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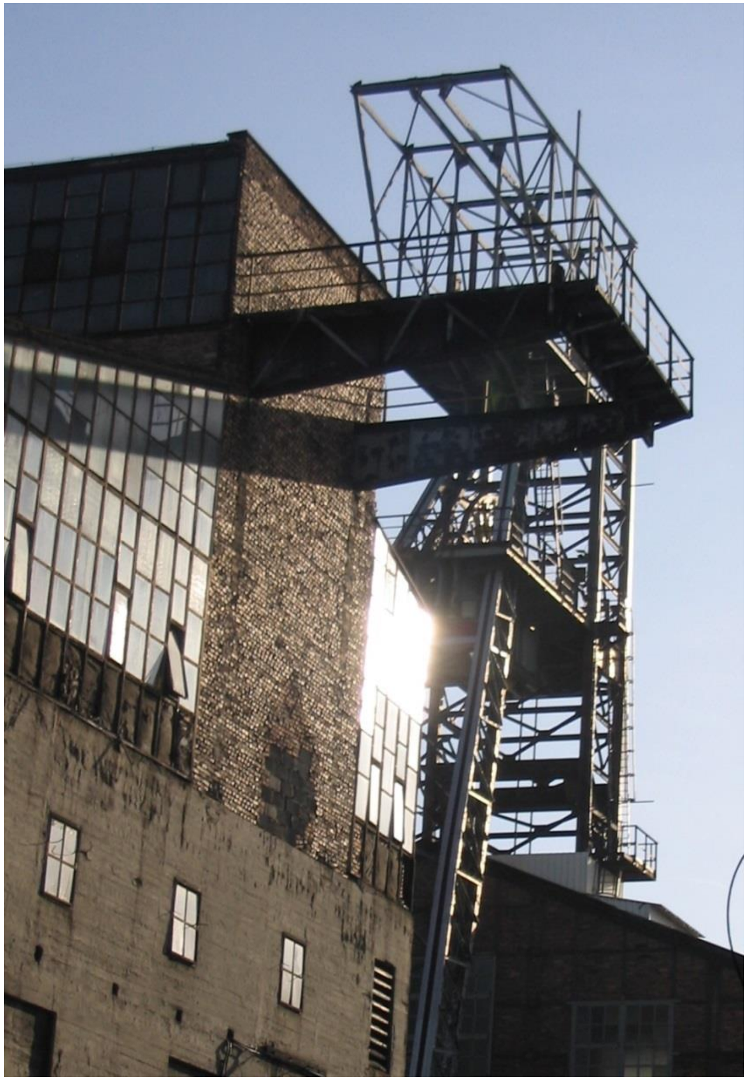
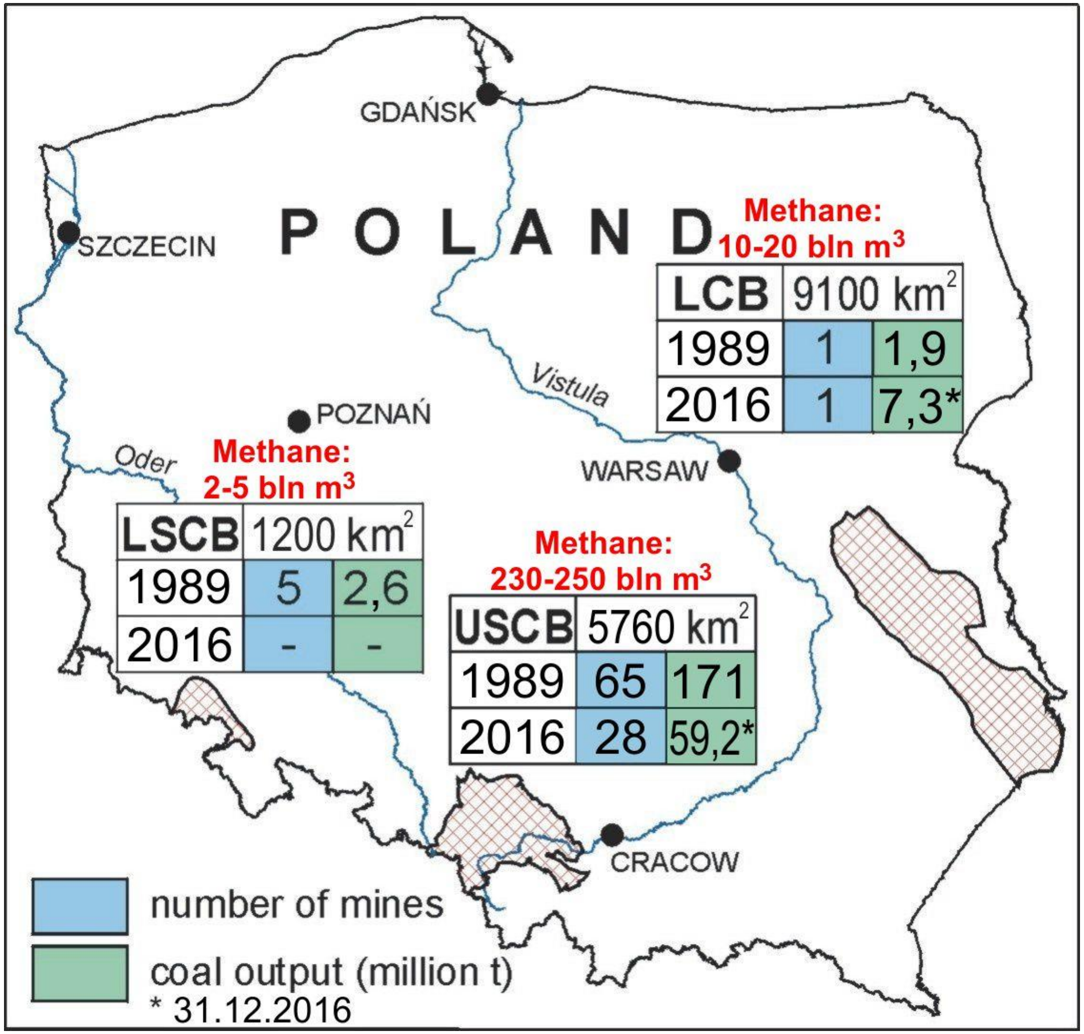
Polish Experience in CBM Developement Gilowice Project as a First Step to Develop Pre-mine Drainage Technology in Poland



