Polish Geological Institute
National Research Institute

Polish Geological Survey
Polish Hydrogeological Survey

HYDROCARBON PROSPECTIVE OF POLAND

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

GRYFICE
TENDER AREA
GEOLOGICAL PACKAGE ENGLISH ABSTRACT

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

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for Environmental Protection
and Water Management

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Warsaw, 2021

1. GENERAL INFORMATION
1.1. LOCATION

The “Gryfice” tender area of 747.96 km^2 is located onshore in NW Poland, in the 62, 82, and 83 concession blocks (Fig. 1.1). The precise location is defined by geographical coordinates listed below.

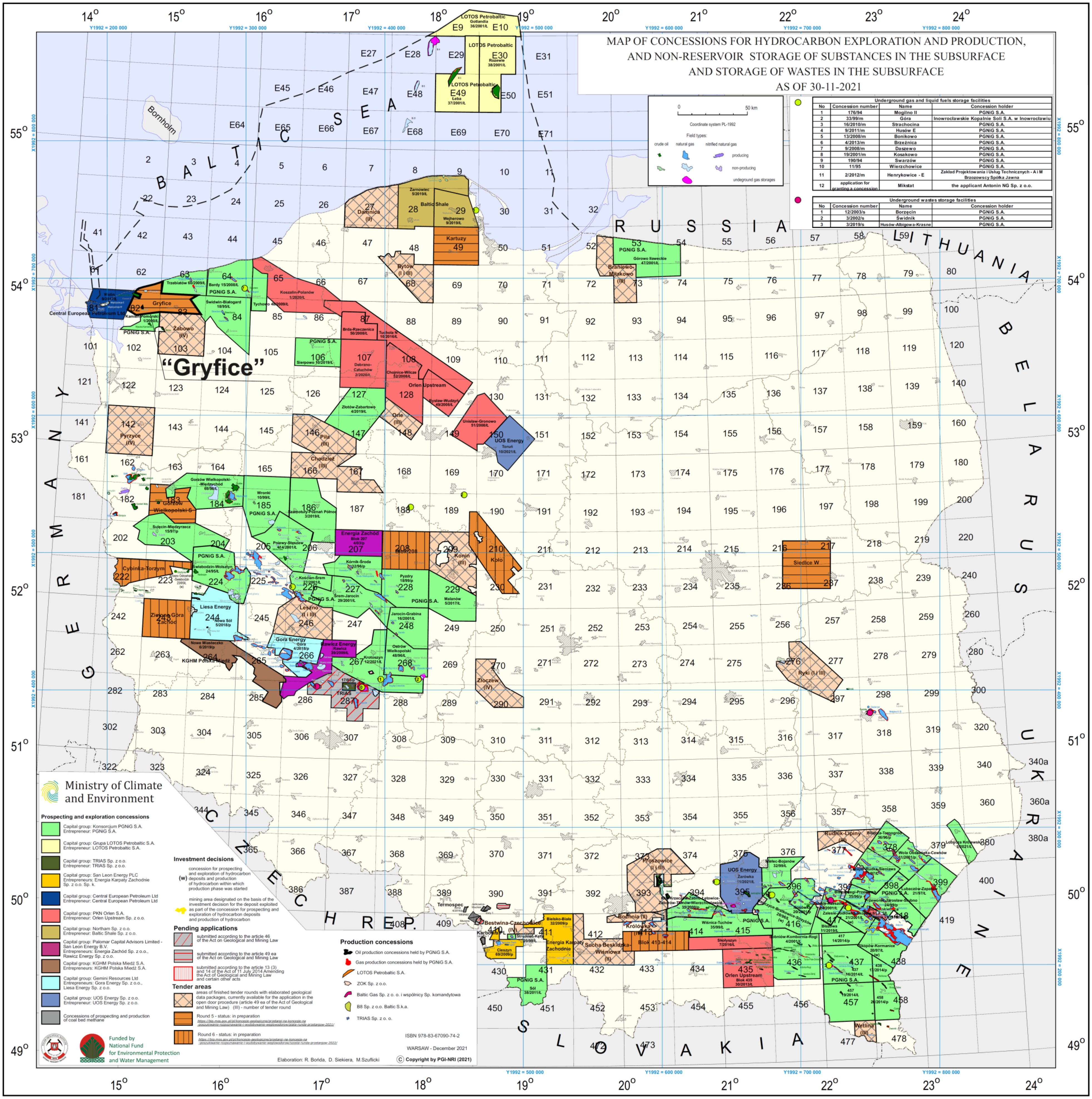
Border points	1992 coordinate system	
	X	Y
1	691055.17	219674.19
2	692737.14	221619.12
3	693771.09	224785.26
4	695846.05	233241.52
5	697800.71	239098.78
6	689034.77	237808.88
7	688700.54	245043.47
8	687684.41	264181.99
9	684723.09	259134.45
10	673948.18	266614.09
11	675598.09	237055.20
12	673865.95	223383.30
13	673409.40	219824.29
14	677185.11	213499.78
15	687174.95	217946.87
16	685637.43	221987.20
17	688367.49	223047.42
18	689636.16	219042.50
excluding the area defined by points 19–23:		
19	679335.20	223870.95
20	679746.86	224268.31
21	679040.45	224478.55
22	678251.69	224485.63
23	678251.81	224056.04

Tab. 1.1. Border points coordinates of the “Gryfice” tender area (Fig. 1.2).

The “Gryfice” tender area was previously subjected to hydrocarbon prospection and exploration concessions No. 12/99/p “Gryfice” (PGNiG), No. 28/2008/p “Kaleń” (PGNiG), and No. 16/2008/p “Rybice” (Blue Energy).

Eight oil and gas fields have been documented in the neighborhood of the “Gryfice” tender area: Rekowo, Wrzosowo, Dargosław, Gorzysław N, Gorzysław S, Kamień Pomorski, Trzebusz, and Wysoka Kamieńska. The main exploration target here is related to conventional gas accumulations in the Carboniferous and Rotliegend sandstones and gas and oil in the Main Dolomite carbonates.

→**Fig. 1.1.** Location of the “Gryfice” tender area on the map of concessions for hydrocarbon exploration and production, and non-reservoir storage of substances in the subsurface and storage of wastes in the subsurface as of 30-11-2021.


MAP OF CONCESSIONS FOR HYDROCARBON EXPLORATION AND PRODUCTION, AND NON-RESERVOIR STORAGE OF SUBSTANCES IN THE SUBSURFACE AND STORAGE OF WASTES IN THE SUBSURFACE
AS OF 30-11-2021
"Gryfice"
BALTIC SEA
RUSSIA
LITHUANIA
BELARUS
UKRAINE
SLOVAKIA
CZECH REP.
GERMANY
Ministry of Climate and Environment
Prospecting and exploration concessions
Investment decisions
Pending applications
Tender areas
Production concessions
Underground gas and liquid fuels storage facilities
Underground wastes storage facilities
Funded by National Fund for Environmental Protection and Water Management
WARSAW - December 2021
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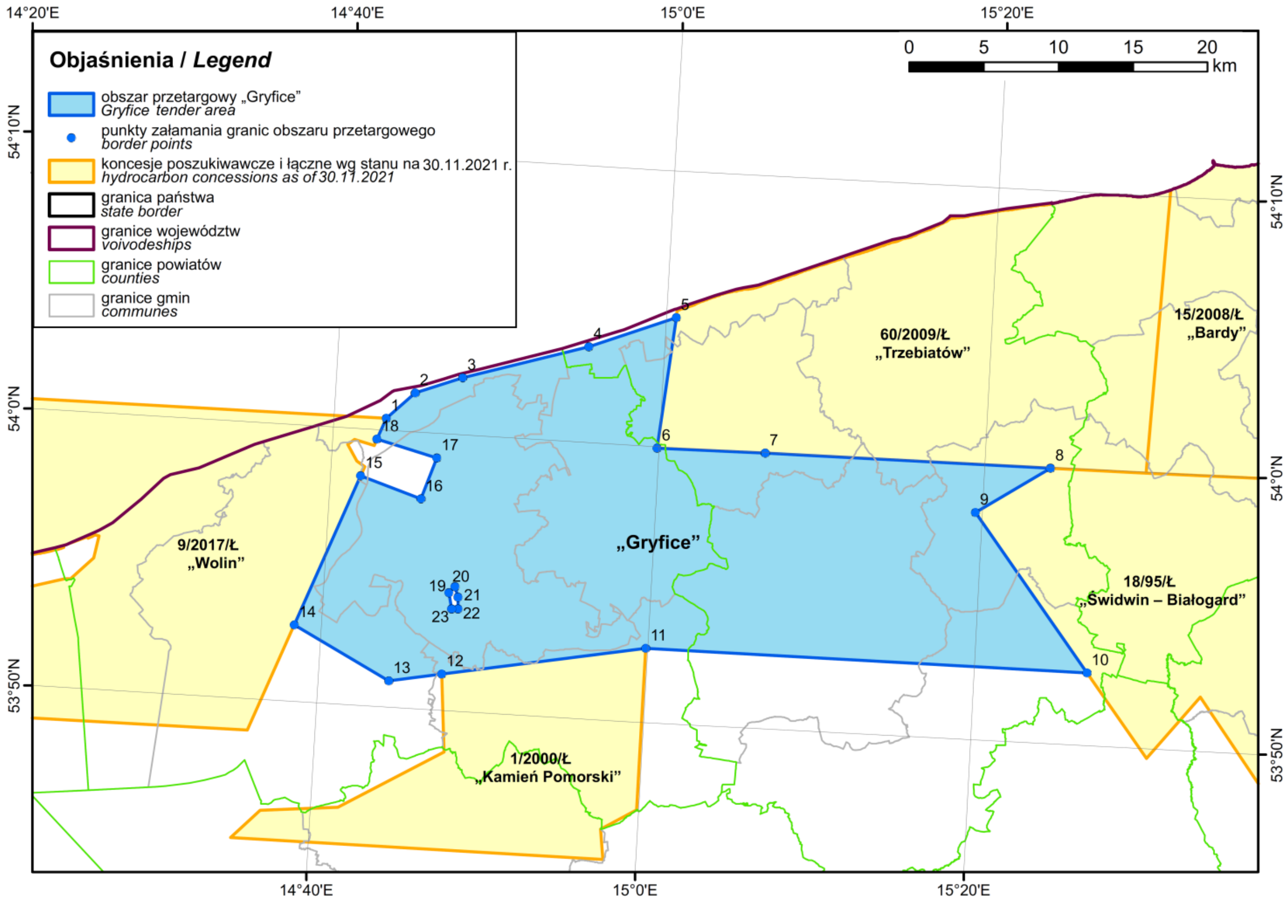

Fig. 1.2. Border points of the "Gryfice" tender area and location of the hydrocarbon concessions in the neighborhood as of 30-11-2021 (CGDB, 2021).

1.2. ENVIRONMENTAL CONDITIONS

The “Gryfice” tender area is located in the Zachodniopomorskie Voivodeship, within 11 communes. The most important towns are Gryfice and Kamień Pomorski, which are local administrative, service, industrial, financial and educational centers. There are numerous architectural monuments in Kamień Pomorski testifying to the thousand-year history of this town, which also has the status of a health resort with a wide range of balneological resorts. The road network is quite well developed. The S6 expressway runs through the eastern margin of the area, which will ultimately connect the largest Baltic cities of Poland from Szczecin to Gdańsk, and according to the future plan, will constitute a road connection of Western European countries with the Kaliningrad Oblast and Lithuania. Generally, the road network of this area consists of voivodeship, county and commune roads. The road infrastructure is complemented by two railway lines, including one electrified railway line and the Narrow-Gauge Coastal Railway, operating seasonally in the summer period. The technical infrastructure is poor and is limited to the DN 700 main gas transmission pipeline running from Szczecin to Gdańsk (section Płoty – Karlino).

The whole “Gryfice” tender area is located within the Szczecin Coast macroregion, of which 75% of the area is covered by the Gryfice Plain mesoregion and 24% by the Trzebiatowskie Coast mesoregion. In terms of hydrography, the described area is located in the Lower Odra and Western Pomerania water regions, separated by the Dziwna River, which connects the waters of the Szczecin Lagoon and the Baltic Sea. An important role in this region is played by the Rega River flowing into the Baltic Sea outside the tender area. The hydrography of the area is complemented by a dense network of canals, drainage ditches, ponds and a few lakes. There are a number of protected areas in the “Gryfice” tender area. These are the forest nature reserve Bór Samliński im. H. Zięciaka and the Stawna Valley nature and landscape complex, with their total acreage less than 2% of the analyzed area. More important are Natura 2000 sites, covering almost 27% of the area, including 3 special protection areas. In addition, there are 4 ecological areas, 1 documentation site, and 50 natural monuments, of which 49 are single trees. Agricultural land of high valuation classes commonly occurs, as well as meadows with soils of organic origin and dense forest complexes, a small part of which has the status of protective forests.

There are 16 mineral deposits in the “Gryfice” tender area, predominantly natural aggregate deposits (9 deposits), as well as: 1 quartz sand deposit for the production of sand-lime bricks, 1 deposit of natural gas, 1 thermal water, and 2 healing waters. Moreover, several tens of prospective areas of sand, gravel and peat occurrence were identified, including a number of prognostic areas.

The environmental conditions for the “Gryfice” tender area are summarized in Tab. 1.2.

THE ENVIRONMENTAL CONDITIONS DATASHEET FOR THE “GRYFICE” TENDER AREA				
1.	LOCATION OF THE TENDER AREA ON THE MAP	Name and number of the map sheet at a scale 1: 50 000	Międzywodzie 75, Dziwnów (Pobierowo) 76, Wolin 114, Kamień Pomorski 115, Gryfice 116, Brojce 117	
2.	ADMINISTRATIVE LOCATION	**Voivodeship**	**Zachodniopomorskie**	
		County	**Kamieńsk**	
		The commune and % of the total tender area	Świerzno (18.72%), Wolin (5.12%), Kamień Pomorski (26.39%), Dziwnów (3.11%), Golczewo (3.09%)	
		County	**Gryfice**	
		Commune	Płoty (4.78%), Karnice (5.60%), Rewal (1.67%), Brojce (6.60%), Trzebiatów (0.75%), Gryfice (24.17%)	
3.	PHYSIOGRAPHIC REGIONALIZATION (after KONDRACKI, 2013 and SOLON et al., 2018)	Macroregion	Szczecin Coastland (313.2-3)	
		Mesoregion	Goleniów Plain (313.25), Gryfice Plain (313.33), Trzebiatów Coast (313.22), Uznam and Wolin islands (313.21)	
4.	COORDINATES OF THE TENDER AREA BORDER POINTS	PL-1992 coordinate system	691055.17	219674.19
			692737.14	221619.12
			693771.09	224785.26
			695846.05	233241.52
			697800.71	239098.78
			689034.77	237808.88
			688700.54	245043.47
			687684.41	264181.99
			684723.09	259134.45
			673948.18	266614.09
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			687174.95	217946.87
			685637.43	221987.20
			688367.49	223047.42
			689636.16	219042.50
			excluding the area defined by points 19–23:	
			679335.20	223870.95
			679746.86	224268.31
			679040.45	224478.55
			678251.69	224485.63
			678251.81	224056.04
5.	ACREAGE	[km^2]	747.96	
6.	CONCESSION TYPE		prospecting, exploration and production of hydrocarbons	
7.	AGE OF HYDROCARBON FORMATION		Carboniferous, Permian – Rotliegend, Permian – Zechstein – Main Dolomite (as additional target)	
8.	PROTECTED NATURAL AREAS:	[yes/ no] if “yes”: the name of the tender area and its % of the total area		
	National Parks		no	
	Natural Reserves		Bór Samliński im. Henryka Zięciaka (<1%)	
	Landscape Parks		no	
	Protected landscape areas		no	
	(Special Area of Conservation, SAC)		PLH320018 Ujście Odry i Zalew Szczeciński (7%), PLH320049 Dorzecze Regi (2%), PLH320017 Trzebiatowsko-Kołobrzeski Pas Nadmorski (<1%)	

THE ENVIRONMENTAL CONDITIONS DATASHEET FOR THE "GRYFICE" TENDER AREA			
	(Special Bird Protection, SPA)		PLB320001 Bagna Rozwarowskie (5%), PLB320011 Zalew Kamieński i Dziwna (9%), PLB320010 Wybrzeże Trzebiatowskie (11%);
	Nature and landscape complexes		Dolina Stawny (<1%)
	Ecological area	[yes (quantity) / no]	4
	Nature monuments		50
	Documentation positions		1
9.	PROTECTED SOIL	[yes / no]	yes
10.	FOREST COMPLEXES	[yes / no]	yes
11.	PROTECTIVE FORESTS	[yes (area % of the total tender area) / no]	29.4 km^2 (3.9%)
12.	CULTURAL HERITAGE FACILITIES Archaeological monuments	[yes (quantity) / no]	
		Hillfort	11
		Hamlet	5
		Cemetery	2
		others	4
13.	MAJOR GROUNDWATER RESERVOIRS	[yes (number, name and age of the aquifer) / no]	no
14.	PROTECTIVE ZONES OF WATER INTAKE	[yes / no]	yes
15.	SPA PROTECTION ZONES	[yes / no]	yes
16.	FLOOD HAZARD AREA	[yes / no]	no
17.	POROVEN MINERAL DEPOSITS	[yes (type of mineral deposit) / no]	yes (natural aggregates, quartz sand for lime-sand products manufacture, thermal water, peat, natural gas)
18.	PROGNOSTIC AND PROSPECTIVE AREAS OF OCCURRENCE OF MINERAL RESOURCES (excluding hydrocarbons)	[yes (type of mineral deposit) / no]	yes (sand, sand and gravel, peat)
19.	NATURAL GAS PIPELINES	[yes / no]	yes
20.	UNDERGROUND GAS STORAGE	[yes / no]	no
21.	DATA COLLECTION AND ELABORATION	Paulina Kostrz-Sikora, Joanna Krasuska	

Tab. 1.2. The environmental conditions datasheet for the "Gryfice" tender area.

→**Fig. 1.3.** Environmental map of the "Gryfice" area.

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INSTYTUT GEOLOGICZNY
PAŃSTWOWY INSTYTUT BADAWCZY
PSG

Mapa środowiskowa obszaru "GRYFICE"
Environmental map of the "GRYFICE" area

Narodowy Fundusz Ochrony Środowiska i Gospodarki Wodnej

Ministerstwo Klimatu i Środowiska

1000 m 0 1 2 3 4 5 6 7 8 9 km

Zestawienie danych oraz redakcja komputerowa mapy: *Joanna Krasuska*
Data compilation and map edition:
Weryfikacja: *Olimpia Kozłowska*
Verification:

Objaśnienia do mapy środowiskowej obszaru Gryfice

Legend of the environmental map of the "GRYFICE" 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
- piaski kwarcowe – quartz sands
- piaski – sands
- torfy – peat
- 4688 – identyfikator z bazy Midas złoża małokonfliktowego – ID from the MIDAS database of the small environmental conflict
- 2493 – identyfikator z bazy Midas złoża konfliktowego – ID from the MIDAS database of the small 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 – perspective area boundary

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

Symbol kopaliny: / Mineral symbol:

- G - gaz ziemny – natural gas
- R - ropa naftowa – crude oil
- pż- piaski i żwiry – sands and gravels
- pk- piaski kwarcowe – quartz sands
- p - piaski – sands
- t - torfy – peat
- Wlm- wody lecznicze, mineralne, – curative, mineral waters
- Wt- wody termalne – thermal waters

Symbol jednostki stratygraficznej: / Symbol of the stratigraphic unit:

- Q - Czwartorzęd – Quaternary
- Cr - Kreda – Cretaceous
- J - Jura – Jurassic
- P - Perm – Permian
- C - Karbon – Carboniferous

WODY POWIERZCHNIOWE I PODZIEMNE

SURFACE AND UNDERGROUNG WATERS

- granica działu wodnego pierwszego rzędu – water divide of first rank
- 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
- 102 – granica głównego zbiornika wód podziemnych wraz z jego numerem – principle boundary aquifer with ID number
- granica strefy ochronnej "C" uzdrowiska – boundary of "C" protected zone within resort
- granica strefy ochrony pośredniej ujęcia wód – water intake protected area boundary
- granica obszaru górniczego eksploatacji wód leczniczych, mineralnych i termalnych – boundary of curative, mineral and thermal waters mining area
- granica terenu górniczego eksploatacji wód leczniczych, mineralnych i termalnych – boundary of curative, mineral and thermal waters mining terrain
- zbiornik retencyjny, nazwa zbiornika – water reservoir with its name
- k Q – ujęcie wód podziemnych o wydajności ≥ 50 m³/h (k - komunalne, p - przemysłowe, Q - wiek ujmowanych utworów) – underground water intake with capacity ≥ 50 m³/h (k - municipal, p - industrial, Q - age of exploited rocks)
- ujęcie wód leczniczych i mineralnych – curative and mineral water intake
- ujęcie wód termalnych – thermal water intake
- KAMIEN POMORSKI – uzdrowisko – resort

STREFA WYBRZEŻA MORSKIEGO

SHORE ZONE

- tor wodny – fairway
- granica strefy ochrony brzegu – border of shore protection zone
- granica wód wewnętrznych – border of internal waters
- falochron – breakwater
- ostrogi – groyne
- 370 – kilometraż linii brzegowej – shoreline mileage
- stacje pomiarowe IMGW – hydrologic and weather monitoring stations
- porty morskie – harbor
- przystanie morskie – marina

OCHRONA PRZYRODY, KRAJOBRAZU I ZABYTKÓW KULTURY

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
- zieleń urządzona – urban greenery
- granice terenów zarządzanych przez Generalną Dyrekcję Lasów Państwowych – boundary of areas managed by General Directorate of the State Forests
- granica parku narodowego, nazwa parku – boundary of national park, park name
- granica strefy ochronnej (otuliny) parku narodowego – boundary of buffer zone of landscape park
- granica zespołu przyrodniczo-krajobrazowego, nazwa zespołu – boundary of nature and landscape complex; complex name
- T – granica rezerwatu przyrody lub obszaru ochrony ścisłej (os) w obrębie parku narodowego (L - leśny, T - torfowisko, Fn - faunistyczny) – boundary of natural reserve or strict nature reserve within national park (L - forests, T - peat, Fn - faunistic)
- granica strefy ochronnej (otuliny) rezerwatu przyrody – boundary of buffer zone of natural reserve
- Obszary Europejskiej Sieci Ekologicznej Natura 2000; kod obszaru – Natura 2000 ecological network; area code
- N – rezerwat przyrody o powierzchni ≤ 5 ha (N - przyrody nieożywionej) – boundary of natural reserve with area ≤ 5 ha (N - inimate nature)
- n – pomnik przyrody żywej (n - liczba obiektów) – animate nature monument (n - numer of objects)
- użytek ekologiczny – ecological area
- n – użytek ekologiczny o powierzchni ≤ 5 ha (n - liczba obiektów) – ecological area with area ≤ 5 ha (n - number of objects)
- stanowisko dokumentacyjne przyrody nieożywionej – documentation site of inanimate nature
- geostanowisko o znaczeniu regionalnym – geosite of regional importance
- geostanowisko o znaczeniu lokalnym – geosite of local importance
- n – stanowisko archeologiczne (n - liczba obiektów) – archeological site (n - number of objects)

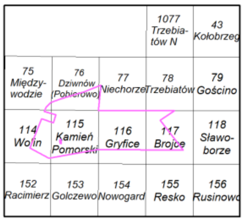
INFORMACJE DODATKOWE

ADDITIONAL INFORMATIONS

- granica państwa – country border
- granica powiatu – district boundary
- granica gminy, miasta – commune or town boundary
- S3 – oś autostrady lub drogi szybkiego ruchu – highway or express route
- DZIWNÓW – siedziba urzędu gminy, miasta – commune or town office headquarter
- sieć gazociągów przesyłowych – natural gas pipeline network
- sieć elektroenergetyczna najwyższych napięć – high-voltage power network
- granica obszaru przetargowego – boundary of tender area

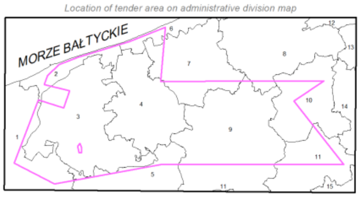
Położenie obszaru koncesyjnego Gryfice na arkuszach 1:50 000

Location of tender area on maps with a scale of 1:50 000



Położenie obszaru koncesyjnego Gryfice na tle podziału administracyjnego

Location of tender area on administrative division map



woj. ZACHODNIOPOMORSKIE

powiat kamieński
1 - gm. Wolin
2 - gm. Dziwnów
3 - gm. Kamień Pomorski
4 - gm. Świerzno
5 - gm. Golczewo
powiat gryficki
6 - gm. Rewal
7 - gm. Karnice
8 - gm. Trzebiatów
9 - gm. Gryfice
10 - gm. Brojce
11 - gm. Płoty

powiat kołobrzeski
12 - gm. Kołobrzeg
13 - gm. Siemyśl
14 - gm. Rymań
powiat łobeski
15 - gm. Resko

* *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 stratigraphic succession of the "Gryfice" tender area is divided into four units. These are: Caledonian Lower Paleozoic succession of the Kujawy-Pomerania fold-and-thrust belt, Variscan West European (Paleozoic) Platform, Laramide Permian-Mesozoic sedimentary succession, and Cenozoic cover (Żelaźniewicz et al., 2011; Nawrocki and Becker, 2017; Figs 2.1–2.2). In terms of regional sub-Cenozoic geology, the "Gryfice" tender area is located in the Pomeranian Segment of the Mid-Polish Anticlinorium (Figs 2.3–2.6, 2.8). Two tectonic blocks – Gryfice and Wolin, separated by the Adler – Kamień Pomorski Fault Zone, can be distinguished there (Dadlez, 1990). In the "Gryfice" tender area, the Permian-Mesozoic strata are folded into the Kamień Pomorski Anticline and Trzebiatów Syncline (Fig. 2.4). Below the Permian, the Devonian – Carboniferous succession of the Variscan Foreland occurs (Figs 2.1–2.2, 2.7–2.10). The angular unconformity clearly separates the Laramide and Variscan structures. The top surface of this Variscan succession lies at depths between 3000 and 3700 m b.g.l. (Lech, 2001; Fig. 2.10.B). The Devonian and Carboniferous rocks are thrust by NW-SE- and NNE-SSW-trending faults that form a set of blocks and half-grabens originated during the post-Variscan extension (Antonowicz et al., 1993, 1994). This was the first step of the German-Polish Permian Basin formation (Kiersnowski and Buniak, 2006), in which the Lower Rotliegend volcanic succession forms the oldest infill. Several elevations occur at the Permian basement top surface, forming possible traps for hydrocarbons. Similar structures occur at the top of the Upper Rotliegend sediments, which lies at depths between 2700 and 3800 m b.s.l. Additionally, several NW-SE- and NNW-SSE-trending faults, with subordinate perpendicular minor faults, form small anticlines and structures at the Rotliegend top, which can be treated as potential traps for gas.

The stratigraphy and lithology of the sedimentary succession are recognized in several boreholes located in the "Gryfice" tender area and its close neighborhood. These are: Benice 1, 2, 3, 4K, Brojce IG-1, Chomino 1, Dobropole 1, Dusin 1, Gostyń 2, Gryfice 1, 2, 3, Jarszewo 1, Kaleń 1, Kamień Pomorski 3, 7, 13, Laska 2, Rekowo 1, 2, 3, 4, 6, Skarchowo 1, Strzeżewo 1, Świerzno 1, 2, 4, 5, 9, Wrzosowo 1, 2, 3, 8, and 9. Their location can be found in Fig. 5.1.

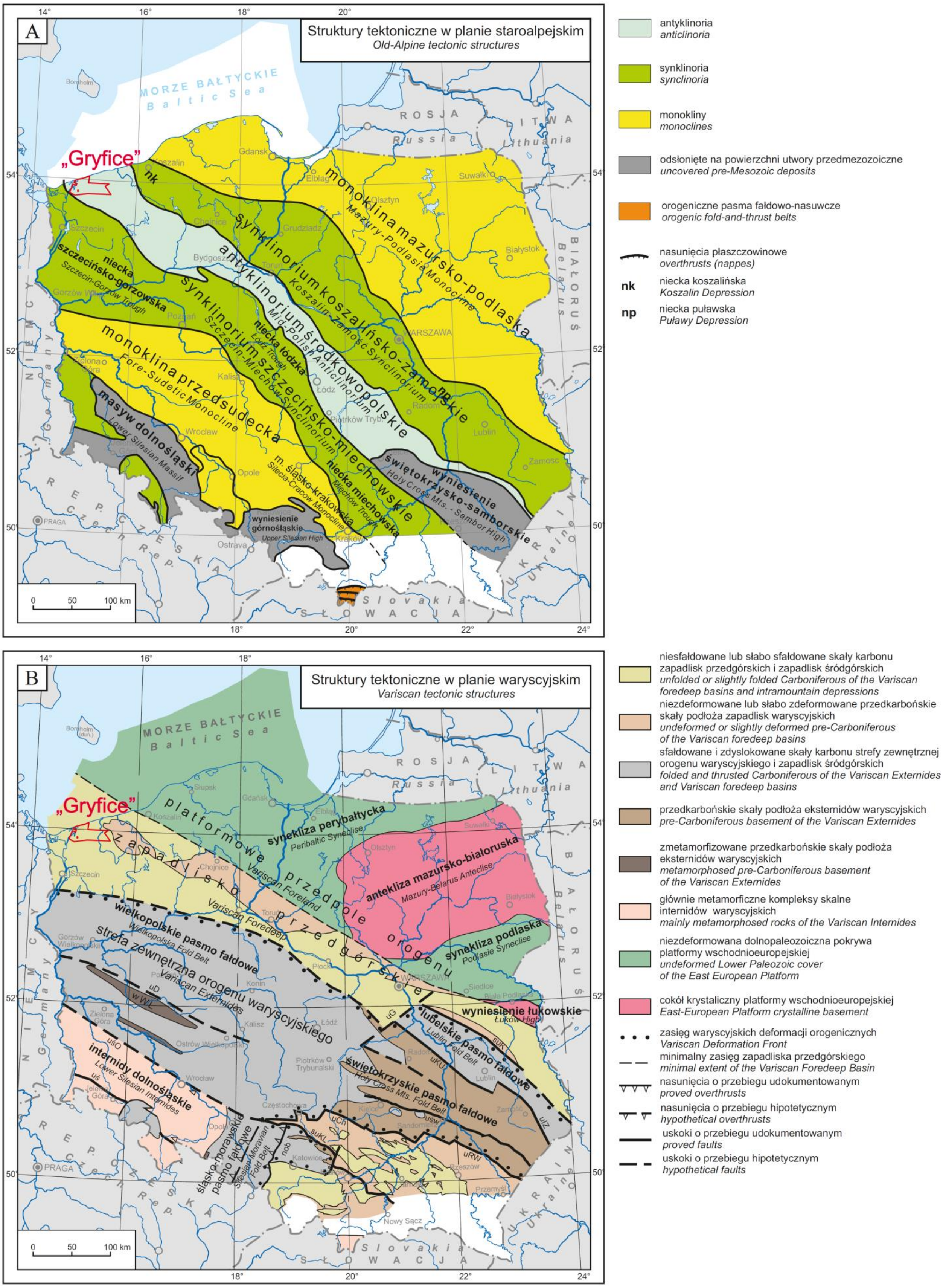


Fig. 2.1.A. Position of the "Gryfice" tender area in relation to the Old-Alpine tectonic structures in the Polish Lowland (Nawrocki and Becker, 2017). **B.** Position of the "Gryfice" tender area in relation to the Variscan tectonic structures in the Polish Lowland (Nawrocki and Becker, 2017).

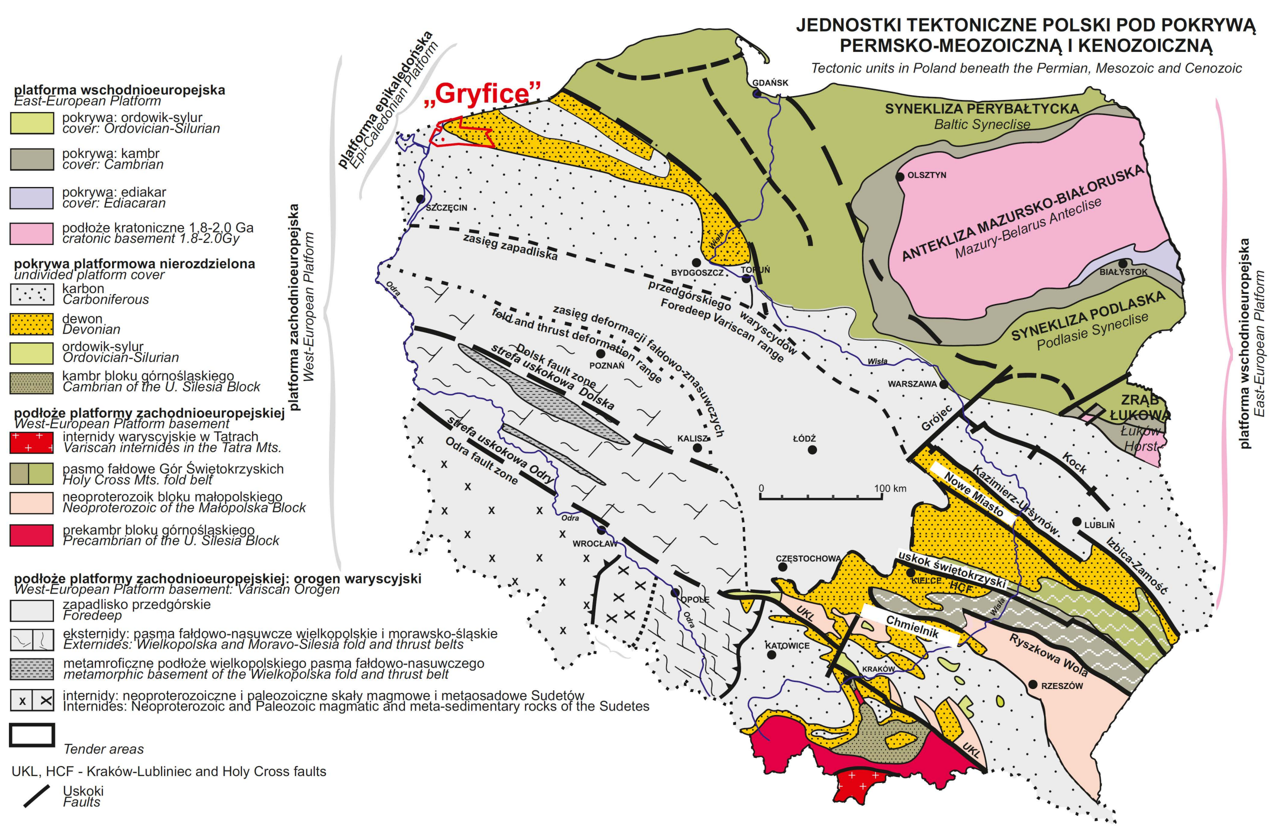


Fig. 2.2. Position of the “Gryfice” tender area in relation to the main tectonic units in Poland beneath the Permian, Mesozoic and Caenozoic (Żelaźniewicz et al., 2011).

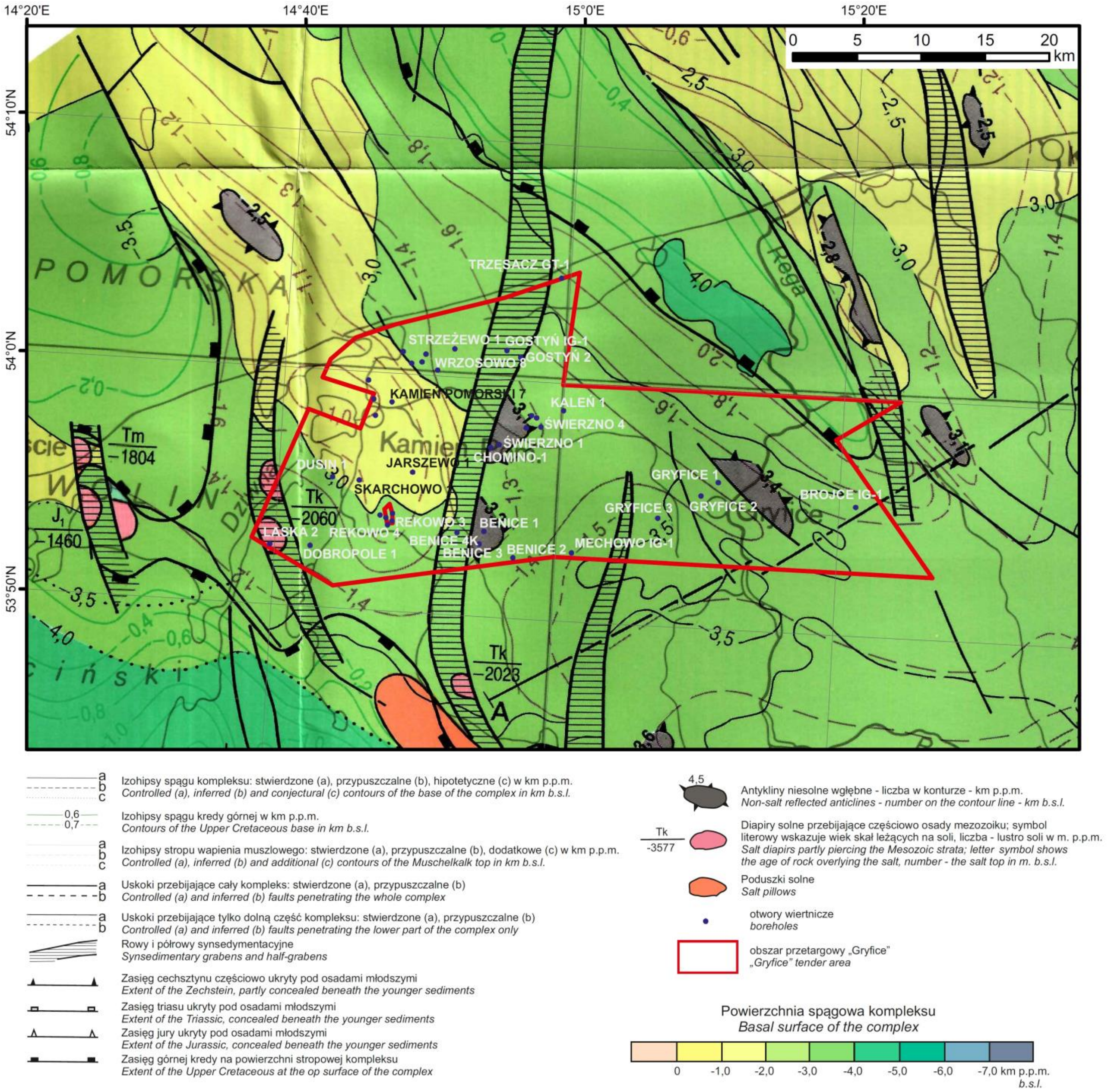


Fig. 2.3. Position of the "Gryfice" tender area in relation to the structural elements of the Zechstein-Mesozoic complex in Poland (Dadlez et al., 1998; modified).

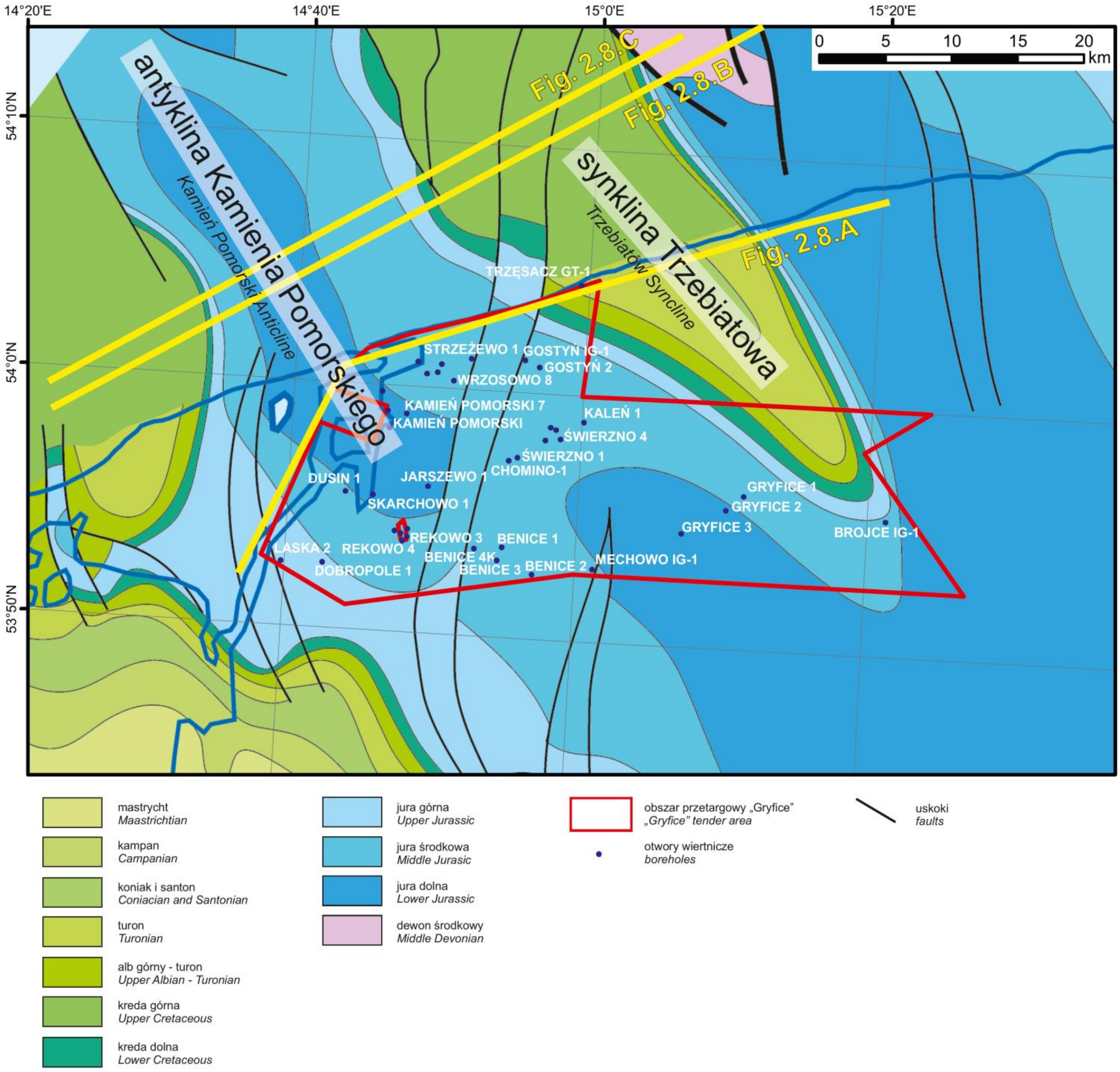


Fig. 2.4. Position of the "Gryfice" tender area on the geological map of Poland without the Caenozoic (Dadlez et al., 2000; modified).

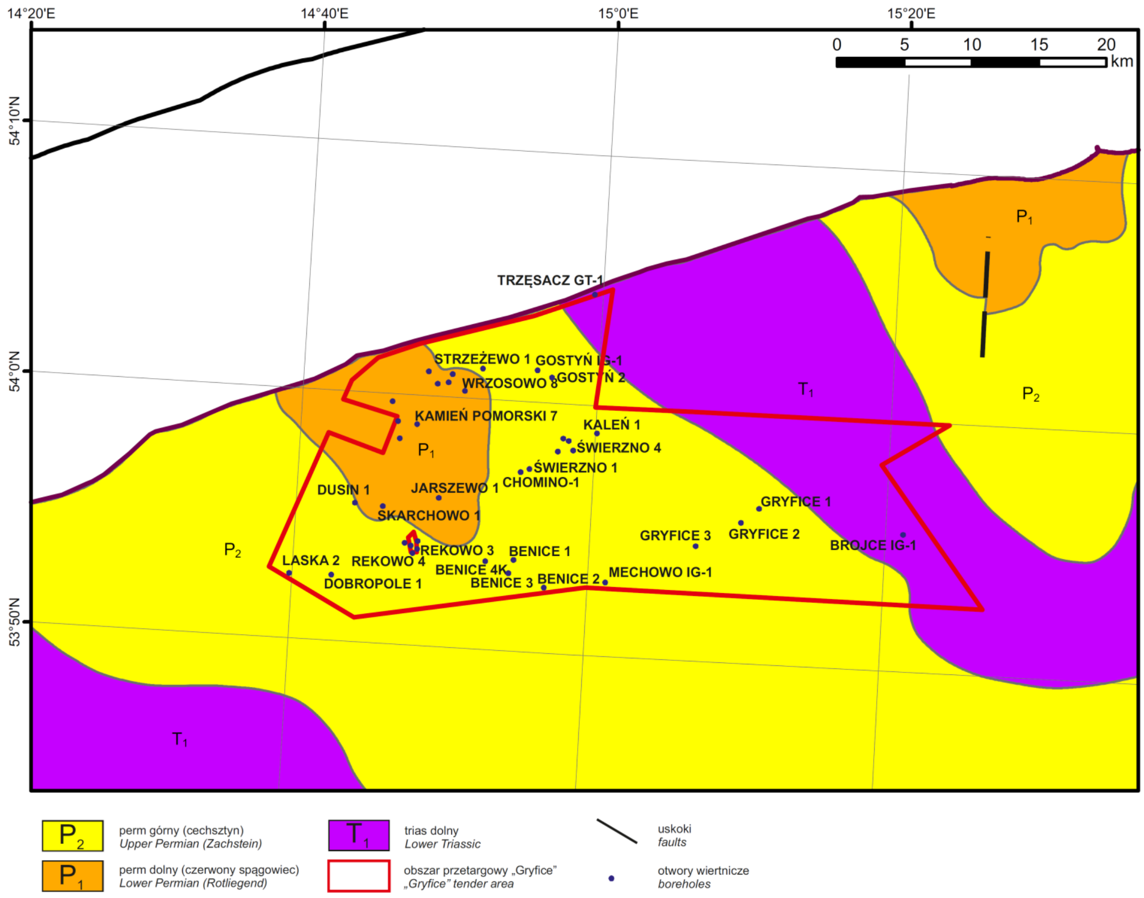


Fig. 2.5. Position of the "Gryfice" tender area on the map of horizontal cutting at 3000 m b.s.l. (Kotański, 1997; modified).

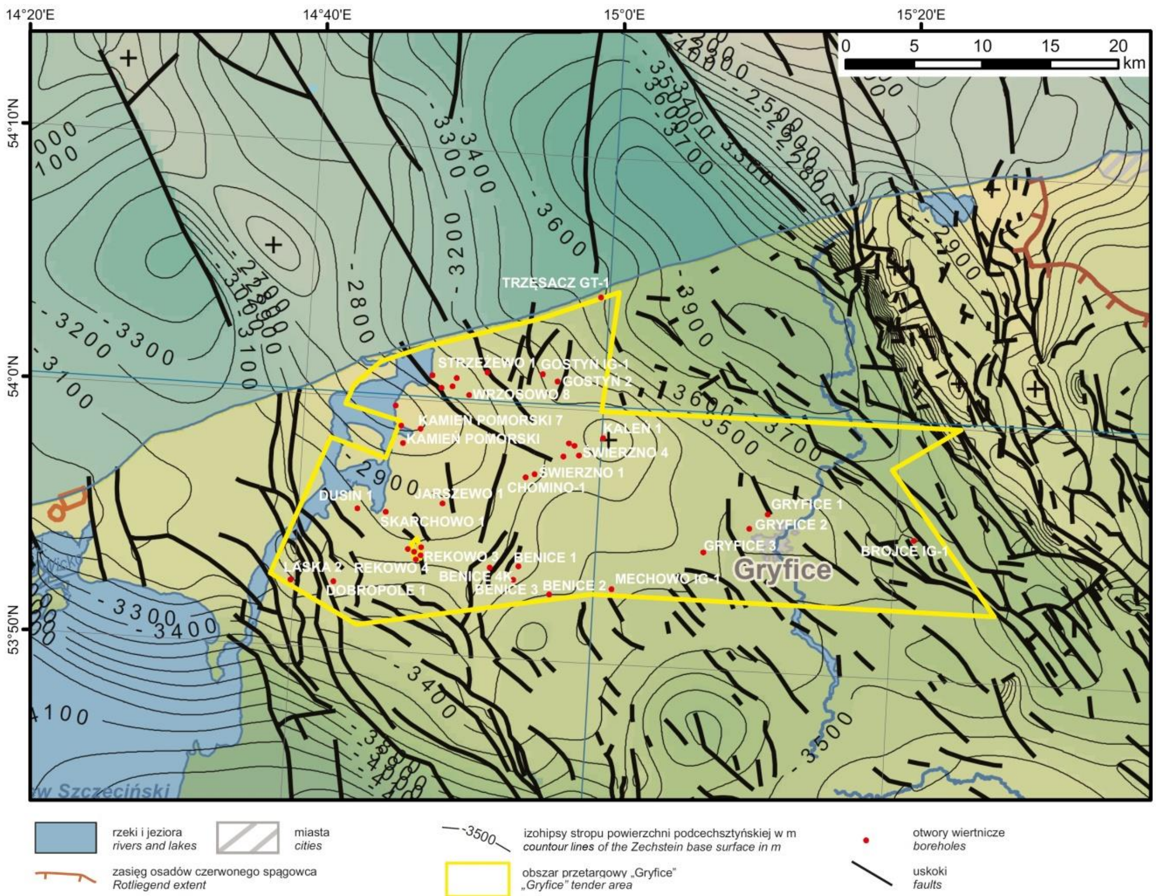


Fig. 2.6. Location of the **"**Gryfice" tender area on the structural map of the Zechstein base surface (Kudrewicz, 2008; modified).

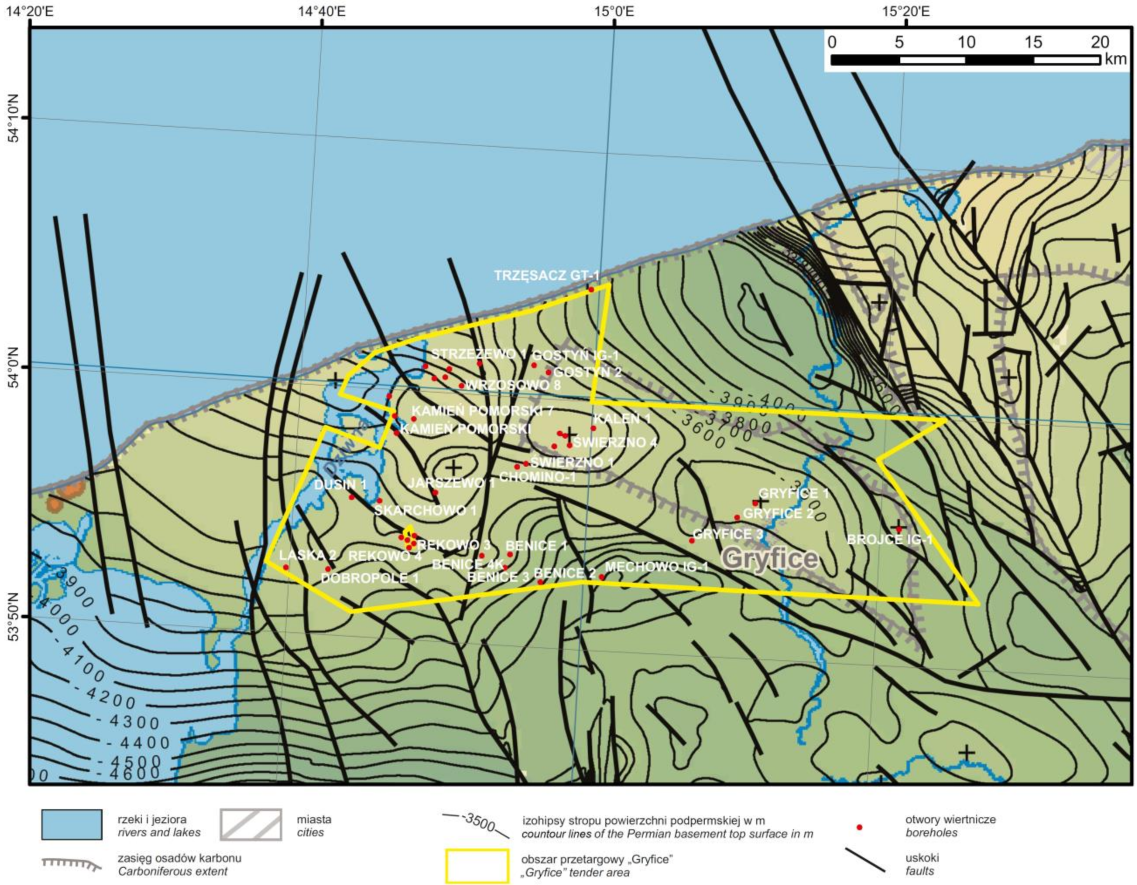


Fig. 2.7. Location of the **"**Gryfice" tender area on the structural map of the Permian basement top surface (Kudrewicz, 2008; modified).

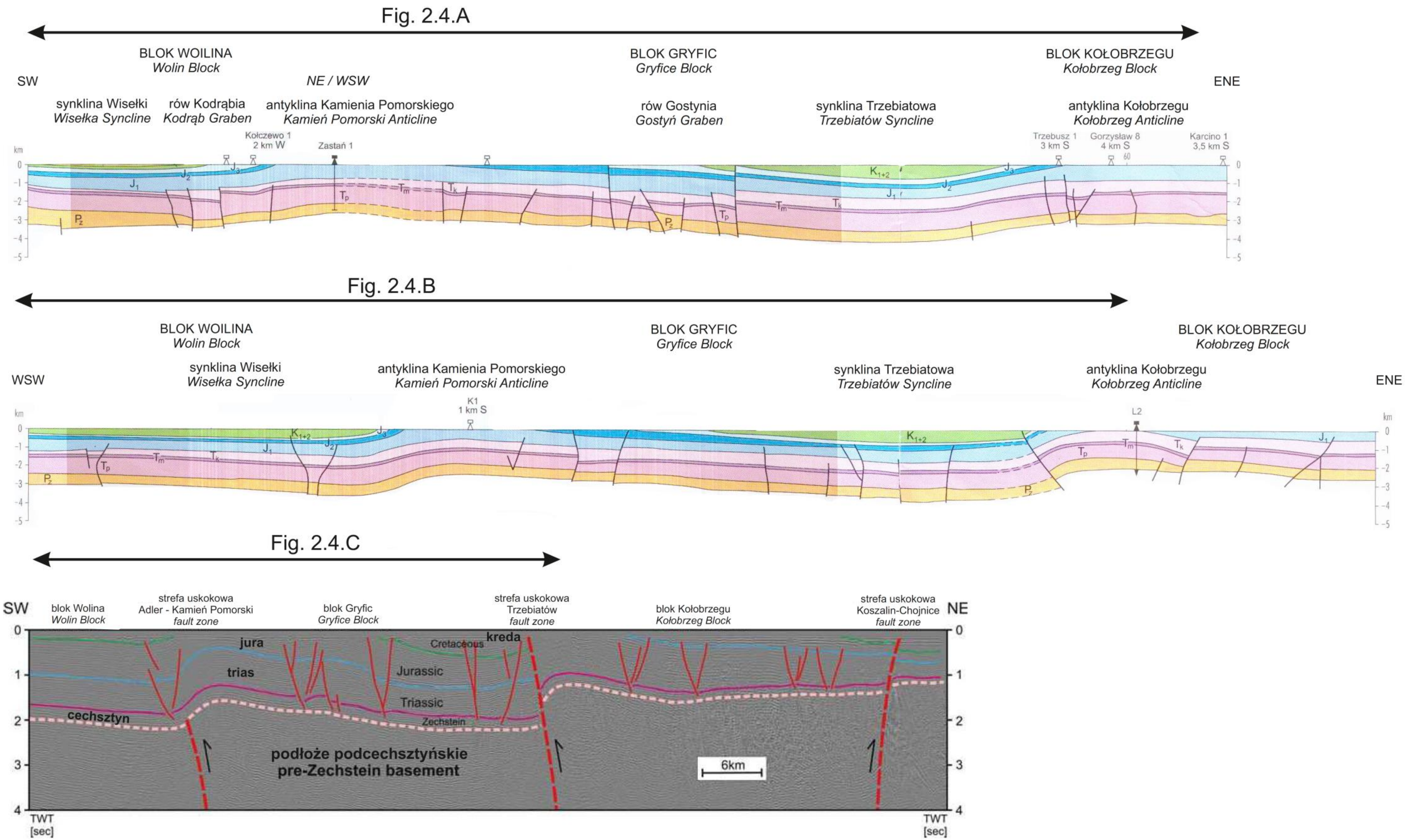


Fig. 2.8. Cross-sections illustrating geology of the “Gryfice” and neighboring areas (Dadlez, 2001; Mazur et al., 2005; modified). Location of the sections – see Fig. 2.4.

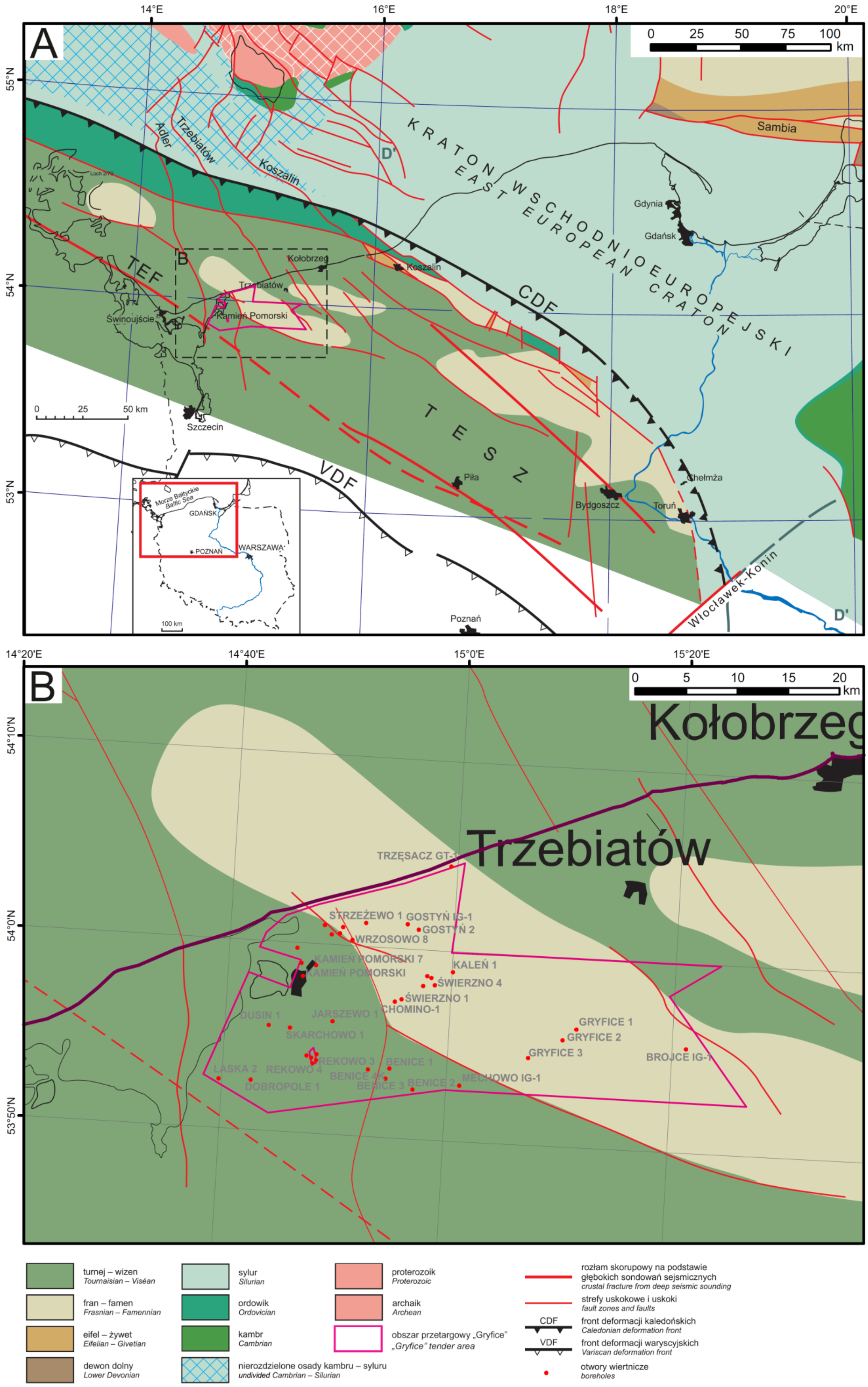


Fig. 2.9. A. Location of the "Gryfice" tender area on the geological map of the Western Pomerania without Pennsylvanian and younger deposits (Matyja, 2006; modified). **B.** Fig. A magnified.

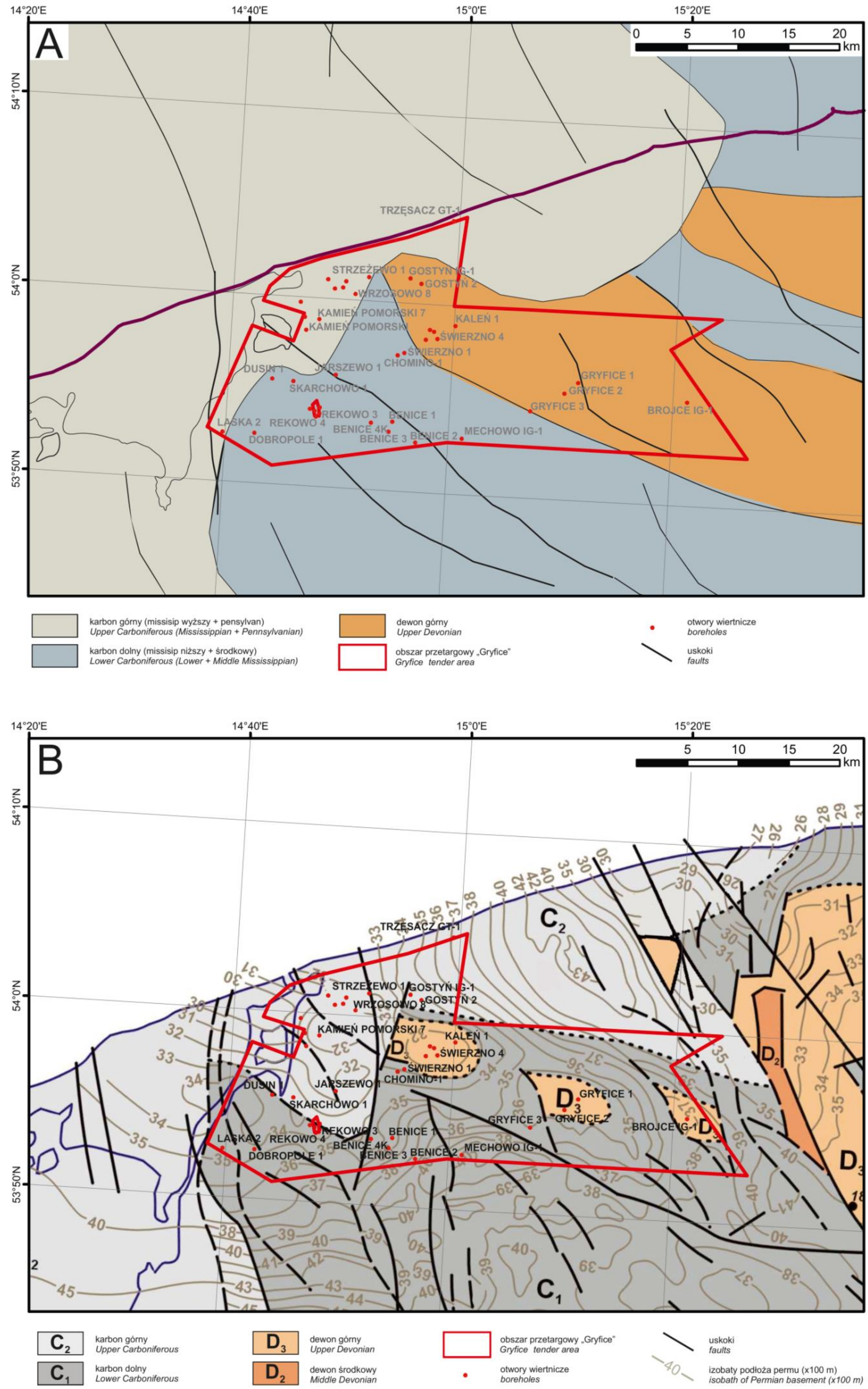


Fig. 2.10. A. Location of the "Gryfice" tender area on the geological map of Poland without Permian and younger deposits (Waksmundzka and Buła, 2020; modified). **B.** Location of the "Gryfice" tender area on the geological-structural map of the Western Pomerania Permian basement (Lech, 2001; modified).

2.2. STRATIGRAPHY
2.2.1. DEVONIAN

Extent and thickness

In the "Gryfice" tender area, the Devonian formations were recognized in 3 wells (Fig. 2.9; Fig. 2.11), at depths:

- Brojce IG-1: 3674.5–4252.0 m,
- Strzeżewo 1: 3890.0–4521.0 m,
- Świerzno 4: 3195–3238.5 m.

The oldest drilled rocks belong to the Givetian. The thickness of the Devonian succession ranges from 43.5 m to ?631.0 m. However, Matyja (2006) points out that the thickness of the Upper Devonian can reach 1300 m in the vicinity of Brojce and Gorzysław.

Lithology and stratigraphy

Lithology, stratigraphy and facies development of the Western Pomerania Devonian formations were discussed by Matyja (1993, 2006, 2008, 2009; Figs 2.11–2.12). Among numerous lithostratigraphic units distinguished by the author, only three formations can be identified in the "Gryfice" area: Givetian Chojnice Formation, Frasnian Unisław and Strzeżewo members of the Człuchów Formation, and Famennian Krojanty Formation (Fig. 2.11).

Chojnice Formation

The Chojnice Formation (Figs 2.11–2.12) is probably present in the Strzeżewo 1 (depth 4518.0– 4521.0 m) and Brojce IG-1 (depth 4025.0–4252.0 m) wells. In the Brojce IG-1 the formation is developed as calcareous sandstones interbedded with marly claystones and marls with some brachiopod fossils. In the Strzeżewo 1 well, the top of the formation is dominated by sandstones. Few conodonts and miospores found in the other wells in the Chojnice Formation suggest that it belongs to the upper Middle - Upper Givetian (Matyja, 2009).

The Człuchów Formation

Within the Człuchów Formation, Matyja (1993, 2006, 2009) identified 5 members (Fig. 2.11), but only the two lowest – Unisław and Strzeżewo members (Figs 2.11–2.12) seem to occur in the Strzeżewo 1 (depth ?3890.0–4518.0 m) and Brojce IG-1 (depth 3674.5–4025.0 m) wells. Both members belong to the Frasnian and are characterized by the presence of thin-bedded sediments represented mainly by calcareous siltstones with inserts of more or less marly micritic limestones, which are sometimes characterized by nodular texture and the presence of cephalopods, tentaculites, bivalves, brachiopods, conodonts and ostracods (Matyja, 2006).

Krojanty Formation

The Krojanty Formation (Figs 2.11–2.12) in the "Gryfice" area is recognized in the Świerzno 4 (depth 3195.0–3238.5 m) well. The formation here is developed as organogenic and detrital limestone, partly dolomitized. The wavy-nodular texture of the rock is also slightly marked. Among the microfossils dominated by calcareous algae and foraminifera, macroscopically distinguishable are fragments of corals and brachiopods.

