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Short communication

Upper Silesian Geophysical Observation System – A unit of the EPOS project

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ABSTRACT

The aim of the paper is to present the structure and research potential of the newly created measurement and information system for observing dynamic phenomena occurring in the Earth's crust in the Upper Silesian Coal Basin (USCB) in Poland as a result of mining activities. The structure of the system is similar to the one developed for monitoring the movements of the European tectonic plate under the European Plate Observation System (EPOS) programme. The measurement part of the system consists of stationary devices and sensors working in monitoring mode, installed in various locations of the USCB, both on the surface and underground, as well as data sets from periodically performed measurements using land, air and satellite techniques. The IT part of the system will create a local data centre with specialized and dedicated processing and modelling software in which all measurement data will be archived and processed to a form which enables the analysis of the short and long-term impact of mining operations on the environment. As one of the elements of the system will be observations of the short and long-term gravity and morphology changes, the collected data will enable research in the field of the geodynamics of mining areas to be conducted.

1. Introduction

The natural environment of the Upper Silesian Coal Basin (USCB) in Poland has been under the significant influence of coal and other minerals mining for centuries. This is reflected in various, gravitational movements of the earth's crust such as subsiding, sinking and shaking. These phenomena change the geodynamics of the Upper Silesia region, which is densely populated and urbanized and has to be better protected against mining induced adverse effects. The Upper Silesian Geophysical Observation System (USGOS) will provide complete data on the geodynamic processes taking place in the Upper Silesian Coal Basin which is under the influence of the underground exploitation of deposits and, in particular, coal. It will be part of the Polish research infrastructure which is being built under the EPOS program to acquire new knowledge, which is needed to understand the mechanisms of anthropogenic threats. The EPOS programme is the Europe's largest infrastructural project in Earth Sciences. EPOS′ mission is to integrate diverse and advanced European Research Infrastructures for solid Earth science and build on new e-science opportunities to monitor and understand the dynamics and complex solid-Earth System.

The EPOS-PL project is an integral part of the EPOS programme. As a part of the EPOS-PL project (https://epos-pl.eu), technical infrastructure for geodynamic and geohazard research in Poland is being built and modernized. The project is being carried out by a Consortium of scientific and industrial partners. The leader of the consortium is the Institute of Geophysics, the Polish Academy of Science (IG PAS) and the members of the consortium are the Academic Computer Centre (ACC Cyfronet AGH), the Central Mining Institute (CMI), the Institute of Geodesy and Cartography (IGC), Wrocław University of Environmental and Life Sciences (WUELS), the Military University of Technology (MUT) and the Polish Mining Group (PMG) as an industrial partner. The first structural layer of research infrastructure (RI) is built by the Research Infrastructure Centres (RICs). RICs provide a complete dataset concerning a given research field. The second layer of the EPOS-PL project integrates RICs in Poland.

One of the tasks of the EPOS-PL project is the construction of a specialized measuring system for integrated observations of geodynamic processes and geohazards in mining and post-mining areas of the

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Upper Silesia Coal Basin (USCB) – Poland (Mutke, Lurka, & Dubiński, 2009; Kotyrba & Mutke, 2015; Mirek & Mirek, 2016; Lurka & Mutke, 2017). Dynamic events in the USCB are induced by mining and natural processes (Marcak & Mutke, 2013). The first step for the creation of the so-called Multidisciplinary Upper Silesian Episode (MUSE) is to build an integrated geophysical measurement system. The system will include local and regional seismological, geodetic and gravimetric networks, as well as periodic geophysical and InSAR observations. Collected data and products will be integrated as a MUSE Episode in the Upper Silesian Geophysical Observation System set up in the Central Mining Institute (CMI) in Katowice and next shared through the IS-EPOS platform (Lasocki & Orlecka-Sikora, 2016; Leptokaropoulos et al., 2018), multiservice of the Thematic Core Service of Anthropogenic Hazard (https://tcs.ah-epos.eu/). One of the episodes integrated in the IS-EPOS platform during the IS-EPOS project (2013–2015) will be developed and significantly expanded in the framework of the EPOS-PL project: Episode USCB: regional seismicity and ground motion associated with underground coal mining (IS EPOS, 2017).

EPOS-PL is a multidisciplinary infrastructural project, but in a broader perspective, it has significant scientific goals, based on newly developed research infrastructure (RI). Integrated measurements and research within MUSE is a new way of building RI for bilateral knowledge transfer between industry and science.

2. The Upper Silesian Geophysical Observation System

In order to conduct integrated observations of geodynamic processes and geohazards in mining and post-mining areas in the USCB, a specialized Upper Silesian Geophysical Observation System (USGOS) is being built in the Central Mining Institute (CMI). It covers two areas in the USCB. MUSE1 has a regional range and covers the northern part of the USCB area where operating and abandoned mines are located. MUSE2 has a local range and covers the "Rydułtowy" Mine area (in the southern part of the USCB). In this task, continuous and periodic measurements will be carried out in post mining and mining areas, showing a relationship between USCB geodynamics, underground mining, surface subsidence, surface flooding, sinkholes and induced seismicity. The USGOS is equipped with servers and 150 TB mass memory to receive and store a stream of digital data from MUSE episodes, as well as metadata. Three reference geophysical stations will be created in three locations, i.e. in the CMI in Katowice, in the "Ignacy" Historical Mine in Rybnik and in the Museum of Zagłębie in Będzin. In these places the following continuous measurements are to be conducted: seismic monitoring of translational and rotational ground motions, observation of the gravimetric field changes and changes of the point coordinates using the GNSS technique. All geophysical sensors deployed in the MUSE test site are presented in Fig. 1.

