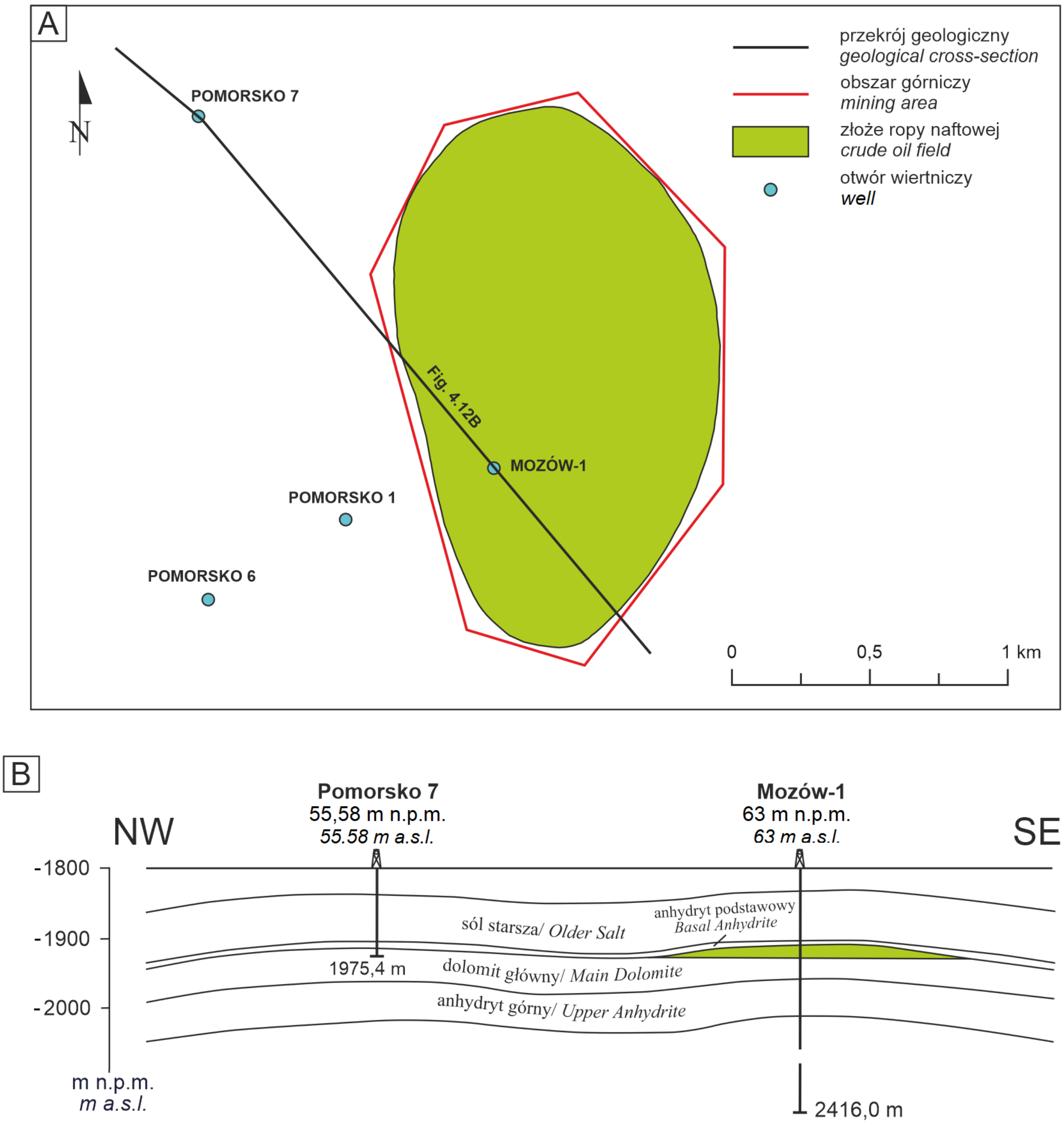


Fig. 4.10. A. Location of wells within Mozów N crude oil field and its neighborhood (on the basis of the Central Geological Database, 2022). **B.** Geological cross-section through Mozów N crude oil field (on the basis of Burdzy, 2001).

Parameter	Minimum value	Maximum value	Average value	Unit	Comments
primary reservoir pressure	---------	---------	21.530	MPa	
effective reservoir thickness	---------	---------	2.000	m	
reservoir thickness	---------	30.000	---------	m	
porosity	---------	---------	2.700	%	
permeability	---------	0.100	---------	mD	
reservoir temperature	---------	---------	73.000	°C	
production factor	---------	---------	0.100	–	
sand encroachment	---------	---------	---------	%	not stated
quality parameters of crude oil (main raw material)					
Parameter	**Minimum value**	**Maximum value**	**Average value**	**Unit**	**Comments**
asphaltenes content	---------	---------	5.430	% w/v	
naphtha fraction content	---------	---------	7.500	% v/v	
oil fraction content	---------	---------	20.600	% v/v	
aromatic hydrocarbons content	---------	---------	22.830	% w/v	
saturated hydrocarbons content	---------	---------	64.130	% w/v	
resin content	---------	---------	7.610	% w/v	
quality parameters of natural gas (accompanying material)					
Parameter	**Minimum value**	**Maximum value**	**Average value**	**Unit**	**Comments**
density	---------	---------	0.852	–	in relation to air
calorific value	---------	---------	45.795	MJ/Nm^3	
C_2H_6 content	---------	---------	20.306	% v/v	
CH_4 content	---------	---------	51.138	% v/v	
carbon dioxide content	---------	---------	0.199	% v/v	
H_2 content	---------	---------	0.037	% v/v	
He content	---------	---------	0.032	% v/v	
N_2 content	---------	---------	18.484	% v/v	
hydrogen sulfide content	---------	---------	0.034	% v/v	
heavy hydrocarbons C_{3+} content	---------	---------	9.771	% v/v	

Tab. 4.5. Parameters of Mozów N crude oil field and quality parameters of raw materials (the MIDAS Database, 2022 according to Zalewska, 1996 and Burdzy, 2001).

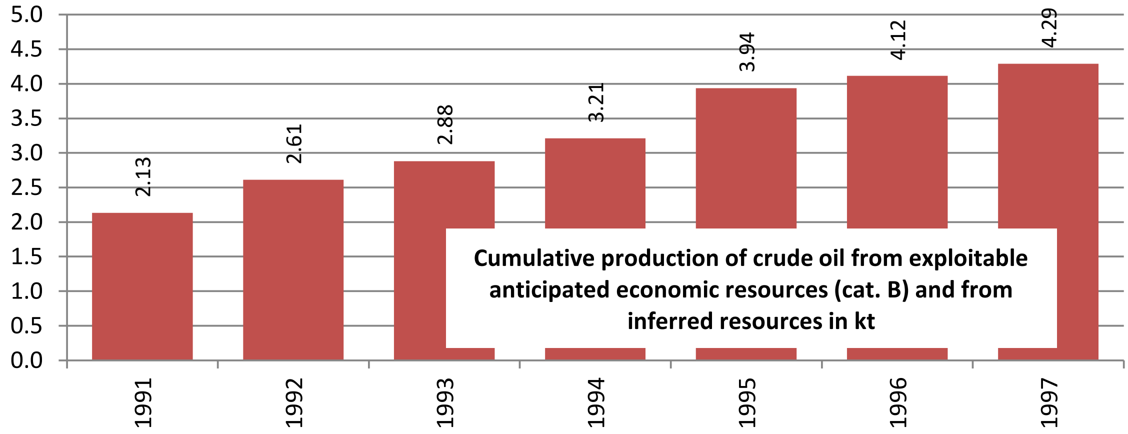


Fig. 4.11. Graph of crude oil (main raw material) production from Mozów N field (according to Annex 2 to geological documentation of the field – Burdzy, 2001).

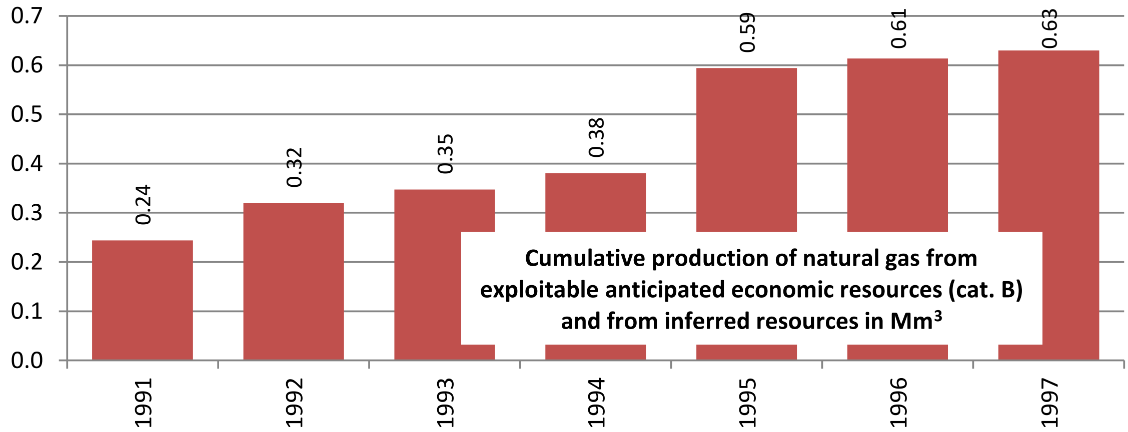


Fig. 4.12. Graph of natural gas (accompanying raw material) production from Mozów N field (according to Annex 2 to geological documentation of the field – Burdzy, 2001).

Mozów S crude oil field

Total field acreage: 158.00 ha
Depth: -1,888.00 m (field bottom)
Stratigraphy: Permian – Zechstein (Stassfurt cyclothem, Main Dolomite)
Resources:

The primary exploitable anticipated economic resources (as of 1995):
- 5.90 kt of crude oil in cat. B
- 2.15 Mm^3 of natural gas in cat. B

The exploitable anticipated economic resources as of 31 XII 2022:
- 1.51 kt of crude oil in cat. B
- 0.14 Mm^3 of natural gas in cat. B

The economic resources in place as of 31 XII 2022:
- 1.32 kt of the crude oil economic resources in place in cat. B
- 33.23 kt of the crude oil sub-economic resources in place in cat. B
- lack of the natural gas economic resources in place in cat. B
- 21.58 Mm^3 of the natural gas sub-economic resources in place in cat. B

The production in 2022:
- 1.19 kt of crude oil in cat. B
- 0.12 Mm^3 of natural gas in cat. B

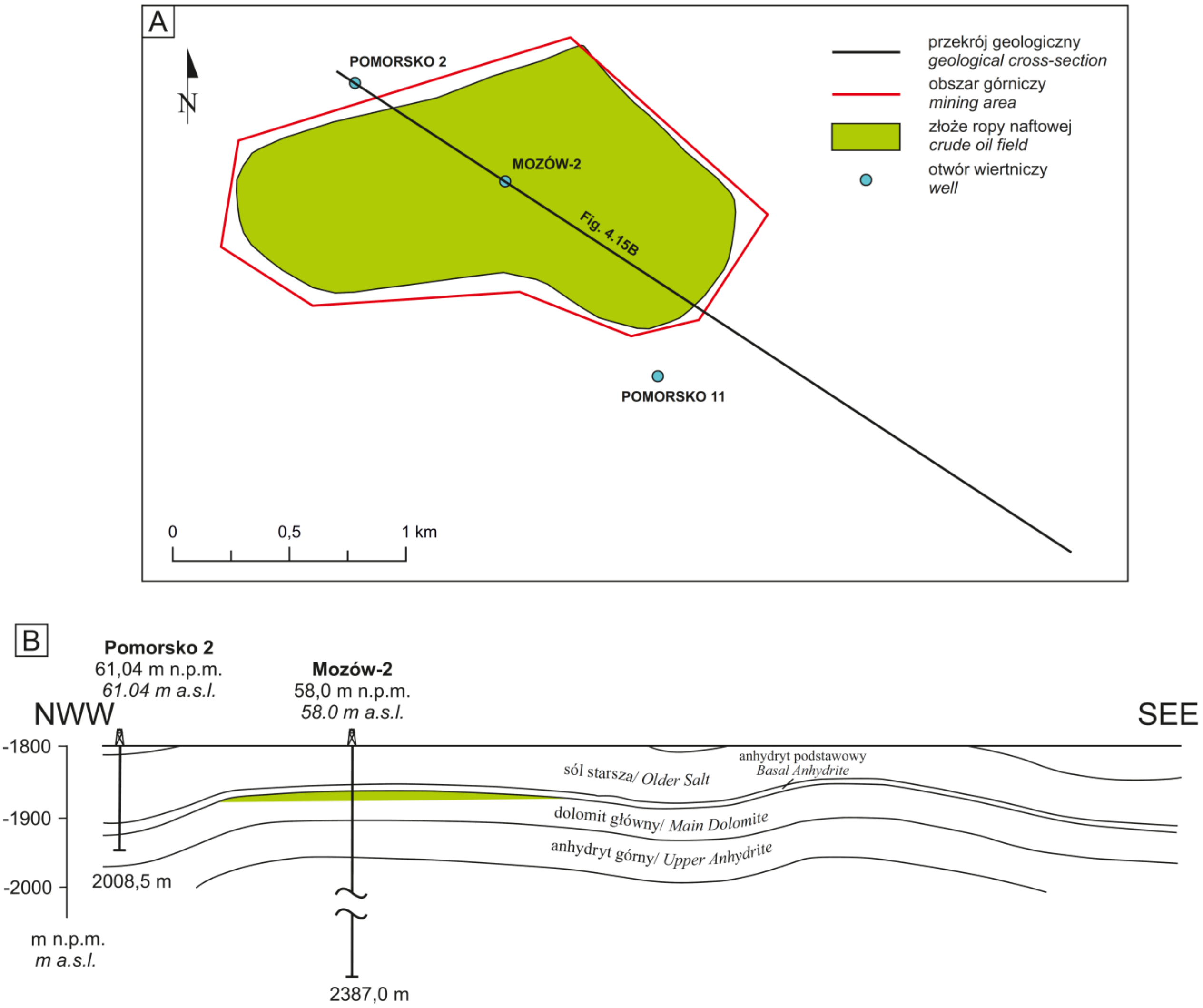


Fig. 4.13. A. Location of wells within Mozów S crude oil field and its neighborhood (on the basis of the Central Geological Database, 2022). **B.** Geological cross-section through Mozów S crude oil field (on the basis of Zalewska, 1996).

Parameter	Minimum value	Maximum value	Average value	Unit	Comments
current pressure	---------	---------	23.540	MPa	06 III 1995
primary reservoir pressure	---------	---------	24.456	MPa	04 IX 1991
effective reservoir thickness	---------	---------	3.500	m	
reservoir thickness	---------	26.000	---------	m	
porosity	---------	---------	2.500	%	
field acreage	---------	---------	1.580	km^2	
permeability	---------	0.100	---------	mD	below 0.1 mD
reservoir temperature	---------	---------	72.000	°C	
quality parameters of crude oil (main raw material)					
Parameter	**Minimum value**	**Maximum value**	**Average value**	**Unit**	**Comments**
asphaltenes content	---------	---------	2.960	% w/v	
naphtha fraction content	---------	---------	17.600	% obj.	
oil fraction content	---------	---------	19.100	% v/v	
aromatic hydrocarbons content	---------	---------	27.180	% w/v	

saturated hydrocarbons con	---------	---------	58.320	% w/v	
resin content	---------	---------	11.540	% w/v	
quality parameters of natural gas (accompanying raw material)					
Parameter	**Minimum value**	**Maximum value**	**Average value**	**Unit**	**Comments**
density	---------	---------	0.858	–	
calorific value	---------	---------	46.008	MJ/Nm^3	
C_2H_6 content	---------	---------	18.308	% v/v	
CH_4 content	---------	---------	52.038	% v/v	
carbon dioxide content	---------	---------	0.511	% v/v	
H_2 content	---------	---------	0.131	% v/v	
He content	---------	---------	0.071	% v/v	
N_2 content	---------	---------	18.236	% v/v	
hydrogen sulfide content	---------	---------	0.025	% v/v	
heavy hydrocarbons C_{3+} content	---------	---------	10.680	% v/v	

Tab. 4.6. Parameters of Mozów S crude oil field and quality parameters of raw materials (the MIDAS Database, 2022 according to Zalewska, 1996).