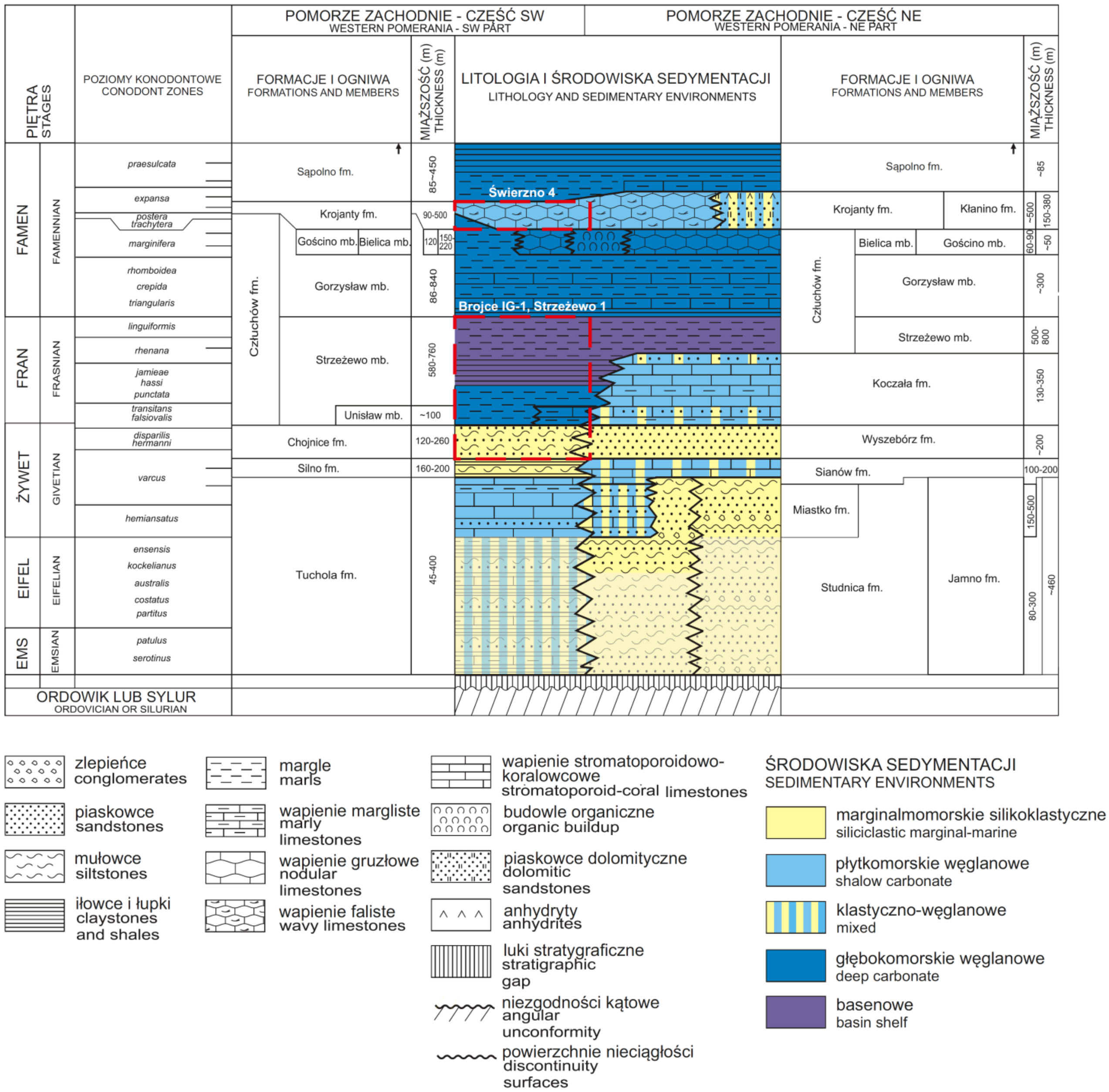
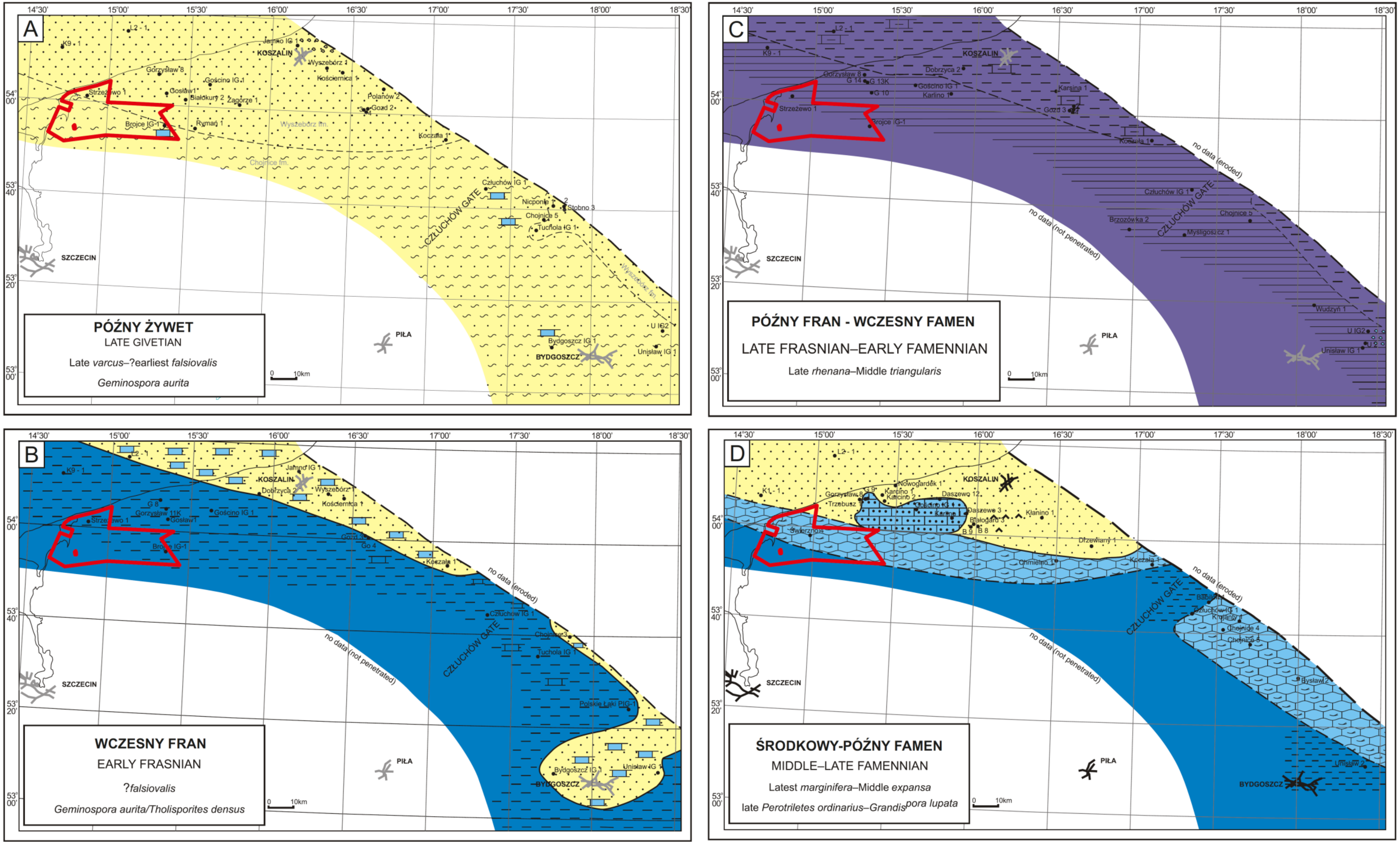


Fig. 2.11. Devonian stratigraphy, lithology and depositional environments in the Western Pomeranian region (Matyja, 2009; modified). Dashed lines indicate identified boundaries of lithostratigraphic units recognized in the Brojce IG-1, Strzeżewo 1 and Świerzno 4 wells in the "Gryfice" tender area.

→**Fig. 2.12.** Devonian palaeogeography and facies distribution in the "Gryfice" tender area (Matyja, 2009; modified) in (A) Late Givetian (Chojnice and Wyszebórz formations), (B) Early Frasnian (Unisław Member), (C) Late Frasnian – Early Famennian (Strzeżewo Member), (D) Middle and Late Famennian (Krojanty and Kłanino formations). The red line indicates the borderline of the "Gryfice" tender area. Explanations as in Fig. 2.11.


A
PÓŹNY ŻYWET
LATE GIVETIAN
Late *varcus*–?earliest *falsiovalis*
Geminospora aurita
KOSZALIN
SZCZECIN
PIŁA
BYDGOSZCZ
CZŁUCHÓW GATE
Wyszebórz fm.
Chojnice fm.
C
PÓŹNY FRAN - WCZESNY FAMEN
LATE FRASNIAN–EARLY FAMENNIAN
Late *rhenana*–Middle *triangularis*
no data (eroded)
no data (not penetrated)
B
WCZESNY FRAN
EARLY FRASNIAN
?*falsiovalis*
Geminospora aurita/Tholisporites densus
D
ŚRODKOWY-PÓŹNY FAMEN
MIDDLE–LATE FAMENNIAN
Latest *marginifera*–Middle *expansa*
late *Perotriletes ordinarius–Grandispora lupata*

2.2.2. CARBONIFEROUS

Extent and thickness

The Carboniferous deposits were identified in 10 wells located mainly in the western part of the “Gryfice” tender area (Fig. 2.9), at depths:

- Gostyń 2: 3314.0–3447.0 m,
- Kaleń 1: information restricted,
- Kamień Pomorski 7: 3230.0–3410.0 m,
- Laska 2: 3456.0–3583.0 m,
- Strzeżewo 1: 3199.0–3890.0 m,
- Wrzosowo 1: 3081.5–3305.0 m,
- Wrzosowo 2: 3059.5–3127.3 m,
- Wrzosowo 3: 3101.0–3255.0 m,
- Wrzosowo 8: 3077.5–3310.0 m,
- Wrzosowo 9: 3084.5–3198.0 m.

The thickness of the Carboniferous strata in the “Gryfice” tender area is up to 691.0 m.

Lithology and stratigraphy

Lithostratigraphic subdivision of the Lower Carboniferous in north-western Poland has been initially proposed by Dadlez (1978), revised and detailed by Żelichowski (1983, 1987, 1995; Żelichowski et al., 1986), later modified by Lipiec (Lipiec and Matyja, 1998; Lipiec, 1999) and recently by Matyja (Fig. 2.13; 2006, 2008; Matyja et al., 2000).

The Upper Carboniferous deposits in the Western Pomerania are divided into three formations (Żelichowski 1983, 1987, 1995). Lithostratigraphic subdivision of the Lower and Upper Carboniferous differs between NE and SW parts of Western Pomerania (Fig. 2.13; Matyja, 2006, 2008) due to different facies architectures.

The formal lithostratigraphic subdivision of the Carboniferous deposits was provided only in the Laska 2 and Strzeżewo 1 wells (Lipiec, 1997; Żelichowski, 1987; Fig. 2.13). The following formations are distinguished:

Czaplinek Formation (Lower Carboniferous):
- Laska 2: 3456.0–3583.0 m;

Wolin Formation (Upper Carboniferous):
- Strzeżewo 1: 3608.0–3890.0 m;

Rega Formation (Upper Carboniferous):
- Strzeżewo 1: 3442.5–3608.0 m;

Dźwina Formation (Upper Carboniferous):
- Strzeżewo 1: 3199.0–3442.5 m.

The Łobżonka Shale Formation is probably the oldest (uppermost Tournaisian/Lower Visean) Lower Carboniferous formation in the “Gryfice” tender area (Fig. 2.13; Matyja, 2006). Its top has not been reached, however. The probable thickness of the formation may reach 550 m. The Łobżonka Shale Formation is represented by claystones and mudstones intercalated with quartz sandstones.

The Czaplinek Limestone Formation of the Visean (Arundian-Brigantian) age is represented by organodetrital and ooid limestones deposited in a rimmed shelf environment. Their thickness may reach 400 m (Fig. 2.13; Lipiec, 1997, 1999). The formation comprises different types of carbonate lithofacies: skeletal, oolite grainstones, packstones, skeletal wackestones, and micrites.

The Nadarzyce Shale Formation (upper Visean – lower Namurian; Górecka et al., 1980; Żelichowski, 1987) is probably the youngest Lower Carboniferous unit in the tender area (Fig. 2.13; Matyja, 2006). It is composed of dark grey claystones with siderites, bioturbation, and carbonaceous plant detritus, as well as rare limestone intercalations (Lipiec, 1999). Its thickness may reach 250m.

The Wolin Formation (Upper Carboniferous) is represented by dark mudstones and claystones with sandstone intercalations up to 30 cm (Fig. 2.13). The thickness of the Wolin Formation varies from 40 m to 300 m (Matyja, 2006). Interbeds of coal paleosols and limestones may occur, as well (Waksmundzka 1997a, b; Waksmundzka and Żelichowski, 1997a; in: Matyja, 2006). Age of the formation was determined by biostratigraphic studies of Waksmundzka and Żelichowski (1997b; in: Matyja, 2006) as the uppermost Westphalian A, B and C.

The Rega Formation (Upper Carboniferous; Fig. 2.13) was identified only in the area between Kamień Pomorski and Trzebiatów. It overlies the Wolin Formation, and its top is marked by an erosional unconformity (Fig. 2.13). The formation consists of up to 30 m thick sandstone beds, mudstones, and claystones with plant detritus. The presence of volcanic rocks is also suggested (Waksmundzka and Żelichowski, 1997a; in: Matyja, 2006). The thickness of the Rega Formation is about 150–170 m. The palynological studies indicate the Westphalian D – Stephanian B–C age (Waksmundzka and Żelichowski, 1997b; in: Matyja, 2006).

The Dźwina Formation is the youngest unit of the Upper Carboniferous succession in the "Gryfice" tender area (Fig. 2.13). It is represented by mudstones and claystones intercalated with sandstones and conglomerates. Rhyolite and dacite clasts are present (Waksmundzka and Żelichowski, 1997a; in: Matyja, 2006). Overall thickness of the formation varies from 70 to 250 m. The age of the Dźwina Formation is interpreted as Stephanian – Autunian (Waksmundzka and Żelichowski, 1997b; in: Matyja, 2006).

Petrography

The Carboniferous deposits are represented mainly by clastic sediments: sandstones (arenites and wackes, according to Pettijohn et al., 1972), mudstones, claystones and carbonates. The petrographic description is based on the research provided earlier by Kozłowska (1997, 2004, 2005, 2006a, 2006b, 2008; Maliszewska et al., 2004a, 2004b; Kuberska et al., 2007), Łoszewska (1983), Połońska (1991) and Lipiec (1997, 1999). Moreover, some information from the final well reports were used from the following wells: Gostyń 2 (Wójcik and Sabura, 1982), Kaleń 1 (Nowicka, 2000), Kamień Pomorski 7 (Ryba and Szpurgis, 1978), Laska 2 (Wójcik, 1980), Strzeżewo 1 (Ryba and Szewc, 1978a), Wrzosowo 1 (Ryba and Stefańska, 1976), Wrzosowo 2 (Ryba and Szewc, 1976), Wrzosowo 3 (Ryba and Szewc, 1979), Wrzosowo 8 (Ryba and Szewc, 1977c), and Wrzosowo 9 (Ryba and Szewc, 1978b). Archival analysis (Narkiewicz, 1996) and research papers of Lipiec and Matyja (1998), Lipiec et al., (1998), Matyja (2006) were also used.

Lower Carboniferous (Mississippian)

Sandstones. The Lower Carboniferous is represented mainly by grey quartz sandstones (arenites and wackes) of the Łobżonka Shale Formation. They are characterized by a very fine- to middle-grained fraction. The main grain framework component is quartz with a minor content of feldspar, mica, lithic grains, and heavy minerals. Sometimes, ooids and bioclasts can be observed. Pore spaces are filled with matrix and/or partially by cement. Matrix is composed of detrital clay minerals mixed with ferruginous minerals. Carbonate, quartz, kaolinite, hematite, pyrite, and sulfate cements are common. Compaction and cementation processes have strongly reduced the porosity of sandstones. The average porosity is 1.6% and the permeability is <0.01 mD.

Mudstones and claystones. Dark grey mudstones and black claystones are common in the Łobżonka Shale Formation. They are characterized by massive or oriented textures. The main components of grain framework are quartz and bioclasts. The clay matrix consists of a mixture of clay minerals (illite, kaolinite), silica, iron oxides and hydroxides, organic matter, carbonates and pyrite.

Carbonates. Lower Carboniferous limestones belong to the Czaplinek Limestone Formation. These are organodetrital and ooid limestones. They are represented by skeletal packstones and grainstones, and algal, crinoid, ooid and skeletal wackestones. Limestones are composed of micrite and calcite sparite, which occur in varying ratios. Bioclasts (fragments of echinoderms, brachiopods, foraminifera, corals, bryozoans, and algae) and ooids, often recrystallized, are abundant. The admixture of terrigenous material, mainly quartz, is small; the content of clay pelite (illite) can be locally high. In addition, anhydrite and less frequently gypsum and calcite are encountered, which form nests or veins. In places, the calcite sparite is impregnated with a ferruginous substance that fills the intergranular fractures. There is a visible influence of mechanical compaction, early cementation and neomorphism (recrystallization of micrite into thicker micrite or microsparite). These limestones are not prospective as reservoir rocks as they are characterized by the porosity of approximately 0% and are impermeable.

Upper Carboniferous (Pennsylvanian)

Sandstones. Upper Carboniferous (Pennsylvanian) sandstones are found in the Wolin and Rega formations (in stratigraphic order). Minor presence of claystones and mudstones with coal interbeds and locally occurring carbonate rocks of the Wolin Formation and mudstones and claystones of the Rega Formation is observed. Grey and brown sandstones of both formations are probably similarly developed and they underwent similar diagenetic processes. Sandstones (Fig. 2.14. A–F) are represented by arenites and wackes, mainly quartz, locally sublithic and subarkosic. They are characterized by fine- to coarse-grained structure and various textures underlined by the presence of mica and argillaceous minerals. Detrital grains are usually subrounded and well sorted. Quartz is the major component; its content is on average 65.0% of the rock volume. Quartz occurs mainly as monocrystalline rather than polycrystalline grains.

K-feldspars are present in a minor amount, although, in the Wrzosowo region, its content may be up to 4% of the rock volume. Feldspars commonly undergo dissolution, alternation to albite and argillaceous minerals, and replacement by carbonate minerals. Additionally, minor amounts of lithic grains are observed, among which volcanoclastics and volcanic glass dominate over metamorphic and sedimentary clasts. Mica grains (primarily muscovite, less frequently biotite alternated by chlorite) occur in variable amounts. Accessory minerals comprise mainly zircon, rather than rutile and titanite. Pore spaces in sandstones are filled with matrix and/or partially by cement. Matrix is composed of detrital argillaceous minerals mixed with quartz and ferruginous minerals. Main cement elements are: authigenic quartz as syntaxial overgrowths on quartz grains (Fig. 2.14.A, C), authigenic clay minerals (kaolinite, dickite, illite, mixed-layer minerals illite/smectite; Fig. 2.1.B–D, F), carbonates (calcite, dolomite, ankerite, siderite; Fig. 2.14.E) hematite (Fig. 2.14. F) and iron hydroxides. Commonly, but in small amounts, sulfate minerals such as anhydrite and barite are observed. Additionally, organic matter is present. The sandstones underwent several diagenetic processes: compaction, cementation, replacement, dissolution, and alteration. Cementation, compaction and local diagenetic dissolution had the main influence on the formation of the pore space and the permeability of sandstones.

Mudstones and claystones. The Upper Carboniferous mudstones and claystones contain a substantial amount of sand material. Quartz is the dominant component over feldspars or lithoclasts. Clay matrix is composed of clay minerals, silica, and ferruginous minerals, which locally dominate among the other minerals.

Summary

1. The Upper Carboniferous (Pennsylvanian) sandstones from the Wolin and Rega formations are represented by quartz/locally subarkosic arenites and wackes. Quartz is the dominant component, mainly of monocrystalline rather than polycrystalline grains. Minor contribution of micaceous minerals, feldspars, lithoclasts, and accessory minerals is observed. Detrital grains are subrounded. Clay matrix is composed of detrital clay minerals. Moreover, authigenic minerals like quartz, kaolinite, calcite, dolomite, ankerite illite, hematite, and iron hydroxides can be observed in the grain framework. Anhydrite, barite and siderite are present in minor amounts.

2. The Upper Carboniferous (Pennsylvanian) sandstone porosity is estimated between <1.0 and >12.0%. Primary porosity dominates over secondary porosity (grain and cement dissolution), which does not exceed a few percent. The permeability of sandstones is estimated at up to several mD. Quartz arenites are characterized by the best reservoir properties. The main cement of quartz arenites is authigenic quartz and kaolinite. In the Wrzosowa region, permeability of sandstones is reduced by fibrous illite.

3. The Lower Carboniferous sandstones (Mississippian) are massive, strongly diagenized, and are characterized by unfavorable petrophysical properties (porosities around 1.6% and permeabilities below 0.01 mD).
4. The carbonate sediments, non-dolomitized limestones, are not prospective as reservoir rocks due to early cementation, widespread neomorphic recrystallization, and lack of secondary porosity. Their porosity is usually close to zero, and the rocks are impermeable.

Carboniferous exploration concept

The geology of the "Gryfice" tender area is rather poorly investigated. The Carboniferous succession was encountered in several wells located close to the Wrzosowo field. The geology below the Zechstein horizon was interpreted based on numerous 2D seismic surveys performed until 1990 and further 2D and 3D mapping. Despite reprocessing of the Świerzno 3D seismic survey (2002), satisfactory results have not been obtained (Chruścińska and Płatek, 2016). However, in the latest papers of Bajewski et al. (2019, 2020), a new method of 2D seismic reprocessing was presented by the Seismic Department of the Oil and Gas Institute – National Research Institute. As a result, the resolution of the Permian-Mesozoic horizons and dislocation zones was enhanced. The sub-Zechstein geology also became more visible, but it is still not sufficient for reliable and valuable interpretation. According to Bajewski et al. (2020) it might be possible to obtain a better image of sub-Zechstein deposits by modeling the formation's velocities.

Due to the presence of gas deposits (Wrzosowo, Gorzysław N, Dargosław) in the close neighborhood of the "Gryfice" tender area, it is suggested to investigate the Upper Carboniferous interval in the north-eastern and northern parts of the area (Fig. 2.10). According to the latest studies presented by Bajewski et al. (2020), a new interpretation of geology below the Zechstein, especially the Upper Carboniferous distribution, is necessary. Similar to the previously discovered fields, elevated zones related to the NW-SE faults (e.g. Gorzysław – Trzebusz – Dargosław zone) seem to be the most prospective areas. Additionally, similar to the Wrzosowo field, zones located close to the Devonian – Lower Carboniferous subcrops seem to be prospective. The half-grabens located at the edge of the Upper Carboniferous seem to be the most prospective for new discoveries.

The Upper Carboniferous deposits in the "Gryfice" tender area might be considered potential unconventional „tight gas" reservoirs, as they meet the criteria for tight gas deposits, proposed by Podhalańska et al. (2016). The Upper Carboniferous succession contains several thick sandstone layers characterized by moderate porosity and weak permeability. Such horizons might be considered as tight sandstones. In the Strzeżewo 1 well the analogous interval was tested, and the flow of gasified brine was obtained (Fig. 2.15). Therefore, it is recommended to drill horizontal/deviated wells and perform fracturing operations in the case of unconventional or hybrid reservoirs.

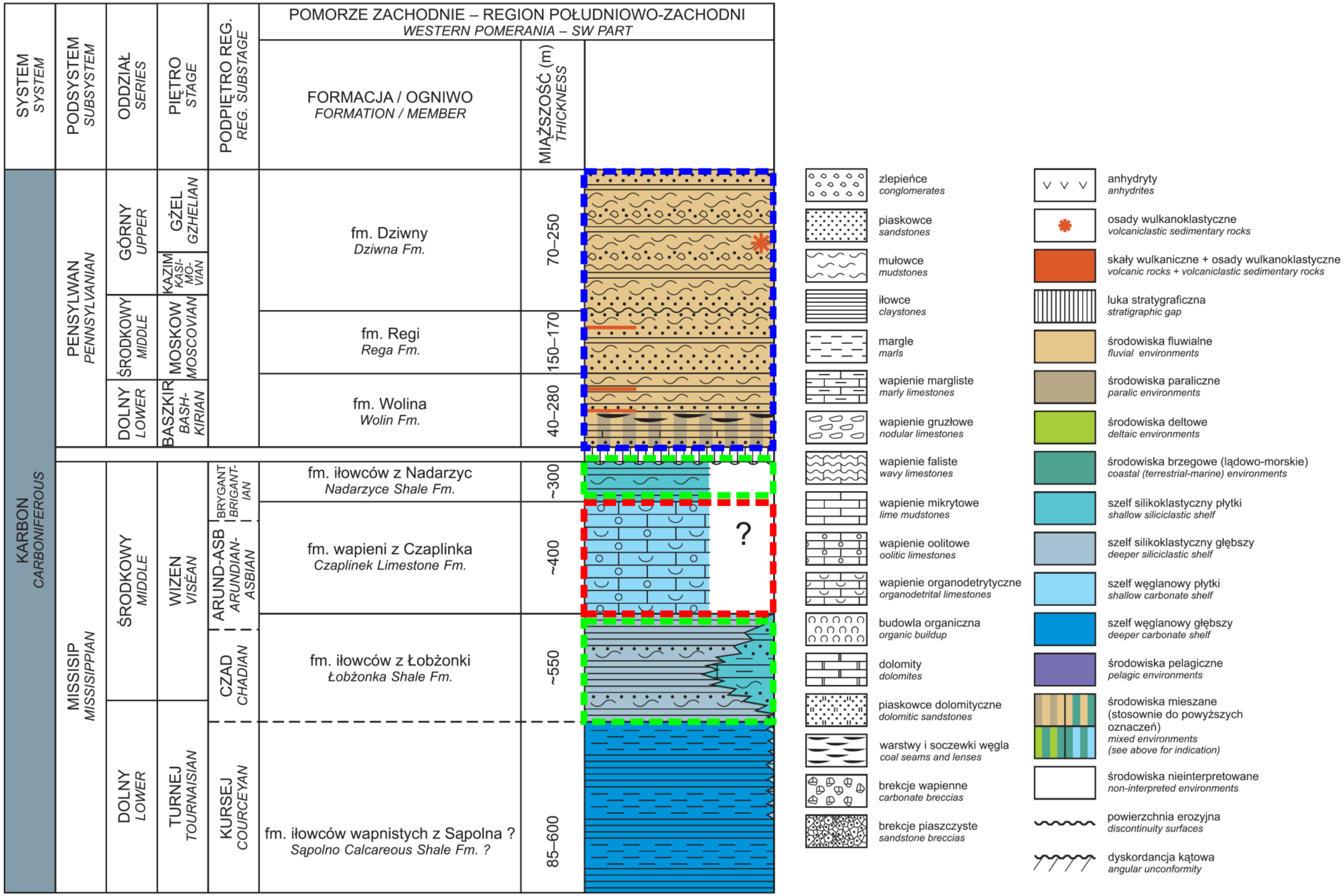


Fig. 2.13. Carboniferous litho- and chronostratigraphy in the south-western part of Western Pomerania (Matyja, 2006, 2008; modified). Dashed lines indicate identified (red, blue) and supposed (green) lithostratigraphic units in the "Gryfice" tender area.

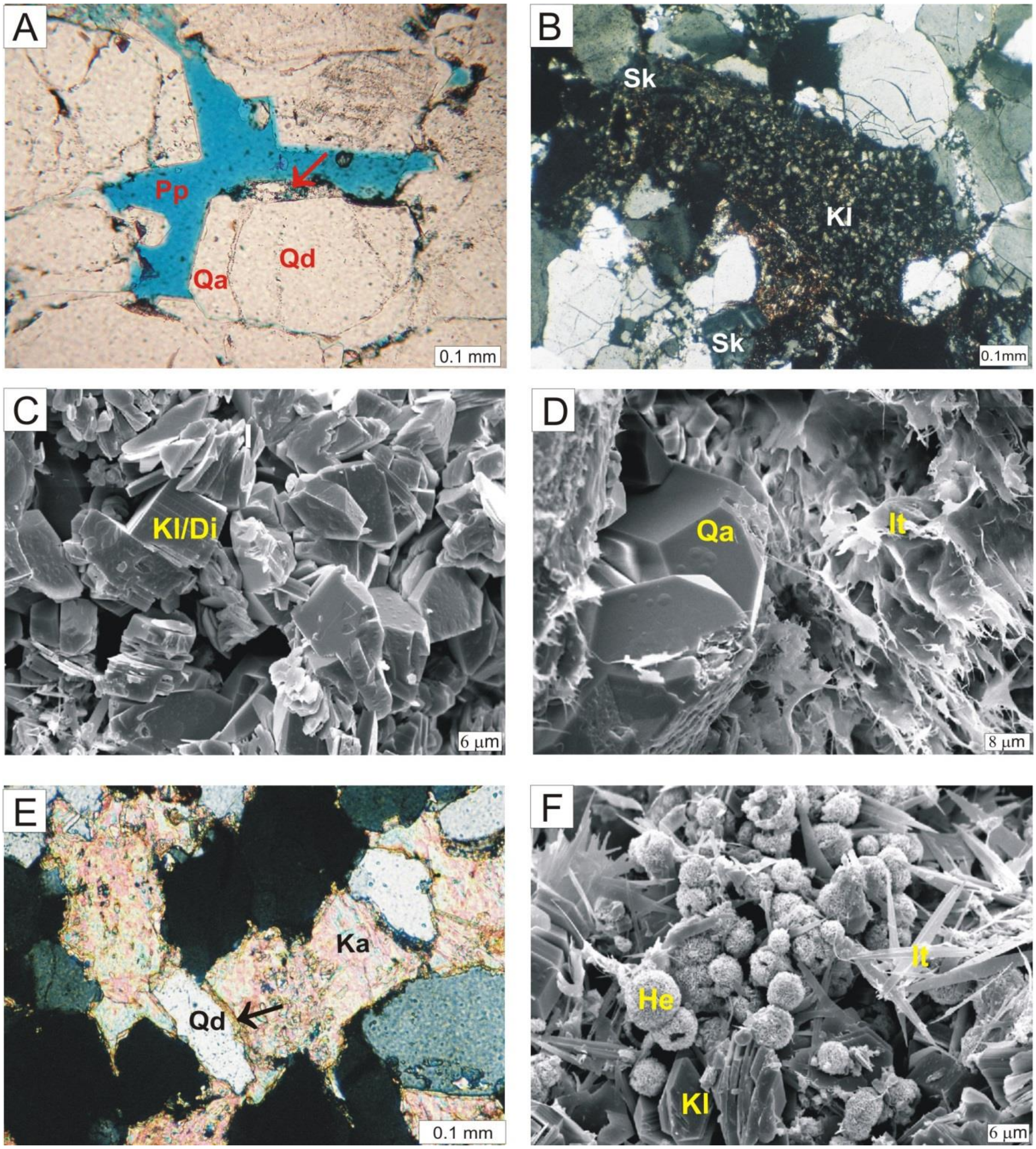


Fig. 2.14. A. Primary (Pp) and secondary (red arrow) porosity formed as a result of the dissolution of authigenic quartz (Qa) on quartz grains (Qd). Sample impregnated with blue resin; Wrzosowo 8 well, depth 3185.9 m; analyzed in plane-polarized light, parallel light. **B.** K-feldspar grain (Sk) altered into kaolinite (Kl); Wrzosowo 3 well, depth 3158.4 m; plane-polarized light, crossed nicols. **C.** Blocky kaolinite/dickite (Kl/Di); Strzeżewo 1 well, depth 3821.2 m; SEM image. **D.** Fibrous illite (It) and authigenic quartz crystals (Qa); Wrzosowo 3 well, depth 3129.8 m; SEM image. **E.** Calcitic cement (Ka) in sandstone; calcite (black arrow) alternates quartz grain (Q); Wrzosowo 8 well, depth. 3193.6 m; plane-polarized light, crossed nicols. **F.** Round forms of hematite (He) between kaolinite crystals (Kl), covered with fibrous illite (It); Strzeżewo 1 well, depth 3724.2 m; SEM image.

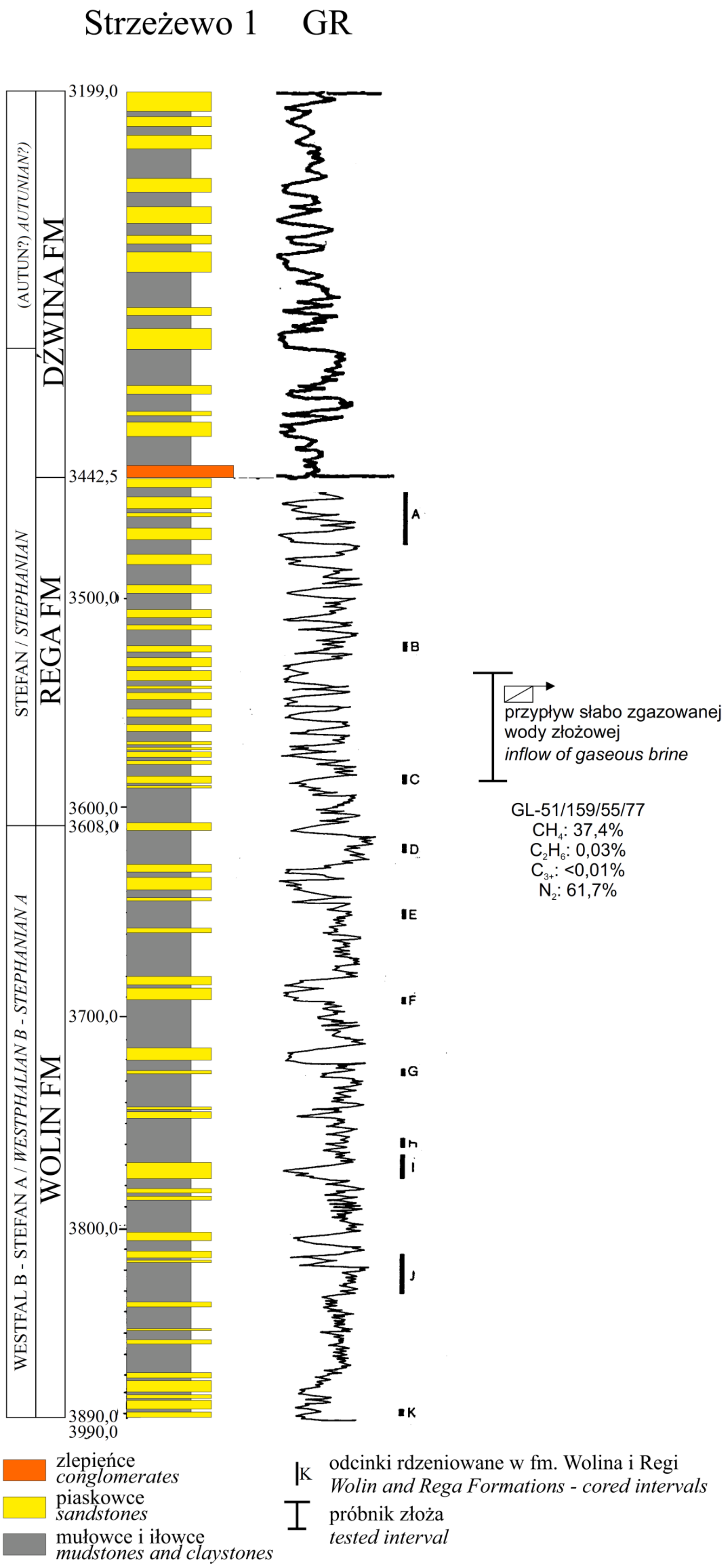


Fig. 2.15. Lithology and the gamma ray log in the Carboniferous of the Strzeżewo 1 well (according to Kombrink et al., 2010; modified). The results of the well test and gas analysis were taken from the final well report (Ryba and Szewc, 1978a).

2.2.3. PERMIAN – ROTLIEGEND

Extent and thickness

The Rotliegend deposits were identified in 19 wells, at depths:

- Benice 1: 3150.0–3247.0 m,
- Brojce IG-1: 3609.5–3674.5 m,
- Gostyń 2: 3262.5–3314.0 m,
- Gryfice 1: 3340.5–3367.0 m,
- Gryfice 2: 3391.0–3415.0 m,
- Jarszewo 1: 2915.0–2998.7 m,
- Kaleń 1: information restricted.
- Kamień Pomorski 7: 2707.5–3230.0 m,
- Kamień Pomorski 13: 2658.5–2672.0 m,
- Laska 2: 3091.5–3456.0 m,
- Rekowo 2: 3014.5–3141.5 m,
- Strzeżewo 1: 3109.0–3199.0 m,
- Świerzno 1: 3084.5–3103.0 m,
- Świerzno 4: 3156.0–3195.0 m,
- Wrzosowo 1: 3077.0–3081.5 m,
- Wrzosowo 2: 3055.5–3059.5 m,
- Wrzosowo 3: 3073.0–3101.0 m,
- Wrzosowo 8: 3075.0–3077.5 m,
- Wrzosowo 9: 3060.5–3084.5 m.

Twelve wells drilled through the Rotliegend and reached the Devonian (2 wells) or Carboniferous (10 wells; Fig. 2.18, Figs 2.21–2.22). The thickness of the Rotliegend varies between 2.5 m and 522.5 m, although the average thickness is between 20 and 100 m.

Lithology and stratigraphy

The informal subdivision of the Rotliegend deposits in Poland was presented by Pokorski (1981, 1988, 1997; Fig. 2.16). In the Upper Rotliegend, Kiersnowski (1997, 1998) distinguished depositional sequences 1–8b. The detailed sequence of the sedimentary cycles for the NW part of Poland and the NE part of Germany was developed by Kiersnowski and Buniak, 2006 (Fig. 2.19).

The Rotliegend of the “Gryfice” tender area is reduced to the lower and middle part of the Odra and the upper part of the Warta groups.

Świniec Formation

The basal part of the Rotliegend succession is composed of sandstone-mudstone cycles intercalated with conglomerates. Dybova-Jachowicz and Pokorski (1984) and Pokorski (1987) identified this interval as the Świniec Formation (Fig. 2.16). These deposits developed in fluvial and limnic environments. The Świniec Formation comprises the lowermost Carboniferous (Stephanian C) and the uppermost Rotliegend intervals (Fig. 2.16; Pokorski, 1987). The Świniec Formation was identified in the Strzeżewo 1, Wrzosowo 2, Wrzosowo 3, Wrzosowo 8, and Wrzosowo 9 wells, in the western and north-western parts of the “Gryfice” tender area.

The Świniec Formation is overlain by volcanic and pyroclastic deposits of the Wielkopolska Volcanic Formation (Fig. 2.16). The pyroclastic succession is composed of tuffs and tuffites, interbedded with sandstones and mudstones (Dybova-Jachowicz and Pokorski, 1984), and may reach a thickness of 58 m (Strzeżewo 1 well). The Wielkopolska Volcanogenic Formation is represented by acidic and basic extrusive rocks described by Ryka (1968, 1978) as rhyolites.

Wielkopolska Volcanic Formation

Volcanic rocks of the Wielkopolska Volcanic Formation are present in the whole “Gryfice” tender area (Fig. 2.17). Its greatest thickness (520 m) is observed in the south-western part (Kamień Pomorski 7 well; Fig. 2.18). The thickness of the volcanic cover decreases rapidly northwards, whereas the eastward thickening has a more gradual character.

Upper Rotliegend

Tectonic activity and intense erosion at the Early/Late Rotliegend transition resulted in the peneplanation of the volcanic cover or its complete erosion and development of a stratigraphic gap of about 10 My (Nawrocki, 1995) or even 20 My (H. Kiersnowski – personal communication). A new stage of sedimentary basin evolution – development of the late Permian-Mesozoic basin – started with a deposition of Upper Rotliegend strata. Its development was connected with the episode of strong subsidence with a significant contribution of thermal subsidence (Wagner, 1994; Dadlez et al., 1998).

In north-western Poland, during Rotliegend deposition, the Drawa and Noteć formations developed (Fig. 2.16). Sediments of both formations do not exhibit significant lithological differences (Pokorski, 1987). The Drawa and Noteć units are represented by a whole range of sedimentary rocks: claystones, mudstones, siltstones, sandstones and conglomerates, deposited in different environments (Kiersnowski, 1997, 1998; Kiersnowski and Buniak, 2006).

Drawa Formation

During the deposition of the lower Drawa Formation, the "Gryfice" was a source area for the basin located southwards (Fig. 2.19). The deposition of the upper part of the Drawa Formation was restricted to the southern and south-western parts of the analyzed area (Fig. 2.19). These deposits can be subdivided into cycles: AL II – alluvial conglomerates and fluvial sandstones (Fig. 2.19; Kiersnowski and Buniak, 2006), and P-L III – fluvial sandstones and fine-grained conglomerates with mudstone interbeds, locally playa-type mudstones (Fig. 2.19).

Noteć Formation

The lower part of the Noteć Formation is identified in the south-western part of the "Gryfice" tender area (Fig. 2.19). It is composed of conglomerates and sandstones deposited in alluvial fans and flood plains (AL III cycle; Fig. 2.19). The next cycle overlies the earlier deposited sediments and is expanding northwards (Fig. 2.19). Thin alluvial conglomerates and sandstones are replaced by fluvial sandstones and mudstones along the NW-SE strike (P-L IV; Fig. 2.19). The upper part of the Noteć Formation covers an area whose extend is similar to the recent facies distribution (Figs 2.19, 2.21). The source area of clastic material is said to be mainly the north-eastern and partly the western part of the analyzed area. The rest of the area is covered by fluvial sandstones passing into mudstones with sandstone intercalations and sandstone-mudstone cyclic deposits to the southwest P-L V (Figs 2.19, 2.21).

The thickness of the Rotliegend succession does not exhibit strong variation in the tender area (Fig. 2.22). The northern part is characterized by a relatively small thickness that gradually increases southwards (Fig. 2.22) due to the fact that the northern part of the "Gryfice" tender area served as a source area for the central part of the Rotliegend sedimentary basin (Fig. 2.19). Only in the southernmost part (region of the Benice 1 well) a rapid increase in thickness is observed as a consequence of activity of the Adler-Kamień Pomorski synsedimentary fault (which also led to the Samlino-Resko graben development).

Petrography

Stratigraphic studies of the Rotliegend strata in the analyzed area were carried out by many authors: Buniak and Solarska, 2004; Jackowicz, 1997; Kuberska et al., 2007; Kuberska et al., 2008; Kuberska, 2008; Maliszewska and Kuberska, 1996, 2008, 2009; Maliszewska et al., 1998; Maliszewska et al., 2016; Rusek et al., 2005). Additional information is also present in the final well reports from the following wells: Benice 1, Brojce IG-1, Gostyń 2, Gryfice 1, 2, Jarszewo 1, Kaleń 1, Kamień Pomorski 7, 13, Laska 2, Rekowo 2, Strzeżewo 1, Świerzno 1, 4, and Wrzosowo 1, 2, 3, 8, 9.

Deposits of the Upper Carboniferous – Lower Permian transition are represented mainly by red-brownish claystones and mudstones with sandstone intercalations and rare conglomerates (Maliszewska et al., 2016).

The Lower Rotliegend volcanic series is represented by rhyolites and dacites. Additionally, pyroclastic tuffs and volcanogenic rocks (pyroclastic-epiclastic and epiclastic-pyroclastic) are observed. Detailed characteristics of the lower Permian deposits can be found in Maliszewska et al. (2016).

The Upper Rotliegend **conglomerate** lithofacies are firmly lithified, usually coarse-grained and grey-brown, red-brown, or grey in color. They were deposited in an alluvial fan environment. Conglomerates are usually very solid, albeit fractured types might occur. The porosity is estimated to be several percent (Maliszewska et al., 2016)

Sandstones are usually fine- and medium-grained, rarely conglomeratic, red-brownish to grey-pinkish in color, occasionally grey. Detrital material is poorly sorted, rather angular than rounded. Almost all analyzed sandstones show similar characteristics, that is: compacted, parallel, rarely unoriented texture. The main components are quartz, feldspars, lithoclasts (predominantly volcanoclasts: grey and brown rhyolites and dacites, aphyric, rarely porphyric and microfelsitic or micropoikilitic). Authigenic clay minerals are represented by illite, kaolinite, chlorite and seladonite. Illite exhibits micaceous and fibrous structures. According to K-Ar dating of illite growth in sandstone sample from, e.g., the Karsk 1 well, illite precipitated in the Toarcian (180.5 Ma; Maliszewska and Kuberska, 2009). Presumably, illite precipitated as a result of feldspar weathering. Zwingmann et al. (1998) suggest illite precipitation from formation/pore water as in the case of Rotliegend deposits in Germany. Kaolinite shows the structure of pseudohexagonal plates forming worm-like or booklet crystals (Maliszewska and Kuberska, 2009). Feldspars and mica minerals might be the source of Al and SiO_2. Chlorites occur as fan-shaped flake aggregates (Fig. 2.26). Such structures developed mainly due to the alteration of volcanic grains. Quartzitic cement occurs as syntaxial overgrowth rims on quartz grains or as isolated hexagonal prisms. Fluid inclusion studies of quartz overgrowth rims in sandstones (Brojce IG-1, Wysoka Kamieńska 2 wells) revealed the homogenization temperatures of 131–165^{o}C and the salinity eq. NaCl around 2–9% (Jarmołowicz-Szulc, 2009). Carbonate minerals comprise mainly calcite and dolomite, occasionally ankerite (Fig. 2.26). Sulfate minerals are represented solely by anhydrite. Anhydrite appears as tabular single crystals or aggregates, sometimes as poikiloblastic cement (Fig. 2.24). Authigenic iron minerals are represented by hematite and iron hydroxides. In sandstones of the Brojce IG-1 well (uppermost part of the succession), pyrite concentrations have been identified.

Petrophysical studies of sandstone revealed their low porosity (at intervals only ca. 20.0%) and permeability below 0.1 mD, occasionally around 300 mD. A decrease in porosity is due to compaction and cement precipitation in newly deposited sediments. Moreover, such low porosity is also due to the presence of fibrous illite in sandstones. The main cause of distinctively low porosity in Rotliegend sandstone lithofacies is a mesodiagenetic dissolution process embracing both detrital grains and cement components.

The Carboniferous/Permian and Lower Permian deposits are represented by sandstones, mudstones and claystones. Conglomerates appear mostly in the uppermost part of the upper Rotliegend profile and sometimes near the Carboniferous/Lower Rotliegend boundary. Sandstones from the Carboniferous/Permian transition (Dźwina and Świniec formations) are represented mainly by quartz arenites and wackes, and therefore contain minor lithoclasts. However, upper Rotliegend sandstones are represented mostly by sublithic deposits with numerous clasts of volcanic rocks. These sandstones can be characterized by promising reservoir properties due to earlier diagenetic alteration.

Sandstones of the uppermost Carboniferous and Lower Permian show the porosity of ca. 0.7–8.0%. Primary porosity has been preserved to a small degree. Intercrystalline secondary porosity is the most common type, it occurs in kaolinitic aggregates (Fig. 2.23). Low permeability is caused by the formation of microporosity, low pore connectivity, and uneven distribution. These deposits do not exhibit satisfying reservoir properties.

The Upper Rotliegend sandstones usually exhibit low porosity, although intervals in which the sandstone porosity is around 16.0–21.0% are observed mostly in wells located close to the “Gryfice” tender area. Intergranular primary porosity is not observed. The Upper Rotliegend sandstones exhibit two types of porosities: intergranular and intercrystalline secondary porosity caused by diagenetic dissolution of minerals, mostly feldspars and carbonaceous cement (Fig. 2.26). Low permeability is largely a result of low porosity, particularly precipitation of fibrous, diagenetic illite in pore spaces. Illite precipitation commenced in the early Jurassic and might have been continued until the late Jurassic or even late Cretaceous.

The Rotliegend deposits of the Dźwina and Świniec formations exhibit low content of organic matter represented by relict forms of vitrinite macerals and inertinite. The low content/lack of organic matter in these deposits is a result of deposition in anoxic environment.

Maturity of organic matter in the Dźwina and Świniec formation deposits reflect the late phase of oil window/late oil-early gas generation (1.27–1.31% R_o) and indicates palaeotemperatures around 120–130^{0}C. The Upper Rotliegend, Dźwina and Świniec formations were highly influenced by the oxic environment during deposition and diagenesis.

Rotliegend exploration concept

The Rotliegend in the “Gryfice” tender area is poorly investigated due to deficient quality and difficulties in interpreting the Z1’ seismic horizon. 2D and 3D seismic reprocessing based on a processing sequence developed at the Seismic Department of the Oil and Gas Institute – National Research Institute is suggested (Bajewski et al., 2019, 2020). According to Bajewski et al. (2020) it might be possible to obtain a better image of sub-Zechstein deposits by proper modeling of formation’s velocities.

The main exploration target of the Rotliegend is its upper part (upper Rotliegend/Noteć Formation; Fig. 2.21). This horizon is present in almost the whole tender area, except for its north-eastern part and to a lesser extent north-western. Rotliegend alluvial fans developed around the Wolsztyn High. The highest exploration potential is related to alluvial sandstones and conglomerate deposits, which might have been cut by alluvial channel facies of desirable petrophysical properties. Additionally, in the southern part of the “Gryfice” tender area, numerous dislocations are present (Fig. 2.16). A number of these fault zones might have been reactivated by later tectonic activity, resulting probably in hydrocarbon migration and accumulation in new structural traps.

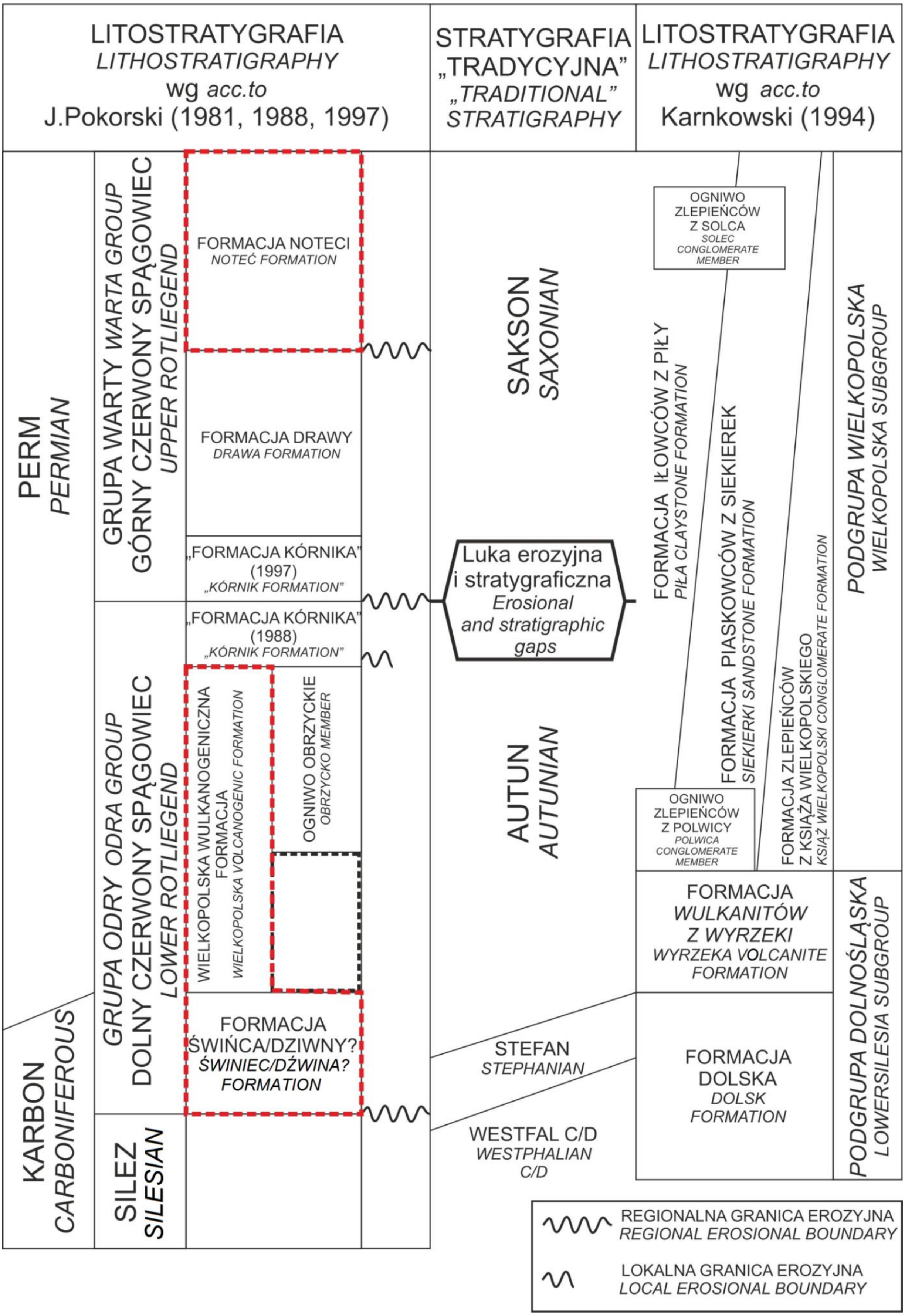


Fig. 2.16. Rotliegend stratigraphy of the Polish South Permian Basin (Kiersnowski; in: Maliszewska et al., 2003). Lithostratigraphic units identified in the “Gryfice” tender area (Pokorski, 1981, 1988, 1997) are marked with a red dashed line.

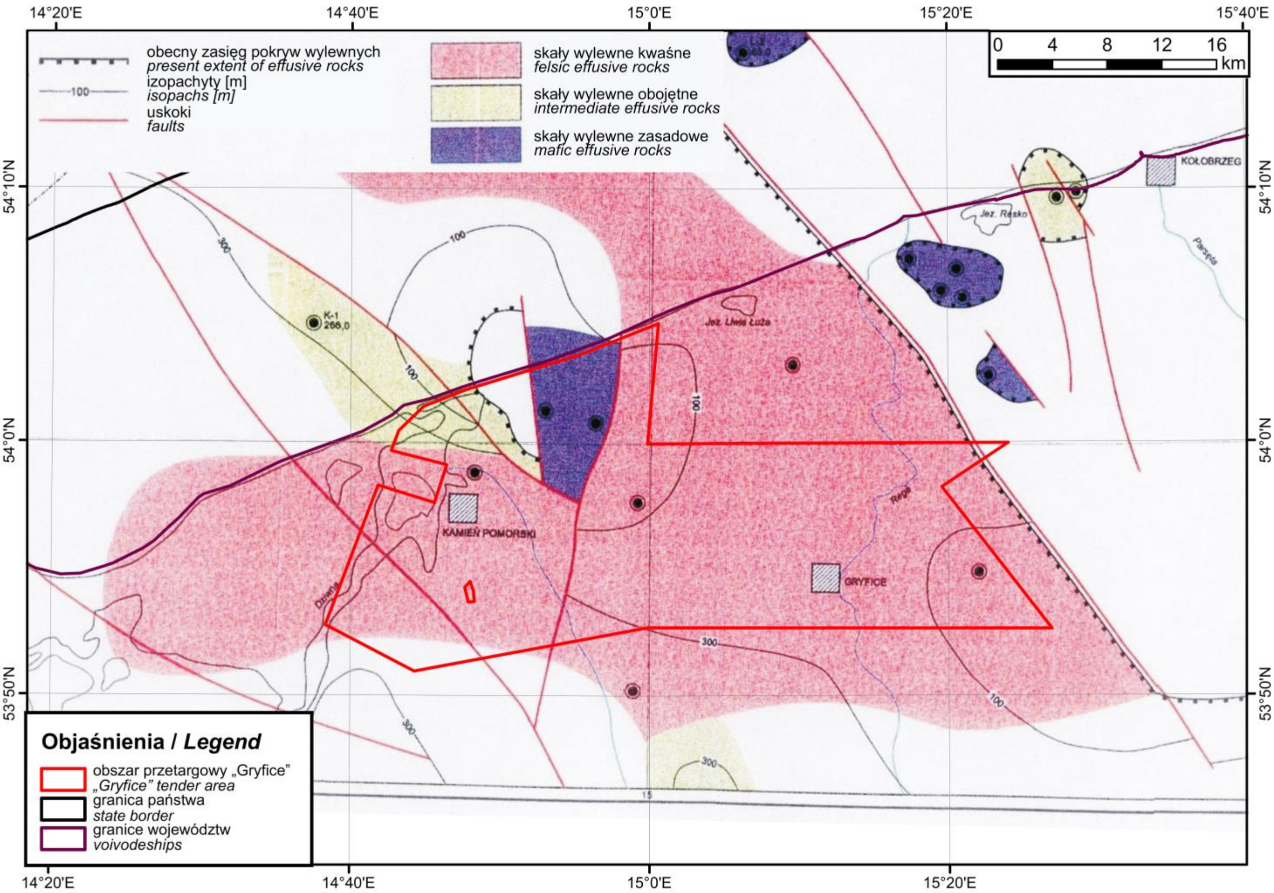


Fig. 2.17. Distribution and thickness of the Wielkopolska Volcanic Formation (Pokorski, handwritten).

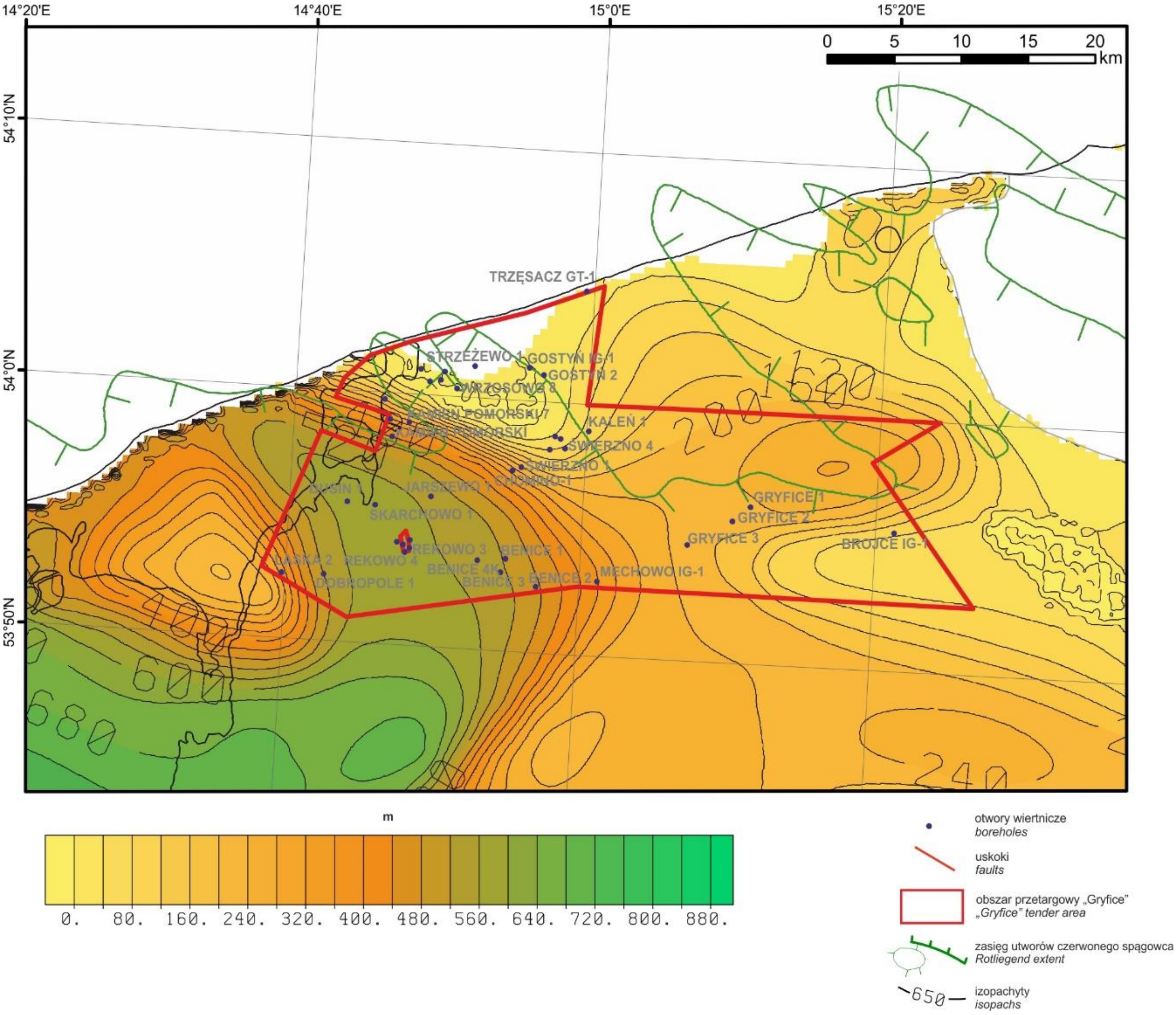


Fig. 2.18. Thickness of the volcanic succession in the “Gryfice” tender area and adjacent areas (Wagner et al., 2008; modified).

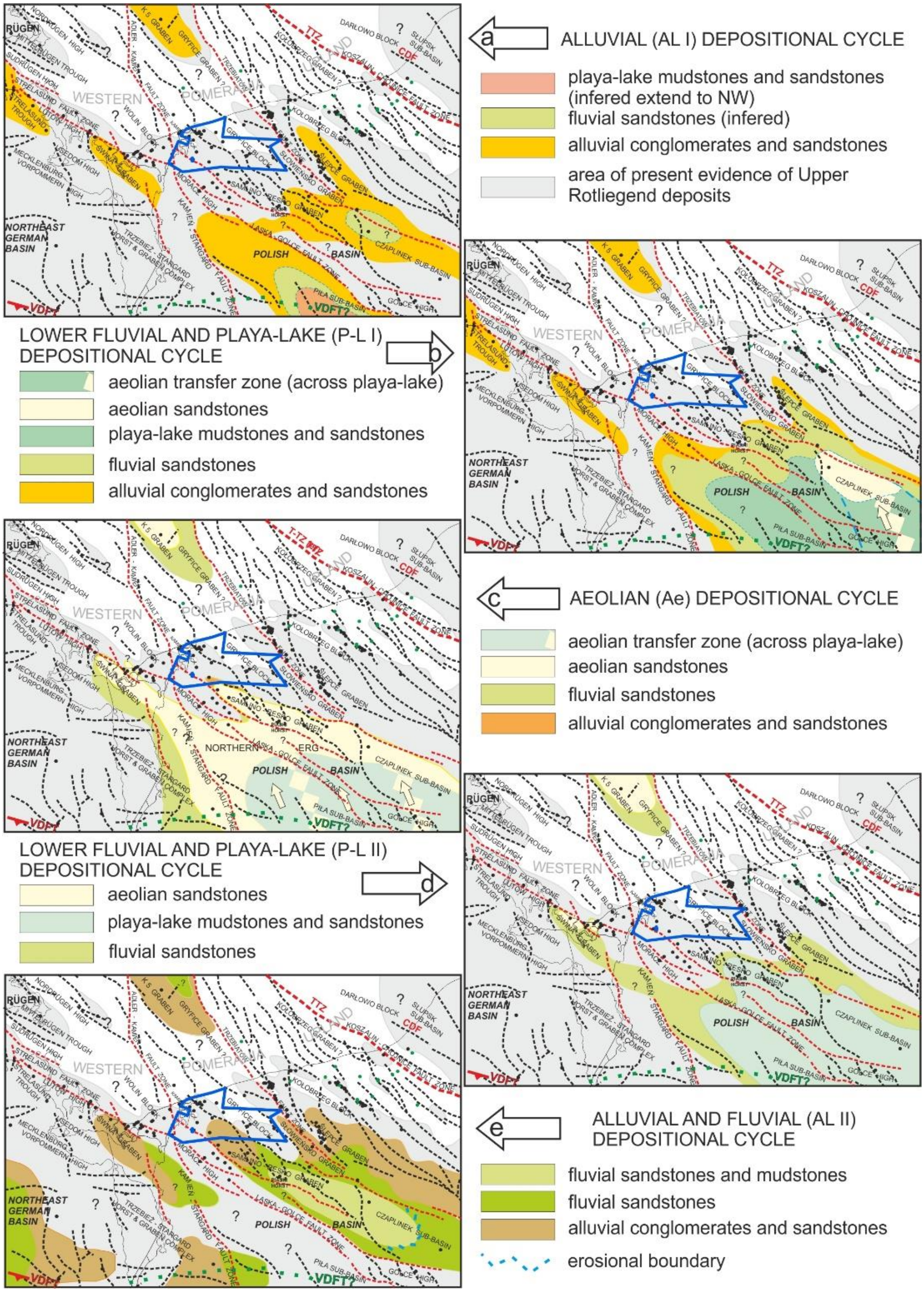


Fig. 2.19. Location of the Gryfice tender area in relation to the Upper Rotliegend consecutive depositional cycles in NW Poland (Kiersnowski and Buniak, 2006).

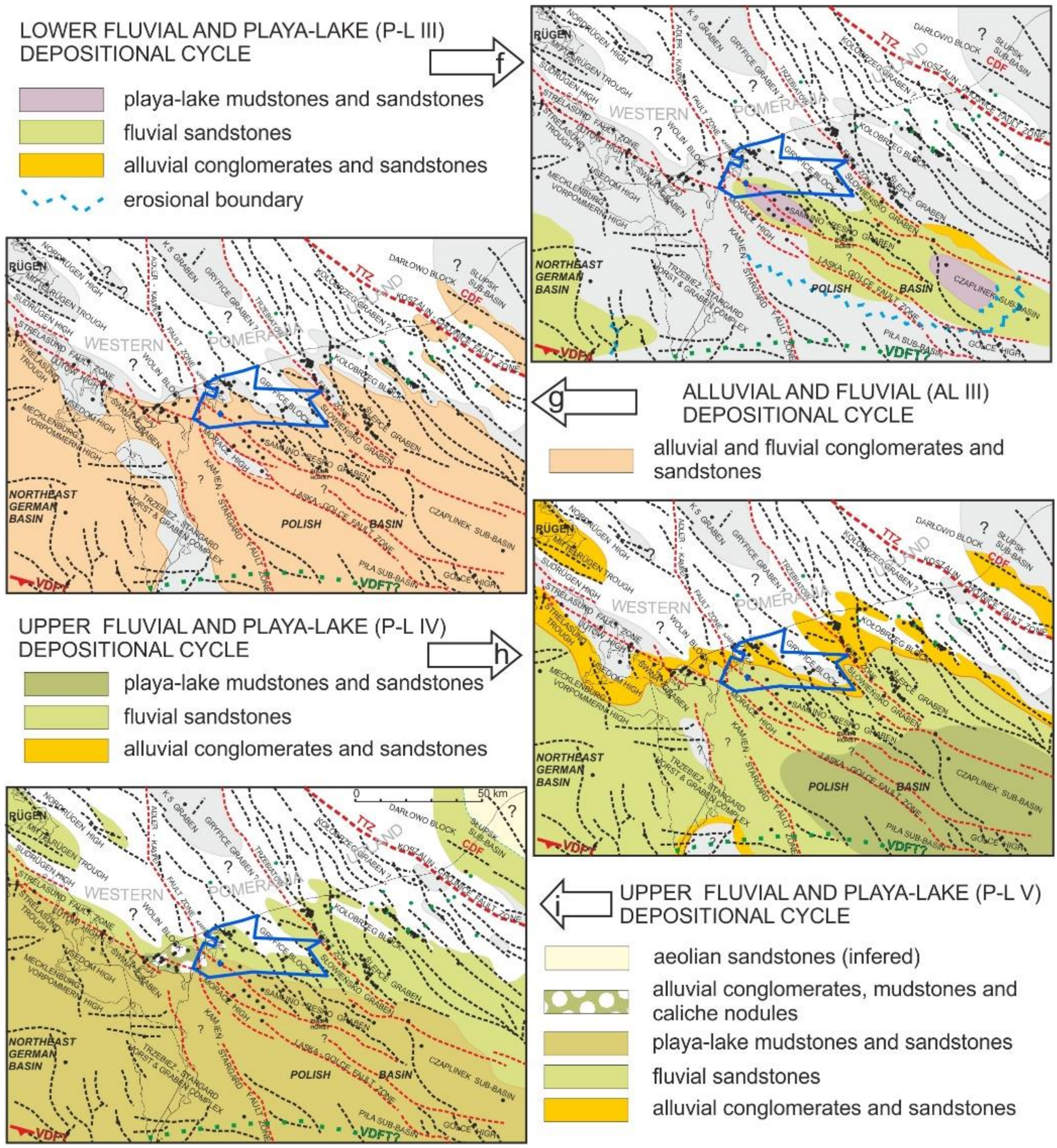


Fig. 2.19. Continuation

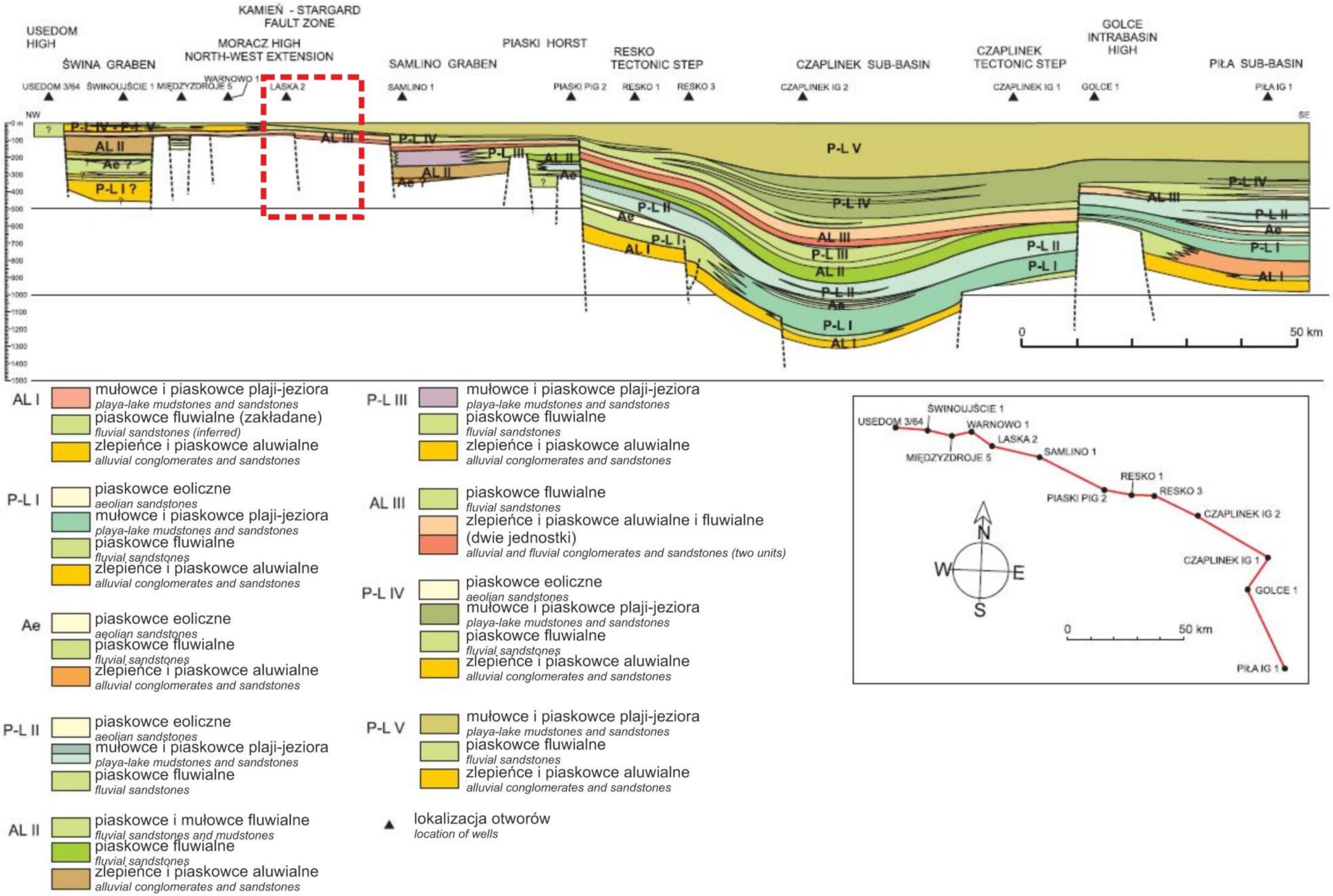


Fig. 2.20. Upper Rotliegend lithofacies in NW Poland – schematic cross-section. "Gryfice" tender area is marked by a red dashed line (Kiersnowski and Buniak, 2006; modified).