The measurement area of MUSE1 is a region located in the northern part of the UCSB, covering an approximate area of 30 × 40 km. The following continuous and periodical measurements will be performed and periodical satellite radar data sets collected as part of MUSE1:

- Continuous monitoring of seismicity in the USCB – Upper Silesian Regional Seismological Network (USRSN) – expanded in the EPOS project by seven additional seismic translational ground motion stations and five seismic rotational ground motion stations,
- Continuous induced seismicity monitoring in mines – underground Seismic Observation System (SOS 96 channels) deployed in the “Bielszowice” mine,
- Continuous measurements of ground motion at 15 stations in the “Ziemowit” Mine,
- Continuous stress measurement – underground Seismic Observation System (SOS-stress 16 channels) deployed in the "Bielszowice" and "Rydultowy" mines,
- Seismic measurements of V_{s30} velocity at GRSS EPOS seismic station locations,
- Continuous measurements of the gravity field variation in Katowice,
- Periodic gravimetric measurements – absolute and relative,
- Continuous geodetic measurements (GNSS) – five stations,
- Periodic radar data sets collected by satellite aperture radar (SAR),
- Seismic catalogues and triggered seismic records from the underground seismic network, elaborated by the PMG company from the MUSE1 field area (the “Bielszowice” mine and “Ziemowit” mine).

The measurement area of MUSE2 is a region located in the south-western part of the USCB, covering an area (approximately 2 × 4 km) of the "Rydułtowy" mine. The mine is still operating and inducing ground displacements and high seismicity. There is multilevel coal mining and a large number of tectonic faults. The following measurements will be made and periodical data sets collected in the MUSE2 test site:

- Seismicity monitoring – underground seismic network SOS consisting of 96 channels installed spatially around the Longwall Panel (LP) No. VIII-E-E1,
- Rotation effect measurement in the near wave field (“Ignacy" Historical Mine station),
- Ground motion measurement in the epicentral zones,
- Seismic and geotechnical measurements in the boreholes, located in the vicinity of the “Kolejowy” fault, which limits the mining panel,
- Continuous measurement of the gravity field variation (“Ignacy” Historical Mine station),
- Periodic gravimetric measurements – absolute and relative,
- Continuous geodetic measurement (GNSS), directly above the mined longwall – five stations,
- Continuous water level measurement in boreholes, located in the vicinity of the “Kolejowy” fault,
- Seismic and radar measurements at the station locations,
- Continuous measurement of cracks and fissures in buildings,
- Continuous measurement of building inclinations,
- Aerial laser scanning – and SAR interferometry,
- Seismic catalogues and triggered seismic records from the underground seismic network, elaborated by PMG from the MUSE2 field area ("Rydułtowy" mine).

In addition, a 3D mine and geological model of the coal deposit will be developed (Fig. 2) and all necessary metadata collected.

The USGOS located in the Central Mining Institute in Katowice integrates continuous as well as periodic seismological, gravimetric, geotechnical, hydrogeological, geodetic leveling, satellite surveys, and 3D geological models and other metadata, enabling this to be archived on the disc matrices of the MUSE Geophysical Data Centre.

Raw and processed data from dispersed measurements taken from the MUSE test area are delivered to USGOS by the Central Mining Institute (CMI), the Institute of Geodesy and Cartography (IGC), the Wrocław University of Environmental and Life Sciences (WUELS), the Military University of Technology (MUT) and the Polish Mining Group (PMG). In USGOS geophysical data and metadata from the MUSE area are integrated and then sent to e-Node Krakow (the International Data Centre of IS-EPOS Platform) located at the Institute of Geophysics (IG PAS). Then, in the form of a MUSE episode, they are published on the IS-EPOS platform (https://tcs.ah-epos.eu), where they are integrated with other observations performed as part of the European Platform Observing System programme (EPOS). The schematic diagram of data transfer to and from USGOS is shown in Fig. 3.

3. In situ observations

3.1. Gravity monitoring and gravity data referencing

The exploitation of minerals may cause significant geodynamical consequences in the Earth's crust. In particular, it causes changes in the

