Monitoring of deformations inside the rock mass

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Continuous and periodic monitoring of gravity

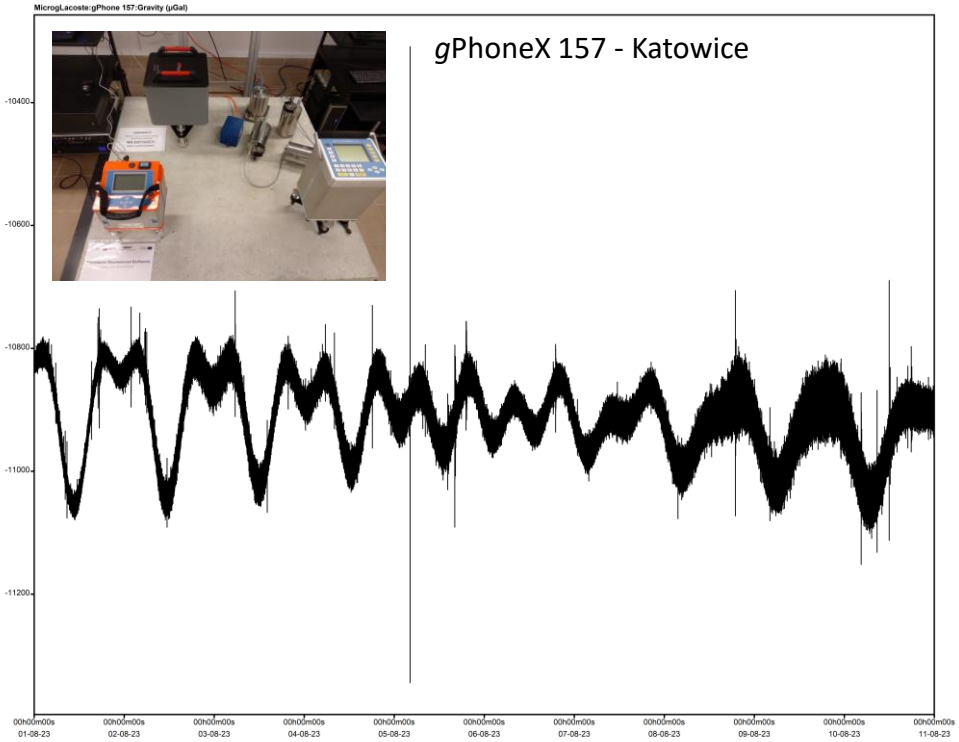
The seismicity in areas of abandoned mines in the process of flooding has a similar origin as the seismicity observed during the process of mining in the rock mass.

Both processes change the density distribution in the rock mass over time and create local areas where additional stresses appear in the geostatic stress field. Such seismogenic phenomena take place in particular in the following regions:

- regions where the mining (primary) and secondary post-mining voids are collapsing,
- regions unevenly saturated by water,
- regions with residual tectonic stress (faults).

The main force which enables and governs these phenomena is gravity.
Gravity can be monitored by continuous and periodic measurements.

Continuous monitoring of gravity



*g*PhoneX 157 - Katowice

Gravity oscillations recorded by a *g*PhoneX tidal gravimeter in Katowice over a period of 10 days. Long-term oscillations correspond to the tides of the Earth's crust, while short-duration anomalies are related to ground movements and vibrations caused by mining induced shocks and earthquakes.