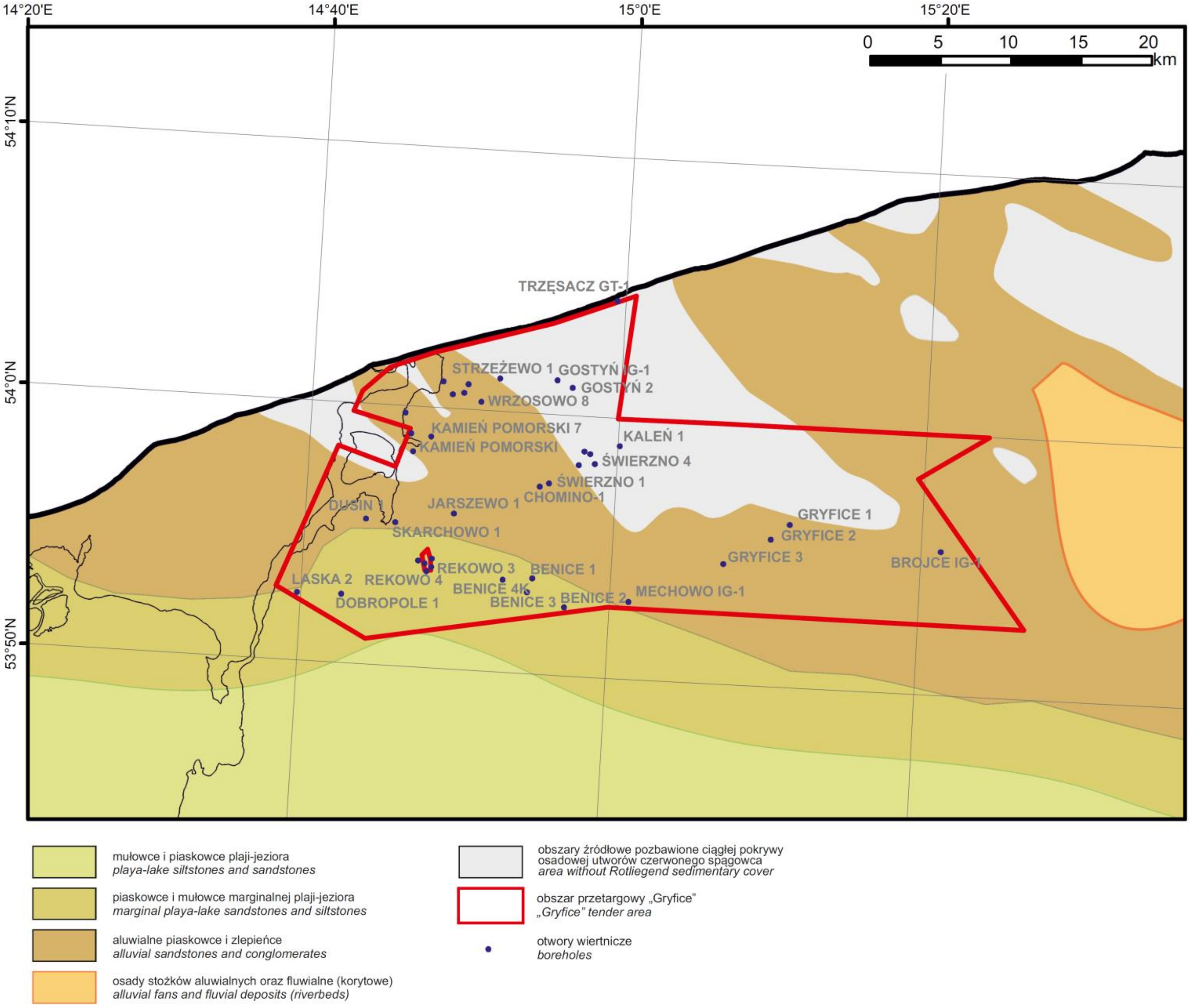


Fig. 2.21. Location of the “Gryfice” tender area on the lithofacies-palaeogeographic map of the uppermost Rotliegend, just before Zechstein transgression (Kiersnowski et al., 2020).

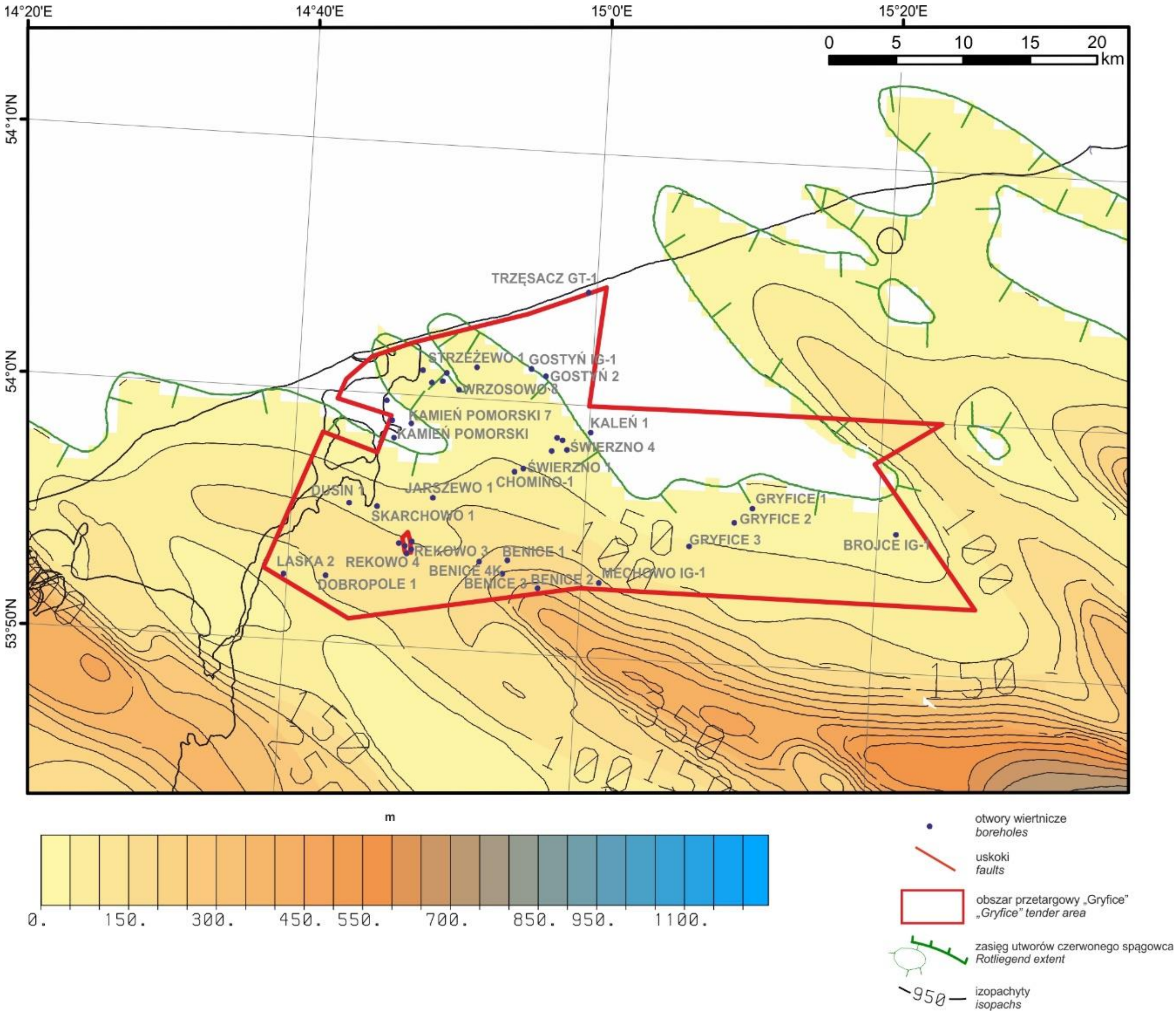


Fig. 2.22. "Gryfice" tender area in relation to the Upper Rotliegend thickness (Wagner et al., 2008; modified).

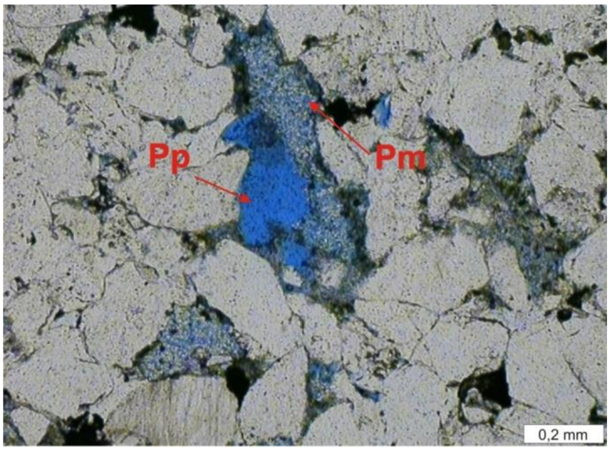


Fig. 2.23. Quartz arenite with visible primary (Pp) and secondary microporosity (Pm) between kaolinite crystals. Wrzosowo 8 well, depth 3145.6 m, parallel light, blue resin.

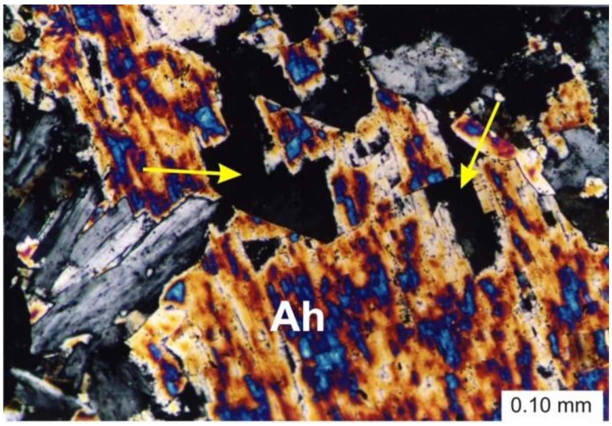


Fig. 2.24. Anhydrite cement (Ah) in orthoconglomerate. Visible secondary porosity (arrows) after partial cement dissolution. Brojce IG-1 well, depth 3611.8 m; polarized light, crossed nicols.

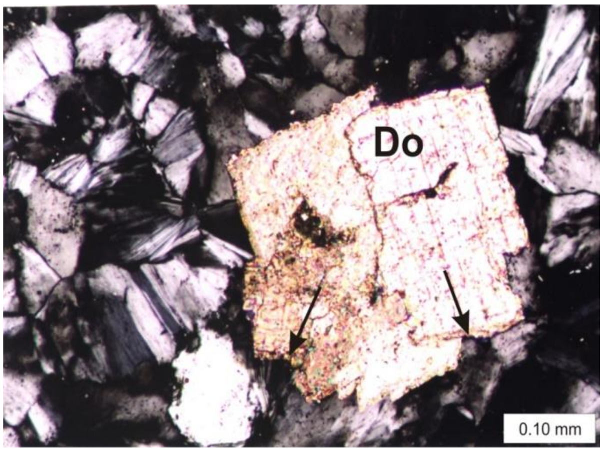


Fig. 2.26. Coarse crystals of chlorite and a dolomite crystal (Do) in pore space of sandstone; visible partial dissolution of dolomite (black arrows); Brojce IG 1 well, depth 3608.5 m; microscopic view (crossed polars).

2.2.4. PERMIAN – ZECHSTEIN

Extent and thickness

The Zechstein deposits were drilled in 35 wells in the "Gryfice" tender area, at depths (Fig. 2.25):

- Benice 1: 2374.5–3150.0 m,
- Benice 2: 2504.0–2916.0 m,
- Benice 3: 2367.5–2842.0 m,
- Benice 4K: 2234.5–2752.0 m,
- Brojce IG-1: 2853.0–3609.5 m,
- Chomino 1: 2331.0–2752.0 m,
- Dobropole 1: 2316.0–2883.0 m,
- Dusin 1: 2205.0–2662.5 m,
- Gostyń 2: 2578.0–3262.0 m,
- Gryfice 1: 2611.0–3340.5 m,
- Gryfice 2: 2512.0–3391.0 m,
- Gryfice 3: 2697.0–3190.0 m,
- Jarszewo 1: 2165.0–2915.0 m,
- Kaleń 1: information restricted,
- Kamień Pomorski 3: 1995.5–2405.0 m,
- Kamień Pomorski 7: 2026.0–2707.5 m,
- Kamień Pomorski 13: 2034.0–2658.5 m,
- Laska 2: 2067.0–3091.5 m,
- Rekowo 1: 2102.0–2667.0 m,
- Rekowo 2: 2126.5–3014.5 m,
- Rekowo 3: 2121.5–2697.0 m,
- Rekowo 4: 2111.5–2736.0 m,
- Rekowo 6: 2035.5–2746.0 m,
- Skarchowo 1: 2189.5–2667.0 m,
- Strzeżewo 1: 2495.0–3109.0 m,

- Świerzno 1: 2300.0–3084.5 m,
- Świerzno 2: 2354.0–2772.2 m,
- Świerzno 4: 2338.0–3156.0 m,
- Świerzno 5: 2290.0–2883.6 m,
- Świerzno 9: 2247.5–2774.7 m,
- Wrzosowo 1: 2299.0–3077.0 m,
- Wrzosowo 2: 2262.0–3055.5 m,
- Wrzosowo 3: 2239.5–3073.0 m,
- Wrzosowo 8: 2258.0–3075.0 m,
- Wrzosowo 9: 2271.0–3060.5 m.

The complete Zechstein succession has been pierced in 19 wells. In 34 boreholes, the Main Dolomite (Ca2) deposits were reached. Most of the wells that drilled the Zechstein succession are located in the north-western and western parts of the "Gryfice" tender area.

The total thickness of the Zechstein deposits varies from 409.5 m (Kamień Pomorski 3 well) to 1024.5 m (Laska 2 well), although usually is between 450–850 m. In the "Gryfice" tender area the Zechstein thickness increases towards the center of the Permian Basin (Wagner et al., 2008; Fig. 2.25).

Lithology and stratigraphy

The Zechstein stratigraphic subdivision for the Polish part of the Permian Basin was developed by Tokarski (1958) and Poborski (1960), and later modified by Wagner et al. (1978; see also: Wagner, 1987, 1988, 1994).

The current Zechstein lithostratigraphy implies the base of the Kupferschiefer to be the base of the Zechstein succession. In the case of the absence of Kupferschiefer, the base of the Zechstein Limestone (Ca1; Wagner et al., 1978) is regarded as the bottom boundary of the Zechstein succession. In the Upper Permian succession, 4 cyclothems are distinguished: PZ1 – PZ2 – PZ3 – PZ4 (Fig. 2.26). PZ1–PZ3 cyclothems are represented by a carbonate-evaporite transgressive-regressive succession (Wagner, 1994; Wagner and Peryt, 1997, 1998). The latest cyclothem PZ4 is composed of terrigenous-evaporite sediments (Fig. 2.26) as a result of periodic climate change from dry to humid conditions (Wagner, 1994). In north-western Poland (including the "Gryfice" tender area), the Rewal Formation marks the Zechstein/Buntsandstein transition (Szyperko-Teller, 1980; Wagner, 1994).

PZ1 cyclothem

The oldest Zechstein deposits correspond to the Kupferschifer (T1; Fig. 2.26; Wagner, 1987, 1994; Wagner and Peryt, 1997). The Kupferschifer is composed of dark grey, horizontally laminated bituminous, calcareous shales with fish remains. The thickness ranges between 0.2 and 0.8 m, rarely exceeding 1.0 m (e.g. Benice 1 and Laska 2 wells). The Kupferschifer (T1) is overlapped by the Zechstein Limestone (Ca1; Fig.2.26). During the sedimentation of the PZ1 cyclothem, the Zechstein Basin reached its greatest extent (Wagner, 1994). Three main palaeogeographic zones are distinguished:

1. marginal part of a carbonate platform,
2. carbonate platform slope,
3. basin plain.

In the "Gryfice" tender area, the deposition of the Zechstein Limestone took place in a basin plain zone (Fig. 2.27). The deposition was controlled by diverse palaeomorphology, and, as a result, carbonate deposits developed on an elevated part of the basin called the Gryfice shoal (Peryt et al., 1978; Wagner, 1987). The lower part of the PZ1 succession is dominated by clayey micrite, whereas in the upper part, microbial deposits, mainly oncoidal with 2 stromatolite horizons, occur. Carbonate deposits (total thickness up to 10 m) of the Zechstein Limestone developed in a photic zone of a shallow basin (Fig. 2.27, 2.27).

The late phase of Zechstein Limestone deposition was marked by an abrupt sea-level fall, which resulted in the emergence of carbonate platforms and basin plains. As a result, sediments deposited on emerged areas underwent intensive diagenetic alteration (Peryt and Piątkowski, 1976, 1977; Peryt, 1984).

The following sea ingression during the late phase of the PZ1 cyclothem resulted in the development of an evaporite sequence in the whole basin, although its extent is smaller than of the Zechstein Limestone. The lower part of the evaporite sequence is represented by the Lower Anhydrite (A1d; Fig. 2.26) deposited during a transgressive event. They exhibit a characteristic transgressive consecution (Wagner, 1994). In the lowest part of the A1d succession, extremely shallow-water anhydrites pass into more deep-water, irregularly bedded anhydrites up to deep-water laminated anhydrites (Kłapciński, 1991). In the "Gryfice" tender area, a sulfate platform occurs in the southern part, which is fringed by a platform border zone. Depending on the palaeogeographic position, the A1d succession thicknesses range from 30 to 70 m in the off-platform zones up to more than 250 m in the platform zones. The Lower Anhydrite (A1d) is overlapped by the Oldest Halite (Na1; Fig. 2.26). In the shallow parts, halite precipitated in local depressions developed due to A1d sedimentation. Anhydrite barriers are regarded as traps preventing brine from outflow from these depressions. This process led to the development of isolated lagoons and salinas (Czapowski, 1983; Czapowski and Tomassi-Morawiec, 1985; Czapowski et al., 1991). Halite is present in all wells that have achieved the oldest cyclothem PZ1. The halite thickness varies from several meters to over 100 m. The youngest part of the PZ1 sequence is represented by the Upper Anhydrite deposits (A1g; Fig. 2.26) reflecting repeated ingressions. The A1g deposits are probably more widespread than the A1d and are characterized by a transgressive sequence (Peryt, 1990). The Upper Anhydrite (A1g) platforms reaching 300 m thickness developed in the transition zone between deep and shallow basins. These platforms are observed e.g. in Pomerania Bay (Wagner, 1987). Some of the A1g is less than 80 m (Laska 2) thick, whereas some reach 240 m (Gryfice 2). These deposits accumulated on a platform area.

At the end of the PZ1 carbonate-sulfate-evaporate deposition, the majority of Ca1 platforms were exposed and affected by erosional and diagenetic alteration. In the remaining part of the basin, the Upper Anhydrite deposition took place on the Lower Anhydrite platforms, and numerous marginal, isolated salinas and open shallow salinas (Wagner, 1994).

The total thickness of the PZ1 cyclothem in the "Gryfice" tender area is substantial and exceeds 300 m (Fig. 2.30). Only in the NW, NE and SW edge, the thickness is less than 300 m (Fig. 2.30).

PZ2 cyclothem

The next Zechstein sea ingression in the Polish part of the Permian Basin led to the accumulation of the Main Dolomite (Ca2). The Main Dolomite (Ca2) succession exhibits transgressive-regressive features (Wagner, 1994). The base of the Upper Anhydrite had a direct influence on the palaeogeographic structure of the Main Dolomite. In the Gryfice tender area, the Kamień Pomorski carbonate platform is a dominant palaeogeographic element (Figs 2.31–2.32). It is composed of a barrier edge zone, low-energy platform plain, and saline lagoon. The south-western and eastern parts of the Gryfice tender area is interpreted to be a carbonate platform slope and a shallower basin plain (Figs 2.31–2.32).

<u>Barrier zone</u>. The Kamień Pomorski outer carbonate platform is composed of high-energy sediments, consisting mainly of oolites and oncoids (Figs 2.31–2.32). Numerous microbial structures developed influenced by hydrodynamic water conditions. A system of barriers developed around almost the whole Kamień Pomorski carbonate platform simultaneously separating its inner lagoon from an open basin (Figs 2.31–2.32).

The thickness of the platform-edge carbonate barrier platform is typically ca. 40 m, although near the Rekowo-Benice area, the thickness of these sediments is/might be greater, e.g. Benice 3 well – 74 m (Fig. 2.31; Tab. 2.1). The platform-edge carbonate barrier deposits have been reached in many wells in the "Gryfice" tender area (e.g. Dusin 1, Gryfice 3, Świerzno 4).

<u>Platform plain zone</u>. In the inner zone of the Kamień Pomorski carbonate platform, an extensive shallow, saline-type lagoon developed (Figs 2.31–2.32). These sediments comprise mainly boundstones and microbial mats with minor oncoid contribution. Concretions and carbonate cements, in some places anhydrite interbeds, are observed. The thickness of the inner zone of the Kamień Pomorski carbonate platform deposits is rather uniform and usually varies between 20 m and 30 m (Fig. 2.31). These deposits have been encountered in sev-

eral wells (e.g. Kamień Pomorski 7, Jarszewo 1; Tab. 2.1).

Carbonate platform slope zone. Beyond the carbonate platform area, the slope facies developed (Figs 2.31–2.32). Slope inclination angles, slope morphology, and sea currents flowing parallel to the slope determined the thickness and facies variability. Slope facies can be subdivided into three main facies zones: upper, middle and lower. The upper slope zone consists mainly of wackestones and irregularly laminated mudstones. Moreover, redeposited high-energy sediments, such as oolite and ooid grainstones, peloids, local breccias and debrites, occur. Middle slope facies accumulated in a mild deposition environment, represented by laminated mudstones and laminated algal boundstones. Greater slope tilting determines slump-and-slide debris flow of variable intensity (from folds to brecciation). Lower slope facies deposits reflect a low-energy environment: bedded mudstones and laminated boundstones.

The lateral extent of the Kamień Pomorski carbonate platform slope is variable in the tender area (Fig. 2.31). The smallest lateral extent is observed in the south-western part of the tender area, where its thickness exceeds 20 m (Rekowo 2 and Rekowo 4 wells; Fig.2.31; Tab.2.1). In the northern part, the thickness is much greater (Strzeżewo 1 well; Tab.2.1) in comparison to the eastern part (Fig.2.31). The widest and thickest carbonate platform slope is located in the southern part of the tender area (Fig.2.31). In this zone thickness of the slope facies deposits can exceed 80 m (Tab.2.1).

Basin plain. The basin plain is characterized by low-energy sedimentation, below the wave base; however, two subfacies may be distinguished depending on the relation to depth during sedimentation, i.e. shallow and deeper ones. The “Gryfice” tender area comprises only shallow facies of the basinal plain (Figs 2.31–2.32), represented by laminated carbonate mudstones, and intercalations of algal boundstones in the lower part. The thickness varies from below 5 m to 10 m (Tab. 2.1).

In the whole “Gryfice” tender area, the Main Dolomite (Ca2) gradually passes into the Basal Anhydrite (A2) deposits (Fig. 2.26) and is represented by laminated and thin-bedded anhydrites (Wagner, 1987; 1994). Carbonate platforms are dominated by shallow-water massive anhydrites, from several meters to 30 m thick (Wagner, 1994), the local thickness may reach 50 m, (near carbonate platform steep slopes Ca2). The thinnest A2 succession is observed in the deep part of the basin, from 2 m to 4 m. The Basal Anhydrite (A2) varies in thickness from 3.5 m (Wrzosowo 3) to 53.0 m (Rekowo 2), and is usually 5–10 m.

The deposition of the Basal Anhydrite (A2) is followed by the Older Halite (Na2), which spans a less extensive area than the Basal Anhydrite. The Na2 sequence accumulated in a shallow-water zone (Czapowski et al., 1991). Post-depositional extensive salt movements, which caused strong deformation, complicated the reconstruction/assessment of its primary thickness (Wagner, 1994).

The thickness of the Na2 succession in the “Gryfice” tender area is usually in the range from 50 m to 150 m. In the Kamień Pomorski 7 well, the Na2 thickness reaches 35.0 m, whereas in the Laska 2 – 784.5 m. In the upper part of the Na2 (Fig. 2.26), shallow-water salinas have formed, and widely distributed potassium and magnesium salts of the Older Potash (K2; Fig. 2.26). The K2 formations consist of a mixture of halite, sylvinite and kieserite. The Older Potash (K2) sediments occur locally in the “Gryfice” tender area, predominantly in its western part. The K2 thickness ranges from 1.5 m (Świerzno 1) to 42.0 m (Rekowo 6).

Thin beds of the Screening Older Halite (Na2r; Fig. 2.26) and the Screening Anhydrite (A2r; Fig. 2.26) end the evaporate sedimentation of the PZ2 cyclothem developed in the shallow-water environment, and its extent is similar to that of the Na2. The Older Potash (K2) is overlain mostly by the Screening Older Halite (Na2r) in the “Gryfice” tender area (Fig. 2.26). The K2 thickness varies from 3.0 m (Jarszewo 1) to 26.5 m (Rekowo 2). The Screening Anhydrite (A2r) was encountered in most of the wells, and its thickness varies from 1 m to more than 5 m. Only in the

Wrzosowo 8 well, the thickness of the A2r largely exceeds 5m. Depending on the location, the Screening Anhydrite (A2r) overlaps the Na2, K2, or Na2r deposits.

According to Wagner (1994): „Extremely shallow-water conditions prevailed during the final phase of the PZ2 basin development. The central part of the basin became the depositional center for halite and potassium salt. Coastal parts of carbonate platforms were exposed, and moderate terrigenous sedimentation continued. Due to extremely arid climate, the sedimentation and erosion processes were rather weak."

The total thickness of the carbonate-evaporite succession of the PZ2 cyclothem in the "Gryfice" tender area is in the range of 100 to 200 m (Fig. 2.32). Only in the south-western part, its thickness exceeds 200 m (Fig. 2.32).

PZ3 cyclothem

Variable palaeorelief of the previous sedimentary cycles was evened by evaporites of the PZ2 cyclothem (Wagner, 1994). Following the transgression, deposition of the third PZ3 cyclothem commenced. The Grey Pelite (T3) is regarded as the lowest member of the PZ3 cyclothem (Fig. 2.26); the thickness of this succession does not exceed 5 m. The T3 deposits are overlain by the Platy Dolomite (Ca3; Fig.2.26), up to a few meters thick, represented by clayey dolomicrites (Wagner, 1990). The upper PZ3 profile is composed of the Main Anhydrite (A3; Fig.2.26) and Younger Halite (Na3; Fig.2.26), locally including the Younger Potash (K3; Fig.2.26). The contribution of terrigenous material in the Na3 sequence is due to climate change from arid into more humid. A gradual palaeoclimatic shift to increasingly humid conditions in the Zechstein basin influenced deposition in the upper part of the PZ3 cyclothem (Wagner, 1994).

The total thickness of the PZ3 succession in the Gryfice tender area varies from 100 m to 200 m (Fig. 2.34).

PZ4 cyclothem

The end of the Na3 deposition was marked by a sea regression that progressively continued during the PZ4 cyclothem deposition (Wagner, 1990). The PZ4 cyclothem was characterized by the progradation of terrigenous deposits towards the evaporitic basin (Wagner, 1994; Wagner and Peryt, 1997). The evaporitic sedimentation of the PZ4 subcyclothems is followed by a gradual shift to terrigenous deposition of the Rewal Formation (Fig. 2.26). This formation (20 to 70 m thick) is represented by red mudstones with numerous anhydrite nodules and sandstone interbeds in the upper part of the formation. The lateral extent of the Rewal Formation is comparable to the maximum reach of the Zechstein basin.

In "Gryfice" tender area, the PZ4 cyclothem thickness usually does not exceed 100 m (Fig. 2.35), except in the south and south-eastern part, where may be between 100 m a 200 m (Fig. 2.35).

Petrography of the Main Dolomite

Petrographic descriptions of the Main Dolomite deposits, included in the final well reports from the 1970s and 1980s, are far from modern standards, e.g. due to lack of information concerning diagenesis or unclear microfacial descriptions. From descriptions presented in the above-mentioned sources it can be concluded that Ca2 deposits from the Kamień Pomorski platform are represented largely by dolomitized ooid/oncoid/peloid grainstones and packstones. In some parts, the important component is microbial deposits. Porosity and permeability are generally poor, which results from the strong cementation (ankerite and dolomite cement). It should be pointed out that many thin sections were made in most wells and they can be used in the petrographic analysis.

Detailed information is available only for three wells: Chomino 1, Benice 3 and Brojce IG-1.

The Chomino 1 well is located at the edge of the oolite-oncoid barrier. According to a short description in the final concession report (Chruścińska and Płatek, 2016), the Ca2 deposits are represented mainly by grainstones, packstones, ooidal and peloidal packstones with bioclasts, and wadoids and intraclasts containing rare microbial laminae. These sediments are characterized by generally very low porosity and permeability. Diagenetic alteration led to a multi-stage development of pore space; moreover, primary structural and textural features were destroyed. Intervals containing granular deposits (grainstones, packstones) are generally characterized by high porosity, whereas in the case of analyzed deposits of the Ca2 intergranular porosity and microporosity are filled with anhydrite cement (Chrościńska and Płatek, 2016). Additionally, halite, dolomite and sellaite cement are observed in the cement. Locally, microporosity may reach 10%, which does not necessarily contribute to an increase in permeability. Permeability improvement is caused solely by microfracturing, which is observed in particular samples.

The Benice 3 well is also drilled within a barrier. The Ca2 is represented mainly by dolomitized grainstones and oolitic packstones (Słowakiewicz et al., 2010; Fig. 2.38.A–B). Biogenic boundstones are rare. They occur only in the middle (boundstones/microbial laminites) and upper (framestones/stromatolites) part of the succession. Floatstones containing granular and biogenic intraclasts of 4–60mm are present in the basal part of the Ca2. Intergranular porosity in these deposits is filled with dolomite (Fig. 2.38.A–B) and anhydrite (Fig. 2.39) cements. Stylolites are present in the Ca2 deposits as a result of chemical compaction (Fig. 2.38.A–B).

Microthermometric studies of fluid inclusions from anhydrite cement showed that mineralized liquids were H_2O-CO_2-NaCl-$CaCl_2$ brines (Słowakiewicz et al., 2010, Słowakiewicz and Poprawa, 2010), crystallization temperatures and pressure were estimated in the range of 94–110ºC and 270–330 bars. Average brine composition yields salinity at 3.9 wt% NaCl equivalent, which implies the formation of anhydrite cement during shallow and middle burial. The formation of anhydrite cement took place in the early Jurassic after dolomitization and migration of hydrocarbon-bearing fluids.

In the Brojce IG-1 well, which is located in the basinal area, three microfacies complexes can be distinguished in the Ca2 deposits (according to Piątkowski, 1986). In the lowest part of the succession (3251.6–3254.0 m) strongly anhydritized laminated dolosparites and dolomicrites (mudstones) are present. Lamination is emphasized by clayey-bituminous substances. Horizontal stylolites were identified in this interval. Similar deposits are present in the topmost part of the succession (3247.0–3247.65 m), which is strongly anhydritized dolomicrites (mudstones), horizontally laminated, containing quartzitic silt. The middle part is composed of a 4 m thick peloid and peloid-bioclastic packstone with a complex of mudstone interbeds.

Mikołajewski and Słowakiewicz (2008) described similar Ca2 deposits in the area of the Grotów Peninsula (southern basin edge). Diagenetic alteration and pore spaces developed during a multi-stage process from depositional-diagenetic to burial phase. Some of the processes contributed to the reduction of the reservoir potential (compaction, cementation) or to its improvement (dissolution, fracturing). Anhydrite and dolomite cementation were the most destructive processes. According to Słowakiewicz et al. (2010), two diagenetic phases affected degradation of the Main Dolomite reservoir properties in the Kamień Pomorski platform. Early diagenesis of barrier deposits (dominated by grainstones and packstones) underwent a minor reduction of primary porosity. Strong degradation of reservoir properties took place during the late diagenesis phase. Diverse cementation processes and chemical compaction were the main cause of the degradation of the reservoir properties. Fracturing and stylolitization may lead to migration of hydrocarbons and mineralizing fluids.

Main Dolomite exploration concept

The Main Dolomite interval in the “Gryfice” tender area is deemed to be fairly or well explored. Most of the wells are located likely among oolite barriers of the carbonate platform edge and in the Trzebieszów – Koplin Graben. 2D and 3D seismic reprocessing of the Main Dolomite horizon based on a processing sequence developed at the Seismic Department of the Oil and Gas Institute – National Research Institute is suggested, as in the case of the Upper Carboniferous and Rotliegend (Bajewski et al., 2019, 2020).

Petrophysical properties of the Main Dolomite are rather unfavorable due to low porosity values and very low permeability. Oolite barriers seem to represent the best collector properties. These deposits have relatively good primary petrophysical properties, and were subjected to subaerial exposition (Peryt et al., 1989). However, later diagenetic processes reduced its collector properties. Microthermal analysis of fluid inclusions in anhydrite cement and burial history studies of the Ca2 deposits from oolite barriers indicate that anhydritization of the carbonate series commenced in the early Jurassic (Słowakiewicz and Poprawa, 2010; Słowakiewicz et al., 2010), after dolomitization and simultaneously during hydrocarbon migration. Nonetheless, an additional and most important factor improving collector properties of the Main Dolomite is the fracture system developed as a result of tectonic activity. The Main Dolomite underwent to some degree disintegration, which enabled development of pore/fracture system due to transtension of the Paleozoic basement and Mesozoic horse-tail trench structures perpendicular to regional dislocation surfaces (Bobek et al., 2021). Among the oolite barrier deposits, which represent the pore-fracture system, the Rekowo field was discovered and documented, which is an analogous exploration concept.

In the oolite barrier rim zone, the least explored area is the Grądy – Rybokarty N – Gryfice, and therefore horizontal directional drilling is suggested to be made. In the case of hydrocarbon presence, greater and more effective flow is expected.

Carbonate platform slope zones in proximity to the Mesozoic trenches seem to be prospective for hydrocarbon exploration. In these zones, the Main Dolomite is characterized by a pore-fracture system and structural-tectonic traps, which are probably associated with transtensional strike-slip movements that led to the Main Dolomite fracturing and development of the formation of Mesozoic trenches. Similar structures occur in the southern part of the tender area, where the Wysoka Kamieńska and Błotno fields of economic value have been found.

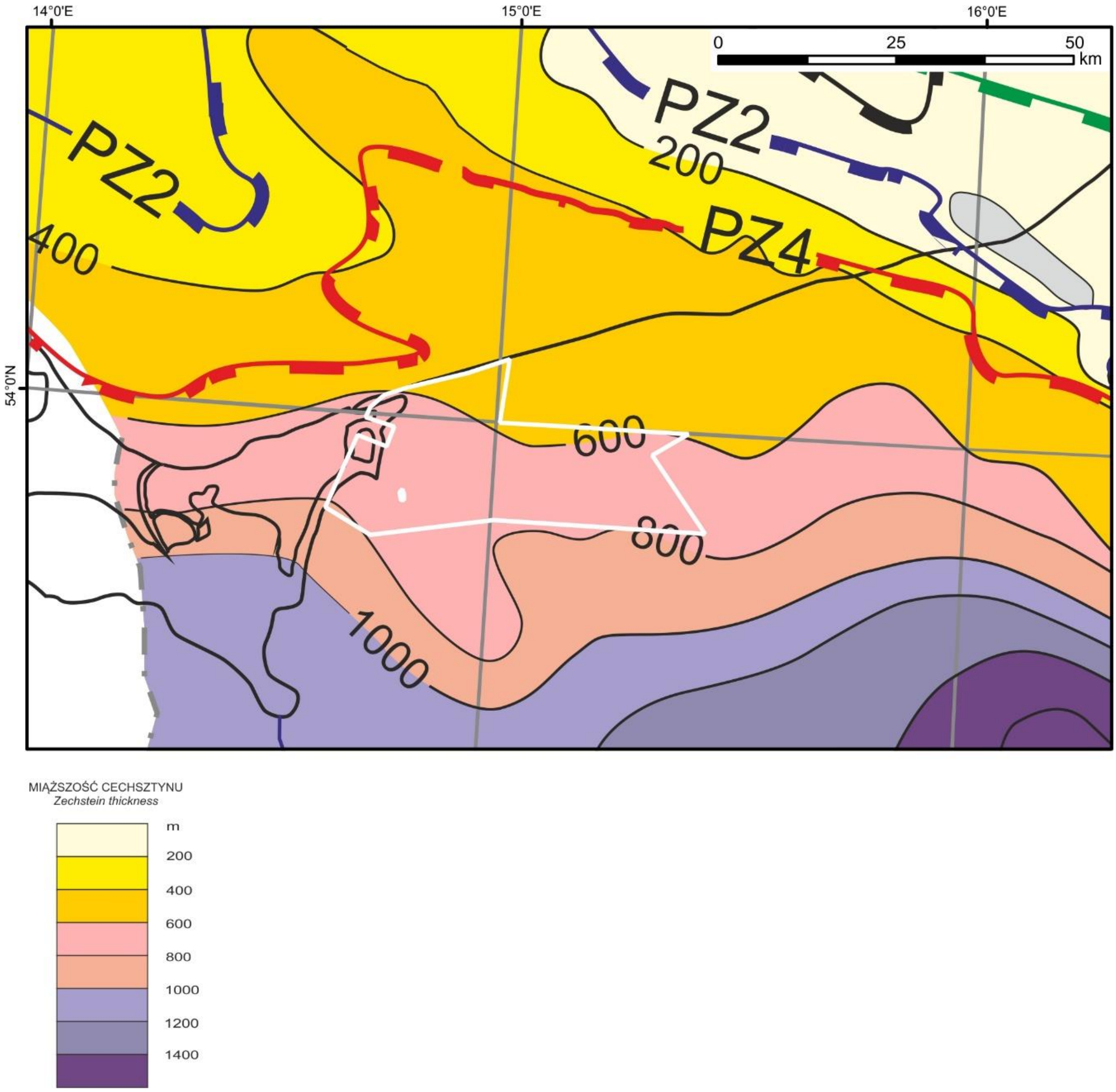


Fig. 2.25. Total thickness of the Zechstein deposits in the "Gryfice" tender area (white line) and adjacent areas (Wagner et al., 2008). PZ2 –Stassfurt cyclothem range (blue line), PZ3 – Leine cyclothem range (green line), PZ4 – Aller cyclothem range (red line).

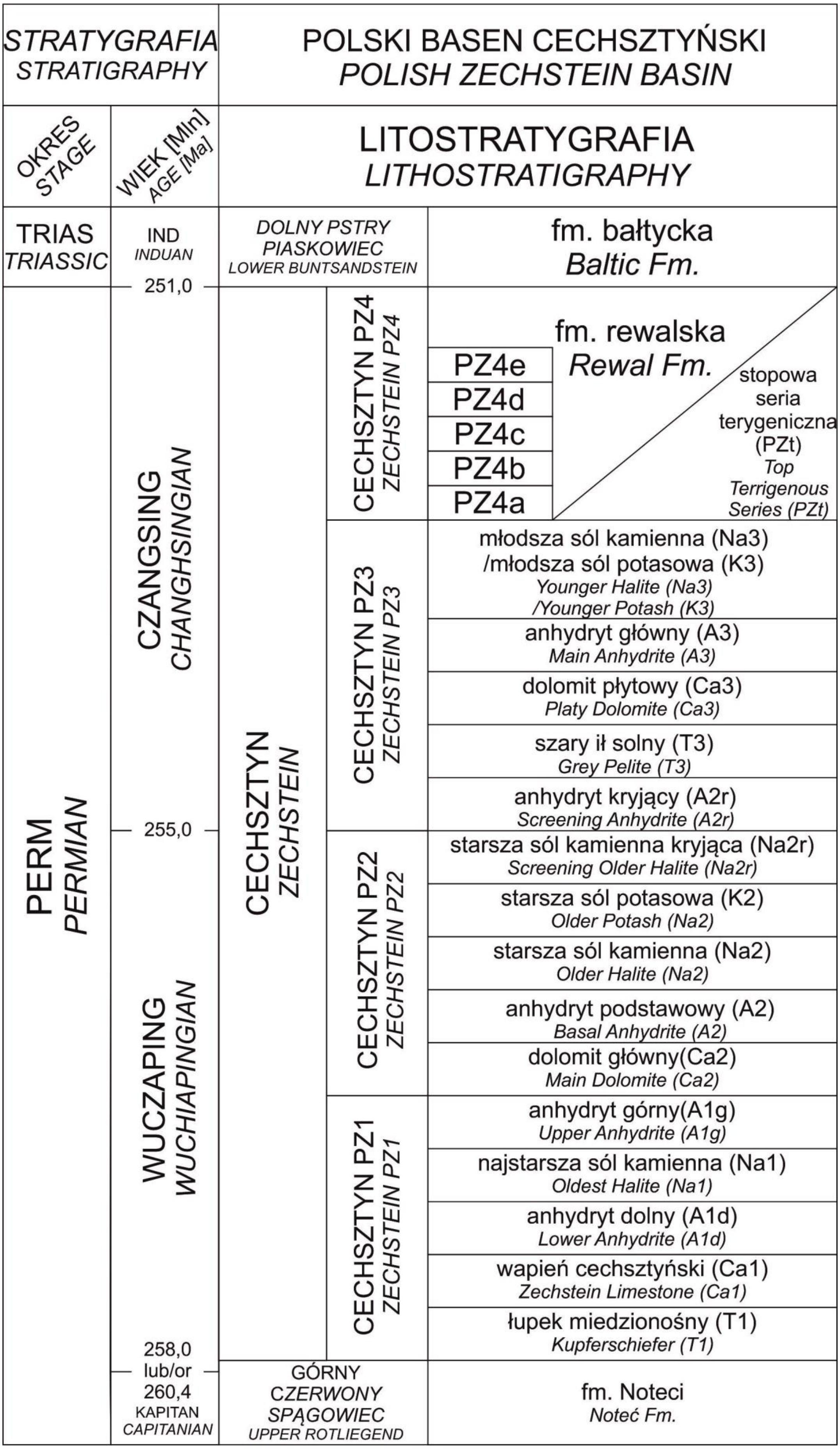


Fig. 2.26. Zechstein stratigraphy in Poland. Lithostratigraphic subdivision is based on Wagner (1987, 1988, 1994; after Słowakiewicz and Mikołajewski, 2009).

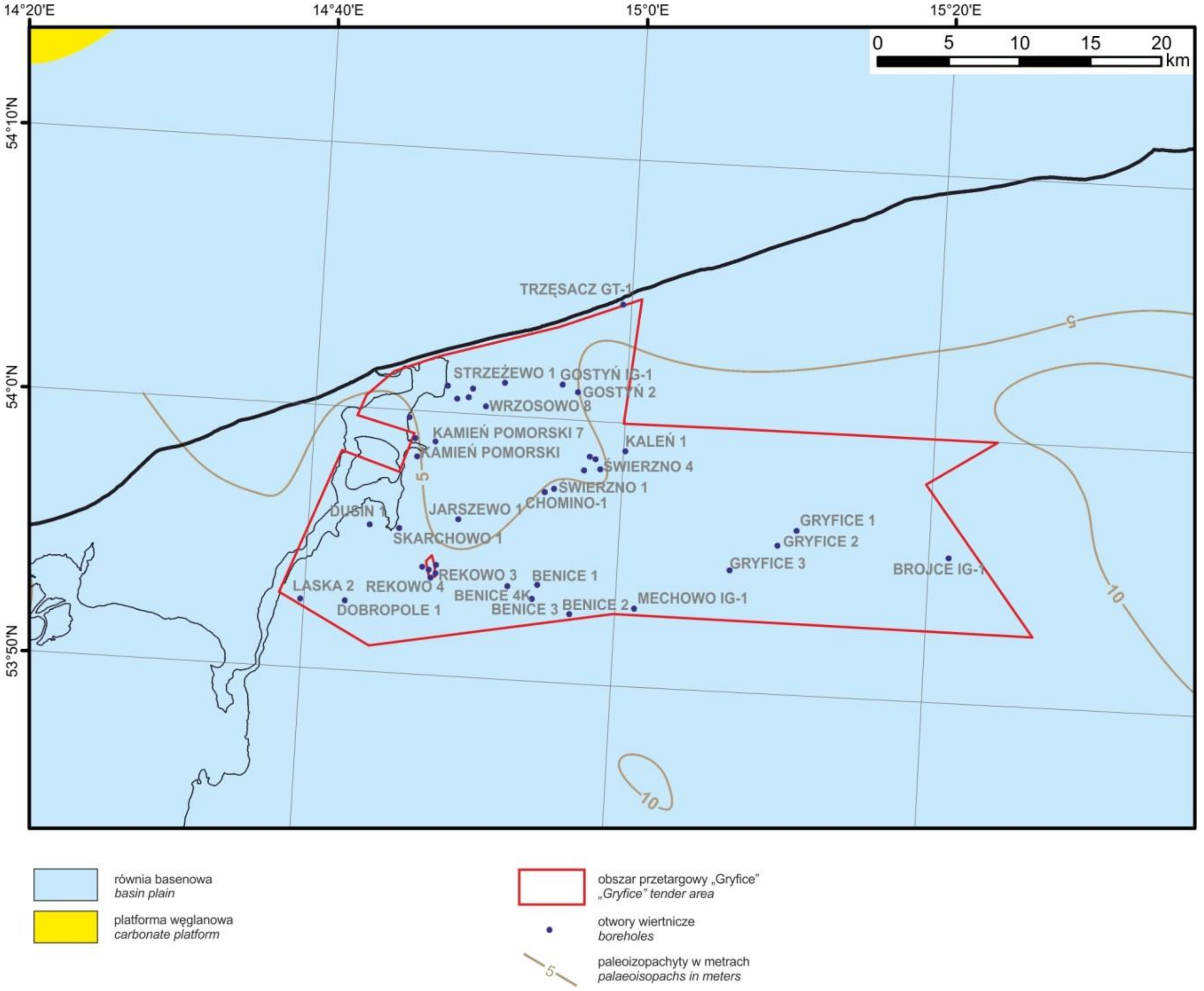


Fig. 2.27. "Gryfice" tender area in relation to the Zechstein Limestone Ca1 palaeogeography and thickness (Buniak et al., 2013a).

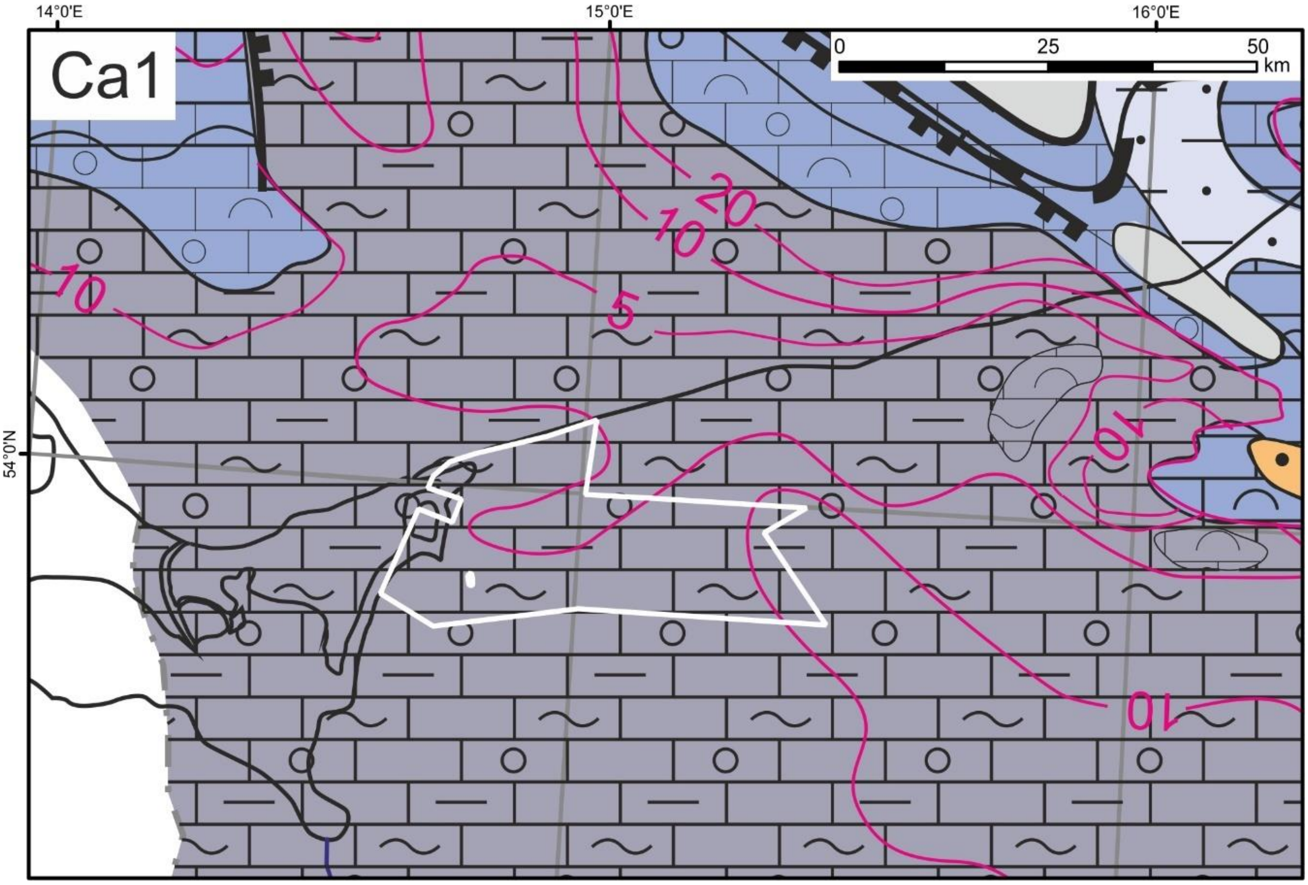


Fig. 2.28. "Gryfice" tender area in relation to the Ca1 palaeogeography and thickness (Wagner, 1998; modified).

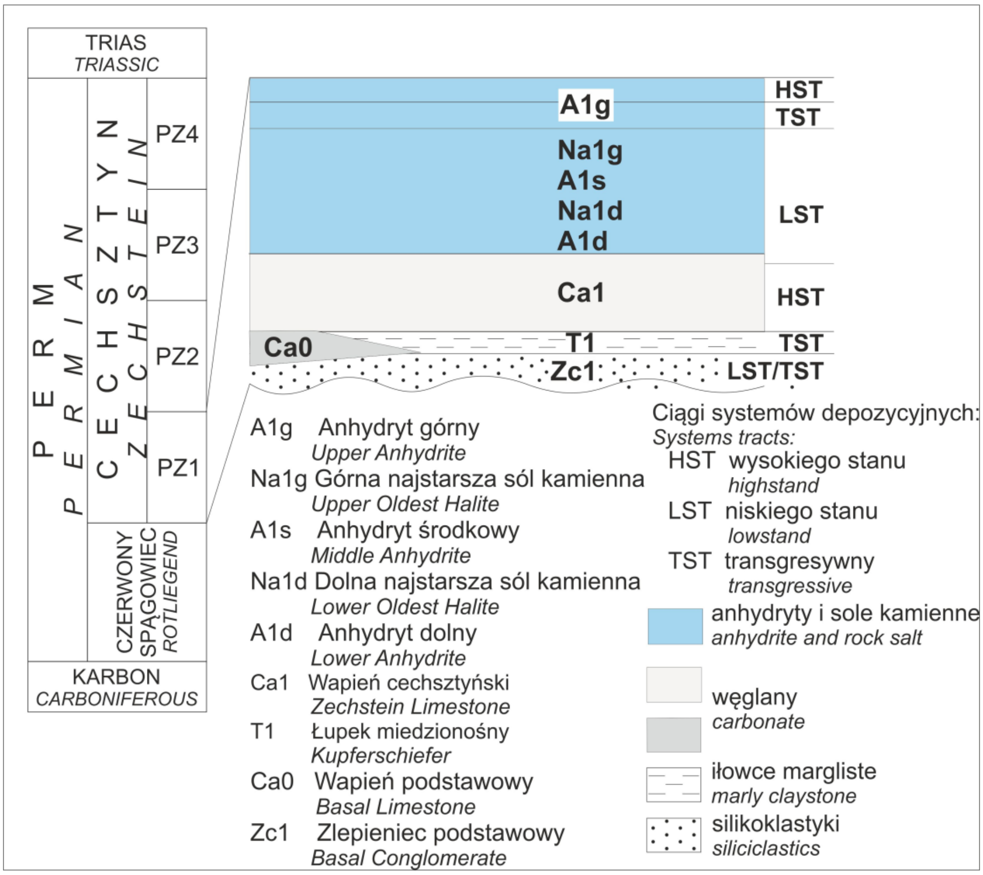


Fig. 2.29. PZ1 cyclothem stratigraphy in the Brandenburg – Wolsztyn – Pogorzela High (Dyjaczyński and Peryt, 2014).

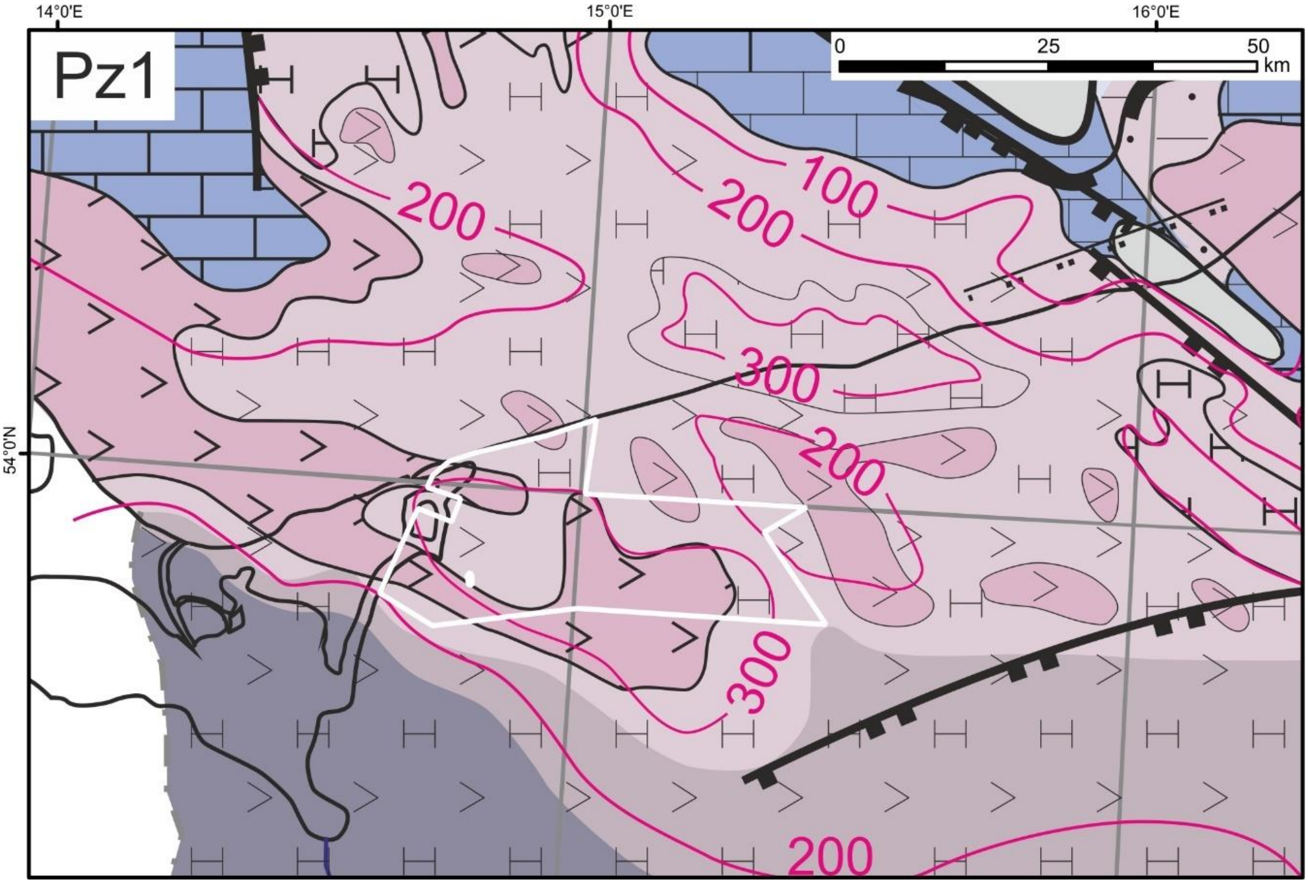


Fig. 2.30. “Gryfice” tender area in relation to the PZ1 palaeogeography and thickness (Wagner, 1998; modified).

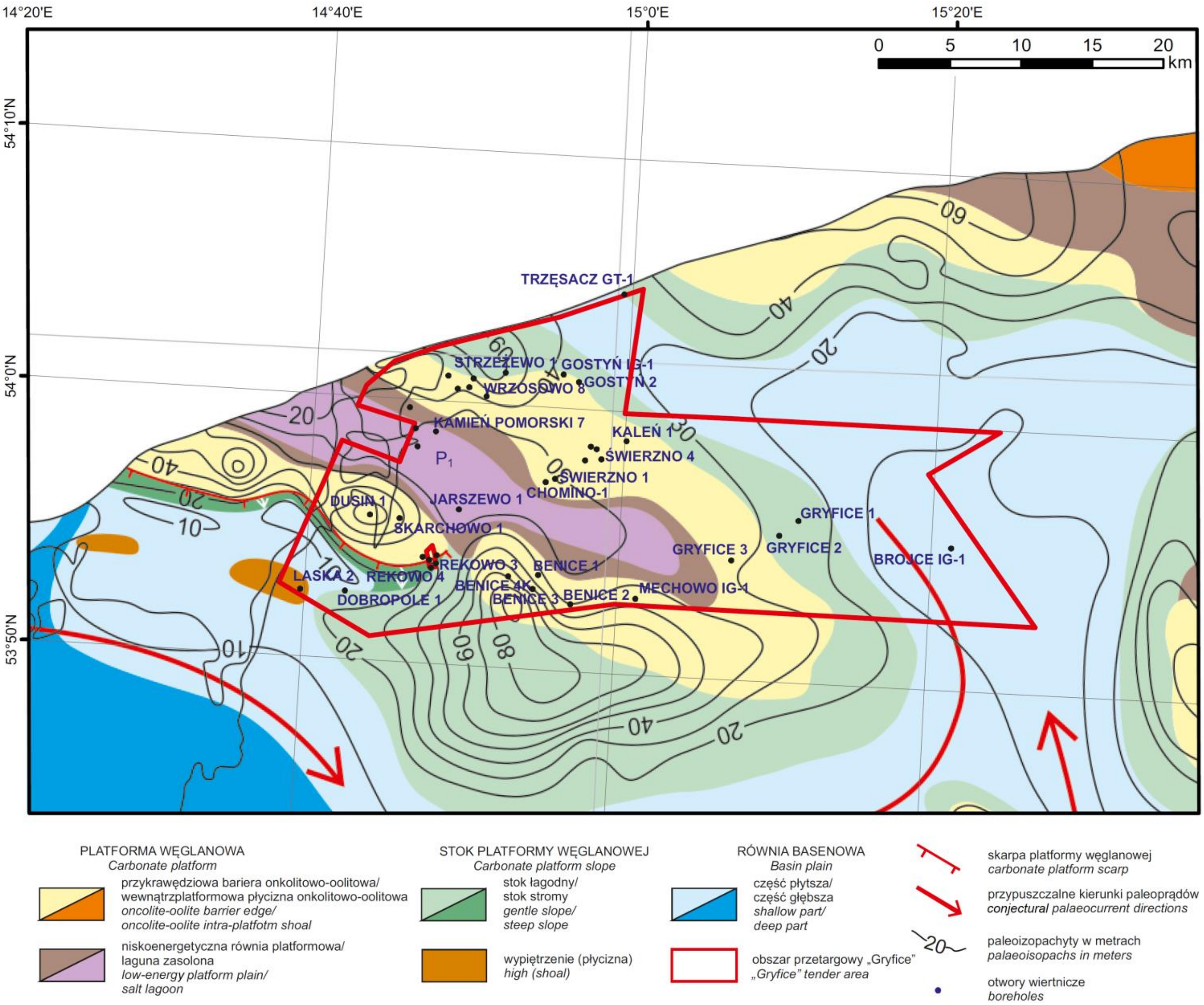


Fig. 2.31. "Gryfice" tender area in relation to the Main Dolomite Ca2 palaeogeography and thickness (Wagner, 2012; modified).

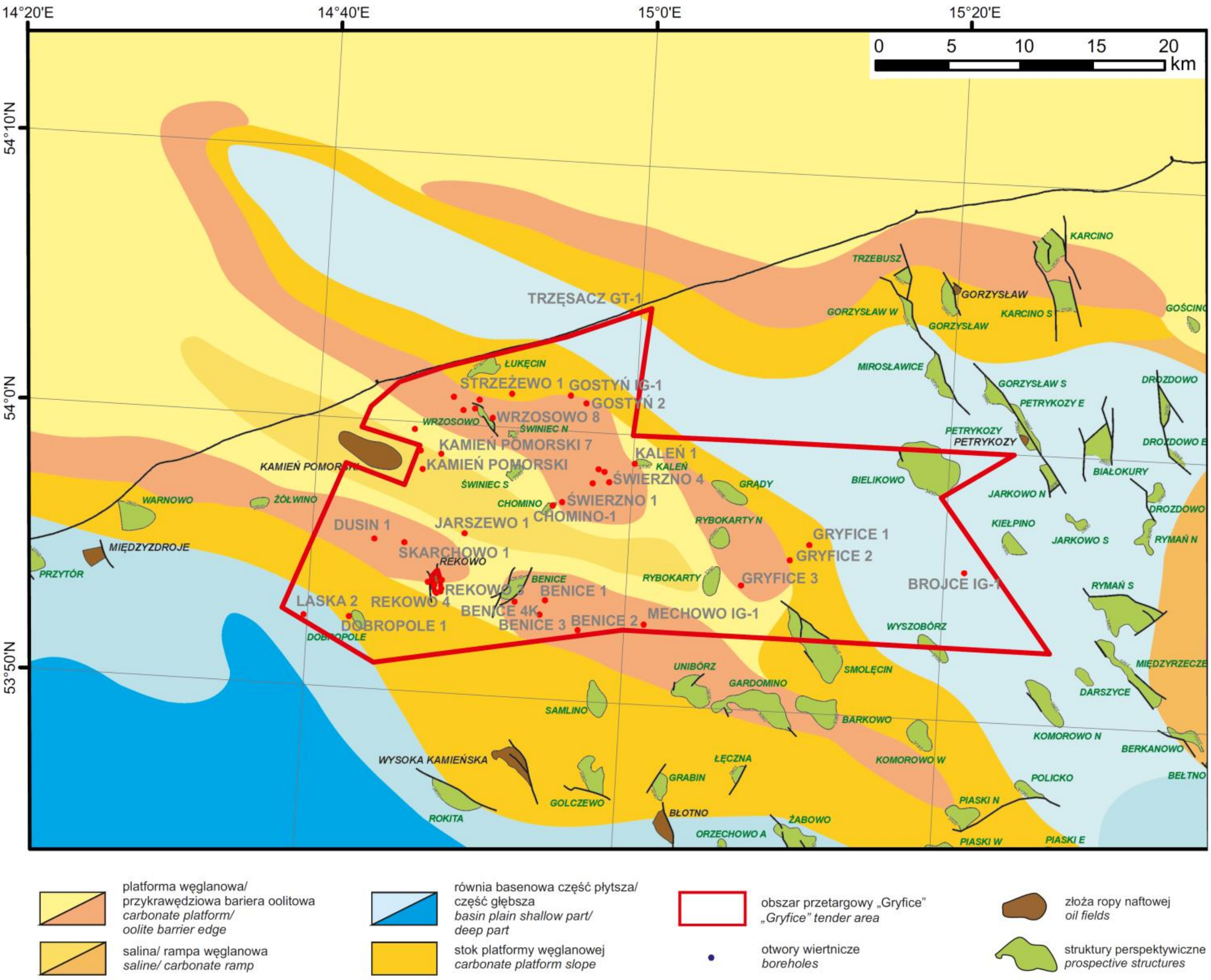


Fig. 2.32. “Gryfice” tender area in relation to the Main Dolomite Ca2 palaeogeography and prospective structures (Buniak et al., 2013b; modified).