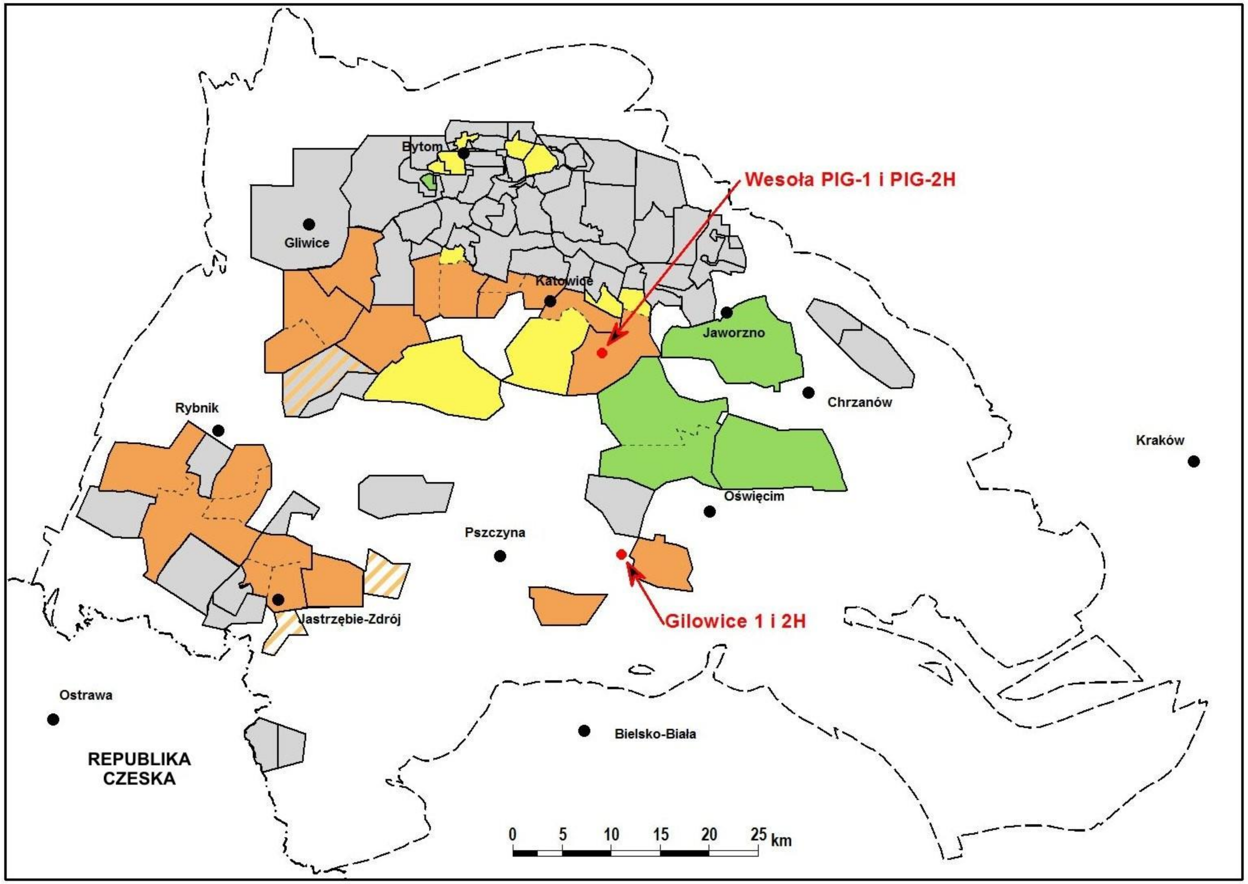
Agenda

1. Introduction to the problem of methane emission in the Upper Silesian Coal Basin
2. Overview of the Geo-Methane experimental program
3. Geo-Methane Phase I – Gilowice pilot project results
4. Further experimental activity in Gilowice CBM License Area
5. Geo-Methane Phase II – new pilot project preparation
6. Geo-Methane Phase III – future implementation

Coalbed Methane Resources in the Polish Coal Basins



Methane Emission from Coal Mines in the USCB



gassy coal mines with degasification

gassy coal mines without degasification

non-gassy coal mines

closed mines

mines under construction

Emissions, Recovery and Utilization of Methane in 2017 [MMm³]			
Methane volume			Emission to atmosphere
total	captured	used	
948.5	337.0	212.0	736.5

Measured volume of methane

(methane released and recorded by mines – methane contained in ventilation air + methane captured)

948.5 MMm³

Unmeasured methane sources

(„non-methane" and „low methane" mines + extracted coal and barren rock consisting of 5–10% of measured methane)

ca. 47–95 MMm³

Total volume of methane emission per year: ca. 780–825 MMm³

(1 CH_4 = 25 CO_2, → 20–21 Bm³ CO_2)

Methane Content of Coal Increasing with Depth

<u>It is critical to initiate systematic efforts leading to</u>

a comprehensive solution or, at least, considerable reduction of coal mine methane problem.

