OIL & GAS IN POLAND NEW OPPORTUNITIES

POLISH GEOLOGICAL INSTITUTE
NATIONAL RESEARCH INSTITUTE

POLISH GEOLOGICAL SURVEY
POLISH HYDROGEOLOGICAL SURVEY

IMPORTANT DATES

16TH CENTURY
First Polish-written mentions on practical use of crude oil found in the Flysch Carpathians

1815
Stanisław Staszic describes geological conditions of crude oil and native paraffin occurrence in the Flysch Carpathians as well as related exploitation and application methods

1851-53
First tests of industrial crude oil production in the Carpathians region of Gorlice city (Ropa, Szymbark, Kobylanka, Kryg, Libusza, Lipinki and Sękowa)

1853
Patent Office in Vienna grants Ignacy Łukasiewicz and Jan Zeh the patent for petroleum distillation method to obtain kerosene for lighting purposes in kerosene lamps

1854
THE FIRST COMMERCIALLY ORGANIZED MODERN OIL WELL IN BÓBRKA VILLAGE FOUNDED BY THE COMPANY OF IGNACY ŁUKASIEWICZ – TYTUS TRZECIESKI, SUBSEQUENTLY EXPANDED BY KAROL KLOBASSA, THE OWNER OF THE BÓBRKA OIL FIELDS

1854
World's first kerosene street lamp lit up in the city of Gorlice

1856
The first oil refinery built by Ignacy Łukasiewicz in Ulaszowice near Jasło

1860-70s (exact date unknown)
The representatives of George Bissel and John D. Rockefeller visited Ignacy Łukasiewicz to learn the secrets of the distillation process he was using in his refinery at Polanka near Krosno

1883
Henry Mac Garvey builds the Drilling Machinery and Equipment Factory and an oil refinery in Glinik Mariampolski near Gorlice

1896
Discovery of the largest Tertiary oil reservoirs within the Flysch Carpathians in the city of Borislav

1909
TOP PRODUCTION OF OIL AMOUNTING TO 2,053,150 TONNES PER YEAR IN THE FLYSCH CARPATHIANS RANKS HISTORICALLY POLISH LANDS ON THE 3RD PLACE IN THE WORLD, JUST BEHIND THE USA AND THE RUSSIAN EMPIRE

1954
Opening the Europe's first underground natural gas storage facility in the Roztoki reservoir near Jasło

1958
Discovery of the "Przemyśl" field in the Miocene strata, the biggest natural gas field in Poland. Discovered by Polish Oil and Gas Company (PGNiG)

1960
Discovery of the "Bogdaj-Uciechów" field. The first Polish conventional natural gas field in the gas-prone Rotliegend

1961
Discovery of the "Rybaki" field in the Zechstein Main Dolomite. The first onshore oil field in the Polish Lowlands.

1981
First offshore oil field discovery – B3 within the Polish Exclusive Economic Zone of the Baltic Sea. Discovered by the Petrobaltic Company

1990s
First coal-bed methane (CBM) exploration and drilling activity in the Upper Silesian Coal Basin (USCB) in Poland

1993
Discovery of the "BMB" field (Barnówko-Mostno-Buszewo field) in the Zechstein Main Dolomite, Poland's biggest onshore oil field. Discovery by Polish Oil and Gas Company (PGNiG)

2007
First tight gas discovery in the Rotliegend of the "Siekierki-Trzek" structure by Aurelian Oil and Gas

2010
FIRST SHALE GAS EXPLORATION WELL SPUDDED IN POLAND

POLISH OIL & GAS_ STORY AT GLANCE

Poland has a long established history of petroleum industry. As early as the Middle Ages, bitumen seeping out in places at the slopes of the Carpathians had been fairly intensively exploited. The invention of safe kerosene (oil distillate) lamp by Ignacy Łukasiewicz encouraged the search for more efficient ways to produce oil. Łukasiewicz – who is called the father of Polish petroleum industry – was among the first in the world to extract oil with drilling wells, develop oil processing and become the leading supplier of petroleum products in Europe.

Geological studies made by Polish naturalists in the 19th century led to discovery of significant crude oil reservoirs in the East Carpathian Mountains. The oil rush that followed these discoveries can be compared to the golden era of the U.S. petroleum industry. At the turn of the 19th century, champagne was flowing profusely in Borysław – the main city in the oil-producing region. As of 1909, over 2 million tonnes of oil were produced, making Polish historical lands (placed under the administration and occupation of the Austro-Hungarian Empire at that time) the third largest oil producing region worldwide.

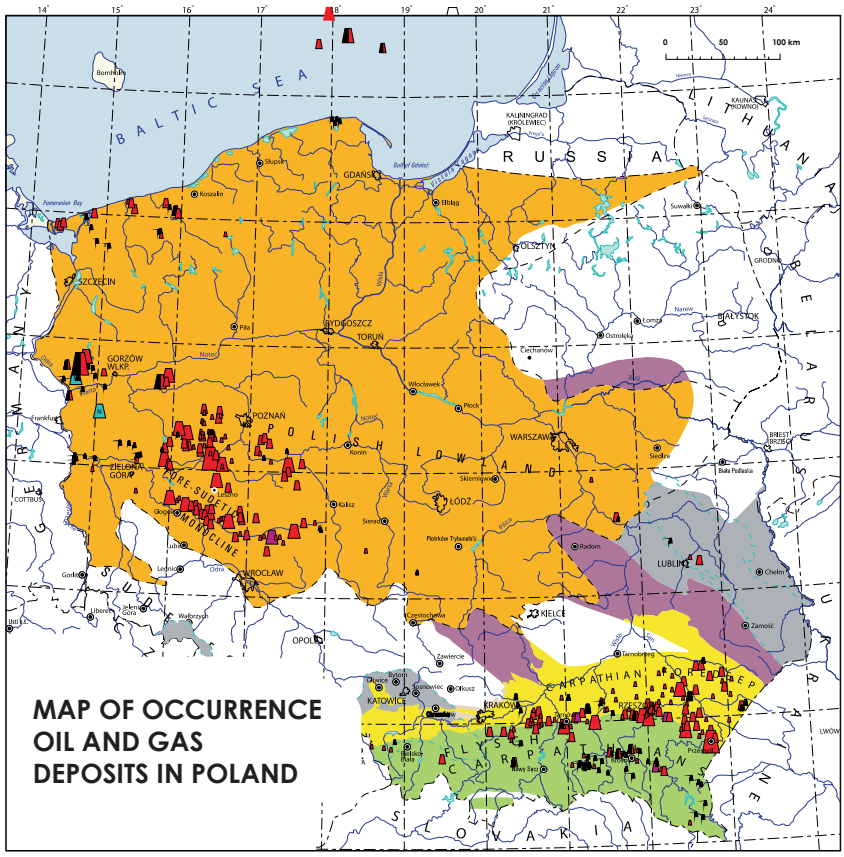
» GEOLOGICAL SURVEYS MADE BY POLISH NATURALISTS IN THE 19TH CENTURY...

Carpathian fields are still being exploited today, but the bulk of oil production comes from plays discovered after WWII located in the Polish Lowlands.
Thanks to extensive geological surveying projects, domestically produced natural gas satisfies one-third of Poland's demand. In the case of oil, however, domestic production accounts for as little as 5% of the demand. These proportions are likely to improve, provided that initially appraised unconventional gas and oil resources are successfully developed.

Ensuring Poland's energy security is a key task of Polish Geological Institute – National Research Institute which performs the role of geological survey in Poland. For the past almost hundred years the Institute has investigated geology of Poland, published complete geological maps and maintained the geological archives. Poland's current oil and gas potential is presented in this publication, along with Environment Ministry's update on legislative and regulatory framework of oil and gas exploration, appraisal and production in Poland.

First Page photography: Tygodnik Ilustrowany, 8 Jule, 1899.
Oil well „Jakub" – rapid oil blow-aut, September 1895, Schodnica near Borysław (Eastern Carpathians) by the Stryj River. Coll. Stanisław Wołkowicz

OIL & GAS_ FIELDS AND STRATIGRAPHY OF RESERVOIRS



Voivodeship towns

Other towns

State boundaries

Rivers

Water reservoirs (natural and artificial)

Oil- and gas-bearing rocks of the Carpathian Foredeep

Oil- and gas-bearing rocks of the Flysch Carpathians

Permian (Zechstein & Rotliegend) oil and gas-bearing formations

Carboniferous oil- and gas-bearing formations

Pre-Carboniferous oil- and gas-bearing formations

Areas without perspective oil and gas occurrence

Boundary of Zechstein formation

POLAND - PRIMARY OIL- & GASBEARING UNITS

ERA	PERIOD	EPOCH - STAGE (EUROPEAN UNITS)			OIL	GAS	TRAPS C	TRAPS UC
CENOZOIC	QUARTERNARY							
	NEOGENE	MIOCENE						
	PALEOGENE							
MESOZOIC	CRETACEOUS	CENOMANIAN						
	JURASSIC							
	TRIASSIC							
PALEOZOIC	PERMIAN	MAIN DOLOMITE						
		ZECHSTEIN LIMESTONE						
		ROTLIEGEND						
	CARBONIFEROUS	WESTPHALIAN						
		VISEAN	NAMURIAN					
	DEVONIAN	GIVETIAN	FRASNIAN	FAMENNIAN				
	SILURIAN	LLANDOVERY						
	ORDOVICIAN	CARADOCIAN						
	CAMBRIAN	ALUM SHALE						
		MIDDLE CAMBRIAN						

CONVENTIONAL - C

UNCONVENTIONAL - UC

RESOURCES:

Oil deposits (0.2 2 Mt)

Oil and gas deposits (0.2 2 10 Mt)

Gas deposits (0.2 2 10 Bm³)

Natural nitrogen gas deposits (N N 2 10 Bm³)

Underground gas storage (0.2 2 Bm³)

Coal Bed Methane perspective areas

OIL & GAS_ RESERVES, RESOURCES AND ECONOMY

Polish growing demand for crude oil and gas supply is in stable upward trend, showing growth of our economy (fig. 1, 2 and 3). Crude oil and natural gas consumption in Poland is still increasing, but country's own oil and gas production is too low for our needs. Natural gas extraction from conventional reservoirs is slightly increasing, but in next 10-15 years it is predicted to decrease (fig. 1).

