Geological and mining conditions of tested mines

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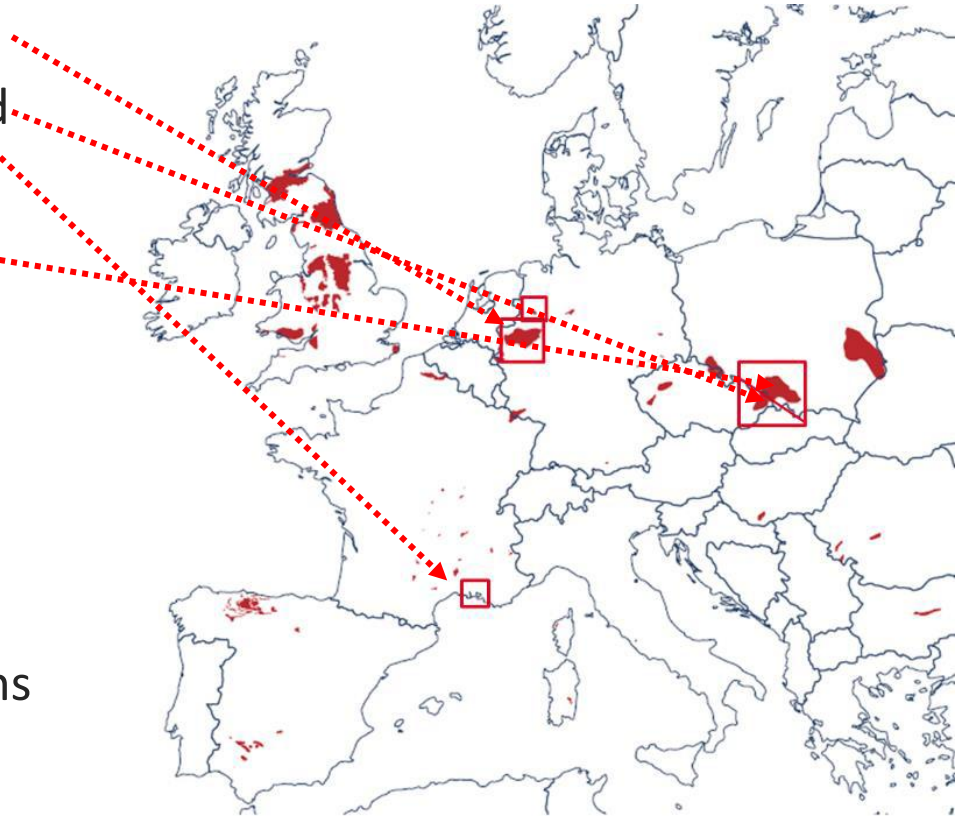
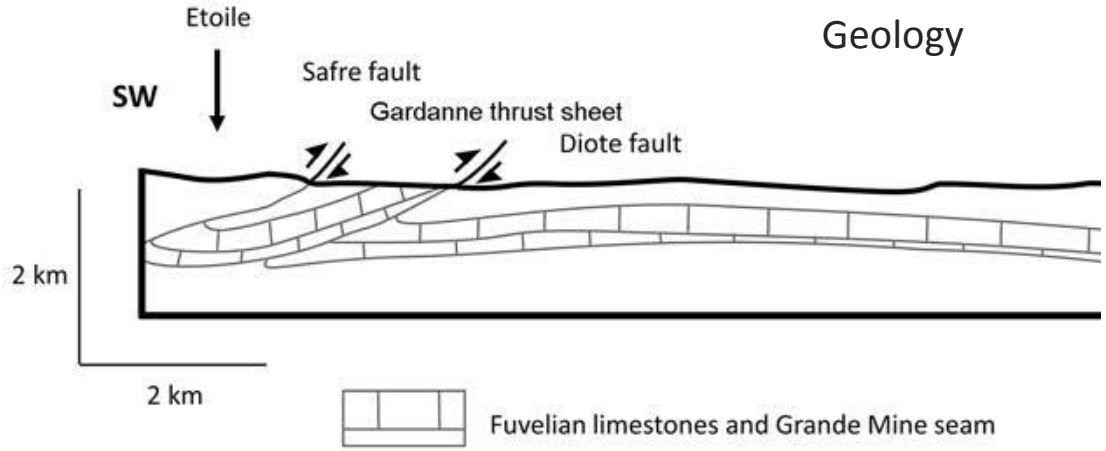
Testing sites

