Mining induced seismicity in Poland

PROBLEMS AND CHALLENGES

IS EPOS International Conference on Digital Research Space for Anthropogenic Hazard Studies
Katowice 19-20.11.2015

Józef DUBIŃSKI Grzegorz MUTKE Adam BARAŃSKI
1. General data about seismicity induced by mining activity in Poland
2. Development of seismological investigations in Polish mining basins
3. Upper Silesian Seismological Network - regional
4. Mine seismological networks - local
5. Importance of the mining seismicity monitoring - safety and environmental aspects.
6. The most important mining problems using mining seismology - rockbursts hazard evaluation, - influence of mining tremors on the surface environment.
7. Conclusions
Location of the Principal Mining Basins in Poland

- Upper Silesian Coal Basin (USCB)
- Legnica-Głogów Copper District (LGCD)
- Lublin Coal Basin (LCB)
Rockburst belongs to a group of natural hazards, the occurrence of which has the character of a mining disaster.

The phenomenon of rockburst occurs in many mining basins around the world, both in hard coal and metal ore mines.

In Poland, the seismicity induced by mining activities and the accompanying rockbursts occur in hard coal mines in the Upper Silesian Coal Basin (the USCB) and copper ore mines in the Legnica-Głogów Copper District (LGCD).

The problem of mining seismicity and rockbursts is the sphere of the widest application of rock mechanics solutions as well as selected methods of mining geophysics.
Continual increase of exploitation depth,
- Multi-seam character of the beds,
- Occurrence of thick and durable roof rock complexes,
- Heavy intensification of mining activities,
- Occurrence of residual pilars, abandoned coal seams and exploitation edges in the adjacent seams,
- Coal seams’ tendency for rock-bumping, self ignition, high methane content, etc.

FACTORS AFFECTING ON INCREASE OF SEISMICITY IN HARD COAL MINES

Average exploitation depth [m]

Years

SEISMIC HAZARD IN POLISH HARD COAL AND COPPER MINES

Number of tremors $E \geq 10^5 J$

- **Hard coal mines**
- **Copper ore mines**
Rockbursts Hazard in Polish Hard Coal and Copper Mines

Number of rockbursts

<table>
<thead>
<tr>
<th>Year</th>
<th>Hard coal mines</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1977</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>1980</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>1985</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>1990</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>1995</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>2000</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>2005</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>2006</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>2007</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>2008</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>2009</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>2010</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>2011</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2012</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2013</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2014</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
ROCKBURSTS HAZARD IN POLISH HARD COAL AND COPPER MINES

Total number of accidents

<table>
<thead>
<tr>
<th>Year</th>
<th>Hard coal mines</th>
<th>Copper ore mines</th>
</tr>
</thead>
<tbody>
<tr>
<td>1977</td>
<td>74</td>
<td>8</td>
</tr>
<tr>
<td>1980</td>
<td>54</td>
<td>9</td>
</tr>
<tr>
<td>1985</td>
<td>30</td>
<td>6</td>
</tr>
<tr>
<td>1990</td>
<td>34</td>
<td>13</td>
</tr>
<tr>
<td>1995</td>
<td>14</td>
<td>5</td>
</tr>
<tr>
<td>2000</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>2005</td>
<td>22</td>
<td>14</td>
</tr>
<tr>
<td>2006</td>
<td>20</td>
<td>19</td>
</tr>
<tr>
<td>2007</td>
<td>26</td>
<td>11</td>
</tr>
<tr>
<td>2008</td>
<td>14</td>
<td>6</td>
</tr>
<tr>
<td>2009</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>2010</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>2011</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>2012</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>2013</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>2014</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

Number of fatalities

<table>
<thead>
<tr>
<th>Year</th>
<th>Hard coal mines</th>
<th>Copper ore mines</th>
</tr>
</thead>
<tbody>
<tr>
<td>1977</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>1980</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>1985</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>1990</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>1995</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>2000</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>2005</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>2006</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2007</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2008</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2009</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2010</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>2011</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2012</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2013</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2014</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
SEISMICITY of the USCB

1977-1980
SEISMICITY of the USCB
SEISMICITY of the USCB

1980 - 2015

LOCAL MAGNITUDE 1980-2015

- mine areas
- boundary of USCB
- main faults

© OpenStreetMap (and) contributors. CC-BY-SA
Development of mining seismicity investigations in Poland