Live gravity data are available at: www.gog.gig.eu

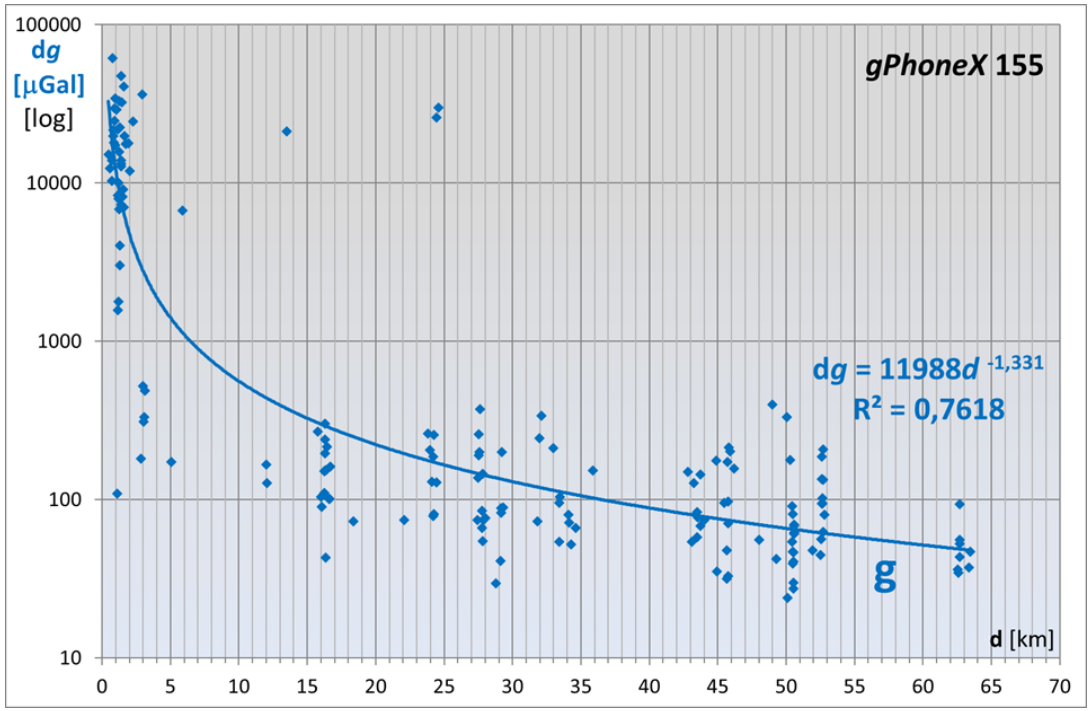
Continuous monitoring enables observation of the Earth's tides, which are temporarily disturbed by ground movements and seismic vibrations produced by near and distant sources. For sources which are located near gravity observation point we observe additional abrupt changes in gravity caused by the shock wave travelling from the source of the mining-quake. This feature can be used to discriminate local mining-quakes from distant tectonic earthquakes.

Continuous monitoring of gravity

Experiences gathered during the realisation of the EPOS-PL project show that the data from continuous gravity measurements correlate well with seismic data collected from seismological networks and supplement them with additional information about the characteristics of ground motion and the source mechanism of specific earthquakes.

Relationship between the maximum amplitude of gravimetric signals (logarithmic scale) and the epicentral distance *d* from the mining-quake in the USCB, for a data set of events collected by GRSS network with local magnitude M_L>2 .