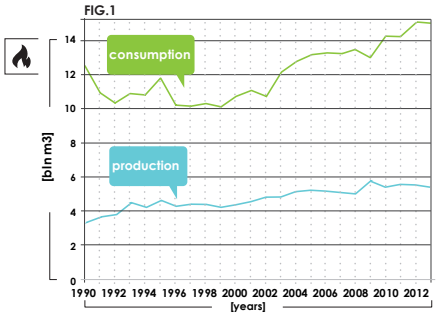
Crude oil extraction in Poland is still increasing (fig. 2), but low scale of production has low economic importance in reference to the growing demand.

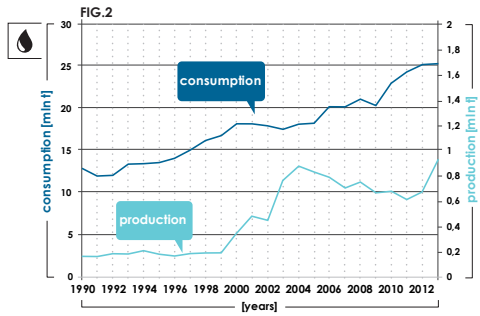
The gap between economy needs and our oil and gas production is covered by oil and gas import, mostly from Russian Federation. This import during last 20 years has also been in a stable upward trend (fig. 3).

Poland has several perspective horizons for hydrocarbon extraction (page 3) and undiscovered potential.

This potential is partly built on shale gas/oil and deep tight gas reservoirs assessments. The estimation of undiscovered oil and gas resources and proven reserves in Poland are exposed below.

TOTAL PETROLEUM CONVENTIONAL AND UNCONVENTIONAL RESOURCES AND RESERVES IN POLAND:	NATURAL GAS (Bcm)		CRUDE OIL (MMtons)	
	Gas In Place **(GIP)**	Recoverable	Oil In Place **(OIP)**	Recoverable
RESERVES OF CONVENTIONAL FIELDS (ONSHORE AND OFFSHORE)	250 **(8.83Tcf)**	134 **(4.73Tcf)** (145) **(5.12Tcf)**	170 **(1267 MMB)**	25 **(186 MMB)**
PROSPECTIVE RESOURCES OF CONVENTIONAL RESERVOIRS (ONSHORE)	2297 **(81.08Tcf)**	--	103 **(768 MMB)**	--
SHALE (UNCONVENTIONAL RESERVOIRS) PROSPECTIVE RESOURCES (ONSHORE AND OFFSHORE)	--	346 - 768 **(12.21÷27.11Tcf)**	--	215 – 268 **(1603 – 1998 MMB)**
TIGHT GAS (UNCONVENTIONAL RESERVOIRS) PROSPECTIVE RESOURCES (ONSHORE)	1528-1995 **(53.94÷70.42Tcf)**	153-200 **(5.40÷7.06Tcf)**	--	--





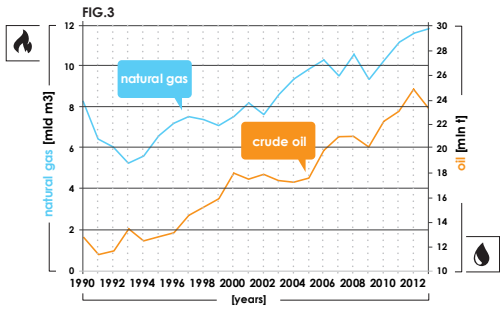
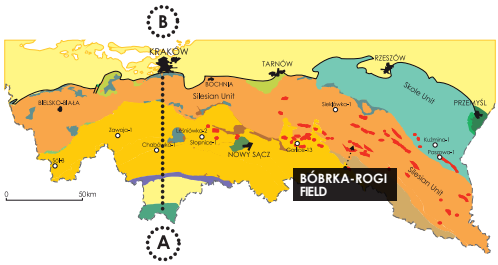


FIG.1 NATURAL GAS CONSUMPTION AND EXTRACTION IN POLAND

FIG.2 CRUDE OIL CONSUMPTION AND EXTRACTION IN POLAND

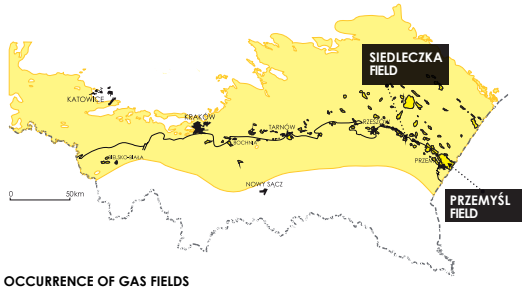
FIG.3 CRUDE OIL AND NATURAL GAS IMPORT TO POLAND

OIL & GAS_ THE CARPATHIANS PLAY



OCCURRENCE OF HYDROCARBON FIELDS IN LOWER CRETACEOUS TO LOWER OLIGOCENE DEPOSITS IN THE FLYSCH CARPATHIANS

- boundary of autochthonous Miocene deposits
- front of the Carpathian overthrust
- hydrocarbon fields



OCCURRENCE OF GAS FIELDS IN MIOCENE DEPOSITS

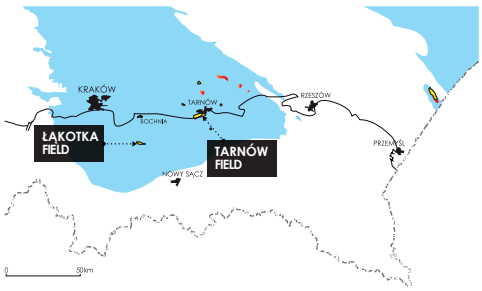
- boundary of autochthonous Miocene deposits
- front of the Carpathian overthrust
- gas fields

OCCURRENCE OF OIL AND GAS FIELDS IN LOWER CARBNIFEROUS AND DEVONIAN DEPOSITS

- boundary of Lower Carboniferous deposits
- boundary of Devonian deposits
- front of the Carpathian overthrust
- gas fields
- oil fields

OCCURRENCE OF OIL AND GAS FIELDS IN CENOMANIAN DEPOSITS

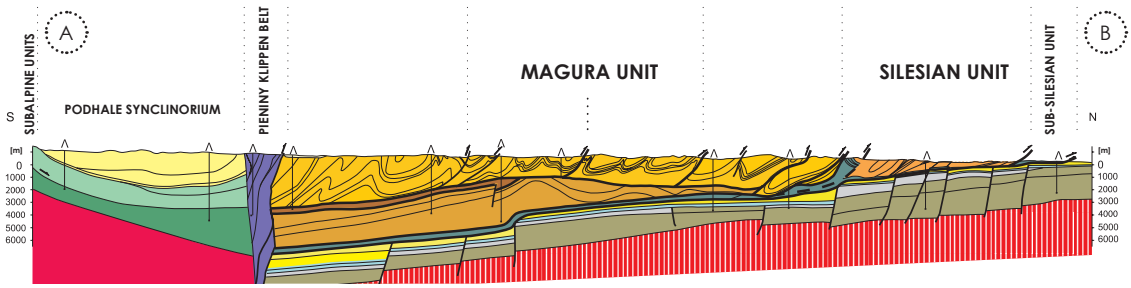
- boundary of Cenomanian deposits
- front of the Carpathian overthrust
- gas fields
- oil fields



OCCURRENCE OF OIL AND GAS FIELDS IN JURASSIC DEPOSITS

- boundary of Jurassic deposits
- front of the Carpathian overthrust
- gas fields
- oil ields

Source: Górka *et al.*, **Polish Geological Review, vol. 55, nr 12/1, 2007**



- Podhale Synclinorium (Oligocene – Lower Miocene)
- Subalpine Units
- Alpine Units
- Inner Carpathians Consolidated Basement (the Tatra Massif)
- Nowy Targ Basin (Lower Badenian – Sarmatian)
- Pieniny Klippen Belt and Grajcarek Thrust Sheets
- Boreholes
- Thrusts
- Magura Unit
- Grybow Unit
- Dukla Unit
- Silesian Unit
- Sub-Silesian Unit
- Cenozoic Platform Cover (Miocene)
- Mesozoic Platform Cover (Upper Jurassic)
- Upper Paleozoic Platform Cover
- Neoproterozoic (Anchimetamorphic) beneath the Upper Paleozoic Platform Cover
- Consolidated Basement of the Outer Carpathians

Source: Żelaźniewicz *et al.*, **Regionalizacja Tektoniczna Polski, Wrocław, 2011**

» TODAY, THE MOST PROLIFIC EXPLORATION TARGET IN THE SOUTHEASTERN POLAND ARE THE MIOCENE DEPOSITS OF THE CARPATHIAN FOREDEEP...

Not many people realize that the Polish lands are one of the cradles of the world's oil production, and are aware that in the late 1800s and in the early 1900s historically Polish lands within the Flysch Carpathians (then under the administration and occupation of the Austro-Hungarian Empire) were the third world's largest oil-producing region, just behind the USA and the Russian Empire. Oil seepages have always accompanied the local people throughout the history and were exploration drivers in the region. The first modern oil well in Bóbrka village is dated 1854 (5 years before Colonel Edwin Drake drilled his first commercial oil well near Titusville city, PA, USA).

The Bóbrka oil field discovery was followed by the oil boom in the Flysch Carpathians and numerous oil and gas field discoveries. Further exploration in the surrounding areas resulted in gas field discoveries in the Carpathian Foredeep Miocene strata and oil and gas fields in the Mesozoic and Paleozoic carbonates and sandstones that underlay the Carpathian Foredeep.