In the light of current and future energy policy of Poland, coal, recovered from domestic resources, will continue to be, over many years, the main source of power supply

<u>It is also important to change the perception of methane</u>,

from a hazardous waste to be disposed of, to <u>a valuable energy commodity</u>

<u>The long-term solution to the problem of gassy mines in USCB</u>

PRE-MINE DRAINAGE OF COAL SEAMS

Methane recovery from coal seams for a few or several years before mining:

- **early recovery of valuable energy source** (1.0–1.5 Bm^3, increasing domestic gas production)
- **extraction of coal in more favorable mining and economic conditions**

  (reducing methane hazard, improved work safety, significant reduction of coal extraction costs)
- **reduction of methane emissions to the atmosphere**

  (mitigation of the greenhouse effect, reducing the cost of emission fees, <u>especially in case of EU ETS</u>)

Objectives of Geo-Methane Program

1. **To support development of CBM production technologies** in the Polish coal basins, as well as **methane drainage of coal mines,** which leads to:
   - increasing gas production potential in Poland
   - supporting domestic coal mining industry by providing a comprehensive solution to the problem of methane emissions in coal mines.
2. **Determining, on an experimental basis, the screening criteria** for pre-mine drainage of coal seam gas depending on geological-mining conditions.
3. **Development of directional drilling technologies** and methods of coalbed gas production enhancement suitable for the Upper Silesian Basin conditions.
4. **In case of positive results**, demonstrate a feasibility of the pre-mine drainage technology with its implementation in selected areas.

Phases of work:

- **Phase I – Experimental Project (Gilowice)**
- **Phase II – Pilot**
- **Phase III – Implementation (Production)**

Phase I – Experimental Project - Gilowice (2016–2018)

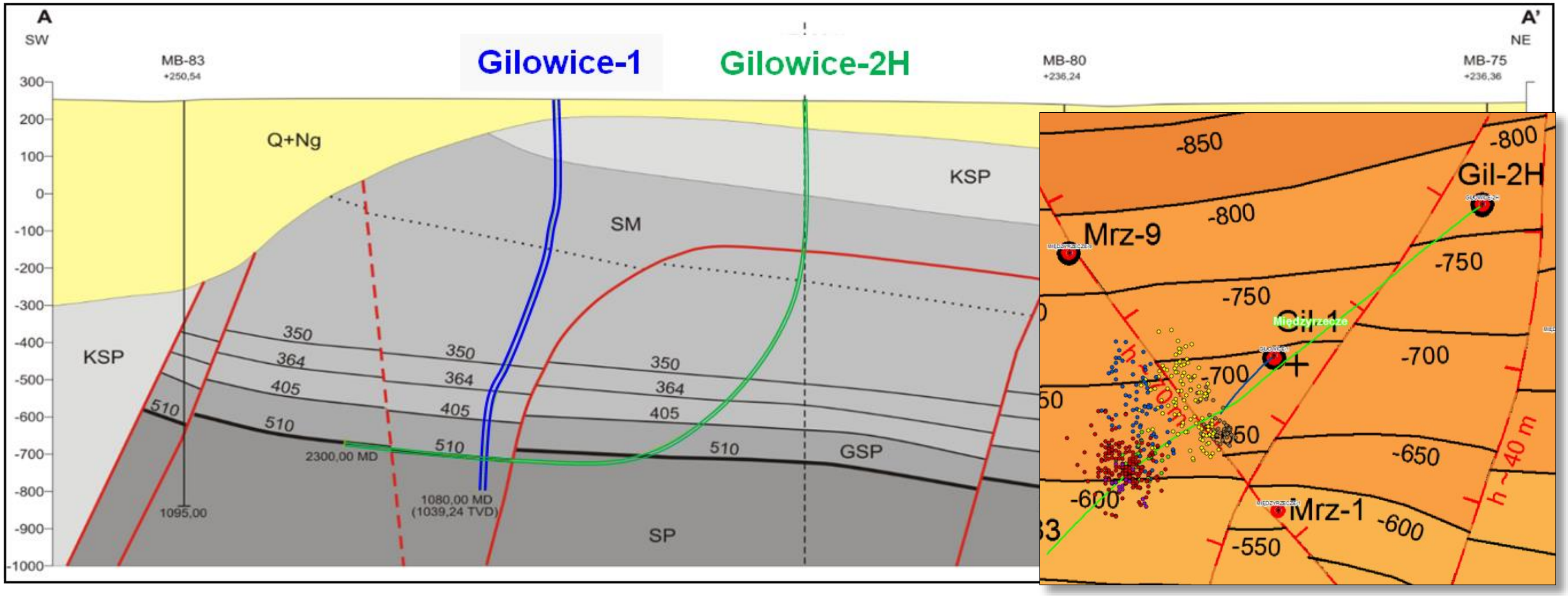
Gilowice-1 and Gilowice-2H wells were drilled (2011–2012) by Dart Energy (Poland).

Following the completion of production tests, the ownership of wells was transferred to the Polish Geological Institute in order to perform further studies.

Scope of work:

1. **Workover of the wells**
2. **Hydraulic fracturing of the Gilowice-2H well**
3. **Methane production testing**
4. **Reporting results**