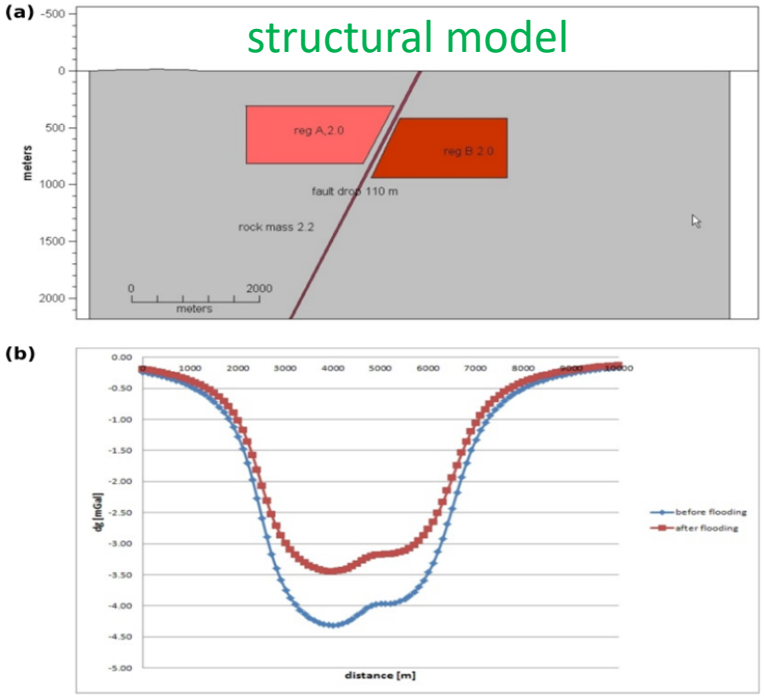
*g*PhoneX 155 - Rybnik

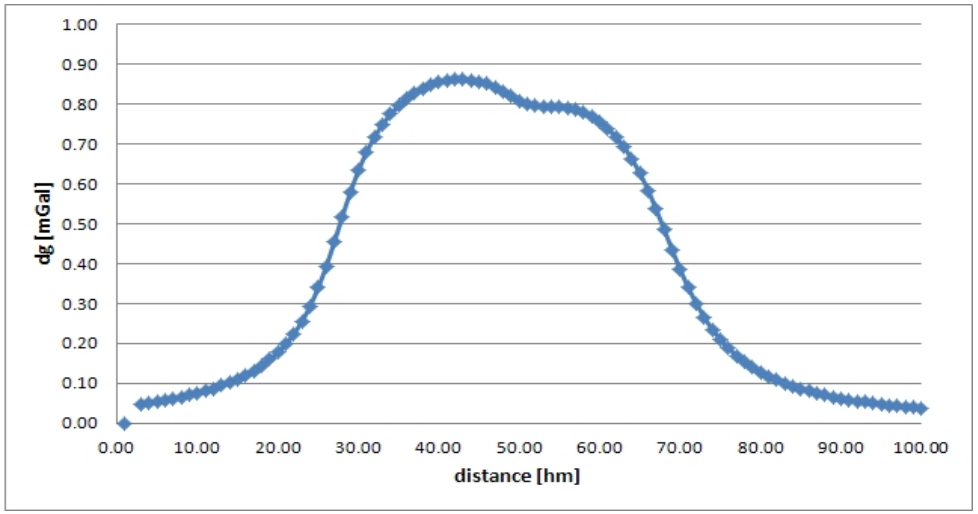


Periodical gravity measurements

In the case of periodical measurements, we observe temporal changes in the bulk density of the surveyed rock mass. This can be caused by increase of the rock mass stress or relaxation and release of seismic energy, followed by changes of the surface morphology (e.g. subsidence, heaving).

Filling the voids left after mining with water changes the mechanics of the rock mass. Key points of that mechanics are borders of exploitation regions and fault planes depicted in a structural model of rock mass (on the left) and the amplitude of the gravity field change observed (on the right).