France – Gardane, Provence
Germany – Hamm and Ibbenbüren
Czech Republic – Ostrava and Petrvald sub-basins
Poland – Kazimierz-Juliusz mine

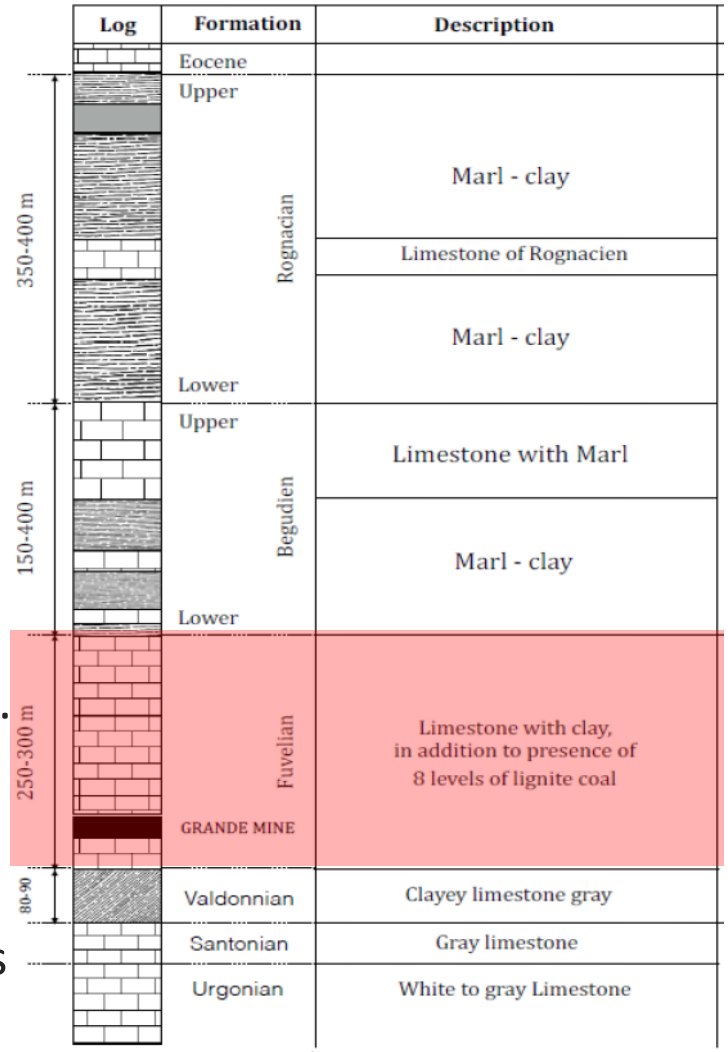
1. More details about geology, hydrogeology and mining.
2. Testing sites comparison.
3. Conclusions – main important conditions in the light of induced seismicity and surface deformations during mines flooding.



Gardane, Provence basin, France



Geology



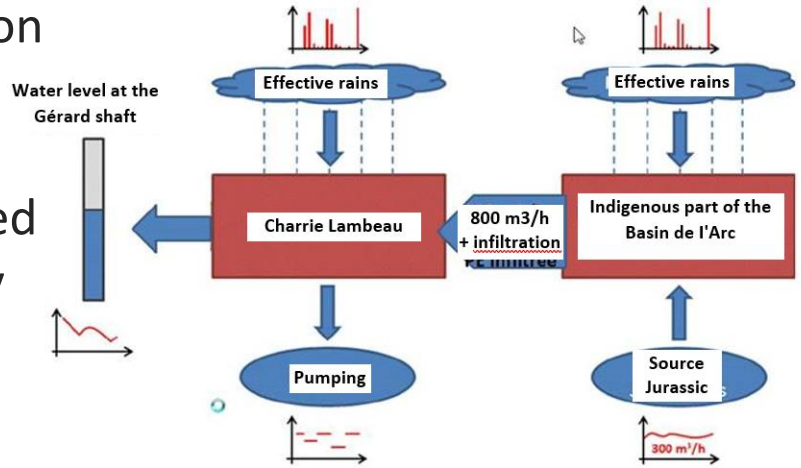
Part of Provence basin (30 km to North from Marseille).
The tectonic formation - at the end of the Eocene.
The coal seams are interbedded in karst limestones.
Four main layers of lignite were exploited:
Grande Mine (thickness 2.5 – 4 m)
Mauvaise Mine (thickness 0.7 – 1.7 m)
4 Pans (thickness 1.2 – 2 m), Gros Rocher (thickness 1 – 1.2 m).