Gilowice-1 and Gilowice-2H wells



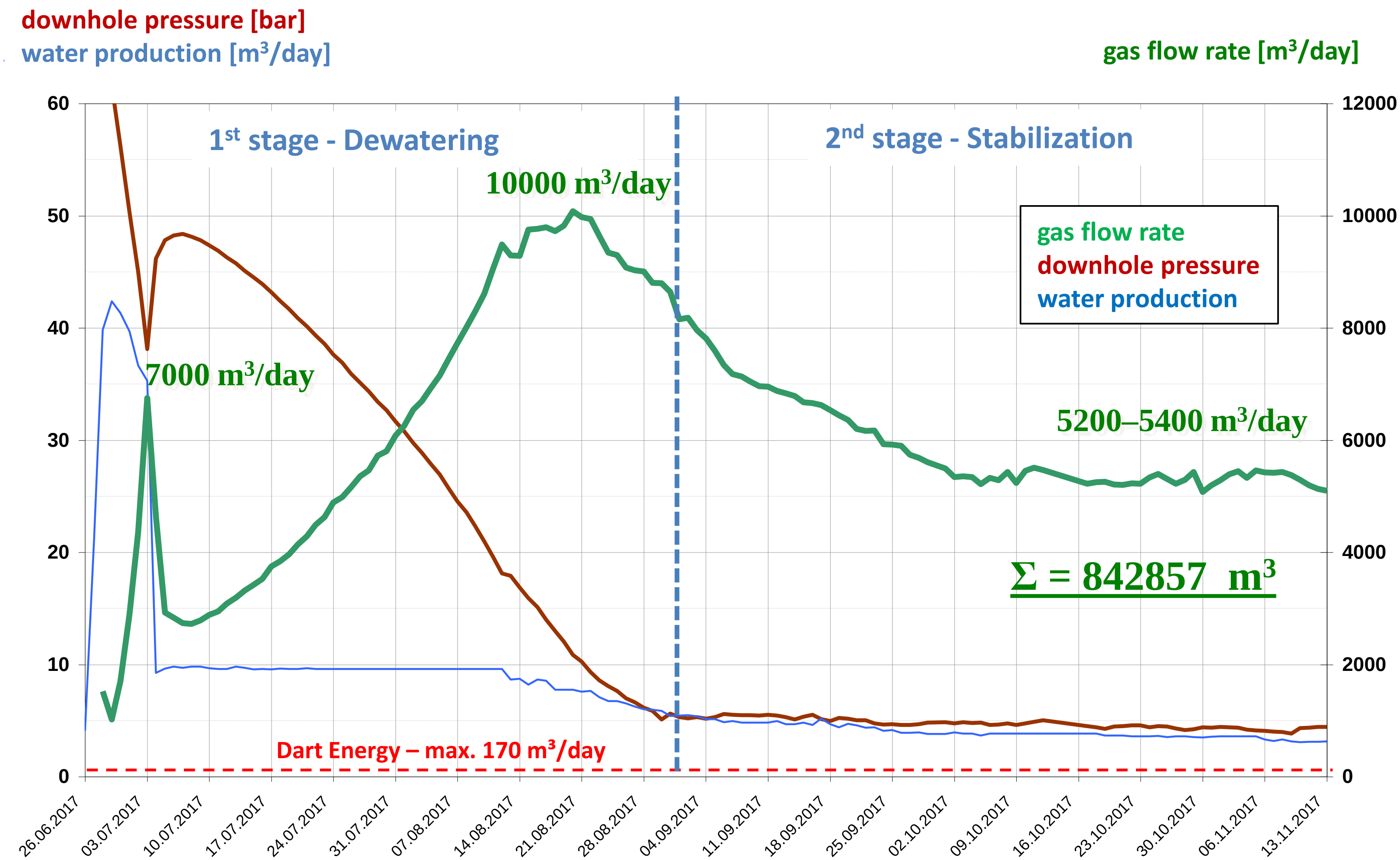
Gilowice-1

- total depth – 1080 m (TVD 1039 m)
- thickness of 510 coal seam – 5.28 m
- gas content of 510 coal seam – 13.7 m^3/t
- methane concentration in gas – 97,7%
- permeability of 510 coal seam – 0.2–0.8 mD

Gilowice -2H

- total depth – 2300 m (TVD 850 m)
- horizontal displacement – 1616 m
- length of the well in 510 coal seam – 795 m