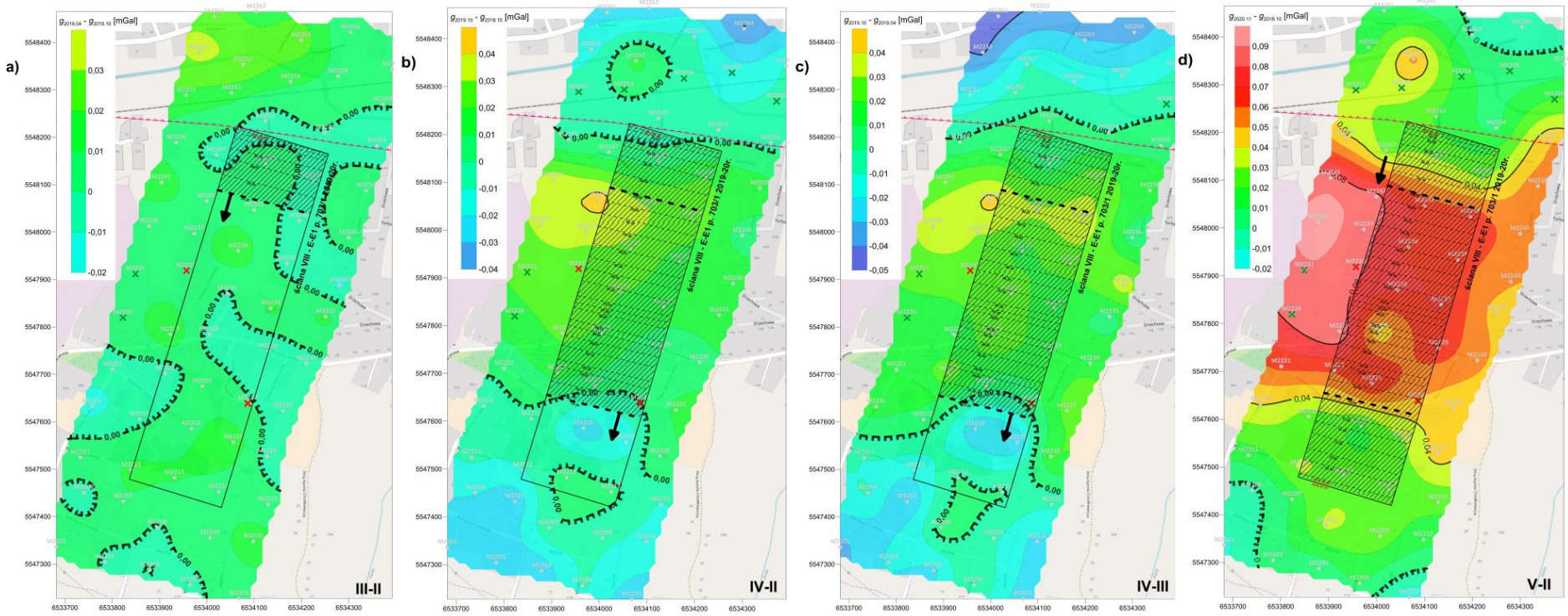




gravity field change

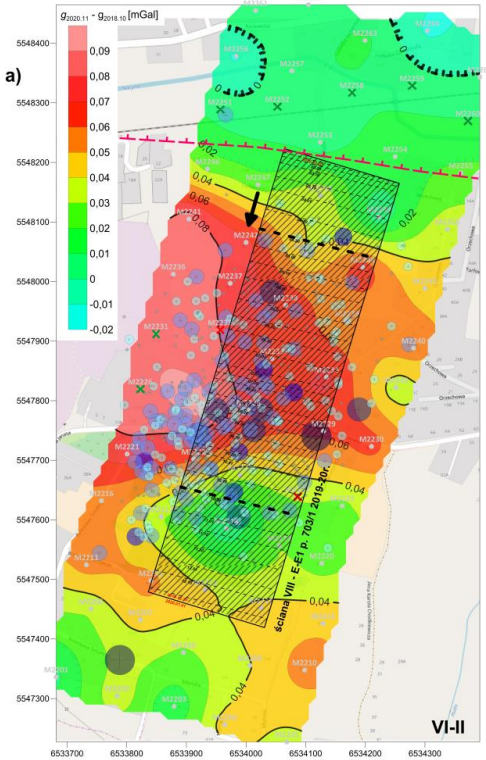
Periodical gravity measurements

Differential maps of changes in the gravity field over the exploited longwall at EPOS-PL test site in 4 time periods