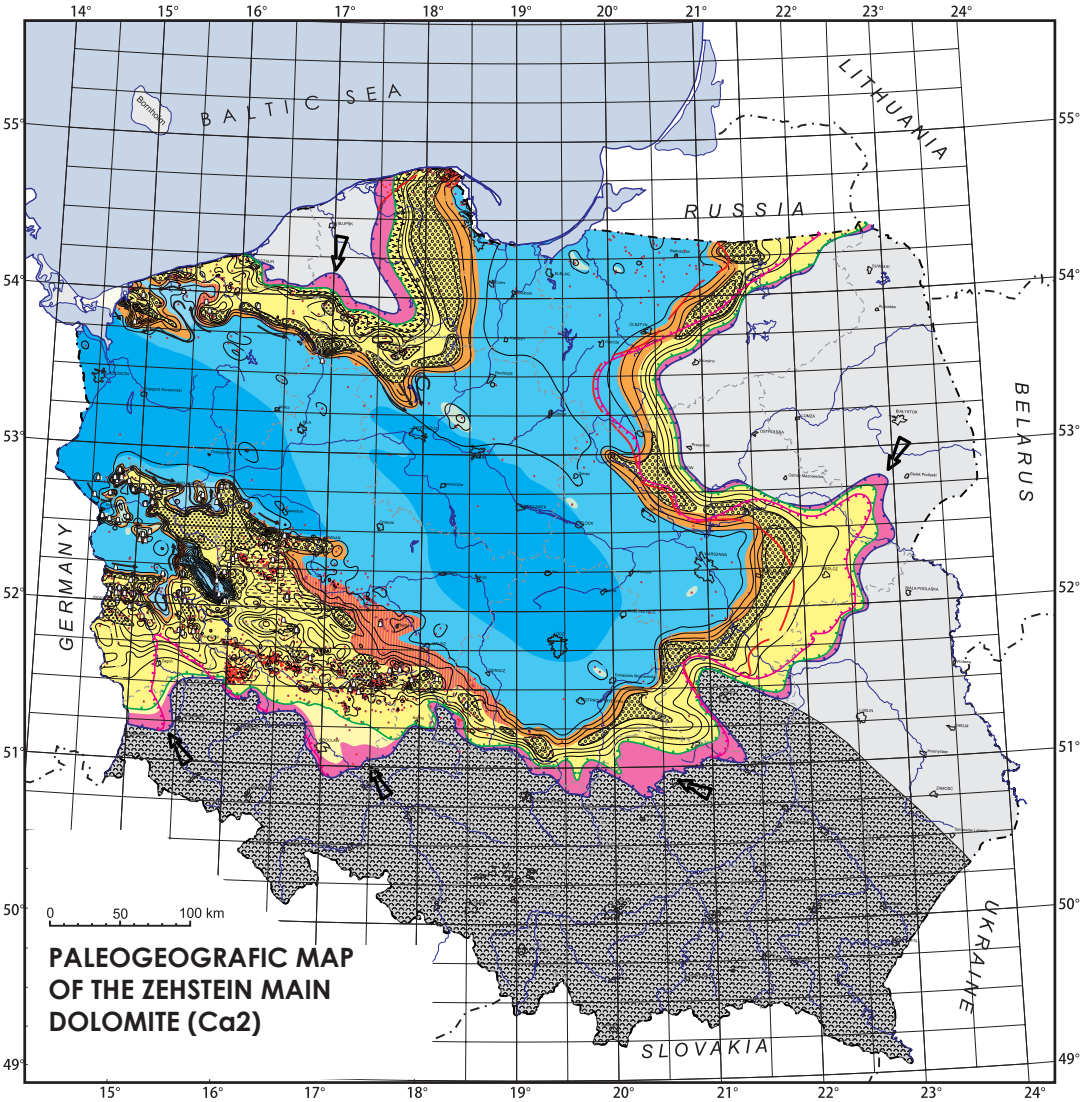
In the thrusted and folded belt of the Flysch Carpathians, a majority of hydrocarbon accumulations occur in different types of structural traps. Oil and gas were found in shallow and deep structures in reservoir rocks of Lower Cretaceous to Lower Oligocene age. Oil and gas fields discovered in the Flysch Carpathians have rather modest reserves and a bulk of them have already been depleted.

In the Carpathian Foredeep, oil is produced mainly from the Oxfordian carbonates and Cenomanian sandstones. Secondary oil producing reservoirs include Devonian, Carboniferous and Cretaceous carbonates. In this region, natural gas is produced predominantly from the Miocene reservoirs. "Przemyśl" gas field is the biggest in Poland. It was discovered in 1958 and its primary natural gas resources were calculated to be around 70 Bcm (2 tcf).

The field is located in the complicated Carpathian overthrust zone and belongs to the multihorizon type of fields reservoired in a number of thin sandstone layers and saturated by biogenic gas with a very high methane content, what is characteristic of Miocene fields.

Today, the most prolific exploration target in the Southeastern Poland are the Miocene deposits of the Carpathian Foredeep with more than 100 discoveries of high methane gas accumulations to date and the last discovery of "Siedleczka" field in 2014. To date, 17 gas and 67 oil fields have been discovered in the Flysch Carpathians.

Potential oil discoveries are expected in the Flysch Carpathians and in the Mesozoic and Paleozoic strata of the Carpathian Foredeep but the lack of new discoveries in the last few years resulted in a slowdown in exploration and drilling activity. It is worth mentioning that the Oligocene Menilite shale and Cretaceous shale, which constitute the source rocks in the Flysch Carpathian petroleum system, are also considered to have a shale oil and gas potential.



Source: PGNiG; Dyjaczyński, Papiernik, Peryt, Protas & Wagner, 1999

CARBONATE PLATFORM (SHALLOW SHELF)

- carbonate platform in general
- oolitic barrier of carbonate platform edge
- intraplatform oolitic shoal
- depression within platform (low hydrodynamic activity)
- salina
- sulfate sabkha
- sulfate-siliciclastic sabkha
- escarpment of carbonate platform

CARBONATE RAMP

- carbonate ramp

SLOPE OF CARBONATE PLATFORM

- platform slope
- zone of gravitational flow
- presumed paleocurrent direction

LAND

- peneplain
- hilly relief
- presumed direction of transportation of terrigenous material

BASIN PLAIN (DEEP SHELF)

- deeper part
- shallower part
- bay
- microplatform
- paleoisopach in meters

- oil & gas fields
- primary extent of PZ2 cyclothem
- primary extent of Ca2
- extent of total erosion of Ca2 and PZ2
- extent of partial erosion of Ca2

OIL & GAS_ PERMIAN PLAY

An epicontinental sea extended across Permian Basin in the Late Permian, where in the sediments were deposited in a series of evaporite-carbonate cycles. Main Dolomite (Ca2) is a marine carbonate formation that begins the second Zechstein cyclothem (PZ2). Main Dolomite sediments are of variable thickness and their facies are highly diversified, due to varying depth of the top of the preceding PZ1 cyclothem and changes in Zechstein sea level.

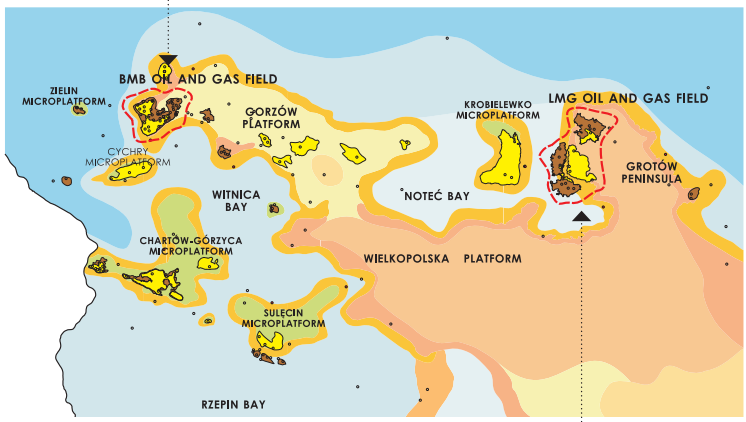
Main Dolomite sediments are mostly developed in a deep open sea facies, while those deposited in shallower parts of the basin are thicker. Organic matter – the source of oil and gas – tended to accumulate at carbonate barriers and platforms in these areas.

Due to facies variability, crude oil, condensate and natural gas reservoirs are scattered and found only in some specific areas with extensive carbonate barriers and brecciated limestone taluses at their base which acted as porous traps for hydrocarbons.

Petroleum system of the Main Dolomite is closed, i.e. source and reservoir rocks are within the same spatial rock structure.

The system is represented by hybrid reservoirs: conventional one in highly permeable porous rocks and unconventional one in rocks with highly reduced permeability. Good external sealing is ensured by overlying anhydrites.

BARNÓWKO - MOSTNO - BUSZEWO (BMB) FIELD and LUBIATÓW - MIEDZYCHÓD - GROTÓW (LMG) FIELD
ARE THE LARGEST OIL AND GAS FIELDS IN POLISH PERMIAN - ZECHSTEIN BASIN



Source: PGNiG; Kwolek, Mikołajewski, 2010

BMB OIL AND GAS FIELD

NATURAL GAS

Primary in-place resources
28.43 Bcm
Primary recoverable reserves
7.65 Bcm

CRUDE OIL

Primary in-place resources
60 million tonnes\444 mln bbl
Primary recoverable reserves
12 million tonnes\88,8 mln bbl

SULFUR

Primary recoverable resources
740 thousand tonnes

LMG OIL AND GAS FIELD

NATURAL GAS

Primary in-place resources
21.9 Bcm
Primary recoverable reserves
7.2 Bcm

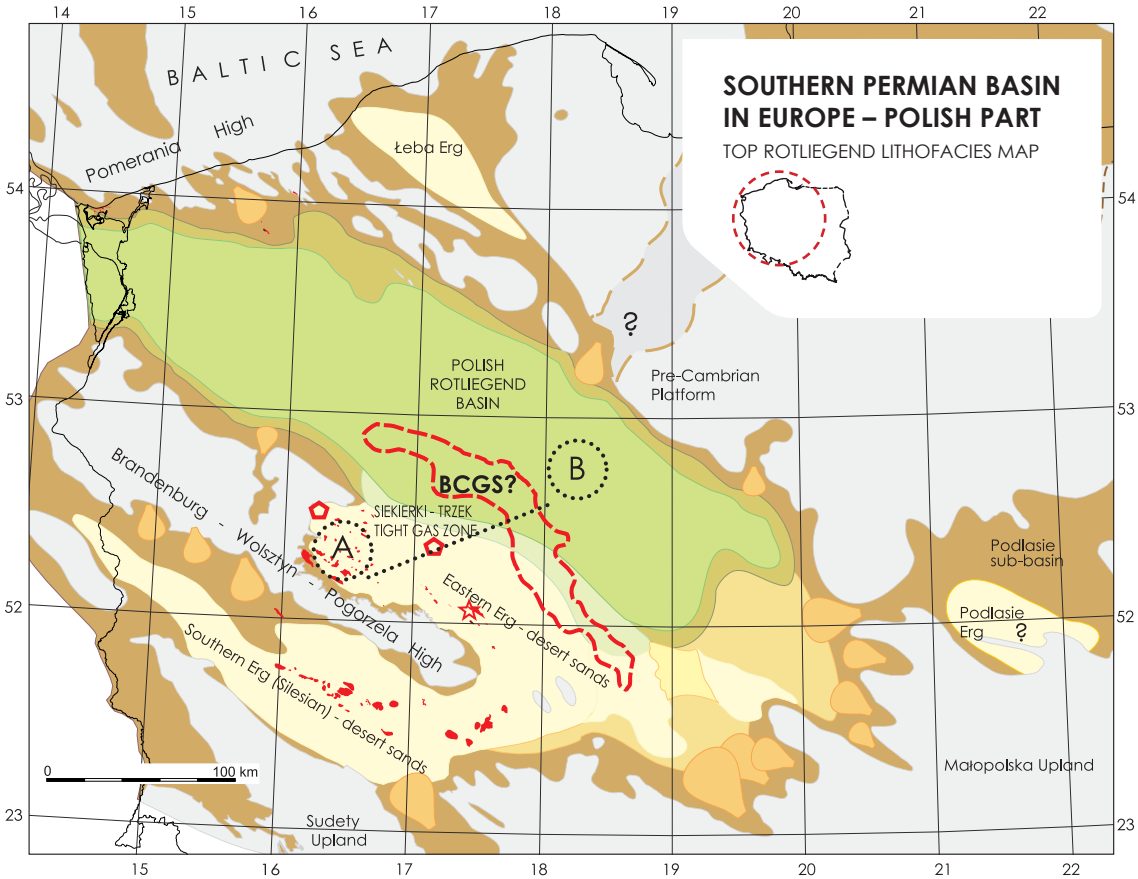
CRUDE OIL

Primary in-place resources
40 million tonnes\296 mln bbl
Primary recoverable reserves
7.3 million tonnes\54,02 mln bbl