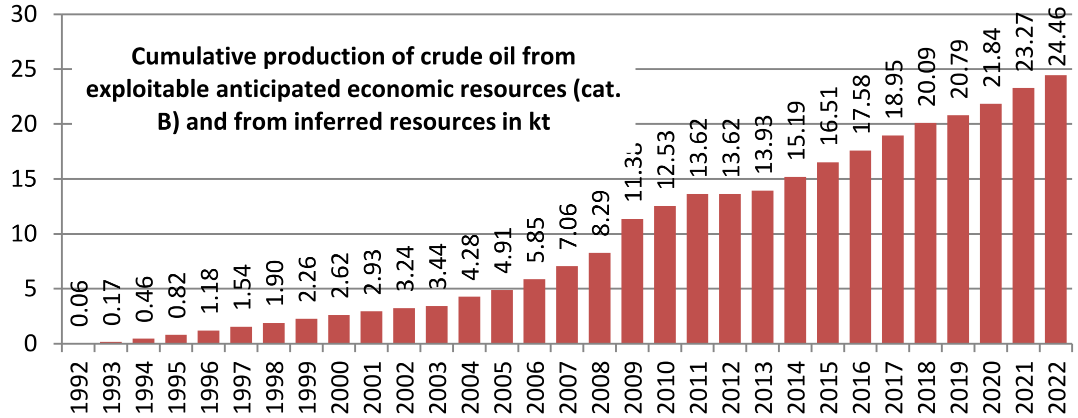


Fig. 4.14. Graph of crude oil (main raw material) production from Mozów S field (on the basis of annual forms of fields resources changes sent to PGI-NRI by concession holders; 1995-2020 period according to the MIDAS Database, 2022; previous years according to Annex 1 to geological documentation of the field – Zalewska, 1996).

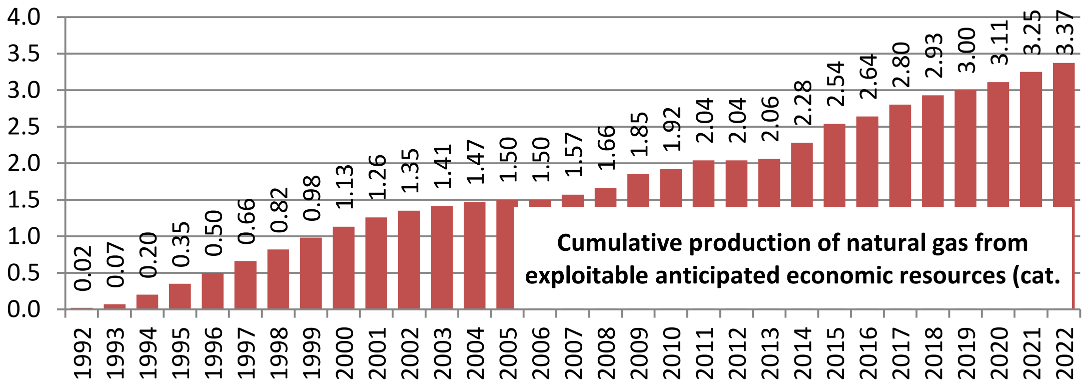


Fig. 4.15. Graph of natural gas (accompanying raw material) production from Mozów S field (on the basis of annual forms of fields resources changes sent to PGI-NRI by concession holders; 1995-2020 period according to the MIDAS Database, 2022; previous years according to Annex 1 to geological documentation of the field – Zalewska, 1996).

Nowa Sól natural gas field

Total field acreage: 60.9 ha
Depth: from -869.10 m to -900.00 m
Stratigraphy: Permian-Zechstein (Stassfurt cyclothem, Main Dolomite)
Resources:

The primary exploitable anticipated economic resources:
lack of resources

The primary exploitable anticipated economic resources (as of 1994):
8.75 Mm^3 of natural gas in cat. B

The exploitable anticipated economic resources:
lack of resources

The exploitable anticipated sub-economic resources as of 31 XII 2022:
8.75 Mm^3 of natural gas in cat. B

The economic resources in place as of 31 XII 2022:
lack of resources

The production in 2022:
lack of resources

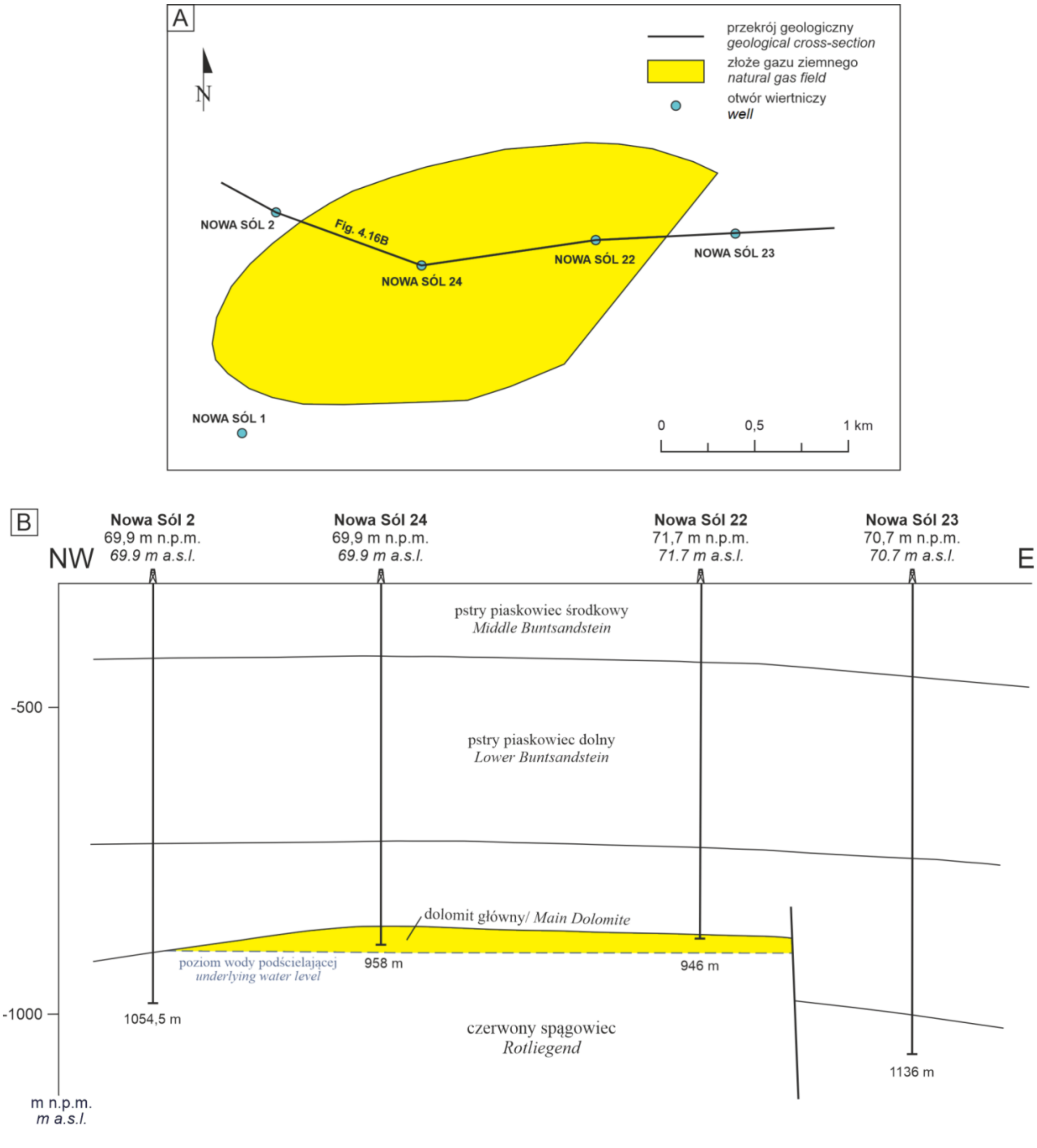


Fig. 4.16. A. Location of wells within Nowa Sól natural gas field and its neighborhood (on the basis of the Central Geological Database, 2022). **B.** Geological cross-section through Nowa Sól natural gas field (on the basis of Dudzińska, 1995).

Parameter	Minimum value	Maximum value	Average value	Unit	Comments
bottom pressure P_{ds}	---------	---------	9.120	MPa	Nowa Sól 24 well
bottom pressure P_{ds}	---------	---------	10.010	MPa	Nowa Sól 22 well
wellhead pressure P_{gs}	---------	---------	8.940	MPa	Nowa Sól 22 well
wellhead pressure P_{gs}	---------	---------	8.110	MPa	Nowa Sól 24 well
primary reservoir pressure	---------	---------	9.560	MPa	
depth of underlying water	---------	---------	-900.000	m	
effective reservoir thickness	---------	30.900	15.400	m	
porosity	---------	---------	2.000	%	
mineralization degree of formation water	---------	---------	330.000	g/l	
reservoir temperature	---------	---------	37.000	°C	
reservoir temperature	---------	---------	310.000	°K	
chemical type of reservoir water	---------	---------	---------	–	Cl-Na brine
hydrocarbons saturation factor	---------	---------	0.700	–	
production factor	---------	---------	0.700	–	
absolute efficiency V_{abs}	---------	---------	811.000	m^3/min	Nowa Sól 22 well
absolute efficiency V_{abs}	---------	---------	7.000	m^3/min	Nowa Sól 24 well
permitted efficiency V_{dozw}	---------	---------	107.000	m^3/min	Nowa Sól 22 well
permitted efficiency V_{dozw}	---------	---------	1.000	m^3/min	Nowa Sól 24 well
quality parameters of natural gas					
Parameter	**Minimum value**	**Maximum value**	**Average value**	**Unit**	**Comments**
combustion heat	24.600	26.100	25.320	MJ/m^3	
density	0.834	0.871	0.847	–	
calorific value	22.300	23.700	22.960	MJ/m^3	
C_2H_6 content	5.900	9.268	7.596	% v/v	
CH_4 content	34.395	40.335	38.058	% v/v	
carbon dioxide content	0.000	0.000	0.000	% v/v	
H_2 content	0.078	0.176	0.109	% v/v	
He content	0.148	0.263	0.228	% v/v	
N_2 content	49.187	50.795	49.725	% v/v	
hydrogen sulfide content	0.000	0.000	0.000	% v/v	
hydrocarbons content	48.851	50.394	49.938	% v/v	
heavy hydrocarbons C_{3+} content	3.378	5.198	4.284	% v/v	
heavy hydrocarbons C_{3+} content	76.295	117.744	96.,829	g/m^3	so-called gasoline content

Tab. 4.7. Parameters of Nowa Sól natural gas field and quality parameters of raw materials (the MIDAS Database, 2022 according to Dudzińska, 1995).

5. WELLS

The following wells deeper than 500 m MD were drilled in the Zielona Góra West tender area:

Well name	Year	Owner	Depth [m]	Stratigraphy at the bottom:
BRONISZÓW	1962	State Treasury		Rotliegend
BRONKÓW-M-27	1988	State Treasury	1564.0	Rotliegend
CHOJNOWO 1	1968	State Treasury	1530.1	Rotliegend
DACHÓW 1	1966	State Treasury	1508.0	Carboniferous
DACHÓW-M-24	1979	State Treasury	1538.4	Rotliegend
DĘBY 1	1966	State Treasury	1370.5	Rotliegend
DRZONÓW 1	1965	State Treasury	1303.0	Zechstein
DRZONÓW 2	1966	State Treasury	1434.0	Zechstein
DYCHÓW M-26	1981	State Treasury	1930.0	Rotliegend
JAROGNIEWICE IG-1	1966	State Treasury	551.6	Triassic
JASIEŃ P-4	1989	State Treasury	1054.0	Permian
JELENIÓW-1	1968	State Treasury	1492.3	Rotliegend
KLĘPINKA	1961	State Treasury	708.2	Rotliegend
KOSIERZ 1	1965	State Treasury	1415.0	Zechstein
KOSIERZ M-25	1982	State Treasury	1810.0	Rotliegend
LUBIATÓW 1	1966	State Treasury	1451.4	Rotliegend
LUBIATÓW M-20	1983	State Treasury	1662.0	Rotliegend
NIWISKA 1	1969	State Treasury	1700.0	Carboniferous
NOWA SÓL 7	1963	State Treasury	1113.2	Rotliegend
NOWA SÓL 9	1963	State Treasury	1137.3	Rotliegend
NOWA SÓL 16	1964	State Treasury	1299.0	Zechstein
NOWA SÓL 18	1964	State Treasury	1241.6	Zechstein
NOWA WIEŚ P-1	1987	State Treasury	1012.0	Rotliegend
PAJĘCZNO 1	1969	State Treasury	1203.0	Zechstein
PIASKI 1	1966	State Treasury	2021.8	Carboniferous
STARY ZAGÓR 1	1967	State Treasury	1984.6	Rotliegend
STRUŻKA 1	1966	State Treasury	1492.4	Rotliegend
ŚWIDNICA-1	1967	State Treasury	1391.0	Zechstein
TARNAWA M-21	1990	State Treasury	1466.0	Rotliegend
TRZEBULE 1	1966	State Treasury	2666.7	Rotliegend
URZUTY IG-1	1962	State Treasury	1250.0	Rotliegend
WYSOKA 1	1967	State Treasury	1440.7	Rotliegend
WYSOKA 2	1968	State Treasury	1305.0	Rotliegend
ŻARKÓW 1	1965	State Treasury	1363.6	Rotliegend
ŻARKÓW 2	1965	State Treasury	994.1	Rotliegend
ŻARKÓW 3	1965	State Treasury	1214.6	Rotliegend
ŻARKÓW 4	1965	State Treasury	1059.7	Rotliegend

Location of the above-mentioned wells is presented in Fig. 5.1. Their general characteristics are shortly summarized in Tab. 5.1. The Piaski 1 well is illustrated in Figs 5.2–5.3 as an example.

The original data from the wells, which belong 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 6th tender round.

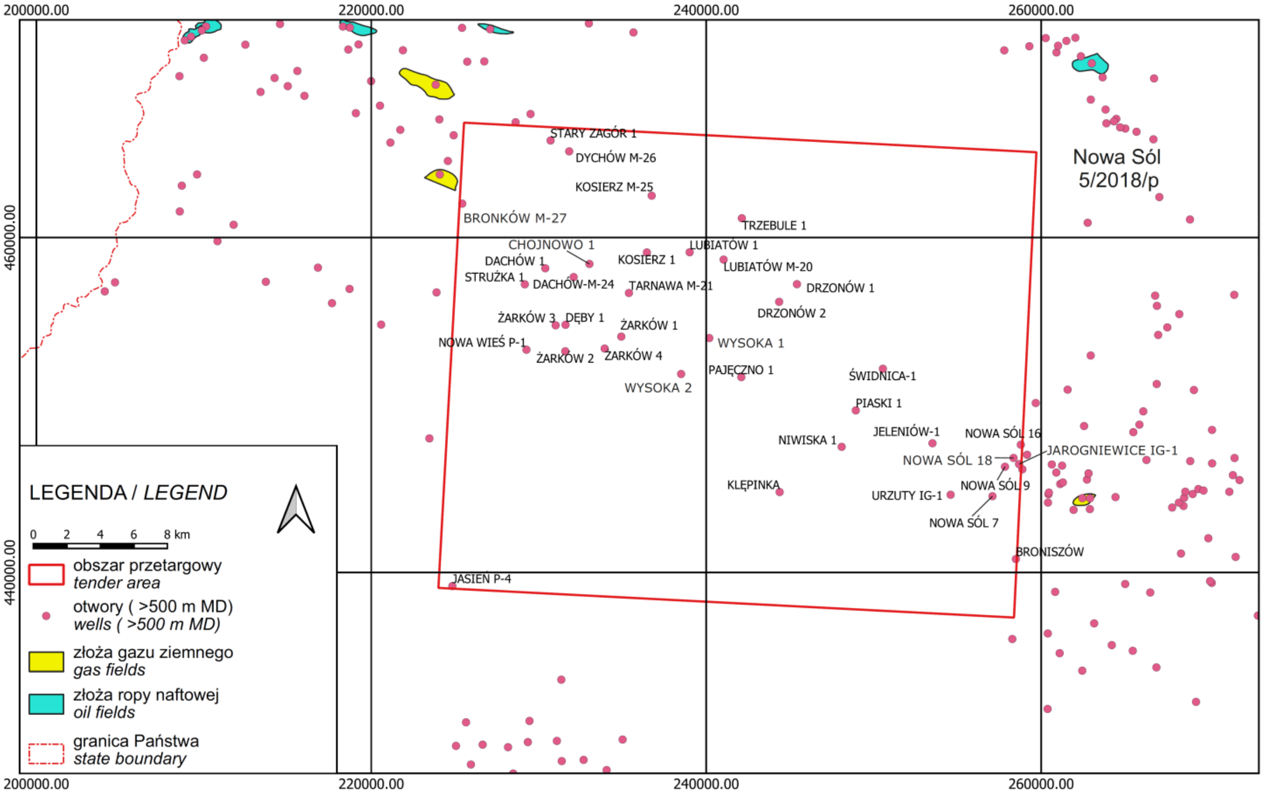


Fig. 5.1. Deep wells (>500 m MD) located within the Zielona Góra West tender area and in its close neighborhood.