- End of the 40-ties years last century – 2 seismological stations with mechanical system of registration in USCB (Bytom and Zabrze).
- 50÷60 ties years last century:
  - development of new seismological stations with optical system of registration (Mikołow, Dąbrowa Górnicza)
  - start of mining seismological observations (IGF PAS – Miechowice mine; GIG – Szombierki mine)
- 1973 – purchase of new modern seismological systems Racal - Thermionic for regional network and 4 coal mines the most threaten by rockbursts.
- End of 70-80 – first seismological observations in copper mines (Lubin, Polkowice) and lignite opencast mine Bełchatów.
- Next decades – development of Polish constructions of new seismological systems (Górnik, AS, ARAMIS, SYLOK, SOS, AMAX).
Upper Silesian Seismological Network (USSN) - currently consists of 20 seismic stations and is based on two independent systems:

- GeoSIG equipment and Seisan software,
- SOS seismic equipment developed by CMI and Multilok software.
SOFTWARE SYSTEMS USED BY USSN

- GeoDAS – Data Acquisition System software: Company: GeoSIG Ltd.
- MULTILOK: Mining Tremors Analysis Software: Central Mining Institute (GIG).
- SEJSGRAM : Data Acquisition System software: CMI (GIG)
THE GOALS OF THE UPPER SILESIAN SEISMOLOGICAL NETWORK

- Monitoring and forecasting of seismicity in Upper Silesian Coal Basin area – tremors with $M \geq 1.5$.

- Preparation of the measuring data for investigation in scope of rockbursts hazard evaluation criteria, genesis of seismicity and mechanisms of mining tremors generated in the area of the USCB.

- Calibration of seismic energy determined by local seismological mine networks.

- Management of the bank containing data about the strongest seismic tremors from USCB.

- Collaboration with mining industry, local autonomies, research institutions, mining courts and provincial critic staffs, etc.

- Evaluation of seismic risk for surface infrastructure in the area of USCB.

- Conducting of the seismological observations on post mining territories.

- Education of the school youth in scope of induced seismicity.

- Using Upper Silesian Seismological Network in investigation projects.
MINE SEISMOLOGICAL NETWORKS

- 20 seismological networks in underground hard coal mines,
- 3 seismological networks in underground copper ore mines,
- 1 seismological network in opencast lignite mine.

The basic tasks of mine seismological networks

- Continuous monitoring of seismicity level in individual panels of mining works.
- Alarming of the increasing states of seismic hazard.
- Evaluation of the rockbursts hazard state based on elaborated local criteria.
- Evaluation of the efficiency of conducted prevention technologies.
Why problem of mining seismicity is so important? ...

- Rockbursts and coal bumps are strongly connected with seismicity
  SAFETY OF MINERS

- Seismic tremors are sources of shocks and vibration on the surface
  IMPACT ON THE SURFACE ENVIRONMENT
The most common effects of rockburst

- damage - and in some cases - destruction of support, particularly as a result of mechanical shock caused by ejected rock mass, as well as excessive static load of support due to the loss of bearing capacity of fractured rock mass and dynamic load resulting from the vibrations connected with a seismic wave,

- damage of machinery and equipment in the area within the rockburst,

- sudden convergence of working, which loses its functionality,

- caving-in of workings,

- incidents involving workers present in the workings in which the above effects of rockburst took place, including serious and fatal accidents.
Examples of rockbursts from the hard coal mines of the USCB and copper mine
Examples of buildings damages
The Upper Silesian Coal Basin
ROCKBURSTS HAZARD EVALUATION BY USING SEISMOLOGICAL METHOD

New Methodology
Mine workings with lack of rock burst hazard (hazard level “a”) all works can be carried out in accordance with established technology.

Mine workings with low rock burst hazard (hazard level “b”) all works can be carried out in accordance with established technology, enhanced supervision should be used on observations of the state of rock burst hazard and of mining technology.

Mine workings at medium rock burst hazard (hazard level “c”) further driving of the working should be performed with use of a prevention method established for such hazard state. The work is done with ongoing analysis of the results of control measurements for at least once a day and without further growth of hazard.

Mine workings with high rock burst hazard (hazard level “d”) mining must be stopped, and the crew must immediately withdraw in a safe place, mining manager should determine the methods of limiting the hazard state. The methods controlling the effectiveness of prevention should be used. The number of the workers involved in prevention work in the mining area should be specified. If the "d" hazard level is kept, only works to reduce the hazard may be conducted.
Instruction
„Mining seismology method for rock burst hazard assessment“

For the assessment of seismic and rock burst hazard using new seismic parameters it is proposed to use such values as:

- location of tremor hypocenter \((X, Y, Z)\),
- seismic energy (magnitude) of seismic event or seismic moment,
- total seismic energy released for every 5 m of the longwall coal face advance,
- weighted value of peak particle velocity \((PPV_w)\) parameter in workings localized in mining panels,
- change of the \(b\)-value in a moving time windows,
- seismic energy index, \(EI\), in a moving time windows
- tomographic velocity image obtained for recorded seismic events (complementary method).