Wells	Ca2 top [m]	Ca2 base [m]	Thickness [m]
Benice 1	2739.0	2793.0	54.0
Benice 2	2836.0	2881.0	45.0
Benice 3	2731.0	2805.0	74.0
Benice 4K	2611.5	2688.5	77.0
Brojce IG-1	3235.0	3243.5	8.5
Chomino 1	2685.5	2728.0	39.0
Dobropole 1	2850.5	2868.0	17.5
Dusin 1	2583.5	2643.0	59.5
Gostyń 2	2916.5	2945.5	29.0
Gryfice 1	2984.0	3012.5	28.5
Gryfice 2	3006.0	3035.0	29.0
Gryfice 3	3136.5	3170.0	33.5
Jarszewo 1	2525.0	2548.0	23.0
Kaleń 1	information restricted		
Kamień Pomorski 3	2352.0	2384.0	32.0
Kamień Pomorski 7	2360.0	2390.0	30.0
Kamień Pomorski 13	2326.5	2356.0	29.5
Laska 2	2855.0	2873.0	18.0
Rekowo 1*	2666.0	2667.0	1.0
Rekowo 2	2705.0	2727.0	22.0
Rekowo 3	2645.0	2667.0	22.0

Rekowo 4	2680.0	2710.0	30.0
Rekowo 6	2700.0	2720.0	20.0
Skarchowo 1	2590.0	2647.0	57.0
Strzeżewo 1	2768.0	2823.0	55.0
Świerzno 1	2687.5	2714.5	27.0
Świerzno 2*	2748.0	2772.2	24.2
Świerzno 4	2777.5	2811.5	34.0
Świerzno 5	2840.0	2872.0	32.0
Świerzno 9*	2769.0	2774.7	5.7
Wrzosowo 1	2742.5	2785.0	42.5
Wrzosowo 2	2675.0	2720.0	45.0
Wrzosowo 3	2696.0	2739.0	43.0
Wrzosowo 8	2735.0	2770.0	35.0
Wrzosowo 9	2714.5	2758.0	43.5

Tab. 2.1. Depth and thickness of the Main Dolomite in the analyzed wells. *Main Dolomite not pierced

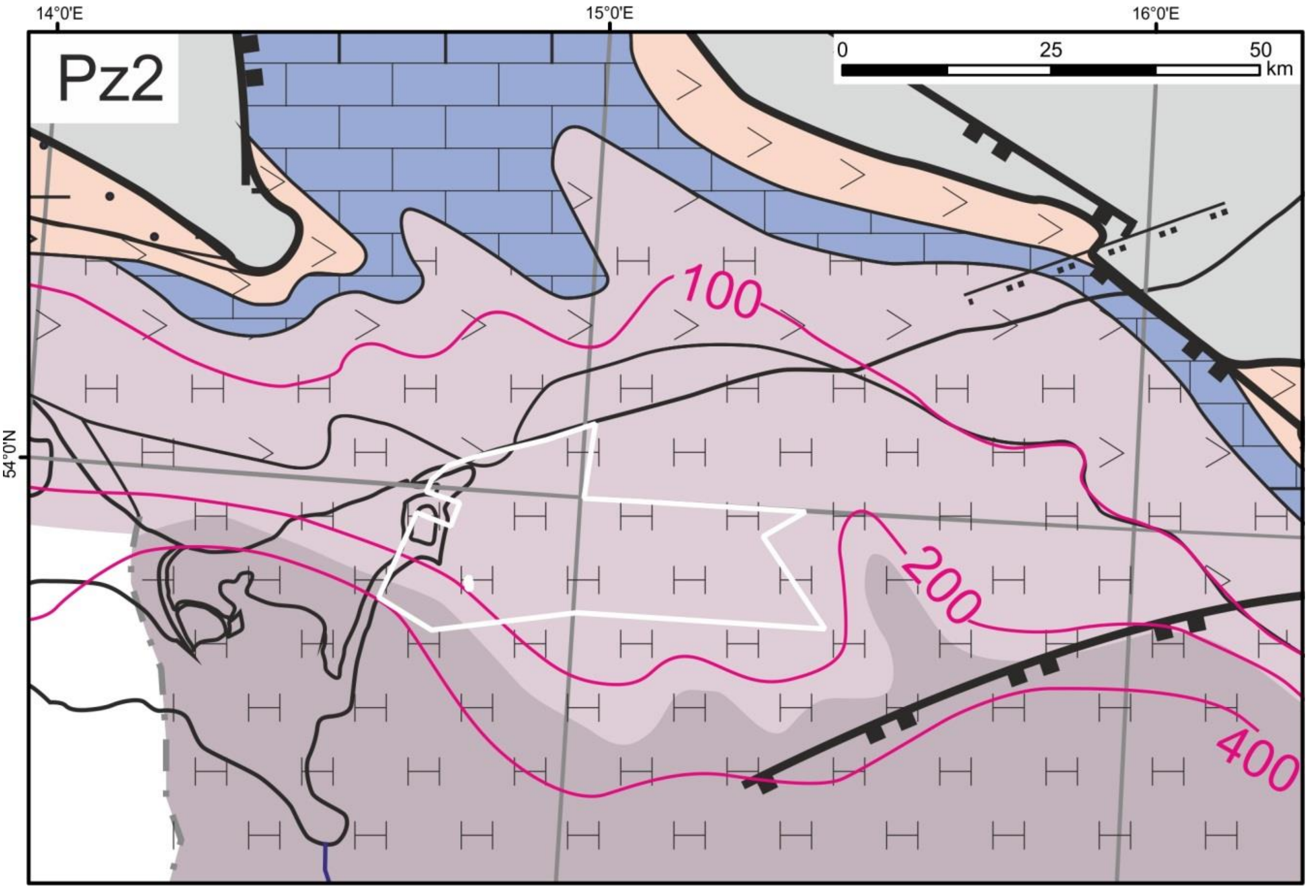


Fig. 2.33. “Gryfice” tender area in relation to the PZ2 palaeogeography and thickness (Wagner, 1998; modified).

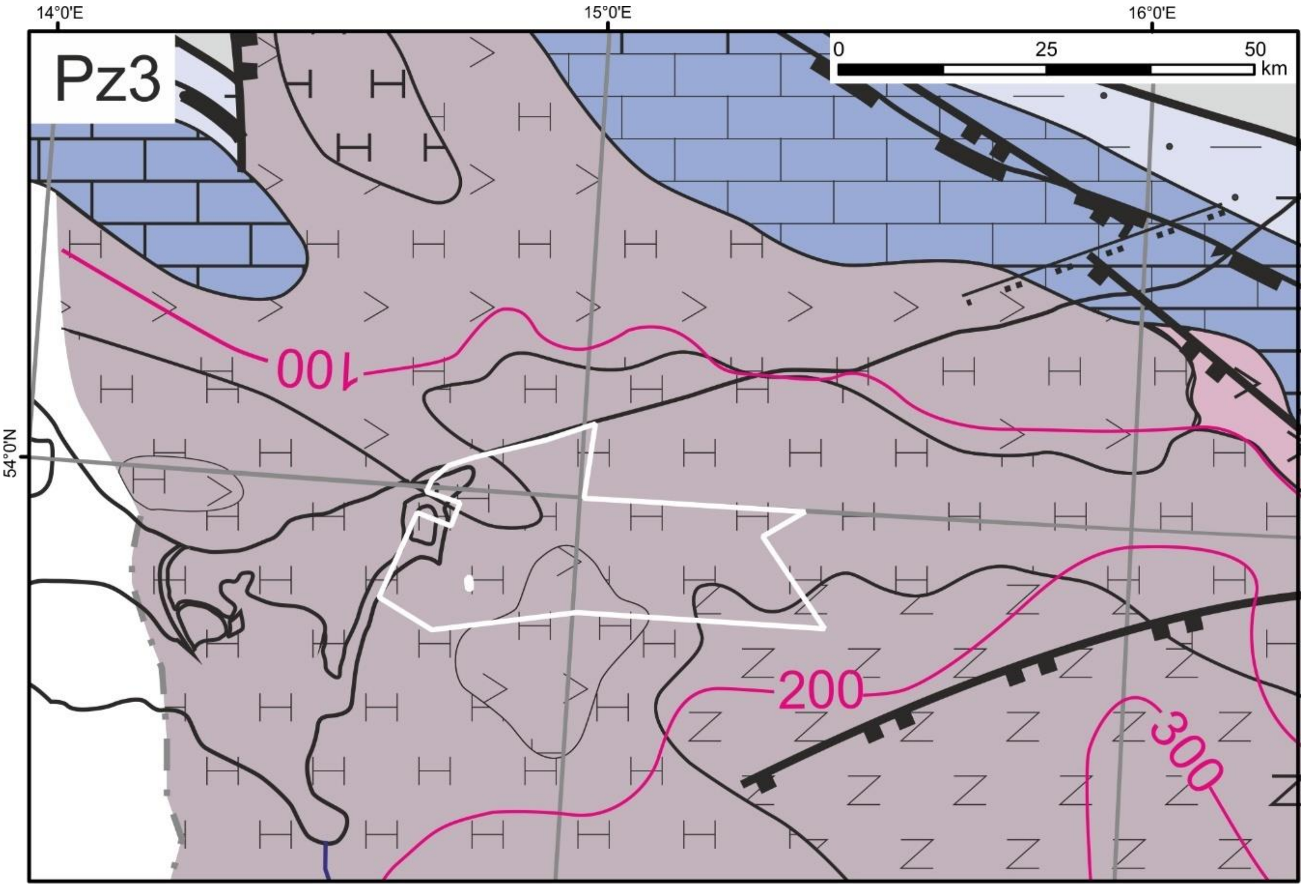


Fig. 2.34. “Gryfice” tender area in relation to the PZ3 palaeogeography and thickness (Wagner, 1998; modified).

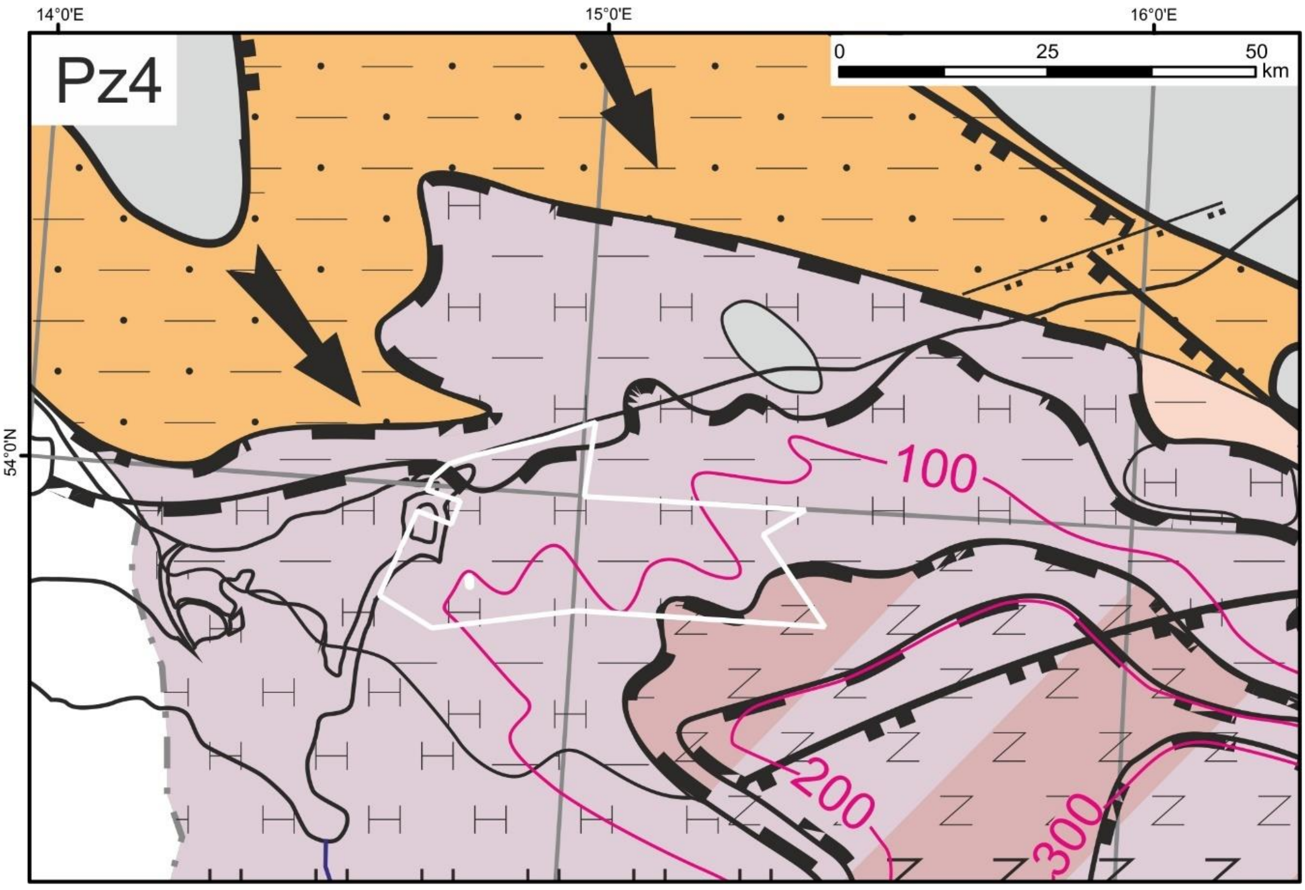


Fig. 2.35. “Gryfice” tender area in relation to the PZ4 palaeogeography and thickness (Wagner, 1998; modified).

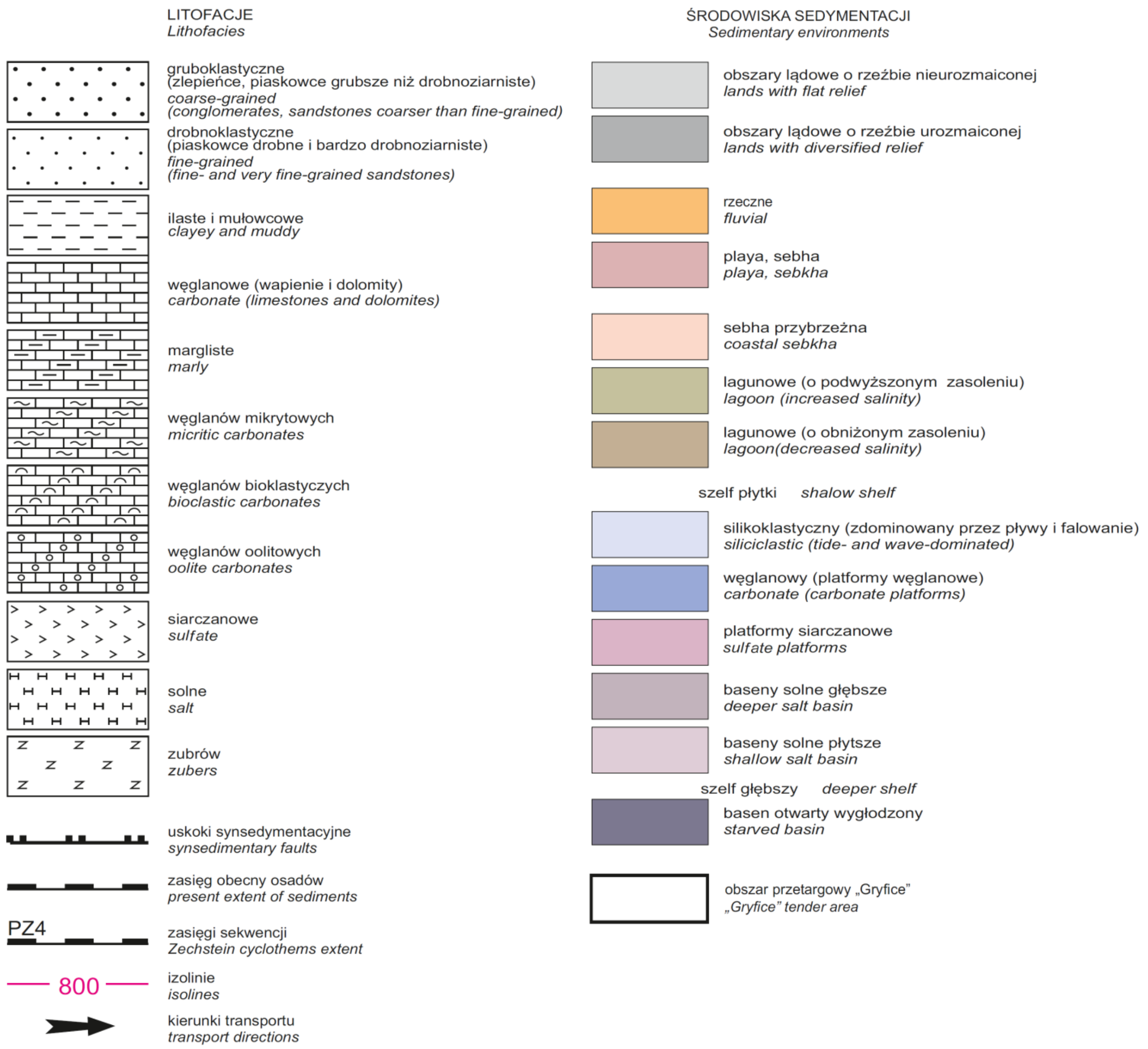


Fig. 2.37. Explanations to palaeogeographic maps (Wagner, 1998; modified).

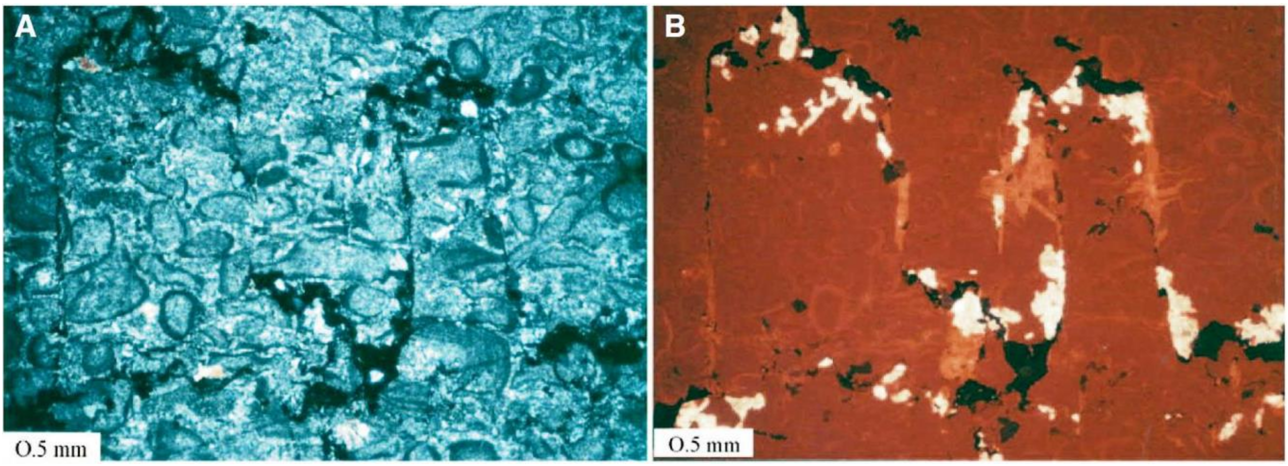


Fig. 2.38. A. Dolomitized oolitic grainstone with stylolite, intergranular pore spaces are filled with dolosparite cement; transmitted light crossed polars. **B.** Sample A – CL image. Stylolite contains: sellaite (light/white luminescence), dolomite (orange luminescence), organic matter (dark luminescence). Benice-3 well, depth 2735.5 m (after: Słowakiewicz et al., 2010).

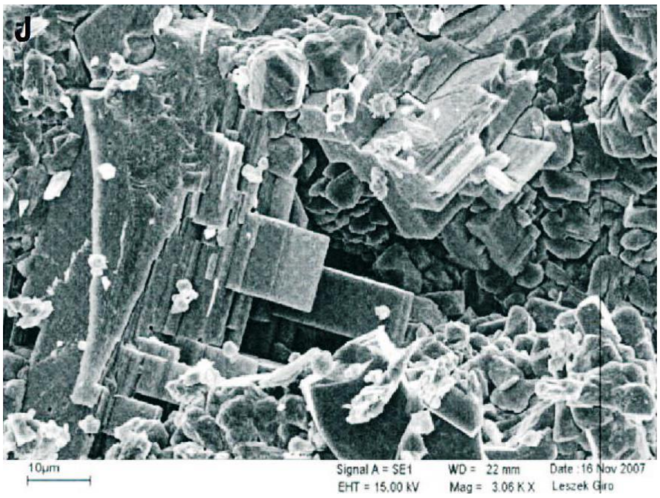


Fig. 2.39. Anhydrite cement, visible intergranular microporosity, SEM image, Benice-2 well, depth 2777.5 m (Słowakiewicz et al., 2010).

2.2.5. TRIASSIC

Extent and thickness

The Triassic deposits were drilled in 36 wells in the "Gryfice" tender area, at depths:

- Benice 1: 1018.0–2374.0 m,
- Benice 2: 1103.0–2504.0 m,
- Benice 3: 1034.0–2367.5 m,
- Benice 4K: 1495.0–2178.0 m,
- Brojce IG-1: 1156.0–2853.0 m,
- Chomino 1: 1055.0–2331.0 m,
- Dobropole 1: 1179.0–2316.0 m,
- Dusin 1: 959.0–2205.0 m,
- Gostyń 2: 1217.0–2578.0 m,
- Gostyń IG-1: 1276.0–2133.4 m,
- Gryfice 1: 954.0–2611.0 m,
- Gryfice 2: 868.0–2512.0 m,
- Gryfice 3: 995.0–2697.0 m,
- Jarszewo 1: 856.0–2165.0 m,
- Kaleń 1: information restricted,
- Kamień Pomorski 3: 655.0–1995.5 m,
- Kamień Pomorski 7: 686.0–2026.0 m,
- Kamień Pomorski 13: 658.0–2034.0 m,
- Laska 2: 1428.0–2067.0 m,
- Mechowo IG-1: 1130.0–1347.0 m, (not pierced)
- Rekowo 1: 917.0–2102.0 m,
- Rekowo 2: 914.0–2126.5 m,
- Rekowo 3: 936.0–2121.5 m,
- Rekowo 4: 936.0–2111.5 m,
- Rekowo 6: 957.0–2035.5 m,
- Skarchowo 1: 890.0–2189.5 m,
- Strzeżewo 1: 930.0–2495.0 m,
- Świerzno 1: 776.0–2300 m,
- Świerzno 2: 819.0–2354.0 m,
- Świerzno 4: 837.0–2338.0 m,
- Świerzno 5: 830.0–2290.0 m,
- Świerzno 9: 815.0–2247.5 m,
- Trzęsacz GT-1: 1208.0–1224.5 m, (not pierced)
- Wrzosowo 1: 840.5–2299.0 m,
- Wrzosowo 2: 820.0–2262.0 m,
- Wrzosowo 3: 817.5–2239.5 m,
- Wrzosowo 8: 852.0–2258.0 m,
- Wrzosowo 9: 811.0–2271.0 m.

The thickness of the Triassic varies from 639.0 m (Laska 2 well) to 1702.0 m (Gryfice 3 well).

Due to the lack of any petroleum potential, the Triassic deposits are not described in detail.

2.2.6. JURASSIC

Extent and thickness

Almost all deep wells located within the "Gryfice" tender area drilled the Jurassic, at depths:

- Benice 1: 28.0–1018.0 m,
- Benice 2: 54.0–1103.0 m,
- Benice 3: 18.0–1034.0 m,
- Benice 4K: 19.5–1504.0 m,
- Brojce IG-1: 31.0–1156.0 m,
- Chomino 1: 46.5–1055.0 m,
- Dobropole 1: 44.5–1179.0 m,
- Dusin 1: 16.0–959.0 m,
- Gostyń 2: 54.0–1217.0 m,
- Gostyń IG-1: 46.0–1276.0 m,
- Gryfice 1: 70.0–954.0 m,
- Gryfice 2: 39.0–868.0 m,
- Gryfice 3: 79.0–995.0 m,
- Jarszewo 1: 35.0–856.0 m,
- Kaleń 1: information restricted,
- Kamień Pomorski: 26.8–580.0 m,
- Kamień Pomorski 3: 40.0–655.0 m,
- Kamień Pomorski 7: 44.0–686.0 m,
- Kamień Pomorski 13: 30.0–658.0 m,
- Laska 2: 104.0–1428.0 m,
- Mechowo IG-1: 120.0–1130.0 m,
- Rekowo 1: 70.0–917.0 m,
- Rekowo 2: 64.0–914.0 m,
- Rekowo 3: 87.0–932.5 m,
- Rekowo 4: 49.5–936.0 m,
- Rekowo 6: 67.0–957.0 m,
- Skarchowo 1: 24.0–890 m,
- Strzeżewo 1: 45.0–930.0 m,
- Świerzno 1: 54.0–776.0 m,
- Świerzno 2: 70.0–819.0 m,
- Świerzno 4: 54.0–837.0 m,
- Świerzno 5: 46.0–830.0 m,
- Świerzno 9: 69.0–815.0 m,
- Trzęsacz GT-1: 94.0–1208.0 m,
- Wrzosowo 1: 55.0–840.5 m,
- Wrzosowo 2: 34.0–820.0 m,
- Wrzosowo 3: 40.0–817.5 m,
- Wrzosowo 8: 52.0–852.0 m,
- Wrzosowo 9: 42.0–811.0 m.

Below the Cenozoic cover, different Jurassic series are present. The Middle occurs in the "Gryfice" tender area, with the NW and SE part dominated by the Lower Jurassic. Upper Jurassic outcrops occur only in the marginal parts of the area. The present geological extent of the Jurassic is an effect of erosional activity during the inversion of the Mid-Polish Through and tectonic movements along the tectonic zones (e.g. Dadlez et al., 2000).

Due to the lack of petroleum potential, the Jurassic deposits are not described in detail.

2.2.7. CRETACEOUS

Extent and thickness

The Cretaceous deposits are present only in the north-eastern and eastern edge of the "Gryfice" tender area, as an isolated depression – the Trzebiatów Syncline. Its north-western limb is steeply inclined, opposite to the south-western limb, which is relatively gentle. The central part of the Trzebiatów Syncline axis strikes NW-SE and is parallel to the central axis of the Mid-Polish Anticlinorium.

In the "Gryfice" tender area, Lower and Upper Cretaceous deposits (46 m thick) were drilled only in the Trzęsacz GT-1 well.

2.2.8. CENOZOIC

Extent and thickness

The Miocene occurs only near Pobierowo, being a fragmentarily preserved Neogene cover developed over the Mesozoic succession (Dobracka et al., 1977), 58.4–89.0 m in thickness.

The Quaternary covers directly the Jurassic and Cretaceous (NE, E part) deposits in the whole tender area. Its total thickness varies from 10.5 m (Dobracka, 2013) to 199.0 m (Dobracka et al., 1977). For more details on the Cenozoic deposits – see the next chapter.

2.3. HYDROGEOLOGY

The "Gryfice" tender area is located in the Lower Oder and Western Pomerania water region and belonging to GWBs 5, 6 and 8. According to the regional classification of fresh groundwater, it is situated in the west sea region of the Coastal Baltic province.

The groundwater system occurs in a multi-level aquifer, within three aquifers: Quaternary, Cretaceous and Jurassic. The Quaternary groundwater level occurs within three levels: unconfined aquifer, upper intertill and lower intertill aquifer. These levels are often discontinuous, layered and lens-like, but the Quaternary groundwater level is of significant utility. The thickness of the Quaternary aquifers is up to 100 m. These are mainly sands of various granulation, and glacial gravel. The Cretaceous groundwater occurs in the south-western slope of the Pomeranian Anticlinorium. Groundwater occurs mainly in carbonate formations. The reservoir rocks of the Jurassic groundwater aquifer are mainly sands and sandstones. Hydrogeological parameters of the Jurassic level depend mainly on the lithology. The permeability coefficient is up to 50 m/d, the water conductivity coefficient is up to 1000 m^2/d.

The water quality is varied in the intakes, but the waters of the Quaternary and Jurassic levels have a similar chemical composition. Good and very good quality waters occurred in the wells capturing the Quaternary upper intertill aquifer and the shallow Jurassic level. This is freshwater of- HCO_3-Ca-Mg type. The Jurassic and Cretaceous groundwater is highly mineralized. Only the groundwater in a close contact and hydraulic connectivity with the Quaternary is freshwater.

The tender area is characterized by an average degree of groundwater hazard. In the "Gryfice" area, the level of groundwater hazard is very high and high. The unconfined Quaternary aquifer is poorly sealed. The second reason for the very high level of groundwater hazard is the ascension of salt waters from the Jurassic aquifer and the ingress of salt waters from the Kamieński Lagoon and the Dziwna Lagoon. Groundwater abstraction shows high annual variability, especially in the coastal zone. In the summer season, the groundwater abstraction is three times greater. Over the years, most of the wells existing in the seaside spa towns, in which each resort usually had its own water intake, were shut down due to very low water quality and often low efficiency. The greatest groundwater abstraction in 2018 took place at the Trzygłowska intake in Gryfice. The groundwater abstraction was ca. 598,000 m^3/y.

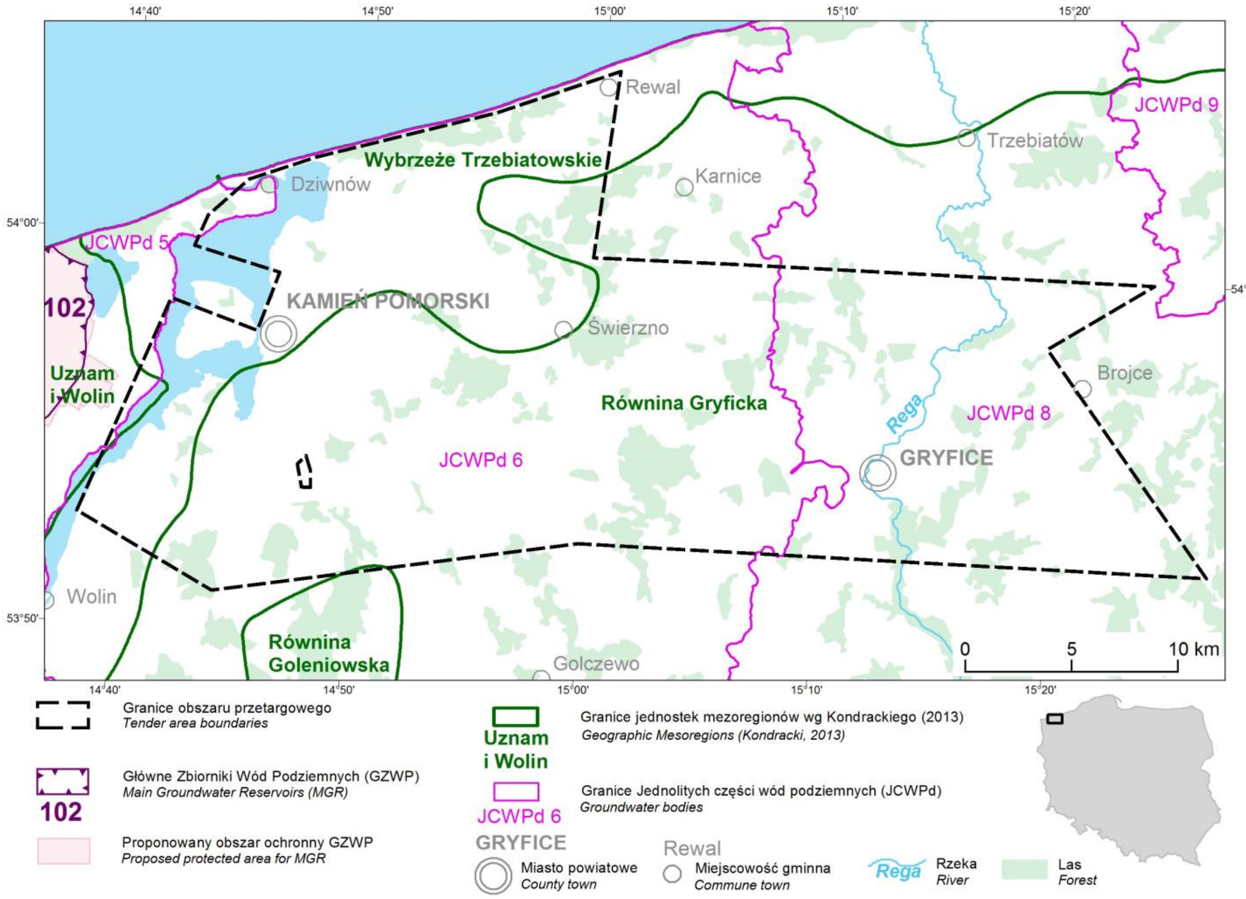


Fig. 2.40. Location of the "Gryfice" tender area on the map of the geographic regions, main groundwater reservoirs, and groundwater bodies.

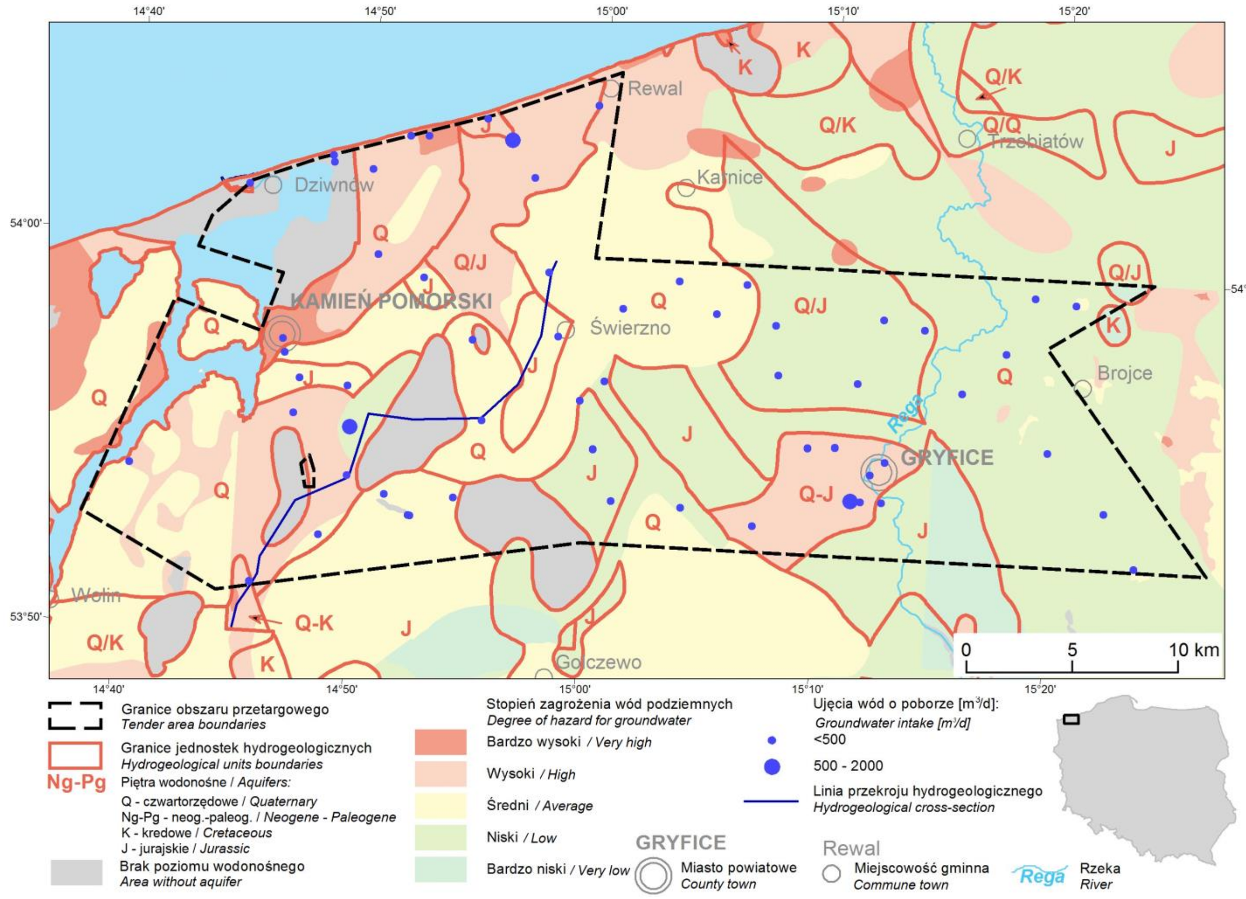


Fig. 2.41. Location of the "Gryfice" tender area in relation to the boundaries of hydrogeological units.

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 the 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 tectonics of the “Gryfice” tender area and petroleum parameters in the individual structural units allows distinguishing two separate petroleum plays within the area. These are:

- Carboniferous – Lower Permian petroleum play,
- Upper Permian/Zechstein – Main Dolomite play.

The main source rocks in the Carboniferous – Lower Permian petroleum play are the Lower Carboniferous deposits (Fig. 3.1). Source rocks of the Upper Carboniferous can have an equally important role (Fig. 3.1), but it depends on its burial depth. The Upper Carboniferous and Upper Rotliegend sandstones are the main reservoir rocks. They are characterized by diverse petrophysical parameters and by frequent hydrocarbon shows (Fig. 3.1). The Zechstein evaporites of the PZ1 cyclothem are the main seal (Fig. 3.1). So far, in the “Gryfice” tender area, one commercial accumulation has been discovered and documented in the Upper Carboniferous formations – Wrzosowo gas field. On the adjacent concession areas, there are a couple of gas deposits documented in the Upper Carboniferous (e.g. Gorzysław, Dargosław) and Upper Rotliegend (Ciechnowo and Sławoborze).

The Main Dolomite is represented by both source rocks and reservoir rocks in the Zechstein petroleum play (Fig. 3.1). Recently, rocks of microbial (cyanobacteria) and algal origin are considered to be the source rocks, and can be developed in two variants: 1) compacted – complexes related to the microbial-algal structures and mudstone layers, 2) dispersed – rocks composed of cyanobacteria laminae that stabilize the grain framework (Słowakiewicz and Gąsiewicz, 2013; Słowakiewicz et al., 2016). Dolomites and limestones are the basic reservoir rocks in the Main Dolomite and they are represented by grainstones and packstones (Fig. 3.1). Many hydrocarbon shows are noted in those levels. Evaporites, which are underlie (cyclothem PZ1) and overlie (cyclothem PZ2) the Main Dolomite form the seal (Fig. 3.1). Numerous oil and gas accumulations have been discovered in the Main Dolomite in the vicinity of the “Gryfice” tender area (e.g. Rekowo, Kamień Pomorski, Wysoka Kamieńska).

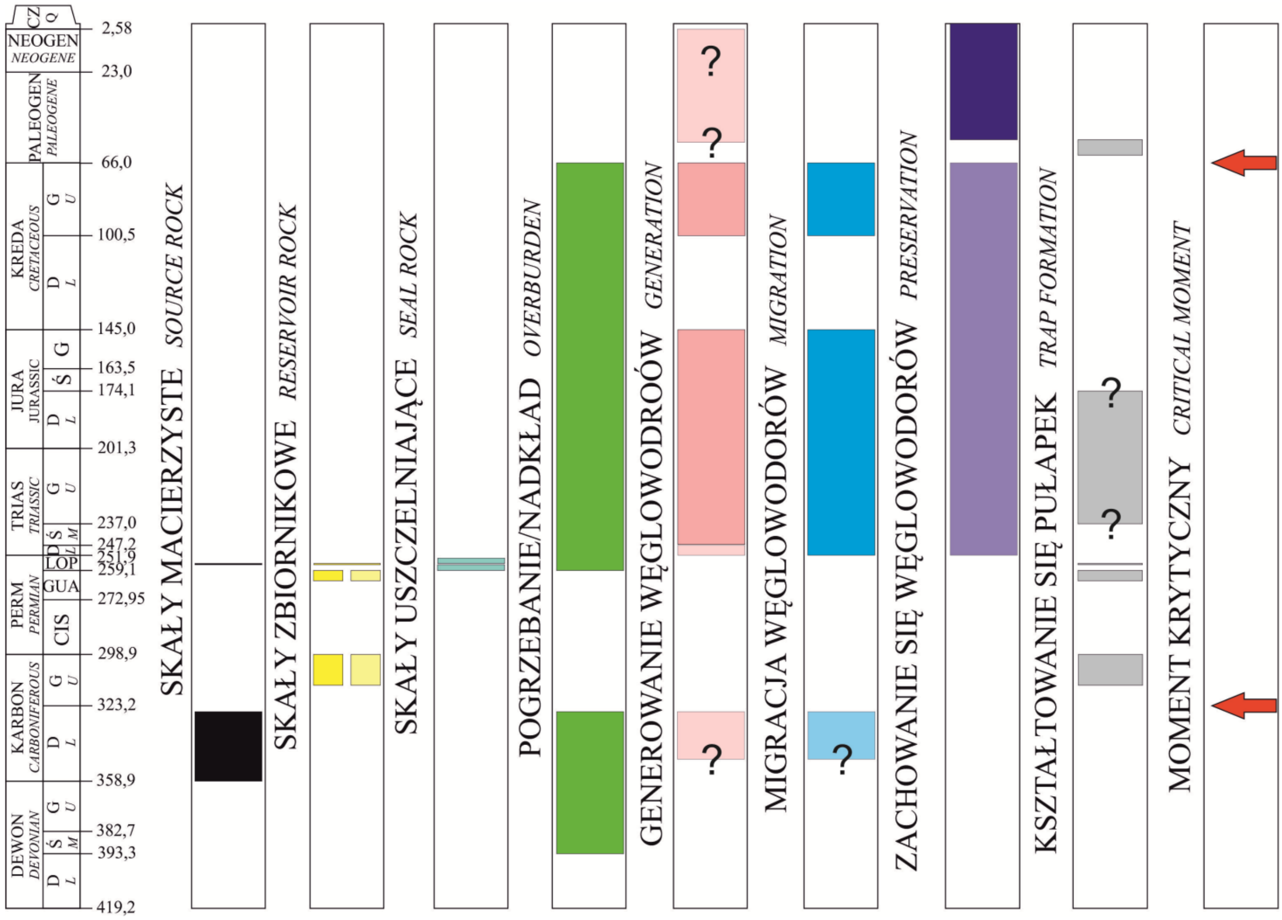


Fig. 3.1. Petroleum play scheme for the "Gryfice" tender area. L – Lower, M – Middle, U – Upper, CIS – Cisuralian, GUA – Guadalupian , LOP – Lopingian, Q – Quaternary; reservoir rocks: normal color – conventional, brightened color – unconventional; other cases: normal color – certain elements of the petroleum play, brightened color – secondary or less certain elements of the petroleum play.

3.2. SOURCE ROCKS

Lower and Upper Carboniferous
Lithology: carbonates, claystones, mudstones

Significant hydrocarbon accumulations discovered in the Carboniferous and Lower Permian of the Western Pomerania reservoir rocks are related to the organic matter dispersed in the Carboniferous carbonate-terrigenous deposits. Analysis of molecular and isotopic gas composition allowed separating products of two individual generation phases (Kotarba et al., 2005). Low-temperature gas was produced from source rocks located 10–20 km from the traps. High-temperature gas was generated from the same kind of organic matter, but it was generated from much deeper rocks, likely from Carboniferous deposits near the Resko – Świdwin fault zone (south of the tender area; Kotarba et al., 2005). In Western Pomerania, the best quality source rocks can be found in the Tournaisian and Visean succession. Some Westphalian and Stephanian horizons also can show some generation potential (Grotek et al., 1998; Kotarba et al., 2004, 2005; Wagner et al., 2008).

Although more than a dozen wells were drilled to the Carboniferous rocks within the tender area, the available results of geochemical analysis of dispersed organic matter are fragmentary. They can be found only in a few wells (Gostyń 2, Kamień Pomorski 7, Laska 2, Strzeżewo 1, Wrzosowo 1, Wrzosowo 2, Wrzosowo 3, Wrzosowo 8, Wrzosowo 9). For this reason, the Carboniferous source rocks were described in a general depiction. It was based on a characteristics of the Western Pomerania Carboniferous organic matter, presented by Wagner et al. (2008 and reference therein). The ranges of maturity parameters for individual Carboniferous levels in the described area are shown in Tab. 3.1.

The total organic carbon (TOC), measured in the Carboniferous deposits of Western Pomerania, varies within a wide range from 0.0 to 10.0 wt%. The highest contents are found in the Tournaisian deposits (TOC median = 0.77 wt%; Tab. 3.1). Over 65% of the analyzed samples surpass the source rock TOC threshold values (carbonate rocks: TOC = 0.3 wt%; clastic rocks: TOC = 0.5 wt%, according to Hunt, 1996). In the Gryfice region, no wells were drilled into the Tournaisian deposits, and the nearest geochemical data were taken from the Kołobrzeg Block. Tournaisian rocks are deposited in the form of alternating carbonates and mudstones. Above-threshold values of TOC are observed, especially within the fine-clastic interbeds. The median of the hydrocarbon generation potential parameter (S2) is very low in those rocks and is 0.51 mg HC/g rock. For this reason, even though the quantitative criterion is fulfilled, the Visean deposits usually show poor (S2 < 2.5 mg HC/g rock; according to Dembicki, 2017) or fair (S2 = 2.5–5.0 mg HC/g rock; according to Dembicki, 2017) hydrocarbon potential. Good, very good, and excellent hydrocarbon potential is observed in individual samples from wells in the Koszalin region.

Values of the TOC parameter in the Visean deposits are 0.0–7.0 wt% (TOC median = 0.59 wt%; Tab. 3.1.). Rock samples that come up to a basic source rock potential criteria derive from wells drilled in the Kołobrzeg Block. TOC contents above 2 wt% are observed sporadically. Higher organic matter content is observed in the Visean clastic-carbonate deposits intercalated with claystone and mudstone, like in the Tournaisian. The Visean succession in the Laska 2 well in the tender area is represented predominantly by red limestones and subordinately by claystones and mudstones (Wójcik, 1980). These rocks are organic matter-lean (TOC < 0.01 wt%) and show no generation potential (Fig. 3.2). In the regional depiction, values of the S2 parameter exceed 2.5 mg HC/g rock only locally. This indicates the poor hydrocarbon potential of these deposits. Increased TOC and S2 parameter values correlate in a few analyzed samples, showing fair or good hydrocarbon potential of some layers of the Visean succession.

The TOC median in the Westphalian is 0.53 wt% (Tab. 3.1). Concentrations over 2 wt% are observed sporadically. Organic matter within the succession is dispersed significantly – rocks rich in organic matter coexist with lean interbeds. The Westphalian deposits in the tender area form a series of clastic rocks. They consist of mudstones and claystones, which are interbedded with sandstones (Ryba and Szewc, 1978a). The TOC content in the Westphalian succession of the Strzeżewo 1 well varies between 0.02 and 0.96 wt% (TOC median = 0.65 wt%; Fig. 3.2). Most of the investigated Westphalian samples from the northern region meet the basic criteria for clastic source rocks, but there was no sample of medium and better quality source rocks in which the generation potential exceeded the threshold value.

The studied Stephanian succession is very poor in organic matter. The median of total organic carbon values is 0.01 wt%, although the organic carbon content in the succession ranges between 0.0 and 3.0 wt% (Tab. 3.1). The discussed deposits were investigated in few wells in the tender area (Gostyń 2, Kamień Pomorski 7, Strzeżewo 1, Wrzosowo 2, Wrzosowo 3, Wrzosowo 8 and Wrzosowo 9). The presence of horizons containing >0.5 wt% TOC was observed solely in the Wrzosowo 2 and Wrzosowo 8 wells (Fig. 3.2).

The organic matter dispersed in the Carboniferous deposits of the Western Pomerania region was characterized based on pyrolytic investigations (Tab. 3.1), isotope analysis, biomarker analysis, and petrological observations. The gas-prone, type III kerogen is the dominant type of kerogen in all of the investigated horizons (median HI = 42–91 mg HC/g TOC; Tab. 3.1; Kotarba et al., 2004; Wagner et al., 2008). Marine organic matter is an important component of the Lower Carboniferous deposits (Tournaisian, Visean) as well. Therefore, it is classified as a mixed type III/II kerogen that was deposited under reducing environmental conditions (pristane/phytane < 1). The predominance of macerals from the vitrinite group and a secondary input from liptinite group macerals indicate that the organic matter is mainly gas-prone. Maceral composition suggests the exclusive occurrence of type III kerogen in the Upper Carboniferous deposits (Westphalian and Stephanian). Conditions prevalent in the depositional environment were most likely slightly oxidizing (pristane/phytane = 1; Matyasik, 1998; Kotarba et al., 2004; Wagner et al., 2008).

The group composition of bitumen extracted from the Carboniferous rocks shows the prevalence of non-hydrocarbon components (resins and asphaltenes) relative to hydrocarbon components (saturated and aromatic hydrocarbons). In hydrocarbons of most samples, the aromatic fraction is dominant. Low values of the oil saturation index (OSI; Tab.3.1) show that the extracted bitumen is syngenetic with the sediments. The presence of migrated hydrocarbons (OSI > 100mg HC/g TOC) is local and limited to several samples from the Tournaisian rocks (in Białogard 10, Bielica 1, Dygowo 1, Dźwirzyno 3 and Gozd 4 wells; Wagner et al., 2008).

The organic matter dispersed within the entire Carboniferous rock complex of Western Pomerania is in a wide range of thermal maturity, between the early stages of catagenesis and the gas window, and locally even metagenesis (Tmax = 403–490ºC; Tab. 3.1). The degree of thermal maturity increases with burial depth to the N (Figs 3.3–3.4; Wagner et al., 2008). The Visean rocks of this region have the lowest thermal maturity, which corresponds with the early and middle stages of the oil window (Ro = 0.5–1.1%). The Westphalian deposits fall within the range of the entire oil window (Ro = 0.5–1.35%). Maturity at the gas window stage can be found in Carboniferous organic matter from the Kołobrzeg region. The highest maturity in the succession is observed in the Stephanian rocks. The thermal maturity of those rocks ranges from the middle to late oil window (Ro = 0.8–1.35%). Locally, in the vicinity of Kamień Pomorski, thermal maturity reaches the phase of high-temperature methane generation (metagenesis, Grotek et al., 1998; Kotarba et al., 2005; Wagner et al., 2008 and reference therein).

A limited number of wells that drilled through the Carboniferous and unrepresentative well testing prevent unequivocal interpretation of source rocks in Western Pomerania. Claystones and mudstones, which form interbeddings in the Lower Carboniferous, show the best values of source rock parameters. Those rocks are the most probable source of gas accumulated in the Carboniferous – Lower Permian complex. Despite the presence of organic matter-rich layers, the low S2 parameter values indicate that most of the Carboniferous rocks have poor or fair hydrocarbon potential. Source rocks with good, very good, or excellent quality are observed in individual layers of the Tournaisian and Visean succession. The best source rocks are found in the Koszalin – Wierzchowo – Kołobrzeg region (Wagner et al., 2008). Due to the predominance of type III kerogen, the rocks are mainly gas-prone. However, certain volumes of oil could have been generated because of the addition of type II kerogen (Kotarba et al., 2004, 2005; Wagner et al., 2008).

Parameters of source rocks	Lower Carboniferous		Upper Carboniferous	
	Tournaisian	Visean	Westphalian	Stephanian
TOC [wt%]	0.00–10.66 (~0.77)	0.00–7.05 (~0.59)	0.00–5.10 (~0.53)	0.00–3.03 (~0.01)
T_{max} [°C]	408–490 (~433)	403–453 (~431)	423–457 (~427)	425–452 (~428)
S1 [mg HC/g rock]	0.00–2.93 (~0.07)	0.00–1.50 (~0.10)	0.00–0.27 (~0.07)	0.00–0.52 (~0.05)
S2 [mg HC/g rock]	0.00–32.84 (~0.51)	0.09–8.14 (~0.58)	0.04–1.88 (~0.42)	0.09–5.29 (~0.41)
HI [mg HC/gTOC]	13–526 (~72)	11–464 (~91)	8–91 (~65)	24–175 (~42)
OSI [mg HC/gTOC]	0–138 (~9)	0–82 (~15)	0–23 (~2)	0–17 (~0)
PI	0.00–0.40 (~0.10)	0.00–0.58 (~0.15)	0.00–0.20 (~0.13)	0.05–0.15 (~0.13)
Kerogen type	III/II	III/II	III	III

Tab. 3.1. Source rocks parameters of the Western Pomerania Carboniferous deposits (Wagner et al., 2008 and references therein).

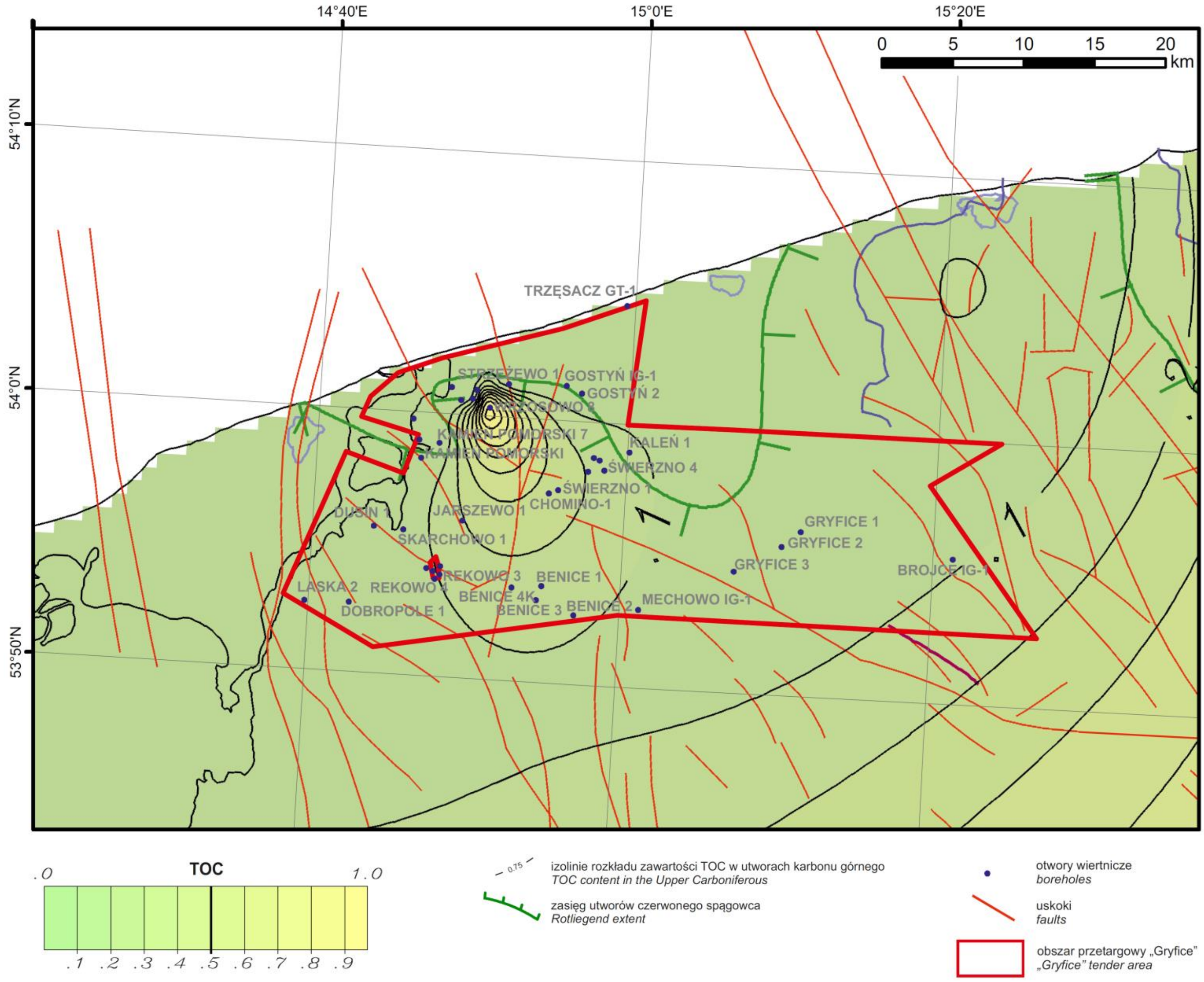


Fig. 3.2. Map of the TOC distribution at the top of the Upper Carboniferous deposits. Location of the “Gryfice” tender area is shown (Wagner et al., 2008; modified).

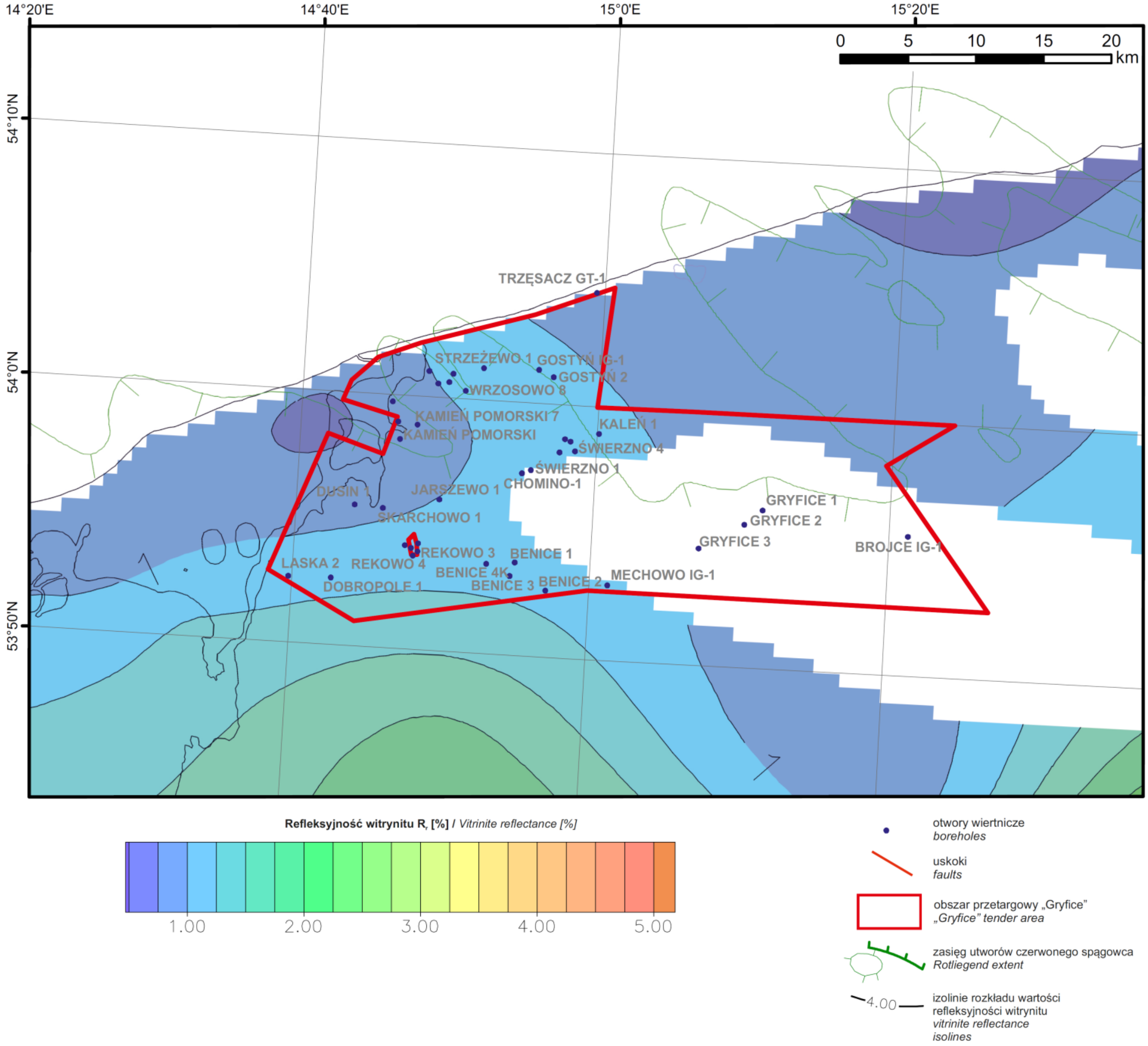


Fig. 3.3. Vitrinite reflectance map at the bottom of the Carboniferous. Location of the “Gryfice” tender area is shown (Wagner et al., 2008; modified).

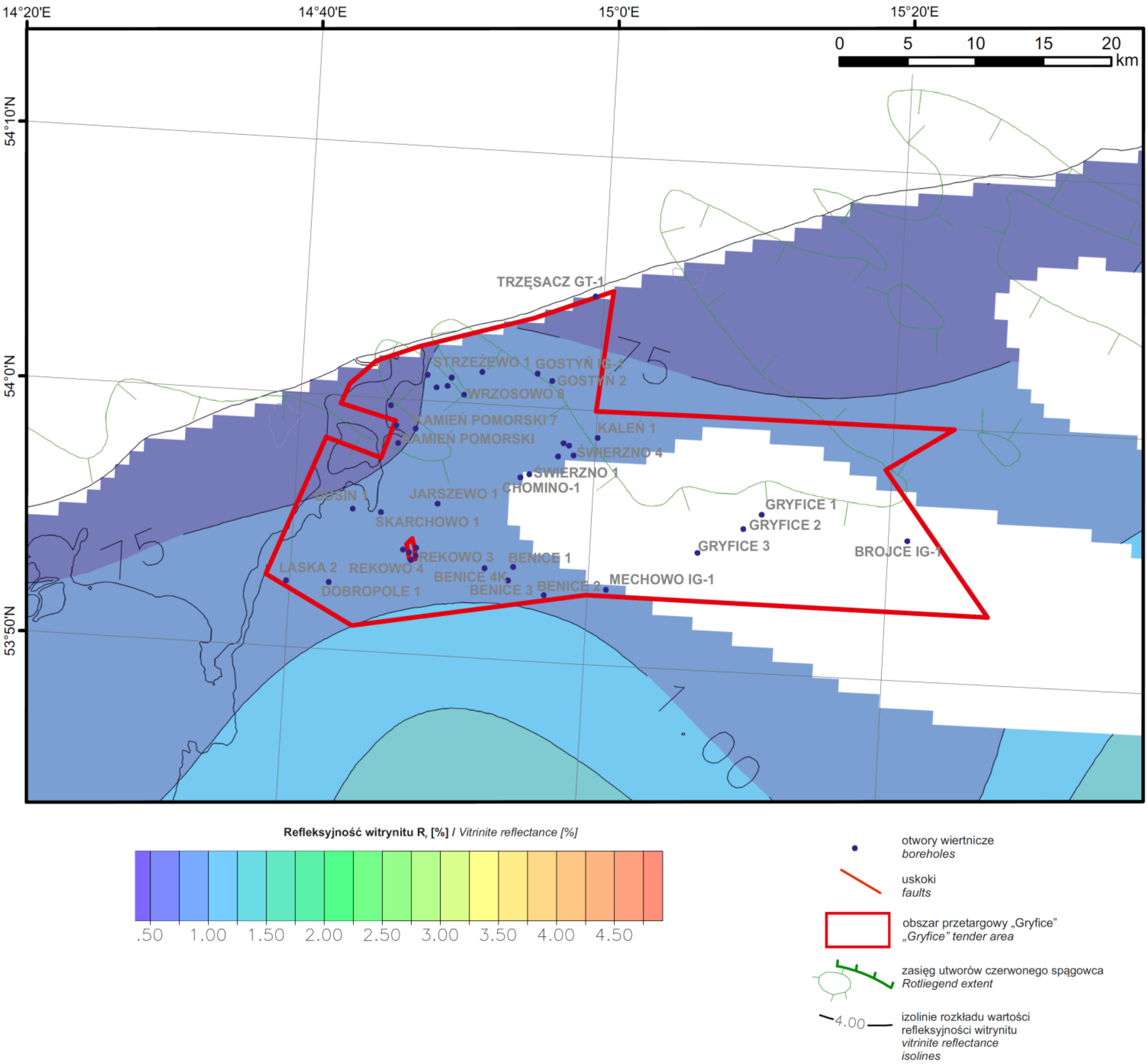


Fig. 3.4. Vitrinite reflectance map at the top of the Carboniferous. Location of the “Gryfice” tender area is shown (Wagner et al., 2008; modified).

Main Dolomite (Ca2)
Lithology: mudstones, grainstones, boundstones

The basin plain bay and shallow-water basin plain deposits are the most promising potential source rocks in the Main Dolomite play (Kotarba et al., 2003; Kosakowski et al., 2003). The tender area covers mainly the Kamień Pomorski carbonate platform and part of the Rewal bay (Wagner, 1990; Zych, 2005). To the west, it also reaches the area of the shallow basin plain of the middle part of the Main Dolomite basin (Figs 2.31–2.32).

Geochemical analysis of the organic matter from 56 Main Dolomite samples in the Kamień Pomorski Zone (Kotarba et al.. 2003; Tab. 3.2) allowed considering the mudstones of the northern and central part of the plain bay (the Rewal bay) as rocks with the most advantageous source rock parameters. The TOC content in the range from 0.01 to 5.8 wt% was claimed in one well that drilled the Rewal bay (Brojce IG-1). More than half of the tested samples fulfill the criteria for carbonate source rocks (TOC >0.3 wt%). Shallow part of basinal plain deposits of the Laska 2 well contain a small amount of organic matter (TOC = 0.01–

2 wt%; Tab. 3.2), and values below 0.3 wt% are predominant. The best source rocks in the described palaeogeographical region are observed in the mudstones from the Międzyzdroje and Wapnica areas. Microfacies and geochemical analysis of the carbonate platform slope (in the Gryfice 1, 2, Rekowo 4 and Dobrepole 1 wells) show that mudstones containing 0.0 to 1.36 wt% TOC (Tab. 3.2) are the dominant lithological type, but most samples from these rocks do not exceed the threshold TOC values for source rocks. The best source rock parameters in the slope area are found in the Strzeżewo 1 well (northern part of the tender area). Three smaller zones are separated in the carbonate platform area: the marginal oolitic barrier, salina, and a proper carbonate platform (Figs 2.31–2.32). The lithologies of the marginal oolitic barrier (in the Benice 1, 2, 3, 4K, Dusin 1, Gryfice 3, Skarchowo 1, Strzeżewo 1, Świerzno 4, 5, Wrzosowo 1, and 8 wells) and lagoons (Jarszewo 1 and Kamień Pomorski 7 wells) are represented mainly by grainstones and boundstones (Fig. 3.5). Values of the TOC parameter in the barrier zone oscillate between 0.0 and 1.2 wt% (Tab. 3.2), but are mostly below 0.3 wt%. Quantitative and qualitative source criteria (S2 >2.5 mg HC/g rock) are satisfied by some Main Dolomite horizons in the Wrzosowo 8 and Strzeżewo 1 wells (Fig. 3.5). Organic matter content in the salina deposits does not exceed the boundary value at any examined point, which is likely related to the depletion of the primary hydrocarbon potential of kerogen in those rocks (Kotarba et al., 2003). According to Kosakowski et al. (2003), the initial average TOC content of salina deposits was about 0.4 wt%, and kerogen fulfilled 70% of its generation potential due to the high degree of source rocks transformation (Kamień Pomorski 7). Marginal oolitic barrier deposits show a similar or higher degree of thermal alteration (Strzeżewo 1, Laska 2, Wrzosowo 8). The initial average TOC content could have been up to 1 wt% of the rock. Source rocks of the carbonate platform were analyzed using core material from the Chomino 1 well. Among core material, a 2-m interval of fair quality source rocks with the maximum TOC content at 0.64 wt% was found (Chruścińska and Płatek, 2016).

Kerogen, from all palaeogeographical zones of the Kamień Pomorski area, is classified as type II (HI = 82–386 mg HC/gTOC). Admixtures of kerogen types I and III are also observed locally (Chomino 1 well; Kotarba et al., 2003). Analysis of bitumen content also indicates the marine origin of dispersed organic matter: short-chain n-alkanes are predominant, and the proportion of pristine to phytane (Pr/Ph) shows values below unity (Chruścińska and Płatek, 2016; Kotarba et al., 2003).

Both syngenetic and epigenetic hydrocarbons occur within the Main Dolomite in the “Gryfice” tender area. This indicates local liquid hydrocarbon migration. Group composition is relatively uniform and does not vary significantly between wells, apart from individual analyses, what suggests their genetic affinity. An approximately equal share of hydrocarbons (aliphatic and aromatic hydrocarbons) and heterocomponuds (resins and asphaltenes) is observed. The weight ratio of aliphatic fraction (15–39 wt% of the extracts) and asphaltenes (13–49 wt% of the extracts) is similar in most samples, and those two fractions have the largest share in the composition. The aromatic fraction content is usually slightly lower and varies from 10 to 32 wt%, but in general, it is close to 20 wt%. Similarly, participation of resins is in the range between 8 and 34 wt%, and the average is ca. 20 wt% (Chruścińska and Płatek, 2016; Kotarba et al., 2003). The thermal maturity of the Main Dolomite in the Kamień Pomorski area expressed by values of the Tmax parameter (412–447ºC) is at the boundary between the final stage of diagenesis and the early stage of catagenesis. The values of the carbon preference index (CPI) close to the number 1 indicate thermal conditions that enable the generation of liquid hydrocarbons (Kotarba et al., 2003). Vitrinite reflectance measurements in the Chomino 1 well (Ro = 0.69–0.72%; Chruścińska and Płatek, 2016) and in the Brojce IG-1 well (Ro = 0.92%; Kosakowski et al., 2003) correspond to the early and middle oil window.