STRATIGRAPHY	Broniszów		Bronków M-27		Chojnowo 1		Dachów 1		Dachów M-24		Dęby 1		Drzonów 1	
	top – bottom [m]		top – bottom [m]		top – bottom [m]		top – bottom [m]		top – bottom [m]		top – bottom [m]		top – bottom [m]	
CENOZOIC	0.0	323.3	0.0	226.8	0.0	230.0	0.0	250.0			0.0	285.0	0.0	262.5
TRIASSIC	323.3	582.0	226.8	1009.0	230.0	992.0	250.0	922.5	230.8	953.2	285.0	737.5	262.5	1152.0
PERMIAN	582.0	791.5	1009.0	1564.0	992.0	1530.1	922.5	1432.5	935.2	1482.3	737.5	1049.0	1152.0	1303.0
Top Terrigenous Series PZt	*582.0*	*613.9*			*992.0*	*1011.0*	*922.5*	*937.0*			*737.5*	*750.0*	*1152.0*	*1175.0*
Top Anhydrite A4g														
Younhest Halite Na4a			*1009.0*	*1036.8*	*1011.0*	*1032.0*	*937.0*	*952.5*					*1175.0*	*1185.0*
Lower Pegmatite Anhydrite A4a1					*1032.0*	*1032.5*	*952.5*	*953.5*					*1185.0*	*1186.0*
Red Pelite T4a					*1032.5*	*1035.0*	*953.5*	*959.5*					*1186.0*	*1190.5*
Top Anhydrite A4a														
Younger Halite Na3					*1035.0*	*1143.0*	*959.5*	*1052.0*					*1190.5*	*1286.0*
Main Anhydrite A3			*1036.8*	*1146.7*	*1143.0*	*1154.0*	*1052.0*	*1062.0*			*750* *766.2*	*764.5* *785.0*	*1286.0*	*1303.0*
Platy Dolomite Ca3														
Grey Pelite T3					*1154.0*	*1156.5*	*1062.0*	*1063.0*			*764.5* *785.0*	*765.5* *785.5*		
Screening Anhydrite A2r					*1156.5*	*1160.0*	*1063.0*	*1065.5*			*765.5* *785.5*	*766.2* *787.5*		
Older Halite Na2			*1146.7*	*1276.4*	*1160.0*	*1204.0*	*1065.5*	*1103.0*						
Basal Anhydrite A2	*613.9*	*651.4*			*1204.0*	*1215.0*	*1103.0*	*1107.0*			*787.5*	*789.5*		
Main Dolomite Ca2	*651.4*	*705.2*			*1215.0*	*1291.5*	*1107.0*	*1170.0*			*789.5*	*855.5*		
Upper Anhydrite A1g	*705.2*	*779.6*			*1291.5*	*1328.5*	*1170.0*	*1213.0*			*855.5*	*896.0*		
Oldest Halite Na1					*1328.5*	*1360.0*	*1213.0*	*1255.0*			*896.0*	*914.5*		
Upper Oldest Halite Na1d														
Middle Anhydrite A1s														
Lower Oldest Halite Na1d			*1276.4*	*1508.3*										
Lower Anhydrite A1d					*1360.0*	*1501.5*	*1255.0*	*1371.0*			*914.5*	*1036.5*		
Zechstein Limestone Ca1	*779.6*	*782.7*			*1501.5*	*1505.0*	*1371.0*	*1374.5*			*1036.5*	*1040.0*		
Kupferschiefer T1	*782.7*	*783.0*					*1374.5*	*1375.0*						
Weissliegend											*1040.0*	*1049.0*		
Upper Rotliegend	*783.0*	*791.5*	*1508.3*	*1564.0*	*1505.0*	*1530.1*	*1375.0*	*1432.5*	*1482.3*	*1538.4*				
Lower Rotliegend														
CARBONIFEROUS							1432.5	1508.0			1049.0	1370.5		
PROTEROZOIC														

STRATIGRAPHY	Drzonów 2		Dychów M-26		Jeleniów 1		Klępinka		Kosierz 1		Kosierz M-26		Lubiatów 1	
	top – bottom [m]		top – bottom [m]		top – bottom [m]		top – bottom [m]		top – bottom [m]		top – bottom [m]		top – bottom [m]	
CENOZOIC	0.0	271.0	0.0	231.0	0.0	275.0	0.0	278.4	0.0	247.5	0.0	265.5	0.0	284.0
TRIASSIC	271.0	1109.0	231.0	1354.7	275.0	944.5			247.5	1093.0	265.5	1252.3	284.0	907.0
PERMIAN	1109.0	1434.0	1354.7	1930.0	944.5	1492.3	278.4	457.4	1093.0	1415.0	1252.3	1810.0	907.0	1451.4
Top Terrigenous Series PZt	*1109.0*	*1122.0*	*1354.7*	*1367.0*	*944.5*	*957.0*			*1093.0*	*1109.0*	*1252.3*	*1266.0*		
Top Anhydrite A4g														
Younhest Halite Na4a	*1122.0*	*1133.5*			*957.0*	*970.0*			*1109.0*	*1131.0*	*1266.0*	*1286.0*		
Lower Pegmatite Anhydrite A4a1	*1133.5*	*1135.0*	*1367.0*	*1468.0*	*970.0*	*971.0*			*1131.0*	*1132.0*	*1286.0*	*1287.3*		
Red Pelite T4a	*1135.0*	*1141.0*			*971.0*	*975.0*			*1132.0*	*1135.5*	*1287.3*	*1295.0*		
Top Anhydrite A4a									*1135.5*	*1136.0*				
Younger Halite Na3	*1141.0*	*1264.5*	*1468.0*	*1496.8*	*975.0*	*1085.0*			*1136.0*	*1235.5*	*1295.0*	*1408.0*		
Main Anhydrite A3	*1264.5*	*1288.0*	*1496.8*	*1513.1*	*1085.0*	*1105.5*			*1235.5*	*1263.5*	*1408.0*	*1426.7*		
Platy Dolomite Ca3							*278.4*	*305.0*						
Grey Pelite T3	*1288.0*	*1288.6*	*1513.1*	*1516.0*	*1105.5*	*1107.0*	*305.0*	*306.1*	*1263.5*	*1265.5*	*1426.7*	*1428.7*		
Screening Anhydrite A2r	*1288.6*	*1289.5*	*1516.0*	*1519.4*	*1107.0*	*1110.0*			*1265.5*	*1269.5*	*1428.7*	*1439.6*		
Older Halite Na2	*1289.5*	*1355.5*	*1519.4*	*1575.7*	*1110.0*	*1162.5*			*1269.5*	*1321.5*	*1439.6*	*1501.4*		
Basal Anhydrite A2	*1355.5*	*1396.5*	*1575.7*	*1581.9*	*1162.5*	*1170.0*			*1321.5*	*1339.5*	*1501.4*	*1522.7*		
Main Dolomite Ca2	*1396.5*	*1434.0*	*1581.9*	*1664.6*	*1170.0*	*1224.0*	*306.1*	*330.7*	*1339.5*	*1411.5*	*1522.7*	*1599.6*		
Upper Anhydrite A1g			*1664.6*	*1682.3*	*1224.0*	*1265.0*			*1411.5*	*1415.0*	*1599.6*	*1632.5*		
Oldest Halite Na1			*1682.3*	*1857.0*	*1265.0*	*1374.0*					*1632.5*	*1642.5*		
Upper Oldest Halite Na1d							*330.7*	*410.8*			*1642.5*	*1655.0*		
Middle Anhydrite A1s											*1655.0*	*1668.7*		
Lower Oldest Halite Na1d														
Lower Anhydrite A1d			*1857.0*	*1907.9*	*1374.0*	*1442.5*					*1668.7*	*1781.4*		
Zechstein Limestone Ca1			*1907.9*	*1911.6*	*1442.5*	*1447.0*	*410.8*	*418.8*			*1781.4*	*1784.7*		
Kupferschiefer T1					*1447.0*	*1449.5*					*1784.7*	*1784.8*		
Weissliegend							*418.8*	*418.8*			*1784.8*	*1784.8*		
Upper Rotliegend			*1911.6*	*1930.0*	*1449.5*	*1492.3*	*418.8*	*457.4*			*1784.8*	*1810.0*	*1350.0*	*1451.4*
Lower Rotliegend														
CARBONIFEROUS														
PROTEROZOIC							457.4	708.2						

STRATIGRAPHY	Lubiatów M-20		Niwiska 1		Nowa Wieś P-1		Nowa Sól 7		Nowa Sól 9		Nowa Sól 16		Nowa Sól 18	
	top – bottom [m]		top – bottom [m]		top – bottom [m]		top – bottom [m]		top – bottom [m]		top – bottom [m]		top – bottom [m]	
CENOZOIC	0.0	268.3	0.0	275.0	0.0	400.0	0.0	320.0	0.0	286.0	0.0	1041.0	0.0	970.5
TRIASSIC	268.3	1134.2	275.0	768.0	400.0	687.0	320.0	800.0	286.0	928.5	275.0	1041.0	380.0	970.5
PERMIAN	1134.2	1662.0	768.0	1645.0	687.0	1012.0	800.0	1113.2	928.5	1137.3	1041.0	1299.0	970.5	1241.6
Top Terrigenous Series PZt			*768.0*	*784.0*			*800.0*	*816.0*			*1041.0*	*1059.0*	*970.5*	*986.5*
Top Anhydrite A4g														
Younhest Halite Na4a			*784.0*	*795.0*			*816.0*	*827.5*			*1059.0*	*1071.0*	*986.5*	*1002.0*
Lower Pegmatite Anhydrite A4a1			*795.0*	*799.0*			*827.5*	*829.0*			*1071.0*	*1072.0*	*1002.0*	*1003.0*
Red Pelite T4a			*799.0*	*801.0*			*829.0*	*835.0*			*1072.0*	*1075.0*	*1003.0*	*1010.0*
Top Anhydrite A4a														
Younger Halite Na3			*801.0*	*920.0*			*835.0*	*915.0*			*1075.0*	*1157.5*	*1010.0*	*1106.5*
Main Anhydrite A3			*920.0*	*954.0*			*915.0*	*976.0*			*1057.5*	*1186.0*	*1106.5*	*1128.5*
Platy Dolomite Ca3														
Grey Pelite T3			*954.0*	*957.0*			*976.0*	*986.5*			*1186.0*	*1188.0*	*1128.5*	*1131.0*
Screening Anhydrite A2r	*1134.2*	*1638.7*	*957.0*	*960.0*	*687.0*	*970.3*					*1188.0*	*1192.5*	*1131.0*	*1134.5*
Older Halite Na2			*960.0*	*1003.0*			*986.5*	*1049.5*			*1192.5*	*1243.0*	*1134.5*	*1190.5*
Basal Anhydrite A2			*1003.0*	*1020.0*			*1049.5*	*1060.0*			*1243.0*	*1251.5*	*1190.5*	*1198.0*
Main Dolomite Ca2			*1020.0*	*1065.0*			*1060.0*	*1108.0*			*1251.5*	*1296.5*	*1198.0*	*1241.6*
Upper Anhydrite A1g			*1065.0*	*1095.0*			*1108.0*	*1113.2*			*1296.5*	*1299.0*		
Oldest Halite Na1			*1095.0*	*1138.0*										
Upper Oldest Halite Na1d														
Middle Anhydrite A1s														
Lower Oldest Halite Na1d														
Lower Anhydrite A1d			*1138.0*	*1277.0*										
Zechstein Limestone Ca1			*1277.0*	*1282.0*										
Kupferschiefer T1														
Weissliegend														
Upper Rotliegend	*1638.7*	*1662.0*	*1282* *1535*	*1410* *1645*	*970.3*	*1012.0*								
Lower Rotliegend			*1410.0*	*1535.0*										
CARBONIFEROUS			1645.0	1700.0										
PROTEROZOIC														

Tab. 5.1. Summary of stratigraphy and prospective horizons (orange and green) in the wells located within the Zielona Góra West tender area (CGDB, 2023).

STRATIGRAPHY	Pajęczno 1 top – bottom [m]		Piaski 1 top – bottom [m]		Stary Zagór 1 top – bottom [m]		Strużka 1 top – bottom [m]		Świdnica 1 top – bottom [m]		Tarnawa M-21 top – bottom [m]	
CENOZOIC	0.0	350.0	0.0	290.0	0.0	230.0	0.0	318.0	0.0	270.0	0.0	228.3
TRIASSIC	350.0	888.0	265.0	907.0	230.0	1415.5	318.0	723.0	270.0	1070.0	228.3	971.7
PERMIAN	888.0	1203.0	935.0	1873.0	1415.5	1984.6	723.0	1445.0	1070.0	1391.0	971.7	1466.0
Top Terrigenous Series PZt	*888.0*	*904.5*	*907.0*	*919.0*	*1415.5*	*1430.0*	*723.0*	*737.5*	*1070.0*	*1081.5*	*971.7*	*986.0*
Top Anhydrite A4g											*986.0*	*986.6*
Younhest Halite Na4a	*904.5*	*919.0*	*919.0*	*932.5*	*1430.0*	*1448.5*	*737.5*	*755.0*	*1081.5*	*1095.5*	*986.6*	*988.2*
Lower Pegmatite Anhydrite A4a1	*919.0*	*922.0*	*932.5*	*933.5*	*1448.5*	*1449.5*	*755.0*	*755.5*	*1095.5*	*1096.0*		
Red Pelite T4a	*922.0*	*926.5*	*933.5*	*936.5*	*1449.5*	*1452.5*	*755.5*	*759.5*	*1096.0*	*1100.5*	*988.2*	*1000.0*
Top Anhydrite A4a												
Younger Halite Na3	*926.5*	*1036.0*	*936.5*	*1038.0*	*1452.5*	*1532.5*	*759.5*	*937.5*	*1100.5*	*1201.5*	*1000.0*	*1000.6*
Main Anhydrite A3	*1036.0*	*1059.5*	*1038.0*	*1058.0*	*1532.5*	*1554.5*	*937.5*	*950.0*	*1201.5*	*1212.5*	*1000.6*	*1080.8*
Platy Dolomite Ca3												
Grey Pelite T3	*1059.5*	*1062.5*	*1058.0*	*1059.0*	*1554.5*	*1556.5*	*950.0*	*951.0*	*1212.5*	*1213.5*	*1080.8*	*1125.0*
Screening Anhydrite A2r	*1062.5*	*1066.5*	*1059.0*	*1063.0*	*1556.5*	*1559.0*	*951.0*	*956.0*	*1213.5*	*1217.5*	*1125.0*	*1125.3*
Older Halite Na2	*1066.5*	*1115.5*	*1063.0*	*1112.0*	*1559.0*	*1620.0*	*956.0*	*1030.0*	*1217.5*	*1353.5*	*1125.3*	*1125.9*
Basal Anhydrite A2	*1115.5*	*1130.0*	*1112.0*	*1132.0*	*1620.0*	*1628.0*	*1030.0*	*1033.0*	*1353.5*	*1359.5*	*1125.9*	*1132.0*
Main Dolomite Ca2	*1130.0*	*1195.5*	*1132.0*	*1177.0*	*1628.0*	*1685.0*	*1033.0*	*1092.0*	*1359.5*	*1387.5*	*1132.0*	*1173.4*
Upper Anhydrite A1g	*1195.5*	*1203.0*	*1177.0*	*1213.0*	*1685.0*	*1725.0*	*1092.0*	*1119.5*	*1387.5*	*1391.0*	*1173.4*	*1180.8*
Oldest Halite Na1			*1213.0*	*1260.0*	*1725.0*	*1908.5*	*1119.5*	*1158.5*				
Upper Oldest Halite Na1d											*1180.8*	*1260.1*
Middle Anhydrite A1s											*1260.1*	*1304.0*
Lower Oldest Halite Na1d											*1304.0*	*1372.5*
Lower Anhydrite A1d			*1260.0*	*1410.0*	*1908.5*	*1958.5*	*1158.5*	*1294.5*			*1372.5*	*1446.2*
Zechstein Limestone Ca1			*1410.0*	*1414.0*	*1958.5*	*1962.5*	*1294.5*	*1299.0*			*1446.2*	*1449.8*
Kupferschiefer T1							*1299.0*	*1299.7*			*1449.8*	*1450.0*
Weissliegend							*1299.7*	*1304.0*			*1450.0*	*1457.4*
Upper Rotliegend			*1414.0*	*1870.0*	*1962.5*	*1984.6*	*1304.0*	*1445.0*			*1457.4*	*1466.0*
Lower Rotliegend												
CARBONIFEROUS			1870.0	2021.8			1445.0	1492.4				
PROTEROZOIC												