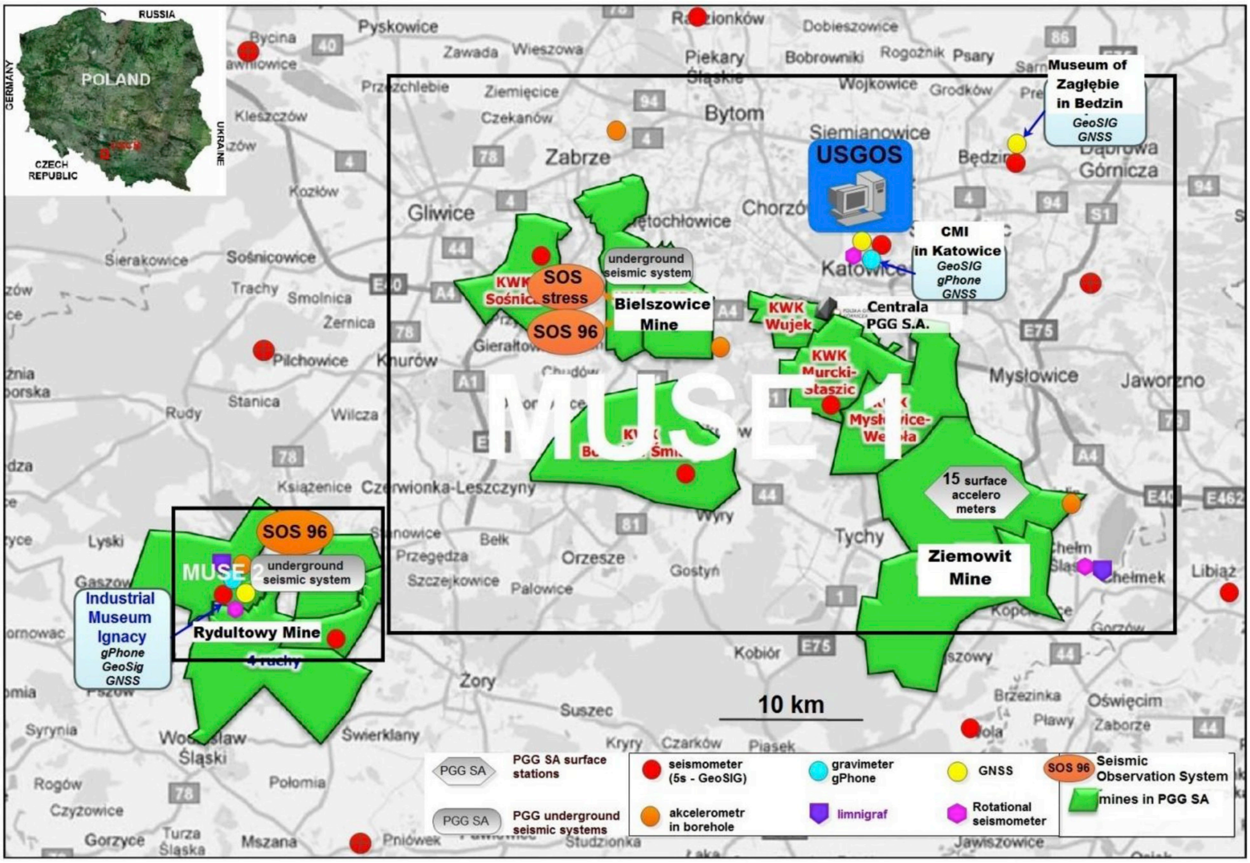

Fig. 1. USGOS – deploy of geophysical sensors on MUSE test sites for continuous monitoring of geodynamic processes in the Upper Silesia.

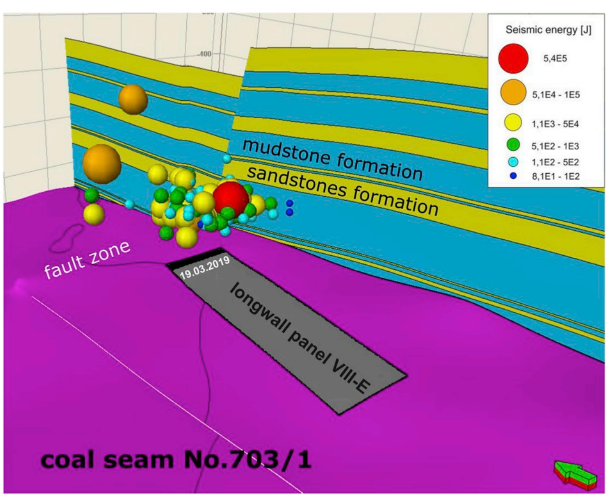

Fig. 2. Seismic events location on 3D model of coal deposit at MUSE2 site ("Rydułtowy" Mine).

gravitational field. Changes in the distribution of this field cause the formation of geological stress fields of anthropogenic origin that overlap the natural stress fields in the Earth's crust. The resultant fields strive for relaxation in accordance with the principles of dynamics shaped by the rotation of the earth and its position relative to the moon and other planets in the solar system (crust tides). Stresses in the near-surface layers of the crust are the cause of rock mass movements and the occurrence of seismic events, such as mining tremors. Therefore, observations of gravity field changes over time can provide new data, which is useful for the analysis of seismic phenomena and hazards (Kotyrba, Balicki, & Kortas, 2005).

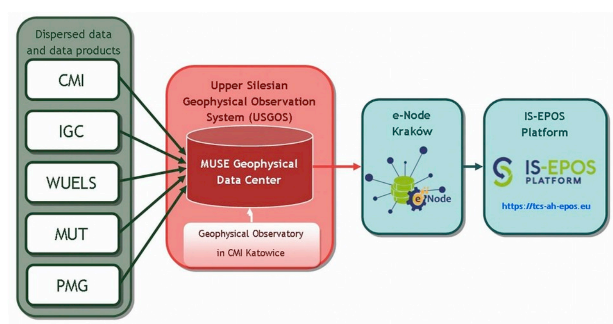

Fig. 3. The schematic diagram of data, data products and metadata transfer to and from USGOS in Katowice and MUSE Episode publication.

The gravity observation system will consist of continuous and periodic gravimetric measurements. A continuous record will be collected at two locations in the Upper Silesian region. Periodic surveys will be performed in the form of periodic hybrid gravimetric campaigns based on dense relative measurements. The data from relative measurements will be referenced to the data obtained from an A10 absolute gravimeter measurements (10 stations at the MUSE test area). This methodology has been proven to be a reliable tool for this task (Dykowski, Kryński & Sękowski, 2014). Data processing of absolute gravity measurements will include the most up to date recommendations of the International Association of Geodesy.