Source: PGNiG

Oil fields
Oil and gas fields
Gas fields

- Carbonate platform in general
- Outer oolite barrier
- Intraplatform oolite shoal
- Platform depression
- Platform slope
- Basin floor – deeper part
- Basin floor – shallower part
- Bay
- High
- Boreholes

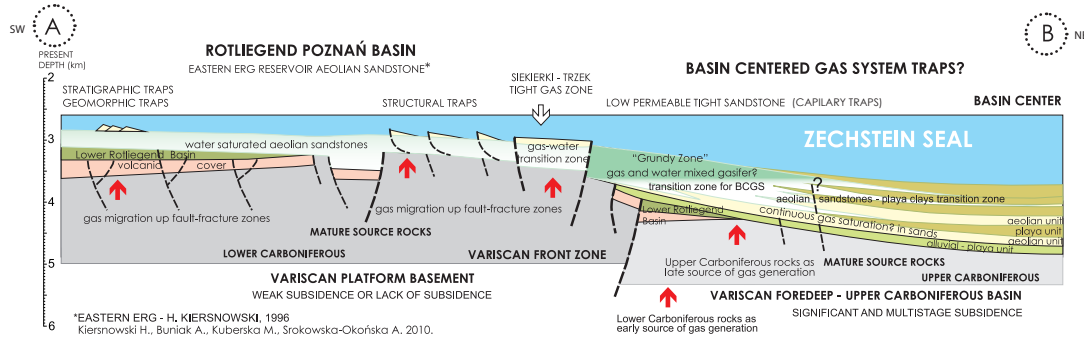


HUBERT KIERSNOWSKI, Polish Geological Institute, Polish Geological Survey, 2014

- playa-lake mudstones, claystones and fine grained sandstones
- playa-lake margin mudstones and fine grained sandstones interbedded with aeolian sandstones
- alluvial and fluvial sandstones and mudstones interbedded with aeolian sandstones
- aeolian dune and interdune sandstones
- alluvial fan and plain sandstones and conglomerates
- source areas without Rotliegend sedimentary cover
- playa-lake margin mudstones and fine grained sandstones

- gas fields in conventional traps
- tight gas fields in conventional traps
- extent of deep tight gas system referred to Basin Centered Gas System (BCGS)

POLISH ROTLIEGEND BASIN



» GAS FIELDS OF THE POLISH ROTLIEGEND BASIN ARE LOCATED IN THE EASTERNMOST PART OF THE EUROPEAN PERMIAN BASIN...

Permian Upper Rotliegend sandstones form a main gas reservoir horizon in Poland. Primarily of aeolian origin, the sandstones generally have excellent reservoir properties. They contain gas of variable quality and composition that migrated from Lower and Upper Carboniferous source rocks.

The gas is mostly dry (methane gas) with an admixture of nitrogen. In places, nitrogen gas with a small content of methane occurs. A specific feature of Rotliegend gas reservoirs is that in some areas they may contain a significant share of helium which is commercially produced.

Gas accumulations occur in stratigraphic gas traps, including geomorphological, structural, lithological and capillary ones. Tight gas accumulations are found in some of the conventional traps.

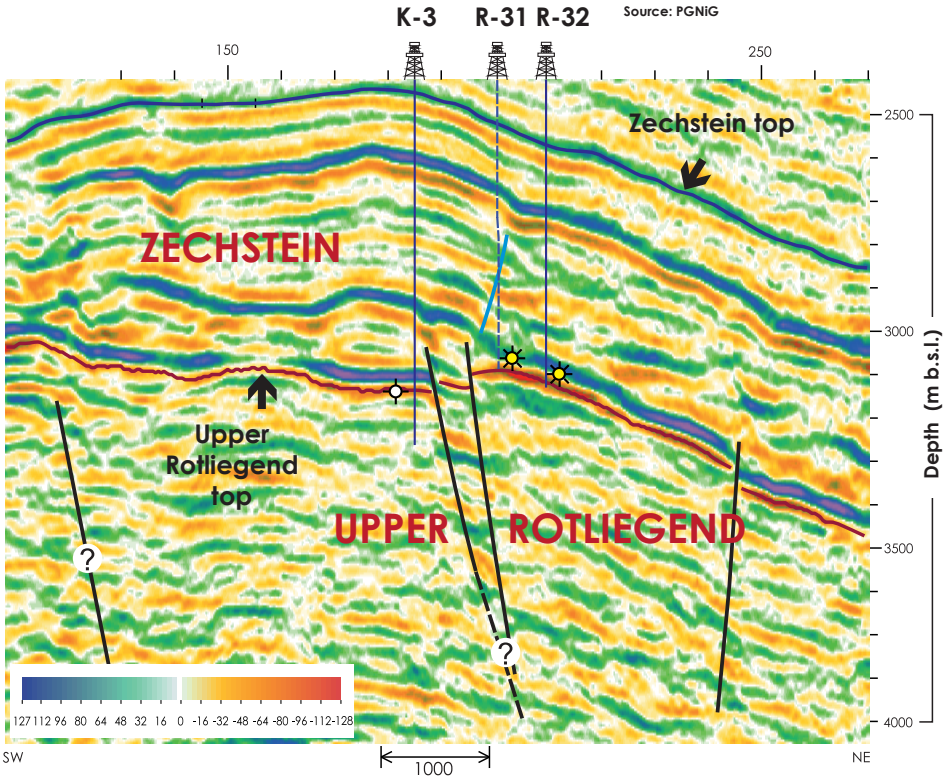
Moreover, tight gas accumulations associated with the BCGS (Basin Centered Gas System) model are expected to occur at significant depths.
Potential Rotliegend gas reserves are estimated at **> 81 Bcm.** Annual (2013) gas production from Rotliegend reservoirs is **~ 3.36 Bcm.**

Gas fields of the Polish Rotliegend Basin (Wielkopolska and Pomerania) are located in the easternmost part of the European Permian Basin that should be regarded as a single petroleum province extending from the U.K. North Sea, through Netherlands to the north of Germany and Poland.

Source: PIG, PSG. Bilans zasobów złóż kopalin w Polsce wg stanu na 31 XII 2013 r.

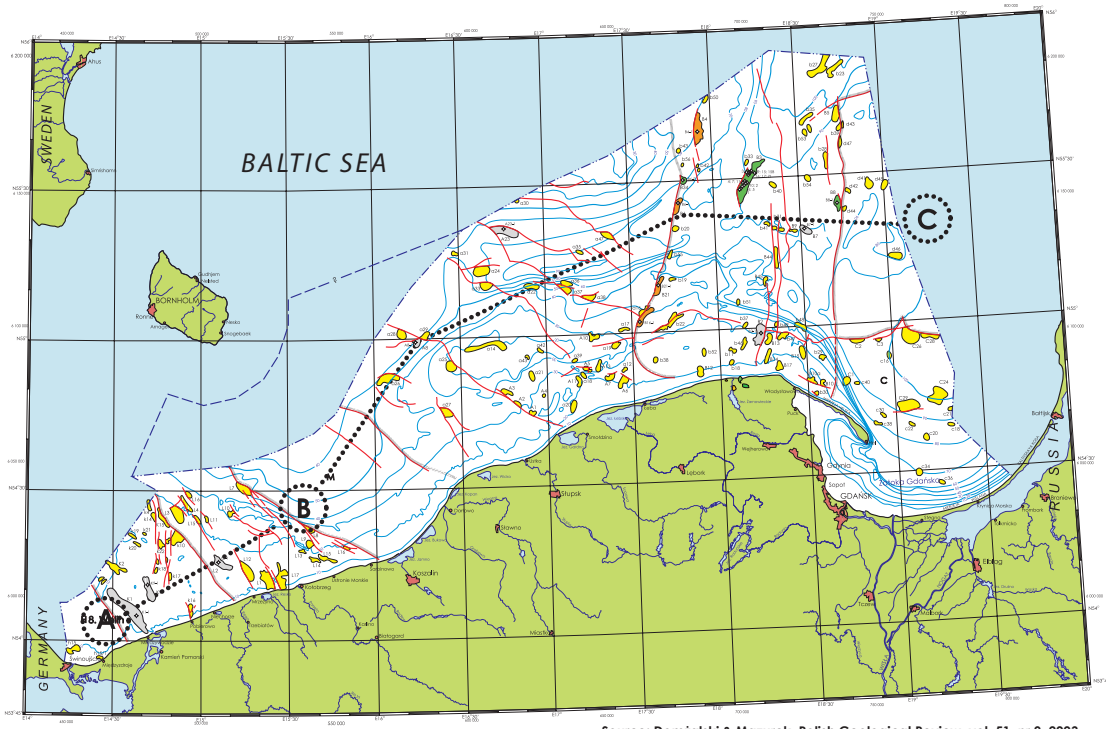
RADLIN GAS FIELD
SEISMIC CROSS-SECTIONTHROUGHOUT RADLIN TECTONIC STRUCTURE
[SEE MAP ON PAGE 9]