Gilowice-1 and 2H testing results



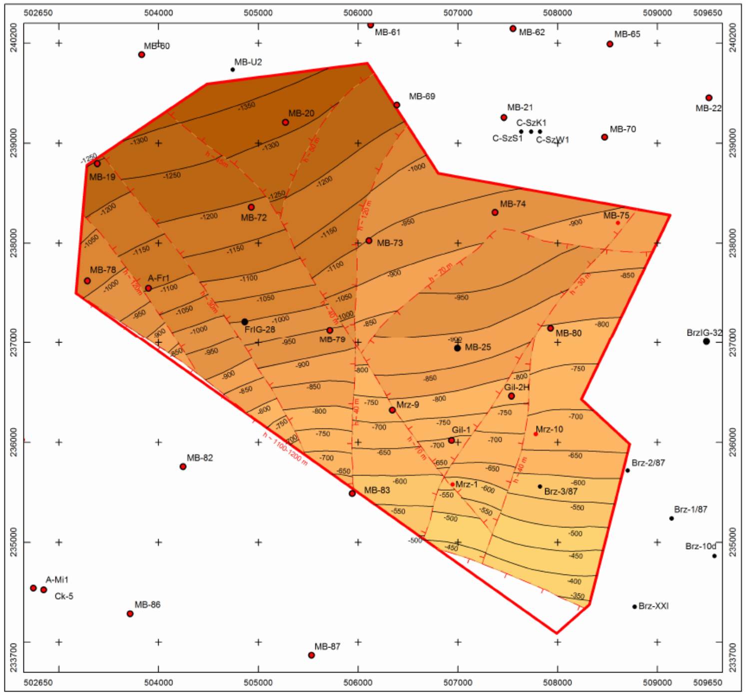
CH_4: 98,04–99,25%

Summary of the Gilowice Project Results

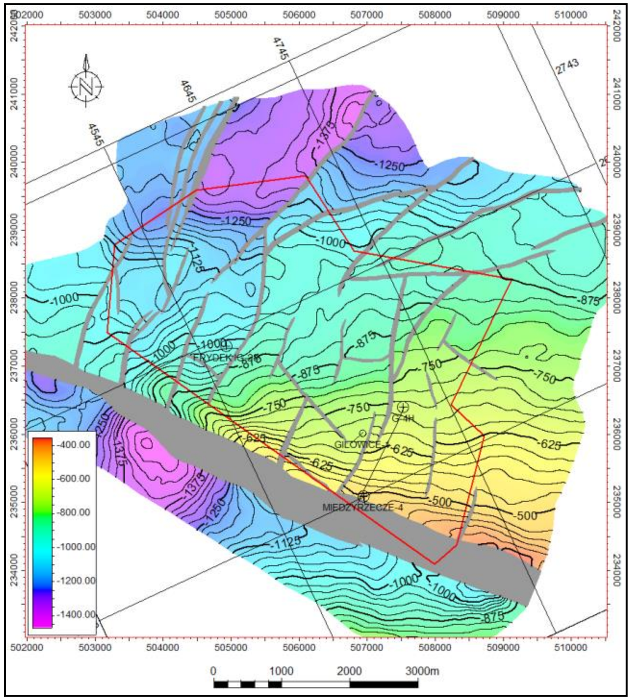
1. Massive fracking of the target coal seam and the surrounding strata, including several gassy coalbeds, (fracture propagation**: height - 50-100 m, length - 200-400 m, Stimulated Rock Volume - 14 million m^3**).
2. Production test results**: maximum initial water rates: 40-70 m^3/d, water rates after dewatering: 5,5-3,1 m^3/d, maximum gas rates: 10 000 m^3/d, stable gas rates after dewatering: 5 000 m^3/d, test duration: 145 days.**
3. Comparison to the previous CBM production tests in the USCB:
   - **openhole completion, horizontal well, (Dart Energy): >30-fold increase in gas rates,**
   - **fracture stimulated completion, vertical wells (Texaco): 15 to 30-fold increase in gas rates,**
4. Gilowice project confirmed that the selected technology of **massive fracture stimulation (with slick water and gel) is the best solution for low permeability coal seams in the USCB.**
5. The most critical factor of success is **fracture stimulation effectiveness which enables creating the network of propped fractures in coal seams and associated rocks.**
6. The most important technical challenge – **selection of suitable downhole pumping equipment for a dewatering stage.**

Further experimental activity in Gilowice CBM License Area

- ✓ Previous interpretation of the 510 coal seam structure contour as of 2016:
  - fault system concept limited to multi-well correlation,
  - high level of uncertainty regarding faults geometry.
- ✓ Previous experience in the Upper Silesian basin demonstrated that the fault network of mature mining areas is generally much more complicated than it was predicted based on pre-mining interpretations.
- ✓ New challenge – **3D seismic** interpretation is critical for the understanding of structural setting in this tectonically complicated area.



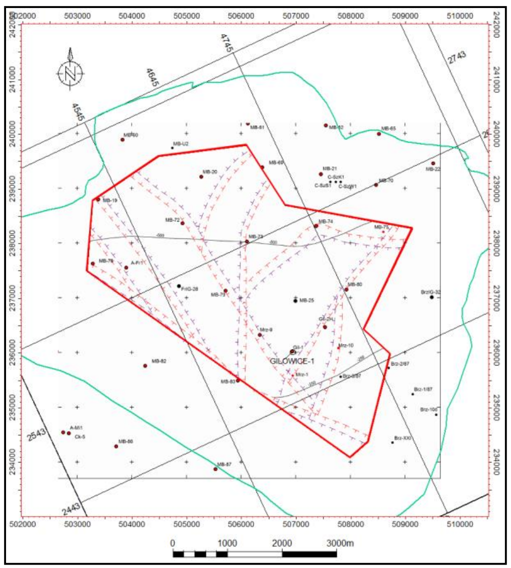
Source: Gilowice geological data package, based on PGI case study (Jureczka et al., 2016) .



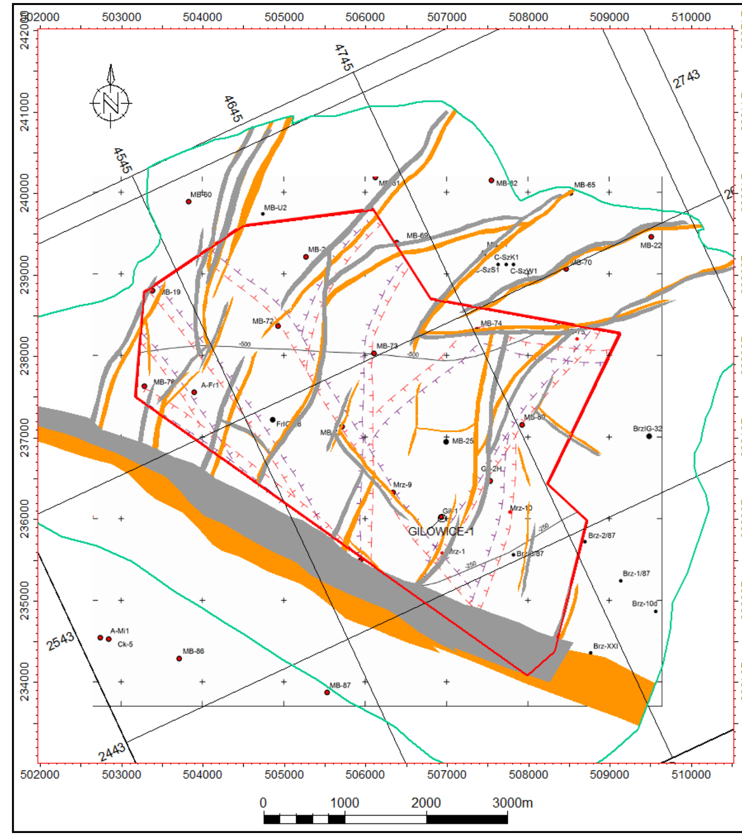
Source: Processing and interpretation of 3D seismic data (Geofizyka Toruń, 2018) .

Structural Interpretation of the Recently Acquired 3D Seismic Data

- ✓ The new geological model differs from the previous interpretation.
- ✓ New insight into coal seams geometry based on structural interpretation.
- ✓ Existence of many normal and reverse faults, almost perpendicular to previously inferred faults (western part of Gilowice block).
- ✓ New interpretation of fault polygons for the 350 and 510 coal seams.