Gardane, Provence basin, France

Hydrogeology

Particular hydrological configuration – location Cretaceous limestone syncline (Fuvelian).

The hydrogeology of the basin is characterized by the presence of the Arc watershed, fed by around thirty tributaries.



The succession of fluvio-lacustrine terrain in the Arc basin is an alternation of either limestone or marl level. Each limestone level has its own aquifer.

Thus, the mining basin includes the aquifers of the Begudian, the Fuvelian in which the mining works are located and that of the Jurassic, the deepest.

Water inflow is 222 $l.s^{-1}$ mainly from Jurassic (83 $l.s^{-1}$) and Fuvelian (139 $l.s^{-1}$).

Gardane, Provence basin, France

Mining

First mention about mining comes form 15th century – outcrops.

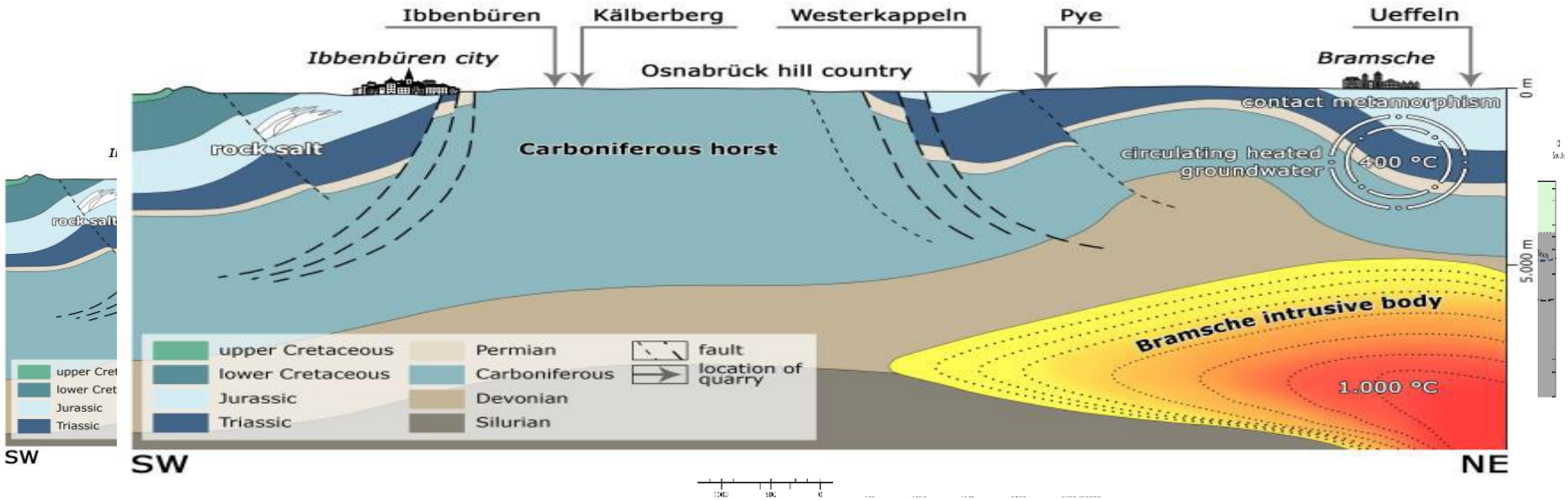
Used mining methods:
1. Very old archaic extraction methods (before 1850) were used near the outcrops.
2. Room and Pillar method between 100 and 700 m deep (east of the mine and on the Lambeau Charrié).
3. Longwall mining between 400 and 1 400 m deep (middle and west of deposit).