Source: PGNiG



OIL & GAS OFFSHORE

CAMBRIAN PLAY



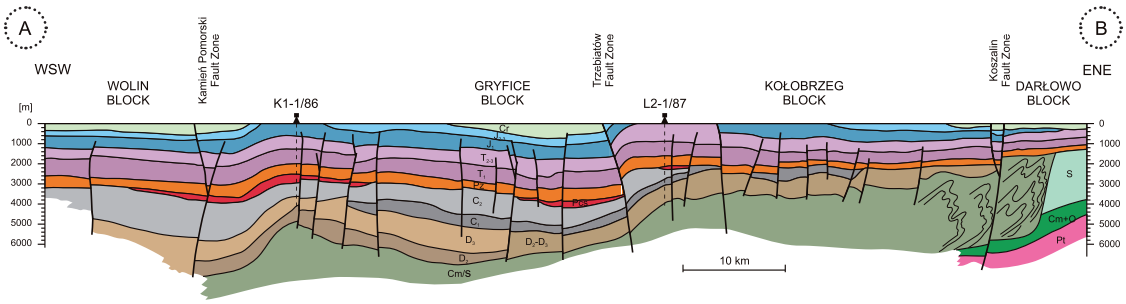
Source: Domżalski & Mazurek, Polish Geological Review, vol. 51, nr 9, 2003

POLISH OFFSHORE ECONOMIC ZONE
LOTOS PETROBALTIC AREA OF INTEREST

- Boundary under international agreements
- Undefined boundary
- 100 Isobaths (in metres above sea level)
- Structures discovered by seismic surveys
- Major fault zones

STRUCTURES DISCOVERED BY GEOLOGICAL/ DRILLING OPERATIONS:

- Structures with no hydrocarbon accumulations
- Oil fields
- Gas condensate fields



Pt Proterozoic, igneous and metamorphic rocks	Cm/S Lower Paleozoic, folded and overthrusted	D_1 Lower Devonian	D_3 Upper Devonian
Cm Cambrian	Or Ordovician	D_2-D_3 Upper and Middle Devonian	C_1 Lower Carboniferous
Cm+O Cambrian + Ordovician undivided	S Silurian	D_2 Middle Devonian	C_2 Upper Carboniferous

Source: Jaworowski *et. al.*, Geological Quarterly, vol. 54, nr 2, 2010

OIL & GAS OFFSHORE

CAMBRIAN PLAY

» A FEW YEARS AGO, IMPROVEMENTS IN SHALE OIL AND GAS PRODUCTION TECHNOLOGY OPENED NEW PROSPECTS FOR OFFSHORE EXPLORATION...

Petroleum exploration in Polish economic zone of the Baltic Sea began in 1975 when "Petrobaltic" Joint Petroleum Exploration Organization (now Lotos Petrobaltic Company) was established. Exploration/appraisal drilling started in 1980 and led to the discovery of five gas condensate reservoirs:
B4 (1991), B6 (1982), B16 (1985) and B21 (1996), as well as of three crude oil reservoirs: B3 (1981), B8 (1983) and B24 (1996).

Conventional oil and gas reservoirs normally occur in structural, lithological or stratigraphic traps in Middle Cambrian sandstones at depths ranging from 1500 to 3500 m below the sea bottom of which depth is estimated at 60 to 100 m.

Upper Cambrian and/or Tremadocian shales (the Called Alum Shales) are believed to be the source rocks for oil and gas in the Lower Paleozoic petroleum sytem.

Currently, oil and gas is only produced from 2 Baltic fields: B3 and B8, holding total recoverable resources estimated at 48.4 million tonnes/358,1 mln bbl of oil and 567.7 million cubic metres of natural gas.

In addition to the aforementioned reservoirs, there is a number of geologically and geophysically proven petroleum structures that are still to be drilled. Furthermore, other oil and accumulations are not considered as commercial ones.

A few years ago, improvements in shale oil and gas production technology opened new prospects for offshore exploration. Onshore and offshore Baltic Basin is considered as the most prospective out of the three basins located in the Polish shale belt. Alum shales (the source rock for conventional oil and gas fields in the Middle Cambrian deposits) are the potential unconventional exploration target.

ACCORDING TO ESTIMATES BY **POLISH GEOLOGICAL SURVEY**, OFFSHORE BALTIC SHALE GAS RESOURCES MAY RANGE FROM:

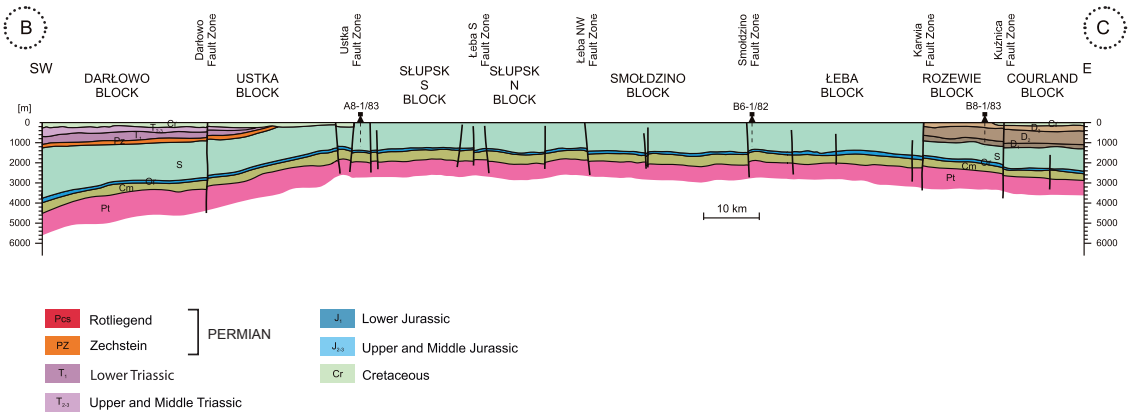
SHALE GAS

14.8 to 371.1 Bcm

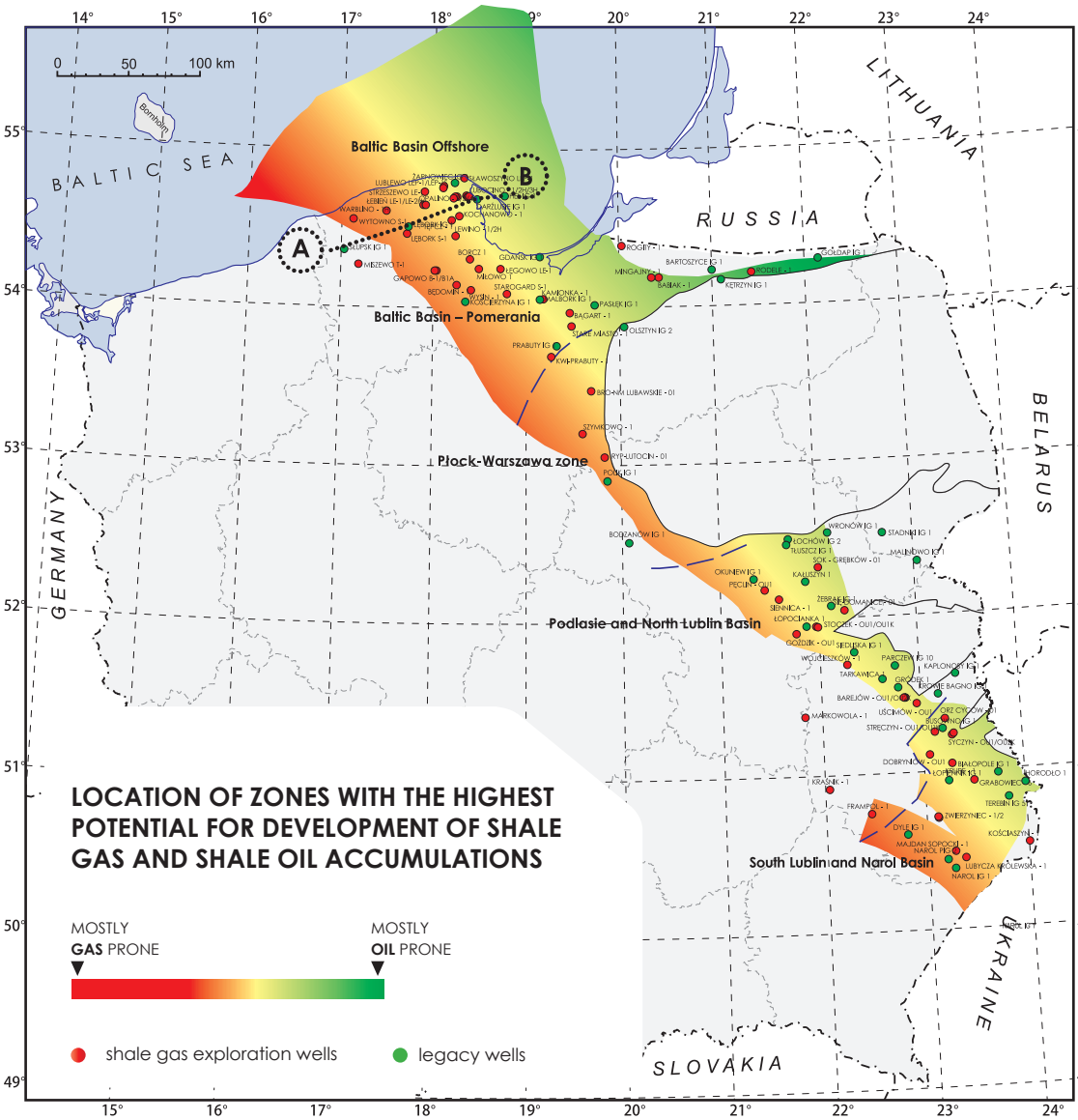
OFFSHORE BALTIC SHALE OIL RESOURCES ARE ESTIMATED:

SHALE OIL

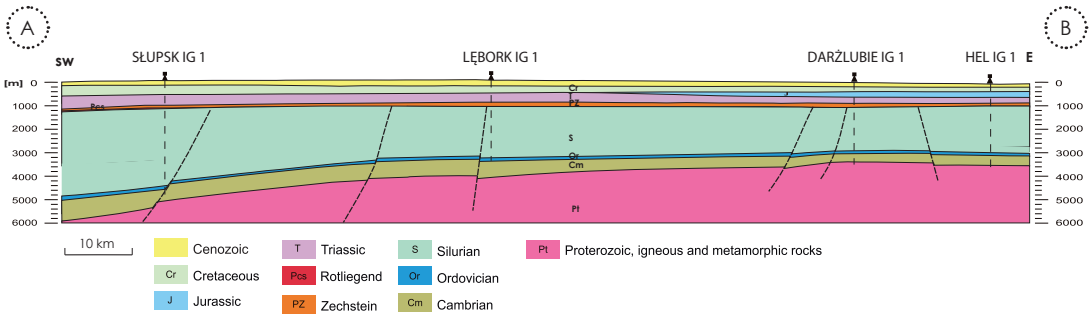
at 100 to 333.2 million tonnes/
at 740 mln bbl to 2465,6 mln bbl



OIL & GAS SHALE_ ORDOVICIAN SILURIAN



Source: Kiersnowski & Dyrka, Polish Geological Review, vol. 61, nr 6, 2013 after Poprawa, Polish Geological Review, vol. 58, nr 3, 2010



Source: Modliński, Profile Głębokich Otworów Wiertniczych, z. 128, Darżlubie IG-1, 2011

OIL & GAS SHALE_ ORDOVICIAN SILURIAN

» FIRST SHALE GAS EXPLORATION WELL IN POLAND WAS SPUDDED IN 2010 AND CURRENTLY THERE ARE 70 EXPLORATION WELLS, OF WHICH 16 ARE HORIZONTAL...