STRATIGRAPHY	Trzebule 1 top – bottom [m]		Urzuty IG-1 top – bottom [m]		Wysoka 1 top – bottom [m]		Wysoka 2 top – bottom [m]	
CENOZOIC	0.0	262.5	0.0	344.5	0.0	256.5	0.0	295.0
TRIASSIC	262.5	1259.0	344.5	683.7	256.5	953.5	295.0	815.0
PERMIAN	1259.0	2666.7	683.7	1250.0	953.5	1440.7	815.0	1305.0
Top Terrigenous Series PZt	*1259.0*	*1275.0*	*683.7*	*714.0*	*953.5*	*965.0*	*815.0*	*830.0*
Top Anhydrite A4g								
Younhest Halite Na4a	*1275.0*	*1300.0*			*965.0*	*977.0*	*830.0*	*844.5*
Lower Pegmatite Anhydrite A4a1	*1300.0*	*1300.5*					*844.5*	*846.5*
Red Pelite T4a	*1300.5*	*1301.5*			*977.0*	*982.5*	*846.5*	*852.0*
Top Anhydrite A4a								
Younger Halite Na3	*1301.5*	*1395.0*			*982.5*	*1046.0*	*852.0*	*958.0*
Main Anhydrite A3	*1395.0*	*1413.5*	*714.0*	*734.0*	*1046.0*	*1104.0*	*958.0*	*973.0*
Platy Dolomite Ca3			*734.0*	*783.4*				
Grey Pelite T3	*1413.5*	*1415.5*			*1104.0*	*1105.5*	*973.0*	*975.0*
Screening Anhydrite A2r	*1415.5*	*1416.0*	*783.4*	*827.6*	*1105.5*	*1109.0*	*975.0*	*979.0*
Older Halite Na2	*1416.0*	*1612.5*	*827.6* *996.0*	*946.9* *1012.7*	*1109.0*	*1156.0*	*979.0*	*1026.5*
Basal Anhydrite A2	*1612.5*	*1619.0*	*946.9* *1012.7*	*996.0* *1016.1*	*1156.0*	*1170.5*	*1026.5*	*1035.5*
Main Dolomite Ca2	*1619.0*	*1645.0*	*1016.1*	*1065.8*	*1170.5*	*1237.5*	*1035.5*	*1115.0*
Upper Anhydrite A1g	*1645.0*	*1681.5*			*1237.5*	*1283.0*	*1115.0*	*1151.0*
Oldest Halite Na1	*1681.5*	*1702.0*			*1283.0*	*1287.5*		
Upper Oldest Halite Na1d							*1151.0*	*1168.5*
Middle Anhydrite A1s							*1168.5*	*1175.5*
Lower Oldest Halite Na1d							*1175.5*	*1211.0*
Lower Anhydrite A1d	*1702.0*	*1837.5*	*1065.8*	*1245.0*	*1287.5*	*1418.0*	*1211.0*	*1280.5*
Zechstein Limestone Ca1	*1837.5*	*1845.0*	*1245.0*	*1248.2*	*1418.0*	*1420.0*	*1280.5*	*1284.0*
Kupferschiefer T1	*1845.0*	*1847.5*	*1248.2*	*1248.6*			*1284.0*	*1285.0*
Weissliegend								
Upper Rotliegend	*1847.5*	*2666.7*	*1248.6*	*1250.0*	*1420.0*	*1440.7*	*1285.0*	*1305.0*
Lower Rotliegend								
CARBONIFEROUS								
PROTEROZOIC								

STRATIGRAPHY	Żarków 1 top – bottom [m]		Żarków 2 top – bottom [m]		Żarków 3 top – bottom [m]		Żarków 4 top – bottom [m]	
CENOZOIC	0.0	245.0	0.0	292.5	0.0	305.0	0.0	288.0
TRIASSIC	245.0	851.5	292.5	605.0	305.0	800.0	288.0	746.0
PERMIAN	851.5	1363.6	605.0	994.1	800.0	1214.6	746.0	1041.5
Top Terrigenous Series PZt	*851.5*	*865.5*	*605.0*	*625.0*	*800.0*	*808.5*		
Top Anhydrite A4g								
Younhest Halite Na4a	*865.5*	*883.0*						
Lower Pegmatite Anhydrite A4a1	*883.0*	*885.0*						
Red Pelite T4a	*885.0*	*889.0*						
Top Anhydrite A4a								
Younger Halite Na3	*889.0*	*1025.5*						
Main Anhydrite A3	*1025.5*	*1041.5*	*625.0*	*685.0*	*808.5*	*833.5*	*746.0*	*759.0*
Platy Dolomite Ca3								
Grey Pelite T3	*1041.5*	*1043.1*	*685.0*	*687.0*	*833.5*	*834.5*	*759.0*	*760.0*
Screening Anhydrite A2r	*1043.1*	*1046.5*			*834.5*	*839.5*		
Older Halite Na2	*1046.5*	*1086.0*			*839.5*	*859.0*		
Basal Anhydrite A2	*1086.0*	*1091.5*	*687.0*	*700.0*	*859.0*	*865.2*	*760.0*	*773.5*
Main Dolomite Ca2	*1091.5*	*1160.0*	*700.0*	*751.0*	*865.2*	*938.0*	*773.5*	*821.0*
Upper Anhydrite A1g	*1160.0*	*1205.0*			*938.0*	*985.4*	*821.0*	*860.5*
Oldest Halite Na1	*1205.0*	*1228.0*			*985.4*	*1001.3*	*860.5*	*908.0*
Upper Oldest Halite Na1d			*751.0*	*918.0*				
Middle Anhydrite A1s								
Lower Oldest Halite Na1d								
Lower Anhydrite A1d	*1228.0*	*1357.5*			*1001.3*	*1156.2*	*908.0*	*1033.5*
Zechstein Limestone Ca1	*1357.5*	*1363.5*	*918.0*	*922.5*	*1156.2*	*1162.0*	*1033.5*	*1039.5*
Kupferschiefer T1			*922.5*	*923.7*				
Weissliegend								
Upper Rotliegend	*1363.5*	*1363.6*	*923.7*	*929.4*	*1162.0*	*1214.6*	*1039.5*	*1041.5*
Lower Rotliegend								
CARBONIFEROUS								
PROTEROZOIC			929.4	994.1			1041.5	1059.7

Tab. 5.1. Cont.

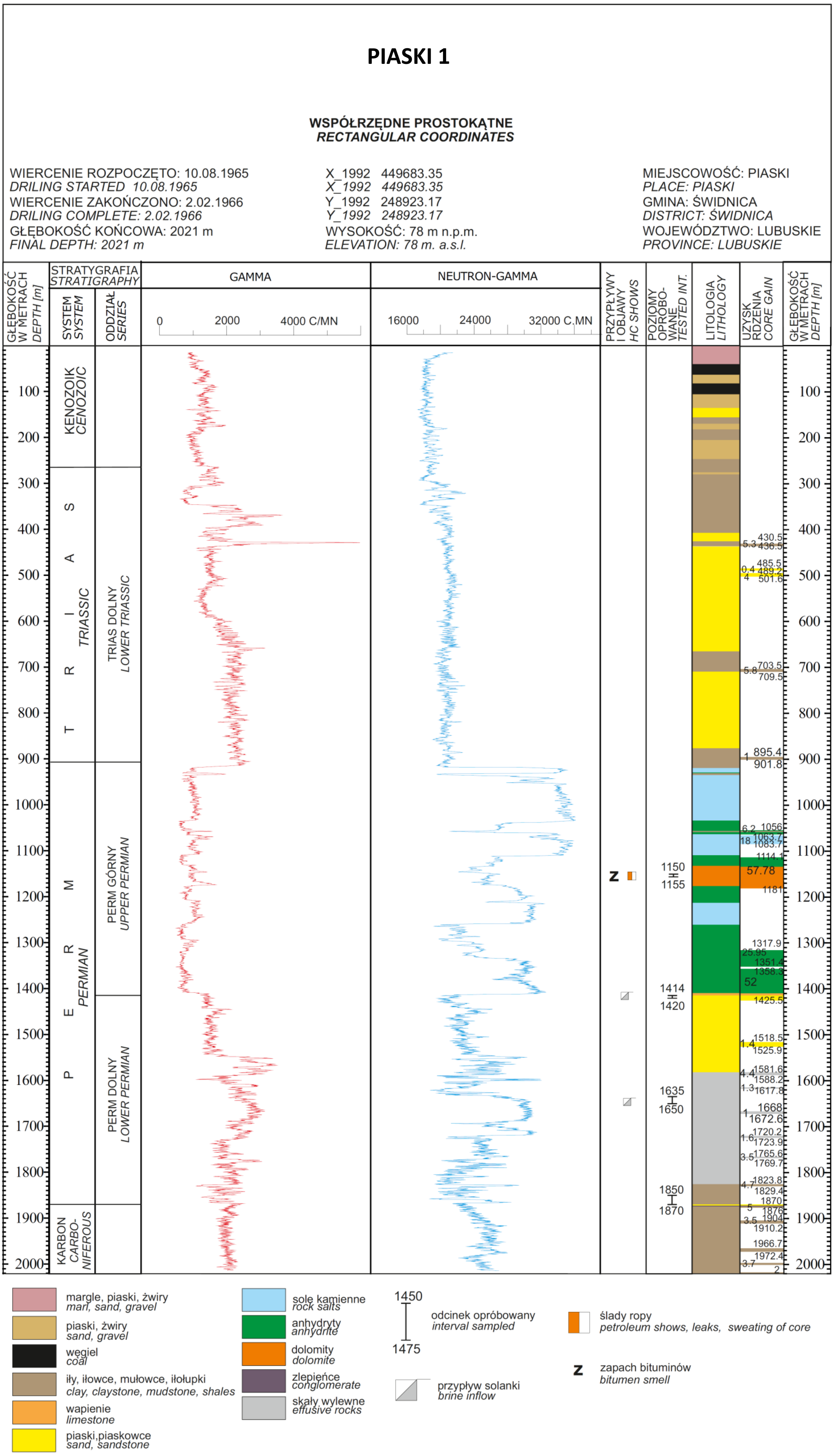


Fig. 5.3. Piaski 1 well lithology, stratigraphy and geophysics (Choiński and Olczak, 1967).

6. SEISMIC SURVEY

LINE NAME	YEAR	PROJECT	CONCESSIONS [after 2001]	OWNER	LENGTH [km]
T0580477	1977	Cybinka-Nowa Sól		State Treasury	3.18
T0610477	1977			State Treasury	3.28
W0080277	1977	Peryklina Żar		State Treasury	7.61
W0120277	1977			State Treasury	7.67
WA060377	1977			State Treasury	13.77
WA120377	1977			State Treasury	4.93
WB060377	1977			State Treasury	10.53
T0030478	1978	Cybinka-Nowa Sól		State Treasury	8.88
T0050478	1978			State Treasury	4.58
T0060478	1978			State Treasury	2.51
T0110478	1978			State Treasury	4.02
T0630478	1978			State Treasury	11.42
T0640478	1978			State Treasury	14.58
T0650478	1978			State Treasury	23.21
T0660478	1978			State Treasury	22.19
T0680478	1978			State Treasury	28.75
T0750478	1978			State Treasury	35.39
TS700478	1978			State Treasury	13.61
T0760479	1979			State Treasury	13.04
T0770479	1979			State Treasury	10.02
W0190279	1979	Niecka Północnosudecka		State Treasury	10.09
T0950690	1990	Słubice-Krosno Odrzańskie		ORLEN S.A.	2.41
T01A7610	2011	Laski	Blok 243 14/2007/p. Laski 37/2008/p	State Treasury	6.93
T02B7610	2011			State Treasury	3.48
T03C7610	2011			State Treasury	2.80
T06F7610	2011			State Treasury	3.75
T07G7610	2011			State Treasury	7.42
T08H7610	2011			State Treasury	11.41
T09J7610	2011			State Treasury	10.83
				State Treasury	299.88
				ORLEN S.A.	2.41

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

NAME	YEAR	CONCESSIONS (after 2001)	OWNER	ACREAGE [km^2]
Laski 3D	2013	Blok 243 14/2007/p. Laski 37/2008/p	State Treasury	81.12
Nowa Sól Zachód 3D	2013	Nowa Sól 5/2009/p	State Treasury	128.07
			Skarb Państwa	209.19

Tab. 6.2. 3D seismic surveys within the Zielona Góra West tender area.

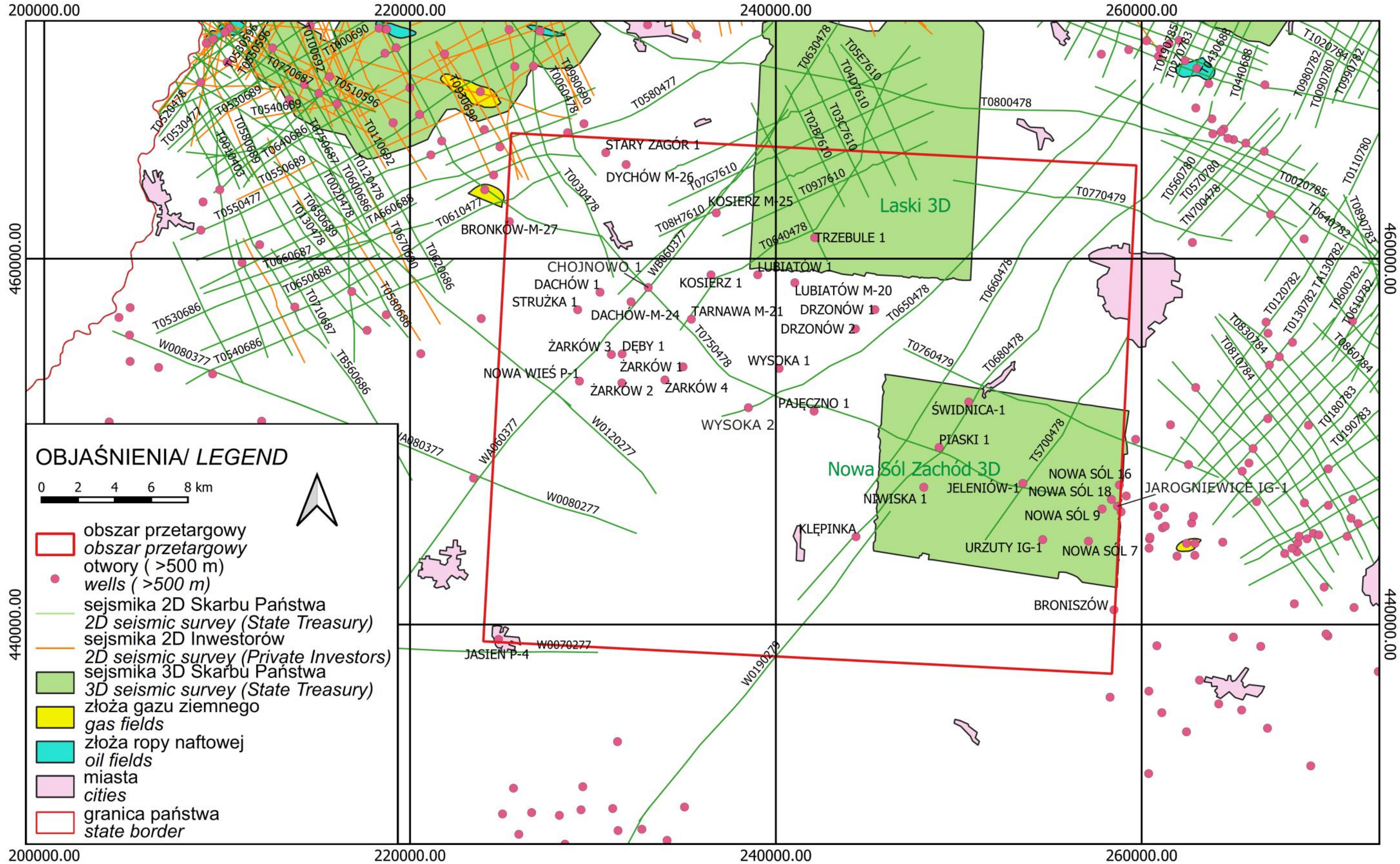


Fig. 6.1. Seismic survey within and in the neighborhood of the Zielona Góra West tender area (CGDB, 2023).