Source rocks have low thickness. Isolated layers are closely connected with the palaeogeographic and microfacies development of the Main Dolomite. Most of the rocks, which have been analyzed within the tender area, are poor in organic matter (TOC <0.3%). Fair to very good quality source rocks are present in the Rewal Bay area. Fair quality is observed in other palaeogeographic regions where source rocks are present (Kotarba et al., 2003). According to the petroleum modeling, the mudstones, grainstones and boundstones of the lagoons and barrier zones in the carbonate platform and its slope originally showed good and very good source rock features. In the basin plain region, the original source rocks potential was predominantly good (Kosakowski et al., 2003). The effective thickness of source rocks in this area varies from 5 m in the Kamień Pomorski 7 and Wrzosowo 8 wells to 23 m in the Strzeżewo 1 well. Due to the presence of oil-forming kerogen type II and the thermal maturity corresponding to the oil window, the rocks could generate predominantly liquid hydrocarbons.

Mikrofacje *Microfacies*	**TOC (% wag.)**			**HI (mg HC/g TOC)**			**PI**			**Tmax (°C)**		
	zakres zmienności *range*	**wartość średnia** *mean*	**n**	**zakres zmienności** *range*	**wartość średnia** *mean*	**n**	**zakres zmienności** *range*	**wartość średnia** *mean*	**n**	**zakres zmienności** *range*	**wartość średnia** *mean*	**n**
Płytsza część równi basenowej *Shallower part of basinal plain* **(Bp)**												
Bandston *boundstone* (B)	0,01-0,10	0,07	9									
Greinston *grainstone* (G)	0,09-1,99	0,58	5	287-361	319	4	0,07-0,35	0,22	4	426-429	428	4
Madston *mudstone* (M)	0,01-1,36	0,27	122	169-371	366	83	0,09-0,35	0,26	83	412-434	427	83
Wakston *wackestone* (W)	0,01-0,16	0,09	3	331		1	0,38		1	422		1
Dolomit zrekrystalizowany *Cristalline dolomite*(CC)	0,01-1,29	0,35	5	300-386	349	3	0,16-0,31	0,24	3	421-428	426	3
Zatoka równi basenowej *Bay of basinal plain* **(Bz)**												
Madston *mudstone* (M)	0,01-5,81	0,87	55	82-300	165	36	0,03-0,38	0,30	36	426-444	437	36
Stok platformy węglanowej *Slope of carbonate platform* **(Sp)**												
Bandston *boundstone* (B)	0,05-0,47	0,16	16	117-191	151	4	0,29-0,38	0,32	4	427-440	434	4
Greinston *grainstone* (G)	0,06-0,81	0,27	15	165-229	200	7	0,29-0,36	0,32	7	427-431	429	7
Madston *mudstone* (M)	0,00-1,36	0,23	135	83-356	184	79	0,21-0,39	0,31	79	416-447	431	75
Pakston *packstone* (P)	0,08-0,14	0,11	6									
Wakston *wackestone* (W)	0,18-0,29	0,24	2	231		1	0,31		1	426		1
Dolomit zrekrystalizowany *Cristalline dolomite* (CC)	0,07-0,48	0,18	4	110		1	0,38		1	442		1
Przykrawędziowa bariera oolitowa *Barrier reef* **(Pb)**												
Bandston *boundstone* (B)	0,01-0,30	0,15	5	308-353	331	2	0,23	0,23	2	435-437	436	2
Greinston *grainstone* (G)	0,00-1,20	0,12	98	145-283	221	13	0,18-0,40	0,27	13	427-442	437	13
Salina platformy węglanowej *Saline of carbonate platform* **(Ps)**												
Bandston *boundstone* (B)	0,00-0,27	0,07	37	167-288	200	4	0,27-0,40	0,34	4	431-436	434	2
Greinston *grainstone* (G)	0,01-0,30	0,08	22	230-252	241	2	0,31-0,36	0,33	2	432-433	432	2
Dolomit zrekrystalizowany *Cristalline dolomite* (CC)	0,05-0,08	0,06	3									

Tab. 3.2. Parameters and indices from Rock-Eval pyrolytic analysis for the Main Dolomite samples from the Kamień Pomorski area excluding samples containing epigenetic hydrocarbons (Kotarba et al., 2003). TOC – total organic carbon content, HI – hydrogen index, PI – productivity index. Tmax – peak maximum temperature S2, n – number of samples.

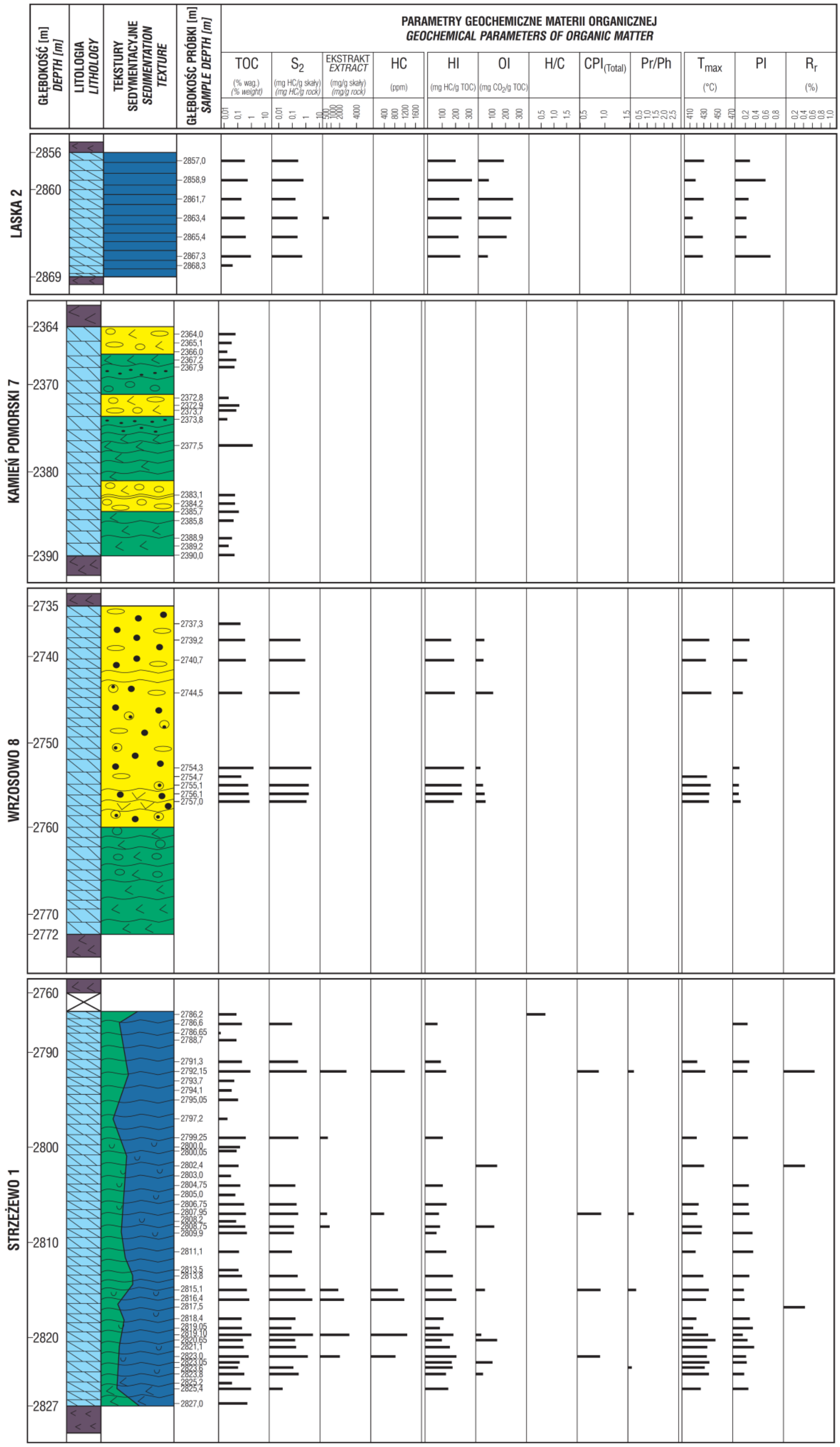


Fig. 3.5. Geochemical/sedimentological successions from selected wells located in the "Gryfice" tender area, which have been used for generation analysis (Kosakowski et al., 2003). TOC – total organic carbon content, S2 – residual hydrocarbon content, HC – hydrocarbons, Hl – hydrogen index, Ol – oxygen index, CPI – carbon preference index, Pr/Ph – pristane/phytane, PI – productivity index.

3.3. RESERVOIR ROCKS

Upper Carboniferous
Lithology: quartz arenites and wackes, mostly fine- and medium-grained

Depth to the top:
Kamień Pomorski 7: 3230.0 m,
Strzeżewo 1: 3199.0 m,
Gostyń 2: 3314.0 m.

The Upper Carboniferous reservoir rocks located in the Kamień Pomorski – Trzebiatów area are characterized by the porosity of approx. 10% and, in some cases, up to 20% (Kozłowski, 2007). Primary porosity dominates in the studied samples; however, secondary porosity occurs locally. The secondary porosity is the result of the dissolution of lithic grains and potassium feldspars, locally of micas. It represents a small percentage of the total porosity of sandstones. Compaction and cementation are dominant diagenetic processes in the studied samples of the Upper Carboniferous formations (Kozłowski, 2007). In the case of sandstones dominated by early quartz cementation, the influence of compaction was less intense and, as a result, some of the original porosity has been preserved (Kozłowski, 2007).

Physical and chemical properties were determined for the Upper Carboniferous formations on the basis of laboratory analysis of core samples. The porosity analyses show various values in the range of 0.1–17.29% (Tab. 3.3). For the entire studied stratigraphic interval, the average rock porosity is about 5.1%. The Upper Carboniferous formations are characterized mostly by very low and low permeabilities reaching several mD (Tab. 3.3). However, in some parts, the permeability is more satisfying (e.g. Wrzosowo 2 – 10.5 mD; Tab. 3.3). Bitumen occurs in trace amounts up to a maximum of 0.03% (Tab. 3.3).

The obtained results of molecular and isotopic composition analyses of gases (Tab. 3.4) indicate that all gases were formed by thermogenic processes mainly from kerogen type III, with a minor component of kerogen type II (Kotarba et al., 1999, 2005). During the first thermogenic low-temperature stage (Carboniferous – Lower Permian thermal episode), an organic matter transformation rate of 0.6–0.8%; methane and higher hydrocarbons (ethane, propane, etc.) were generated. Only methane was generated during the second thermogenic high-temperature stage (Mesozoic – Cenozoic thermal episode) with a 1.4–1.8% transformation rate (Kotarba et al., 2005). Carbon dioxide is present in low concentrations in the basic gases generated exclusively by thermogenic transformations, whereas nitrogen most likely formed in the final stage of thermocatalytic transformations of Carboniferous organic matter (Kotarba et al., 2005). However, it cannot be excluded that part of it is abiogenic and related to the presence of Lower Permian effusive rocks.

Only 4 formation water analyses were performed in the Upper Carboniferous deposits (Tab. 3.5). These are chloride-lime-soda or chloride-soda-lime brines from 19.0% to 30.0% mineralization. Five natural gas deposits were documented in the "Gryfice" tender area and its vicinity in the Upper Carboniferous and the lowermost Rotliegend (most probably the Świniec Formation) deposits. These are the Dargosław, Gorzysław N, Gorzysław S, Trzebusz, and Wrzosowo fields. Their detailed description is presented in Chapter 4.

Wells	Interval [m] (stratigraphy)	Samples porosity/ permeability/ bitumins	Porosity [%] (average)	Permeability (average)	Bitumen content [%] Min–Max (average)
Gostyń 2	3342.0–3400.0 U. Carboniferous	26/26/26	0.72–9.19 (5.91)	9.17–4800.5 [nm^2] (5.83)	0.008–0.393 (0.11)
Kamień Pomorski 7	3296.55–3363.45 U. Carboniferous	4/4/4	0.21–7.11 (3.93)	0.01–0.83 [mD]	traces–0.022
Strzeżewo 1	3199.0–3890.0 U. Carboniferous	129/0/58	0.1–11.4 (3.7)	–	traces –0.024
Wrzosowo 1	3081.75–3246.45 U. Carboniferous	34/21/34	1.44–13.43 (5.64)	0.024–2.247 [mD] (0.345)	0.004–0.017 (0.0098)
Wrzosowo 2	3059.55–3121.55 U. Carboniferous	73/68/44	0.49–15.41 (8.20)	0.0–10.50 [mD]	0.002–0.036 (0.0151)
Wrzosowo 3	3107.45–3242.35 U. Carboniferous	93/79/93	0.19–10.00 (4.79)	0.01–1.87 [mD] (0.126)	traces –0.017
Wrzosowo 8	3078.05–3239.15 U. Carboniferous	78/35/78	0.84–17.29 (5.67)	0.0–0.68 [mD]	traces –0.030
Wrzosowo 9	3084.5–3198.0 U. Carboniferous	8/8/0	1.81–7.52 (3.65)	0.0–0.73 [mD]	–

Tab. 3.3. Petrophysical properties of the Upper Carboniferous in selected wells from the "Gryfice" tender area and its close neighborhood, based on final well reports.

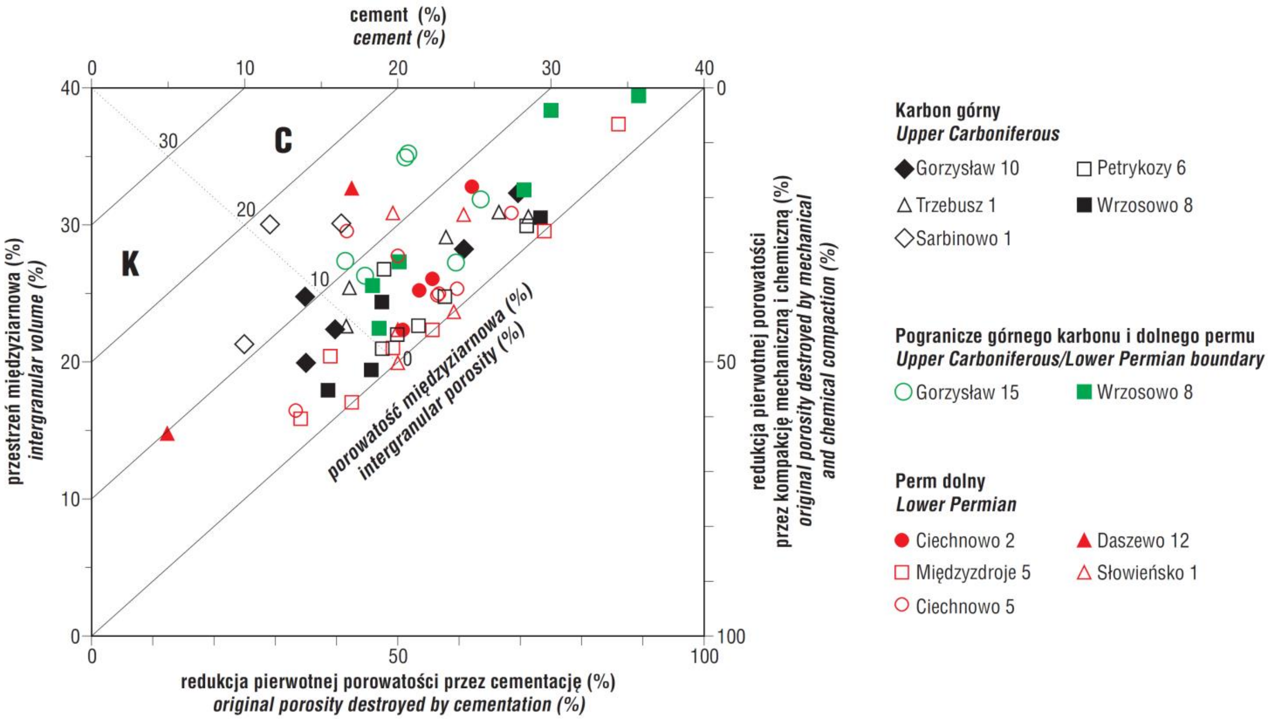


Fig. 3.6. Influence of compaction and cementation on porosity of sandstones in selected wells from Western Pomerania (according to Houseknecht, 1987). C – field with prevalence of cementation over compaction, K – field with prevalence of compaction over cementation (Kuberska et al., 2007).

Wells	Interval [m] (stratigraphy)	Gas analysis [% vol.]	Comments
Gostyń 2	3388.0–3447.0 (Upper Carboniferous)	CH_4–20.62 C_2H_6–0.05 C_3H_8–0.01 N_2–77.51 He–0.28	gas taken from line after drill-stem test
Kamień Pomorski 7	3293.0–3305.0 (Upper Carboniferous)	CH_4–28.78 C_2H_6–0.02 N_2–68.33 H_2–2.09	taken by formation tester, analysis in clean gas
Strzeżewo 1	3450.0–3524.0 (Upper Carboniferous)	CH_4–17.41 C_2H_6–0.02 C_3H_8–0.002 N_2–81.27 H_2–0.594 He–0.701	taken by formation tester, analysis in clean gas
Wrzosowo 1	3083.7–3085.2 (Carboniferous)	CH_4–0.76 N_2–99.17 CO_2–trace amount H_2–0.07	after degasification of well core, calculated as total hydrocarbons
	3142.0–3195.0 (Carboniferous)	CH_4–25.59 C_2H_6–0.53 N_2–70.56 O_2–2.89 H_2–0.32 Ar–0.11	taken by formation tester, analysis in clean gas
Wrzosowo 2	3044.2–3122.2 (Zechstein Limestone, Rotliegend, Carboniferous)	CH_4–42.65 C_2H_6–1.64 C_3H_8–0.50 N_2–54.72 O_2–none He–0.20 Ar–0.035	directly from lifting casings, analysis in clean gas
Wrzosowo 8	3226.0 (Carboniferous)	CH_4–39.42 C_2H_6–0.16 C_3H_8–0.004 N_2–58.39 H2–0.75 He–1.81 Ar–0.04	taken by formation tester, analysis in clean gas
Wrzosowo 9	3205.5–3210.0 (Carboniferous)	CH_4–8.23 C_2H_6–0.38 C_3H_8–0.47 N_2–90.55 O_2–none H_2–0.35	after degasification of well core, analysis in clean gas

Tab. 3.4. Gas analyses from the Upper Carboniferous intervals in selected wells from the “Gryfice” tender area and its neighborhood, based on final well reports.

Wells	Interval [m] (stratigraphy)	Water analyses [g/l]	Comments
Gostyń 2	3388.0–3447.0 (Carboniferous)	Cl^-–152.74 Ca^+–43.33 Mg^+–2.01 Na^+ –45.40 pH–5.9	brine approx. 24.6% sodium-chloride-calcium
Strzeżewo 1	3535.0–3587.5 (Upper Carboniferous)	Cl^-–117.89 Br^-–0.85 Fe^+–0.28 Ca^+–34.61 Mg^+–1.60 Na^+ –34.15 pH–5.7	brine approx. 19.1% sodium-chloride-calcium
Wrzosowo 1	3075.0–3149.3 (Rotliegend, Upper Carbon-iferous)	Cl–48.93 Br^-–none Ca^+–1.91 Mg^+–none Na^+–30.12 pH–6.77	
Wrzosowo 8	3180.0–3226.0 (Carboniferous)	Cl^-–155.49 Br^-–0.52 Ca^+–36.65 Mg^+–3.13 Na/K^+ – 52.73 pH–5.76	brine approx. 25.0% sodium-chloride-calcium

Tab. 3.5. Formation water analyses from the Upper Carboniferous intervals in selected wells from the "Gryfice" tender area and its neighborhood, based on final well reports.

Upper Rotliegend
Lithology: sublithic, lithic and quartz arenites

Thickness:
from 50.0 m in the northern part up to over 100.0 m in the SW, S and SE parts of the tender area
Depth to the top:
Świerzno 1: 3084.5 m,
Rekowo 2: 3014.5 m,
Benice 1: 3150.0 m,
Gryfice 1: 3340.5 m.

Petrophysical properties (porosity and permeability) of the Upper Rotliegend reservoir rocks are variable. Their values depend on the sedimentary environment in which the Upper Rotliegend was deposited. The porosities determined by computer image analysis range from 2.17 to 17.44% (Kuberska et al., 2007). They reach permeability values from <0.01 mD to about 30.0 mD.

Primary porosity of the Upper Rotliegend sandstones is low (except in depositional areas such as Ciechnowo; Kuberska et al., 2007). Intergranular and intercrystalline secondary porosity, which is a result of dissolution of feldspar grains and carbonate cement, was observed most frequently. Mechanical compaction and cementation were the processes that strongly reduced the primary porosity of the Upper Rotliegend rocks (Kuberska and Maliszewska, 2007). A result of compaction is reduced porosity by about 5–60%, while cementation from 12% to 86%.

Samples, in which the threshold pore diameter does not exceed 4 μm, are characterized by very poor filtration properties (Kuberska and Maliszewska, 2007). Considerable differences in the values of the hysteresis effect (23–80%) indicate the formation of the intergranular space, which in most samples is in the form of micropores, as evidenced by the size of the average capillary (0.05–0.36 μm). The percentage of pore diameter above 1 μm ranges from 9 to 79%. Based on the comparison of selected pore sizes, it can be assumed that the pores are isometric in shape, with lengths and widths mostly around 0.01 mm. The crystallization of fibrous illite was the main factor limiting permeability in the

Upper Rotliegend reservoir rocks (Kuberska and Maliszewska, 2007). Based on the studies of fluid inclusions, which have been made in authigenic quartz crystals, it is estimated that they were formed at temperatures of 131–165ºC. It corresponds to the crystallization temperature of fibrous illite. Using the K-Ar method, it was determined that it was formed in the Early Jurassic and at the beginning of the Middle Jurassic (Maliszewska and Kuberska, 2009).

The physicochemical properties are determined based on laboratory tests of core samples from the Lower and Upper Rotliegend (Pokorski, 1988). The porosity of these rocks ranges from 1.42% to 9.83% (Tab. 3.6). The average porosity for all studied Rotliegend sections is 3.93%. The results of permeability analyses are mostly very low and do not exceed 1 mD (Tab. 3.6). Bitumen content ranges from trace amounts to a maximum of 0.034% (Tab. 3.6).

Analyses of gas were conducted in 7 wells (Tab. 3.7), and of water in 2 wells (Tab. 3.8). No hydrocarbon accumulations in the Upper Rotliegend formations have been documented in the “Gryfice” area, so far. The nearest deposits in the discussed horizon are Ciechnowo and Sławoborze, which are situated SE of the tender area.

Wells	**Interval [m] (stratigraphy)**	**Number of samples porosity/ permeability bitumen**	**Porosity [%] Min–Max(average)**	**Permeability [mD] Min–Max (average)**	**Bitumen content [%]Min–Max (average)**
Benice 1	3150.0–3166.6	46/46/46	2.3–8.93 (4.39)	low–0.730	trace amount
Brojce IG-1	3609.5–3666.6	12/12/0	0.74–3.33	0.1	–
Gryfice 1	3345.0–3362.5	23/23/23	1.42–6.47 (2.51)	<0.01–0.06	trace amount–0.034
Jarszewo 1	2928.0–2945.0	18/18/18	4.09–7.07 (5.33)	0.028–0.734 (0.165)	0.0039–0.0066 (0.0052)
Świerzno 4	3156.0–3160.75	11/10/11	2.09–3.34 (2.83)	0.146–0.023 (0.211)	trace amount–0.005
Świerzno 1	3085.0–3102.95	19/19/19	2.31–9.83 (6.33)	low–0.302	trace amount–0.0078
Wrzosowo 1	3078.85–3081.25	6/6/6	4.49–8.00 (6.03)	0.622–1.926 (1.393)	0.004–0.023 (0.0113)
Wrzosowo 2	3043.05–3059.25	2/2/2	1.65 and 1.92	0.01 and 0.05	0.012 and 0.015
Wrzosowo 8	3075.55–3077.55	5/5/0	1.05–2.04 (1.50)	0.0–0.56 (0.19)	
Wrzosowo 9	3060.5–3084.5	2/1/2	1.54 and 3.13	0.22	0.007 and 0.009

Tab. 3.6. Petrophysical properties of the Rotliegend in selected wells from the “Gryfice” tender area and its close neighborhood, based on final well reports.

Wells	Interval [m] (stratigraphy)	Gas analyses [% vol.]	Comments
Benice 1	3126.0–3169.1 (Zechstein base, Rotliegend)	CH_4–0.86 CO_2–0.13 N_2–98.56 He –0.45	from formation tester, calculated as total hydrocarbons
Brojce IG-1	3596.0–3642.0 (Zechstein base)	CH_4–0.67 C_2H_6–0.01 C_3H_8–trace amount N_2–85.38 H_2–12.59	examined using a formation tester
Jarszewo 1	2930.3–2938.0 (Rotliegend)	CH_4–trace amount N_2–92.90 Ar–1.05 H_2–4.80 He–trace amount	after degasification of well core, calculated as total hydrocarbons
Laska 2	3078.0–3115.0 (Zechstein base and Rotliegend top)	CH_4–11.36 C_2H_6–0.02 C_3H_8–0.014 N_2–83.96 H_2–2.20 He–1.19 Ar–0.04	examined using a formation tester, analysis in clean gas
Świerzno 4	3149.0–3155.0 (Zechstein Limestone, Kupferschifer, Upper Rotliegend)	CH_4–trace amount CO_2–0.84 N_2–98.96 H_2–0.20	after degasification of well core. calculated as total hydrocarbons
Wrzosowo 1	3075.0–3149.3 (Rotliegend)	CH_4–44.00 C_2H_6–1.97 C_3H_8–0.61 N_2–53.42 He–trace amount	analysis in clean gas
Wrzosowo 2	3044.2–3122.2 (Zechstein Limestone, Rotliegend, Carboniferous)	CH_4–42.66 C_2H_6–1.66 C_3H_8–0.51 N_2–54.72 He–0.20 Ar–0.035	directly from lifting casings, analysis in clean gas

Tab. 3.7. Gas analyses from the Rotliegend deposits in selected wells from the “Gryfice” tender area and its neighborhood, based on final well reports.

Wells	Interval [m] (stratigraphy)	Water analyses [g/l]	Comments
Laska 2	3072.0–3115.0 (Zechstein base. Rotliegend)	Cl^-–164.24 Br^-–0.64 Ca^+–28.59 Mg^+–0.47 Na^+–73.29 pH–6.47	brine about 27.25% sodium-chloride-calcium
	3429.0–3475.0 (Rotliegend, Devonian)	Cl^-161.13 Br^-–0.57 Ca^+–26.06 Na^+–74.22 pH–6.42	brine about 26.50% sodium-chloride-calcium, heavily contaminated with drilling fluid
Wrzosowo 1	3077.0–3082.0 (Rotliegend, Carboniferous)	Cl^-–48.93 Ca^+–1.91 Mg^+–none Na^+–30.12 pH–6.77	

Tab. 3.8. Formation water analyses from the Rotliegend deposits in selected wells from the "Gryfice" tender area and its neighborhood, based on final well reports.

Main Dolomite (Ca2)
Lithology: limestones and dolomites

Thickness:
from 10 m (marginal SW and E parts of the tender area) to 80 m (S part).
Depth to the top:
Kamień Pomorski 13: 2326.5 m,
Benice 4K: 2611.5 m,
Gryfice 1: 2984.0 m.

The Main Dolomite reservoir rocks are distributed in various facies types. The horizons in which hydrocarbons are accumulated were recognized in the internal and external zones of carbonate barriers and slopes of carbonate platforms, and in the transition zone between basin-floor facies. The inner part of the carbonate platform is represented mostly by granular carbonate facies and minor mudstone facies. The distribution of porosity and permeability in the analyzed samples is not very differentiated, and their petrophysical division is poorly marked (Protas, 1981; Gąsiewicz and Wichrowska, 1996; Gąsiewicz et al., 1998).

According to the classification of Lucia (1995), three types of porosity can be distinguished in granular carbonate facies: 1) intergranular and intercrystalline, 2) separated – mainly intergranular, and 3) combined – fractured formed by dissolution, whereas, in muddy facies, only the first and the second types occur (Gąsiewicz and Wichrowska, 1996; Gąsiewicz et al., 1998). The porosity of the Main Dolomite developed at various stages of diagenesis and was mainly related to the influence of the dolomitization process of meteoric waters and fracturing. Initial porosity was largely (or completely) reduced due to filling the pore spaces with late stages of sulfate (anhydrite) cement.

In the Main Dolomite of the Kamień Pomorski carbonate platform and its vicinity, a considerable variation in porosity is observed, ranging from 1.0 to 22.0% (Fig. 3.7). Visibly higher porosity values were measured in carbonate granular facies. The presence of significant secondary porosities in muddy facies indicates a strong influence of diagenetic factors. Petrographic studies have shown that low porosity values of dolomites are related to the late-diagenetic filling of primary and secondary pores with anhydrite. As a result, fractures which are locally very abundant are essential.

Most of the samples, taken from the area of Kamień Pomorski and its surroundings and studied by Gąsiewicz et al. (1998), have low permeabilities that do not exceed 10 mD (Fig. 3.7). Among the low-permeable rocks, micropores above 1 μm account for 3.0% to 97.0%. However, in most of the analyzed samples, they constitute 50% showing a dependence on lithology. The highest permeability is associated mainly with granular facies. The analysis of the size of the crystals and their arrangement (degree of crystallinity) shows that the observed permeability distribution has not been affected by the original sedimentary textures. However, they had an impact on the nature of the pore space influenced by the various diagenetic factors.

The results of the petrophysical analysis show that the Main Dolomite has good reservoir properties in contrast to filtration parameters (Darłak et al., 1998). Samples of rocks with quite high porosity values and threshold diameters are characterized by very low permeability. This system has a direct impact on the hydrodynamic properties of the Main Dolomite. The transmission of the formation fluids was carried out by a system of fractures. Reservoirs are usually pore-fracture in character. Basic laboratory analysis of core samples allowed determining the petrophysical properties of the Main Dolomite. The porosity ranges from 0.07% to 19.93% (Tab. 3.9). The Main Dolomite, in most cases, is characterized by very low permeability, reaching several mD (Tab. 3.9). Very good permeability exceeding 10 mD was found in single boreholes (Tab. 3.9). The measured bitumen values range from trace amounts to 1.13% (Tab. 3.9).

So far, several economic oil accumulations have been discovered in the Main Dolomite in the area of the Kamień Pomorski carbonate platform and its vicinity. The analyzed oil samples did not undergo secondary biodegradation processes and their hydrocarbon composition was not depleted by the processes of water washing oxidation or fractional evaporation in the trap (Mikołajewski et al., 2012). It was also found that there was no thermal cracking of the oil, proving its original hydrocarbon composition (Kotarba et al., 1998).

Apart from the economic accumulation of oil and its symptoms in many boreholes, admixtures of natural gas are also present in the Main Dolomite in the “Gryfice” tender area and the adjacent regions (Tab. 3.10). Studies of geochemical indicators (Kotarba et al., 1998) and stable isotopes on selected components of gas (Mikołajewski et al., 2012) confirm the genetic link with oil, proving that the gas was generated from type II kerogen. The main part of ethane and propane and some of methane were formed in the early phase of low-temperature thermogenic processes. However, studies of the stable isotope composition showed that some methane was also produced at the stage of microbial transformations (Kotarba et al., 1998). Gas of such origin has been recognized, among others, in the Rekowo deposit (Mikołajewski et al., 2012).

In the Main Dolomite formations, 18 samples of formation water were analyzed (Tab. 3.11). These are 12–33% sodium chloride brines in some cases with varying amounts of magnesium or calcium. Most of the deposits discovered so far in NW Poland occur in the area of the Kamień Pomorski platform, its slope, and the adjacent shallow shelf (Mikołajewski et al., 2012). Within the “Gryfice” tender area, the Rekowo field was discovered and in its western and southern neighborhood – the Kamień Pomorski and Wysoka Kamieńska fields. Their detailed characteristics can be found in Chapter 4.

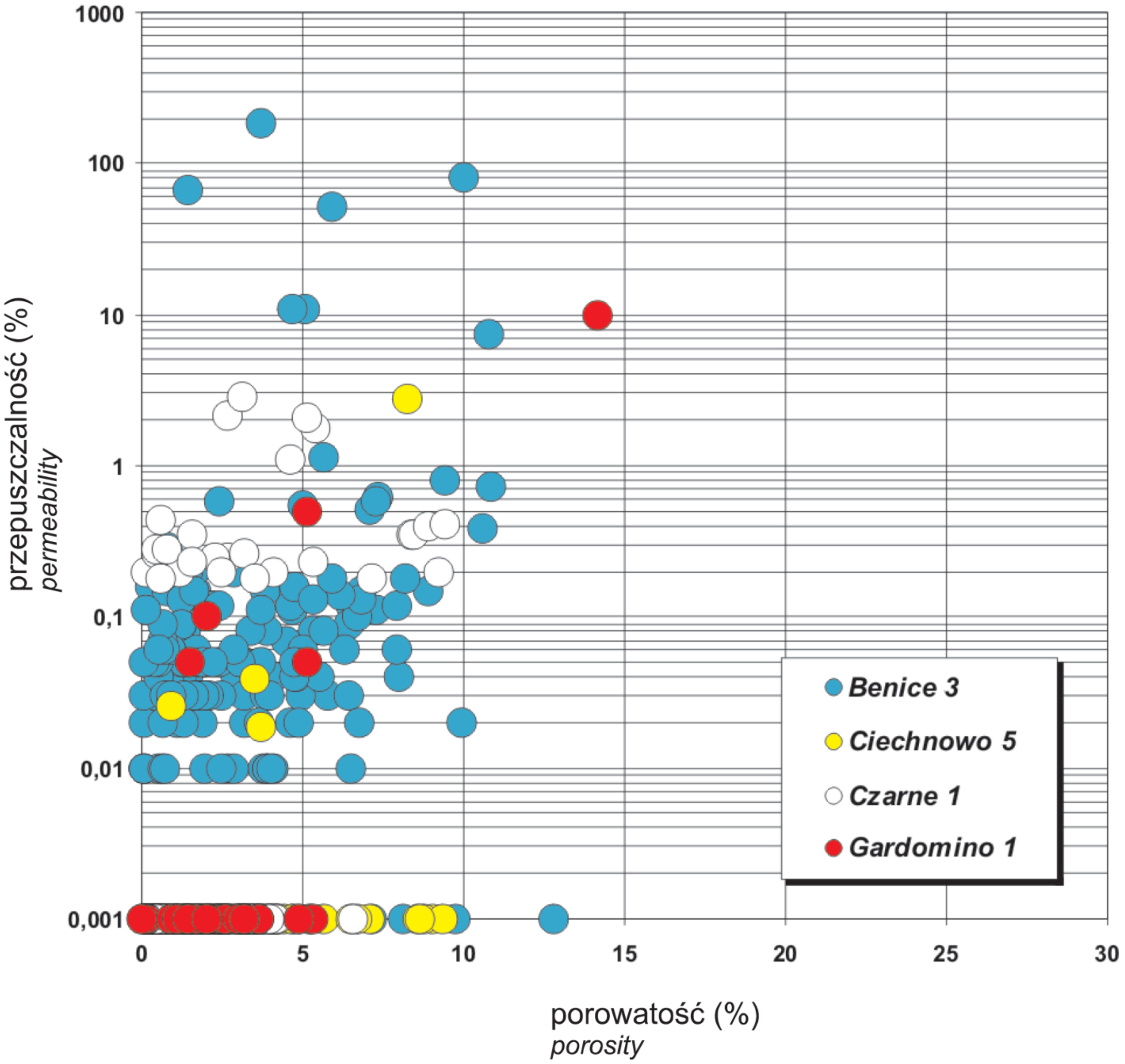


Fig. 3.7. Porosity versus permeability graph in selected barrier formations of the Main Dolomite in Western Pomerania (Słowakiewicz et al., 2008).

Wells	Interval [m] (stratigraphy)	Samples porosity/ permeability / bitumens	Porosity [%] (average)	Permeability (average)	Bitumen content [%] (average)
Benice 1	2748.3–2792.8 (Main Dolomite)	92/92/92	0.07–7.81 (2.65)	low–0.265 [mD]	0.0055–0.0409 (0.0186)
Benice 2	2835.5–2887.3 (Main Dolomite)	92/92/92	0.07–10.25 (3.0)	low–1.786 [mD]	0.009–0.062 (0.021)
Benice 3		163/155/163	0.06–12.78 (3.3)	0.01–185.1 [mD]	0–0.151 (0.019)
Benice 4K		154/113/154	0.07–22.52 (3.70)	1–2003 [nm^2] (83)	0.0006–0.033 (0.015)
Chomino1	2687.1–2721.8 (Main Dolomite)	71/71/0	0.19–10.57 (2.43)	<0.0001–0.1020 [mD] (0.03)	–
Dobropole 1	2851.05–2860.55 (Main Dolomite)	20/10/20	1.09–10.86 (3.35)	1–2182 [nm^2] (116.0)	0.038–0.139 (0.084)
Dusin 1	2584.0–2643.0 (Main Dolomite)	116/116/116	0.07–19.93 (5.48)	low	0.005–0.467 (0.060)
Gostyń 2	2919.0–2959.0 (Main Dolomite)	69/no data./no data	0.14–6.2 (1.94)	0.53–7873.23 [nm^2] (3.47)	0.008–0.110 (0.2)

Gryfice 1	2985.0–3020.0 (Main Dolomite, Upper Anhydrite)	51/43/51	0.07–3.3 (0.884)	<0.01–2.31 [mD]	0.006–0.085 (0.024)
Gryfice 2	3013.3–3048.0 (Main Dolomite, Upper Anhydrite)	44/b.d./b.d.	0.31–4.60 (1.38)	< 0.014 [mD]	0.0046–0.0346 (0.024)
Gryfice 3	3136.55–3169.85 (Main Dolomite)	51/47/?	0.29–9.39 (2.32)	low –0.219 [mD]	traces–0.151
Jarszewo 1	2518.5–2547.9 (Basal Anhydrite, Main Dolomite)	53/53/53	0.14–5.73 (1.33)	low –0.200 [mD]	0.0032–0.0276 (0.0055)
Kamień Pomorski 3	2353.8–2357.4 (Main Dolomite)	6/b.d./b.d.	0.35–6.16 (1.88)	low –0.225 [mD]	0.0265–0.1204 (0.0773)
Kamień Pomorski 7	2356.75–2384.25 (Basal Anhydrite, Main Dolomite)	57/55/57	0.07–12.88 (11.24)	<0.01–0.62 [mD]	0.010–0.058 (0.025)
Kamień Pomorski 13	2327.75–2351.45 (Main Dolomite)	29/29/29	0.14–4.65 (0.911)	low –0.3393 [mD]	0.0074–0.0556 (0.0253)
Rekowo 2	2705.5–2741.5 (Main Dolomite, Upper Anhydrite)	39/b.d./b.d.	0.14–7.59 (1.22)	low –0.405 [mD]	0.003–0.087 (0.023)
Rekowo 3	2650.55–2669.05 (Main Dolomite, Upper Anhydrite)	53/b.d./b.d.	0.07–5.94 (1.85)	low –0.333 [mD]	0.007–0.466 (0.077)
Rekowo 4	2681.95–2705.65 (Main Dolomite)	58/b.d./b.d.	0.07–10.38 (1.39)	low –55.74	0.020–0.488 (0.097)
Rekowo 6	2701.75–2721.55 (Main Dolomite)	39/b.d./b.d.	1.09–28.80 (10.15)	0.013–2.147 [mD] (0.451)	0.01–1.131 (0.478)
Skarchowo 1	(Basal Anhydrite, Main Dolomite, Upper Anhydrite)	118/102/117	0.21–17.37 (3.614)	0.0–0.20 [mD] (93 samples = 0)	0.002–0.160 (0.038)
Świerzno 2	2748.55–2766.85 (Main Dolomite)	20/b.d./b.d.	0.07–1.1 (0.34)	low –0.980 [mD]	0.0152–0.0323 (0.0226)
Świerzno 4	2778.3–2811.6 (Main Dolomite, Upper Anhydrite)	47/45/46	0.07–6.22 (1.35)	low –0.138 [mD]	0.003–0.066 (0.0138)
Świerzno 5	2845.0–2872.0 (Main Dolomite)	72/72/72	0.22–11.05 (2.48)	low –7.502 [mD]	0.006–0.037 (0.023)
Świerzno 9	2769.1–2774.7 (Basal Anhydrite, Main Dolomite)	11/11/11	1.23–4.5 (2.96)	low–0.049 [mD]	0.014–0.041 (0.023)
Laska 2	2859.55–2872.55 (Main Dolomite)	21/14/b.d.	0.27–5.17 (2.35)	0.22–1.29 [mD] (0.24)	0.043–0.416 (0.138)
Strzeżewo 1	2768.0–2823.0 (Main Dolomite)	98/-/30	0.054–6.164 (1.040)	–	0.015–0.249 (0.074)
Wrzosowo 1	2741.75–2787.63 (Main Dolomite, Upper Anhydrite)	94/74/94	0.36–11.75 (3.16)	low –1.169 [mD]	0.015–0.059 (0.0296)
Wrzosowo 2	2676.05–2715.25 (Main Dolomite)	75/65/75	0.28–13.03 (3.51)	0.0–0.26 [mD] 44 samples = 0	0.011–0.058 (0.0264)
Wrzosowo 8	2737.73–2771.05 (Main Dolomite, Upper Anhydrite)	68/59/68	0.21–14.60 (5.39)	0.0–0.81 [mD]	0.05–0.040 (0.019)
Wrzosowo 9	2714.5–2758.0 (Main Dolomite)	91/89/91	0.07–9.92 (3.82)	0.0–1.30 [mD]	0.008–0.074 (0.22)

Tab. 3.9. Petrophysical properties of the Main Dolomite in selected wells from the “Gryfice” tender area and its close neighborhood, based on final well reports.

Wells	Interval [m] (stratigraphy)	Gas analyses [% vol.]	Comments
Benice 1	2775.0–2784.0 (Main Dolomite)	CH_4 –0.83 C_2H_6–0.27 N_2–98.49 H_2–0.41	after degasification calculated as total hydrocarbons
Benice 2	2833.5–2838.5 (Basal Anhydrite, Main Dolomite)	CH_4–traces CO_2– traces O_2–20.30 N_2–79.61	gas from well core
	2867.8–2870.8 (Main Dolomite)	CH_4–8.06 C_2H_6–0.61 C_3H_8– traces CO_2–1.54 N_2–89.79	after degasification of well core, hydrocarbons and others
Benice 3	2731.5–2804.5 (Main Dolomite)	CH_4–39.08 C_2H_6–0.94 C_3H_8–0.20 N_2–13.10 H_2S–44.85	analysis in clean gas, gasolineless with hydrogen sulfide
	2730.5–2750.0 (Main Dolomite)	CH_4–24.51 C_2H_6–4.80 C_3H_8–2.41 N_2–66.09 H_2S–not detected	after degasification of well core
Benice 4K	2658.5–2696.0 (Main Dolomite, Upper Anhydrite)	CH_4–73.74 C_2H_6–3.68 C_3H_8–1.98 N_2–17.88 H_2S–not detected	analysis in clean gas
Dusin 1	2613.6–2622.3 (Main Dolomite)	CH_4–19.58 C_2H_6–7.83 C_3H_8–11.09 N_2–50.04 He– traces	after degasification analysis in clean gas
Gryfice 1	2897.0–3014.0 (Main Dolomite, Upper Anhydrite)	CH_4–76.69 C_2H_6–7.03 C_3H_8–2.71 N_2–10.72 H_2–0.81 He–0.06	examined using a formation tester. analysis in clean gas
Gryfice 2	3015.0–3018.3 (Main Dolomite)	CH_4–15.70 C_2H_6–2.67 C_3H_8–0.87 N_2–56.33 H_2–21.01 He–0.12	after degasification of well core, calculated as total hydrocarbons
	3029.8–3030.3 (Main Dolomite)	CH_4–67.86 C_2H_6–9.25 C_3H_8–2.67 N_2–18.99 H_2–0.48 He– traces Ar–0.25	after degasification of well core, calculated as total hydrocarbons
Gryfice 3	3139.5–3143.3 (Basal Anhydrite, Main Dolomite)	CH_4–1.01 CO_2–0.06 N_2–97.65 H_2–1.28	after degasification of well core, calculated as total hydrocarbons
Kamień Pomorski 3	2357.4 (Main Dolomite)	CO_2–5.05 N_2–94.95 no hydrocarbons	after degasification of a drilling fluid calculated as total hydrocarbons
	2353.8–2357.4	CH_4–13.31	

	(Main Dolomite)	C_2H_6–1.93 C_3H_8–0.77 N_2–66.81 H_2–9.38 H_2S–not detected	after degasification of well core, hydrocarbons and others
	2353.5–2405.0 (Main Dolomite, Upper Anhydrite)	CH_4–69.25 C_2H_6–2.34 C_3H_8–0.02 N_2–16.25 H_2–11.38 H_2S–not detected	gas collected from the weight space while the formation tester was pulled out, gasoline-free with high hydrogen content –11.38%
Kamień Pomorski 13	2329.0–2332.7 (Main Dolomite)	CH_4–2.96 N_2–92.86 H_2–2.66 Ar–1.18	after degasification of well core, calculated as total hydrocarbons
Rekowo 2	2714.5–2723.5 (Main Dolomite)	CH_4–26.15 C_2H_6–2.67 C_3H_8–1.44 N_2–69.05 H_2–0.27	after degasification of well core, calculated as total hydrocarbons
Rekowo 4	2676.4–2695.6 (Basal Anhydrite, Main Dolomite)	CH_4–8.61 C_2H_6–0.88 C_3H_8–0.56 N_2–88.91 H_2–0.69	gas from a formation tester (?)
Rekowo 6	2697.0–2707.4 (Basal Anhydrite,. Main Dolomite)	CH_4–67.26 C_2H_6–11.29 C_3H_8–7.70 N_2–10.99 H_2–0.29	gas from a formation tester in clean gas, gasolineless
	2697.0–2721.8 (Basal Anhydrite, Main Dolomite)	CH_4–74.83 C_2H_6–5.07 C_3H_8–2.13 N_2–16.84 H_2–0.20	gas taken from line
Świerzno 2	2767.8 (Main Dolomite)	CH_4–74.05 C_2H_6–9.54 C_3H_8–6.21 N_2–7.58	examined using a formation tester
	2770.2 (Main Dolomite)	CH_4–37.51 C_2H_6–9.48 C_3H_8–14.46 N_2–9.99 H_2S–12.73	gas taken from a production tree, high content of hydrogen sulfide
Świerzno 4	2790.6–2792.4 (Main Dolomite)	CH_4–0.48 C_2H_6–0.03 C_3H_8–0.03 N_2–99.20 H_2–0.10	after degasification of well core, calculated as total hydrocarbons
Świerzno 9	2766.5–2774.7 (Basal Anhydrite, Main Dolomite)	CH_4–4.48 C_2H_6–0.76 C_3H_8–0.41 N_2–93.56 H_2–0.25	after degasification of well core, calculated as total hydrocarbons
	2774.7 (Main Dolomite)	CH_4–49.71 C_2H_6–11.73 C_3H_8–10.62 N_2–2.68 Ar–0.26 H_2–not detected H_2S–15.92	Sample taken during bleed off, in clean gas, argon appeared, a lot of hydrogen sulfide
Wrzosowo 1	2743.4–2746.4	CH_4–7.80	after degasification of well core, calculat-

	(Main Dolomite)	C_2H_6–0.41 N_2–91.27 CO_2–0.23 H_2–0.29	ed as total hydrocarbons
Wrzosowo 8	2757.0–2770.0 (Main Dolomite)	CH_4–18.66 C_2H_6–3.28 C_3H_8–2.04 N_2–73.92 H_2–0.27 CO_2–1.09	after degasification of well core, analysis in clean gas
Wrzosowo 9	2757.1–2774.5 (Main Dolomite)	CH_4–24.10 C_2H_6–6.16 C_3H_8–1.93 N_2–59.58 O_2–not detected H2–0.32 He–traces	after degasification of well core, calculated as total hydrocarbons

Tab. 3.10. Gas analyses from the Main Dolomite deposits in selected wells from the “Gryfice” tender area and its close neighborhood, based on final well reports.

Wells	Interval [m] (stratigraphy)	Water analyses [g/l]	Comments
Benice 3	2731.5–2804.5 (Main Dolomite)	Strong smell H_2S Cl^-–195.39 Br^-–2.12 HCO_3^-–1.54 NH_4–0.57 Ca^+–5.19 Mg^+–11.50 Na/K^+–100.19 pH–6.0	brine about 32.0% sodium-chloride
Benice 4K	2658.5–2696.0 (Main Dolomite)	Strong smell H_2S Cl^-–198.01 Br^-–1.28 HCO_3^-–2.87 SO_4^-–0.80 NH_4^+–0.97 Al/Fe^+–0.07 Ca^+–5.44 Mg^+–11.13 Na/K^+–101.62 pH–6.3	brine about 32.2% sodium-chloride
Chomino1	2686.0–2722.0 (Main Dolomite)	Cl^-–190.0 Ca+–1.77 Mg^+–0.02 pH–7.7	sample taken from a digester
	2686.0–2722.0 (Main Dolomite)	Cl^-–187.0 Ca^+–0.9 Mg^+–0.39 pH–7.9	sample taken from a digester
Gryfice 1	2897.0–3014.0 (Main Dolomite)	Cl^-–193.86 Br^-–1.04 NH_4^+–1.91 Ca^+–5.19 Mg^+–11.57 Na/K^+–96.09 pH–5.5	brine about 31.18% sodium-chloride slightly contaminated
Gryfice 3	3136.4–3172.3 (Basal Anhydrite, Main Dolomite, Upper Anhydrite)	Cl^-–142.23 Br^-–0.31 HCO_3^-–1.00 SO_4^-–3.18 NH_4^+–0.26	brine about 24.1% sodium-chloride with a small amount of magnesium

		Ca^{+}–2.87 Mg^{+}–3.27 Na/K^{+}–84.44 pH–6.7	
Kamień Pomorski 13	2355.1 (Main Dolomite)	Cl^{-}–190.26 Br^{-}–1.22 HCO_3^{-}–1.43 SO_4^{-}–1.20 NH_4^{+}–0.39 Ca^{+}–4.29 Mg^{+}–15.87 Na/K^{+}–89.41 pH–5.75	brine about 30.8% sodium-chloride. sample taken during the washing
Rekowo 6	2721.8 (Basal Anhydrite, Main Dolomite)	Cl^{-}–70.57 Ca^{+}–7.56 Na^{+}–35.75 pH–6.5	brine about 12% sodium-chloride
Świerzno 2	2770.2 (Main Dolomite)	Cl^{-}–99.27 HCO_3^{-}–0.85 SO_4^{-}–4.03 Ca^{+}–0.72 Mg^{+}–0.15 Na^{+}– 62.53 pH–8.2	brine about 17.4% sodium-chloride
Świerzno 4	2832.0 (Main Dolomite)	Cl^{-}–189.71 Br^{-}–1.07 HCO_3^{-}–0.85 SO_4^{-}–1.29 NH_4^{+}–0.81 Ca^{+}–5.58 Mg^{+}–12.91 Na/K^{+}–93.39 pH–8.0	brine about 30.9% sodium-chloride with high amount of magnesium, sample taken during the washing, intensive smell of hydrogen sulfide
Świerzno 9	2774.7 (Main Dolomite)	Cl^{-}–197.22 Br^{-}–1.00 SO_4^{-}–1.84 Ca^{+}–4.68 Mg^{+}–11.06 Na^{+}–104.48 pH–6.15	brine about 32.4% sodium- chloride
Wrzosowo 8	2725.0–2793.0 (Older Halite, Basal Anhydrite, Main Dolomite, Upper Anhydrite)	Cl^{-}–192.21 Br^{-}–1.40 Ca^{+}–6.51 Mg^{+}–15.94 Na/K^{+}–87.08 pH–6.55	brine about 33.0% chloride-sodium-magnesium

Tab. 3.11. Formation water analyses from the Main Dolomite deposits in selected wells from the “Gryfice” tender area and its close neighborhood, based on final well reports.

3.4. SEAL AND OVERBURDEN

The most important seal rocks of the Carboniferous – Lower Permian and Zechstein/Main Dolomite petroleum plays are the Zechstein evaporites. In the former, the main seal is represented by anhydrite horizons (A1d, A1s and A1g) and halite (Na1) belonging to the PZ1 cyclothem. For the Zechstein/Main Dolomite, the seal rocks are anhydrites (A2, A2r), halite (Na2, in some cases Na2r), and partially potassium-magnesium salts (K2) of the cyclothem PZ2. Additionally, the Triassic formations can be classified as seal rocks.

3.5. HYDROCARBON GENERATION, MIGRATION, ACCUMULATION AND PETROLEUM TRAPS

Carboniferous – Lower Permian petroleum play

Source rocks: Tournaisian and Visean claystones and mudstones, Westphalian and Stephanian claystones and mudstones.

Reservoir rocks: Upper Carboniferous fluvial sandstones (quartz arenites and wackes, mostly fine and medium-grained) and Upper Rotliegend fluvial sandstones (arenites, occasionally quartz, sublithic and lithic wackes).

Seal rocks: Except for the northern part of the Wrzosowo – Strzeżewo area, the Upper Carboniferous reservoir rocks are isolated from the top by the succession of the Lower Rotliegend volcanic rocks or by the PZ1 evaporites. This succession may also include lithological seals associated with fine-clastic deposits (claystones and mudstones). The Upper Carboniferous reservoir rocks can also have an internal seal (cement). In the case of the Upper Rotliegend reservoir rocks, the basic seal is the PZ1 cyclothem evaporites. Among the sandstone complexes, there are also lithological seals (conglomerates), as well as internal diagenetic seals.

Shape and size of petroleum traps: Considering the Zechstein base seismic horizon (Kudrewicz, 2008) and the discoveries in the Upper Carboniferous formations, it was found that the main types of traps are mixed structural-lithological-tectonic. Typical structural traps can be expected. Based on petrological analyses (Kuberska et al., 2007), there are (most likely) tight gas traps present in the thick sandstone complexes. Based on the structural map of the Zechstein base (Kudrewicz, 2008), the occurrence of conventional combined (structural-tectonic) traps should be expected at the top of the Rotliegend deposits. Considering the reprocessing of 2D and 3D seismic images, we should expect the appearance of further structural traps. Additionally, taking into account the facies distribution of the Upper Rotliegend, there is a possibility of intraformation stratigraphic traps in alluvial-fluvial facies.

Age and mechanism of traps generation: Many of the traps in the Upper Carboniferous rocks are synsedimentary in nature. Among them, we can expect several lithological and lithological-structural traps., It should be assumed that unconventional deposits of the tight gas type occur in the thicker sandstone packages as a result of subsequent diagenetic processes. The traps in the Upper Carboniferous formations also arose as a result of the subsequent restructuring of the basement and its overburden (Cimmerian and Laramide movements). Most of the traps occurring in the Upper Rotliegend in the “Gryfice” tender area were formed during the deposition of these sediments; hence, the genesis is synsedimentary. In addition, several lithological traps may have formed during sedimentation of the Rotliegend, which are expected to be observed in the vicinity of the elevated blocks. As a result of the subsequent restructuring of the area (Cimmerian and Laramide movements), there could have been several traps with structural and tectonic foundations (a positive structure limited by faults).

Age and mechanism of generation, expansion, migration and accumulation of hydrocarbons: Burial, thermal and hydrocarbon generation histories were modeled for the Carboniferous – Lower Permian petroleum play in Western Pomerania (Kotarba et al., 2004; Pletsch et al., 2010; Botor et al., 2013). Following Dadlez et al. (1995), the Polish Basin's heat flow was the highest in the Late Permian and Early Triassic. Throughout the rest of the Mesozoic, it cooled down until it reached a temperature close to the present-day at the end of the Cretaceous. In the NW part of the Polish Basin (including the “Gryfice” area), starting from the Permian, increased subsidence initiated by rift processes (Dadlez et al., 1995) is observed (Fig. 3.8). Then, from the Zechstein on, the development of the Polish Basin was controlled by regional thermal subsidence, the action of which was also postulated in the Triassic and Early and Middle Jurassic (Fig. 3.8; Dadlez et al., 1995). The progressive subsidence reached its maximum in the Late Cretaceous (Fig. 3.8), where the burial depth of the formations in Western Pomerania could be over 5000 m (Fig. 3.8; including the Strzeżewo 1 well).

In Western Pomerania, the main hydrocarbon generation phase occurred in two stages. The first has occured in some places since the Early Triassic, where the source rock reached 0.5 to 0.7% Ro (initial maturity phase; Fig. 3.9; Kotarba et al., 2004). However, in most cases, the main hydrocarbon generation phase was from the Middle Triassic to the Late Jurassic (Fig. 3.8; Kotarba et al., 2004; Botor et al., 2013; Krzywiec et al., 2017). The source rocks used from 25.0 to 65.0% of their generation potential (Fig. 3.9). The second hydrocarbon generation phase continued during the Late Cretaceous (Pletsch et al., 2010; Botor et al., 2013). It was characterized by lower intensity than the previous phase. As a result of the Late Cretaceous generation phase, the source rocks used from 65 to 90% of their generation potential (Fig. 3.9; Kotarba et al., 2004).

The migration of hydrocarbons in the “Gryfice” tender area and the adjacent regions was simultaneous with their generation from the source rocks. The main migration period was in the Triassic and Jurassic (Pletsch et al., 2010). Late Cretaceous migration, like the generation of hydrocarbons from this period, is much less intense.

According to Kotarba et al. (2005), the generated hydrocarbons in the high-temperature phase (Middle Triassic – Late Jurassic) arose probably from the same genetic type of source rock as the hydrocarbons generated in the low-temperature phase (Early Carboniferous). However, it suggests that the later generation of hydrocarbons took place in a deeply buried area, mainly in the S part of the tender area, behind the Resko – Świdwin fault zone.

Zechstein/Main Dolomite petroleum play

Source rocks: Mudstones, grainstones, boundstones.

Reservoir rocks: Dolomites, partially calcified dolomites and limestones represented by grainstones and packstones.

Seal rocks: Evaporite/anhydrite deposits of the cyclothem PZ1 at the base, and evaporite/anhydrite deposits of the cyclothem PZ2 at the top.

Shape and size of petroleum traps: Structural, structural-tectonic, facies.

Age and mechanism of traps generation: Most of the traps in the Main Dolomite of the tender area are synsedimentary (Semyrka, 1985). This may be evidenced, among other factors, by the presence of microbial methane in their accumulations, which was formed at a very early stage of hydrocarbon generation (Kotarba et al., 1998). The other positive structures have their tectonic foundations in the Lower Buntsandstein and Muschelkalk. These are fault-bounded structures associated with geofracture zones. The few structures of Early Jurassic or later foundations are the result of tectonic phases of the Alpine orogeny (Kotarba et al., 1998).

Age and mechanism of generation, expansion, migration and accumulation of hydrocarbons: The palaeorelief of the Main

Dolomite sedimentary basin was determined by palaeogeographic factors. Depending on the deposition of the Main Dolomite deposits (depth of burial and the amount of heat flux), individual areas entered the so-called "generation window" of hydrocarbons. After Dadlez et al. (1995), it was adopted that heat flow magnitude was the highest in the Late Permian and Early Triassic. Throughout the rest of the Mesozoic, it cooled down until it reached a temperature close to the present day at the end of the Cretaceous.

The first stage of hydrocarbon generation from the Main Dolomite deposits was most likely at the end of Zechstein deposition, taking into account the processes of bacterial generation of hydrocarbons. The proper generation phase for the basin plain sediments started in the Middle Triassic, while for the platform facies and their slopes in the Late Triassic (Fig. 3.10; Kosakowski et al., 2009). The heat flow value at that time was from 20 to 40 mW/m2. At the same time, at the end of the Triassic, the Main Dolomite deposits were buried to over 2.000 m, entering the so-called "oil window". The kerogen transformation factor (TR) achieved by the basin plains and slope platform facies in the Late Triassic was above 10% (Fig. 3.11; Kosakowski et al., 2009; Pletsch et al., 2010).

Further subsidence of the Main Dolomite deposits lasting from the Late Triassic through the early Middle and Late Jurassic caused these rocks to enter the main phase of the "oil window" (Fig. 3.10; Kosakowski et al., 2003). The hydrocarbon generation potential for the basin sediments was completed in the Late Jurassic (Fig. 3.11; Kosakowski et al., 2009), reaching the maximum value of the kerogen transformation (TR; Fig. 3.11). Contrary to the Main Dolomite basin facies, the facies of carbonate platforms and their slopes generated hydrocarbons until the Cretaceous (Kosakowski et al., 2009), or they may even still be generated today (Karnkowski and Matyasik, 2016), when buried more than 2700 m (Pletsch et al., 2010). The present kerogen transformation factor for the Kamień Pomorski platform and other carbonate platforms in Pomerania is low and does not exceed 70% (Fig. 3.11; Kosakowski et al., 2009). The analysis of the plunge history conducted by Mikołajewski et al. (2012) shows that the northern part of the Kamień Pomorski platform generated less oil than its southern part. The southern slope is characterized by a higher (approx. 70%) kerogen transformation factor and a greater thickness of the carbonate source rocks reaching 30.0 m (Wagner et al., 2008).

2D modeling performed in the BasinModTM program shows that the migration and accumulation of hydrocarbons took place simultaneously to the processes of generation and expulsion. For the basin plain, sediments migration and accumulation began in the Middle Triassic and continued until the Late Jurassic. In the facies of carbonate platforms and their slopes, migration and accumulation lasted from the Jurassic to the Cretaceous. It should be noted that the migration paths of hydrocarbons in the Main Dolomite formations are very short, and therefore their accumulation took place in the vicinity of reservoir rocks (Kotarba and Wagner, 2007).

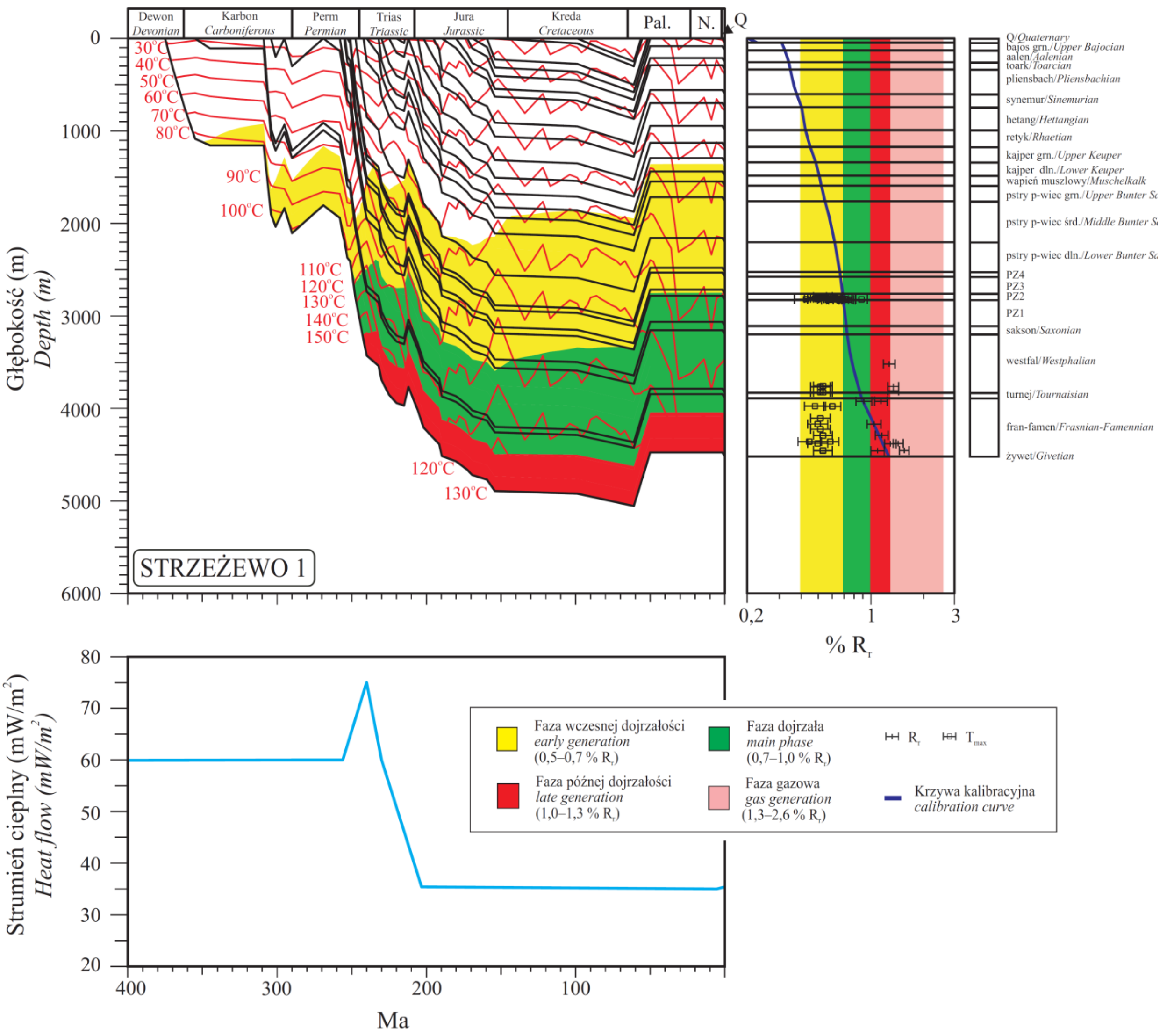


Fig. 3.8. Burial history of the Strzeżewo 1 well with maturity intervals, calibration curve of the thermal-erosion model, and the curve of the heat flow evolution for the area around the well (Wagner et al., 2008); Pal. – Paleogene, N. – Neogene, Q – Quaternary.

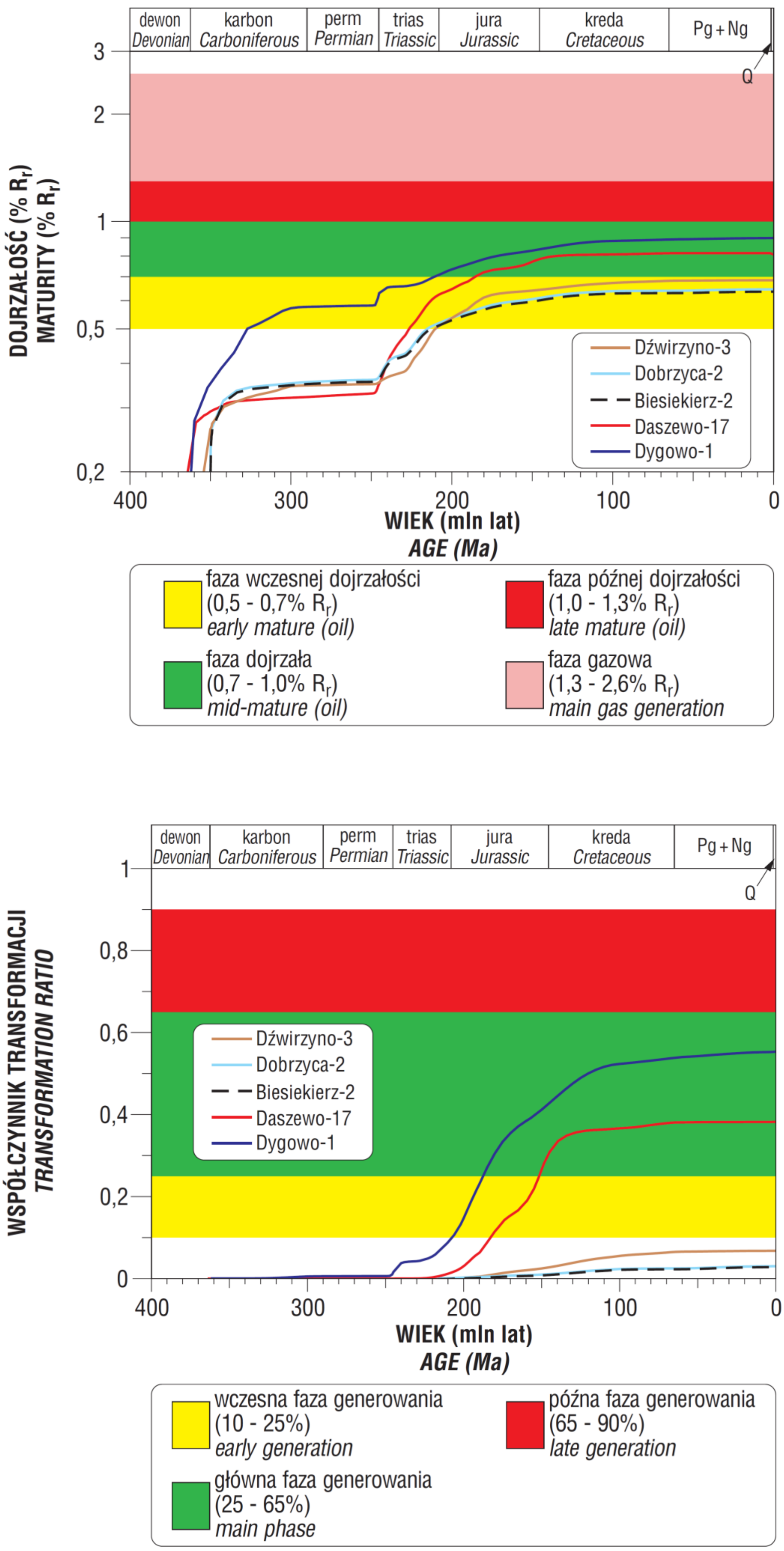


Fig. 3.9. Maturity evolution and the degree of kerogen transformation in the Carboniferous in selected wells (Kotarba et al., 2004). Pg + Ng – Paleogene and Neogene.