Coal seam extraction thickness varied form 1.8 to 5.3 m

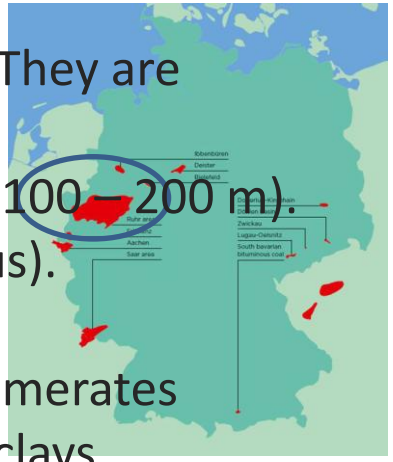
Rockbursts was recorder during mining period (longwall mining period).

Flooding mines after mining termination form 2003.

Hamm and Ibbenbüren, Germany

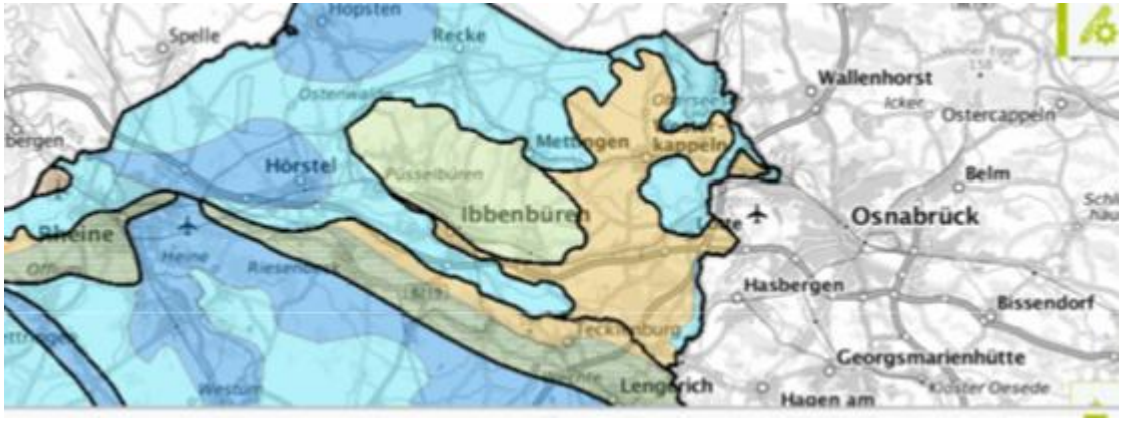


Location – west par of Germany.
Hamm (Ruhr basin) - coal seams are not outcropping at the surface. They are overlaid powerful overburden (thickness 250 m – 800 m).
Ibbenbüren – parts without cover layers and some with cover rocks (100 – 200 m).
Tectonic structure formation - Variscan orogeny (Upper Carboniferous).
Coal seams about thickness 1 – 6 m. Coal has carboniferous age.
Accompanying rocks – mudstones, siltstones, sandstones and conglomerates
Carboniferous cover – siltstones, mudstones, limestones, sands and clays.



Hamm and Ibbenbüren, Germany

Hydrogeology



Quaternary aquifer in cover rocks located above carboniferous rock mass
Cretaceous aquifer (saline waters) in cover rocks.
Carboniferous rock mass.
Inflows due to tectonic faults.

Total inflow water into the mines was relatively high but areas are very large.

Ruhr basin – ca. 500 $l.s^{-1}$

Ibbenbüren – 650 $l.s^{-1}$.