The continuous measurements of gravity variations will be carried out by two gPhoneX relative spring gravity meters which are proven to be effective for precise gravity variation monitoring as well as for seismic signal recording (Meurers, 2012; Niebauer, Mac Queen, Aliod, & Francis, 2011). They will be installed in specially designed sites in the USGOS in the CMI (area of abandoned mining) and "Ignacy" Historical

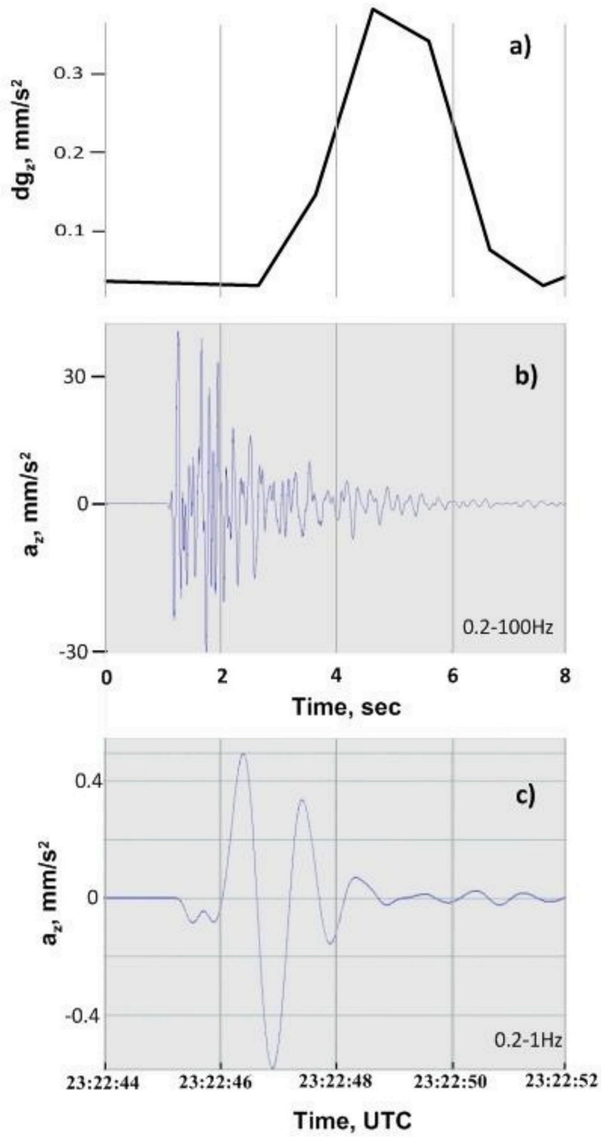

Fig. 4. Recordings of mining tremor with local magnitude M = 2.6 by gPhoneX - vertical acceleration (a) and GeoSIG VE-53 BB seismometer - vertical acceleration in band 0.2–100 Hz (b) and low pass filtered vertical acceleration (c) at "Ignacy" Historical Mine in Rybnik.

Mine station (area of active mining). These instruments record time synchronized gravity variations at a 5 Hz sampling rate. Therefore they provide a valuable signal in seismic and tidal frequency ranges, respectively 0–2 Hz and $1–2{\cdot}10^{-5}$ Hz. For a reliable gravity variation record, each gPhoneX gravimeter will be properly calibrated using co-located gravity observations. An example of a gravity record of mining seismic event (tremor) by the gPhoneX system at the "Ignacy" Historical Mine is presented in Fig. 4a, after removal of the tidal effect. Although this record has low time resolution, which is not comparable to seismometers, it shows clear seismic signal characteristics. The gPhoneX record shows averaged over periods of 1 s raw gravity readings (5 values per second). For comparison purposes, Fig. 4b shows a signature of the same tremor recorded by a 5 s GeoSIG VE-53 BB seismometer which is then differentiated in a 0.2–100 Hz band. Fig. 4c shows the result of a low pass filtration of seismogram data in the band 0.2–1 Hz. The tremor occurred in the area of the "Rydułtowy" Mine on November 20th, 2018 at an epicentral distance of approximately 1 km from the recording stations.

A set of periodic gravity surveys of time will be carried out in a two-stage process in approximately 6-month intervals:

- A reference gravity survey – carried out in 10–11 stations with a portable absolute gravimeter A10 (sn 020) by the Institute of Geodesy and Cartography, Warsaw.
- A densification relative gravity survey – carried out in 180–200 field stations by a CG5 and a CG6 gravimeter by the Central Mining Institute. These surveys allow spatially distributed gravity variations in the Upper Silesia area to be determined.

Periodic, gravity surveys will be carried out in the following regions:

– MUSE1 – in this area a net of 93 irregularly spaced benchmarks has been set up. The distance between benchmarks varies from 4 to 5 km. There are areas of abandoned and active deep mines in the region – Fig. 5.
– MUSE2 – in this area a net of quasi-regularly spaced benchmarks has been set up over planned long walls in coal beds lying approximately 1000 m deep – Fig. 5.

The location of gravity stations at the MUSE1 and MUSE2 test sites are shown in Fig. 5a and b.

The data from the periodic measurements will be used to map regions where the gravity increases or decreases over time. An example of this type of differential map, elaborated from data sets collected in the years 2003 and 2011, is shown in Fig. 6 (Kotyrba, 2014).

Temporal changes in the regional gravity field and continuous recordings of gravity will be analysed in relation to lithostratigraphy, tectonics, the location of mining works and seismic events. 10 series of periodic gravity measurements in the MUSE test sites are scheduled between the years 2017–2022.

3.2. Seismicity monitored by surface stations

Seismicity in the USCB is characterized by phenomena induced by coal mining. The strongest seismic events reach the magnitudes of M3-M4 and can cause damage in buildings on the surface and sometimes damage in underground workings (Mutke & Dubiński, 2016). The strongest seismic events usually result from stress relaxation in tectonic structures and are triggered by a local change in stresses and strain caused by underground exploitation (Marcak & Mutke, 2013). In the case of the strongest tectonic earthquakes, deformation of the rock mass in the vicinity of the seismic source and in the epicentre area on the surface, but sometimes not located directly above the extracted coal in the Longwall Panel area, is expected. These deformations which are associated with strong mining seismic events cause additional subsidence in the area, which is independent to continuous deformations induced directly by the extraction of hard coal. This geodynamic process will be monitored by the Upper Silesian Regional Seismic Network (USRSN) network and compared with airborne and satellite data. The differential airborne and satellite deformation maps will be compared with locations and the distribution of strong mining seismic events in the MUSE area. In the USCB each year dozens of seismic events that reach magnitude of above 3 are registered (Fig. 7).