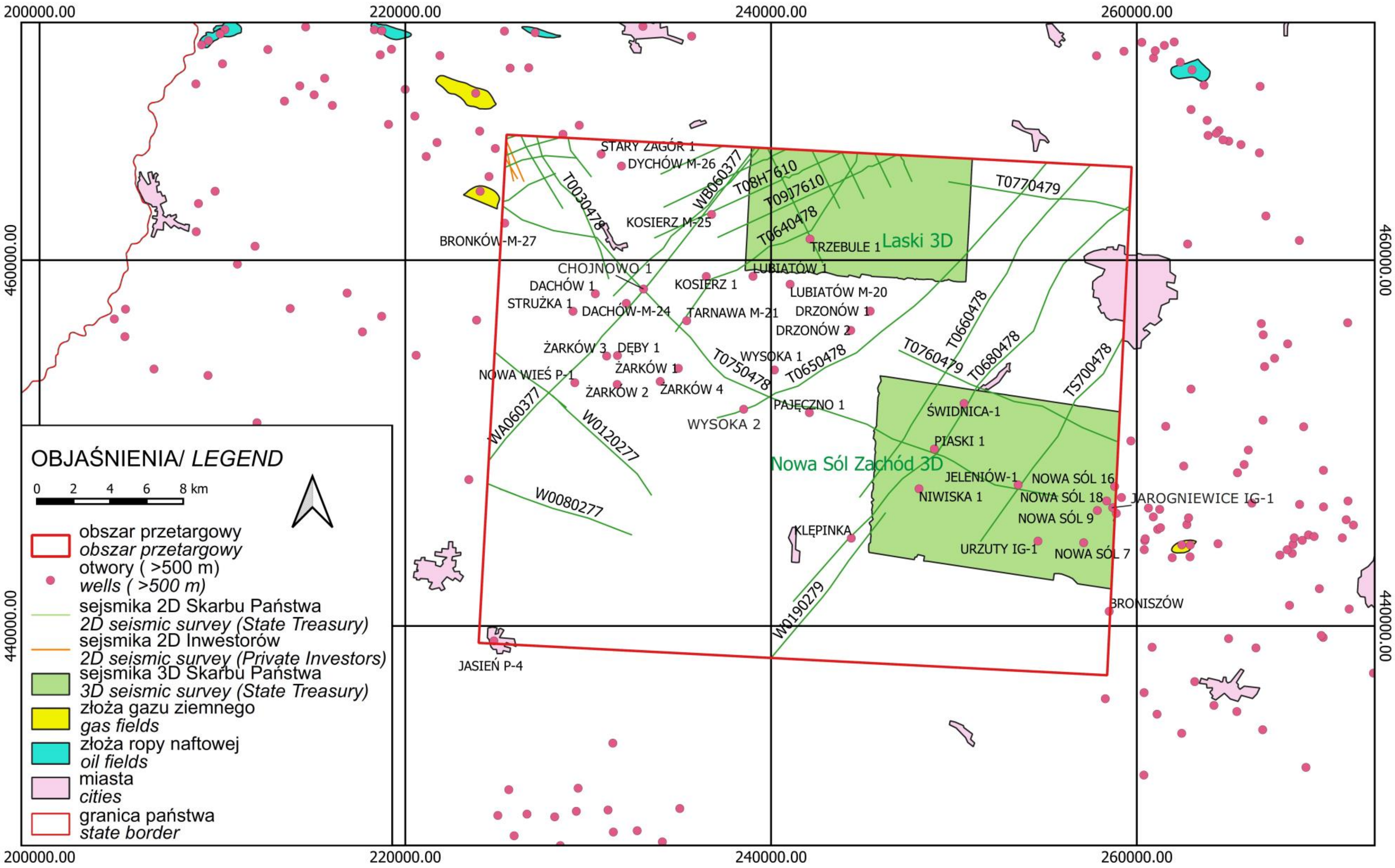


Fig. 6.2. Seismic survey within the Zielona Góra West tender area (CGDB, 2023).

7. GRAVIMETRY, MAGNETOMETRY AND MAGNETOTELLURICS

7.1. GRAVIMETRY

There are two semidetailed surveys in the Zielona Góra West tender area (Fig. 7.1), with 5343 data points within it. First survey – Dzierżoniów-Legnica-Bolesławiec (Cieśla and Okulus, 1974) covers the eastern part of the tender area and was collected with a point density ca. 4,5 point/km^2. The second survey, in the Gubin-Zielona Góra area (Pisuła and Ostrowski, 1990) covers the western part of the tender area and was collected with similar point density.

There are some detailed surveys in the tender area, as well. Most of them were focused on lignite exploration. There are 9 profiles collected with 50 m step (Łaszczyńska et al., 1982) and 3 profiles collected with 100 m step (Ostrowska and Pisuła, 1991) within the Zielona Góra West tender area.

The image of detailed surveys is complemented by the profile in the eastern part of the area (Okulus, 1980), with an average measuring step of 50 m.

Królikowski and Petecki (1995) proposed a division of Poland into several gravity regions. Thus, the Zielona Góra West tender area is placed within the north-eastern part of the Silesia High – co called Ostrzeszów-Krosno High.

The origin of the regional anomaly in the Fore-Sudetic Monocline is usually associated with the elevation of the Moho surface. From the other hand the second-order anomaly results presumably from the Cambrian-Devonian metamorphic rocks (Królikowski and Grobelny 1991; Królikowski and Petecki, 1995).

7.2. MAGNETOMETRY

First magnetic survey at the Zielona Góra West tender area was the regional vertical component Z survey (Kozera, 1955; Fig. 7.3), collected with a density ca. 0.22 stations/km^2. The next survey was a slightly denser (Tałuc and Ciszewski, 1962) with an average density of 1.2 stations /km^2. As part of this survey, measurements were also taken along the profiles that are visible in the western part of the tender area (Fig. 7.3). The last Z survey are profiles taken with a step of 50 m (Tałuc and Ciszewski, 1964).

The central and eastern part of the Zielona Góra West tender area is covered with Foresudetic Monocline T – total intensity magnetic survey (Pasik, 1974), with ca. 1 station/km^2 density. From the west it is bordered by the newer and denser survey called Western, central and south-eastern Poland (3 points/km^2; Kosobudzka, 1991; Fig. 7.3).

An image of magnetic anomalies presented on 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 Zielona Góra West tender area is located at the north-western edge of the Sudetic domain (Sd). There is a range of positive anomalies with the extent of NW-SE (mainly south of the tender area). Petecki and Rosowiecka (2017) linked them with sub-Permian Wolsztyn-Leszno High.

As a part of another study (Cieśla et al., 1997), maps of anomalous elements of both potential fields (linear and structural) were developed. The results are presented in Fig. 7.5. As a result of the potential fields modelling, it was found that the top of the anomaly sources occurs at a depth of 4–5 km.

7.3. MAGNETOTELLURICS

So far, no magnetotelluric works have been carried out directly within the Zielona Góra West tender area.

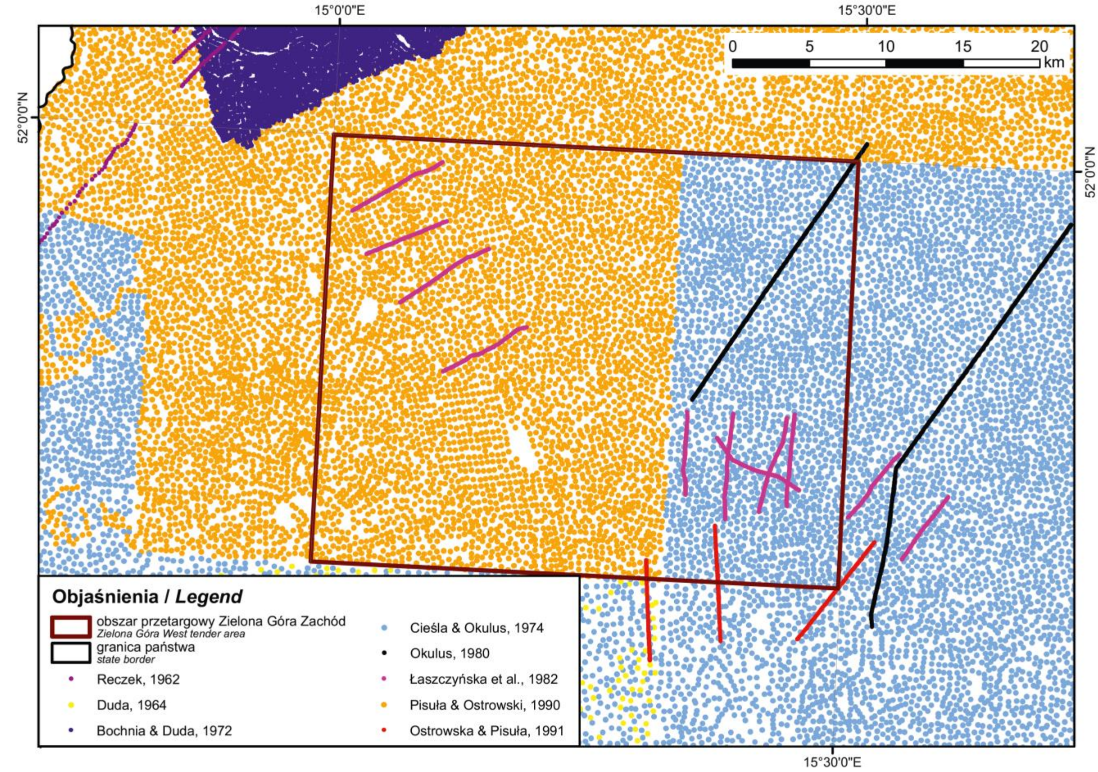


Fig. 7.1. Distribution of gravimetric measurements in the Zielona Góra West tender area (based on CGDB, 2023).

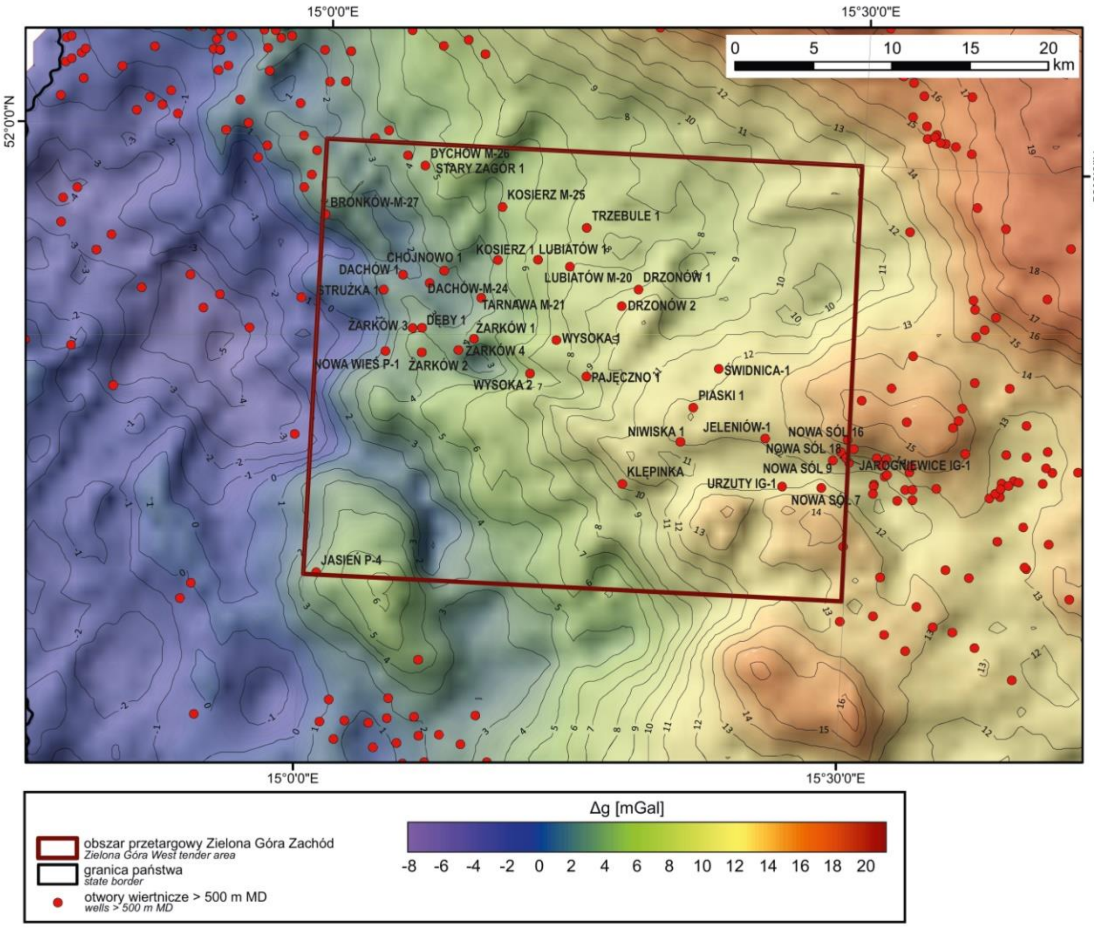


Fig. 7.2. Location of the Zielona Góra East tender area on the Bouguer gravity anomaly map of Poland (Królikowski and Petecki, 1995).

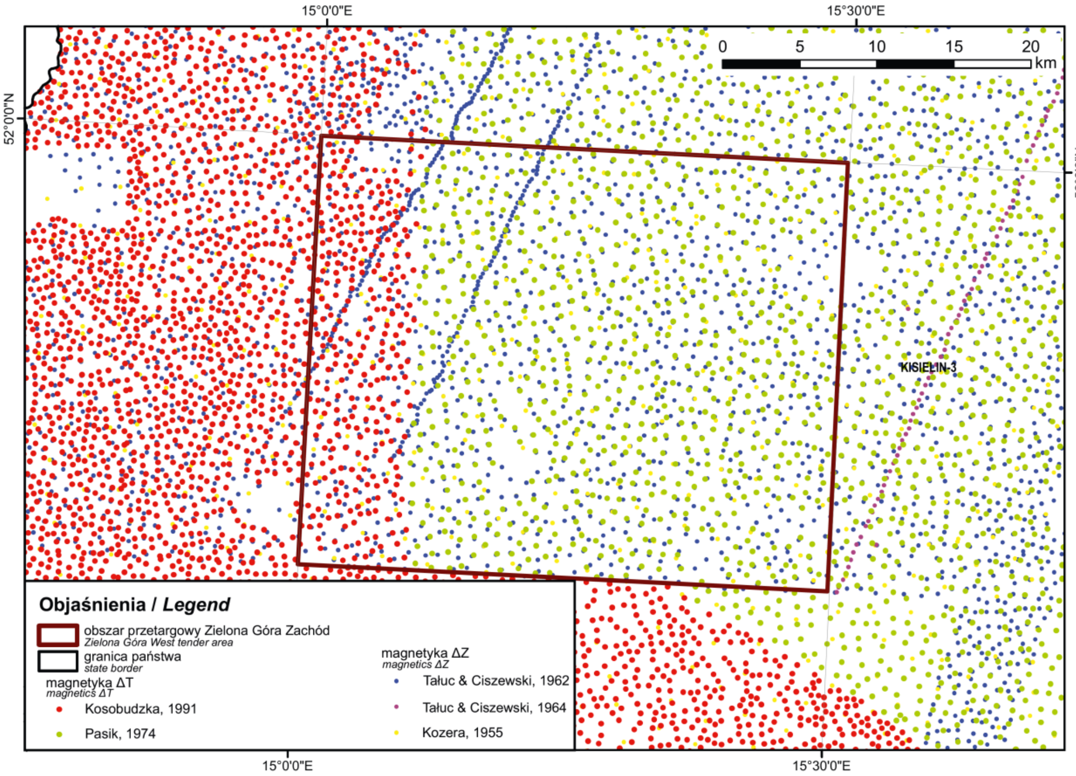


Fig. 7.3. Distribution of magnetic stations in the Zielona Góra West tender area (based on CGDB, 2023).