Hamm and Ibbenbüren, Germany

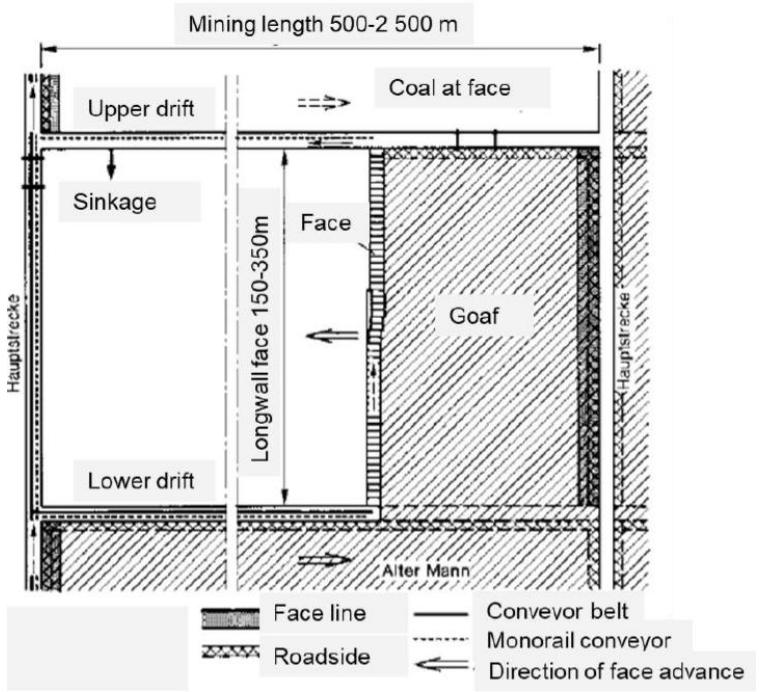
Mining

Start of mining in 16th century. Main period of development during industrial revolution.

Mining methods:
Driving of roadways and room and pillar (in the beginning), longwall mining from 20s century (sometimes with backfilling).

Coal seam thickness 5-6 m (Hamm), up to 3 m (Ibbenbüren).

Dept of mining – up to 1500 m (Hamm), 200–1400 (Ibbenbüren).



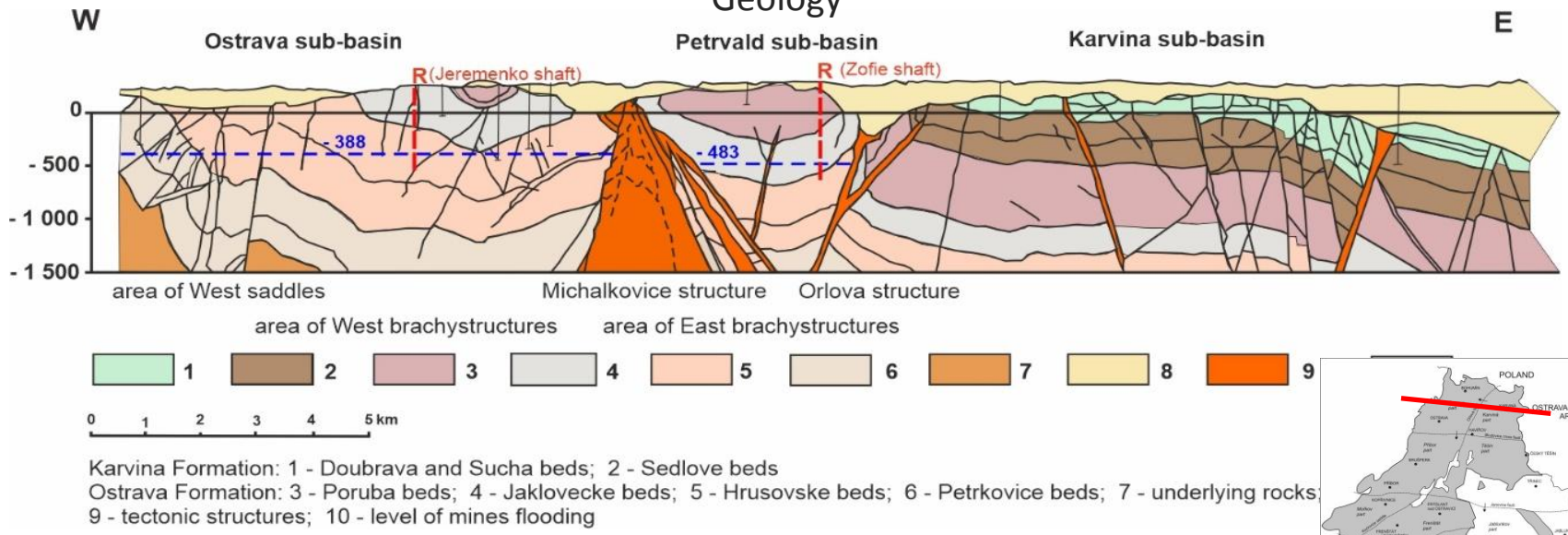
Mines closing in 2010 (Hamm) and 2018 (Ibbenbüren).