In the MUSE1 test site, continuous measurements of seismicity are carried out on a regional scale. For this purpose, as part of the EPOS-PL project, the Upper Silesian Regional Seismic Network (USRSN) will be extended. The seismic events will be recorded by 15 seismometers, 10 accelerometers, 5 boreholes accelerometers and 5 rotational vibration sensors. The angular velocity of ground motion can be important for structures located in the epicentral zone of induced seismic events (Zembaty, Mutke, Nawrocki, & Bobra, 2017). This zone will be permanently monitored on the MUSE1 test site. All measurements will be recorded continuously and the data sent to the MUSE Geophysical Data Centre located in CMI in Katowice. The photos of the stations in CMI and in the “Ignacy” Historical Mine in Rybnik are shown in Fig. 8.

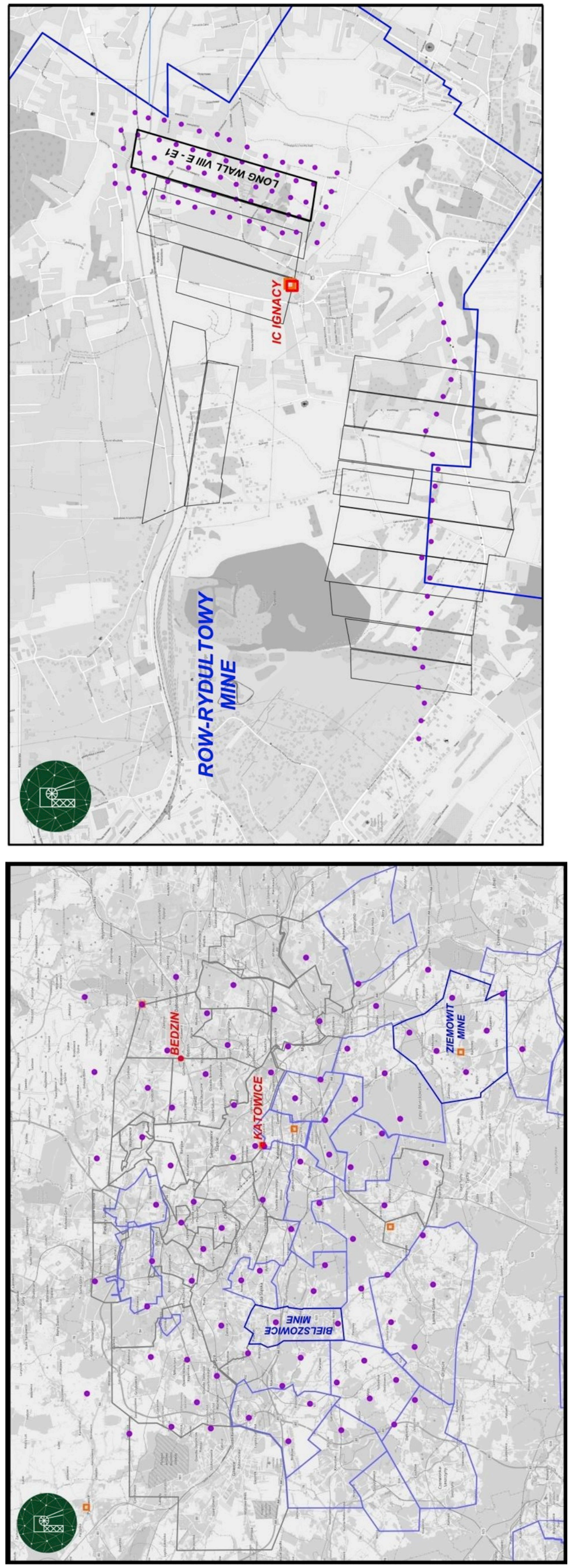

Fig. 5. (a). Location of periodic gravity surveying stations at MUSE1 on the background of abandoned (grey line) and operating mines (blue line) (b). Location of periodic gravity surveying stations at MUSE2 on the background of long wall panels.