Poland is an undisputed leader in the shale gas and shale oil exploration in Europe. Nevertheless, the scale of prospection in Poland and other European countries is incomparable with that of the USA. First shale gas exploration well in Poland was spudded in 2010 and currently (first quarter of 2015) there are 70 exploration wells, of which 16 are horizontal.

High expectations of successful development in the near future were based on enormous potential resources of shale gas, as estimated by specialized consulting agencies (the U.S. Energy Information Administration among them), and were followed by a rush for exploration concessions. Exploration operations have been carried out by international companies like ExxonMobil, Chevron, Conoco Phillips, Marathon Oil, Eni, BNK Petroleum, Talisman Energy, San Leon Energy to name just a few, and three national companies: Polish Oil and Gas Company (PGNiG), Orlen Upstream and Lotos Petrobaltic. The production from the Polish Lower Paleozoic shales turned out to be more complicated than in their U.S. counterparts, though.

The prospective shale formations are spread over a large area of 37000 squared km (9142899 ac) and occur at depths ranging from about 2000 m (6600 ft) to 5000 m (16400 ft).

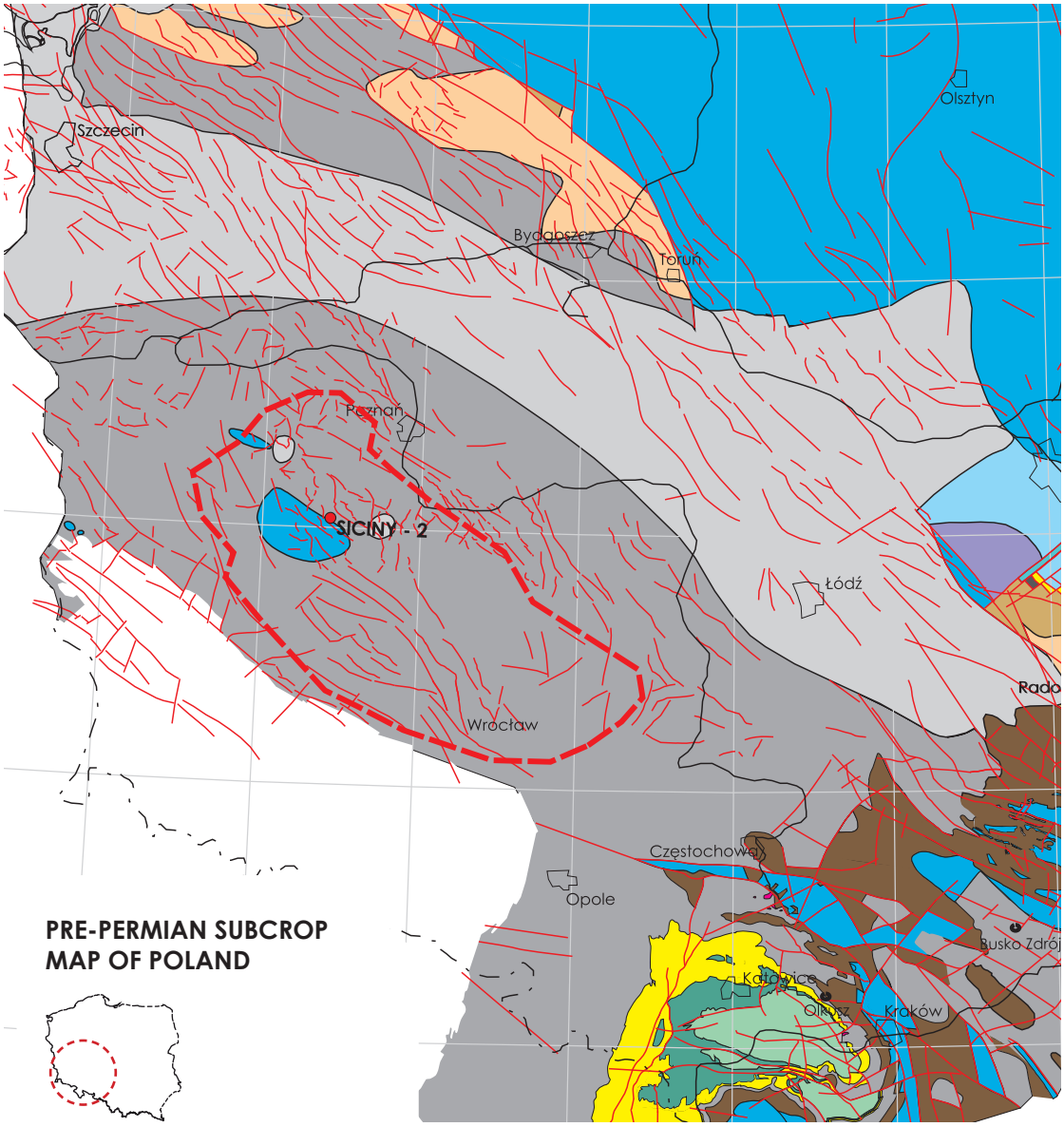
The thickness of the individual prospective formations of about 20 m (65 ft), fracking barriers between the prospective formations, significant share of clays in the shale mineralogical composition, geomechanical properties, formation pressures, condensate character of the reservoir fluids in the high graded areas and rather low average organic carbon contents were the probable obstacles to achieving a successful production so far.

Hydraulic fracturing difficulties coupled with unsatisfactory initial production rates and the downturn in oil and gas market discouraged some companies from exploration and drilling activity in Poland.
For the time being, hydraulic fracture stimulation jobs have been performed in 25 wells, of which only 12 are horizontal. The best initial production rates were achieved in the Baltic Basin: about 10000-15000 cm/d of natural gas (380000-512000 scf/d) with 100-150 b/d of light oil (according to 3Legs Resources plc).

Photography: United Oilfield Services, Poland

It is believed that the current level of economical production in Poland should be at least three times higher than the rates that were achieved so far. Therefore, more exploration wells and new rock stimulation ideas are needed to contour the sweet spots and unlock the potential of the Polish shales.

TIGHT GAS PLAY__CARBONIFEROUS



Source: M.I. Waksmundzka after Buła & Żaba, 2005; Matyja, 2006; Dadlez et al., 2007; Żelichowski & Porzycki, 1983; Pożaryski, Dembowski, 1983; modified, 2010

CARBONIFEROUS PROMISING TIGHT GAS AREA

Stephanian	P	Westphalian B-D	P	Tournaisian	M	Middle Devonian	
Westphalian D		Westphalian A-B		Silesian		Lower Devonian	
Westphalian C		Westphalian		Dinantian		Devonian	
Westphalian B		Namurian	M	Carboniferous		preDevonian	
Westphalian A		Visean		Upper Devonian		volcanic rocks	
						faults	

EUROPEAN STRATIGRAPHY UNITS \ **M- MISSISSIPIAN P- PENNSYLVANIAN**

TIGHT GAS PLAY_ CARBONIFEROUS AND PERMIAN

» ACCORDING TO A PRELIMINARY ASSESSMENTS, POLAND'S PROBABLE TIGHT GAS RESOURCES IN PLACE ARE IN THE ORDER OF 1528-1995 BCM...

In 2015, Polish Geological Survey identified three most prospective geological complexes in Central and North Poland and provided for them an estimate of potential tight gas resources. The first complex of Rotliegend sandstones is located in the Permian Basin.
Rotliegend sandstones are considered as the most important reservoir rocks for tight gas accumulations. Aeolian and fluvial Rotliegend sandstones, located at depths between 5100/5500 to 6000 m in the Poznań-Kalisz area, are believed to be the most prospective rocks.

Tight gas was found in conventional structural traps of these reservoirs (e.g. Siekierki – Trzek field), which either have been or are now in process of hydraulic fracture stimulation. The development is complicated by insufficient amplitude of these accumulations and the inflows of formation fluid. See page 9.

Lower Carboniferous sandstones occurring at depths ranging from 1800 to 3500 m in the Wielkopolska-Silesia Region (at the base of the Fore-Sudetic Monocline) is the second prospective area. The sandstones are part of Visean and Lower Namurian flysch complexes of alternating sandstones, claystones and mudstones. That layout of beds forms an exceptionally advantageous system of interbedding source and reservoir rocks. San Leon Energy reported encouraging gas flow rates from several sandstone and shale intervals at its Siciny-2 Well drilled out in 2013. See map page 15.

Middle Cambrian sandstones that occur at depths ranging from 2800 to 3100 m in the Baltic Basin is the third prospective complex.

The sandstones are the main reservoir rocks of conventional oil and gas accumulations in that region of Poland and, in addition, may contain tight gas resources in a specified low porosity and permeability area.

According to a preliminary assessments, Poland's probable tight gas resources in place are in the order of 1528-1995 Bcm. Carboniferous sandstones account for the largest share of these resources (57-75%), followed by Rotliegend (23-41%), while Cambrian sandstones are the least prospective exploration target, accounting for only 2% of the total estimated resources.