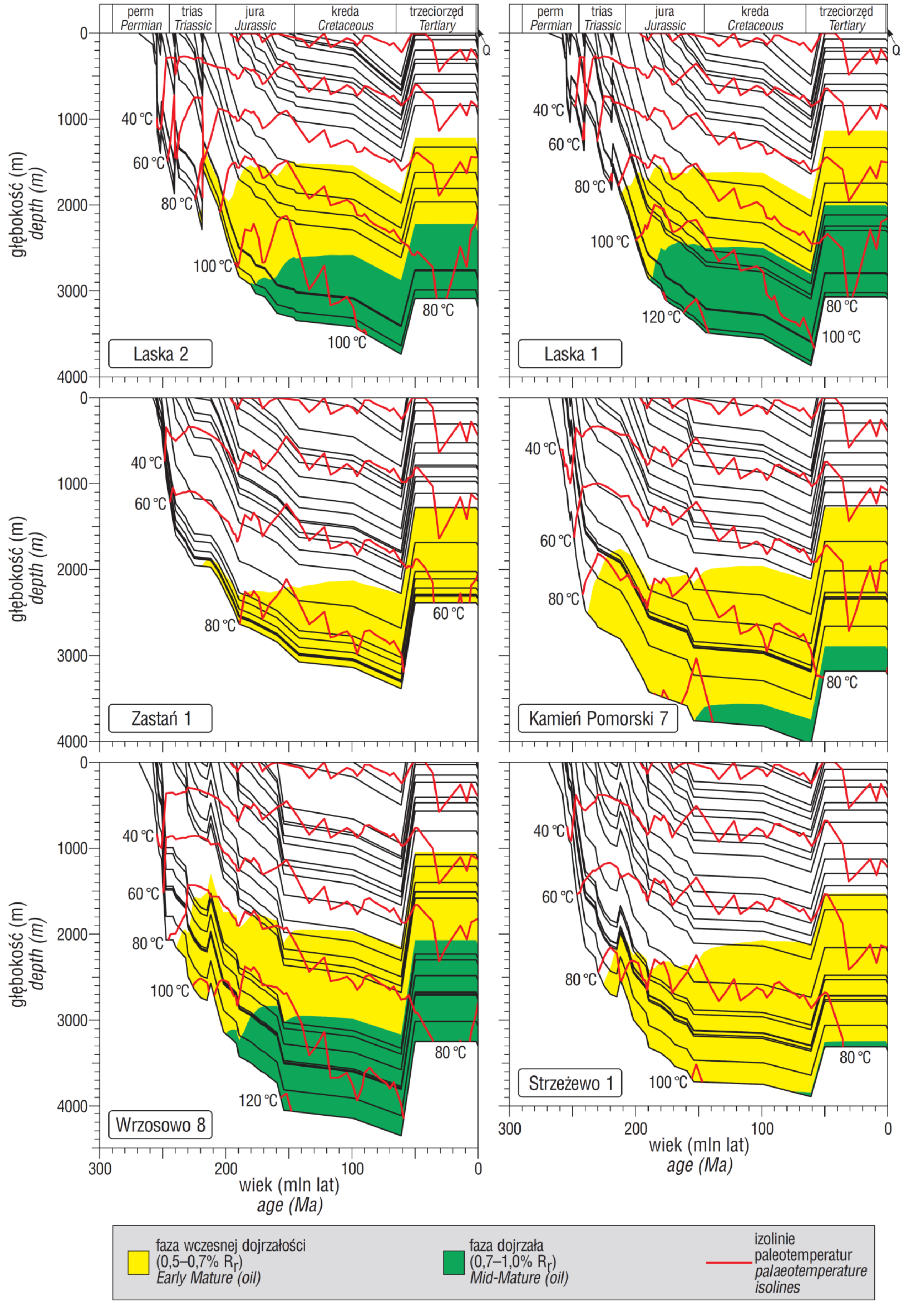


Fig. 3.10. Burial history in selected wells from the "Gryfice" tender area and its vicinity with kerogen maturity intervals (Kosakowski et al., 2003). Q – Quaternary.

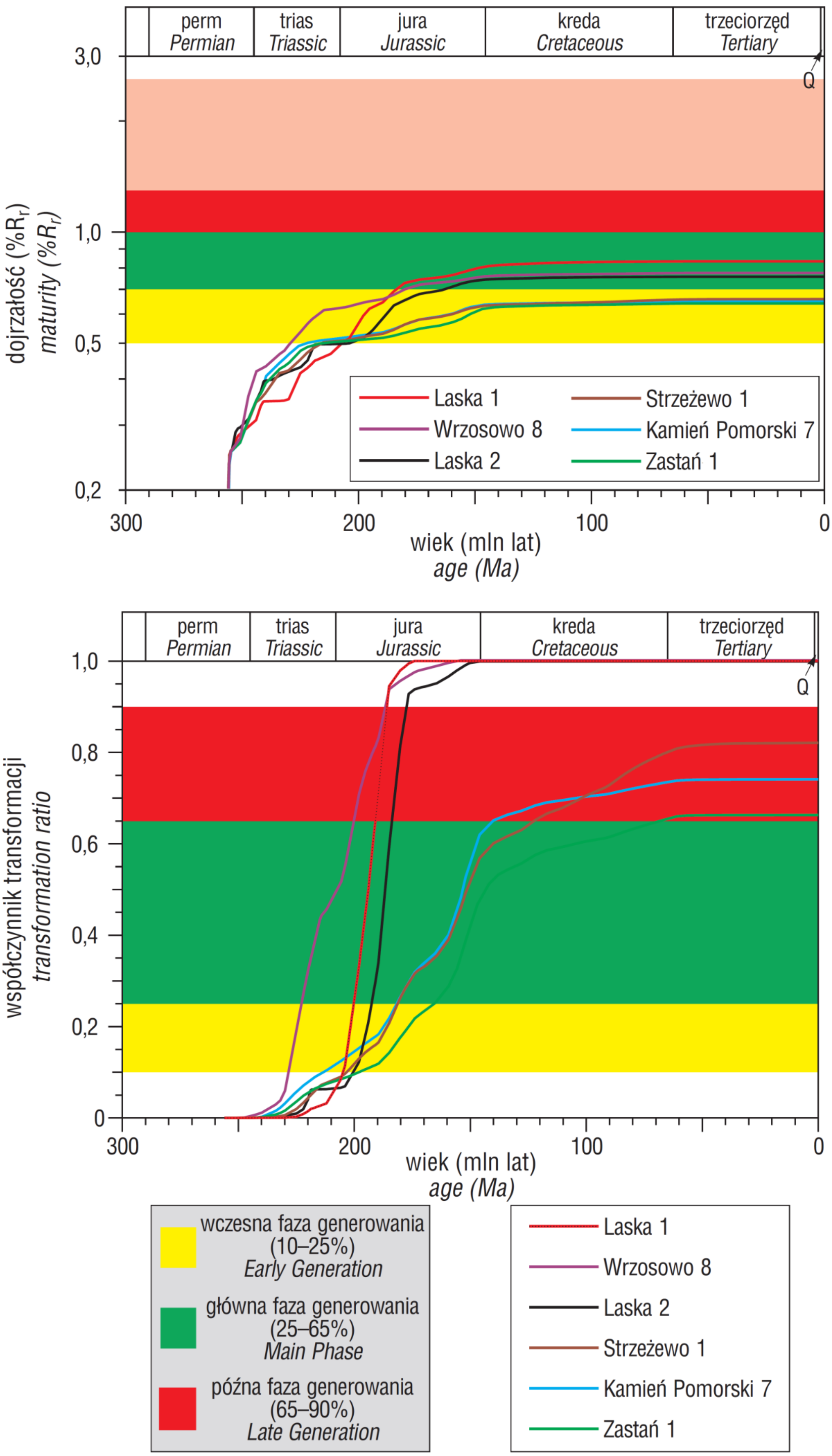


Fig. 3.11. Maturity evolution and the degree of kerogen transformation in the Main Dolomite in the wells from the Kamień Pomorski area (Kosakowski et al., 2003).

4. HYDROCARBON FIELDS

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

- Rekowo crude oil field (NR 4847; Figs 4.2–4.4, Tab. 4.1);
- Wrzosowo natural gas field (GZ 4732; Fig. 4.5, Tab. 4.2).

In the close neighborhood of the “Gryfice” tender area there are also six natural gas and crude oil fields discovered (Fig. 4.1). These are:

- Dargosław natural gas field (GZ 20146; Fig. 4.6, Tab. 4.3);
- Gorzysław N natural gas field (GZ 4687; Figs 4.7–4.8, Tab. 4.4);
- Gorzysław S natural gas field (GZ 4688; Fig. 4.9–4.10, Tab. 4.5);
- Kamień Pomorski crude oil field (NR 4802; Figs 4.11–4.13, Tab. 4.6);
- Trzebusz natural gas field (GZ 4686; Figs 4.14–4.15, Tab. 4.7);
- Wysoka Kamieńska crude oil field (NR 4804; Figs 4.16–4.17, Tab. 4.8).

The Gorzysław N, Gorzysław S, Kamień Pomorski, Trzebusz, Wysoka Kamieńska and Rekowo fields are being still exploited.

→ **Fig. 4.1.** Hydrocarbon fields in the “Gryfice” tender area and in its neighborhood.

Obszary wytypowane do postępowania przetargowego na koncesje na poszukiwanie i rozpoznawanie złóż węglowodorów oraz wydobywanie węglowodorów ze złóż w 2021 r.

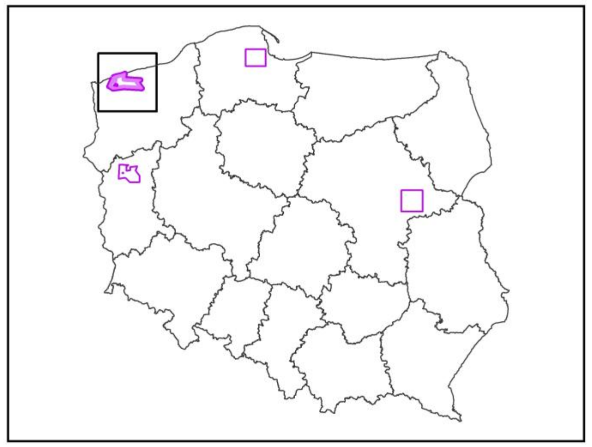
Areas selected to the tender procedure for concessions for hydrocarbon exploration and production in 2021

Objaśnienia
Legend

- obszary wytypowane do przetargu / areas selected to the tender procedure
- złoża węglowodorów / hydrocarbon fields
- obszary górnicze / mining areas
- granice gmin / municipalities
- granice powiatów / counties
- granice województw / voivodeships

Współrzędne punktów wyznaczających granice obszaru Gryfice, układ współrzędnych PL-1992
Coordinates determining the borders of Gryfice tender area, coordinate system PL-1992

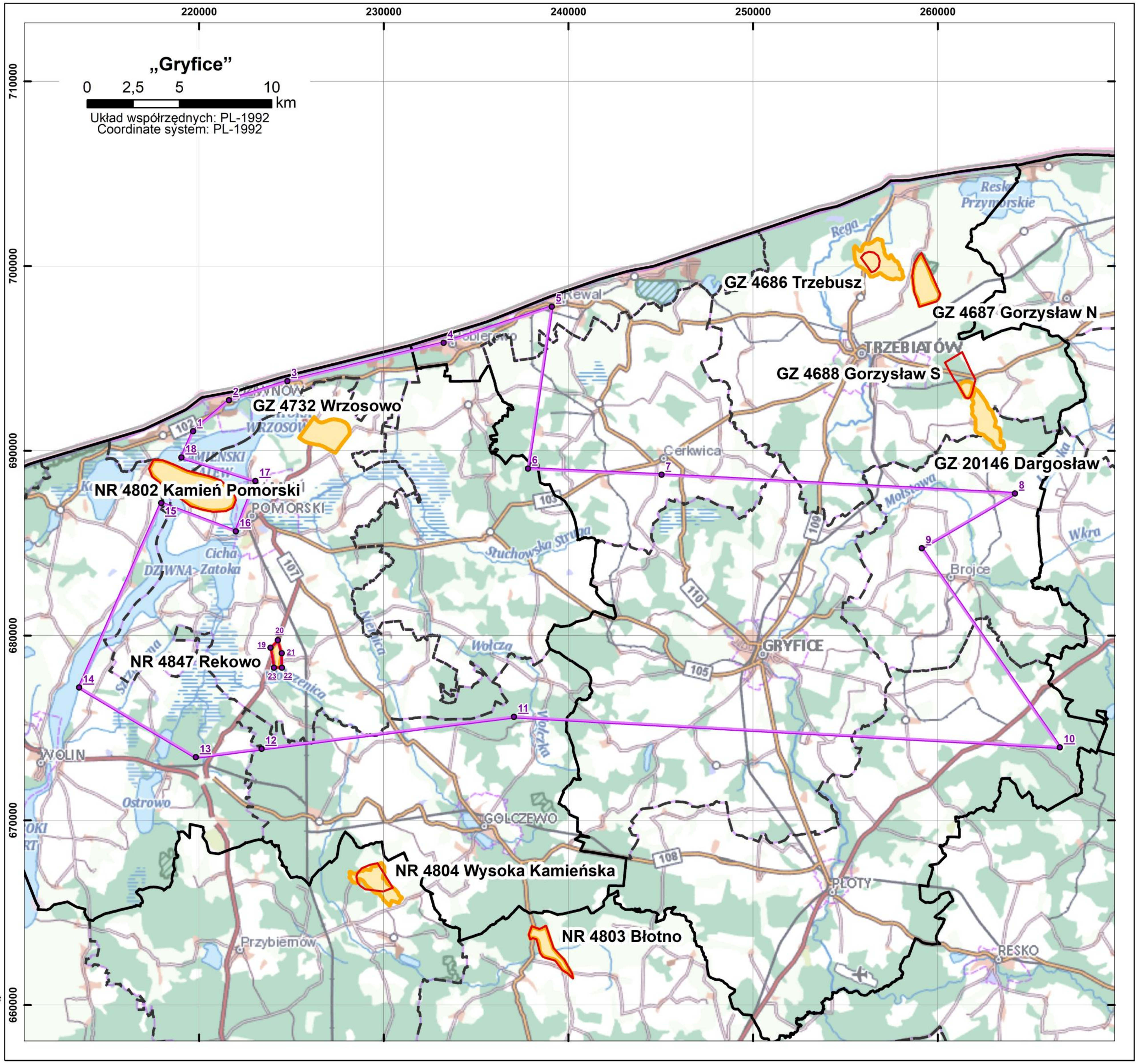
Nr punktu Point No	x	y	Nr punktu Point No	x	y
1	691 055,17	219 674,19	14	677 185,11	213 499,78
2	692 737,14	221 619,12	15	687 174,95	217 946,87
3	693 771,09	224 785,26	16	685 637,43	221 987,20
4	695 846,05	233 241,52	17	688 367,49	223 047,42
5	697 800,71	239 098,78	18	689 636,16	219 042,50
6	689 034,77	237 808,88	z wyłączeniem poligonu zdefiniowanego punktami 19-23: excluding the polygon defined by points No 19-23:		
7	688 700,54	245 043,47			
8	687 684,41	264 181,99			
9	684 723,09	259 134,45	19	679 335,20	223 870,95
10	673 948,18	266 614,09	20	679 746,86	224 268,31
11	675 598,09	237 055,20	21	679 040,45	224 478,55
12	673 865,95	223 383,30	22	678 251,69	224 485,63
13	673 409,40	219 824,29	23	678 251,81	224 056,04



Udokumentowane złoże kopalin, obszary i tereny górnicze: PIG-PIB
System Gospodarki i Ochrony Bogactw Mineralnych Polski MIDAS
Podkład topograficzny: GUGiK
Baza Danych Obiektów Ogólnogeograficznych (BDOO)

Documented field, mining areas and mining counties: the System of management and protection of mineral resources in Poland MIDAS (PGI-NRI)
Topographic background: the Head Office of Geodesy and Cartography (GUGiK)
General-geographical Database (BDOO)

PIG-PIB
Warszawa 2021



4.1. REKOWO CRUDE OIL FIELD

Total field acreage: 53.12 ha
Depth of occurrence: from -2658.05 to -2665.00 m b.s.l.
Stratigraphy: Permian/Zechstein (Main Dolomite)
Resources:

- The primary exploitable anticipated economic resources (as of 2006):
  32.00 ktonnes of crude oil in cat. B
  3.63 million m^3 of natural gas in cat. B
- The exploitable anticipated economic resources as of 31.12.2019:
  1.37 ktonnes of crude oil in cat. B
  0.27 million m^3 of natural gas in cat. B
- The economic resources in place as of 31.12.2019:
  1.46 ktonnes of the crude oil economic resources in place in cat. B and 61.41 ktonnes of the crude oil sub-economic resources in cat. B
  lack of natural gas economic resources in place, 6.95 million m^3 of the natural gas sub-economic resources in cat. B
- Production in 2019:
  lack of production

Reports:

1. Binder, I. 1994. Rekowo crude oil field report. Inv. 710/95, Arch. CAG PIG, Warsaw. [In Polish]

2. Mularczyk, A. 1996. Rekowo crude oil field report – app. 1. Inv. 331/97, Arch. CAG PIG, Warsaw. [In Polish]

3. Pawłowski, A. 2005. Rekowo crude oil field report – app. 2. Inv. 569/2007, Arch. CAG PIG, Warsaw. [In Polish]

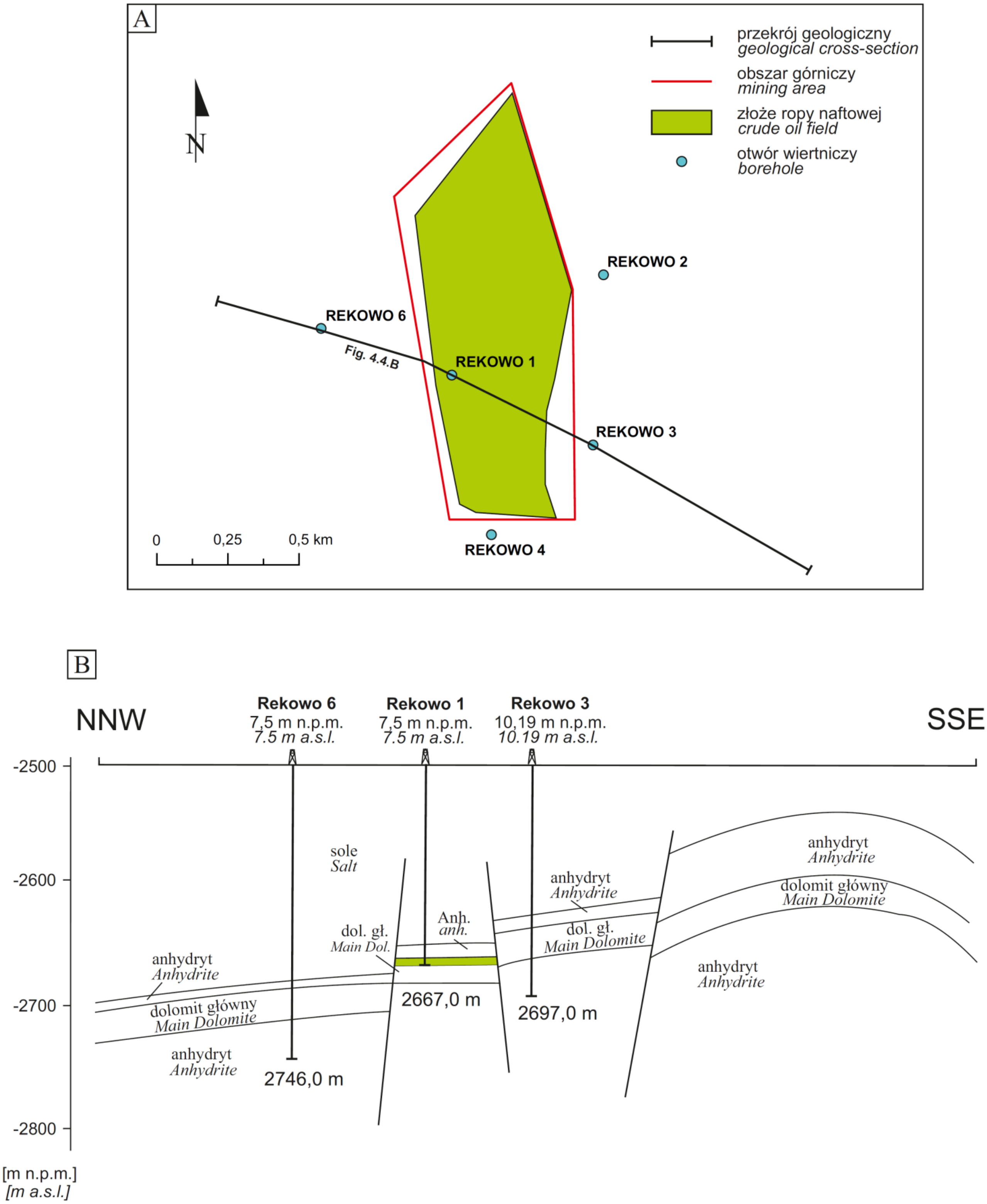


Fig. 4.2. A. Location of the boreholes within the Rekowo crude oil field and its neighborhood (CGDB, 2021). **B.** Geological cross-section through the Rekowo crude oil field (based on Pawłowski, 2005).

Parameter	Minimum value	Maximum value	Average value	Unit	Comments
current pressure	---------	---------	---------	MPa	not measured (run down deep-well pump)
saturation pressure	---------	---------	18.428	MPa	defined from correlation
primary reservoir pressure	---------	---------	49.911	MPa	
depth of underlying water	---------	---------	---------	m	unknown
effective reservoir thickness	---------	---------	---------	m	unknown
porosity	0.500	3.100	---------	%	
permeability	0.016	1.163	---------	mD	and diaphragm permeability
mineralization degree of formation water	117.000	---------	---------	g/l	
reservoir temperature	---------	---------	347.000	°K	
chemical type of formation water	---------	---------	---------	–	Cl-Na brine
production conditions	---------	---------	---------	–	pumping
hydrocarbon saturation factor	---------	---------	0.700	–	
production factor	---------	---------	0.330	–	
absolute efficiency V_{abs}	---------	---------	---------	t/d	not measured
permitted efficiency V_{dozw}	7.000	12.000	---------	t/d	based on the production forecast
gas exponent	---------	---------	104.000	m^3/t	
water exponent	---------	---------	---------	t/d	not stated
sand encroachment	---------	---------	---------	%	not measured
quality parameters of crude oil (main raw material)					
Parameter	**Minimum value**	**Maximum value**	**Average value**	**Unit**	**Comments**
crude oil specific gravity	0.856	0.878	0.861	g/cm^3	
viscosity	10.750	29.910	20.720	MPa/s	viscosity at temperature of 20°C (dynamic)
asphaltenes content	4.700	9.500	7.130	% m/m	hard asphaltenes
asphaltenes content	2.500	6.150	4.180	% m/m	
Hg content	---------	---------	---------	% m/m	not measured
paraffin content	4.130	11.940	5.600	% m/m	residue after distillation
sulfur content	---------	---------	---------	% m/m	not measured
quality parameters of natural gas (co-occurring raw material)					
Parameter	**Minimum value**	**Maximum value**	**Average value**	**Unit**	**Comments**
calorific value	37.230	50.290	43.760	MJ/m^3	
C_2H_6 content	8.080	12.260	10.170	% v/v	
CH_4 content	53.220	73.650	63.430	% v/v	
carbon dioxide content	0.140	0.530	0.330	% v/v	
He content	0	0.060	0.030	% v/v	
N_2 content	5.000	9.920	7.460	% v/v	
hydrogen sulfide content	3.040	6.320	4.680	% v/v	
heavy hydrocarbons C_{3+} content	4.970	20.080	12.480	% v/v	

Tab. 4.1. Parameters of the Rekowo crude oil field and quality parameters of the raw materials (MIDAS, 2021 according to Pawłowski, 2005).

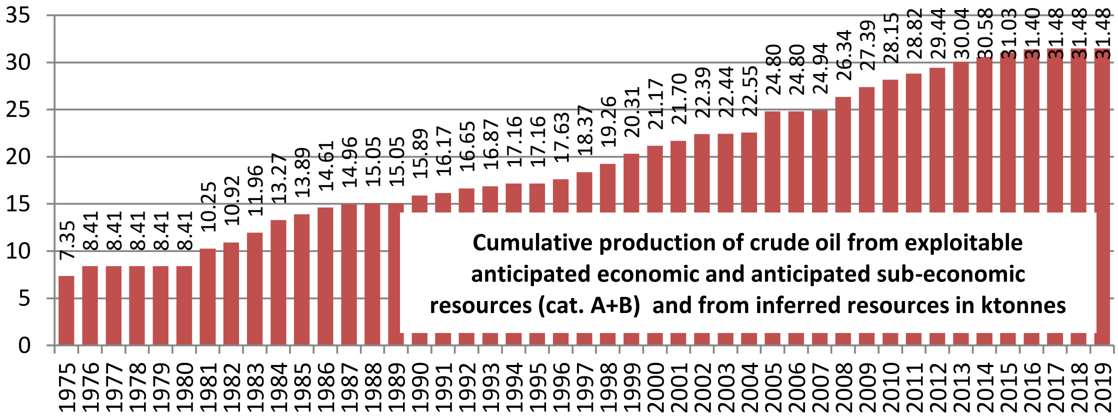


Fig. 4.3. Graph of the crude oil (main raw material) production from the Rekowo field (based on annual forms of the fields resources changes sent to PGI-NRI by concession holder; 1995-2019 period according to MIDAS, 2021; previous years according to the new geological documentation of the field with recalculated resources (Supplement No. 2) – Pawłowski, 2005; lack of data from 1975-1994 period in the paper version of "The balance of mineral resources deposits in Poland").

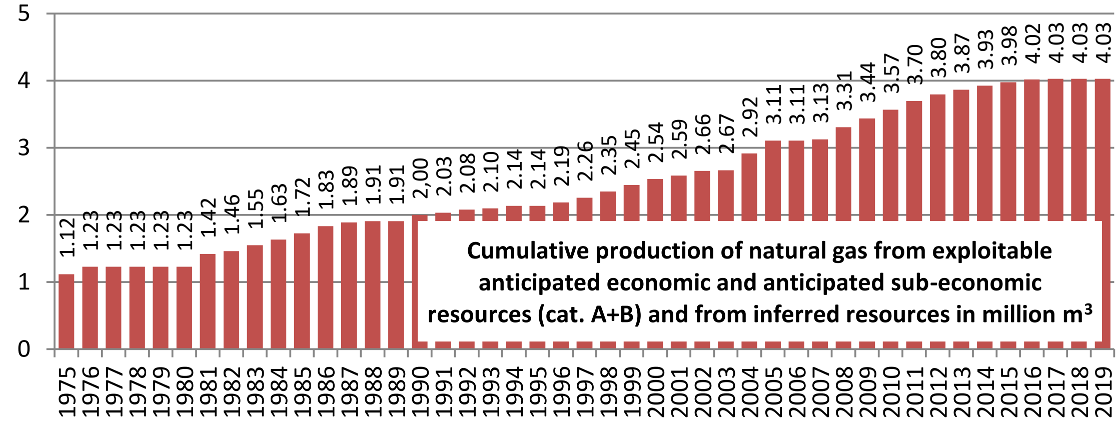


Fig. 4.4. Graph of the natural gas (co-occurring raw material) production from the Rekowo field (based on annual forms of the fields resources changes, sent to PGI-NRI by concession holder; 1995-2019 period according to MIDAS, 2021; previous years according to the new geological documentation of the field with recalculated resources (Supplement No. 2) – Pawłowski, 2005; lack of data from 1975-1994 period in the paper versions of "The balance of mineral resources deposits in Poland").

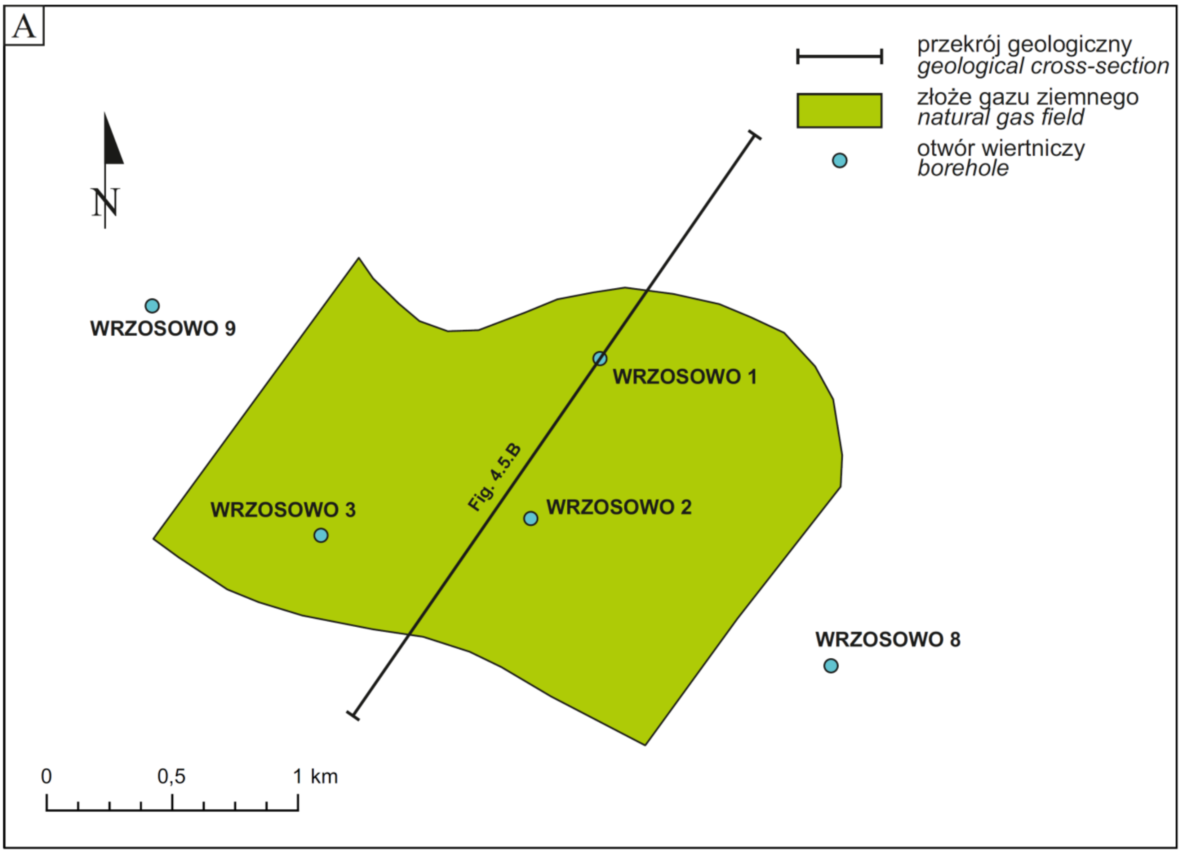
4.2. WRZOSOWO NATURAL GAS FIELD

Total field acreage: 320 ha
Depth of occurrence: from -2910.0 m b.s.l. to -3140.0 m b.s.l.
Stratigraphy: Permian – Rotliegend, Carboniferous
Resources:

- The primary exploitable anticipated economic resources (as of 1975):
  not designated
- The exploitable anticipated economic resources as of 31.12.2019:
  600.00 million m^3 of natural gas in cat. C
- The economic resources in place as of 31.12.2019:
  lack of resources
- Production in 2019:
  lack of production

Reports:

1. Binder, I., Sikorski, B. 1975. Wrzosowo natural gas field report. Inv. 11409 CUG, Arch. CAG PIG, Warsaw. [In Polish]



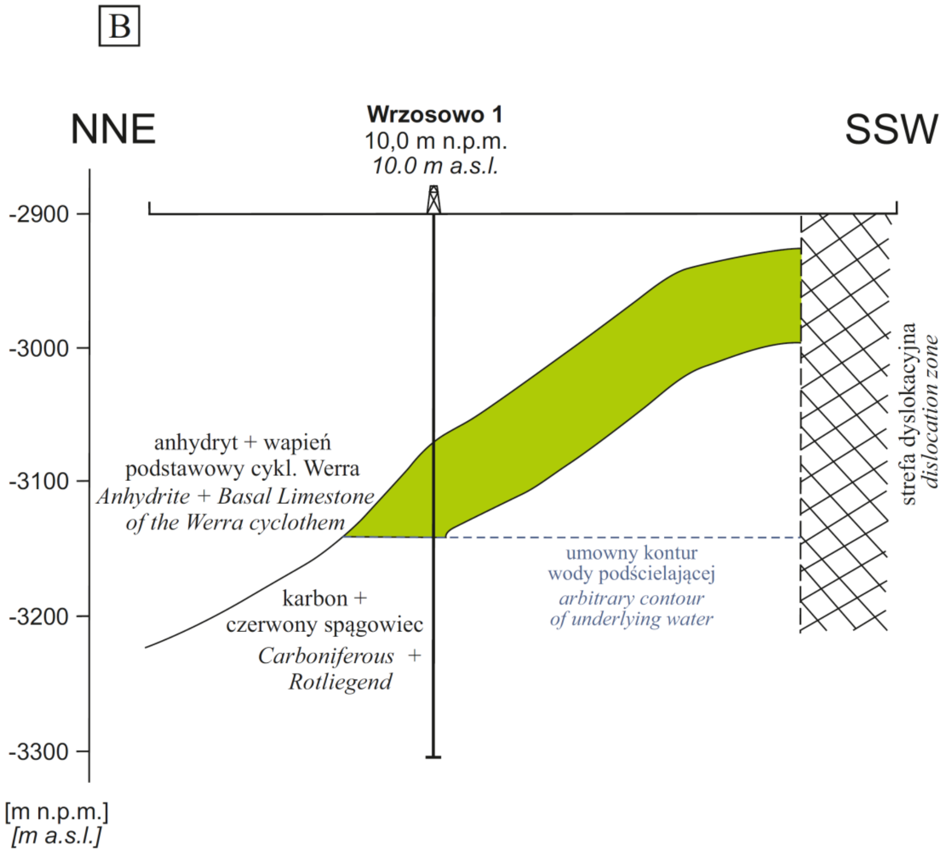


Fig. 4.5. A. Location of the boreholes within the Wrzosowo natural gas field and its neighborhood (based on CGDB, 2021). **B.** Geological cross-section through the Wrzosowo natural gas field (based on Binder and Sikorski, 1975).

Parameter	Minimum value	Maximum value	Average value	Unit	Comments
primary reservoir pressure	---------	---------	275.550	atm	
primary reservoir pressure	---------	---------	284.660	ata	
depth of underlying water	---------	---------	-3188.00	m	determined on the basis of the geophysical exploration
depth of underlying water	---------	---------	-3140.00	m	arbitrary level accepted for calculations
effective reservoir thickness	---------	43.000	---------	m	
porosity	---------	---------	7.000	%	
permeability	0.075	1.037	---------	mD	Carboniferous
permeability	0.622	1.926	---------	mD	Rotliegend
reservoir temperature	---------	---------	80.000	°C	
hydrocarbon saturation factor	---------	---------	0.800	–	
absolute efficiency V_{abs}	---------	---------	16.500	Nm^3/min	Wrzosowo 1 borehole
quality parameters of natural gas					
Parameter	**Minimum value**	**Maximum value**	**Average value**	**Unit**	**Comments**
density	---------	---------	0.803	–	relative to air
calorific value	3,995.000	---------	---------	$Kcal/Nm^3$	
C_2H_6 content	---------	---------	2.240	% v/v	
CH_4 content	---------	---------	40.360	% v/v	
carbon dioxide content	---------	---------	---------	% v/v	marks
H_2 content	---------	---------	0.020	% v/v	
He content	---------	---------	0.220	% v/v	
N_2 content	---------	---------	56.590	% v/v	
hydrogen sulfide content	---------	---------	---------	% v/v	not stated

Tab. 4.2. Parameters of the Wrzosowo natural gas field and quality parameters of raw material (MIDAS, 2021 according to Binder and Sikorski, 1975).

4.3. DARGOSŁAW NATURAL GAS FIELD

Total field acreage: 266.07 ha
Depth of occurrence: from -2674.24 to -2851.61 m b.s.l.
Stratigraphy: Upper Carboniferous
Resources:

- The primary exploitable anticipated economic resources (as of 2018):
  555.00 million m^3 of natural gas in cat. C
- The exploitable anticipated economic resources as of 31.12.2018:
  536.26 million m^3 of natural gas in cat. C
- The economic resources in place as of 31.12.2018:
  536.26 million m^3 of the natural gas economic resources in place in cat. C,
  185.00 million m^3 of the natural gas subeconomic resources in cat. C
- Production in 2019:
  lack of data

Reports:

1. Gamrot, J. 2019. Dargosław natural gas field report. Inv. 1245/2021, Arch. CAG PIG, Warsaw. [In Polish]

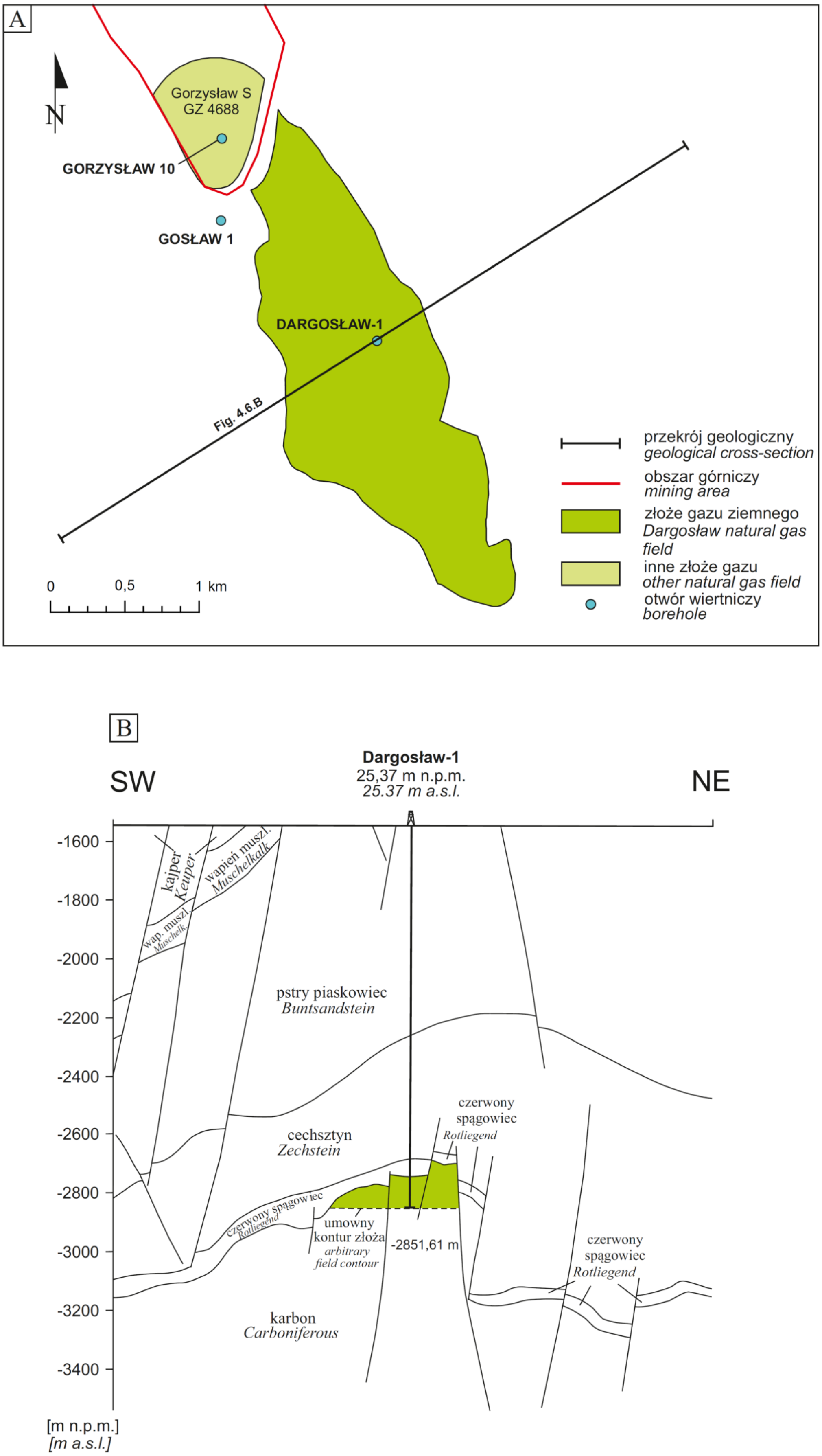


Fig. 4.6. A. Location of the boreholes within the Dargosław natural gas field and its neighborhood (CGDB, 2021). **B.** Geological cross-section through the Dargosław natural gas field (based on Gamrot, 2019).

Parameters	Minimum value	Maximum value	Average value	Unit	Comments
current pressure	---------	---------	23.890	MPa	May 2019
primary reservoir pressure	---------	---------	29.280	MPa	at the depth of -2798.92 m TVDSS
depth of underlying water	---------	---------	---------	m	not applicable, impossible to determine
effective reservoir thickness	---------	---------	17.920	m	average from the map of the effective thickness
porosity	---------	---------	9.330	%	average for the effective series determined from the Dargosław-1 borehole
permeability	---------	---------	2.960	mD	average for the effective series determined from the Dargosław-1 borehole
reservoir temperature	---------	---------	72.300	°C	at the depth of -2798.92 m TVDSS
production conditions	---------	---------	---------	–	volumetric
hydrocarbon saturation factor	---------	---------	77.370	%	based on the Dargosław-1 borehole
production factor	---------	---------	0.750	.	
absolute efficiency V_{abs}	132.000	581.000	358.000	m^3/min	
permitted efficiency V_{dozw}	---------	100.000	---------	m^3/min	proposed, based on the efficiency measurement in the Dargosław-1 borehole
crude oil/condensate exponent	---------	---------	---------	g/m^3	not applicable
water exponent	---------	---------	---------	g/m^3	not applicable
quality parameters of natural gas					
Parameter	**Minimum value**	**Maximum value**	**Average value**	**Unit**	**Comments**
combustion heat	17.450	19.470	18.300	MJ/m^3	
calorific value	15.720	17.510	16.480	MJ/m^3	
C_2H_6 content	0.630	0.680	0.650	% v/v	
CH_4 content	44.210	47.080	45.480	% v/v	
carbon dioxide content	0.040	0.160	0.140	% v/v	
He content	0.080	0.230	0.190	% v/v	
Hg content	5.014	5.978	5.492	µg/m^3	
N_2 content	51.850	54.740	53.410	% v/v	
hydrogen sulfide content	0.000	0.000	0.000	% v/v	
heavy hydrocarbons C_{3+} content	0.100	0.230	0.160	% v/v	

Tab. 4.3. Parameters of the Dargosław natural gas field and quality parameters of the raw material (MIDAS, 2021 according to Gamrot, 2019).

4.4. GORZYSŁAW N NATURAL GAS FIELD

Total field acreage: 233.00 ha
Depth of occurrence: from -2692.8 m b.s.l. to -2819.3 m b.s.l.
Stratigraphy: Upper Carboniferous – Westphalian
Resources:

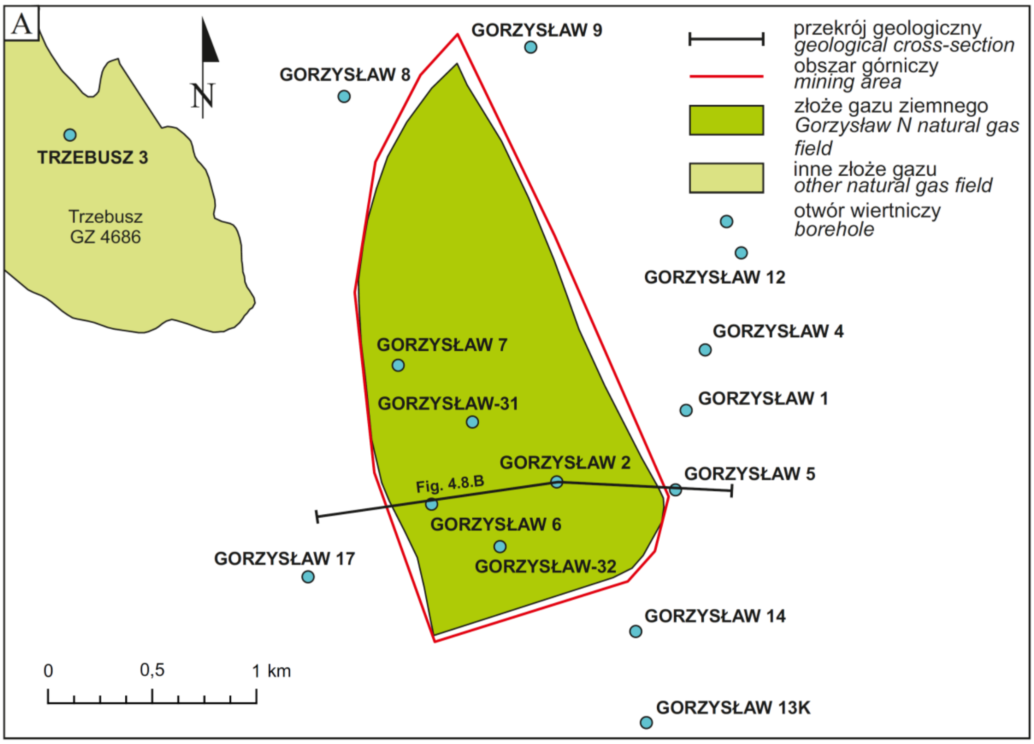
- The primary exploitable anticipated economic resources:
  lack of data
- The exploitable anticipated economic resources as of 31.12.2019:
  109.99 million m^3 of natural gas in cat. B and 160 million m^3 in cat. C
- The economic resources in place as of 31.12.2019:
  67.99 million m^3 of the natural gas economic resources in place in cat. B,
  324.00 million m^3 of the natural gas sub-economic resources in cat. B and 200.00 million m^3 of the natural gas sub-economic resources in cat. C
- Production in 2019:
  19.62 million m^3 of natural gas in cat. B

Reports:

1. Binder, I., Lech, I., Sikorski, B. 1976. Gorzysław natural gas field report. Inv. 11780a CUG, Arch. CAG PIG, Warsaw. [In Polish]

2. Binder, I., Lech, I., Sikorski, B. 1978. Gorzysław-Trzebusz natural gas field report – app. 1. Inv. 11780b CUG, Arch. CAG PIG, Warsaw. [In Polish].

3. Binder, I., Lech, I., Sikorski, B. 1980. Gorzysław-Trzebusz natural gas field report – app. 2. Inv. 11780c CUG, Arch. CAG PIG, Warsaw. [In Polish]



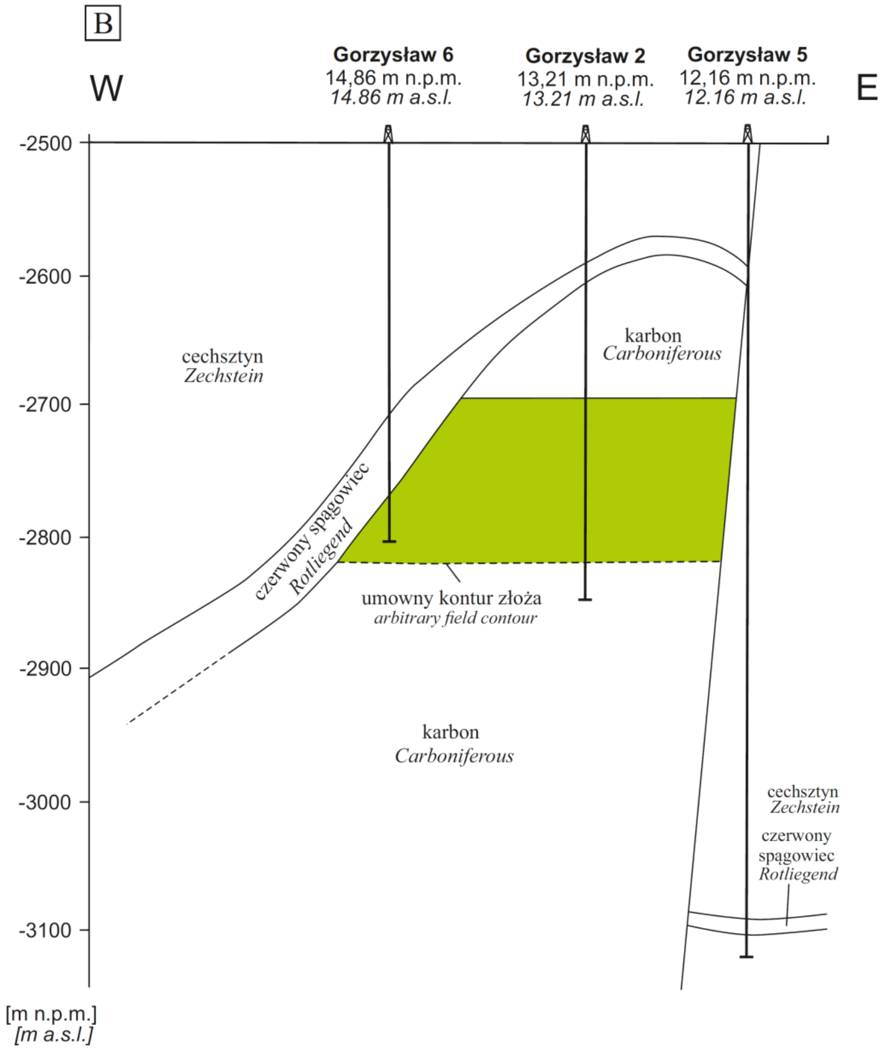


Fig. 4.7. A. Location of the boreholes within the Gorzysław N natural gas field and its neighborhood (based on CGDB, 2021). **B.** Geological cross-section through the Gorzysław N natural gas field (based on Binder et al., 1978).

Parameter	Minimum value	Maximum value	Average value	Unit	Comments
primary reservoir pressure	299.840	303.070	301.070	ata	
depth of underlying water	---------	---------	-2813.30	m	arbitrarily accepted
reservoir thickness	---------	64.300	---------	m	
porosity	0.210	21.520	10.000	%	
reservoir temperature	341.000	343.000	342.000	°K	
chemical type of formation water	---------	---------	---------	–	Cl-Na-Ca brine
hydrocarbon saturation factor	---------	---------	0.840	–	
production factor	---------	---------	0.800	–	
absolute efficiency V_{abs}	---------	---------	135.000	Nm^3/min	Gorzysław 2 borehole
absolute efficiency V_{abs}	---------	---------	321.000	Nm^3/min	Gorzysław 6 borehole
absolute efficiency V_{abs}	---------	---------	37.000	Nm^3/min	Gorzysław 7 borehole
permitted efficiency V_{dozw}	---------	---------	4.000	Nm^3/min	Gorzysław 7 borehole
permitted efficiency V_{dozw}	---------	---------	25.000	Nm^3/min	Gorzysław 2 borehole
permitted efficiency V_{dozw}	---------	---------	68.000	Nm^3/min	Gorzysław 6 borehole
quality parameters of natural gas					
Parameter	**Minimum value**	**Maximum value**	**Average value**	**Unit**	**Comments**
density	0.748	0.784	0.771	–	relative to air
calorific value	4158.000	4851.000	4443.000	$Kcal/Nm^3$	
C_2H_6 content	1.110	1.250	1.180	% v/v	
CH_4 content	44.700	52.930	47.600	% v/v	
carbon dioxide content	0.050	---------	---------	% v/v	marks
He content	0.240	0.260	0.250	% v/v	
N_2 content	45.380	53.650	50.720	% v/v	
hydrogen sulfide content	---------	---------	---------	% v/v	not stated
hydrocarbons content	---------	---------	43.620	% v/v	
heavy hydrocarbons C_{3+} content	---------	---------	0.250	% v/v	

Tab. 4.4. Parameters of the Gorzysław N natural gas field and quality parameters of the raw material (MIDAS, 2021 according to Binder et al., 1978).

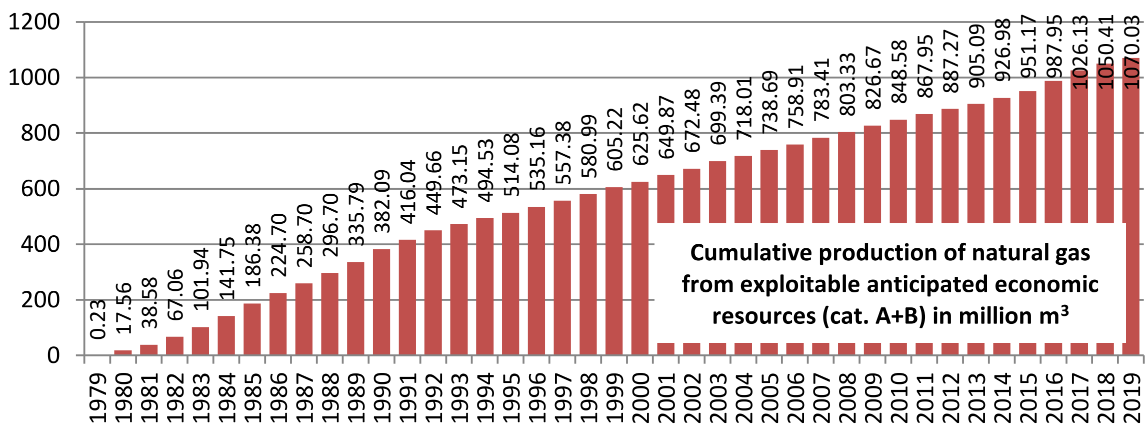


Fig. 4.8. Graph of the natural gas production from the Gorzysław N field (based on annual forms of the fields resources changes, sent to PGI-NRI by concession holder; 1992-2019 period according to MIDAS, 2021; previous years according to the paper versions of “The balance of mineral resources deposits in Poland”).

4.5. GORZYSŁAW S NATURAL GAS FIELD

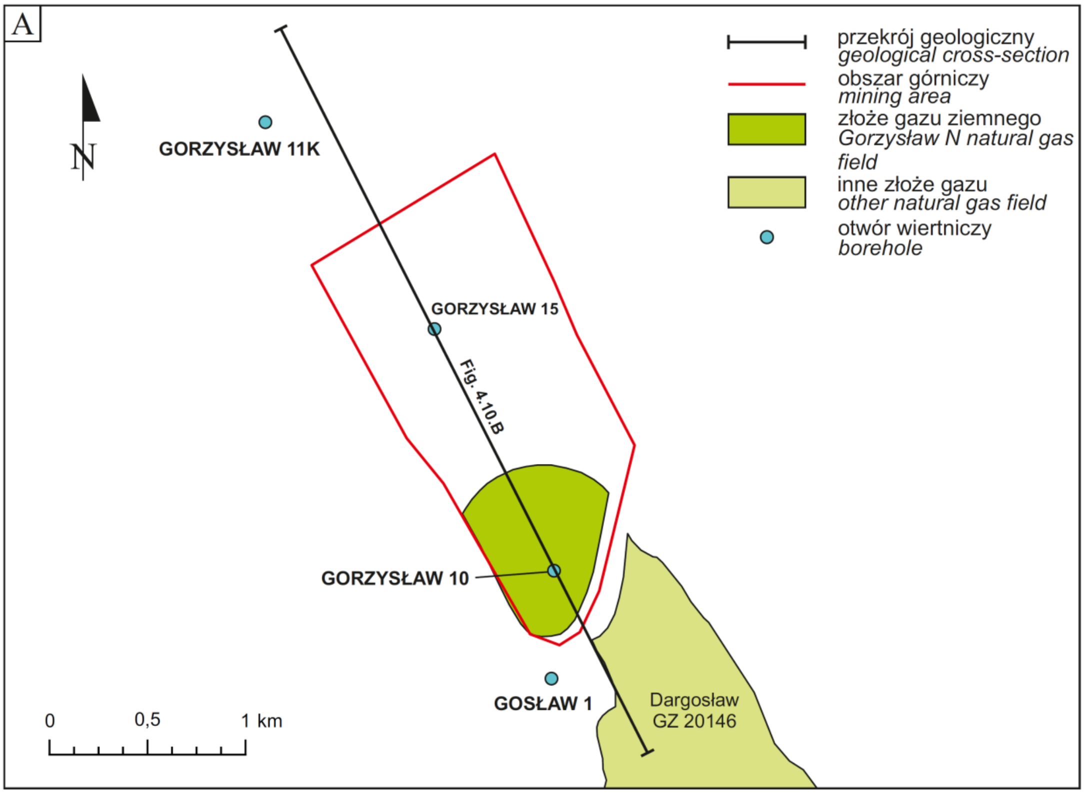
Total field acreage: 44.24 ha
Depth of occurrence: from -2743.5 m b.s.l. to -2832.5 m b.s.l.
Stratigraphy: Upper Carboniferous – Westphalian
Resources:

- The primary exploitable anticipated economic resources:
  lack of data
- The exploitable anticipated economic resources as of 31.12.2019:
  417.88 million m^3 of natural gas in cat. B
- The economic resources in place as of 31.12.2019:
  4.68 million m^3 of the natural gas economic resources in place in cat. B,
  533.21 million m^3 of the natural gas subeconomic resources in cat. B
- Production in 2019:
  lack of production

Reports:

1. Binder, I., Lech, I., Sikorski, B. 1978. Gorzysław-Trzebusz natural gas field report – app. 1. Inv. 11780b CUG, Arch. CAG PIG, Warsaw. [In Polish].

2. Binder, I., Lech, I., Sikorski, B. 1980. Gorzysław-Trzebusz natural gas field report – app. 2. Inw. 11780c CUG, Arch. CAG PIG, Warsaw. [In Polish]



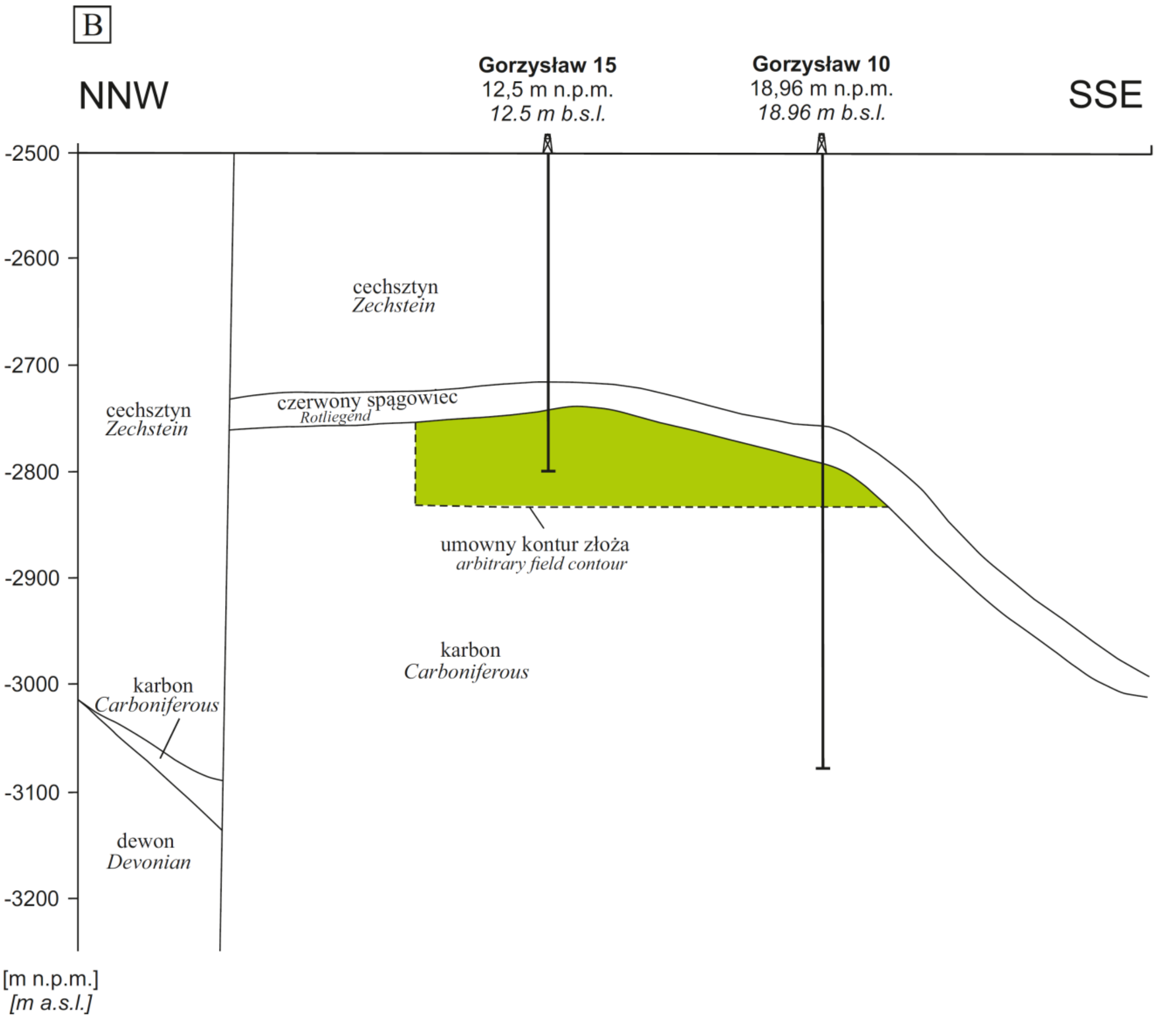


Fig. 4.9. A. Location of the boreholes within the Gorzysław S natural gas field and its neighborhood (CGDB, 2021). **B.** Geological cross-section through the Gorzysław S natural gas field (based on Binder et al., 1980).

Parameter	Minimum value	Maximum value	Average value	Unit	Comments
bottom pressure Pds	---------	---------	29.071	MPa	Gorzysław 15 borehole
bottom pressure Pds	---------	---------	29.230	MPa	Gorzysław 10 borehole
primary reservoir pressure	---------	---------	29.150	MPa	
depth of underlying water	---------	---------	-2832.50	m	arbitrarily accepted
reservoir thickness	---------	24.000	---------	m	
porosity	6.000	15.000	10.850	%	
reservoir temperature	345.000	346.000	345.500	°K	
chemical type of formation water	---------	---------	---------	–	Cl-Na-Ca brine
hydrocarbon saturation factor	---------	---------	0.800	–	
production factor	---------	---------	0.800	–	
absolute efficiency V_{abs}	---------	---------	59.000	Nm^3/min	Gorzysław 10 borehole
absolute efficiency V_{abs}	---------	---------	219.000	Nm^3/min	Gorzysław 15 borehole
permitted efficiency V_{dozw}	---------	---------	13.000	Nm^3/min	Gorzysław 10 borehole
permitted efficiency V_{dozw}	---------	---------	31.000	Nm^3/min	Gorzysław 15 borehole
quality parameters of natural gas					
Parameter	**Minimum value**	**Maximum value**	**Average value**	**Unit**	**Comments**
density	---------	---------	0.781	–	relative to air
calorific value	---------	---------	17.580	MJ	
C_2H_6 content	---------	---------	0.920	% v/v	
CH_4 content	---------	---------	45.950	% v/v	
He content	---------	---------	0.220	% v/v	
N_2 content	---------	---------	52.760	% v/v	
hydrocarbons content	---------	---------	47.010	% v/v	
heavy hydrocarbons C_{3+} content	---------	---------	3.200	g/Nm^3	

Tab. 4.5. Parameters of the Gorzysław S natural gas field and quality parameters of the raw material (MIDAS, 2021 according to Binder et al., 1980).

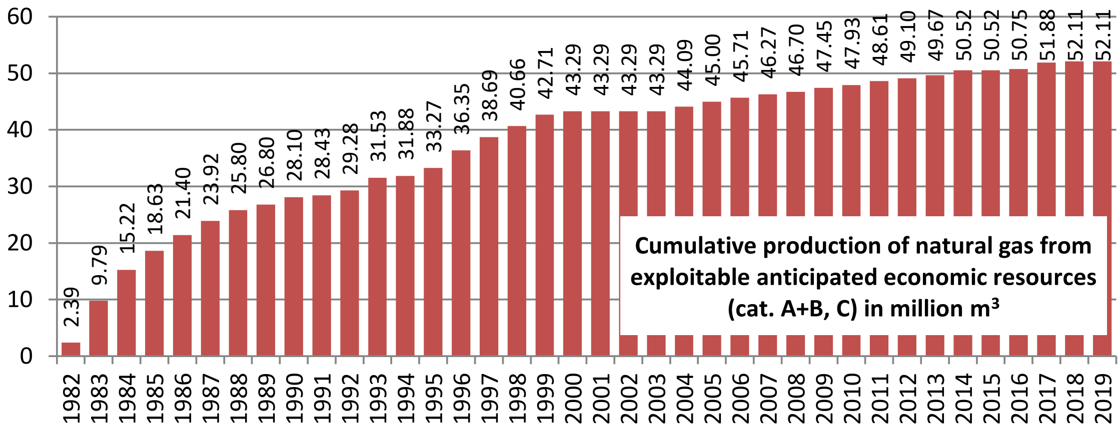


Fig. 4.10. Graph of the natural gas production from the Gorzysław S field (based on annual forms of the fields resources changes, sent to PGI-NRI by concession holder; 1992-2019 period according to MIDAS, 2021; previous years according to the paper versions of “The balance of mineral resources deposits in Poland”).

4.6. KAMIEŃ POMORSKI CRUDE OIL FIELD

Total field acreage: 620.00 ha
Depth of occurrence: from -2227.4 m b.s.l. to -2315.0 m b.s.l.
Stratigraphy: Permian/Zechstein (Main Dolomite)
Resources:

- The primary exploitable anticipated economic resources (as of 2007):
  1,925.00 ktonnes of crude oil in cat. B
  270.40 million m^3 of natural gas in cat. B
- The exploitable anticipated economic resources as of 31.12.2019:
  4.24 ktonnes of crude oil in cat. B
  8.93 million m^3 of natural gas in cat. B
- The economic resources in place as of 31.12.2019:
  6.34 ktonnes of the crude oil economic resources in place in cat. B
  2,117.90 ktonnes of the crude oil sub-economic resources in cat. B
  lack of natural gas economic resources in place, 373.52 million m^3 of the natural gas sub-economic resources in cat. B
- Production in 2019:
  1.25 ktonnes of crude oil in cat. B
  0.21 million m^3 of natural gas in cat. B

Reports:

1. Oświęcimska, A., Sikorski, B. 1972. Kamień Pomorski crude oil field report. Inv. 9777 CUG, Arch. CAG PIG, Warsaw. [In Polish]
2. Hannes, A., Sikorski, B. 1973. Kamień Pomorski crude oil field report – app. 2. Inv. 10535a CUG, Arch. CAG PIG, Warsaw. [In Polish].
3. Mularczyk, A., Pyzik, M. 1981. Kamień Pomorski crude oil field report – app. 2. Inv. 10535b CUG, Arch. CAG PIG, Warsaw. [In Polish].
4. Nowak, J. 2008. Kamień Pomorski crude oil field report – app. 3. Inv. 557/2009, Arch. CAG PIG, Warsaw. [In Polish].