Gradual flooding after liquidation of mines.

Rockburst occurrents during mining period in great depth of mining.

Ostrava and Petrvald sub-basins, Czechia

Geology



Location – NE part of Czechia near border with Polad.
Formation in in the foreland of the Variscan orogen as a part of the outer zones.
Vertical profile – Quaternary sediments (10–30 m), ca. 250 m of Baden clays overly the main Carboniferous units (0 m of cover in Ostrava-Karvina Graben)
170 coal seams about thickness 0.4 – 1.1 m (sporadically 1.5 m - 4 m).
Coal seam deposition – sub horizontal as well as steep (near main tectonic structures).
Accompanying rocks – mudstones, siltstones, sandstones and conglomerates

Ostrava and Petrvald sub-basins, Czechia

Hydrogeology

Ostrava sub-basin ($l.s^{-1}$)

Mine	Water inflow	Carboniferous	Detritus	Miocene cover units	Quaternary
Odra (1)	59.7		22.0	1.2	36.5
Sverma,	77.0		43.4	3.6	30.0
Hermanice (2)	64.5		15.5	15.5	33.5
Ostrava (3)	122.1	4.9	40.0	3.5	73.7
TOTAL	**323.3**	**4.9**	**120.9**	**23.8**	**173.7**

Petrvald sub-basin ($l.s^{-1}$)

Mine	Water inflow	Detritus, undifferentiated Miocene cover units	Quaternary
Pokrok	38.6	26.7	11.9
Zofie	34.4	21.5	12.9
TOTAL	**73.0**	**48.2**	**24.8**

Quaternary groundwater

Carboniferous mantle water

Groundwater of Early Badenian

Carboniferous rock mass water

Ostrava and Petrvald sub-basins, Czechia

Mining

Start of simply mining – 1753

Mining due to roadways, Room and Pillar method – in the beginning (shallow depth).

The intensive excavation from industrial revolution - longwall mining.
Mined tens of coal seams from surface to depth ca. 1000 m.

Mine thickness of coal seam - from 0.6 m to 1.1 m (occasionally up to 1.5).
Coal seams deposition – mostly sub-horizontal, locally steep (near tectonic structures).

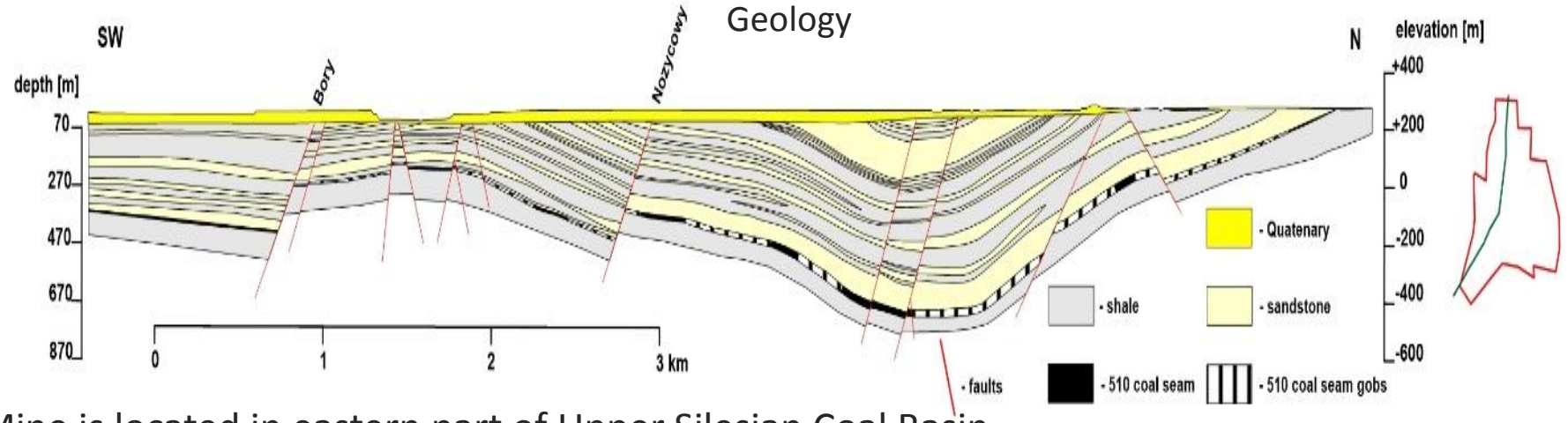
Flooding from 1994 after mines liquidation. Area flooded only partly – due to overflooding of water to Karvina sub-basin (600 m below surface in Ostrava sub-basin and 680 m below surface in Petrvald sub-basin)