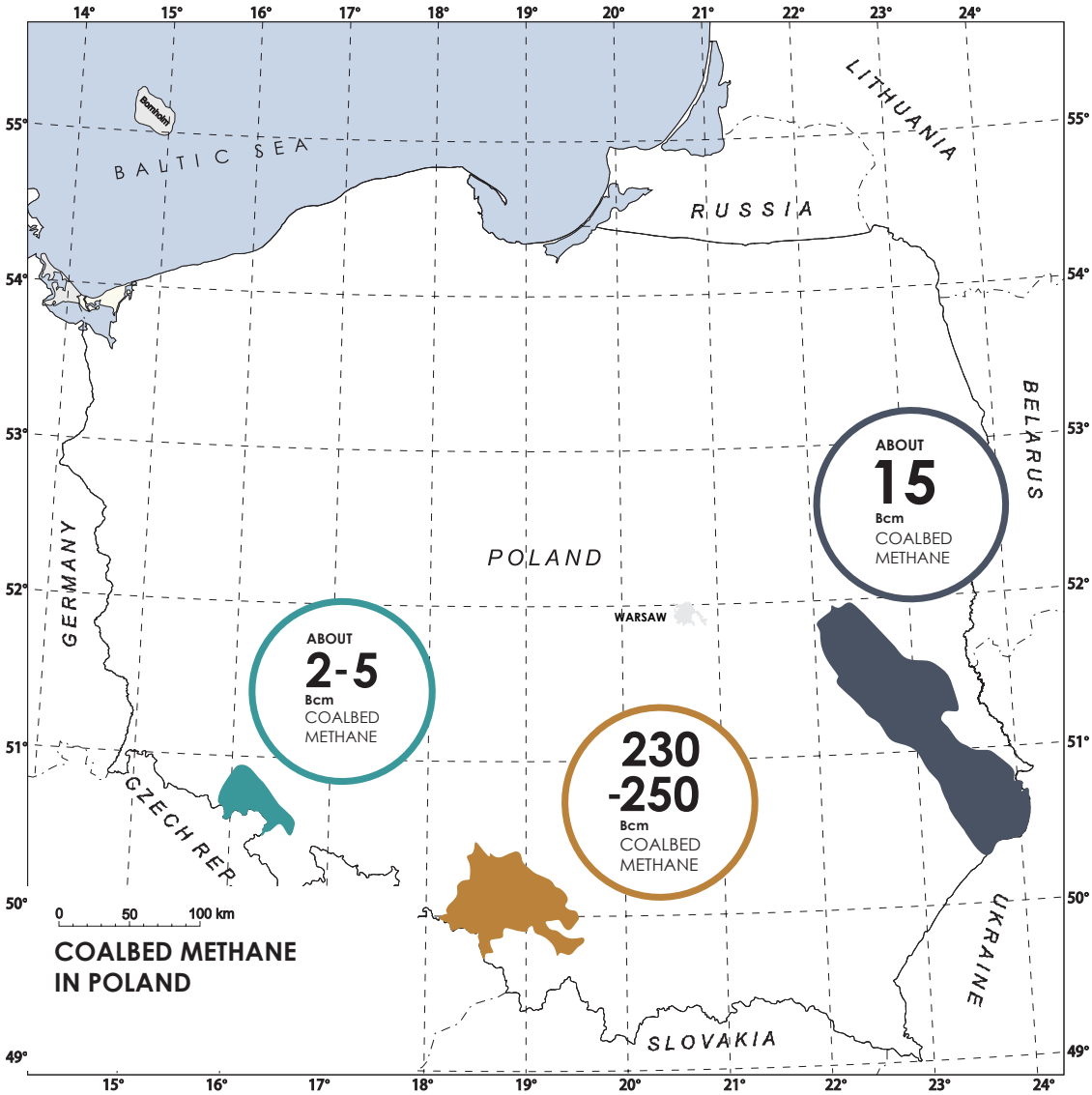
Photography: Gas Flare on Trzek 1 Well

TRZEK 1 WELL, FIRST „TRUE" TIGHT GAS FIELD DISCOVERED, AFTER FRACKING TREATMENT, BY AURELIAN OIL AND GAS IN NOVEMBER 2007. THE RESERVOIR IS IN CONVENTIONAL STRUCTURAL TRAP IN ROTLIEGEND SANDSTONES AT THE DEPTH 3765 M.

GAS COLUMN OF 89 METERS DISCOVERED CONFIRMATION OF POTENTIALLY COMMERCIAL FLOW RATES:
- INITIAL SHORT TERM FLOW RATES UP TO 215,000 CM/D. (7.6 MMSCF/D) THEN ON RESTRICTED FLOW OF 71,000 CM/D. (2.5 MMSCF/D)

Source: Aurelian Oil and Gas Poland, 2007

COALBED METHANE_ BENEFITS AND SAFETY



UPPER SILESIAN COAL BASIN USCB

5760 km²

1989	65	171
2013	29	*61,6

LUBLIN COAL BASIN LCB

9100 km²

1989	1	1,9
2013	1	*6,8

LOWER SILESIAN COAL BASIN LSCB

1200 km²

1989	5	2,6
2013	-	-

*31.12.2013

NUMBER OF MINES
COAL OUTPUT (MILLION T)

COALBED METHANE_ BENEFITS AND SAFETY

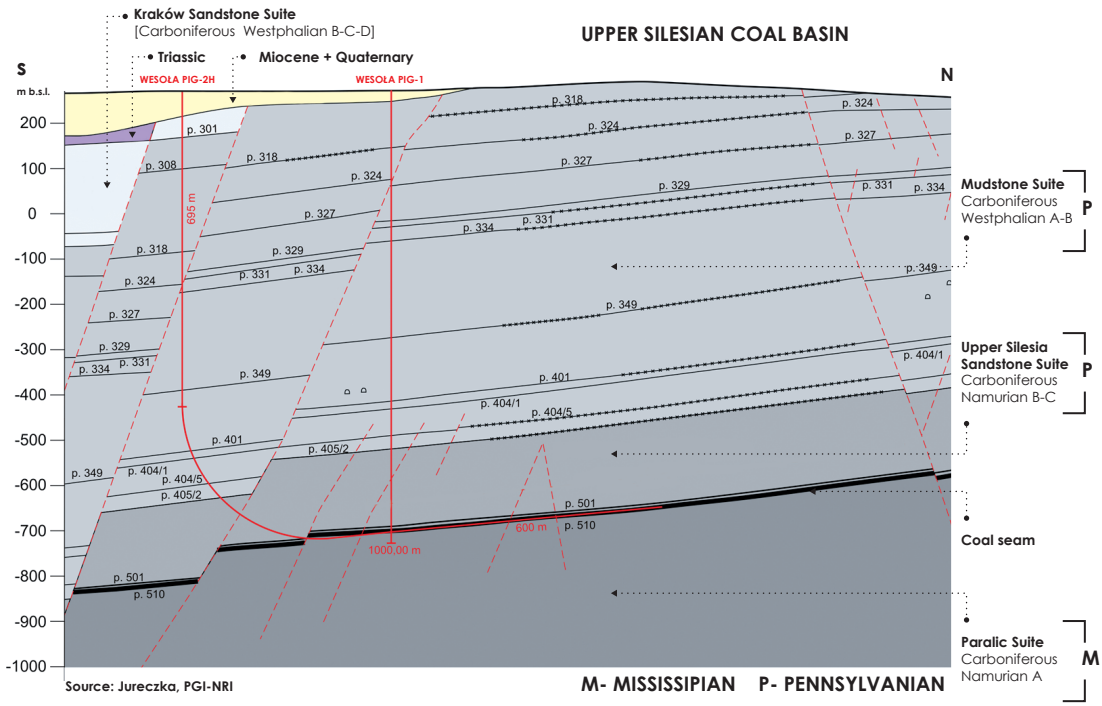
» THE KEY PURPOSE OF THE PGI-NRI PROJECT IS TO ENHANCE SAFETY OF COAL EXTRACTION BY REMOVING EXCESS METHANE OVER 3-5 YEARS BEFORE THE COMMENCEMENT OF MINING OPERATIONS....

Poland's coalbed methane (CBM) resources may amount to several hundred billion cubic metres. According to PGI-NRI, the Upper Silesian Coal Basin (USCB) holds the largest potential coalbed resources, estimated at 250 Bcm. The resources of the Lublin Coal Basin (LCB) and Lower Silesia Coal Basin (LSCB) are much smaller, in the order of 15 Bcm and 2-5 Bcm, respectively.

USCM coalbed methane resources are best known and proven. The geological resources in place are in excess of 85 Bcm. Currently, small volumes of methane are recovered at scheduled venting of underground mine workings, but much more gas is released to the atmosphere. Attempts to produce methane directly from the coalbeds (made in the 1990's) failed due to a very low productivity of wells. Improvements in horizontal drilling technology openes new prospects for CBM production. The first two test wells have been drilled in the Mysłowice-Wesoła Coal Mine, one of the most exposed to methane risk in Poland.

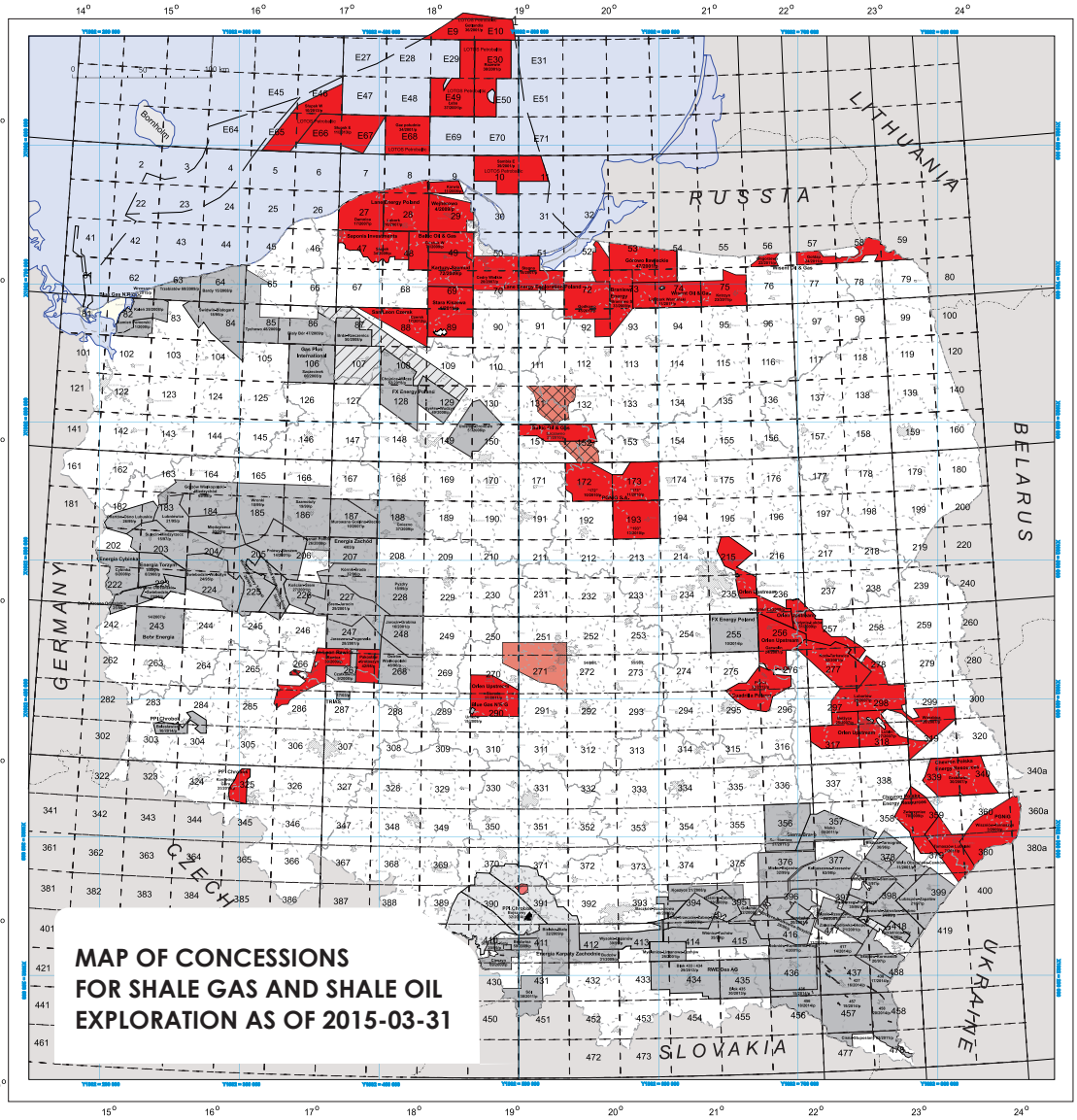
Geophysical logs were made in both wells (the vertical 1000 m deep Wesoła PIG–1 and the directional 1918 m deep Wesoła PIG–2H. (see geological cross section below). Moreover, coal samples from Wesoła PIG-1 Well were laboratory tested for gas, petrophysical and petrographic properties according to both Polish and U.S. methodologies.
The horizontal leg of the well produced approx. 250 cm of gas per day before well stimulation jobs.
The horizontal leg was hydraulically fracturing stimulated at the turn of October 2014. Most probably, it was the first operation of this kind in the world made in an active coal mine.