# Quantitative assessment of the seismic and rock burst hazard level according to the observed seismicity in the mining activity area

<table>
<thead>
<tr>
<th>Hazard level</th>
<th>Mine workings</th>
<th>Seismic criteria</th>
<th>Seismic characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>a lack of hazard</td>
<td>Longwalls</td>
<td>Tremors with energy magnitude $10^2 \div 10^3$ J, occasionally $10^4$ J. $\sum E &lt; 10^5$ J per of coal face advance $PPV_W$ in „a” hazard level; parameters $M_o$, $EI$ and $b$-value do not indicate increase of hazard (level „a” and „b” – at least two in „a” state)</td>
<td>Low seismicity, lack of damaging effects</td>
</tr>
<tr>
<td></td>
<td>Roadways</td>
<td>Without tremors or individual tremors with energy $&lt; 5 \cdot 10^3$ J $PPV_W$ in „a” hazard level</td>
<td></td>
</tr>
<tr>
<td>b low hazard</td>
<td>Longwalls</td>
<td>Tremors with energy magnitude $10^2 \div 10^4$ J, occasionally $10^5$ J. $1 \cdot 10^5 \leq \sum E &lt; 10^6$ J per of coal face advance $PPV_W$ in „b” hazard level; parameters $M_o$, $EI$ and $b$-value do not indicate increase of hazard (level „a” and „b” – at least two in „b” level)</td>
<td>Medium seismicity, lack of damaging effects, in the workings area seismic events are felt by the miners</td>
</tr>
<tr>
<td></td>
<td>Roadways</td>
<td>Tremors with energy $&lt; 5 \cdot 10^4$ J $PPV_W$ in „b” hazard level; parameters $M_o$, $EI$ and $b$-value do not indicate increase of hazard (level „a” and „b”, at least two in „a” level)</td>
<td></td>
</tr>
<tr>
<td>c medium hazard</td>
<td>Longwalls</td>
<td>Tremors with energy magnitude $10^2 \div 10^6$ J, occasionally $10^6 \leq E &lt; 10^7$ J per 5m of progress. $PPV_W$ in „c“ hazard level; parameters $M_o$, $EI$ and $b$-value indicate increase of hazard (at least two in „c“ level and none in „d“ level).</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>Roadways</td>
<td>Tremors with energy magnitude $10^2 \div 10^4$ J, occasionally $10^5$ J. $PPV_W$ in „c“ hazard level; parameters $M_o$, $EI$ and $b$-value indicate increase of hazard (at least two in „c“ level and none in „d“ level).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d high hazard</td>
<td>Longwalls</td>
<td>Tremors with energy magnitude $10^2 \div 10^6$ J, occasionally $E \geq 10^7$ J. $\sum E \geq 10^7$ J per 5m of progress. $PPV_W$ in „c“ or „d“ hazard level; parameters $M_o$, $EI$ and $b$-value indicate increase of hazard (at least two in „c“ level and one in „d“ level).</td>
<td></td>
</tr>
<tr>
<td>Roadways</td>
<td>Tremors with energy magnitude $10^2 \div 10^5$ J, occasionally $E \geq 10^6$ J. $PPV_W$ in „c“ or „d“ hazard level; parameters $M_o$, $EI$ and $b$-value indicate increase of hazard (at least two in „c“ level and one in „d“ level).</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

High seismicity, rock mass relaxation occurs with the effects not decreasing the stability and functionality of the workings support; in the workings area seismic events are highly felt by the miners.