Rockburst has been occasionally registered in some parts of sub-basins.

Region with long term recorded natural seismicity.

Kazimierz-Juliusz mine, Poland

Geology



Mine is located in eastern part of Upper Silesian Coal Basin.

Part of the basin is a asymmetrical structure with NWW SEE main axis orientation.
Main tectonic structures - faults – Jakubowski, Feliksowski, Nożycowy and Będziński (Varsiscan orogeny).

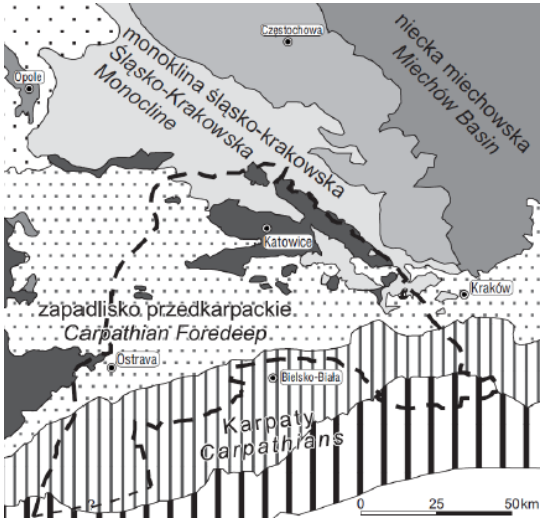
Tens of coal seams about thickness from 1.2 to 22 m (in case of seams connection).
The carboniferous series is composed of mudstones, siltstones, sandstones and conglomerates with increasing of share of competent rock with increasing depth.

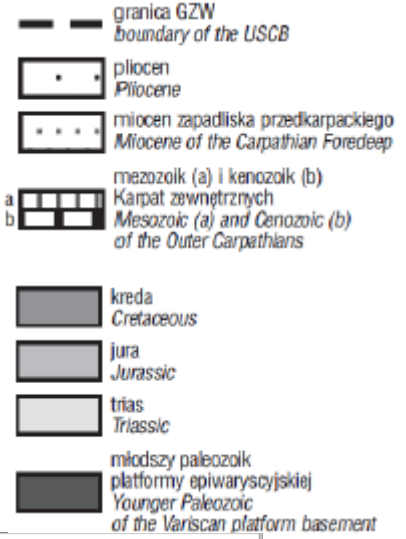
Cover layers - Quaternary formations (sands, clays, gravels – thickness around 50 m and Triassic formations (limestones, sandstones, marls and dolomites – thickness from 35 to 170 m).