The key purpose of the PGI-NRI Project is to enhance safety of coal extraction by removing excess methane over 3-5 years before the commencement of mining operations.
Test results have demonstrated that the procedure may be combined with commercial methane production, so as to improve overall project profitability.



Source: Jureczka, PGI-NRI

OIL & GAS CONCESSIONS



Elaboration: Bońda, Siekiera, Szuflicki, PGI-NRI, 2015 Source: Ministry of Environment
Department of Geology And Geological Concessions

- shale oil and shale gas exploration concessions
- shale oil and shale gas pending applications
- conventional oil and gas prospecting concessions
- conventional oil and gas pending applications
- shale oil and shale gas pending applications subitted according to the article 46 of the Act on Geological and Mining Law
- pending applications subitted according to the article 47 of the Act on Geological and Mining Law

Since 2007, when the first unconventional hydrocarbon concession was issued, Poland is the top destination in Europe for major players in the shale gas sector.

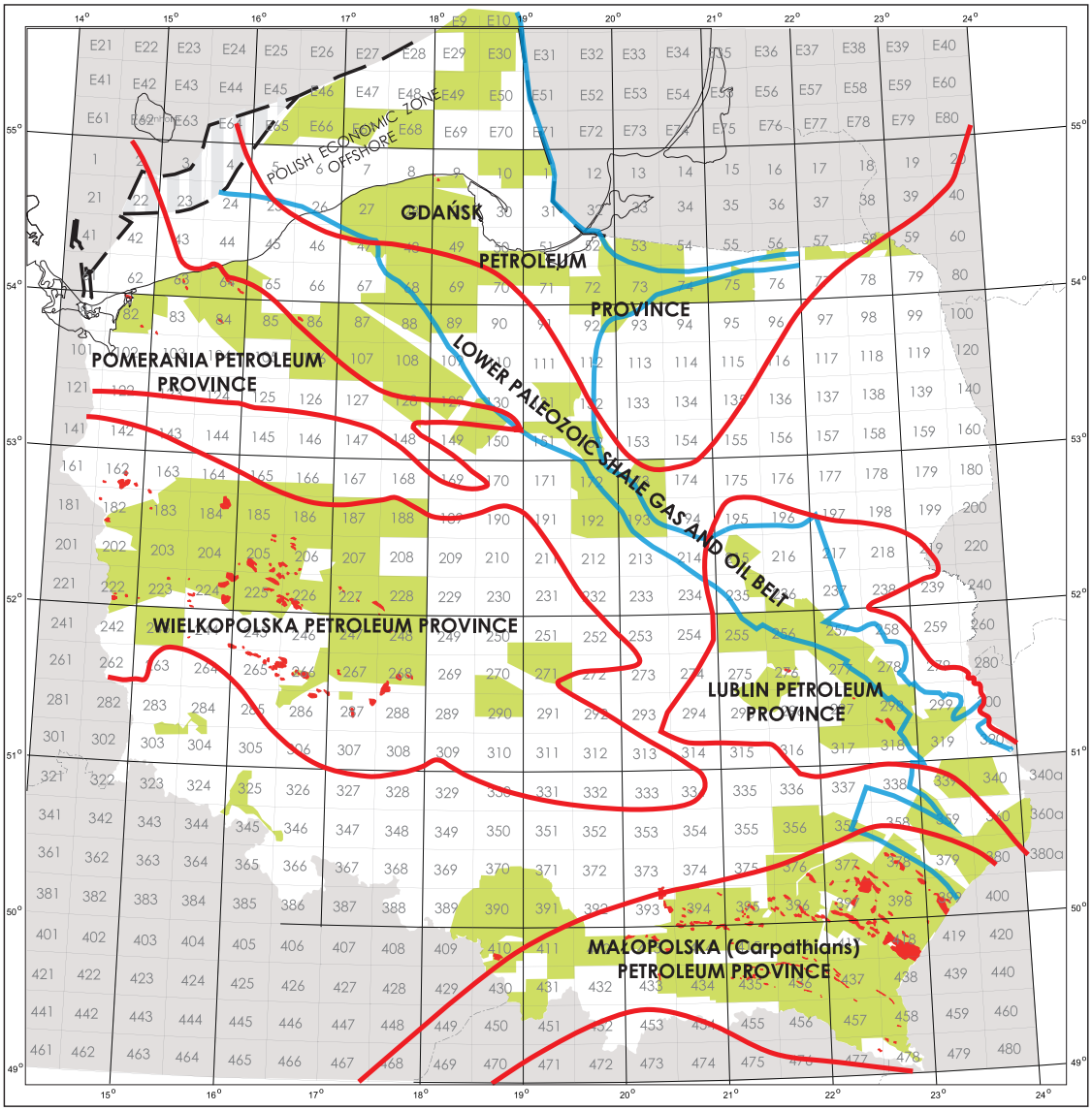
In Poland a business activity regarding hydrocarbons prospecting, exploration and production requires a concession granted by the concession authority - the Minister of the Environment.
Each concession set down a unique area where the concession holder is authorized to exclusively conduct unconventional hydrocarbons prospecting, exploration and subsequently production for period between 10 and 30 years.

The hydrocarbon concessions are obtained by the companies due to the Geological and Mining Law (GML) which stipulates rights and obligations of investors and the state represented by the public administration. The latest GML entered into force in 2015, the new regulations reflects expectations of parties (inc. local communities, scientists, investors) and responds to the needs of the industry.

THE HIGHLIGHTS OF 2015 POLISH GML:

- only one concession covering prospecting, exploration and production of hydrocarbons,
- granting of a concession for prospecting, exploration and production of hydrocarbons only in a tender procedure,
- time-efficient environmental procedure which means swift concession issuing procedure,
- the qualification procedure: the Minister of the Environment verifies applicant for a hydrocarbon concession in terms of the state security and experience in a field of hydrocarbon exploitation,
- geophysical survey possible without a concession,
- possibility of joint execution of a concession by several entities (with cooperation agreement),
- preservation of the acquired rights (ius quaesitum) - validity of the concessions granted before the entry of the amended GML into force (2015). Concession for prospecting and exploration may be transformed into new type of concession which covers prospecting, exploration and production.

OIL & GAS CONCESSIONS



Petroleum Provinces after P.H. Karnkowski

AWARDED AND PENDING CONCESSION AREAS
As of 1 April 2015

Source: Ministry of the Environment.
Map of oil and gas exploration, appraisal and production concessions.

BOUNDARIES OF PETROLEUM PROVINCES

HYDROCARBON CONCESSION PROCEDURE

To apply for the hydrocarbon concession, all entities interested in prospecting, exploration and production of hydrocarbons in Poland, need to present the positive assessment of the Minister of the Environment.

The assessment of the Minister is valid for 5 years, therefor it enables its holder to multiple participation in tenders.

Each year, before the 30th June the Minister of the Environment set out boundaries of areas which have been selected to the concession procedure in the next year due to good prospects for hydrocarbon exploitation. The area is partitioned as a acreage of a single concession cannot exceed 1200 square km.

Concession can be granted in tender procedure only. A tender notice is publicized by the Minister of the Environment in the **Official Journal of the European Union (http://www.ojec.com).** After a selection of the most favorable offer, the concession is issued and an agreement on the establishment of the mining usufruct is concluded.

HYDROCARBON EXPLOITATION FEES

Concession fee – determined in a concession, paid per square km

Mining usufruct fee – depends of a concession duration, acreage and type of deposit

Exploitation charge/royalty (during production phase only) – **depends of a product e.g. high metan gas 4,75$/100k CF (6,38 pln/1000 CM); natural gas 3,96$/100k CF (5,31 pln/1000 CM)**

Concessioner is also obliged to deposit a security fund (up to 20% of geological works cost) for eventual costs of undue execution of concessioner liabilities.

TAXATION

CIT (Corporate Income Tax) – flat rate of 19%

VAT (Value Added Tax) – the base VAT rate of 23% is charged on most goods e.g. oil & gas production

For more information please visit the Ministry of the Environment web page **http://www.mos.gov.pl/?j=en**

POLAND

PROJECT:
"Support to informational, analytical and implementation shale oil and gas activities aimed at ensuring Poland's energy security and protection of the environment, including public participation in the licensing process"

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SOURCE PAGE 1:

Światło z ziemi, Praca zbiorowa wydana staraniem Stowarzyszenia Naukowo-Technicznego Inżynierów i Techników Przemysłu Naftowego i Gazowniczego, Wydawnictwo Tekst 2002 r., Gorlice, Krosno, Sanok;

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shale gas and oil

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PSG POLISH GEOLOGICAL SURVEY

MINISTRY OF THE ENVIRONMENT

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