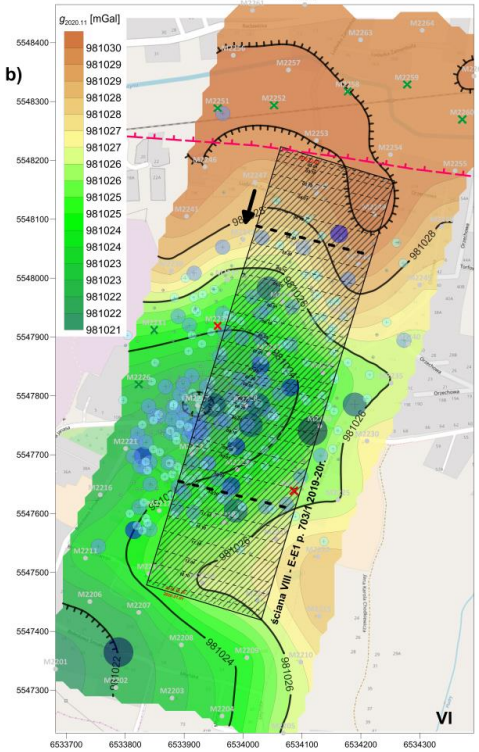


a) 2018.10-2019.04 b) 2018.10-2019.10 c) 2019.04-2019.10 d) 2018.10-2020.06

Periodical gravity measurements & tremors



2 year changes of *g* over the exploited longwall



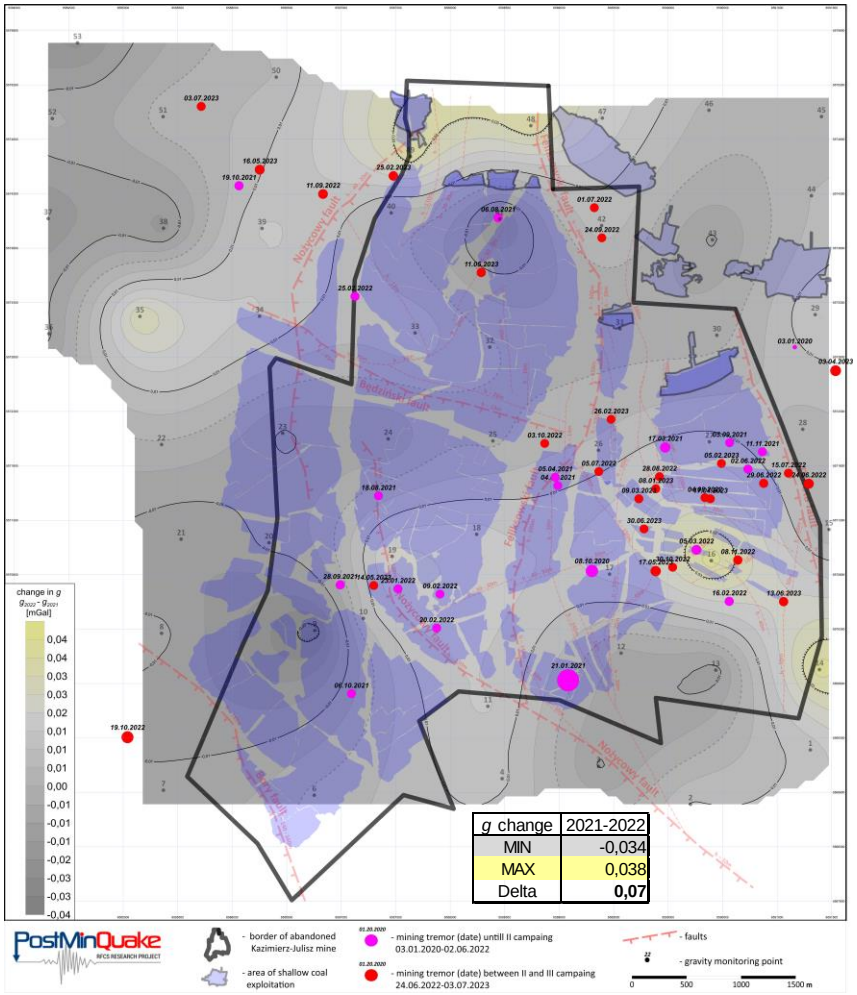
Gravity field distribution over the exploited longwall

Seismic tremors (466) with energy > 10E4 J from the period of longwall exploitation (EPOS-PL test site) on the background of the map of:

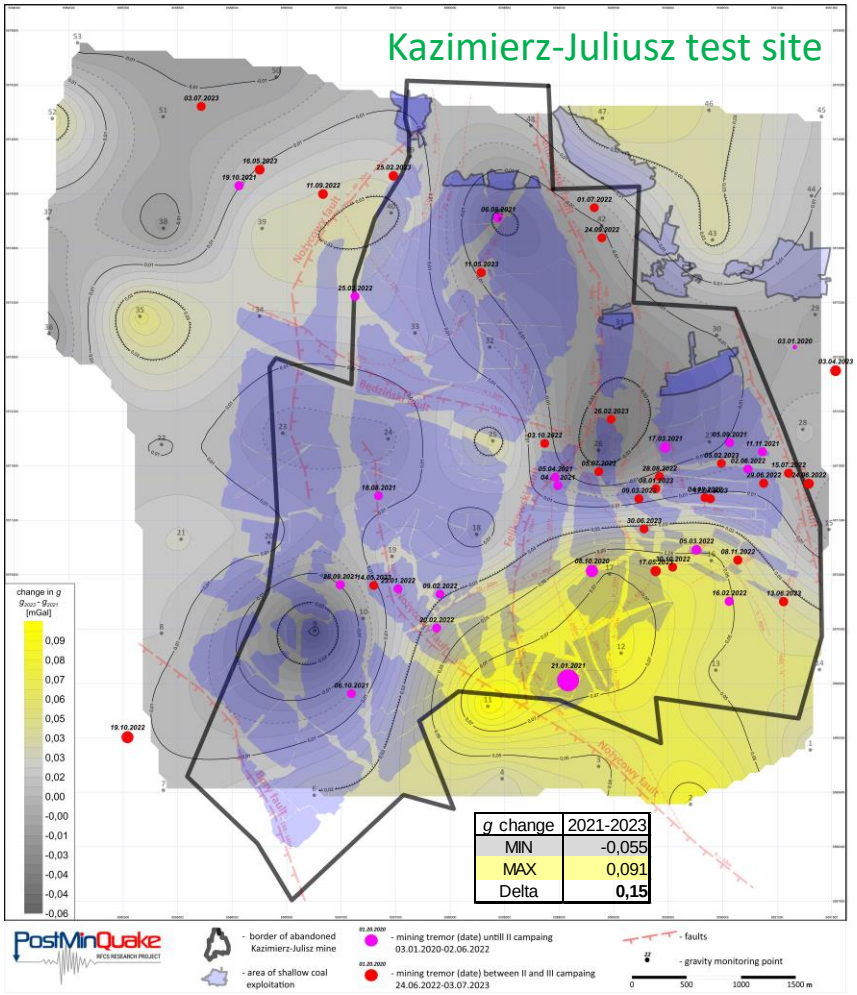
a) differential changes of the gravity field over the exploited longwall 11 months after completion