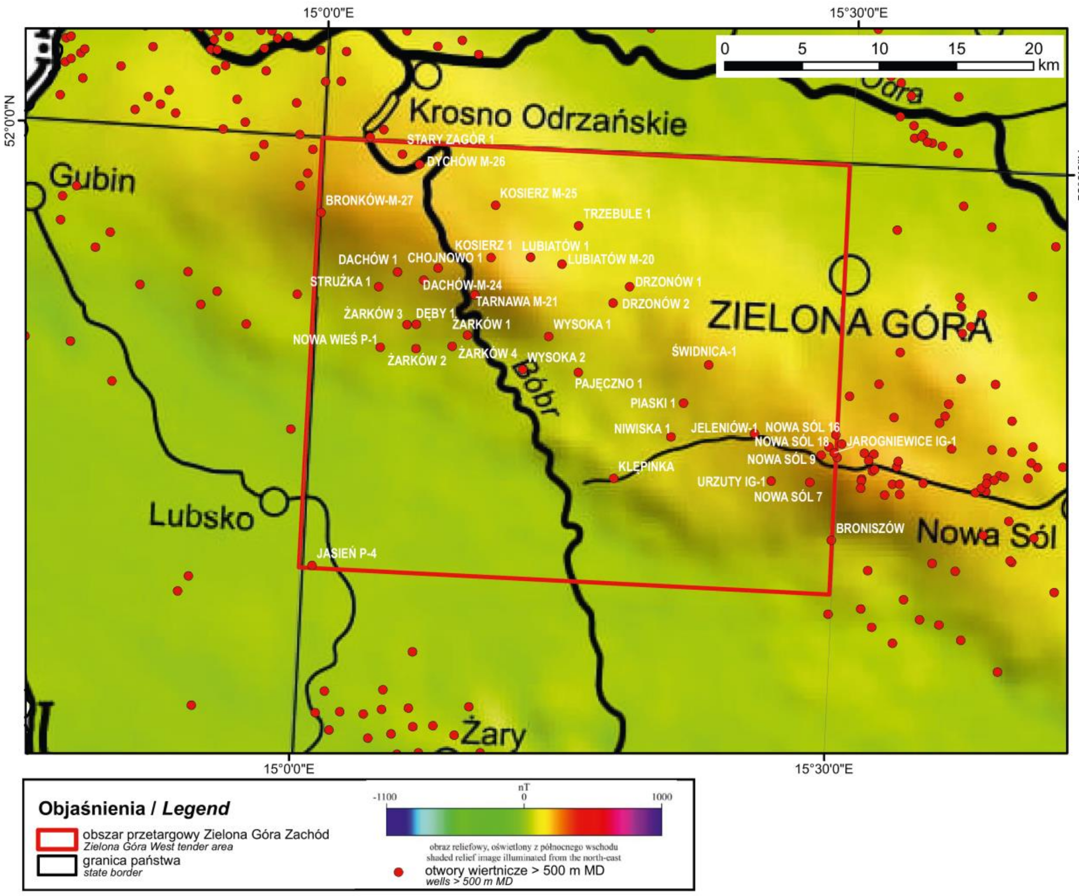


Fig. 7.4. Location of the Zielona Góra West tender area on the magnetic anomaly map of Poland (Petecki and Rosowiecka, 2017).

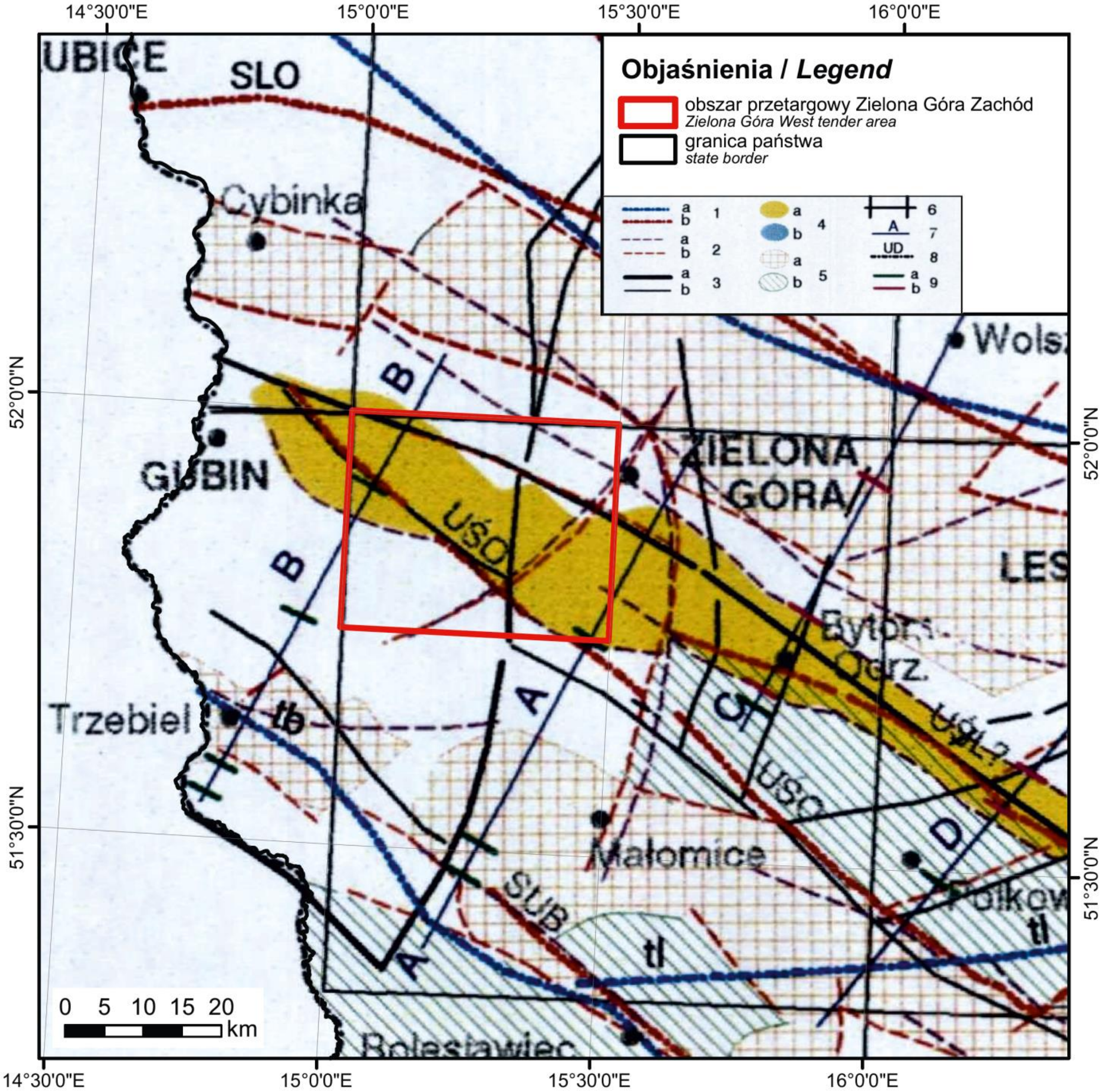


Fig. 7.5. Linear and structural elements interpreted on the basis of magnetics and gravimetry surveys (Cieśla et al., 1997). 1 – boundaries of larger geophysical and geological units on the basis of a – magnetics (small letters), b – gravimetry (capital letters); 2 – the most important discontinuities (contacts and/or dislocations) on the basis of a – magnetics, b – gravimetry; 3 – linear elements: a – boundaries of groups of structural units, b – main faults and faut zones; 4 – blocks on the basis of magnetics: a – with higher values of magnetic properties, b –with lower values of magnetic properties; 5 – blocks on basis of gravimetry: a – with higher density, b – with lower density; 6 –S-part of VII DSS profile with the mark of the positions of deep splits; 7 – interpreted profiles; 8 – Dolsk fault; 9 – borders on the basis of modelling: a – dislocations (gravimetry), b – magnetic contacts.

8. SUMMARY CHART

<table>
<tr><td rowspan="4">General information:</td><td>Tender area:</td><td>ZIELONA GÓRA WEST</td></tr>
<tr><td>Location:</td><td>Onshore
Hydrocarbon concession blocks: 243
Administrative location: Lubuskie Voivodeship, Krosno Odrzańskie county, communes: Bobrowice (14.76%), Dąbie (10.05%), Krosno Odrzańskie (0.44%); Nowa Sól country, commune Kożuchów (2.04%); Zielona Góra City county, commune Zielona Góra (8.70%); Zielona Góra country, communes: Czerwieńsk (4.16%), Nowogród Bobrzański (26.57%), Świdnica (16.86%); Żagań country, communes: Brzeźnica (1.57%), Żagań (0.25%); Żary country, communes: Żary (1.13%), Lubsko (6.98%), Jasień (6.49%)</td></tr>
<tr><td>Concession type:</td><td>prospection and exploration of hydrocarbon deposits
and production of hydrocarbons from a deposit</td></tr>
<tr><td>Time:</td><td>concession for 30 years, including:
prospection and exploration phase (5 years),
production phase – after investment decision</td></tr>
<tr><td colspan="2">Participation:</td><td>winner of the tender 100%</td></tr>
<tr><td colspan="2">Acreage [km^2]:</td><td>954.57</td></tr>
<tr><td colspan="2">Accumulation type:</td><td>conventional oil and gas fields</td></tr>
<tr><td colspan="2">Structural stages:</td><td>Cenozoic, Laramide, Variscan</td></tr>
<tr><td colspan="2">Petroleum plays:</td><td>I – Main Dolomite
II – Carboniferous/Lower Permian</td></tr>
<tr><td colspan="2">Reservoir rocks:</td><td>I – Main Dolomite dolomitized grainstones and packstones
II – Upper Rotliegend fine- and medium grained aeolian sandstones</td></tr>
<tr><td colspan="2">Source rocks:</td><td>I – Main Dolomite mudstones, greinstones and boundstones
II – Carboniferous claystones and siltstones</td></tr>
<tr><td colspan="2">Seal rocks:</td><td>I – PZ2 evaporites
II – PZ1 evaporites</td></tr>
<tr><td colspan="2">Trap type:</td><td>I – structural or structural-tectonic
II – structural or structural-tectonic</td></tr>
<tr><td colspan="2">Oil and gas fields:</td><td>Brzózka, Czeklin, Czerwieńsk, Lelechów, Morzów N, Mrozów S, Nowa Sól</td></tr>
<tr><td colspan="2">Seismic surveys (owner):</td><td>1977 Cybinka-Nowa Sól, 2 lines (State Treasury)
1977 Peryklina Żar, 5 lines (State Treasury)
1978 Cybinka-Nowa Sól, 13 lines (State Treasury)
1979 Niecka Północnosudecka, 1 line (State Treasury)
1990 Słubice-Krosno Odrzańskie, 1 line (PGNiG S.A.)
2011 Laski, 7 lines (State Treasury)
2013 Laski 3D (State Treasury)
2013 Nowa Sól Zachód 3D (State Treasury)</td></tr>
<tr><td colspan="2">Wells (depth):</td><td>BRONISZÓW (791.5 m)
BRONKÓW-M-27 (1564.0 m)
CHOJNOWO 1 (1530.1 m)
DACHÓW 1 (1508 m)
DACHÓW-M-24 (1538.4 m)
DĘBY 1 (1370.5 m)
DRZONÓW 1 (1303.0 m)
DRZONÓW 2 (1434.0 m)
DYCHÓW M-26 (1930.0 m)
JAROGNIEWICE IG-1 (551.6 m)
JASIEŃ P-4 (1054.0 m)
JELENIÓW-1 (1492.3 m)
KLĘPINKA (708.2 m)
KOSIERZ 1 (1415.0 m)
KOSIERZ M-25 (1810.0 m)
LUBIATÓW 1 (1451.4 m)
LUBIATÓW M-20 (1662.0 m)
NIWISKA 1 (1700.0 m)
NOWA SÓL 7 (1113.2 m)
NOWA SÓL 9 (1137.3 m)
NOWA SÓL 16 (1299.0 m)
NOWA SÓL 18 (1241.6 m)
NOWA WIEŚ P-1 (1012.0 m)
PAJĘCZNO 1 (1203.0 m)
PIASKI 1 (2021.8 m)
STARY ZAGÓR 1 (1984.6 m)
STRUŻKA 1 (1492.4 m)</td></tr>
</table>

	ŚWIDNICA-1 (1391.0 m) TARNAWA M-21 (1466.0 m) TRZEBULE 1 (2666.7 m) URZUTY IG-1 (1250.0 m) WYSOKA 1 (1440.7 m) WYSOKA 2 (1305.0 m) ŻARKÓW 1 (1363.6 m) ŻARKÓW 2 (994.1 m) ŻARKÓW 3 (1214.6 m) ŻARKÓW 4 (1059.7 m)

Possible minimum work program for the prospection and exploration phase

- Archival data reinterpretation and analysis
- Conducting of 2D seismic survey (at least 100 km) or 3D seismic survey (at least 50 km^2)
- Drilling of one well to the maximal depth 5000 m TVD with obligatory coring of prospective intervals

9. REFERENCES

- **Aleksandrowski P. 1995.** Rola wielkoskalowych przemieszczeń przesuwczych w ukształtowaniu waryscyjskiej struktury Sudetów. [Role of large-scale strike-slipe movements for the Variscan structure of Sudetes Mts (SW Poland)]. *Przegląd Geologiczny*, **43**, 745–754. [in Polish with English summary]
- **Aleksandrowski P., Kryza R., Mazur S., Żaba J. 1997.** Kinematic data on major Variscan strike-slip faults and shear zones in the Polish Sudetes, northeast Bohemian Massif. *Geological Magazine*, **134**, 727–739.
- **Badura J., Przybylski B. 2002.** Objaśnienia do szczegółowej mapy geologicznej Polski 1 : 50 000. Arkusz Chotków (611). [Detailed Geological Map of Poland 1 : 50 000. Chotków Sheet (611)]. Description. Polish Geological Institute, Warsaw. [in Polish]
- **Bartczak E. 2002.** Objaśnienia do szczegółowej mapy geologicznej Polski 1 : 50 000. Arkusz Krzystkowice (610). [Detailed Geological Map of Poland 1 : 50 000. Krzystkowice Sheet (610)]. Description. Polish Geological Institute, Warsaw. [in Polish]
- **Bochnia N., Duda W. 1972.** Dokumentacja szczegółowych badań grawimetrycznych, temat Krosno Odrzańskie, 1971 r. [Detailed gravimetric survey report, topic Krosno Odrzańskie, 1971]. Inv. 1696, 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., Kwolek K., Nowicka A., Dyjaczyński K., Papiernik B., Peryt T., Protas A., Wagner R. 2013.** Mapa perspektyw poszukiwawczych w utworach dolomitu głównego. [Map of petroleum prospective structures in the Main Dolomite in Poland]. PGNiG; Polish Geological Institute – National Research Institute, Warsaw. [in Polish]
- **Burdzy M. 2001.** Dokumentacja geologiczna złoża ropy naftowej Mozów S i Mozów N. [Mozów S and Mozów N oil fields geological documentation]. Inv. 72/2002, CAG PIG, Warsaw. [in Polish]
- **Burdzy M. 2009.** Dokumentacja geologiczna złoża ropy naftowej Czerwieńsk w kat. A. Dodatek nr 3 – wniosek o rozliczenie zasobów. [Czerwieńsk oil fields geological documentation]. Inv. 5321/ 2009, CAG PIG, Warsaw. [in Polish]
- **Burzewski W., Górecki W., Maćkowski T., Papiernik B., Reicher B. 2009.** Zasoby prognostyczne – nieodkryty potencjał gazu ziemnego w polskim basenie czerwonego spągowca. [Prognostic gas reserves – undiscovered potential of gas in the Polish Rotliegend basin]. *Geologia*, **35**, 123–128. [in Polish with English summary]
- **CGDB, 2023.** Central Geological Data-Base. baza.pgi.gov.pl
- **Chmal R. 2002.** Objaśnienia do szczegółowej mapy geologicznej Polski 1 : 50 000. Arkusz Bobrowice (573). [Detailed Geological Map of Poland 1 : 50 000. Bobrowice Sheet (573). Description]. Polish Geological Institute, Warsaw. [in Polish]
- **Choiński L., Olczak D. 1967.** Dokumentacja wynikowa otworu Piaski 1. [Piaski 1 final well report]. Inv. 88634, CAG PIG, Warsaw. [in Polish]
- **Cieśla E., Okulus H. 1974.** Dokumentacja półszczegółowych badań grawimetryczno-magnetycznych. Temat: Blok przedsudecki, rejon: Dzierżoniów-Legnica-Bolesławiec, 1973. [Semidetailed gravimetric survey documentation. Topic: Fore-Sudetic Block, region: Dzierżoniów-Legnica-Bolesławiec, 1973]. Inv. 1799, CAG PIG, Warsaw. [in Polish]
- **Cieśla E., Petecki Z., Wybraniec S., Gientka D., Staniszewska B., Twarogowski J., Żółtowski Z. 1997.** Kompleksowa interpretacja grawimetryczno-magnetyczna Polski zachodniej, 1997 rok. [Complex gravimetric and magnetic inter-

pretation of western Poland 1997]. Inv. 7/98, 4746/2015, CAG PIG, Warsaw. [in Polish]