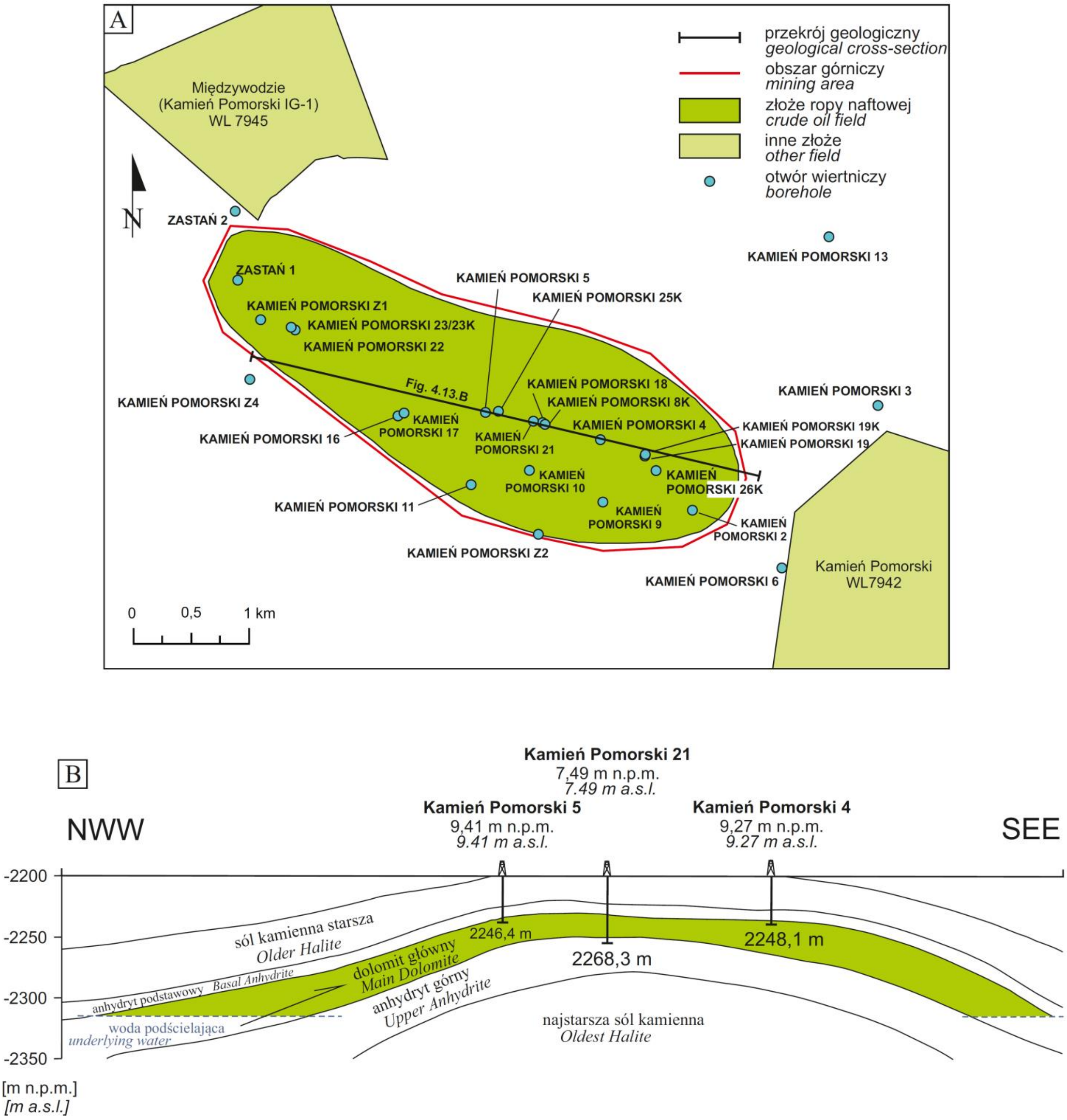


Fig. 4.11. A. Location of the boreholes within the Kamień Pomorski crude oil field and its neighborhood (CGDB, 2021). **B.** Geological cross-section through the Kamień Pomorski crude oil field (based on Nowak, 2008, detailed lithostratigraphic based on Sikorski and Hannes, 1973).

Parameter	Minimum value	Maximum value	Average value	Unit	Comments
current pressure	---------	---------	20.700	MPa	as of 30.08.2007
saturation pressure	---------	---------	17.260	MPa	calculated
primary reservoir pressure	---------	---------	44.160	MPa	
depth of underlying water	---------	---------	-2315.00	m	primary
effective reservoir thickness	---------	---------	18.500	m	
porosity	---------	---------	6.000	%	
permeability	0.010	0.440	---------	mD	
mineralization degree of formation water	---------	---------	314.000	g/l	
reservoir temperature	---------	---------	72.000	°C	
chemical type of formation water	---------	---------	---------	–	Cl-Ca (according to Bojarski); Na-Cl (according to Cimaszewski)

production conditions	---------	---------	---------	–	periodic self-acting production
hydrocarbon saturation factor	---------	---------	0.900	–	
production factor	---------	---------	0.480	–	
permitted efficiency V_{dozw}	---------	---------	560.000	t/month	
gas exponent	---------	---------	157.000	m^3/t	annual average from 24 years of production
quality parameters of crude oil (main raw material)					
Parameter	**Minimum value**	**Maximum value**	**Average value**	**Unit**	**Comments**
crude oil specific gravity	0.855	0.861	0.859	g/cm^3	
density	---------	---------	0.859	g/cm^3	at temperature of 15°C
viscosity	---------	---------	11.970	cSt	at temperature of 30°C
viscosity	---------	---------	22.230	cSt	at temperature of 20°C
pour point	---------	---------	6.750	°C	
paraffin content	3.000	4.300	3.700	% m/m	
sulfur content	---------	---------	---------	% m/m	>1.0
hydrogen sulfur content	---------	---------	961.000	mg/dm^3	
water content	---------	---------	0.190	% m/m	
quality parameters of natural gas (accompanying raw material)					
Parameter	**Minimum value**	**Maximum value**	**Average value**	**Unit**	**Comments**
Wobbe index	---------	---------	54.290	MJ/Nm^3	
combustion heat	49.140	50.370	49.755	MJ/Nm^3	
C_2H_6 content	10.940	11.220	11.080	% v/v	
CH_4 content	46.530	47.640	47.085	% v/v	
carbon dioxide content	0.049	0.059	0.054	% v/v	
He content	0.0198	0.020	0.0199	% v/v	
Hg content	0.966	2.893	1.787	$\mu g/Nm^3$	
N_2 content	7.181	7.614	7.398	% v/v	
hydrogen sulfide content	15.000	15.640	15.320	% v/v	
heavy hydrocarbons C_{3+} content	18.450	19.685	19.067	% v/v	

Tab. 4.6. Parameters of the Kamień Pomorski crude oil field and quality parameters of the raw materials (MIDAS, 2021 according to Nowak, 2008).

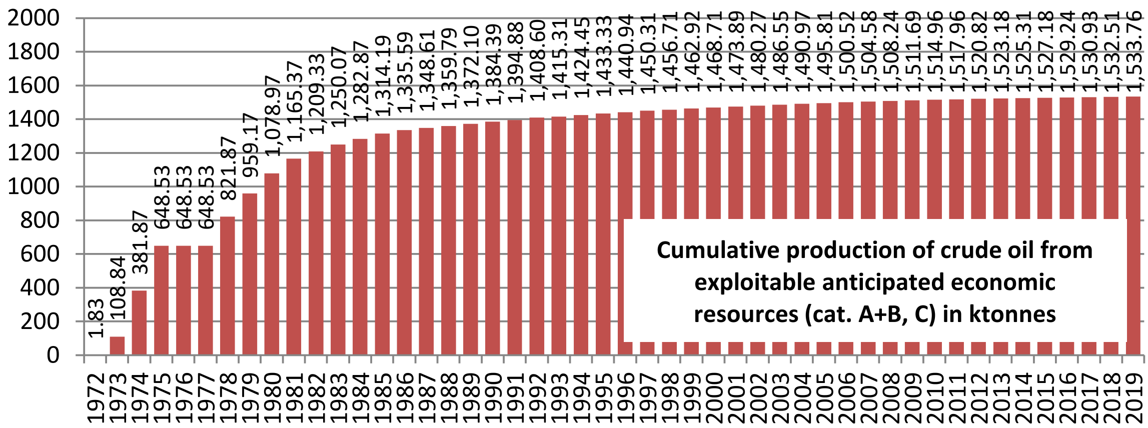


Fig. 4.12. Graph of the crude oil (main raw material) production from the Kamień Pomorski field (based on annual forms of the fields resources changes, sent to PGI-NRI by concession holder; 1992-2019 period according to MIDAS, 2021, previous years according to the paper versions of “The balance of mineral resources deposits in Poland”).

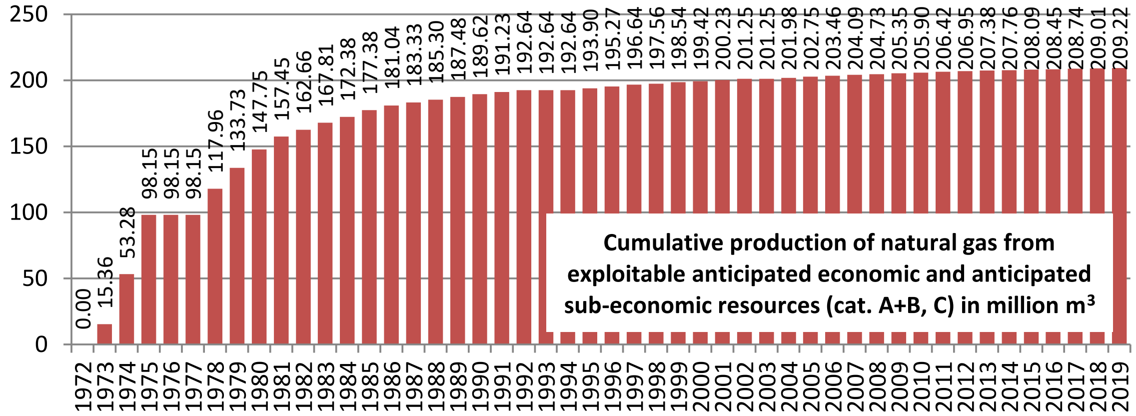


Fig. 4.13. Graph of the natural gas (accompanying raw material) production from the Kamień Pomorski field (based on annual forms of the fields resources changes, sent to PGI-NRI by concession holder; 1992-2019 period according to MIDAS, 2021, previous years according to the paper versions of "The balance of mineral resources deposits in Poland").

4.7. TRZEBUSZ NATURAL GAS FIELD

Total field acreage: 336.48 ha
Depth of occurrence: from -2732.6 m b.s.l. to -2906.0 m b.s.l.
Stratigraphy: Upper Carboniferous – Westphalian
Resources:

- The primary exploitable anticipated economic resources (as of 2018):
  710.00 million m^3 of natural gas in cat. C, including 1.78 million m^3 of helium
- The exploitable anticipated economic resources as of 31.12.2019:
  596.79 million m^3 of natural gas in cat. C, including 1.49 million m^3 of helium
- The economic resources in place as of 31.12.2019:
  587.24 million m^3 of the natural gas economic resources in place in cat. C, including 1.46 million m^3 of helium and 299.55 million m^3 of the natural gas sub-economic resources in cat. C, including 0.75 million m^3 of helium
- Production in 2019:
  5.75 million m^3 of natural gas in cat. C

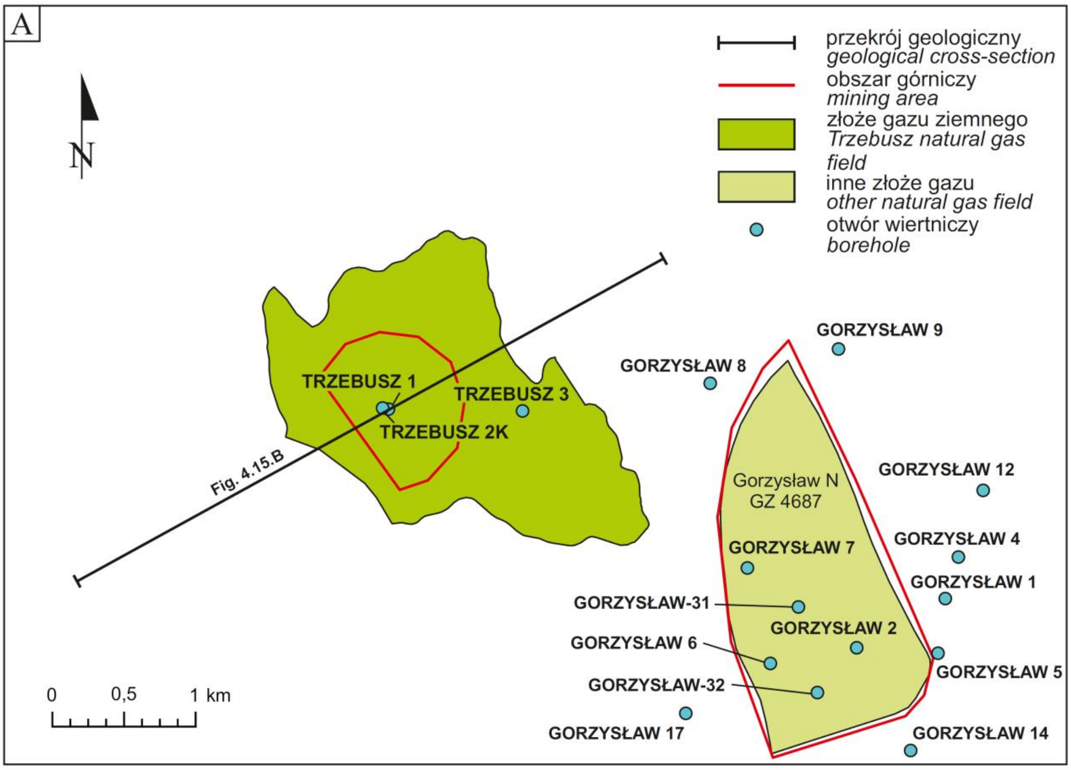
The main raw material is high nitrogenous natural gas, with helium as the accompanying admixture in the field. Its averaged content is equal 0.25% v/v. During the exploitation, as a result of the technological process accompanying the natural gas production from the field, there is also hydrocarbon condensate obtained.

Reports:

1. Binder, I., Lech, I., Sikorski, B. 1978. Gorzysław-Trzebusz natural gas field report – app. 1. Inv. 11780b CUG, Arch. CAG PIG, Warsaw. [In Polish]

2. Binder, I., Lech, I., Sikorski, B. 1980. Gorzysław-Trzebusz natural gas field report – app. 2. Inw. 11780c CUG, Arch. CAG PIG, Warsaw. [In Polish]

3. Czajka, D. 2019. Trzebusz natural gas field report. Inv. 9379/2020, Arch. CAG PIG, Warsaw. [In Polish]



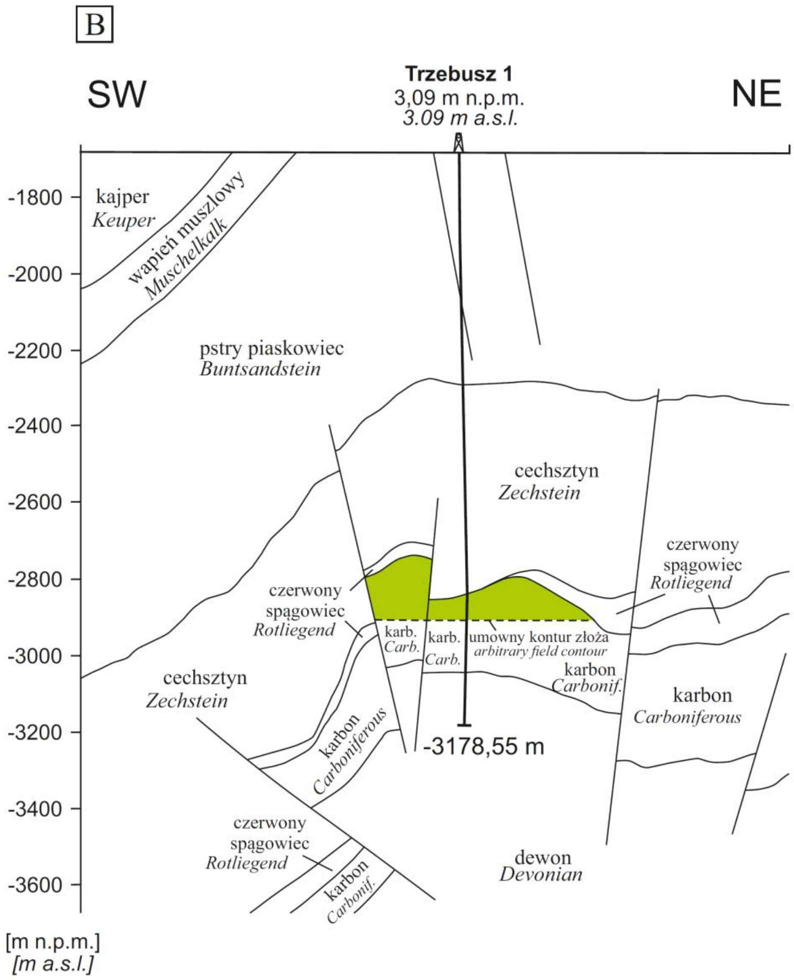


Fig. 4.14. A. Location of the boreholes within the Trzebusz natural gas field and its neighborhood (based on CGDB, 2021). **B.** Geological cross-section through the Trzebusz natural gas field (based on Czajka, 2019).

Parameter	Minimum value	Maximum value	Average value	Unit	Comments
estimation error of average values of the reservoir parameters and resources	---------	---------	6.000	%	
current wellhead pressure	---------	---------	24.800	MPa	-2819.3 m TVDSS
primary reservoir pressure	---------	---------	30.140	MPa	-2819.3 m TVDSS
depth of underlying water	---------	---------	-2906.00	m	TVDSS
effective reservoir thickness	---------	---------	15.480	m	
porosity	---------	---------	8.680	%	from Trzebusz 1 borehole
permeability	---------	---------	4.480	mD	from Trzebusz 1 borehole
mineralization degree of formation water	---------	---------	227.800	g/l	
reservoir temperature	---------	---------	70.200	°C	
chemical type of formation water	---------	---------	---------	–	Cl-Na-Ca
production conditions	---------	---------	---------	–	volumetric
hydrocarbon saturation factor	---------	---------	0.800	–	
production factor	---------	---------	0.710	–	
absolute efficiency V_{abs}	9.000	141.000	72.000	m^3/min	
permitted efficiency V_{dozw}	3.000	25.000	16.200	m^3/min	
crude oil/condensate exponent	0.000	12.570	7.000	g/m^3	
water exponent	0.000	2.120	1.130	g/m^3	
quality parameters of natural gas					
Parameter	**Minimum value**	**Maximum value**	**Average value**	**Unit**	**Comments**
calorific value	14.230	21.470	18.150	MJ/m^3	
C_2H_6 content	0.950	2.590	1.460	% v/v	
CH_4 content	35.110	53.560	45.220	% v/v	
carbon dioxide content	0.130	0.230	0.150	% v/v	
He content	0.190	0.390	0.250	% v/v	
Hg content	1.466	3.981	2.724	μg/m^3	
N_2 content	43.940	62.960	52.190	% v/v	
hydrogen sulfide content	0.000	0.000	0.000	% v/v	
heavy hydrocarbons C_{3+} content	0.190	1.350	0.730	% v/v	

Tab. 4.7. Parameters of the Trzebusz natural gas field and quality parameters of the raw material (MIDAS, 2021 according to Czajka, 2019).

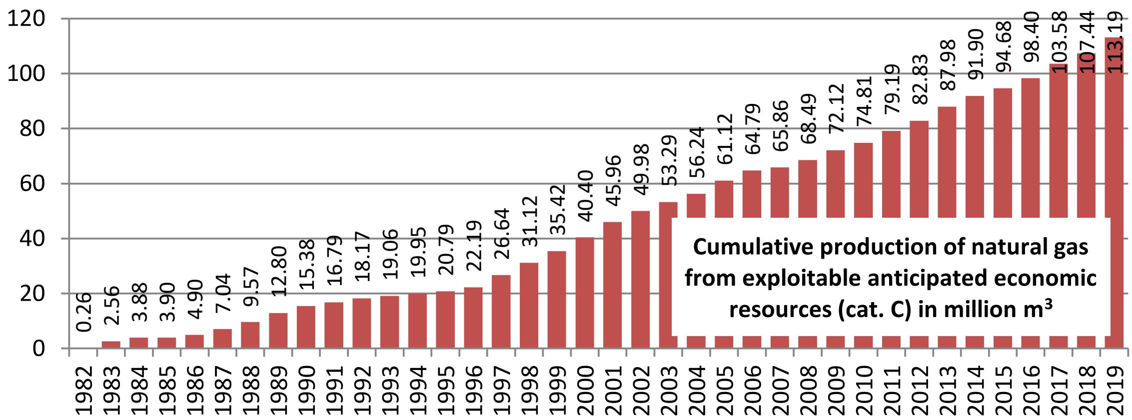


Fig. 4.15. Graph of the natural gas production from the Trzebusz field (based on annual forms of the field resources changes, sent to PGI-NRI by concession holder; 1992-2019 period according to MIDAS, 2021, previous years according to the paper versions of "The balance of mineral resources deposits in Poland").

4.8. WYSOKA KAMIEŃSKA CRUDE OIL FIELD

Total field acreage: 256.20 ha
Depth of occurrence: from -3010.30 m b.s.l. to -3060.70 m b.s.l.
Stratigraphy: Permian/Zechstein (Main Dolomite)
Resources:

- The primary exploitable anticipated economic resources (as of 2003):
  450.00 ktonnes of crude oil in cat. A
  32.92 million m^3 of natural gas in cat. A
- The exploitable anticipated economic resources as of 31.12.2019:
  8.39 ktonnes of crude oil in cat. A
  2.19 million m^3 of natural gas in cat. A
- The economic resources in place as of 31.12.2019:
  8.90 ktonnes of the crude oil economic resources in place in cat. A and 899.48 ktonnes of the crude oil sub-economic resources in cat. A
  lack of natural gas economic resources in place, 67.81 million m^3 of the natural gas sub-economic resources in cat. A
- Production in 2019:
  3.90 ktonnes of crude oil in cat. A
  0.28 million m^3 of natural gas in cat. A

Reports:

1. Ryba, J., Sikorski, B. 1980. Wysoka Kamieńska crude oil field report. Inv. 13095 CUG, Arch. CAG PIG, Warsaw. [In Polish]
2. Zoła, K. 1996. Wysoka Kamieńska crude oil field report – app. 1. Inv. 739/97, Arch. CAG PIG, Warsaw. [In Polish]
3. Nowak, J. 2004. Wysoka Kamieńska crude oil field report – app. 2. Inv. 1969/2004, Arch. CAG PIG, Warsaw. [In Polish]

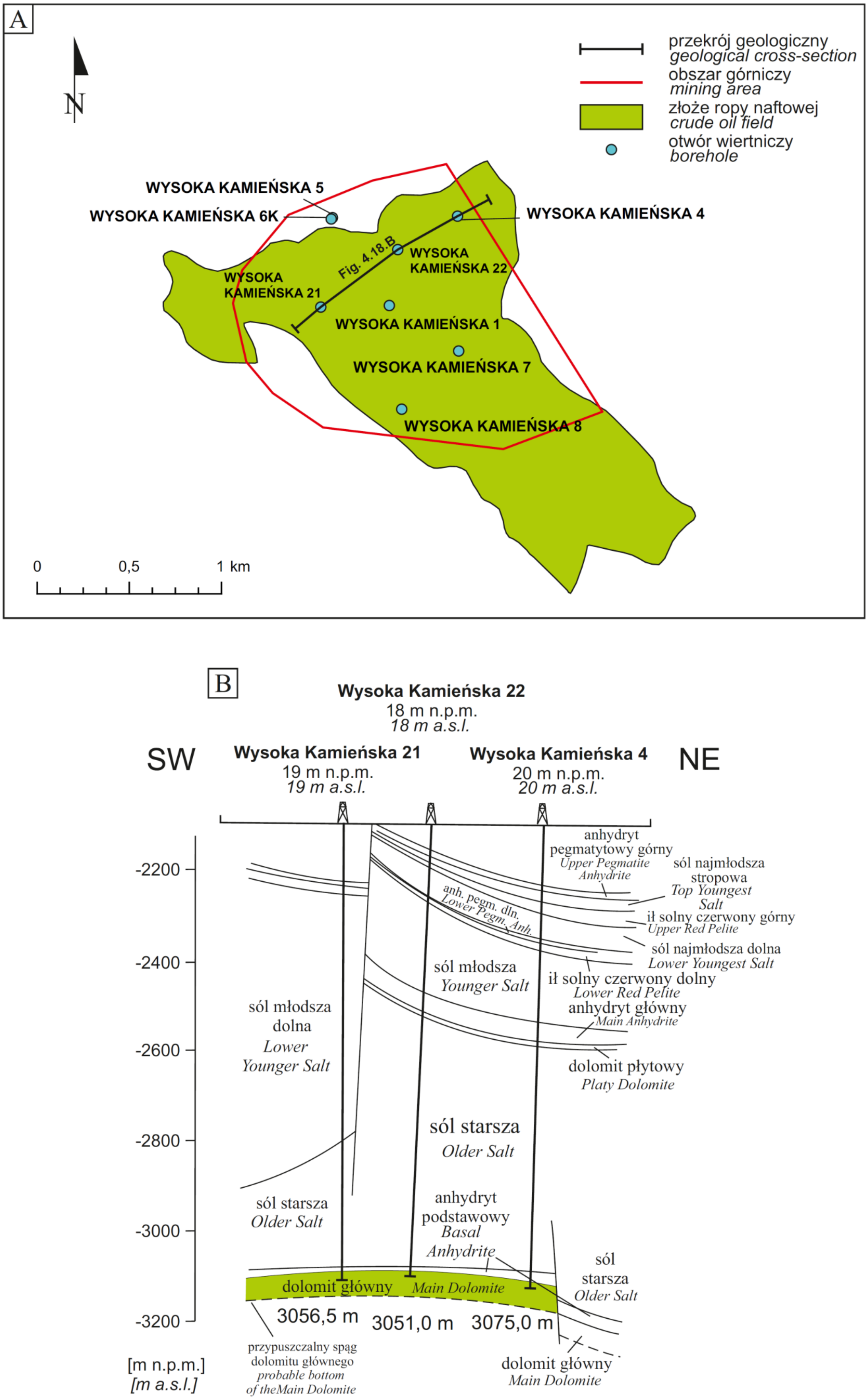


Fig. 4.16. A. Location of the boreholes within the Wysoka Kamieńska crude oil field and its neighborhood (based on CGDB, 2021). **B.** Geological cross-section through the Wysoka Kamieńska crude oil field (based on Zoła, 1996).

Parameter	Minimum value	Maximum value	Average value	Unit	Comments
current pressure	---------	---------	18.130	MPa	measurement of 05.05.2001
primary reservoir pressure	---------	---------	54.600	MPa	
depth of underlying water	---------	---------	-3060.70	m	
effective reservoir thickness	---------	---------	21.430	m	
crude oil saturation	---------	---------	75.000	%	
porosity	3.710	5.440	4.580	%	
permeability	0.010	298.350	10.210	mD	
mineralization degree of formation water	---------	---------	332.000	g/l	
reservoir temperature	---------	---------	81.000	°C	
chemical type of formation water	---------	---------	---------	–	Cl-Ca genetic type according to Sulin; I Na-I Cl water type according to Ci-maszewski
production conditions	---------	---------	---------	–	mixed: gas dissolved in crude oil and partial water pressure from the limited aquifer
water saturation factor	---------	---------	0.250	–	
production factor	---------	---------	0.330	–	
permitted efficiency V_{dozw}	---------	---------	8.000	t/month	Wysoka Kamieńska 21 borehole: 8 t per cycle, 30 cycles/month
permitted efficiency V_{dozw}	---------	---------	8.000	t/month	Wysoka Kamieńska 1 borehole: 8 t per cycle, 16 cycles/month
permitted efficiency V_{dozw}	---------	---------	8.000	t/month	Wysoka Kamieńska 7 borehole: 8 t per cycle, 30 cycles/month
permitted efficiency V_{dozw}	---------	---------	608.000	t/month	for the whole field
gas exponent	---------	---------	73.000	m^3/t	
quality parameters of crude oil (main raw material)					
Parameter	**Minimum value**	**Maximum value**	**Average value**	**Unit**	**Comments**
density	---------	---------	0.856	g/cm^3	density at temperature of 20°C
viscosity	---------	---------	4.240	°E	viscosity at temperature of 30°C
viscosity	---------	---------	30.330	cSt	viscosity at temperature of 30°C
viscosity	---------	---------	27.160	cP	viscosity at temperature of 30°C
pour point	---------	---------	24.000	°C	
chlorides content	---------	---------	5.100	mg/dm^3	
paraffin content	---------	---------	6.180	% m/m	according to PN-71/C-04105
sulfur content	---------	---------	0.330	% m/m	total sulfur content
water content	---------	---------	0.030	% m/m	
quality parameters of natural gas (accompanying raw material)					
Parameter	**Minimum value**	**Maximum value**	**Average value**	**Unit**	**Comments**
density	---------	---------	0.887	-	relative to air
Wobbe index	---------	---------	57.240	MJ/Nm^3	
calorific value	---------	---------	49.160	MJ/Nm^3	lower calorific value of pure gas
C_2H_6 content	---------	---------	12.433	% v/v	
CH_4 content	---------	---------	62.280	% v/v	
carbon dioxide content	---------	---------	2.719	% v/v	
He content	---------	---------	0.020	% v/v	
N_2 content	---------	---------	5.470	% v/v	
hydrogen sulfide content	---------	---------	0.050	% v/v	
hydrocarbons content	---------	---------	91.730	% v/v	

heavy hydrocarbons C_{3+} content	---------	---------	17.020	% v/v	
heavy hydrocarbons C_{3+} content	---------	---------	411.460	g/Nm^3	

Tab. 4.8. Parameters of the Wysoka Kamieńska crude oil field and quality parameters of raw materials (MIDAS, 2021 according to Nowak, 2004).

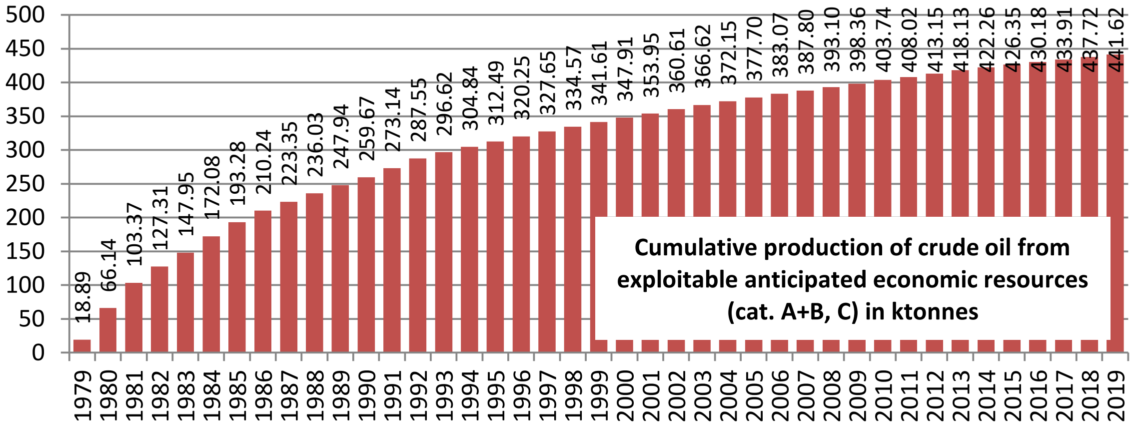


Fig. 4.17. Graph of the crude oil (main raw material) production from the Wysoka Kamieńska field based on annual forms of the fields resources changes, sent to PGI-NRI by concession holder; 1992-2019 period according to MIDAS, 2021; previous years according to the paper versions of “The balance of mineral resources deposits in Poland”).

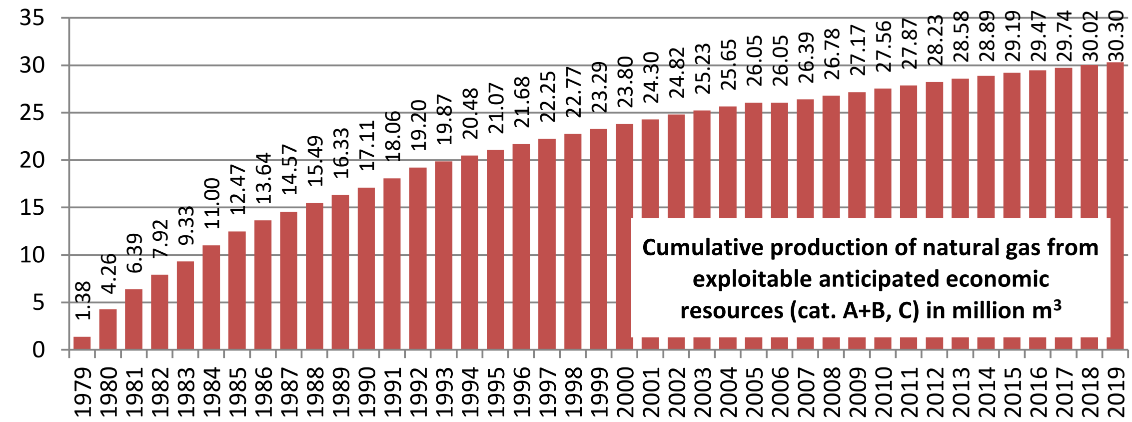


Fig. 4.18. Graph of the natural gas (accompanying raw material) production from the Wysoka Kamieńska field (based on annual forms of the fields resources changes, sent to PGI-NRI by concession holder; 1992-2019 period according to MIDAS, 2021, previous years according to the paper versions of “The balance of mineral resources deposits in Poland”).

5. WELLS

Among 40 deep wells (> 500 m MD), which are located within the “Gryfice” tender area (Fig. 5.1), 35 wells reached the prospective horizons. These are:

Well name	Year	Owner	Concession (for wells after 1994)	Depth [m]	Stratigraphy at the bottom
BENICE 1	1973	State Treasury		3247.0	Permian
BENICE 2	1974	State Treasury		2916.0	Permian
BENICE 3	1979	State Treasury		2842.0	Permian
BENICE 4K	1986	State Treasury		2732.5	Permian
BROJCE IG-1	1986	State Treasury		4252.0	Permian
CHOMINO-1	2014	State Treasury	Kaleń 28/2008/p	2750.0	U. Permian
DOBROPOLE 1	1987	State Treasury		2883.0	Permian
DUSIN 1	1977	State Treasury		2662.5	Permian
GOSTYŃ 2	1982	State Treasury		3447.0	Westphalian
GRYFICE 1	1979	State Treasury		3367.0	Permian
GRYFICE 2	1974	State Treasury		3415.0	L. Permian
GRYFICE 3	1975	State Treasury		3190.0	Permian
JARSZEWO 1	1974	State Treasury		2998.7	Permian
KALEŃ 1	2000	PGNiG S.A.	Świerzno-Rybokarty 3/97/p	3232.0	Carboniferous
KAMIEŃ POMORSKI 13	1973	State Treasury		2672.0	Permian
KAMIEŃ POMORSKI 3	1978	State Treasury		2405.0	U. Permian
KAMIEŃ POMORSKI 7	1974	State Treasury		3410.0	Westphalian
LASKA 2	1980	State Treasury		3583.0	Visean
REKOWO 1	1974	State Treasury		2667.0	Permian
REKOWO 2	1975	State Treasury		3141.5	Permian
REKOWO 3	1976	State Treasury		2697.0	Permian
REKOWO 4	1975	State Treasury		2736.0	Permian
REKOWO 6	1976	State Treasury		2746.0	Permian
SKARCHOWO 1	1976	State Treasury		2667.0	Permian
STRZEŻEWO 1	1978	State Treasury		4521.0	Givetian
ŚWIERZNO 1	1973	State Treasury		3103.0	Permian
ŚWIERZNO 2	1975	State Treasury		2772.2	Permian
ŚWIERZNO 4	1975	State Treasury		3238.5	Famennian
ŚWIERZNO 5	1975	State Treasury		2883.6	Permian
ŚWIERZNO 9	1975	State Treasury		2774.7	Permian
WRZOSOWO 1	1975	State Treasury		3305.0	Westphalian
WRZOSOWO 2	1976	State Treasury		3127.3	Westphalian
WRZOSOWO 3	1979	State Treasury		3255.0	Westphalian
WRZOSOWO 8	1977	State Treasury		3310.0	Westphalian
WRZOSOWO 9	1977	State Treasury		3198.0	Westphalian

Their general characteristics, including hydrocarbon shows and inflows, as well as petrophysical properties of gas-and-oil bearing intervals, are shortly summarized in Tab. 5.1. Two exemplary wells – Laska 2 and Wrzosowo 1 – are illustrated in Fig. 5.2.

The original data from 34 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 5th tender round.

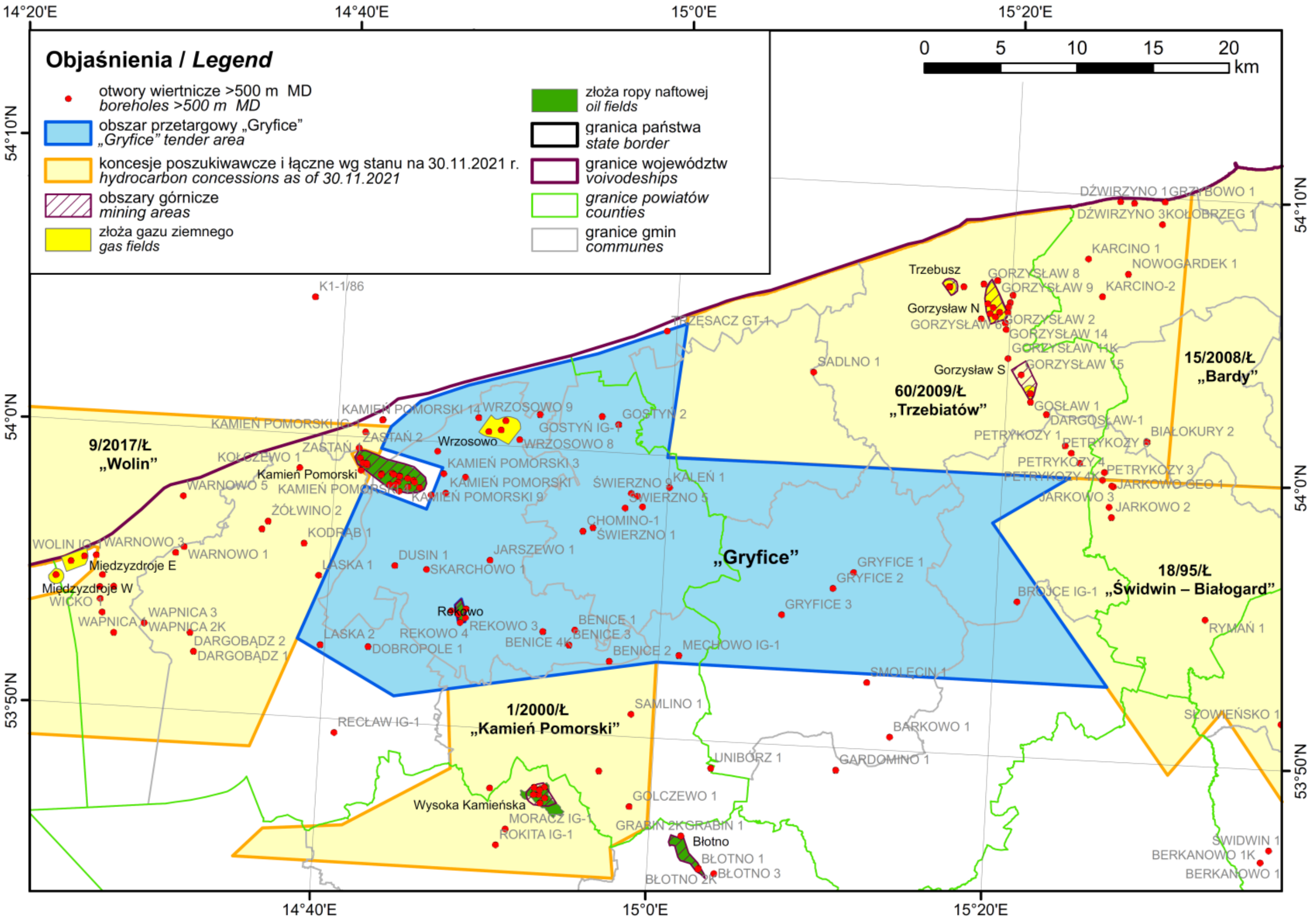


Fig. 5.1. Deep wells (>500 m MD) located within the "Gryfice" tender area and in its close neighborhood.

→ **Tab. 5.1.** Summary of stratigraphy, petrophysical properties, hydrocarbon shows (blue squares), hydrocarbon inflows and geophysics in deep wells located within the "Gryfice" tender area and in its close neighborhood.

STRATIGRAPHY	BENICE 1 1973			BENICE 2 1974			BENICE 3 1979			
	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	HC Inflow
Caenozoic	0,0	28,0		0,0	54,0		0,0	18,0		
Jurassic	28,0	1018,0		54,0	1103,0		18,0	1034,0		
Triassic	1018,0	2374,5		1103,0	2504,0		1034,0	2367,5		
Permian	2374,5	3247,0		2504,0	2916,0		2367,5	2842,0		
Rewal Fm	2374,5	2428,5		2504,0	2554,0		2367,5	2413,5		
PZ4	2428,5	2550,0		2554,0	2677,5		2413,5	2532,0		
Upper Younger Halite Na3g	2550,0	2584,5								
Middle Anhydrite A3s				2677,5	2731,0					
Lower Younger Halite Na3d										
Younger Halite Na3							2532,0	2620,0		
Main Anhydrite A3	2584,5	2644,5		2731,0	2763,0		2620,0	2642,0		
Platy Dolomite Ca3	2644,5	2652,5		2763,0	2767,5		2642,0	2649,0		
Grey Pelite T3										
Screening Anhydrite A2r	2652,5	2653,5		2767,5	2770,0		2649,0	2650,5		
Screening Older Halite Na2r							2650,5	2655,0		
Older Potash K2							2655,0	2664,5		
Older Halite Na2	2653,5	2728,0		2770,0	2829,0		2664,5	2726,0		
Basal Anhydrite A2	2728,0	2739,0		2829,0	2836,0		2726,0	2731,0		
Main Dolomite Ca2	2739,0	2793,0	0,07–7,81/ 0,0-0,265	2836,0	2881,0	0,07–10,25/ 0,0-1,786	2731,0	2805,0	0,06–12,78/ 0,01–185,1	brine with H_2S
Upper Anhydrite A1g	2793,0	3000,0		2881,0	2916,0		2805,0	2842,0		
Oldest Halite Na1	3000,0	3091,5								
Upper Oldest Halite Na1g										
Middle Anhydrite A1s										
Lower Oldest Halite Na1d										
Lower Anhydrite A1d	3091,5	3142,0								
Zechstein Limestone Ca1	3142,0	3150,0								
Kupferschiefer T1										
Basal Conglomerate Zp1										
Rotliegend	3150,0	3247,0	2,30–8,93/ -							
Autun										
Carboniferous - Westphalian										
Carboniferous - Visean										
Czaplinek Fm										
Devonian - Famennian										
Krojanty Fm										
Devonian - Frasnian										
Devonian - Gievtian										

STRATIGRAPHY	BENICE 4K 1986				BROJCE IG-1 1986				CHOMINO 1 2014			
	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	HC Inflow	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	HC Inflow	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	HC Inflow
Caenozoic	0,0	19,5			0,0	31,0			0,0	46,5		
Jurassic	19,5	1504,0			31,0	1156,0		brine	46,5	1055,0		
Triassic	1504,0	2234,5			1156,0	2853,0		brine	1055,0	2331,0		
Permian	2234,5	2752,0			2853,0	3674,5			2331,0	2752,0		
Rewal Fm					2853,0	2912,5	1,85-7,41/ 0,1-0,15					
PZ4	2234,5	2364,5			2912,5	3028,5			2331,0	2407,0		
Upper Younger Halite Na3g									2407,0	2557,5		
Middle Anhydrite A3s									2557,5	2592,5		
Lower Younger Halite Na3d									2592,5	2605,5		
Younger Halite Na3	2364,5	2424,0			3028,5	3080,0						
Main Anhydrite A3	2424,0	2540,5			3080,0	3106,0			2605,5	2619,0		
Platy Dolomite Ca3	2540,5	2543,0	0,40–12,93/ -		3106,0	3109,0	1,34/ 0,1		2619,0	2622,0	~5,3/ <0,0001	
Grey Pelite T3	2543,0	2546,5			3109,0	3112,5			2622,0	2623,0		
Screening Anhydrite A2r	2546,5	2550,5			3112,5	3114,0			2623,0	2624,5		
Screening Older Halite Na2r					3114,0	3120,0	0,68-7,01/ 0,1-2,3					
Older Potash K2	2550,5	2606,0			3120,0	3141,0	0,647-1,75/ 0,1-0,25					
Older Halite Na2					3141,0	3235,0			2624,5	2682,5		
Basal Anhydrite A2	2606,0	2611,5							2682,5	2688,5		
Main Dolomite Ca2	2611,5	2688,5	0,07–22,52/ -	brine with H_2S	3235,0	3243,5			2688,5	2728,0	~2,43/ ~0,0368	
Upper Anhydrite A1g	2688,5	2752,0			3243,5	3460,0	0,67-2,16/ 0,1		2728,0	2752,0		
Oldest Halite Na1					3460,0	3542,5	0,34-0,67/ 0,1					
Upper Oldest Halite Na1g												
Middle Anhydrite A1s												
Lower Oldest Halite Na1d												
Lower Anhydrite A1d					3542,5	3601,0	0,67-1,04/ 0,1					
Zechstein Limestone Ca1					3601,0	3609,5	0,73-1,49/ 0,1					
Kupferschiefer T1												
Basal Conglomerate Zp1												
Rotliegend					3609,5	3674,5	0,74-3,3/ 0,1					
Autun												
Carboniferous - Westphalian												
Carboniferous - Visean												
Czaplinek Fm												
Devonian - Famennian												
Krojanty Fm												
Devonian - Frasnian					3674,5	4025,0	0,79-2,19/ 0,1					
Devonian - Gievtian					3674,5	4252,0	1,06-2,17/ 0,1					

STRATIGRAPHY	DOBROPOLE 1 1987				DUSIN 1 1977				GOSTYŃ 2 1982			
	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	HC Inflow	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	HC Inflow	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	HC Inflow
Caenozoic	0,0	44,5			0,0	16,0			0,0	54,0		
Jurassic	44,5	1179,0			16,0	959,0			54,0	1217,0		
Triassic	1179,0	2316,0			959,0	2205,0			1217,0	2578,0		
Permian	2316,0	2883,0			2205,0	2662,5			2578,0	3314,0		
Rewal Fm	2316,0	2347,5			2205,0	2245,0			2578,0	2636,0		
PZ4	2347,5	2430,0			2245,0	2331,0			2636,0	2670,5		
Upper Younger Halite Na3g	2430,0	2454,0										
Middle Anhydrite A3s												
Lower Younger Halite Na3d	2454,0	2563,5										
Younger Halite Na3					2331,0	2401,0			2670,5	2808,0		
Main Anhydrite A3	2563,5	2584,5			2401,0	2492,5			2808,0	2822,5		
Platy Dolomite Ca3	2584,5	2588,5			2492,5	2498,0			2822,5	2834,5		
Grey Pelite T3												
Screening Anhydrite A2r	2588,5	2591,5							2834,5	2836,0		
Screening Older Halite Na2r					2498,0	2502,0						
Older Potash K2	2591,5	2847,0							2836,0	2907,0		
Older Halite Na2					2502,0	2580,0			2836,0	2907,0		
Basal Anhydrite A2	2847,0	2850,5			2580,0	2583,5			2907,0	2916,5		
Main Dolomite Ca2	2850,5	2868,0	1,09-10,86/ -	water with gas	2583,5	2643,0	0,07-19,93/ 0,0-126,77	water with gas, oil and H_2S	2916,5	2945,5	0,14–6,20/ 0,53–7873,23	drilling fluid
Upper Anhydrite A1g	2868,0	2883,0			2643,0	2662,5			2945,5	3108,0		
Oldest Halite Na1									3108,0	3186,5		
Upper Oldest Halite Na1g												
Middle Anhydrite A1s									3186,5	3212,5		
Lower Oldest Halite Na1d									3212,5	3218,5		
Lower Anhydrite A1d									3218,5	3257,0		
Zechstein Limestone Ca1									3257,0	3262,0		
Kupferschiefer T1												
Basal Conglomerate Zp1									3262,0	3262,5		
Rotliegend												
Autun									3262,5	3314,0		
Carboniferous - Westphalian									3314,0	3447,0	0,72–9,19/ 9,17–4800,5	brine with gas
Carboniferous - Visean												
Czaplinek Fm												
Devonian - Famennian												
Krojanty Fm												
Devonian - Frasnian												
Devonian - Gievtian												

STRATIGRAPHY	GRYFICE 1 1979				GRYFICE 2 1974				GRYFICE 3 1975			
	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	HC Inflow	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	HC Inflow	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	HC Inflow
Caenozoic	0,0	70,0			0,0	39,0			0,0	79,0		
Jurassic	313,0	120,0			313,0	868,0			313,0	995,0		
Triassic	954,0	2611,0			868,0	2512,0			995,0	2697,0		
Permian	2611,0	3367,0			2512,0	3415,0			2697,0	3190,0		
Rewal Fm	2611,0	2666,0			2512,0	2575,0			2697,0	2759,0		
PZ4	2666,0	2769,5			2575,0	2721,5			2759,0	2831,5		
Upper Younger Halite Na3g												
Middle Anhydrite A3s												
Lower Younger Halite Na3d												
Younger Halite Na3	2769,5	2869,5			2721,5	2859,0			2831,5	3000,0		
Main Anhydrite A3	2869,5	2886,0			2859,0	2885,0			3000,0	3023,0		
Platy Dolomite Ca3	2886,0	2891,5			2885,0	2887,5			3023,0	3027,0		
Grey Pelite T3					2887,5	2889,5			3027,0	3030,0		
Screening Anhydrite A2r	2891,5	2894,0			2889,5	2892,5			3030,0	3032,5		
Screening Older Halite Na2r	2894,0	2903,5			2892,5	2896,0			3032,5	3048,0		
Older Potash K2	2903,5	2923,5			2896,0	2921,5			3048,0	3055,0		
Older Halite Na2	2923,5	2971,0			2921,5	2991,0			3055,0	3127,0		
Basal Anhydrite A2	2971,0	2984,0			2991,0	3006,0			3127,0	3136,5		
Main Dolomite Ca2	2984,0	3012,5	0,07–3,30/ <0,01–0,29	brine with gas	3006,0	3035,0	0,31–4,60/ <0,14	brine with H_2S	3136,5	3170,0	00,29–9,39/ 0,0-0,219	gas
Upper Anhydrite A1g	3012,5	3243,5			3035,0	3275,0			3170,0	3190,0		
Oldest Halite Na1	3243,5	3280,0			3275,0	3349,0						
Upper Oldest Halite Na1g												
Middle Anhydrite A1s												
Lower Oldest Halite Na1d												
Lower Anhydrite A1d	3280,0	3334,0			3349,0	3384,0						
Zechstein Limestone Ca1	3334,0	3340,5			3384,0	3390,6	0,34–1,11/ <0,055					
Kupferschiefer T1					3390,6	3391,0						
Basal Conglomerate Zp1												
Rotliegend	3340,5	3362,5	1,42–6,47/ <0,01–0,06		3391,0	3415,0	1,37–4,81/ 0,009–0,366					
Autun	3362,5	3367,0										
Carboniferous - Westphalian												
Carboniferous - Visean												
Czaplinek Fm												
Devonian - Famennian												
Krojanty Fm												
Devonian - Frasnian												
Devonian - Gievtian												

STRATIGRAPHY	JARSZEWO 1 1974				KAM. POMORSKI 3 1973				KAM. POMORSKI 7 1978			
	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	HC Inflow	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	HC Inflow	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	HC Inflow
Caenozoic	0,0	35,0			0,0	40,0			0,0	44,0		
Jurassic	35,0	856,0			40,0	655,0			44,0	686,0		
Triassic	856,0	2165,0			655,0	1995,5			686,0	2026,0		
Permian	2165,0	2998,7			1995,5	2405,0			2026,0	3230,0		
Rewal Fm	2165,0	2205,0			1995,5	2038,0			2026,0	2060,0		
PZ4	2205,0	2298,0			2038,0	2131,0			2060,0	2148,0		
Upper Younger Halite Na3g												
Middle Anhydrite A3s												
Lower Younger Halite Na3d												
Younger Halite Na3	2298,0	2420,0			2131,0	2178,0			2148,0	2191,5		
Main Anhydrite A3	2420,0	2435,0			2178,0	2276,0			2191,5	2306,5		
Platy Dolomite Ca3	2435,0	2440,0			2276,0	2282,5			2306,5	2313,0		
Grey Pelite T3												
Screening Anhydrite A2r	2440,0	2442,5			2282,5	2287,0			2313,0	2316,0		
Screening Older Halite Na2r	2442,5	2445,5										
Older Potash K2	2445,5	2447,5										
Older Halite Na2	2447,5	2515,0			2287,0	2344,0			2316,0	2351,0		
Basal Anhydrite A2	2515,0	2525,0			2344,0	2352,0			2351,0	2360,0		
Main Dolomite Ca2	2525,0	2548,0	0,14–5,73/ 0,0-0,2		2352,0	2384,0	0,07–6,16/ 0,0-0,333	brine with gas	2360,0	2390,0	0,07–12,88/ <0,01–0,62	drilling fluid
Upper Anhydrite A1g	2548,0	2758,5			2384,0	2405,0			2390,0	2520,0		
Oldest Halite Na1									2520,0	2659,0		
Upper Oldest Halite Na1g												
Middle Anhydrite A1s	2758,5	2844,0										
Lower Oldest Halite Na1d	2844,0	2865,0										
Lower Anhydrite A1d	2865,0	2909,0							2659,0	2702,0	0,09–2,72/ <0,01–0,01	
Zechstein Limestone Ca1	2909,0	2915,0							2702,0	2706,0		
Kupferschiefer T1									2706,0	2707,5		
Basal Conglomerate Zp1												
Rotliegend	2915,0	2994,5	4,09–7,07/ 0,028–0,734						2707,5	2709,0		
Autun	2994,5	2998,7							2709,0	3230,0		
Carboniferous - Westphalian									3230,0	3410,0	0,21–7,11/ 0,01-0,83	drilling fluid with gas
Carboniferous - Visean												
Czaplinek Fm												
Devonian - Famennian												
Krojanty Fm												
Devonian - Frasnian												
Devonian - Gievtian												

STRATIGRAPHY	KAM. POMORSKI 13 1974				LASKA 2 1980				REKOWO 1 1974			
	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	HC Inflow	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	HC Inflow	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	HC Inflow
Caenozoic	0,0	30,0			0,0	104,0			0,0	70,0		
Jurassic	30,0	658,0			104,0	1428,0			70,0	917,0		
Triassic	658,0	2034,0			1428,0	2067,0			917,0	2102,0		
Permian	2034,0	2672,0			2067,0	3456,0			2102,0	2667,0		
Rewal Fm	2034,0	2060,0							2102,0	2135,0		
PZ4	2060,0	2128,0							2135,0	2255,0		
Upper Younger Halite Na3g									2255,0	2278,0		
Middle Anhydrite A3s												
Lower Younger Halite Na3d									2278,0	2397,5		
Younger Halite Na3	2128,0	2221,0										
Main Anhydrite A3	2221,0	2237,0							2397,5	2420,0		
Platy Dolomite Ca3	2237,0	2243,0							2420,0	2426,5		
Grey Pelite T3												
Screening Anhydrite A2r	2243,0	2244,5							2426,5	2428,5		
Screening Older Halite Na2r												
Older Potash K2					2067,0	2851,0			2428,5	2658,5		
Older Halite Na2	2244,5	2321,5										
Basal Anhydrite A2	2321,5	2326,5			2851,0	2855,0			2658,5	2666,0		
Main Dolomite Ca2	2326,5	2356,0	0,14–4,65/ 0,0-0,393		2855,0	2873,0	0,27–5,17/ 0,02-1,318		2666,0	2667,0	0,50–3,1/ 0,0-1,163	oil production
Upper Anhydrite A1g	2356,0	2531,0			2873,0	2957,0						
Oldest Halite Na1	2531,0	2576,5			2957,0	3033,0						
Upper Oldest Halite Na1g												
Middle Anhydrite A1s												
Lower Oldest Halite Na1d												
Lower Anhydrite A1d	2576,5	2652,0			3033,0	3084,0						
Zechstein Limestone Ca1	2652,0	2658,5			3084,0	3089,9	0,36–0,99/ 0,002-0,051	water with gas				
Kupferschiefer T1					3089,9	3091,5						
Basal Conglomerate Zp1												
Rotliegend	2658,5	2662,5			3091,5	3190,0	2,18–3,64/ 0,004–0,085					
Autun	2662,5	2672,0			3190,0	3456,0						
Carboniferous - Westphalian								water and drilling fluid				
Carboniferous - Visean					3456,0	3583,0						
Czaplinek Fm					3456,0	3583,0	1,4–1,89/ 0,004-0,006					
Devonian - Famennian												
Krojanty Fm												
Devonian - Frasnian												
Devonian - Gievtian												

STRATIGRAPHY	REKOWO 2 1975				REKOWO 3 1976				REKOWO 4 1975			
	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	HC Inflow	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	HC Inflow	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	HC Inflow
Caenozoic	0,0	64,0			0,0	49,5			0,0	49,5		
Jurassic	64,0	914,0			49,5	936,0			49,5	936,0		
Triassic	914,0	2126,5			936,0	2121,5			936,0	2111,5		
Permian	2126,5	3141,5			2121,5	2697,0			2111,5	2736,0		
Rewal Fm	2126,5	2158,5			2121,5	2153,5			2111,5	2145,5		
PZ4	2158,5	2262,0			2153,5	2267,0			2145,5	2248,0		
Upper Younger Halite Na3g												
Middle Anhydrite A3s												
Lower Younger Halite Na3d												
Younger Halite Na3	2262,0	2458,5			2267,0	2425,0			2248,0	2417,5		
Main Anhydrite A3	2458,5	2507,0			2425,0	2454,0			2417,5	2465,0		
Platy Dolomite Ca3	2507,0	2522,5			2454,0	2463,0			2465,0	2473,0		
Grey Pelite T3	2522,5	2526,0										
Screening Anhydrite A2r	2526,0	2532,5			2463,0	2465,5			2473,0	2474,5		
Screening Older Halite Na2r	2532,5	2559,0			2465,5	2477,5			2474,5	2478,0		
Older Potash K2	2559,0	2588,0			2477,5	2519,0			2478,0	2510,0		
Older Halite Na2	2588,0	2652,0			2519,0	2638,0			2510,0	2672,0		
Basal Anhydrite A2	2652,0	2705,0			2638,0	2645,0			2672,0	2680,0		
Main Dolomite Ca2	2705,0	2727,0	0,14–7,59/ 0,0-0,405		2645,0	2667,0	0,07–5,94/ 0,0-0,333		2680,0	2710,0	0,07–10,38/ 0,0-55,742	
Upper Anhydrite A1g	2727,0	2948,0			2667,0	2697,0			2710,0	2736,0		
Oldest Halite Na1	2948,0	2962,0										
Upper Oldest Halite Na1g												
Middle Anhydrite A1s												
Lower Oldest Halite Na1d												
Lower Anhydrite A1d												
Zechstein Limestone Ca1	2962,0	3014,5										
Kupferschiefer T1												
Basal Conglomerate Zp1												
Rotliegend	3014,5	3106,0	0,36–7,16/ 0,01–0,26									
Autun	3106,0	3141,5										
Carboniferous - Westphalian												
Carboniferous - Visean												
Czaplinek Fm												
Devonian - Famennian												
Krojanty Fm												
Devonian - Frasnian												
Devonian - Gievtian												

STRATIGRAPHY	REKOWO 6 1976				SKARCHOWO 1 1976				STRZEŻEWO 1 1978			
	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	HC Inflow	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	HC Inflow	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	HC Inflow
Caenozoic	0,0	67,0			0,0	24,0			0,0	45,0		
Jurassic	67,0	957,0			24,0	890,0			45,0	930,0		
Triassic	957,0	2035,5			890,0	2189,5			930,0	2495,0		
Permian	2035,5	2746,0			2189,5	2667,0			2495,0	3199,0		
Rewal Fm	2035,5	2123,5			2189,5	2225,5			2495,0	2529,0		
PZ4	2123,5	2225,0			2225,5	2320,0			2529,0	2576,0		
Upper Younger Halite Na3g												
Middle Anhydrite A3s												
Lower Younger Halite Na3d												
Younger Halite Na3	2225,0	2383,5			2320,0	2432,0			2576,0	2670,0		
Main Anhydrite A3	2383,5	2407,0			2432,0	2453,5						
Platy Dolomite Ca3	2407,0	2412,0			2453,5	2460,5						
Grey Pelite T3												
Screening Anhydrite A2r	2412,0	2415,0			2460,5	2462,5						
Screening Older Halite Na2r	2415,0	2419,5										
Older Potash K2	2419,5	2461,5							2670,0	2676,5		
Older Halite Na2	2461,5	2690,0			2462,5	2584,0			2676,5	2760,0		
Basal Anhydrite A2	2690,0	2700,0			2584,0	2590,0		brine	2760,0	2768,0		
Main Dolomite Ca2	2700,0	2720,0	1,09–28,80/ 0,13–2,147	brine with gas and H_2S	2590,0	2647,0	0,21–17,37/ 0,0–0,20	brine with drilling fluid	2768,0	2823,0	0,054–6,164/ 0,0–4,45	
Upper Anhydrite A1g	2720,0	2746,0			2647,0	2667,0						
Oldest Halite Na1												
Upper Oldest Halite Na1g												
Middle Anhydrite A1s												
Lower Oldest Halite Na1d												
Lower Anhydrite A1d									2823,0	3105,0		
Zechstein Limestone Ca1									3105,0	3109,0		
Kupferschiefer T1												
Basal Conglomerate Zp1												
Rotliegend									3109,0	3199,0		
Autun												
Carboniferous - Westphalian									3199,0	3890,0	0,1–11,4/ 0,0–6,3	drilling fluid with gas, brine with gas
Carboniferous - Visean												
Czaplinek Fm												
Devonian - Famennian												
Krojanty Fm												
Devonian - Frasnian									3890,0	4518,0		
Devonian - Gievtian									4518,0	4521,0		

STRATIGRAPHY	ŚWIERZNO 1 1973				ŚWIERZNO 2 1976				ŚWIERZNO 4 1975			
	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	HC Inflow	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	HC Inflow	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	HC Inflow
Caenozoic	0,0	54,0			0,0	70,0			0,0	54,0		
Jurassic	54,0	776,0			24,0	819,0			54,0	837,0		
Triassic	776,0	2300,0			819,0	2354,0			837,0	2338,0		
Permian	2300,0	3103,0			2354,0	2772,2			2338,0	3195,0		
Rewal Fm	2300,0	2333,5			2354,0	2398,0			2338,0	2390,0		
PZ4	2333,5	2422,0			2398,0	2503,0			2390,0	2492,0		
Upper Younger Halite Na3g												
Middle Anhydrite A3s												
Lower Younger Halite Na3d												
Younger Halite Na3	2422,0	2571,0			2503,0	2661,0			2492,0	2645,0		
Main Anhydrite A3	2571,0	2595,0							2645,0	2667,5		
Platy Dolomite Ca3	2595,0	2601,0	2,72–8,21/ 0,0-0,393						2667,5	2675,0		
Grey Pelite T3												
Screening Anhydrite A2r	2601,0	2602,5							2675,0	2678,0		
Screening Older Halite Na2r	2602,5	2609,5										
Older Potash K2	2609,5	2611,0										
Older Halite Na2	2611,0	2682,0			2661,0	2741,5			2678,0	2769,0		
Basal Anhydrite A2	2682,0	2687,5			2741,5	2748,0			2769,0	2777,5		
Main Dolomite Ca2	2687,5	2714,5			2748,0	2772,2	0,07–1,10/ 0,0-0,980	oil and gas production	2777,5	2811,5	0,07–6,22/ 0,0-0,138	brine with gas and H_2S
Upper Anhydrite A1g	2714,5	2919,0							2811,5	3012,5		
Oldest Halite Na1	2919,0	3018,0										
Upper Oldest Halite Na1g									3012,5	3045,0		
Middle Anhydrite A1s									3045,0	3087,0		
Lower Oldest Halite Na1d									3087,0	3095,0		
Lower Anhydrite A1d	3018,0	3072,5							3095,0	3148,5		
Zechstein Limestone Ca1	3072,5	3084,0							3148,5	3155,3	0,07–0,52/ 0,011–0,561	
Kupferschiefer T1	3084,0	3084,5							3155,3	3156,0		
Basal Conglomerate Zp1												
Rotliegend	3084,5	3103,0	2,31–9,83/ 0,0-0,302						3156,0	3195,0	2,09–3,34/ 0,146-0,23	
Autun												
Carboniferous - Westphalian												
Carboniferous - Visean												
Czaplinek Fm												
Devonian - Famennian									3195,0	3238,5		drilling fluid with gas
Krojanty Fm									3195,0	3238,5		
Devonian - Frasnian												
Devonian - Gievtian												

STRATIGRAPHY	ŚWIERZNO 5 1975				ŚWIERZNO 9 1976				WRZOSOWO 1 1975			
	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	HC Inflow	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	HC Inflow	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	HC Inflow
Caenozoic	0,0	46,0			0,0	69,0			0,0	55,0		
Jurassic	46,0	830,0			69,0	815,0			55,0	840,5		
Triassic	830,0	2290,0			815,0	2247,5			840,5	2299,0		
Permian	2290,0	3195,0			2247,5	2774,7			2299,0	3081,5		
Rewal Fm	2290,0	2330,0			2247,5	2389,5			2299,0	2335,0		
PZ4	2330,0	2421,0			2389,5	2488,5			2335,0	2370,0		
Upper Younger Halite Na3g												
Middle Anhydrite A3s												
Lower Younger Halite Na3d												
Younger Halite Na3	2421,0	2652,5			2488,5	2611,0			2370,0	2536,0		
Main Anhydrite A3	2652,5	2673,0			2611,0	2637,0			2536,0	2640,0		
Platy Dolomite Ca3	2673,0	2694,0			2637,0	2647,5						
Grey Pelite T3	2694,0	2703,0										
Screening Anhydrite A2r	2703,0	2708,0			2647,5	2653,0			2640,0	2643,0		
Screening Older Halite Na2r	2708,0	2716,0										
Older Potash K2	2716,0	2734,0			2653,0	2763,5						
Older Halite Na2	2734,0	2832,5							2643,0	2730,0		
Basal Anhydrite A2	2832,5	2840,0			2763,5	2769,0			2730,0	2742,5		
Main Dolomite Ca2	2840,0	2872,0	0,22–11,05/ 0,0-7,502		2769,0	2774,7	1,23–4,5/ 0,0-0,049	oil with gas, brine with gas	2742,5	2785,0	0,36–11,75/ 0,0-1,169	
Upper Anhydrite A1g	2872,0	2883,6							2785,0	2988,5		
Oldest Halite Na1									2988,5	2992,5		
Upper Oldest Halite Na1g												
Middle Anhydrite A1s												
Lower Oldest Halite Na1d												
Lower Anhydrite A1d									2992,5	3072,0		
Zechstein Limestone Ca1									3072,0	3077,0		
Kupferschiefer T1												
Basal Conglomerate Zp1												
Rotliegend									3077,0	3081,5	4,49–8,0/ 0,622–1,926	gas
Autun												
Carboniferous - Westphalian									3081,5	3305,0	1,44–13,43/ 0,024–2,247	
Carboniferous - Visean												
Czaplinek Fm												
Devonian - Famennian												
Krojanty Fm												
Devonian - Frasnian												
Devonian - Gievtian												