Very high seismicity, rock mass relaxation occurs, in the workings area shocks are highly felt by the miners.
INVESTIGATION OF NEW SEISMOLOGICAL CRITERIA
MEASUREMENTS OF NEAR WAVE FIELD PARAMETERS

Characteristic of mining seismic events recorded in the near wave field:
- Peak particle velocity: PPV up to 0.38 m/s
- Peak particle acceleration: PPA up to 50 m/s²
- Hypocentral distances: from 30 m to 400 m
- Duration time of vibration: from 0.05 to 0.25 s

Requirements for underground seismic sensors to study PPV:
- not clip velocity amplitude up to 1.0 m/s
- frequency range: 1-500 Hz
- ATEX certificate

DLM geophone probe
Peak particle velocity parameter in vicinity of operational workings - PPV method

- Relationship between PPV and dynamic stress increment.
- Only mining tremors located in short distances from longwall face are dangerous for excavations.

\[
\Delta p_X = \rho \cdot C_p \cdot PPV_X \\
\Delta p_{XY} = \rho \cdot C_s \cdot PPV_Y
\]

<table>
<thead>
<tr>
<th>PPV, m/s</th>
<th>(\sigma_{xy}), Mpa</th>
<th>(\sigma_x), MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.22</td>
<td>1.2</td>
<td>2.1</td>
</tr>
<tr>
<td>0.6</td>
<td>3.2</td>
<td>5.8</td>
</tr>
<tr>
<td>1.6</td>
<td>9.6</td>
<td>15.4</td>
</tr>
</tbody>
</table>

Almost 90% of tremors in USCB resulted in rockbursts were situated at a distance of up to 100m from the damaged workings.

PPV from 50 to 1000 mm/s

\(\Delta p\) - dynamic preassure increase
\(\rho\) - density of rock mass
\(C_p, C_s\) - P and S wave velocity

PPV - peak particle velocity

\(PPV = 50\) mm/s

\(PPV = 1000\) mm/s
PPV parameter creates good relation between seismicity and rockbursts hazard

a – lack of hazard: $PPV_W \leq 0.05 \text{ m/s}$
b - low hazard: $0.05 < PPV_W \leq 0.2 \text{ m/s}$
c - medium hazard: $0.2 < PPV_W \leq 0.4 \text{ m/s}$
d - high hazard: $PPV_W > 0.4 \text{ m/s}$

for seismic energy $E \geq 1 \cdot 10^5 \text{ J}$ and frequency of vibration $f < 40 \text{ Hz.}$
Verification of the PPV parameter

Geophone 29Z

- E=3E5 J
- r=132m

- E=6E3 J
- r=60m

50 mm/s
Investigation on special underground site in hard coal mine „Bobrek”, during exploitation of No 3 longwall in coal seam No 503
Verification of the b-value and $A_{G-R}$ anomaly criterion

Changes of the „b” – value before the rockburst

Seismic energy, J

Date

$A_{G-R}$
The local criterion for seismic hazard level at Bobrek mine using the Gutenberg-Richter law and anomaly coefficient

<table>
<thead>
<tr>
<th>Hazard level</th>
<th>G-R anomaly, %</th>
<th>Criterion G-R</th>
</tr>
</thead>
<tbody>
<tr>
<td>„a” lack of hazard</td>
<td>( A_{G-R} &lt; 0 )</td>
<td>( b &gt; b_S )</td>
</tr>
<tr>
<td>„b” low hazard</td>
<td>( 25 &gt; A_{G-R} \geq 0 )</td>
<td>( b \leq b_S )</td>
</tr>
<tr>
<td>„c” medium hazard</td>
<td>( 50 &gt; A_{G-R} \geq 25 )</td>
<td>( b &lt; b_S )</td>
</tr>
<tr>
<td>„d” high hazard</td>
<td>( A_{G-R} \geq 50 )</td>
<td>( b &lt; b_S )</td>
</tr>
</tbody>
</table>

\[ A_{G-R} = \left[ \frac{(b_S - b)}{b_S} \right] \cdot 100\% \]

where: \( b \) - momentary value of „b” parameter, calculated for tremors recorded within a specified time window.

\( b_S \) - mean value of „b” parameter calculated from whole entire catalog of tremors for the whole area of the mine or the selected area of exploitation.
Verification of the EI criterion

where:

\[ E(M_o) = 10^{(c \cdot \log M_o - d)} \]

where: 
\( c, d \) – constant for given area,
\( M_o \) – scalar seismic moment,
\( E \) – seismic energy

\[ EI = \frac{E}{E(M_o)} \]
Passive tomography have been used to assess the seismic hazard in Polish mines.

The velocity images can be used to assess places of seismic hazard and P-wave velocity anomaly correlates well, in time and space, with strongest seismic events.