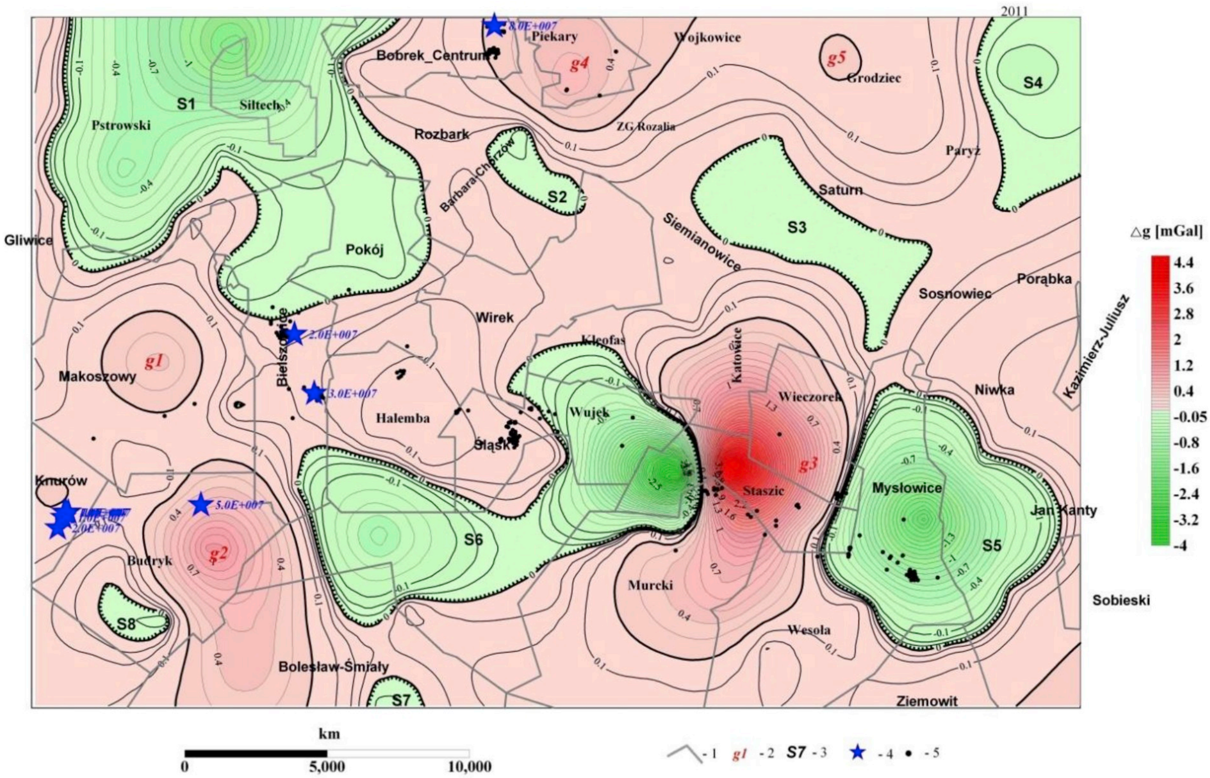

Fig. 6. Temporal changes of gravity g between years 2003 and 2011 on the background of active mines location (1 – border of the mining area, 2 – positive anomaly of g, 3 – negative anomaly of g, 4 – epicentre of a tremor of with energy > 10^7 J, 5 – epicentre of a tremor with energy < 10^7 J).

A seismo-geological model showing the distribution of seismic events induced by mining in the test site will be constructed to provide better understanding of “in rock” mass deformations due to mining tremors.

3.3. Seismicity and changes of stress in rock mass monitored by underground stations

In 2018 the construction of two sets of 96-channel flameproof Seismic Observation Systems (SOS) started in the Central Mining Institute (Fig. 9). The systems will be installed in the “Bielszowice” (MUSE1) and "Rydułtowy" (MUSE2) coal mines. One of the main features of these systems is integrated software which enables the analysis and interpretation of the seismic events recorded. The software is especially useful for fast 3D seismic event location, the calculation of seismic energy and seismic source parameters and passive tomographic imaging (Lurka & Mutke, 2017). The system is mobile, easy to install and can easily locate uniaxial and triaxial seismic borehole sensors in places that surround areas of high seismic activity in mines. The system is able to conduct bent-ray passive tomographic imaging which utilizes the recorded events and is based on the extremely fast Levenberg-Marquardt optimization algorithm.

The main purpose of the installation of these seismic systems is to assess seismic and rock burst hazard in the two mines with the use of the following methods: tomographic P-wave velocity images, the 3D distribution of seismic events, peak particle velocity (PPV) values and temporal changes of the b value of the Gutenberg-Richter relation (Mutke et al., 2009; Mutke, Masny, & Prusek, 2016). Additionally, within the project, a 16-channel continuous in-situ stress measuring system is also planned to be installed in the “Bielszowice” mine. This stress changes measuring system is going to supplement the 96-channel seismic monitoring system and will provide information on the dynamic changes of stress state in a rock mass.

The regional seismic network USRSN will be supported by local underground Seismic Observation Systems (SOS) in mines. The data collected by those systems enables displacements of rock mass in near wave field and processes occurring near to seismic focal zones to be studied.

3.4. Surface deformations monitored by GNSS

In the case of Global Navigation Satellite System (GNSS) measurements (Araszkiewicz, Figurski, & Jarosiński, 2016), it has already been proven that the general pattern of strain rates in Poland shows rather small deformation rates and requires long-term GNSS measurements and appropriate mathematical methods. Even after data processing, the estimated GNSS strain rates have a low level of reliability. Therefore, most current pieces of work mainly focus on motions in the mountain (Jamroz & Kaplon, 2005) or mining areas (Mirek & Mirek, 2016). In this project, we will try to identify the ongoing surface deformations and to study the relationship between the geometry of the USCB and its geodynamics.

This will be carried out at two levels of point density in the dedicated MUSE test sites. As previously stated, the first site, named MUSE1, contains 95 points which are spread over a USCB area of about 40 km^2. The second site, located in the MUSE2 area, was designed to monitor terrain subsidence and lateral displacements during movement of long wall No. VIII E-E1 in the coal mine “Rydułtowy” and is much smaller than MUSE1. GNSS measurements have been scheduled twice a year until the end of 2021. The first two series of measurements took place in April 2018 and November 2018 and they show subsidence of 0.20 m at one of the points located in the MUSE2 test site. GNSS data from MUSE points are processed together with the GNSS data from the local Continuously Operating Reference Station (CORS) collected in the GNSS Data Research Infrastructure Centre (http://www.gns.wat.edu.pl). The processing strategy follows the EUREF Permanent Network (EPN) guidelines and is consistent with the MUT analysis for operational EPN products and was used successfully in the EPN Repro2