STRATIGRAPHY	WRZOSOWO 2 1976				WRZOSOWO 3 1979				WRZOSOWO 8 1977				WRZOSOWO 9 1978			
	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	HC Inflow	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	HC Inflow	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	HC Inflow	Depth from [m]	Depth to [m]	Porosity [%] / Permeability [mD]	HC Inflow
Caenozoic	0,0	34,0			0,0	40,0			0,0	52,0			0,0	42,0		
Jurassic	34,0	820,0			40,0	817,5			52,0	852,0			42,0	811,0		
Triassic	820,0	2262,0			817,5	2239,5			852,0	2258,0			811,0	2271,0		
Permian	2262,0	3059,5			2239,5	3101,0			2258,0	3077,5			2271,0	3084,5		
Rewal Fm	2262,0	2305,0			2239,5	2279,5			2258,0	2290,0			2271,0	2304,0		
PZ4	2305,0	2339,5			2279,5	2426,5			2290,0	2357,5			2304,0	2433,0		
Upper Younger Halite Na3g																
Middle Anhydrite A3s																
Lower Younger Halite Na3d																
Younger Halite Na3	2339,5	2609,5			2426,5	2510,5			2357,5	2508,0			2433,0	2592,0		
Main Anhydrite A3					2510,5	2610,5			2508,0	2516,0			2592,0	2605,5		
Platy Dolomite Ca3	2609,5	2616,5			2610,5	2617,0			2516,0	2541,0			2605,5	2612,5		
Grey Pelite T3																
Screening Anhydrite A2r	2616,5	2619,0			2617,0	2621,0			2541,0	2556,0			2612,5	2615,5		
Screening Older Halite Na2r					2621,0	2626,0			2556,0	2573,5			2615,5	2624,0		
Older Potash K2					2626,0	2633,0			2573,5	2598,0			2624,0	2636,0		
Older Halite Na2	2619,0	2667,0			2633,0	2692,5			2598,0	2729,0			2636,0	2708,0		
Basal Anhydrite A2	2667,0	2675,0		water	2692,5	2696,0			2729,0	2735,0			2708,0	2714,5		
Main Dolomite Ca2	2675,0	2720,0	0,28–13,03/ 0,0–0,26		2696,0	2739,0			2735,0	2770,0	0,21–14,60/ 0,0-0,81	water with gas and H_2S	2714,5	2758,0	0,07–9,92/ 0,0-1,3	
Upper Anhydrite A1g	2720,0	2931,5			2739,0	2914,0			2770,0	2945,0			2758,0	2917,5		
Oldest Halite Na1					2914,0	2980,0										
Upper Oldest Halite Na1g	2931,5	2951,0							2945,0	2972,5			2917,5	2960,5		
Middle Anhydrite A1s	2951,0	2976,0							2972,5	2997,0			2960,5	2987,5		
Lower Oldest Halite Na1d	2976,0	2981,0							2997,0	3004,0			2987,5	2992,5		
Lower Anhydrite A1d	2981,0	3051,0			2980,0	3068,5			3004,0	3070,0			2992,5	3055,0		
Zechstein Limestone Ca1	3051,0	3055,0	0,36–6,94/ 0,0–0,56		3068,5	3072,4			3070,0	3074,3	0,98–1,98/ 0,0–0,15		3055,0	3059,9	0,07–0,79/ 0,0–0,23	
Kupferschiefer T1	3055,0	3055,5			3072,4	3073,0			3074,3	3075,0			3059,0	3060,5		
Basal Conglomerate Zp1																
Rotliegend	3055,5	3059,5		gas	3073,0	3101,0		drilling fluid	3075,0	3077,5	1,05–2,04/ 0,0–0,56					brine with gas
Autun													3060,5	3084,5	1,54–3,13/ 0,22	
Carboniferous - Westphalian	3059,5	3127,3	0,49–15,41/ 0,0-10,50		3101,0	3255,0	0,19–10,30/ 0,001–1,87		3077,5	3310,0	0,84–17,29/ 0,0–0,68	water with gas	3084,5	3198,0	1,81–8,78/ 0,0-12,51	
Carboniferous - Visean																
Czaplinek Fm																
Devonian - Famennian																
Krojanty Fm																
Devonian - Frasnian																
Devonian - Gievtian																

GEOPHYSICS

- Benice 1: (PK): 250–3240 m; (PSr): 15–3246 m; (PS): 26–3246 m; (PO): 25–3246 m; (POst): 2290–3246 m; (PG): 11–3246 m; (PNG): 13–3246 m; (PAa): 250–3245 m; (PAdt): 235–3245 m; (Pat1): 2617–3245 m; Tx2: 20–3180 m; TW: 20–3180 m; Tr_PW1: 126–3176 m; Tr_PW2: 136–3191 m; Tr_PW3: 96–3191 m; Tr_PO: 96–3191 m; DT_VSP: 20– 3180 m.
- Benice 2: (PK): 100–2900 m; (PSr): 106–2907 m; (PS): 106–2907 m; (PO): 106–2907 m; (POst): 2486–2907 m; (PG): 10–2907 m; (PNG): 10–2907 m; (PAa): 108–2907 m; (PAdt): 108–2907 m; (Pat1): 108–2907 m.
- Benice 3: (PK): 5–2815 m; (PSr): 155–2815 m; (PS): 155–2340 m; (PO): 155–2815 m; (POst): 2335–2815 m; (logPOst): 2335–2815 m; (mPOst): 2730–2815 m; (logmPOst): 2730–2815 m; (PG): 15–1810 m; (PNG): 15–2810 m; (logPNG): 2300–2815 m; (PAa): 250–3245 m; (PAdt): 1250–2820 m; (Pat1): 1250–2820 m; (Pat2): 1250–2820 m; (PGaz): 161–2842 m; Tx2: 20– 2400 m; TW: 20– 2400 m; Tr_PW1: 915–2415 m; Tr_PW2: 1170–2415 m; Tr_PW3: 810–2400 m; Tr_PO: 810–2415 m; DT_VSP: 20– 2400 m.
- Benice 4K: (PK): 0–2725 m; (PSr): 170–2735 m; (PS): 177–2731 m; (PO): 177–2731 m; (POst): 1696–2400 m; (logPOst): 1696–2731 m; (mPOst): 2395–2731 m; (logmPOst): 2395–2731 m; (PG): 3–2733 m; GGDN): 1682–2732 m; (PNG): 3–2733 m; (logPNG): 1682–2732 m; (PAdt): 1682–2745 m; (Pat1): 1682–2732 m; (Pat2): 2370–2732 m; (PGaz): 260–2752 m; (TEMP): 2570–2731 m; Tx2: 20–2700 m; TW: 20–2700 m; Tr_PW1: 65–2712 m; Tr_PW2: 35–2712 m; Tr_PW3: 35–2712 m; Tr_PO: 35–2712 m; DT_VSP: 20–2700 m.
- Brojce IG-1: (PK): 0–4225 m; (PSr): 0–4234,5 m; (PS): 8–4232 m; (PO): 8–4230 m; (POg): 8–3562 m; (POp): 8–3562 m; (POpl): 2425–2920 m; (POst): 2917–4229,5 m; (logPOst): 2917–4230 m; EL02 (PO): 2–2921 m; EL03 (PO): 4–4230 m; EL09 (PO): 5–4232 m; EL18 (PO): 9–4230 m; EL26(PO): 10–4230 m; E10 (PO): 7–4232 m; EN16 (PO): 1–2917 m; (logmPOst): 3000–4230 m; (PG): 0–4232 m; (GGDN): 290–4232 m; (PNG): 0–4232 m; (logPNG): 268–4232 m; (PAdt): 250–4232 m; (Pat1): 250–3960 m; (Pac): 90–3562 m; (PEksc): 3564–4130 m; (TEMP): 2570–2731 m; (PTn): 1800–1900 m; Tx2: 20–4180 m; TW: 20–4180 m; Tr_PW1: 56–4196 m; Tr_PW2: 11–4196 m; Tr_PW3: 56–4196 m; Tr_PO: 11–4196 m; DT_VSP: 20–4180 m.
- Dobropole 1: (PK): 25–2880 m; (PSr): 0–2883 m; (BS): 0–2883 m; (PS): 10–2883 m; (PO): 10–2883 m; (mPO): 224–2350 m; (POst): 2357–2883 m; (logmPOst): 2357–2883 m; EL03 (PO): 2–2883 m; (PG): 0–2872 m; (GGDN): 220–2883 m; (PNG): 0–2880 m; (logPNG): 193–2878 m; (PAdt): 171–2883 m; (Pat1): 171–2883 m; (Pat2): 171–2883 m; (TEMP): 1770–2880 m; Tx2: 20–2860 m; TW: 20–2860 m; Tr_PW1: 22–2872 m; Tr_PW2: 22–2872 m; Tr_PW3: 22–2872 m; Tr_PO: 22–2872 m; DT_VSP: 20–2860 m.
- Dusin 1: (PK): 25–2650 m; (PSr): 10–2658 m; (PS): 18–2658 m; (PO): 18–2658 m; (POst): 2175–2658 m; (logPOst): 2175–2658 m; EL03 (PO): 15–2657,5 m; (mPOst): 2583–2658 m; (logmPOst): 2583–2658 m; (PG): 10–2658 m; (PNG): 10–2662 m; (logPNG): 2100–2658 m; (PA): 1100–2000 m; (PAdt): 1100–2658 m; T1 (Pat1): 1100–2658 m; (PGaz): 1333–2586 m; Tx2: 20–2560 m; TW: 20–2560 m; Tr_PW1: 70–2365 m; Tr_PW2: 55–2560 m; Tr_PW3: 55–2560 m; Tr_PO: 55–2560 m; DT_VSP: 20–2560 m.
- Gostyń 2: (PK): 25–3425 m; (PSr): 110–3438 m; (mPSr): 3249–3376 m; (POst): 2775–3436 m; (logPOst): 25–2438 m; EL28 (PO): 120–3435 m; (mPOst): 2775–3436 m; (logmPOst): 1491–3436 m; (PG): 13–3468 m; (PNG): 18–3468 m; (logPNG): 25–3468 m; (PAdt): 1491–3438 m; (Pat): 10–2753 m; (Pat1): 1491–3438 m; (Pat2): 1491–3438 m; (PGaz): 0–3400 m; odwojony Tx2: 20–3340 m; TW: 20–3340 m; Tr_PW1: 40–3355 m; Tr_PW2: 40–3355 m; Tr_PW3: 40–3355 m; Tr_PO: 40–3355 m; DT_VSP: 20–3340 m.
- Gryfice 1: (logmPOst): 2978–3334 m; (logPNG): 2597–3342 m; (logPOst): 2662–3334 m; (mPOst): 2978–3334 m; (PG): 30–3355 m; (PGaz): 250–3367 m; (PK): 25–3335 m; (PNG): 30–3342m; (PO): 13–3334 m; (POst): 2662–3354 m; (PS): 13–2620 m; (PSr): 13–3334 m; (PT): 3300–3355 m; (PTc): 3–2896 m; Tx2: 20–3320 m; TW: 20–3320 m; Tr_PW1: 55–2590 m; Tr_PW2: 55–3325 m; Tr_PW3: 70–3325 m; Tr_PO: 55–3325 m; DT_VSP: 20–3320 m.
- Gryfice 2: (mPSr): 3336–3407 m; (PA): 1355–3407 m; (PG): 3–3410 m; (PK): 25–3415 m; (PNG): 3–3410 m; (PO): 18–3406 m; (POst): 2100–3405 m; (PS): 18–3406 m; (PSr): 18–3406 m.
- Gryfice 3: (PAa1): 104–3170 m; (PAdt): 104–3170 m; (PAt1): 104–3170 m; (PG): 22–3170 m; (PK): 25–3175 m; (PNG): 22–3170 m; (PO): 15–3174 m; (POst): 2 658–3174 m; (PS): 15–2658 m; (PSr): 15–3174 m.
- Jarszewo 1: (PA): 150–2420 m; (PG): 5–2980 m; (PK): 25–2980 m; (PNG): 5–2980 m; (PO): 149–2982 m; (POst): 1124–2892 m; (PS): 149–2982 m; (PSr): 149–2982 m; Tx2: 20–2900 m; TW: 20–2900 m; Tr_PW1: 65–2900 m; Tr_PW2: 65–2900 m; Tr_PW3: 65–2900 m; Tr_PO: 65–2900 m; DT_VSP: 20–2900 m.
- Kam. Pomorski 3: (PA): 1950–2258 m; (PG): 135–2404 m; (PK): 600–2400 m; (PNG): 135–2404 m; (PO): 148–2405 m; (POst): 1096–2405 m; (PS): 148–2405 m; (PSr): 148–2405 m; Tx2: 20–2240 m; TW: 20–2240 m; Tr_PW1: 63–2253 m; Tr_PO: 63–2253 m; DT_VSP: 20–2240 m.
- Kam. Pomorski 7: (logmPOst): 2355–3201 m; (logPNG): 3200–3402 m; (logPOst odwr.): 2705–2755 m; (logPOst): 2355–3201 m; (mPOst): 2355–3402 m; (PAdt): 2140–3400 m; (PAt1): 2140–3400 m; (PAt2): 2303–3400 m; (PG): 0–3403 m; (PK): 25–3400 m; (PNG): 0–3403 m; (PO): 27–3402 m; EL03(PO): 125–3402 m; (POst odwr.): 2705–2755 m; (POst): 1960–3402 m; (PS): 127–1987 m; (PSr): 125–3395 m; Tx2: 20–3260 m; TW: 20–3260 m; Tr_PW1: 95–3275 m; Tr_PW2: 95–3300 m; Tr_PW3: 95–2765 m; Tr_PO: 95–3275 m; DT_VSP: 20–3260 m.
- Kam. Pomorski 13: (PG): 0–2670 m; (PK): 5–2670 m; (PNG): 0–2670 m; (PO): 18–2671 m; (POst): 1078–2322 m; (SP): 18–2671 m; (PSr): 18–2671 m.
- Laska 2: (logPNG): 1720–3473 m; (logPOst): 1763–3103 m; (mPSr): 3035–3111 m; (PG): 20–3473 m; (PGaz): 1054–3565 m; (PK): 25–3100 m; (PNG): 35–3473 m; (PO): 8–3471 m; EL03 (PO): 5–3470 m; (POst): 1 763–3109 m; (PS): 8–3471 m; (PSr): 5–3471 m; (PTc): 5–2780 m; Tx2: 20–2820 m; TW: 20–2820 m; Tr_PW1: 728–2813 m; Tr_PW2: 728–2828 m; Tr_PW3: 728–2828 m; Tr_PO: 728–2828 m; DT_VSP: 20–2820 m.
- Rekowo 1: (PG): 0–2660 m; (PK): 25–2660 m; (PNG): 0–2660 m; (PO): 90–2658 m; EL03 (PO): 90–2658 m; (PS): 93–2005 m; (PSr): 90–2642 m.
- Rekowo 2: (mPOst): 2700–3125 m; (mPSr): 2862–3062 m; (PAdt): 1094–2655 m; (PAt1): 1094–2655 m; (PAt2): 1094–2655 m; (PG): 1–3128 m; (PK): 5–3125 m; (PNG):6–3128 m; (PO): 4–3125 m; EL03(PO): 5–3125 m; (POst odwr.): 2656–3125 m; (POst): 2656–2727 m; (PS): 4–2006 m; (PSr): 0–3125 m; Tx2: 20–3100 m; TW: 20–3100 m; Tr_PW1: 90–3110 m; Tr_PW2: 90–3090 m; Tr_PO: 90–3110 m; DT_VSP: 20–3100 m.
- Rekowo 3: (mPOst): 2640–2690 m; (PAdt): 2590–2690 m; (PAt1): 2590–2690 m; (PAt2): 2590–2690 m; (PG): 0–2690 m; (PK): 125–2690 m; (PNG): 0–2690 m; (PO): 138–2690 m; EL03 (PO):0–2690 m; (POst): 2640–2690 m; (PS): 138–2690 m; (PSr): 5–2690 m.
- Rekowo 4: (Adt): 140–2730 m; (PAt1): 143–2730 m; (PAt2): 143–1 081 m; (PG): 0–2733 m; (PK): 5–2725 m; (PNG): 0–2733 m; (PO): 6–2733 m; EL03 (PO): 5–2730 m; (POst): 2040–2733 m; (PS): 6–2733 m; (PSr): 5–2733 m.
- Rekowo 6: (mPOst): 2696–2718 m; (PAdt): 2646–2719 m; (PAt1): 2646–2719 m; (PAt2): 2646–2719 m; (PG): 5–2738 m; (PK): 25–2675 m; (PNG): 5–2738 m; (PO): 10–2718 m; EL03 (PO): 10–2736 m; (POst odwr.): 2696–2718 m; (POst): 2696–2718 m; (PS): 10–2119 m; (PSr): 0–2737 m.
- Skarchowo 1: (PA): 2589–2666 m; (PAdt): 2581–2666 m; (PG): 0–2666 m; (PK): 5–2650 m; (PNG): 0–2666 m; (PO): 19–2664 m; EL03 (PO): 15–2664 m; (POst): 2589–2665 m; (PS): 19–2193 m; (PSr): 15–2666 m.
- Strzeżewo 1: (mPOst): 3000–3643 m; (mPSr): 3453–3837 m; (PA): 171–3454 m; (PAdt): 2519–3324 m; (PAt1): 2519–3324 m; (PEksc): 2520–3167 m; (PG): 0–4510 m; (PK): 25–4510 m; (PNG):35–4510 m; (PO): 171–4512 m; (POst): 2519–4505 m; (PS): 171–4512 m; (PSr): 170–4512 m; Tx2: 20–2600 m; TW: 20–2600 m; Tr_PW1: 105–2610 m; Tr_PW2: 105–2610 m; Tr_PW3: 105–2610 m; Tr_PO: 105–2610 m; DT_VSP: 20–2600 m.
- Świerzno 1: (PA): 800–3095 m; (PAdt): 2292–3086 m; (PG): 2–3099 m; (PGaz): 27–3075 m; (PGG): 10–165 m; (PK): 25–3095 m; (PM): 300–1300 m; (PNG): 4–3099 m; (PO): 27–3095 m; EL03 (PO): 25–3095 m; (POst): 2275–3095 m; (PS): 27–3095 m; (PSr): 0–3095 m; (PT): 5–2490 m; Tx2: 20–3000 m; TW: 20–3000 m; Tr_PW1: 119–3014 m; Tr_PW2: 149–3014 m; Tr_PW3: 119–3014 m; Tr_PO: 119–3014 m; DT_VSP: 20–3000 m.
- Świerzno 2: (PA): 1345–2480 m; (PAdt): 1322–2480 m; (PG): 15–1888 m; (PK): 1–2650 m; (PNG): 15–1888 m; (PO): 17–2744 m; EL03 (PO):15–2744 m; (POst): 2 275–2744 m; (PSr): 15–2480 m.
- Świerzno 4: (PA): 2776–3186 m; (PAdt): 2757–3188 m; (PG): 0–3235 m; (PK): 25–3235 m; (PNG): 0–3235 m; (PO): 89–3235 m; EL03 (PO): 85–3188 m; (POst): 2325–3235 m; (PS): 89–2348 m; (PSr): 85–3235 m; Tx2: 20–3180 m; TW: 20–3180 m; Tr_PW1: 79–3199 m; Tr_PW2: 879–3019 m; Tr_PO: 79–3199 m; DT_VSP: 20–3180 m.
- Świerzno 5: (PA): 2655–2875 m; (PAdt): 2655–2875 m; (PG): 0–2875 m; (PK): 25–2875 m; (PNG): 0–2875 m; (PO): 119–2872 m; EL03 (PO): 115–2872 m; (POst): 2656–2872 m; (PS): 890–2872 m; (PSr): 115–2872 m.
- Świerzno 9: (PA): 1280–2748 m; (PAdt): 1268– 2748 m; (PG): 2–2763 m; (PK): 25–2750 m; (PNG): 2–2763 m; (PO): 5–2763 m; EL03 (PO):0–2763 m; (POst): 2225–2763 m; (PS): 5–2252 m; (PSr): 0–2757 m.
- Wrzosowo 1: (BS): 0–3304 m; (mPSr): 2731–3304 m; (PA): 1352–3303 m; (PAdt): 1351–3304 m; (PG): 0–3303 m; (PK): 25–3300 m; (PNG): 0–3303 m; (PO): 5–3302 m; EL03 (PO): 0–3302 m; (POst odwr. kosa): 3075–3304 m; (POst): 2295–3303 m; (PS): 5–3302 m; (PSr): 0–3304 m; Tx2: 20–2980 m; TW: 20–2980 m; Tr_PW1: 130–2990 m; mierzony Tr_PW2: 130–2650 m; Tr_PO: 130–2990 m; DT_VSP: 20–2980 m.
- Wrzosowo 2: (BS): 0–3125 m; (mPOst): 3040–3123 m; (PA): 1275–3123 m; (PAdt): 1269–2665 m; (PG): 13–3124 m; (PK): 5–3125 m; (PNG): 15–3125 m; (PO): 4–3123 m; EL03(PO): 4–3123 m; (POpl): 1324–2288 m; (POst odwr. kosa): 2671–3092 m; (POst): 2263–3123 m; (PS): 4–3123 m; (PSr): 0–3125 m.
- Wrzosowo 3: (BS):136– 3255 m; (mPOst): 2237–3255 m; (mPSr): 3030–3257 m; (PAdt): 2969–3255 m; (PG): 15–3255 m; (PGaz): 2613–3035 m; (PK): 125–3250 m; (PNG): 17–3255 m; (PO): 135–3255 m; EL03 (PO): 130–3255 m; (POst): 2237–3255 m; (PS): 135–3255 m; (PSr): 135–3255 m; (PT): 3000–3258 m.
- Wrzosowo 8: (BS): 84–3301 m; (mPOst): 2737–3300 m; (mPSr): 3124–3296 m; (PA): 2715–3300 m; (PAdt): 2722–3299 m; (PG): 15–3301 m; (PGaz): 1484–3192 m; (PK): 0–3300 m; (PNG): 15–3301 m; (PO): 90–3300 m; EL03 (PO): 89–3300 m; (POst): 1480–3300 m; (PS): 90–2740 m; (PSr): 84–3301 m; (PT): 2737–3300 m
- Wrzosowo 9: (mPOst): 2714–2801 m; (mPSr): 2976–3076 m; (PG): 18–3198 m; (PGaz): 1570–3210 m; (PK): 25–3175 m; (PNG): 18–3198 m; (PO): 135–2801 m; (POst): 2285–2801 m; (PS): 135–2311 m; (PSr):135–3076 m; (PT): 25–2638 m.

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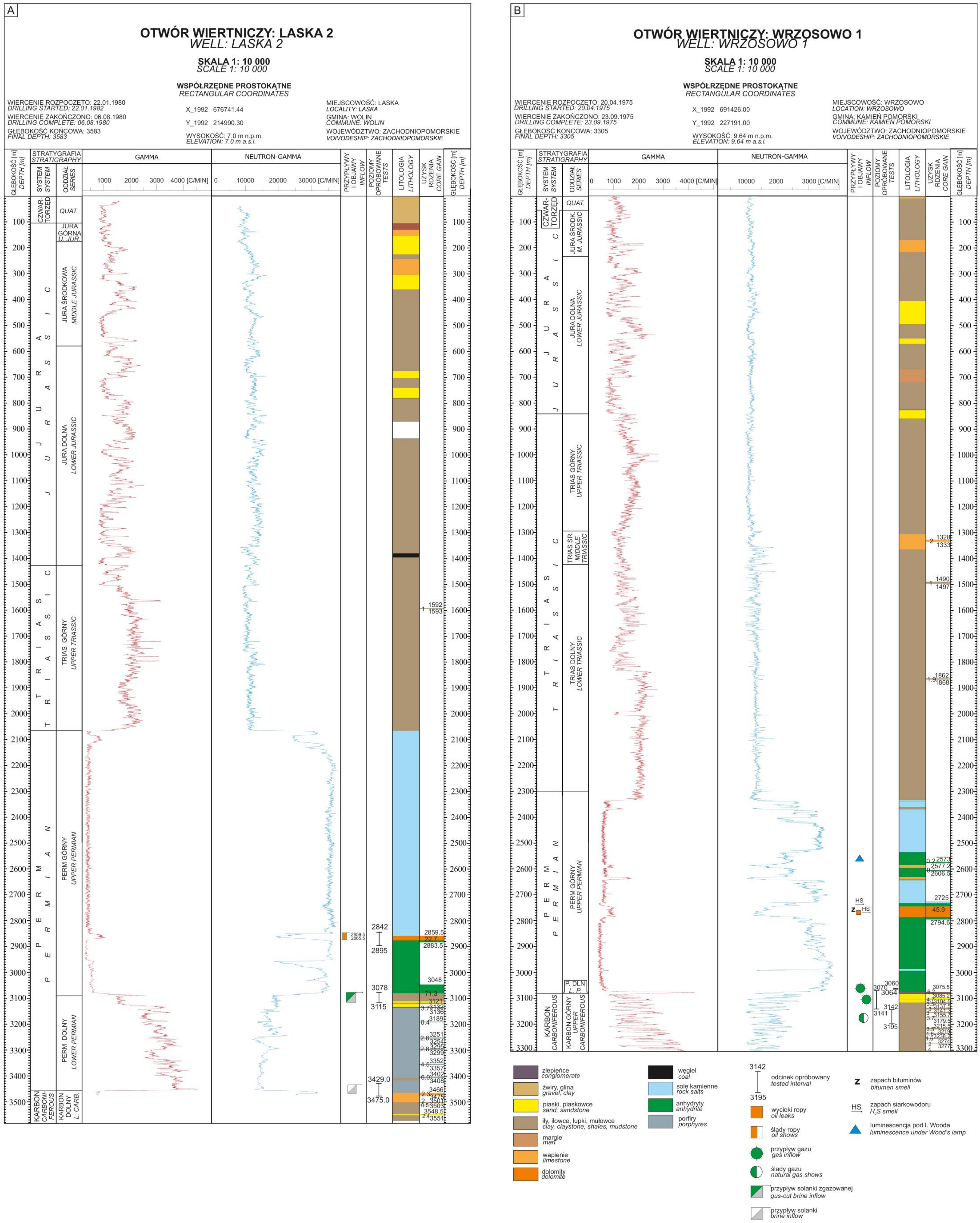

Fig. 5.2. A. Stratigraphy, lithology, selected geophysics and hydrocarbon shows in the Laska 2 well (according to Wójcik, 1980). **B.** Stratigraphy, lithology, selected geophysics and hydrocarbon shows in the Wrzosowo 1 well (according to Ryba and Stefańska, 1976).

6. SEISMIC SURVEYS

The "Gryfice" tender area is explored by a dense grid of 2D seismic lines and 3D surveys (Figs 6.1–6.2). Seismic surveys in this area were acquired from the beginning of the 1960s. Those first surveys have only historic merit due to technical capabilities and they are not used presently to analyse structural geology.

Majority of digital 2D seismic data were acquired in the 1970s and at the begging of the 1980s (Tab.6.1, Fig. 6.3). More recent data were not acquired until 1996-1997, but they include only the extreme parts of the lines in the E part of the "Gryfice" area. In this area there are also 5 profiles acquired at the turn of 1999 and 2000. Two of those lines overlie each other. Within the area there are also parts of seismic lines acquired in 2006, located mainly in its SW portion.
There are also 3D surveys within the area. Two of them were acquired in 2014 and 2018. They cover the area only partially. They belong to the State Treasury, but are currently left in the hands of investor, mainly due to still active neighbouring HC concessions. A large part of the area (about 200km^2) is explored by the "Świerzno" seismic survey of the Polish Oil and Gas Company (PGNiG).

Seismic surveys acquired over the years allowed identifying lots of geological structures mainly at the Permian level on which exploration activities focused:

STRUCTURES	SEISMIC HORIZON
Rybokarty Structure	Z2, Z1'
Rybokarty N Structure	Z2
Gryfice Structure	Z2, Z1'
Smolęcin W High	Z2
Smolęcin Structure	Z2, Z1'
Wyszobór High	Z2
Pruszcz Structure	Z1'
Modlimowo High	Z1'
Wrzosowo High	Z2
Strzeżewo High	Z2
Świniec High	Z2
Świniec E High	Z2
Świniec S High	Z2
Świerzno High	Z2
Świerzno S High	Z2
Świerzno N High	Z2
Brojce S High	
Brojce Structure	Z2, Z1', P1
Strzeżewo High	Z2, Z1'
Wrzosowo High	Z2
Łukęcin High	Z2, Z1'
Benice Structure	Z2
Gostyń High	Z1'
Świerzno Structure	Z1'

NAME	YEAR	SURVEY	CONCESSION (surveys after 2001)	OWNER	LENGTH [km]
T0010574	1974	Świnoujście – Kamień Pomorski – Gryfice		State Treasury	22.2
T0020574	1974			State Treasury	7.19
T0030574	1974			State Treasury	19.31
T0040574	1974			State Treasury	19.67
T0050574	1974			State Treasury	25.56
T0060574	1974			State Treasury	8.42
T0090574	1974			State Treasury	14.8
T0100574	1974			State Treasury	6.21
T0120574	1974			State Treasury	8.18
T0130574	1974			State Treasury	19.09
T0140574	1974			State Treasury	17.9
T0150574	1974			State Treasury	11.36
T0170574	1974			State Treasury	2.34
T0180574	1974			State Treasury	15.15
T0200574	1974			State Treasury	10.08
T0210574	1974			State Treasury	21.73
T0280574	1974			State Treasury	7.67
T0290574	1974			State Treasury	13.92
T0300574	1974			State Treasury	5.8
T0430574	1974			State Treasury	18.72
T0480574	1974			State Treasury	6.12
T0510574	1974			State Treasury	19.97
T0520574	1974			State Treasury	16.13
T0070575	1975			State Treasury	5.37
T0080575	1975			State Treasury	7.33
T0100575	1975			State Treasury	17.21
T0110575	1975			State Treasury	7.84
T0180575	1975			State Treasury	13.48
T0190575	1975			State Treasury	4.93
T0200575	1975			State Treasury	12.1
T0220575	1975			State Treasury	15.19
T0270575	1975			State Treasury	9.86
T0280575	1975			State Treasury	2.05
T0320575	1975			State Treasury	11.78
T0340575	1975			State Treasury	10.66
T0360575	1975			State Treasury	4.79
T0420575	1975			State Treasury	2.87
T0450575	1975			State Treasury	4.54
T0510575	1975			State Treasury	5
T0530575	1975			State Treasury	18.82
T0680575	1975			State Treasury	2.77
T0030576	1976	Gorzysław – Petrykozy		State Treasury	15.08
T0180576	1976			State Treasury	5.22
T0230576	1976			State Treasury	21.52
T0300576	1976			State Treasury	5.38
TA030576	1976			State Treasury	8.69
T0280576	1976	Wysoka Kamieńska		State Treasury	3.12
T0010279	1979	Wysoka Kamieńska – Białogard		State Treasury	2.75
T0020279	1979			State Treasury	5.4
T0030279	1979			State Treasury	7.69
T0050279	1979			State Treasury	13.37
T0710579	1979			State Treasury	18.48
T0720579	1979			State Treasury	24.35
T0730579	1979			State Treasury	23.07
T0750579	1979			State Treasury	19.79
T0760579	1979			State Treasury	23.43
TA750579	1979			State Treasury	3.27
T0060280	1980			State Treasury	3.22

T0270280	1980			State Treasury	7.57
T0740580	1980			State Treasury	17.5
T0860580	1980			State Treasury	3.96
T0870580	1980			State Treasury	16.9
T0900580	1980			State Treasury	2.12
T0910580	1980			State Treasury	20.92
T0970580	1980			State Treasury	14.76
T0980580	1980			State Treasury	11.83
TA280280	1980			State Treasury	8.64
TA740580	1980			State Treasury	3.54
TA900580	1980			State Treasury	13.66
T0020581	1981			State Treasury	20.12
T0270281	1981			State Treasury	2.75
T0290281	1981			State Treasury	2.44
T0300281	1981			State Treasury	6.09
T0640581	1981			State Treasury	13.53
T0780581	1981			State Treasury	7.06
T0790581	1981			State Treasury	4.98
T0880581	1981			State Treasury	16.85
T0890581	1981			State Treasury	16.25
T0920581	1981			State Treasury	26.87
T0930281	1981			State Treasury	3.67
T0930581	1981			State Treasury	25.08
T0940281	1981			State Treasury	10.32
T0950281	1981			State Treasury	4.63
TA010581	1981			State Treasury	16.71
TA120281	1981			State Treasury	2.76
TA500281	1981			State Treasury	2.42
TA510281	1981			State Treasury	4.18
TA780581	1981			State Treasury	13.96
TA790581	1981			State Treasury	10.04
T0040582	1982			State Treasury	16.16
T0070582	1982			State Treasury	10.17
T0080582	1982			State Treasury	3.62
T0090582	1982			State Treasury	5.2
T0100582	1982			State Treasury	13.47
T0110582	1982			State Treasury	5.88
T0120582	1982			State Treasury	9.67
T0150582	1982			State Treasury	6.82
T0170582	1982			State Treasury	12.53
T0470282	1982			State Treasury	9.01
T0690582	1982			State Treasury	12.95
T0700582	1982			State Treasury	9.88
T0770582	1982			State Treasury	23.81
T0810582	1982			State Treasury	9.84
T0940582	1982			State Treasury	18.18
T0950582	1982			State Treasury	19.14
T0960582	1982			State Treasury	14.89
T0030583	1983			State Treasury	2.81
T0060583	1983			State Treasury	16.32
T0130583	1983			State Treasury	6.73
T0140583	1983			State Treasury	6.27
T0180583	1983			State Treasury	5.57
T0190583	1983			State Treasury	11.27
T0200583	1983			State Treasury	8.64
T0210583	1983			State Treasury	14.83
TA080583	1983			State Treasury	16.41
TA220583	1983			State Treasury	7.07
T0020796	1996	Jarkowo – Piaski		PGNiG S.A.	5.33
T0050796	1996			PGNiG S.A.	2.66

T2020496	1996			PGNiG S.A.	5.48
T0150797	1997			PGNiG S.A.	2.64
T2010599	1999	Kamień Pomorski – Gryfice – Trzebiatów		PGNiG S.A.	11.04
TA010599	1999			PGNiG S.A.	11.04
T0010500	2000			PGNiG S.A.	12.15
T0040500	2000			PGNiG S.A.	26.01
T0050500	2000			PGNiG S.A.	11.61
T0270402	2002	Piaski – Resko	Gryfice 12/99/p, Łobez 21/2000/p	State Treasury	7.65
T0013106	2006	Rybokarty – Komorowo	Gryfice 12/99/p, Kamień Pomorski 01/2000/p, Nowogard 20/2000/p	State Treasury	17.48
T0023106	2006			State Treasury	14.03
T0033106	2006			State Treasury	10.36
T0043106	2006			State Treasury	7.78
T0053106	2006			State Treasury	6.71
T0063106	2006			State Treasury	2.48
T0073106	2006			State Treasury	10.97
T0083106	2006			State Treasury	2.75
T0113106	2006			State Treasury	3.14
T0123106	2006			State Treasury	3.25
T0133106	2006			State Treasury	3.01
T0143106	2006			State Treasury	2.9
				TOTAL	
				State Treasury:	**1399.7**
				Private investor:	**87.96**

Tab. 6.1. 2D seismic surveys (limited to the lines longer than 2 km) in the “Gryfice” tender area.

NAME	YEAR	AREA	CONCESSION (surveys after 2001)	OWNER	ACREAGE [km^2]
Świerzno 3D	1997	Świerzno		PGNiG S.A.	200.11
Moracz 3D	2014	Moracz	Kamień Pomorski 1/2000/Ł	State Treasury	22.63
Jarkowo 3D	2018	Jarkowo	Trzebiatów 60/2009/Ł, Bardy 15/2008/Ł, Świdwin-Białogard 18/95/Ł	State Treasury	90.38
				TOTAL	
				State Treasury:	**113.01**
				Private investor:	**200.11**

Tab. 6.2. 3D seismic surveys in the “Gryfice” tender area,

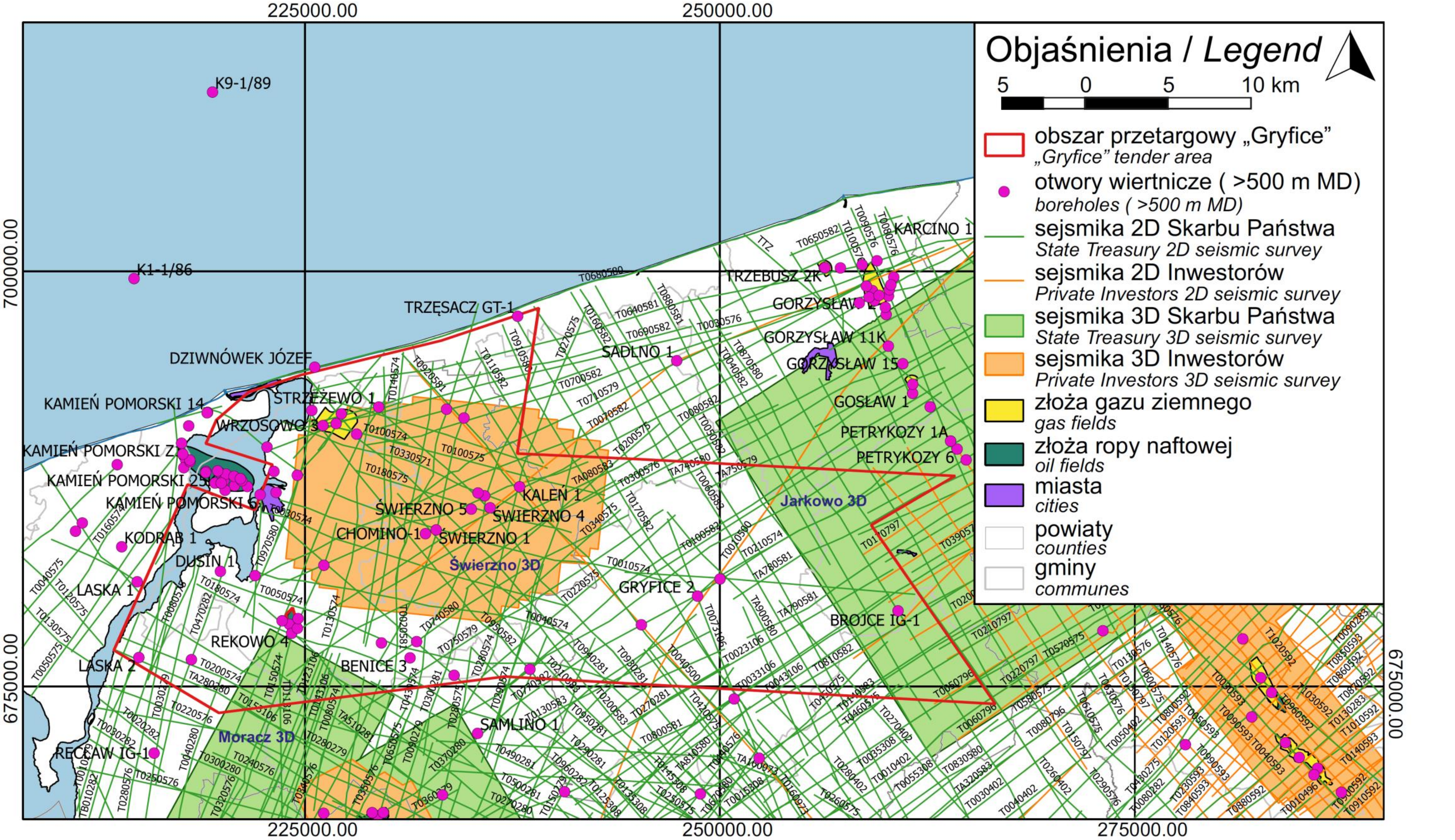

Fig. 6.1. Seismic surveys in the “Gryfice” tender areas and in its neighborhood with location of deep boreholes and hydrocarbon fields (CGDB, 2021).

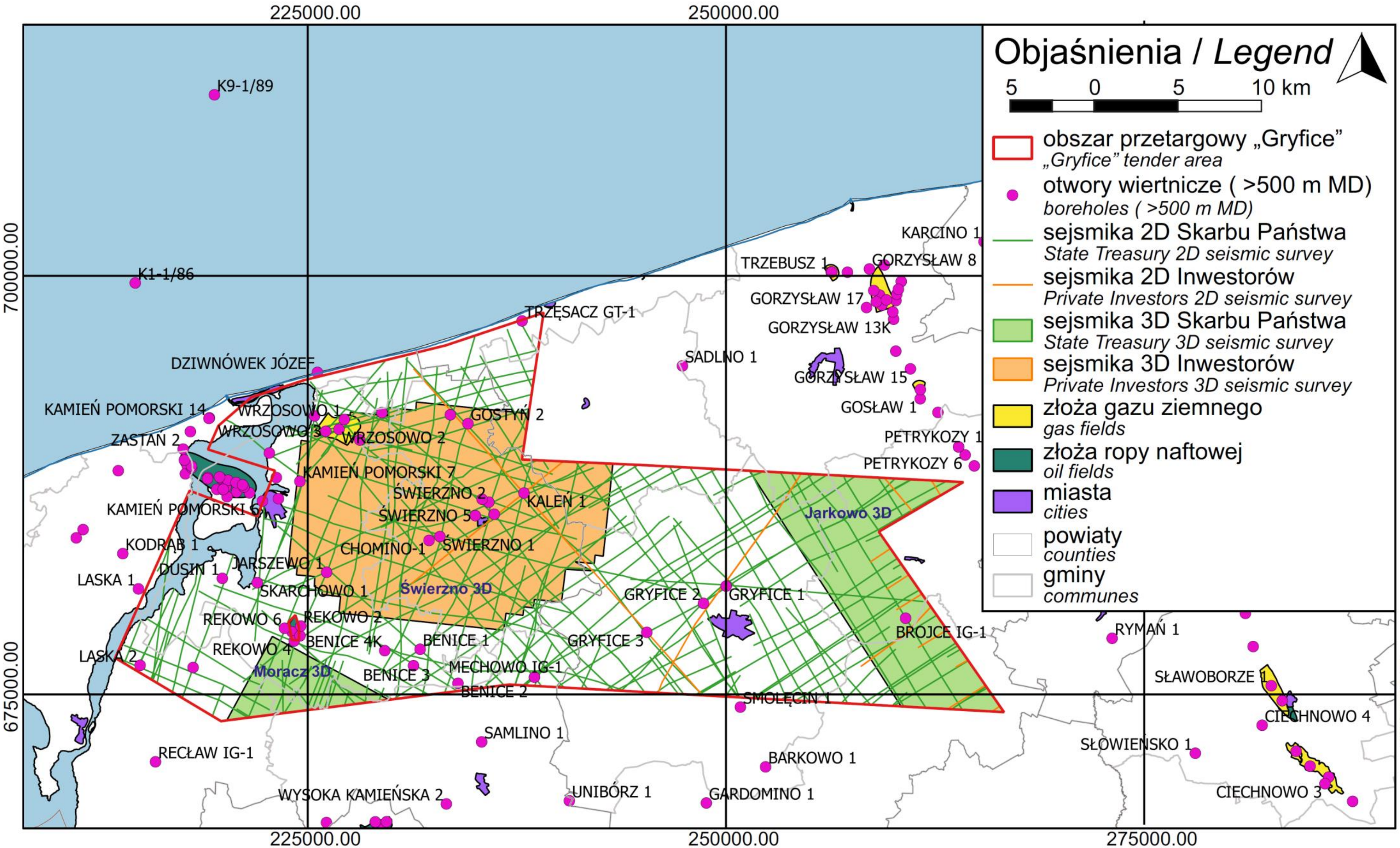

Fig. 6.1. Seismic surveys in the “Gryfice” tender areas with location of deep boreholes and hydrocarbon fields (CGDB, 2021).

7. GRAVIMETRY, MAGNETOMETRY AND MAGNETOTELLURICS
7.1. GRAVIMETRY

Semidetailed gravimetric surveys in the “Gryfice” tender area and in its close neighbourhood were collected with a point density of ca. 1.9 stations/km^2 (Fig. 7.1). All data are available in the CGDB (2021). There are 1494 data points within the tender area (Fig. 7.1) coming from the “Pomeranian Anticlinorium” survey (Wasiak et al., 1973). The tender area is adjoined to the south by the “Szczecin Synclinorium” survey (Bochnia and Duda, 1963).

There are 1036 data points of the “Kamień Pomorski” detailed survey (Duda and Kruk, 1973), collected with a point density of 16 stations/km^2.

The most recent detailed surveys, not included in the CGDB yet, cover the eastern part of the tender area. The „Trzebiatów–Dobrzyca–Koszalin” survey (Ostrowska and Pisuła, 2000) was collected with a point density of 5 stations/km^2. The second one is the “Piaski-Resko” profile survey (Ostrowski, 2002). Both surveys were focused on the tectonic structure of Permo-Mesozoic and sub-Permian Paleozoic deposits.

Królikowski and Petecki (1995) proposed a division of Poland into several gravity regions. Thus, the “Gryfice” tender area is placed within the north part of the Pomeranian High (Fig. 7.2) – a positive anomaly divided into two parts by negative anomaly of the Trzebiatów Trough (to the north-east of the “Gryfice” tender area). The sub-Permian origin seems to be the dominant factor in the creation of the positive anomaly (Grobelny and Królikowski, 1988).

7.2. MAGNETOMETRY

A ground, semidetailed survey of the total magnetic field intensity was conducted in the “Gryfice” tender area (Cieśla and Wybraniec, 1995 in: Kosobudzka and Paprocki, 1997). The survey has an average density of 2 stations/km^2. All data are available in the CGDB (2021). There are 979 data points within the “Gryfice” tender area (Fig. 7.3).

From the north-east, the tender area is adjacent to another survey with a similar density, covering western, central and south-eastern Poland (Kosobudzka, 1988).

An image of magnetic anomalies presented in Fig. 7.4 is taken from a magnetic map of Poland (Petecki and Rosowiecka, 2017). The map is divided into several regions with different magnetic characteristics. The “Gryfice” tender area is located within the Western Pomerania domain (WPd). According to Petecki (2001) the subdued anomaly pattern in this area reflects a considerable depth of ~18.5 km to the top of the magnetic basement, estimated based on the spectral method of Spector and Grant (1970).

7.3. MAGNETOTELLURICS

In the years 2007-2008, the first stage of the magnetotelluric project was carried out in the Pomeranian segment of the Mid-Polish Trough (Stefaniuk et al., 2008). Two profiles: BMT-5 (300 km) and D-PL (230 km) were collected. The D-PL profile crosses the “Gryfice” tender area (Fig. 7.5). Measurements were made as single soundings distant by approx. 4.5 km along the profile. The general aim of the project was to identify the deep-seated structure of the Pomeranian zone of the Mid-Polish Trough and the neighboring areas, and to determine the nature of the contact between the East European Craton and the structures of the Paleozoic Platform. As a result of the 2D inversion, a geoelectric cross-section was obtained in which all the main geological structures along the profile were marked (Stefaniuk et al., 2008).

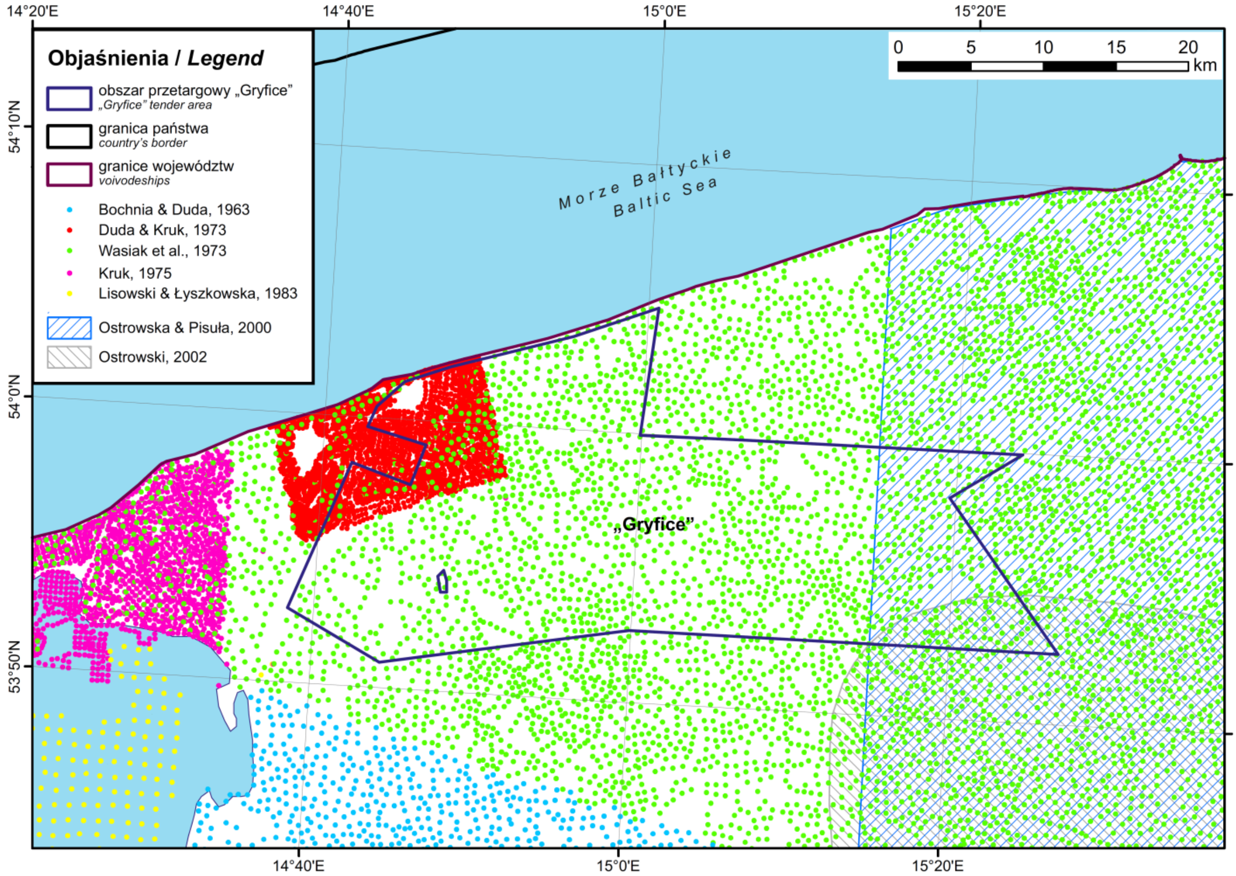

Fig. 7.1. Distribution of gravimetric measurements in the “Gryfice” tender area (based on CGDB, 2021).

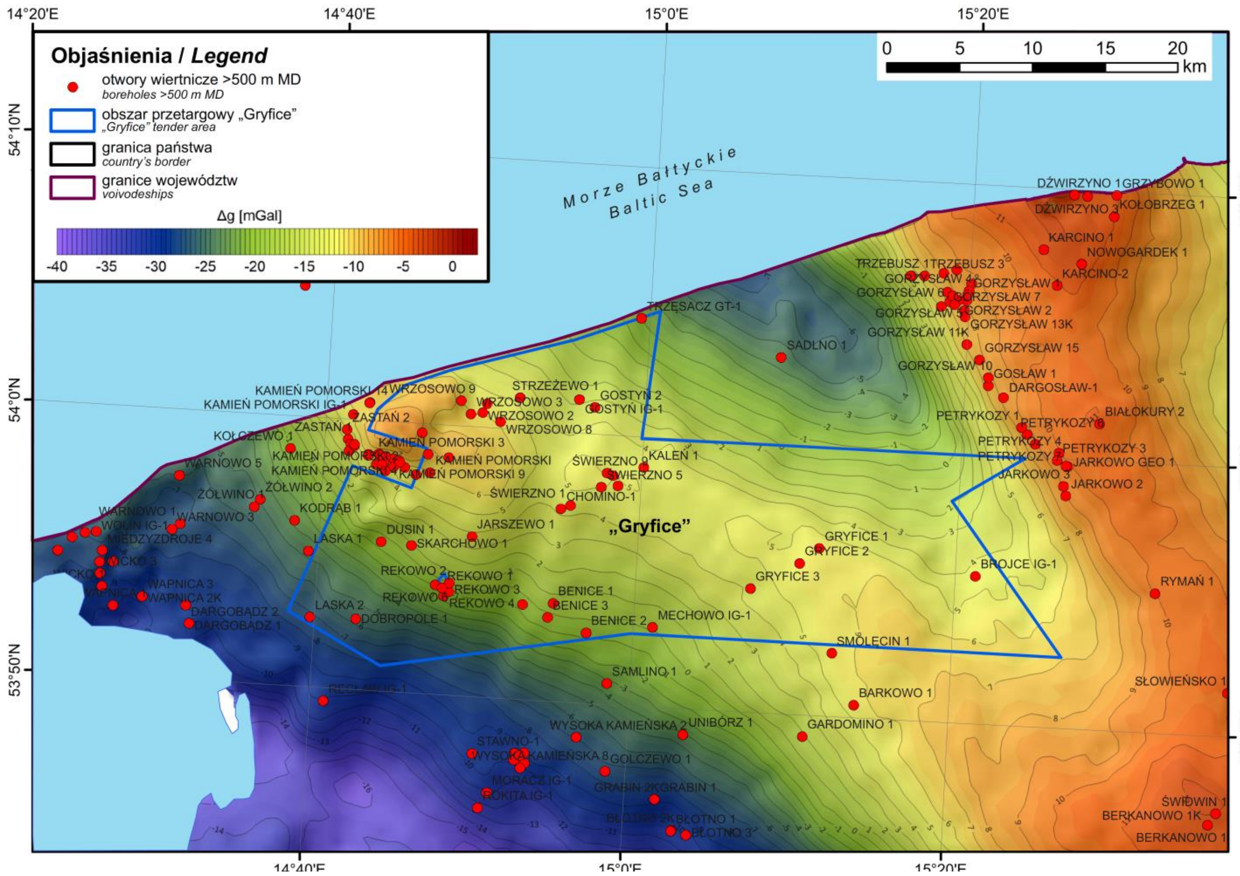

Fig. 7.2. Location of the “Gryfice” tender area on the Bouguer gravity anomaly map of Poland.

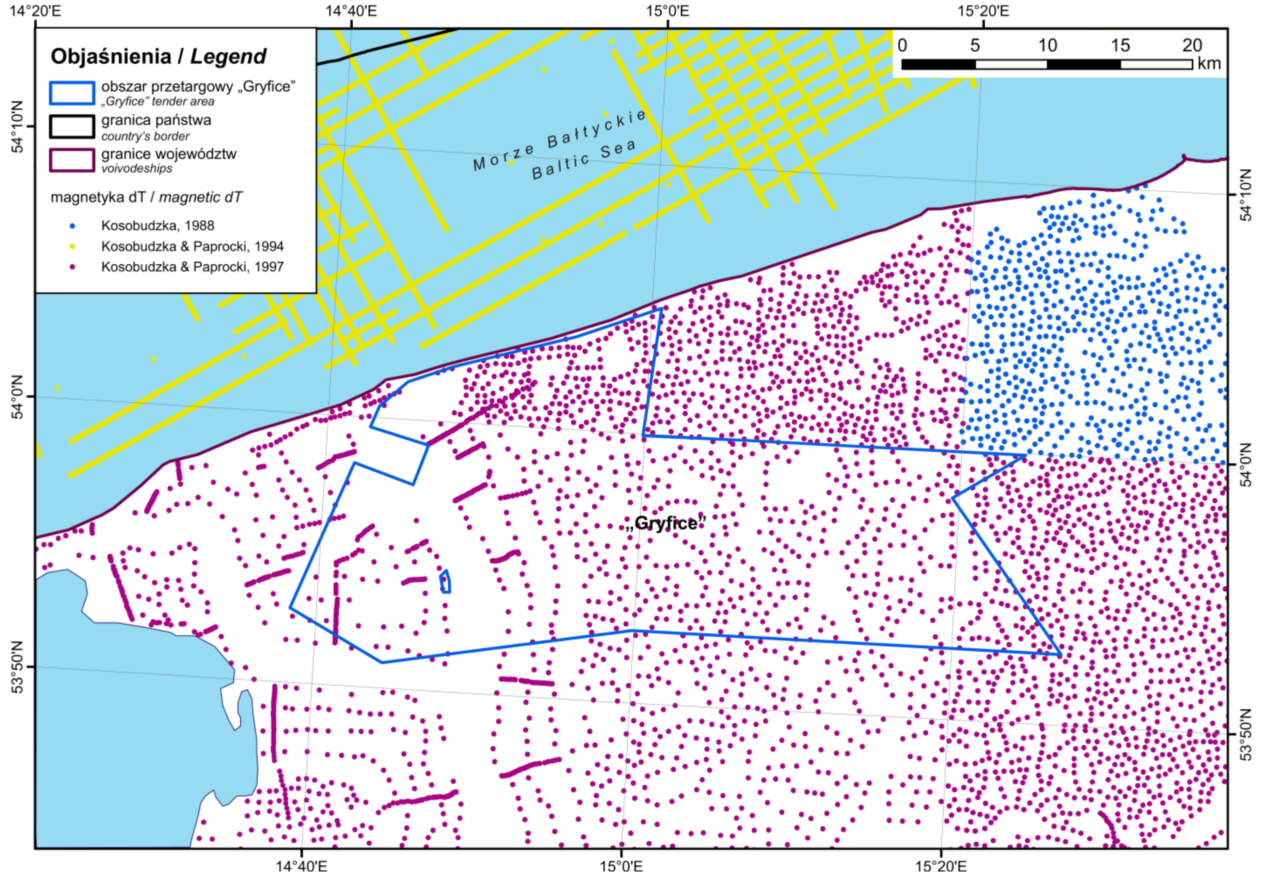

Fig. 7.3. Distribution of magnetic stations in the "Gryfice" tender area (based on CGDB, 2021).

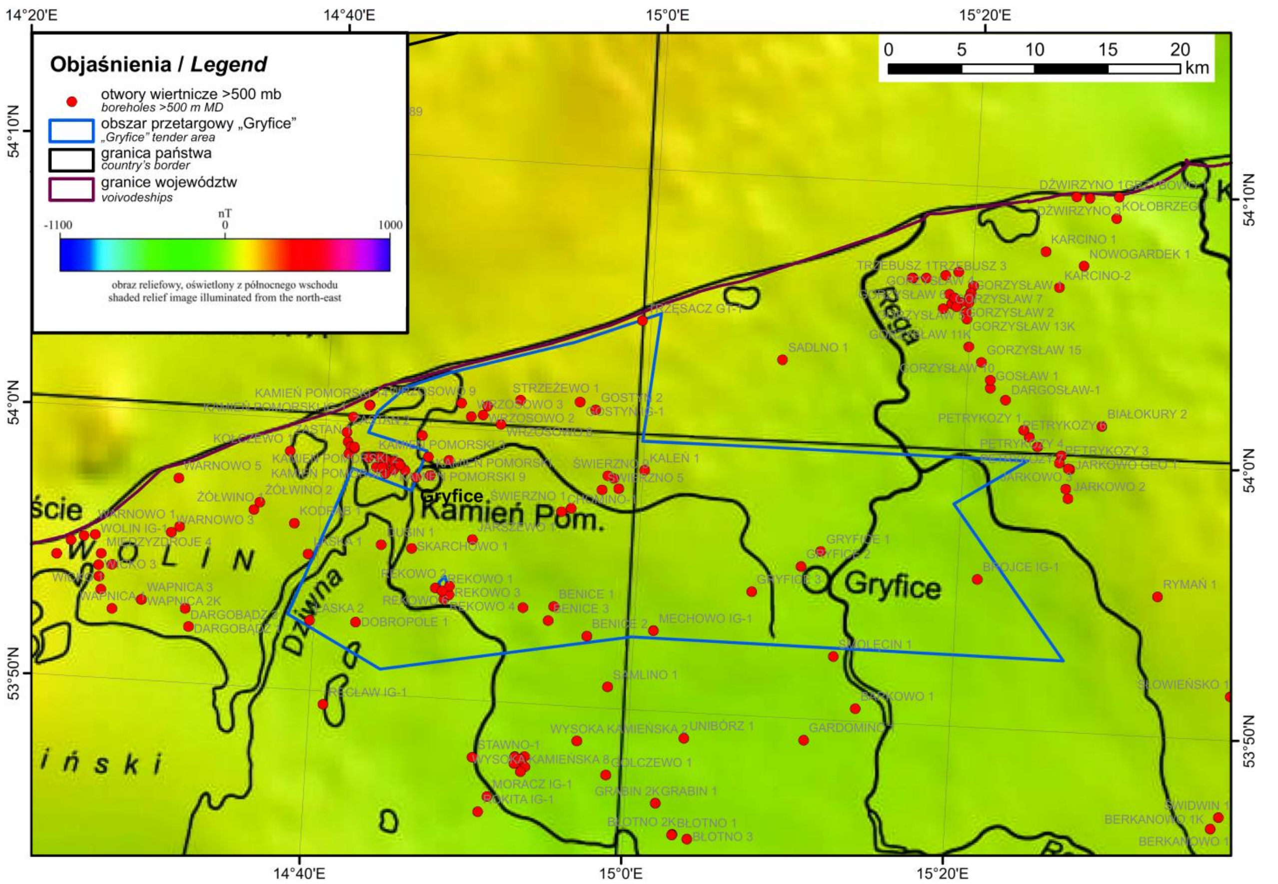

Fig. 7.4. Location of the "Gryfice" tender area in the magnetic anomaly map of Poland (Petecki and Rosowiecka, 2017).

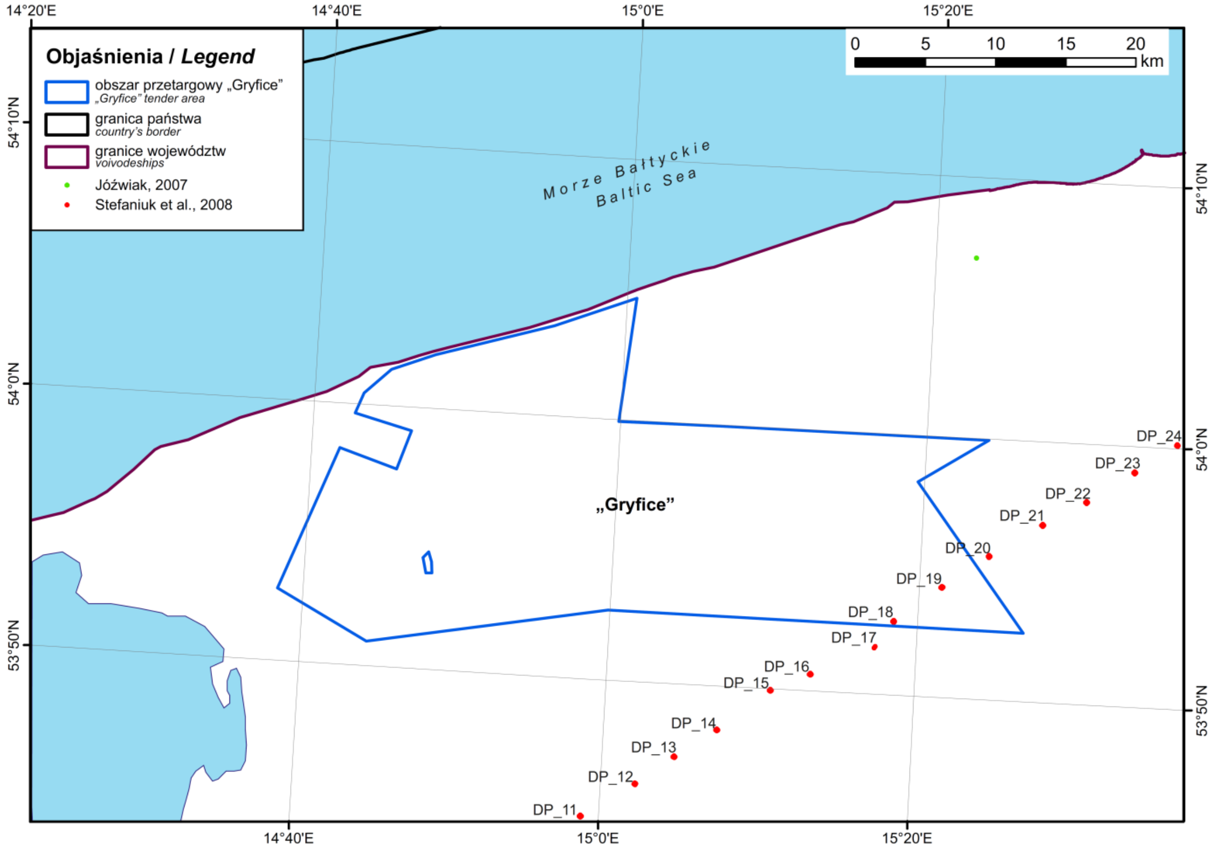

Fig. 7.5. Distribution of magnetotelluric surveys in the “Gryfice” tender area (based on CGDB, 2021).

8. SUMMARY CHART

General information:	**Tender area:**	**"GRYFICE"**
	Location:	Onshore Hydrocarbon concession blocks: 62, 82 and 83 Administrative location: Zachodniopomorskie voivodeship, Kamieńsk county, communes: Świerzno (18.72%), Wolin (5.12%), Kamień Pomorski (26.39%), Dziwnów (3.11%), Golczewo (3.09%); Gryfice county, communes: Płoty (4.78%), Karnice (5.60%), Rewal (1.67%), Brojce (6.60%), Trzebiatów (0.75%), Gryfice (24.17%)
	Concession type:	prospection and exploration of hydrocarbon deposits and production of hydrocarbons from a deposit
	Time:	concession for 30 years, including: prospection and exploration phase (5 years), production phase – after investment decision
Participation:		winner of the tender 100%
Acreage [km^2]:		747.96
Accumulation type:		conventional for oil and gas unconventional for tight gas
Structural stages:		Cenozoic Laramide Variscan Caledonian
Petroleum plays:		I. Carboniferous – Lower Permian II. Upper Permian/Zechstein – Main Dolomite (additional target)
Reservoir rocks:		I. Upper Carboniferous fluvial sandstones, Upper Rotliegend fluvial sandstones II. Main Dolomite carbonate rocks
Source rocks:		I. Carboniferous claystones and mudstones II. Main Dolomite mudstones, grainstones and boundstones
Seal rocks:		I. Lower Rotliegend volcanic rocks and PZ1 evaporites II. Zechstein evaporites
Trap type:		I. mixed, structural-lithological-tectonic, unconventional – continuous II. structural, structural-tectonic, facies
Oil and gas fields in the neighborhood:		Rekowo (NR 4847), Wrzosowo (GZ 4732), Dargosław (GZ 20146), Gorzysław N (GZ 4687), Gorzysław S (GZ 4688), Kamień Pomorski (NR 4802), Trzebusz (GZ 4686), Wysoka Kamieńska (NR 4804)
Seismic surveys (owner):		1974-1975 Świnoujście – Kamień Pomorski – Gryfice 2D, 41 lines (State Treasury) 1976 Gorzysław – Petrykozy 2D, 5 lines (State Treasury) 1976 Wysoka Kamieńska 2D, 1 line (State Treasury) 1979-1983 Wysoka Kamieńska – Białogard 2D, 69 lines (State Treasury) 1996-1997 Jarkowo – Piaski 2D, 4 lines (PGNiG) 1999-2000 Kamień Pomorski – Gryfice – Trzebiatów 2D, 5 lines (PGNiG) 2002 Piaski – Resko 2D, 1 line (State Treasury) 2006 Rybokarty – Komorowo 2D, 12 lines (State Treasury) 1997 Świerzno 3D (PGNiG) 2014 Moracz 3D (State Treasury) 2018 Jarkowo 3D (State Treasury)
Wells (depth):		Benice 1 (3247.0 m), Benice 2 (2916.0 m), Benice 3 (2842.0 m), Benice 4K (2732.5 m), Brojce IG-1 (4252.0 m), Chomino-1 (2750.0 m), Dobropole 1 (2883.0 m), Dusin 1 (2662.5 m), Gostyń 2 (3447.0 m), Gryfice 1 (3367.0 m), Gryfice 2 (3415.0 m), Gryfice 3 (3190.0 m), Jarszewo 1 (2998.7 m), Kaleń 1 (3232.0 m), Kamień Pomorski 13 (2672.0 m), Kamień Pomorski 3 (2405.0 m), Kamień Pomorski 7 (3410.0 m), Laska 2 (3583.0 m), Rekowo 1 (2667.0 m), Rekowo 2 (3141.5 m), Rekowo 3 (2697.0 m), Rekowo 4 (2736.0 m), Rekowo 6 (2746.0 m), Skarchowo 1 (2667.0 m), Strzeżewo 1 (4521.0 m), Świerzno 1 (3103.0 m), Świerzno 2 (2772.2 m), Świerzno 4 (3238.5 m), Świerzno 5 (2883.6 m), Świerzno 9 (2774.7 m), Wrzosowo 1 (3305.0 m), Wrzosowo 2 (3127.3 m), Wrzosowo 3 (3255.0 m), Wrzosowo 8 (3310.0 m), Wrzosowo 9 (3198.0 m)

Possible minimum work program for prospection and exploration phase

- Archival data reinterpretation and analysis

- 2D seismic survey reprocessing (60 km)
or conducting sejsmic survey 2D (50 km SP)
or conducting sejsmic survey 3D (25 km^2)

- Drilling of one well (of max. depth 5000 m TVD) reaching the Carboniferous deposits with obligatory coring of prospective intervals

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