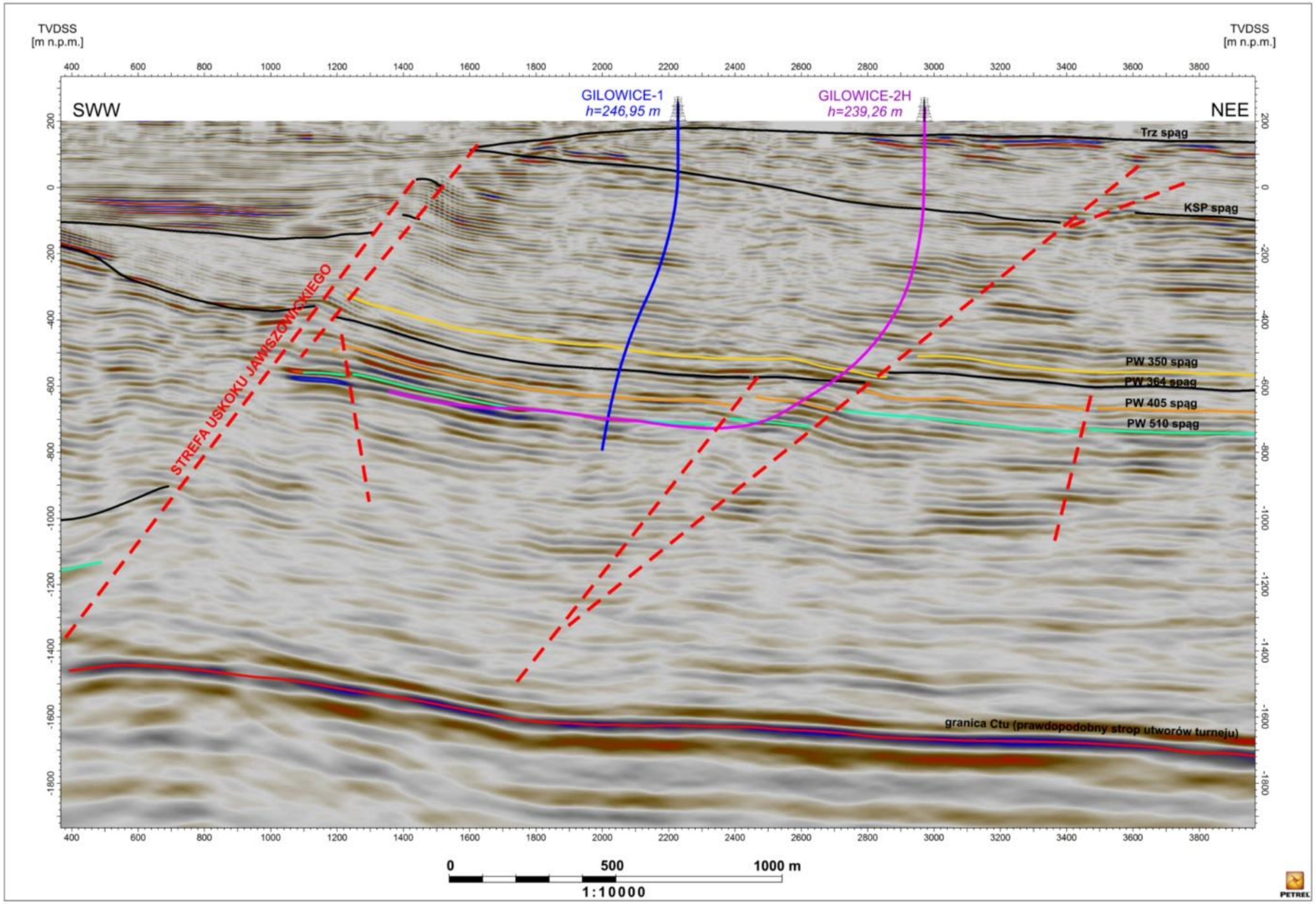


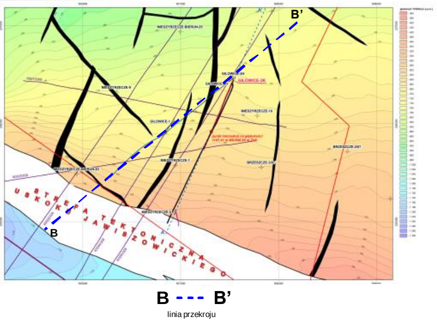
Contour on top of gassy coal seams (Jureczka J. et al., 2016). Red – faults of the 350 coal seam, purple – faults of the 510 coal seam.