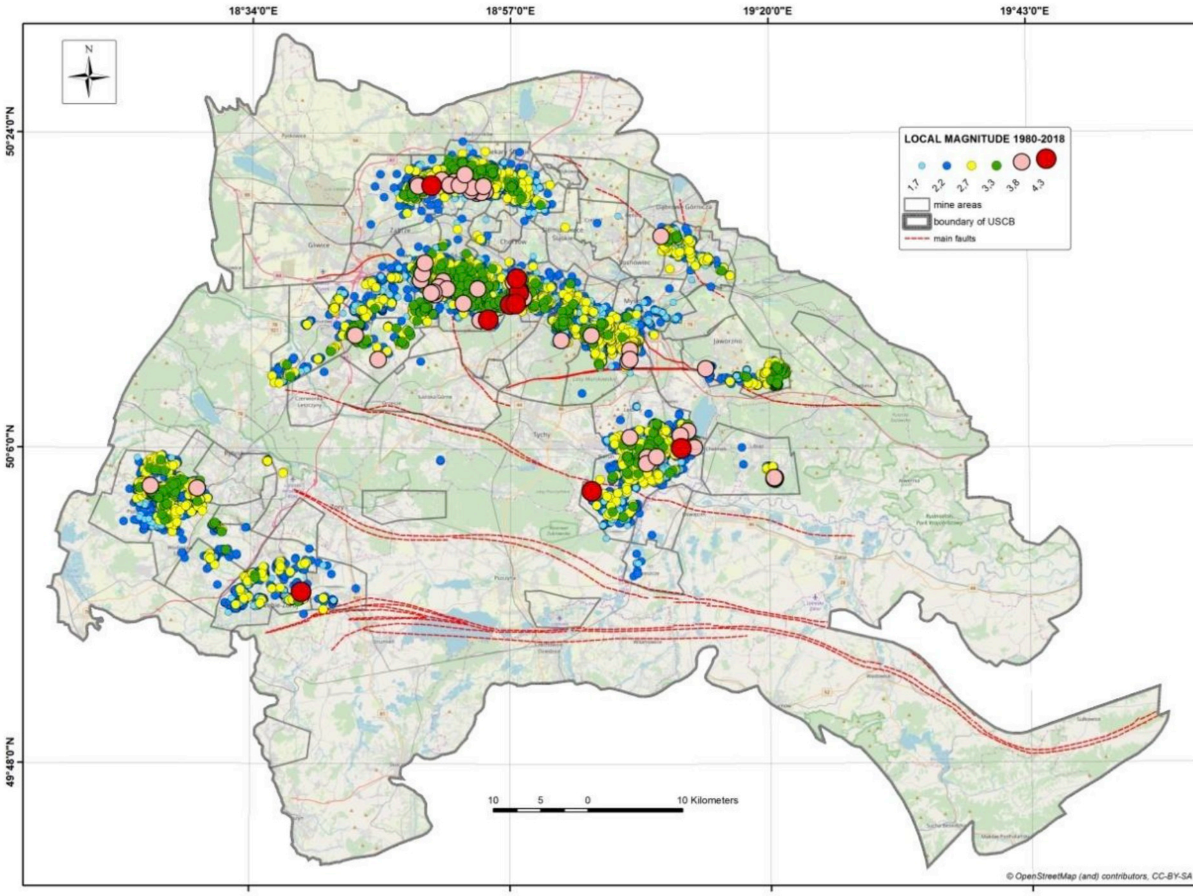

Fig. 7. Mining-induced seismic events with magnitude M > 3.0 recorded in the Upper Silesia Coal Basin – Poland from 1980 to 06.2018 on the situational map and the main tectonic faults.

project (Araszkiewicz & Völksen, 2017). Finally, to ensure proper alignment with the current ITRS/ETRS realization, the MUSE solution is combined with the MUT-PL solution provided in the frame of Task 5 of the EPOS-PL project.

3.5. Ground water table movements

Activation of tectonic faults is one of the factors triggering seismic events. Analysis of seismic tremors in the USCB shows that the strongest of them originate in tectonic stress and fault activation. Hydrological effects in the vicinity of faults (in shallow and deep aquifers) have been reported in many seismic prone areas across the world (Cooper, Bredehoeft, Bredehoeft & Papadopulos, 1965; Wang & Manga, 2010). These effects are time dependent and can occur before, during and after seismic events (Doglioni, Barba, Carminati, & Riguzzi, 2014). Variations of the water table level during the earthquakes are similar to the records of ground vibrations. For observation and study of the water-related effects of mining-induced seismicity, three locations were selected at MUSE test sites. In these locations, PM Ecology water table observation systems will be installed in shallow boreholes which are close to fault lines. In the MUSE2 area, the monitoring points are located on both sides of the “Kolejowy” fault (throw 180 m to the North). Single monitoring stations will be installed in the areas of the “Piast-Ziemowit” mine (the “Imielinski” fault with 180 m throw to the North-East) and the “Bielszowice” mine (the “Kłodnicki" fault with 200 m throw to the South) (MUSE1).

3.6. Terrain deformation monitoring using aerial and satellite observations

In order to measure subsidence across the whole project range, a mixture of different measurement techniques has to be deployed. These techniques should provide dense information covering areas of interest. The InSAR (Synthetic Aperture Radar Interferometry) technique and photogrammetric techniques were used to measure terrain subsidence in the study areas. The radar data is acquired by the ESA (European Space Agency) Sentinel-1 sensor with a six day revisiting time. Both ascending and descending imagery (Ilieva et al., 2018) and two deformation determination methods are used, these being: (1) DInSAR (differential InSAR) using ESA's SNAP toolbox and (2) PSI (Persistent Scatterer Interferometry) using SARscape software. The subsidence determination using the InSAR remote technique will be performed continuously throughout the project. Geodetic levelling data from the PMG company and GNSS measurements will be used as validation data for InSAR. Moreover, to improve InSAR determined deformations, a troposphere delay model based on GNSS observations will be developed for the study area. The initial results related to the monitoring of the mining deformation life cycle using differential InSAR have already been published by (Ilieva et al., 2019) for the MUSE1 study area. Furthermore, five corner reflectors have been deployed in the MUSE2 study area, close to the mining activity region. The reflector design (Fig. 10) allows SAR data from both the ascending and descending Sentinel-1 orbit to be acquired, provided that the reflector is oriented in the east-west direction. Typically, phase differences allow deformations in LOS (Line of Sight) to the satellite to be determined. Using these reflectors, it will be possible to decompose LOS deformation vectors into horizontal and vertical components of deformation.