The data we need are only digital records from mines seismological networks.
Velocity imaging results from passive tomography inversion of P-wave arrived times. The dots indicate mining tremors. Marked seismic events were occurring within one month after calculating. We can see that tremors lie in the area of the highest velocity and highest gradient.
INFLUENCE OF MINING TREMORS ON THE SURFACE ENVIRONMENT
The MSIIS-15 scale correlates instrumentally measured ground motion parameters (peak horizontal ground velocity, $\text{PGV}_{H\text{max}}$ and the duration time of tremor, $t_h$) with the observed macroseismic impact on buildings and infrastructures, perceiving the vibrations by people and the nuisance of used buildings.

The scale describes the 6 degrees of intensity, from harmless vibrations to vibrations causing damages to non-structural and decorative elements up to slight structural damages.

The MSIIS-15 scale refers both to the buildings in good and in poor technical condition.

The vulnerability levels of historical buildings and impact of mining seismic events on the old shallow mining to induce sinkhole hazard were also elaborated.
Mining Seismic Instrumental Intensity Scale (MSIIS-15) – verification in coal basins

- $I_{\text{MSIIS}} = \text{VI}$: fear and panic, structural damages which do not endanger to the stability of the whole load-bearing structure of the building - observed in few cases
- $I_{\text{MSIIS}} = \text{V}$: slight single structural elements
- $I_{\text{MSIIS}} = \text{IV}$: damage to decorative elements
- $I_{\text{MCHF}} = \text{III}$: intensification of existing damages
- $I_{\text{MCHF}} = \text{II}$: felt indoors by many people
- $I_{\text{MCHF}} = \text{I}$: not felt or week felt

PGV $H_{\text{max}}$, m/s

duration time $t_{\text{Hmax}}$, sek
MINING SEISMIC INSTRUMENTAL INTENSITY SCALE

MSIIS-2015

Developed within the project COMEX – Grant Agreement Number: RFCS-CT-2012-00003

Editor
Grzegorz Mutke

TEAM OF AUTHORS:
G. Mutke, J. Dubiński, L. Muszynski, K.Stec, A. Lurka, J. Chodacki – Central Mining Institute (GIG), Poland
S.Kremers, S.Peters, R.Fritschen – DMT, Germany
A.Baranński, T.Kowal – KWSA Coal Company, Poland
Results of verification MSIIS-15 scale on the basis of seismic and macroseismic observation from Upper Silesia Coal Basin – Poland
The quality of this correlation was studied and tested using recordings of miming seismic events originating from Polish and German coal basins. The results show strong relationships between chosen instrumental parameters and macroseismic effects.

The MSIIS-15 scale allows describing in details intensity above 5 mm/s, from very slight in non-structural elements to damages in structural elements and home equipments as well perceptibility of vibrations by people and nuisance of used buildings.

The threshold values of the velocity parameter PGV, to classify hazard of potential instability of the old shallow mining tunnels or shafts is following:
- tunnels in fractured rock - PGV > 50 mm/s
- tunnels in intact rock – PGV>200 mm/s.

MSIIS scale is very important for mining industry because of:
- correlating numerous of seismic records with damage distribution
- assessing of seismic risk for planned exploitation
- indicating the liability for seismic damages and scope of compensation of mining industry.
Seismometric network in mines Piast and Ziemowit

1.
Stations of apparatus AMAX-GSI KWK Ziemowit (od 1 do 12)

1.
Stations of apparatus ARP-2000 KWK Piast (od 1 do 14)
LMMIS is laboratory of passive seismic records for monitoring seismicity induced by underground mining

Lab possess of all the history of the seismic events recorded during mined of the longwall panel no. 3, both registered close to the seismic sources (near field) as well as those from far field and all geological and technological data
Episodes of seismicity induced by coal mining developed under IS EPOS project

ESI-1  BOBREK: seismicity linked to longwall mining

ESI-6  USCB: regional seismicity and ground motion associating underground coal mining
1. Seismicity induced by mining activity occurs in a few mining areas in Poland and creates problems concerned to safety, environment and social aspects.

2. Seismology method is a basic one for investigation mining seismicity and is a key measurement tool of mining practice.

3. The Upper Silesian Seismological Network plays an important role for development of new solutions in scope of mining seismology.

4. New seismic criteria for better evaluation of rockburst hazard using several new parameters has been elaborated.
5. Elaboration of Mining Seismic Instrumental Intensity Scale is one of the achievements in this scope.

6. The future challenges of mining seismology in Poland concern to improving efficiency of daily evaluations of rockbursts hazard in mines and to enable a better forecast of induced seismicity for projected mining activity.

8. We hope that collaboration in the frame of EPOS help us in this.
THANK YOU FOR ATTENTION!