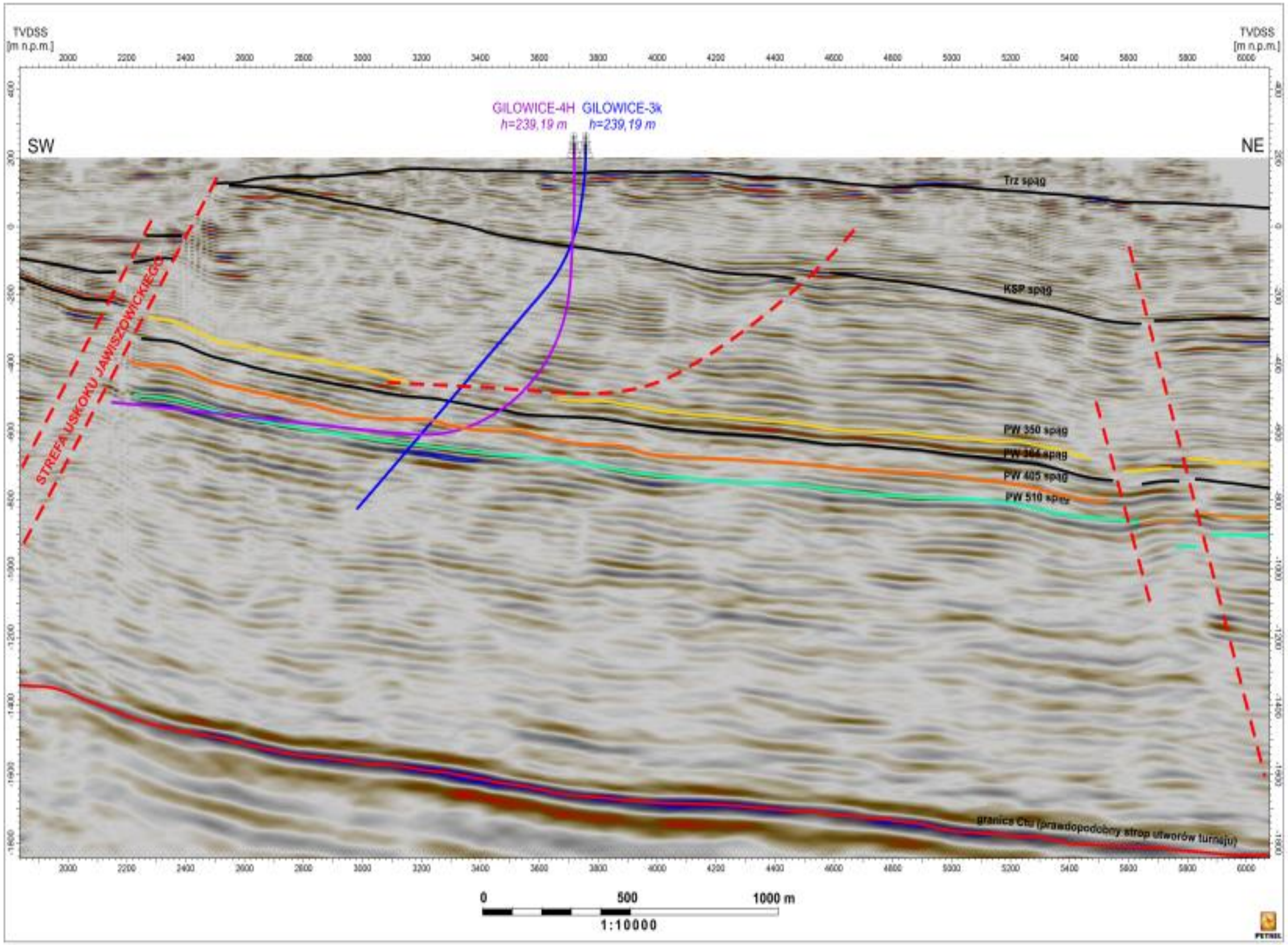
Contour on top of gassy coal seams (Geofizyka Toruń, 2018). Grey – of the 350 coal seam, orange – faults of the 510 coal seam.

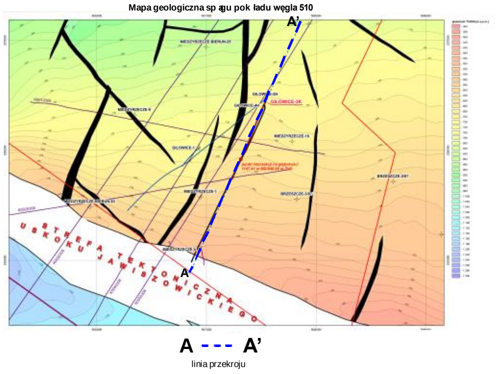
Seismic Cross-section Through Gilowice-1 and Gilowice-2H wells





Seismic Cross-section Through Gilowice-3K and Gilowice-4H wells





Well Gilowice-3K

- final depth – 1360 m (TVD 1062.8 m)
- max. inclination ~ 45°

Well Gilowice-4H

- final depth – 2200 m (TVD 752.2 m)
- maximum inclination ~ 95°
- length of horizontal section – 1070 m

Hydraulic Fracturing – specyfication comparison

Gilowice-2H

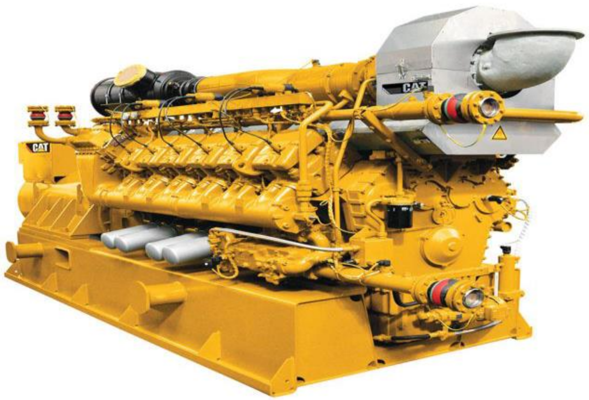
- **5 stages** with Hybrid technology
- Fluid: 20-30# linear gel avg 390 m^3/stage + 30# X-link avg 125 m^3/stage. Total over **2580 m^3**
- Sand: 100mesh avg 6,8 tons/stage + 40/70mesh avg 74 tons/stage (at the last stage 30/50mesh 40,5 tons instead of 40/70mesh). Total over **404 tons**
- Flow rate avg 6,7 m^3/min
- Plug&Perf with 6 clusters/stage
- **1 stage/day**

Gilowice-4H

- **9 stages** with Hybrid technology
- Fluid: 20-25# linear gel avg 240 m^3/stage + 25-30# X-link avg 114 m^3/stage. Total over **3186 m^3**
- Sand: 40/70mesh avg 39 tons/stage + 30/50mesh avg 29 tons /stage. Total over **612 tons**
- Flow rate avg 7,9 m^3/min
- Plug&Perf with 4 clusters/stage
- **2 stage/day**

Gilowice-1 Pad Development

- ✓ Installing the Caterpillarr Power Station CG170-12 – electrical power 999 kW.
- ✓ Preparing gas on the installation and transfer to the Power Station.
- ✓ Transferring power to local network.