One additional corner reflector is located in MUSE1 close to a tectonic fault. This reflector is integrated with a permanent GNSS station. It will enable the validation and correlation of both deformation time series.

Fig. 8. Photos of geophysical stations at GIG in Katowice (a) – on pedestal are seen gravity meters CG-6, gPhoneX, 5 s GeoSIG seismometer and 1 s Willmore'a MKIII seismometer and at "Ignacy" Historical Mine in Rybnik (b) – on pedestal are seen gPhoneX gravimeter, 5 s GeoSIG seismometer and rotational R1 angular velocity sensor.

Using InSAR, it is possible to determine small initial deformation or deformation in post-mining areas. To determine larger values of subsidence (more than 0.1 m) and especially high dynamic subsidence photogrammetric techniques are used. Among various laser scanning variants (airborne, terrestrial and mobile) first of all low cost-sensors mounted on a UAV platform (Unmanned Aerial Vehicle) will be utilized. Two variants of this type of low-cost systems will be tested: (1) UAV photogrammetry based on a consumer grade RGB camera and (2) a laser scanning system based on the Velodyne HDL-32 scanner. In both variants, the UAV platform is the Aibot X6 drone. Detail about the sensors and their configurations are provided in (Jóźków, Wieczorek, Karpina, Walicka, & Borkowski, 2017). The final product both in (1) and (2) is a very dense point cloud, which consists of points with 3D coordinates. These point clouds are then the subject of filtering in order to select points representing terrain surface only. Using terrain points, a Digital Terrain Model (DTM) can be generated. With the use of

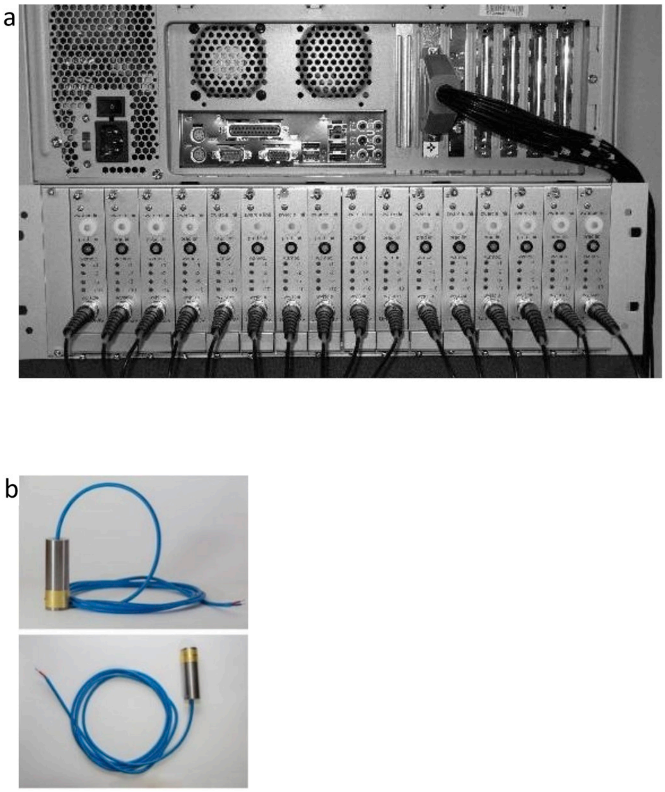

Fig. 9. Seismic recording system SOS – (left) panels of seismic signal receiver station DLM-SO; (right) low frequency DLM geophone sensor with natural frequency 1 Hz and effective bandwidth 1–600 Hz.

multitemporal DTMs, time lapsed differential terrain models can be determined. These models represent terrain subsidence over a given time span.

4. Summary

In the context of the EPOS-PL project, research infrastructure is being built to conduct integrated observations of geodynamic processes and their effects in the form of geohazards in the area of the Upper Silesian Coal Basin. Observations are carried out on a regional scale, covering mining and post-mining areas in the northern part of Upper Silesia – MUSE1 (30 km × 40 km) and more specifically on a local scale, in an area covering part of the "Rydułtowy" coal mine – MUSE2 (2 km × 4 km).

In order to create the MUSE episode in the project, it was necessary to build the Upper Silesian Geophysical Observation System (USGOS), located in the Central Mining Institute in Katowice. The system will gather and integrate data from continuous and periodic measurements and surveys, as well as geological 3D models and other metadata. All data will be filed on disc matrices of the MUSE Geophysical Data Centre.

The MUSE episode makes it possible to document and analyze geophysical and geodetic observations in order to investigate causal relations between geodynamic processes taking place in Upper Silesia and mining. These processes are a source of anthropogenic hazards related to induced seismicity, terrain deformations and floods. Within USGOS a virtual research laboratory for anthropogenic hazards in the Upper Silesia Coal Basin (VLAH-USCB) will be created, constituting a new approach to building research infrastructure (RI) for bilateral knowledge transfer between industry and science.

The research infrastructure being built as part of the MUSE episodes and the regular conduct of dedicated observations and research will allow for a deeper understanding of the mechanism of anthropogenic hazards in the area of Upper Silesia and in the future for better control of these hazards.

Conflicts of interest

None declared.

Ethical statement

Authors state that the research was conducted according to ethical standards.

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Fig. 10. SAR reflector deployed on the study area.

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