- **Czapowski G. 1983.** Zagadnienia sedymentacji soli kamiennej cyklotemu PZ1 we wschodnim skłonie wyniesienia Łeby. [Sedimentation of the PZ1 halite in the eastern side of the Łeba High]. *Przegląd Geologiczny*, **31**, 278–284. [in Polish]
- **Czapowski G., Tomassi-Morawiec H. 1985.** Sedymentacja i geochemia najstarszej soli kamiennej w rejonie Zatoki Puckiej. [Sedimentation and geochemistry of the Oldest Halite in the Puck area]. *Przegląd Geologiczny*, **33**, 663–670. [in Polish]
- **Czapowski G., Nowacki Ł., Chełmiński J., Głuszyński A., Skowroński L. 2018.** Ewaporaty górnego permu (cechsztynu) na obszarze centralnej części monokliny przedsudeckiej (SW Polska) – warunki występowania i wykształcenia. [Geology of Upper Permian (Zechstein) evaporites in the central Fore-Sudetic Monocline (SW Poland)]. *Przegląd Solny*, 29–53. [in Polish with English summary]
- **Dadlez R., Narkiewicz M., Stephenson R. A., Visser M. T. M., Van Wess J.-D. 1995.** Tectonic evolution of the Mid-Polish Trough: modelling implications and significance for central European geology. *Tectonophysics*, **252**, 179–195.
- **Dadlez R., Marek S., Pokorski J. 2000.** Geological Map of Poland without Cenozoic deposits, 1 : 1 000 000. Polish Geological Institute, Warsaw. [in Polish with English abbreviations]
- **Deczkowski Z. 1997.** Trias górny. Noryk i retyk. Formalne i nieformalne jednostki litostratygraficzne. [Upper Triassic. Norian and Rhaetian. Formal and informal lithostratigraphic units]. (In): The epicontinental Permian and Mesozoic in Poland; (Eds): Marek S., Pajchlowa M. *Prace Państwowego Instytutu Geologicznego*, **153**, 184–186. [in Polish with English summary]
- **Deczkowski Z., Gajewska I. 1977.** Charakterystyka starokimeryjska i laramijskich struktur blokowych monokliny przedsudeckiej. [The characteristics of late Cimmerian and Laramian block structures of the Fore-Sudetic Monocline]. *Geological Quarterly*, **21**, 467–481. [in Polish with English summary]
- **Deczkowski Z., Gajewska I. 1980.** Mezozoiczne i trzeciorzędowe rowy obszaru monokliny przedsudeckiej. [Mesozoic and Tertiary troughs of the Fore-Sudetic Monocline]. *Przegląd Geologiczny*, **28**, 151–156. [in Polish with English summary]
- **Deczkowski Z., Oszczepalski S., Rydzewski A. 1993.** Budowa geologiczna i surowce mineralne perykliny Żar. [Geology and resources of the Żary Pericline]. (In): Geology of the Peryklina Żar in mineral resources aspects; (Eds): S. Oszczepalski, A. Rydzewski. Inv.1457/93, CAG PIG, Warsaw. 9–18. [in Polish]
- **Duda W. 1964.** Opracowanie półszczegółowych badań grawimet-rycznych: Monoklina Przedsudecka (Leszno-Ostrzeszów), 1963. [Semidetailed gravimetric survey report: Fore-Sudetic Monocline (Leszno-Ostrzeszów), 1963]. Inv. 1044, CAG PIG, Warsaw. [in Polish]
- **Dudzińska K. 1995.** Dokumentacja geologiczna w kat. B złoża gazu ziemnego Nowa Sól. [Nowa Sól gas field geological documentation]. Inv. 1071/95, CAG PIG, Warsaw. [in Polish]
- **Dyjaczyński K., Peryt T.M. 2014.** Controls on basal Zechstein (Wuchiapingian) evaporite deposits in SW Poland. *Geological Quarterly*, **58**, 485–502.
- **Gajewska I. 1997a.** Trias środkowy (wapień muszlowy-kajper dolny). Formalne i nieformalne jednostki litostratygraficzne. [Middle Triassic (Muschelkalk and Lower Keuper). Formal and informal lithostratigraphic units]. (In): The epicontinental Permian and Mesozoic in Poland; (Eds): Marek S., Pajchlowa M. *Prace Państwowego Instytutu Geologicznego*, **153**, 133–136. [in Polish with English summary]
- **Gajewska I. 1997b.** Trias górny. Kajper. Formalne i nieformalne jednostki litostratygraficzne. [Upper Triassic. Keuper. Formal and informal lithostratigraphic units]. (In): The epicontinental Permian and Mesozoic in Poland; (Eds): Marek S., Pajchlowa M. *Prace Państwowego Instytutu Geologicznego*, **153**, 164–166. [in Polish with English summary]

- **Górecka T., Parka Z., Ślusarczyk S., Templin L. 1977.** Wyniki badań palinologicznych osadów podpermskich południowo-wschodniej części monokliny przedsudeckiej. [Results of sediments in the south-eastern part of the Fore-Sudetic Monocline]. *Prace Naukowe Instytutu Górnictwa Politechniki Wrocławskiej, Studia i Materiały*, **12**, 29–55. [in Polish]
- **Grocholski W. 1991.** Budowa geologiczna przedkenozoicznego podłoża Wielkopolski. [Geology of the sub-Cenozoic basement of Wielkopolska]. Conference materials of the 62. Meeting of the Polish Geological Society, Poznań. [in Polish]
- **Hoffmann N., Pokorski J., Lindert W., Bachmann H. 1997.** Rotliegend stratigraphy, paleogeography and facies in eastern part of the central European Basin. *Prace Państwowego Instytutu Geologicznego*, **157**, 75–86.
- **Hryniewiecka A. 1988.** Geneza produktywności dolnopermskiego basenu gazonośnego południowej części monokliny przedsudeckiej. [Genesis of productivity of the Lower Permian gas-bearing basin in the southern part of the Fore-Sudetic Monocline]. *Gospodarka Surowcami Mineralnymi*, **4**. [in Polish]
- **Hunt J.M. 1979.** Petroleum Geochemistry and Geology. W.H. Freeman and Company, San Francisco, 617.
- **Hunt J.M. 1996.** Petroleum Geochemistry and Geology. W.H. Freeman and Company, San Francisco, 743.
- **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**, 1017–1024.
- **Juroszek C., Kłapciński J., Sachanbiński M. 1981.** Wulkanity dolnego permu południowej części monokliny przedsudeckiej i perykliny Żar. [The Lower Permian Volcanites in the southern part of the Fore-Sudetic Monocline and the Żary Pericline]. *Annales Societatis Geologorum Poloniae*, **51**, 517–546. [in Polish with English summary]
- **Karnkowski, P.H. 1994.** Rotliegend lithostratigraphy in the central part of the Polish Permian Basin. *Geological Quarterly*, **38**, 27–42.
- **Karnkowski P.H. 1987.** Litostratygrafia czerwonego spągowca w Wielkopolsce. [Lithostratigraphy of the Rotliegendes in Wielkopolska (Western Poland)]. *Geological Quarterly*, **31**, 643–672. [in Polish with English summary]
- **Kiersnowski H. 2003.** Środowiska sedymentacji osadów czerwonego spągowca dolnego na obszarze Wielkopolski. Sedimentary environments of the Lower [Rotliegend deposits in Wielkpolska]. (In): Volcanoclastic deposits of the Lower Rotliegend in Wielkopolska, (Ed.): Maliszewska A. *Prace Państwowego Instytutu Geologicznego*, **179**, 15–27. [in Polish with English summary]
- **Kiersnowski H. 2008.** Litostratygrafia osadów czerwonego spągowca dolnego na obszarze platformy waryscyjskiej oraz jej związki z litostratygrafią niemiecką w NE Brandenburgii. [Lower Rotliegend lithostratigraphy of the Variscan platform and its relations with German lithostratigraphy in NE Brandenburg]. Polish Geological Institute – National Research Institute, Warsaw. [in Polish]
- **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]
- **Kiersnowski, H. Waśkiewicz, K., Buniak, A. 2020.** Mapa litofacji stropu osadów czerwonego spągowca górnego. [Lithofacies map at the top of the Upper Rotliegend]. Polish Geological Institute – National Research Institute, Warsaw. [In Polish]
- **Kłapciński J. 1991.** Zechstein anhydrites in western Poland. *Zentralblatt für Geologie und Paläontologie*, **Teil I, H.4**, 1171–1188.

- **Kondracki J. 2013.** Geografia regionalna Polski. [Regional Geography of Poland]. Wydawnictwa Naukowe PWN, Warsaw. [In Polish]
- **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., 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.
- **Kosobudzka I. 1991.** Sprawozdanie z półszczegółowych badań magnetycznych ΔT, temat: Polska zachodnia, centralna i południowo-wschodnia, rok 1990. [Semidetailed magnetic survey ΔT report, topic: western, central and south-eastern Poland, 1990]. Inv. 1287/91, 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., Więcław 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]
- **Kozera A. 1955.** Sprawozdanie z prac magnetycznych. Temat: Regionalne badania na Śląsku, Ziemi Lubuskiej i w Wielkopolsce przeprowadzonych przez Grupę Magnetyczną II PPG w 1955 r. [Magnetic survey report. Topic: Regional research in Silesia, Lubuskie and Wielkopolska areas carried out by Magnetic Group II PPG in 1955]. Inv. 40604, CAG PIG, Warsaw. [In Polish]
- **Krawczyńska-Grocholska H., Grocholski W. 1976.** Uwagi o karbonie północno-zachodniego obrzeżenia bloku przedsudeckiego. [Some remarks on the Carboniferous occurring on the north-western margin of the Fore-Sudetic Block]. *Geological Quarterly*, **20**, 53–64. [in Polish with English summary]
- **Królikowski C., Grobelny A. 1991.** Preliminary results of the geophysical interpretation (stripping method) in respect to the pre-Permian basement of south-western Poland. *Geological Quarterly*, **35**, 449–476.
- **Królikowski C., Petecki Z. 1995.** Atlas grawimetryczny Polski. [Gravimetric Atlas of Poland]. Polish Geological Institute, Warsaw. [In Polish]
- **Kuberska M., Kozłowska A. 2011.** Nowe dane o petrografii skał czerwonego spągowca z zachodniej części monokliny przedsudeckiej. [New data on petrography of the Rotliegend rocks in the western part of the Fore-Sudetic Monocline]. *Biuletyn Państwowego Instytutu Geologicznego*, **444**, 135–148. [in Polish with English summary]
- **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]

  Kwolek K. 2000. Wiek ruchów tektonicznych w strefie dyslokacji Poznań – Kalisz, monoklina przedsudecka. [The age of tectonic movements in the Poznań–Kalisz Dislocation Zone, Fore–Sudetic Monocline]. *Przegląd Geologiczny*, **48**, 804–814. [in Polish with English summary]
- **Leenheer M.J. 1984.** Missisipian Bakken and equivalent formations as source rocks in the western Canadian basin. *Organic Geochemistry*, **6**, 521 – 532.
- **Łaszczyńska B., Okulus H., Wojas 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 annomalies (Oborniki, Kłecko, Pogorzela, Świebodzin-Boryszyn, Studzieniec, Bobrowice regions), 1981]. Inv. 2189, CAG PIG, Warsaw. [In Polish]

- **Maliszewska A., Kuberska M. 2008.** Spoiwa skał górnego czerwonego spągowca w zachodniej części Niżu Polskiego w ujęciu kartograficznym. [Mapping of cement types in the Upper Rotliegend rocks from the western Polish Lowlands]. *Biuletyn Państwowego Instytutu Geologicznego*, **429**, 79–90. [in Polish with English summary]
- **Maliszewska A., Kiersnowski H., Jackowicz E. 2003.** Wulkanoklastyczne osady czerwonego spągowca dolnego na obszarze Wielkopolski. [Volcanoclastic deposits of the Lower Rotliegend in Wielkopolska]. *Prace Państwowego Instytutu Geologicznego*, **179**, 1–59. [in Polish with English summary]
- **Maliszewska A., Jackowicz E., Kuberska M., Kiersnowski H. 2016.** Skały permu dolnego (czerwonego spągowca) zachodniej Polski – monografia petrograficzna. [Lower Permian (Rotliegend) rocks of western Poland : a petrographic monograph]. *Prace Państwowego Instytutu Geologicznego*, **204**. [in Polish with English summary]
- **Markiewicz A. 2007.** Naskórkowa struktura południowej części monokliny przedsudeckiej a zagospodarowanie utworów najstarszej soli kamiennej (Na1). [The structure of the southern part of the Fore-Sudetic Monocline and use of the Oldest Salt (Na1) rocks]. *Gospodarka Surowcami Mineralnymi*, **23**, 35–49. [in Polish]
- **Markiewicz A. 2010.** Morfotektonika rejonu Zielonej Góra. [Morphotectonic of the Zielona Góra region]. *Zeszyty Naukowe Uniwersytetu Zielonogórskiego*, **139**, 81–92. [in Polish]
- **Markiewicz A., Kraińska A. 2002**. Neotektoniczna reaktywacja struktur halotektonicznych a zaburzenia glacitektoniczne w strefach marginalnych zlodowaceń plejstoceńskich na przykładzie wzgórz Dalkowskich (SW Polska). [Neotektonische reaktivierung der Halotektonischen Strukturen und Glacitektonische störungen auf dem Marginalen Gebiet der Europäischen Pleistozänen vereisung (Beispiel : Dalkowskie-Gebirge, SW-Polen)]. *Zeszyty Naukowe Uniwersytetu Zielonogórskiego*, **129**, 123–142. [in Polish with German summary]
- **Markiewicz A., Winnicki J. 2005.** Plejstoceńska reaktywacja cienkopokrywowej struktury monokliny przedsudeckiej a strefy dużych zaburzeń glacitektonicznych w rejonie Zielonej Góry, Kożuchowa i Głogowa (SW Polska). [Pleistocene reactivation of the thin-skinned structure of the Fore-Sudetic Monocline and huge glacitactonic disturbance zones in the Zielona Góra, Kożuchów and Głogów regions (SW Poland)]. Materials of the VI Polish Conference "Neotectonic of Poland" Middle European Active Faults. [in Polish]
- **Markiewicz A., Winnicki J. 2007a.** Morfotektonika Wału Trzebnickiego (Śląskiego). [Morphotectonics of Trzebnica (Silesian) Ridge]. *Zeszyty Naukowe Uniwersytetu Zielonogórskiego*, **134**, 113–131. [in Polish with English summary]
- **Markiewicz A., Winnicki J. 2007b.** Gravitational collapse in the Nysa Łużycka River Valley between Łęknica and Dübern (Polish-German borderland). Materials of the VII Polish Conference "Neotectonic Cross-Bordering the Western and Eastern European Platform", 183–184. [in Polish]
- **MIDAS, 2022.** System of management and protection of mineral resources in Poland. http://geoportal.pgi.gov.pl/portal/page/portal/midas
- **Milewicz J., Koraś J. 1971.** Uwagi o podłożu podpermskim rejonu Gubina. [Remarks on the sub-Permian basement in the Gubin region]. *Geological Quarterly*, **15**, 870–875. [in Polish with English summary]
- **Milewicz J., Wroński J. 1975.** Budowa geologiczna obszaru między Gubinem, Lubuskiem i Przewozem. [Geology of the area between Gubin, Lubusko and Przewóz]. *Biuletyn Instytutu Geologicznego*, **287**. [in Polish]
- **Nawrocki J. 1995.** Skala magnetostratygraficzna dla utworów czerwonego spą-

gowca, cechsztynu i pstrego piaskowca z obszaru Polski. [Magnetic polarity scale for the Rotliegend, Zechstein and Buntsandstein of Poland]. *Przegląd Geologiczny*, **43**, 1027–1029. [in Polish with English summary]