Gilowice-3K Pad Development Plan

- ✓ Construction of surface infrastructure and pipeline to local network
- ✓ Surface infrastructure:
  - Pre-separation system
  - Heating and measuring system
  - Filtering system prior to compression
  - Installation of gas compressor with acoustic shield
- ✓ Pipeline:
  - Connection to local DN65 (350 m from G-3K)
  - Connection to DN150 with pipeline passing near G-1 well (approx. 1150 m)
  - Conversion to electricity of excess gas volume using G-1 infrastructure

Geo-Methane Phase II – Pilot

Phase II objectives:

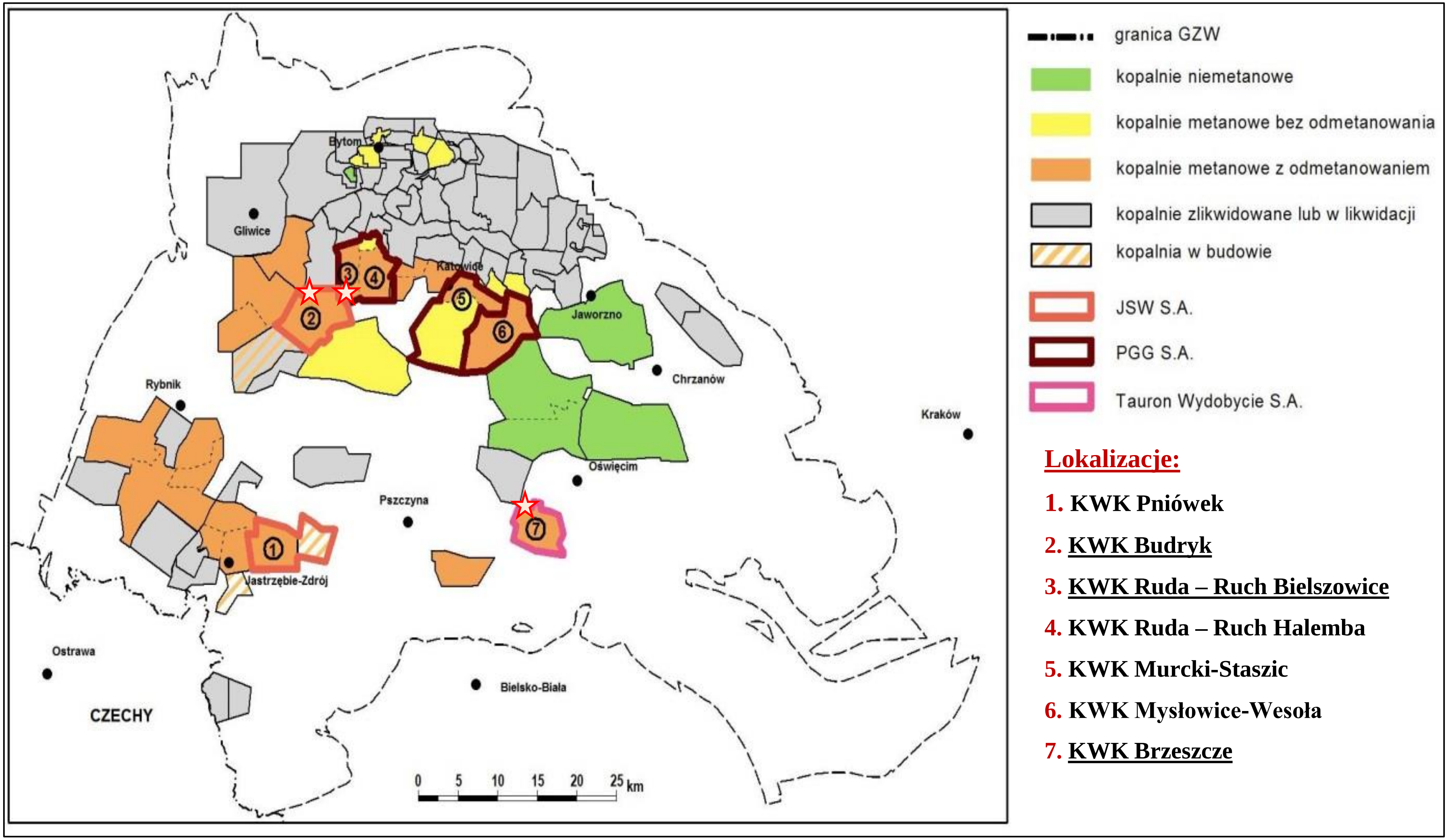
1. **Research focusing on:**
   - determination of optimal geological-mining conditions for methane drainage;
   - optimizing drilling and fracture stimulation technology.
2. **Demonstration focusing on:**
   - pilot project of effective methane recovery by the wells drilled from surface;
   - carrying out long-term production tests.

Scope of work:

1. **Drilling of pilot wells** in 3 areas with different geological and mining conditions, with variable patterns of laterals and type of intersections.
2. **Comprehensive evaluation** of CBM reservoir parameters (field and lab tests).
3. **Methane production enhancement** – fracture stimulation using different techniques, with a possibility of refracturing.
4. **CBM gas production tests** with determination of gas flow rates in a long period (min. 2-3 years).
5. **Verification of technical parameters** of gas recovery and the feasibility of the CBM development project (on a stand alone basis).
6. **Evaluation of pre-mine drainage effects** for gas emission of the planned longwall panels.
7. **Detailed feasibility study of pre-mine drainage** of coal seams in the mining industry including underground demethanisation cost analysis.

Completion time of Phase II: 4–5 years

Geo-Methane Phase II – new pilot project site selection



- **Geological, mining and environmental criteria for pre-mine drainage site selection were elaborated**
- **Seven gassy mines (of three different mining groups) were initially selected based on the applied criteria**
- **The three most favorable mines were finally selected based on extensive research.**

Geo-Methane Phase III – Implementation

Phase objectives:

1. **Commercialization of solutions** developed during phase I and phase II.
2. **Implementation of gas production** in the area of the selected coal deposit.

Scope of work:

1. **Drilling a number of directional wells** with special production stimulation treatments and installations for gas recovery and transmission (or local use); 12 multilateral clusters of directional wells in the area of 18-20 km^2 are assumed.
2. **Carrying out gas production** until the flow rates drop to the level predetermined based on the previous phases, as justified by geological, mining, and economic conditions.
3. **Report** on the implementation phase and business evaluation of the work performed.

Completion time of Phase III: 5–7 years


Thank you
for your attention
Gilowice, 2017