Kazimierz-Juliusz mine, Poland

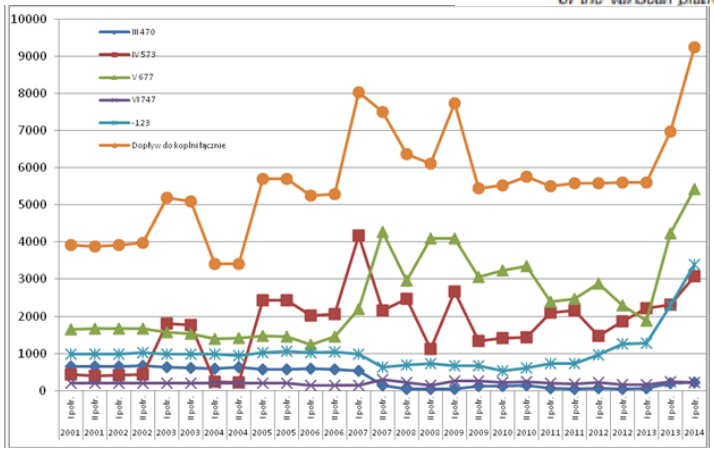
Hydrogeology

Within the range of the Śląsko-Krakowska Monocline, the main levels of ordinary waters occur in Triassic carbonate rocks, Carboniferous sandstones and Pleistocene sandy formations, while in the Carpathian Foredeep and Carpathians - in Pleistocene and Holocene sands.





Primarily waters of tectonic structures of the Upper Carboniferous and the deeper underlying rocks of the productive basin sediments.



Water inflow varied form 56 to 154 l . s^{-1}

Kazimierz-Juliusz mine, Poland

Mining

Mining form 1880 – 2016.

Mined thickness of cola seam varied from 1 to 6 m.
Average depth of mining 788, maximum 1288 m

The extraction of coal started in outcrops (northern part of mine) using an opencast method in the first half of the 19th century (NE part of mine area).

Principal mining method is longwall mining (in history R&P and corridors was used as a mining method near surface).

After the closure of the mine flooding was started. the current water level in the Carboniferous reservoir can be estimated at about 400 m below ground level.

Rockburst has been registered during increasing of depth of mining mainly in rock mass with high ration of competent rock layers.

Continual seismic monitoring form 1970s.

Testing sites comparison

Geology

Testing site	Lithology	Type of coal	Coal seam thickness	Thickness of cover
Gardanne	limestones, dolomites mudstones, clays	brown coal	0.4 –5.3 m	100 – 800 m
Hamm	mudstones, siltstones sandstones, conglomerates	hardcoal	do 5-6 m	250 – 800 m
Ibbenbüren	mudstones, siltstones sandstones, conglomerates	hardcoal	up to 3 m	do 6 m
Kazimierz-Juliusz	limestones, mudstones siltstones, sandstones conglomerates	hardcoal	1 - 6 m	35 – 170 m
Ostrava & Petrvald sub-basins	mudstones, siltstones sandstones	hardcoal	0.4 – 1.1 m (sporadically 1.5 m - 4 m)	0 – 250 m

Testing sites comparison

Mining

Testing site	Mining depth	Mining method	Mined coal seam thickness	Rockburst occurence during mining
Gardanne	100–400 (700) m	Room&pillar	1.8 – 5.3	YES (longwall mining)
	400–1400 m	Longwall mining		
Hamm	up to 1500 m	Longwall mining	3 – 5 m	YES
Ibbenbüren	200–1400 m	Longwall mining	2 – 3 m	YES
Kazimierz-Juliusz	Average 788 m (maximum 1288)	Longwal mining	1 – 3.2	YES
Ostrava & Petrvald sub-basins	0–1000 m	corridors room&pillar Longwall mining (from 1930s)	0.6 – 1.1 m (sporadically 1.5 m)	YES - sporadically

Conclusions

Mining technology (dimeson of pillars on short time – safety mining NOT for long term stability (e.g. impact of water during mines flooding). Longwall mining means large amount of deformations conserved in rock mass which can be released during mines flooding → induced seismicity, re-subsidence , uplifts.

Composition of cover layers – more strong and competent rocks can contribute to increasing of seismicity unlike weakness and plastic rocks where is this risk lower.

Tectonic structure – water can impact cohesion of tectonic faults → movements restart, loosing of stability in rock mass (e.g. pillars) can overload tectonic structures (Gradanne).

Competent rocks can occurring mass increasing of induced seismicity during mines flooding (similarly as in case of rockburst risk) → restart of fracturing.

Mined thickness of coal seams – lower thickness (1- 2 m) → smaller impacted volume of rock mass → low induced seismicity during mines flooding VS higher thickness (3 to 6 m) → higher risk of induced seismicity during mines flooding.

Natural seismicity cannot be excluded if region is typical long term natural seismicity.

Thank you very much for your attention.

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