- **Nawrocki J., Becker A. 2017.** Geological Atlas of Poland. Polish Geological Institute – National Research Institute, Warsaw.
- **Nowak G. 1999.** Analiza możliwości generacji węglowodorów w skałach karbonu podłoża monokliny przedsudeckiej w świetle badań materii organicznej. [Analysis of hydrocarbon generation possibility from the Carboniferous rocks of the Fore-Sudetic Monocline in the light of organic matter investigations]. Inv. 2235/99, CAG PIG, Warsaw. [in Polish]
- **Nowak G. 2003.** Petrologia materii organicznej rozproszonej w poźnopaleozoicznych 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. 2016.** Wyniki badan petrologicznych materii organicznej rozproszonej w skałach karbonu podłoża monokliny przedsudeckiej. [Results of petrological studies of organic matter dispersed in the Carboniferous rocks of the Fore-Sudetic Monocline]. (In): Investigations of prospective zones for the unconventional hydrocarbon accumulation occurrences in Poland, Stage I; (Eds): Podhalańska T. et al. Inv. 4878/2016, CAG PIG, Warsaw. [in Polish]
- **Oberc J. 1972.** Sudety i obszary przyległe. Budowa geologiczna Polski. Tektonika, 4. [Sudetes and neighboring areas. The geology of Poland. Tectonic, 4]. Wydawnictwa Geologiczne, Warsaw. [in Polish]
- **Oberc J. 1990.** Monoklina przedsudecka i jej tło geologiczne. Materiały Konferencyjne Komitetu Tektonicznego KNG PAN: Problemy tektoniki Legnicko-Głogowskiego Okręgu Miedziowego, cz. 1, 7–14. [Fore-Sydetic Monocline and geological review. Conference materials Materiały Konferencyjne of the Tectinic Comission KNG PAN: Tectonic problems of the Legnica-Głogów Cooper Regiono, part 1, 7–14]. CUPRUM, Wrocław. [in Polish]
- **Okulus H. 1980.** Sprawozdanie techniczne z pomiarów grawimetrycznych wykonanych w rejonie obszaru północno-sudeckiego i perykliny Żar, 1977. [Gravimetric survey technical report from the Northern Sudetes and Żary Pericline areas, 1977]. Inv. 2051, CAG PIG, Warsaw. [in Polish]
- **Ostrowska K., Pisuła M. 1991.** Dokumentacja szczegółowych badań grawimetrycznych dla tematu: Poszukiwanie złóż węgla brunatnego w obrębie anomalii grawimetrycznych, II faza, 1990 rok. [Detailed gravimetric survey report: Searching of the brown coal fields in gravimetric anomalies, stage II, 1990]. Inv. 1281/91, CAG PIG, Warsaw. [in Polish]
- **Oszczepalski S., Rydzewski A. 1987.** Paleogeography and sedimentary model of the Kuperschiefer in Poland. *Lecture Notes in Earth Sciences*, **10**, 189–205.
- **Pasik J. 1974.** Dokumentacja półszczegółowych badań magnetycznych. Temat: Monoklina Przedsudecka, 1974. [Semidetailed magnetic survey report. Topic: Fore-Sudetic Monocline, 1974]. Kat. M-164, PBG, Warsaw. [in Polish]
- **Pawłowski A., Zoła K. 2000.** Dodatek nr 1 do dokumentacji geologicznej złoża ropy naftowej Lelechów. [Lelechów oil field documentation]. Inv. 2291/2000, CAG PIG, Warsaw. [in Polish]
- **Peryt T.M. 1978.** Charakterystyka mikrofacjalna cechsztyńskich osadów węglanowych cyklotemu pierwszego i drugiego na obszarze monokliny przedsudeckiej. [Microfacies characteristics of the Zechstein PZ1 and PZ2 carbonates of the Fore-Sudetic Monocline]. *Studia Geologica Polonica*, **54**, 1–88. [in Polish]
- **Peryt T.M. 1984.** Sedymentacja i wczesna diageneza utworów wapienia cechsztyńskiego w Polsce zachodniej. [Sedimentation and early diagenesis of the Zechstein limestone in western Poland]. *Prace Państwowego Instytutu Geologicznego*, **109**, 1–80. [in Polish with English summary]
- **Peryt T.M. 1990**. Cechsztyński anhydryt górny (A1g) na obszarze polskiej części

syneklizy perybałtyckiej. [Zechstein Upper Anhydrite (A1g) in the Polish part of the Peribaltic Syneclise]. *Biuletyn Państwowego Instytutu Geologicznego*, **364**, 5–29. [in Polish]

- **Peryt T.M., Piątkowski T.S. 1976**. Osady caliche w wapieniu cechsztyńskim zachodniej części syneklizy perybałtyckiej. [Caliche deposits in the Zechstein Limestone in the western part of the Peri-baltic Syneclise (Northern Poland)]. *Geological Quarterly*, **20**, 525–538.
- **Peryt T.M., Piątkowski T.S. 1977.** Algal vadose pisoliths in the Zechstein Limestone (Upper Permian) of Poland. *Sedimentary Geology*, **19**, 275–286.
- **Petecki Z., Rosowiecka O. 2017.** A new magnetic anomaly map of Poland and its contribution to the recognition of crystalline basement rocks. *Geological Quarterly*, **61**, 934–945.
- **Peters K.E., Cassa M.R. 1994.** Applied source rock geochemistry. [In]: The Petroleum System – from Source to Trap, [Eds]: Magoon L.B., Dow W.G., *AAPG Memoir*, **60**, 93–120.
- **Pettijohn, F.J., Potter, P.E., Siever, R. 1972.** Sand and sandstone. New York, Springer – Verlag.
- **Pisuła M., Ostrowski C. 1990.** Dokumentacja półszczegółowych badań grawimetrycznych, temat: Gubin-Zielona Góra 1987-1989. [Semidetailed gravimetric survey report, topic: Gubin-Zielona Góra area 1987-1989]. Kat. G-569 PBG, CAG PIG, Warsaw. [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. (In): Petroleum Geological Atlas of the Southern Permian Basin Area; (Eds): Doornenbal J.G., Stevenson A.G., 225–253. EAGE Publications b. v., Houten.
- **Poborski J. 1960.** Cechsztyńskie zagłębie solne Europy Środkowej na ziemiach Polski. [Central European Zechstein Salt Basin in Poland]. *Prace Instytutu Geologicznego*, **30**, 355–366. [in Polish]
- **Podemski M. 1973.** Sedymentacja cechsztyńska w zachodniej części monokliny przedsudeckiej na przykładzie okolicy Nowej Soli. [Sedimentation of the Zechstein in the western part of the Fore-Sudetic Monocline with Nowa Sól example]. *Prace Instytutu Geologicznego*, **71**, 1–101. [in Polish]
- **Podhalańska T. et al. 2016.** Rozpoznanie stref perspektywicznych dla występowania niekonwencjonalnych złóż. weglowodorów w Polsce, Etap I. [Investigations of prospective zones for the unconventional hydrocarbon accumulation occurrences in Poland, Stage I]. Inv. 4878/2016, CAG PIG, Warsaw. [in Polish]
- **Pokorski J. 1981**. Propozycja formalnego podziału litostratygraficznego czerwonego spągowca na Niżu Polskim. [Formal lithostratigraphic subdivision proposed for the Rotliegendes of the Polish Lowlands]. *Geological Quarterly*, **25**, 41–58. [in Polish with English summary]
- **Pokorski J. 1988.** Rotliegendes lithostratigraphy in north-western Poland. *Bulletin of the Polish Academy of Sciences, Earth Sciences*, **36**, 99–108.
- **Pokorski J. 1997.** Perm dolny (czerwony spągowiec). Litostratygrafia i litofacje. Formalne i nieformalne jednostki litostratygraficzne. [Lower Permian (Rotliegend). Lithostratigraphy and lithofacies. Formal and informal lithostratigraphic units]. (In): The epicontinental Permian and Mesozoic in Poland; (Eds): Marek S., Pajchlowa M. *Prace Państwowego Instytutu Geologicznego*, **153**, 35–38. [in Polish with English summary]
- **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]
- **Pożaryski W., Dembowski Z. 1983.** Mapa geologiczna Polski i krajów ościennych bez utworów kenozoicznych, mezozoicz-

nych i permskich, 1 : 1 000 000. [Geological Map of Poland without Permian, Mesozoic and Cenozoic Deposits, 1 : 1 000 000]. Geological Institute, Warsaw. [in Polish]

- **Reczek, J. 1962.** Opracowanie półszczegółowych badań grawimetrycznych w północnej części Monokliny Przedsudeckiej, 1962 r. [Semidetailed gravimetric survey report from the northern part of the Fore-Sudetic Monocline, 1962]. Inv. 062/63, CAG PIG, Warsaw. [in Polish]
- **Richter Bernburg G. 1955.** Stratigraphische Gliederung des deutschen Zechsteins. *Z. dt. Geol. Ges.*, **105**, 843–854.
- **Roman M.G. 2016.** Interpretacja i wizualizacja danych otworowych w utworach niższego paleozoiku obszaru kratonu wschodnioeuropejskiego i karbonu podłoża monokliny przedsudeckiej. [Interpretation and visualization of well data in the lower Palaeozoic of the East European Craton and in the Carboniferous of the Fore-Sudetic Homocline basement]. *Przegląd Geologiczny*, **64**, 976–981. [in Polish with English summary]
- **Semyrka R. 2013.** Jakościowa i ilościowa charakterystyka petrofizyczna subfacji dolomitu głównego w strefach paleogeograficznych. [Quantitative and qualitative petrophysical characteristics of Main Dolomite subfacies in pleogeographic zones]. *Gospodarka Surowcami Mineralnymi*, 29, 99–114. [in Polish with English summary]
- **Semyrka R., Jarzyna J.J., Krakowska P.I. Semyrka G. 2015.** Analiza statystyczna parametrów mikrofacji dolomitu głównego w granicznej strefie platformy węglanowej. [Statistical analysis of the main dolomite microfacies parameters in the boundary zone of carbonate platform]. *Gospodarka Surowcami Mineralnymi*, **31**, 123–140. [in Polish with English summary]
- **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. (In): Palaeozoic Climatic Cycles: Their Evolutionary and Sedimentological Impact; (Eds): Gąsiewicz A., Słowakiewicz M., *Geological Society of London, Special Publications*, **376**, 523–538.
- **Słowakiewicz M., Tucker M.E., Hindenberg K., Mawson M., Idiz E.F., Pancost R.D. 2016.** Nearshore euxinia in the photic zone of an ancient sea: Part II – The bigger picture and implications of understanding ocean anoxia. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **461**, 432–448.
- **Sokołowski J. 1967.** Charakterystyka geologiczna i strukturalna obszaru przedsudeckiego. [Geological and structural characteristics of the Fore-Sutetic area]. *Geologia Sudetica*, **3**, 297–367. [in Polish]
- **Solon J., Borzyszkowski J., Bidłasik M., Richling A., Badora K., Balon J., Brzezińska-Wójcik T., Chabudziński Ł., Dobrowolski R., Grzegorczyk I., Jodłowski M., Kistowski M., Kot R., Krąż 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.** Physico-geographic mesoregions of Poland – verification and adjustment of boundaries on the basis of contemporary spatial data. *Geographia Polonica,* **91**.
- **Szyperko-Teller A. 1997.** Formalne i nieformalne jednostki litostratygraficzne. Litostratygrafia i litofacje. Trias dolny (pstry piaskowiec). [Lower Triassic (Bunter Sandstone). Formal and informal lithostratigraphic units. Lithostratigraphy and lithofacies]. (In): The epicontinental Permian and Mesozoic in Poland; (Eds): Marek S., Pajchlowa M. *Prace Państwowego Instytutu Geologicznego,* **153**, 112–117. [in Polish with English summary]
- **Tałuc S., Ciszewski S. 1962.** Opracowanie półszczegółowych badań magnetycznych w rejonie monokliny przedsudeckiej, 1962. [Semidetailed magnetic survey report from the FOre-Sudetic Monocline, 1962]. Kat. M-106 PBG, CAG PIG, Warsaw. [in Polish]
- **Tałuc S., Ciszewski S. 1964.** Opracowanie zwiadowczych profili magnetycznych w środkowej części regionu przedsudeckiego, 1963 rok. [Reconnaissance of magnetic profiles in the central part of the

Fore-Sudetic region, 1963]. Inv. 2086, CAG PIG, Warsaw. [in Polish]

- **Tokarski A. 1958.** Poszukiwawcze zadania wiercenia Mogilno 1. [Exploration task of the Mogilno 1 well]. *Nafta*, **14**, 4–12. [in Polish]
- **Urbański K. 2002.** Objaśnienia do szczegółowej mapy geologicznej Polski 1 : 50 000. Arkusz Buchałów (574). [Detailed Geological Map of Poland 1 : 50 000. Buchałów Sheet (574). Description]. Polish Geological Institute, Warsaw. [in Polish]
- **Urbański R., Żurawik J., Wojtkowiak Z. 1975.** Dokumentacja geologiczna złoża gazu ziemnego Czeklin w rejonie Krosna Odrzańskiego. [Czeklin gas field documentation]. Inv. 11402 CUG, CAG PIG, Warsaw. [in Polish]
- **Wagner, R. 1987.** Cechsztyn. [Zechstein]. (In): Geological structure of the Pomerani-an Swell and its basement, (Ed.): Raczyński, 1987. *Prace Instytutu Geologicznego*, **119**, 64–81. [In Polish with English summary]
- **Wagner, R. 1988.** Ewolucja basenu cechsztyńskiego w Polsce. [The evolution of the Zechstein basin in Poland]. *Geological Quarterly*, **32**, 33–51. [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.
- **Wagner R., Peryt T.M. 1998.** O możliwości podziału cechsztynu na sekwencje stratygraficzne w basenie Polskim. [On the possibility of dividing the Zechstein into stratigraphic sequences in the Polish basin]. *Prace Państwowego Instytutu Geologicznego*, **165**, 129–146. [in Polish]
- **Wagner R., Piątkowski T.S., Peryt T.M. 1978.** Polski basen cechsztyński. [Polish Zechstein basin]. *Przegląd Geologiczny*, **26**, 673–686. [in Polish]
- **Wagner R., Buniak A., Dadlez R., Grotek I., Kiersnowski H., Kuberska M., Kudrewicz R., Lis P., Maliszewska A., Mikołajewski Z., Papiernik B., Pokorski J., Poprawa P., Skowroński L., Słowakiewicz M., Szewczyk J., Wolnowski T. 2008.** Zasoby prognostyczne, nieodkryty potencjał gazu ziemnego w utworach czerwonego spągowca i wapienia cechsztyńskiego w Polsce – badania geologiczne. [Prognostic resources, undiscovered potential of natural gas in the Rotliegend and Zechstein Limestone in Poland – geological investigations]. Inv. 2293/2009, CAG PIG, Warsaw. [in Polish]
- **Waksmundzka, M.I.; Buła, Z. 2017.** Geological Map of Poland without Permian, Mesozoic and Cenozoic Deposits. (In): Geological Atlas of Poland; (Eds): Nawrocki, J., Becker, A. Polish Geological Institute—National Research Institute, Warsaw. [in Polish]
- **Waśkiewicz K., Kiersnowski H. 2020.** Systemy naftowe basenów permskich. Basen permski (czerwony spągowiec; dolomit główny). [Petroleum systems in the Permian basins. (Rotliegend and Main Dolomite)]. (In): A five-year plan of evaluation of the geology of Poland using modern exploration techniques, especially at greater depths and in new geological structures, in terms of exploration and production of hydrocarbons; (Ed.): Feldman-Olszewska A., 41–78. Polish Geological Institute—National Research Institute, Warsaw. [in Polish]
- **Wierzchowska-Kicułowa K. 1984.** Budowa geologiczna utworów podpermskich monokliny przedsudeckiej. [Geology of the

pre-Permian series of the Fore-Sudetic Monocline]. *Geologia Sudetica*, **19**, 121–142. [In Polish with English summary]

- **Wierzchowska-Kicułowa K. 1987.** Charakterystyka geologiczna podłoża permu obszaru przedsudeckiego. [Geological features of the Permian basement in the Fore-Sudetic area]. *Geological Quarterly*, **31**, 557–568. [In Polish with English summary]
- **Wierzchowska-Kicułowa K. 2007.** Podłoże monokliny. [Fore-Sudetic Monocline basement]. KGHM Polska Miedź S.A. Monography (Second edition): 90–92, Lubin. [In Polish]
- **Wolańska A., 2012.** Dokumentacja geologiczna złoża gazu ziemnego Brzózka w kat. C. [Brzózka gas field documentation]. Inv. 271/2013, CAG PIG, Warsaw. [in Polish]
- **Wójcicki A., Kiersnowski H., Dyrka I., Adamczak-Biały T., Becker A., Głuszyński A., Janas M., Kozłowska A., Krzemiński L., Kuberska M., Pacześna 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]
- **Zalewska M. 1996.** Dokumentacja geologiczna w kat. B złóż ropy naftowej – Mozów S i Mozów N. Dodatek nr 1. Wniosek o zmianę decyzji zasobowej. [Mozów S and Mozów N oil fields documentation]. Inv. 332/97, CAG PIG, Warsaw. [in Polish]
- **Żelaźniewicz A., Aleksandrowski P., Buła Z., Karnkowski P.H., Konon A., Ślączka A., Żaba J., Żytko K. 2011.** Regionalizacja tektoniczna Polski. [Tectonic subdivision of Poland]. Komitet Nauk Geologicznych PAN, Wrocław. [in Polish]