b) distribution of the gravity field according to measurements of the last series

Temporal changes of the absolute gravity



2021-2022



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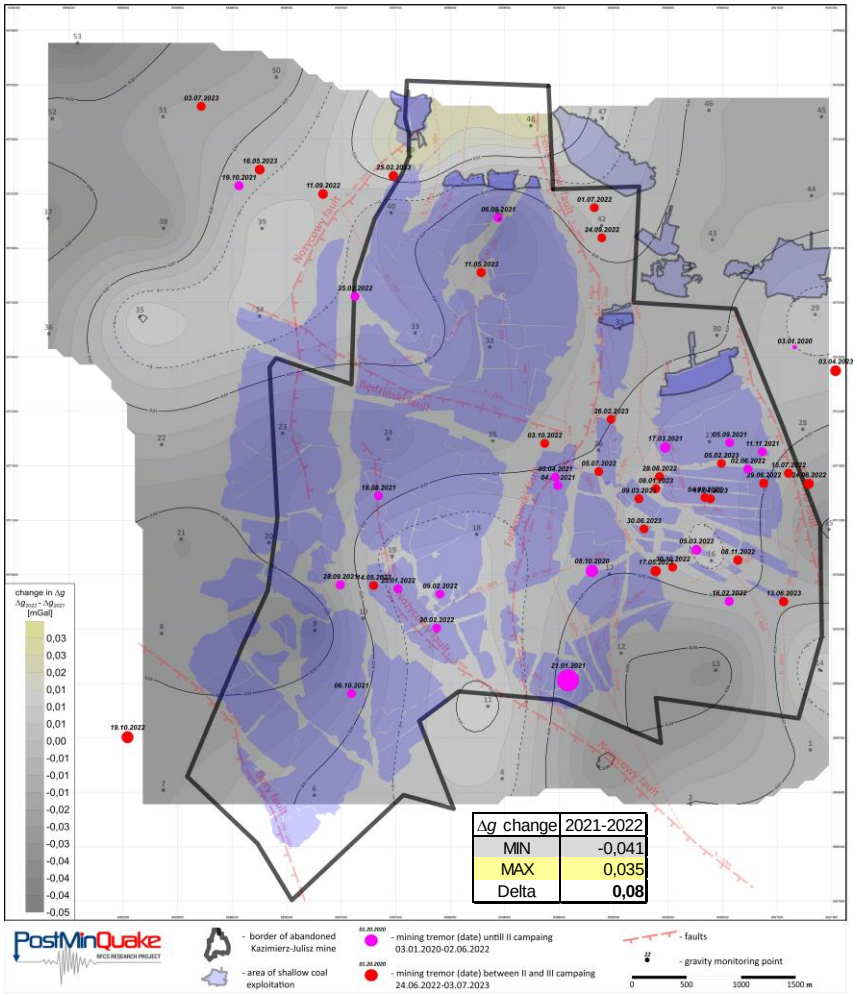
Temporal changes of Bouguer anomaly



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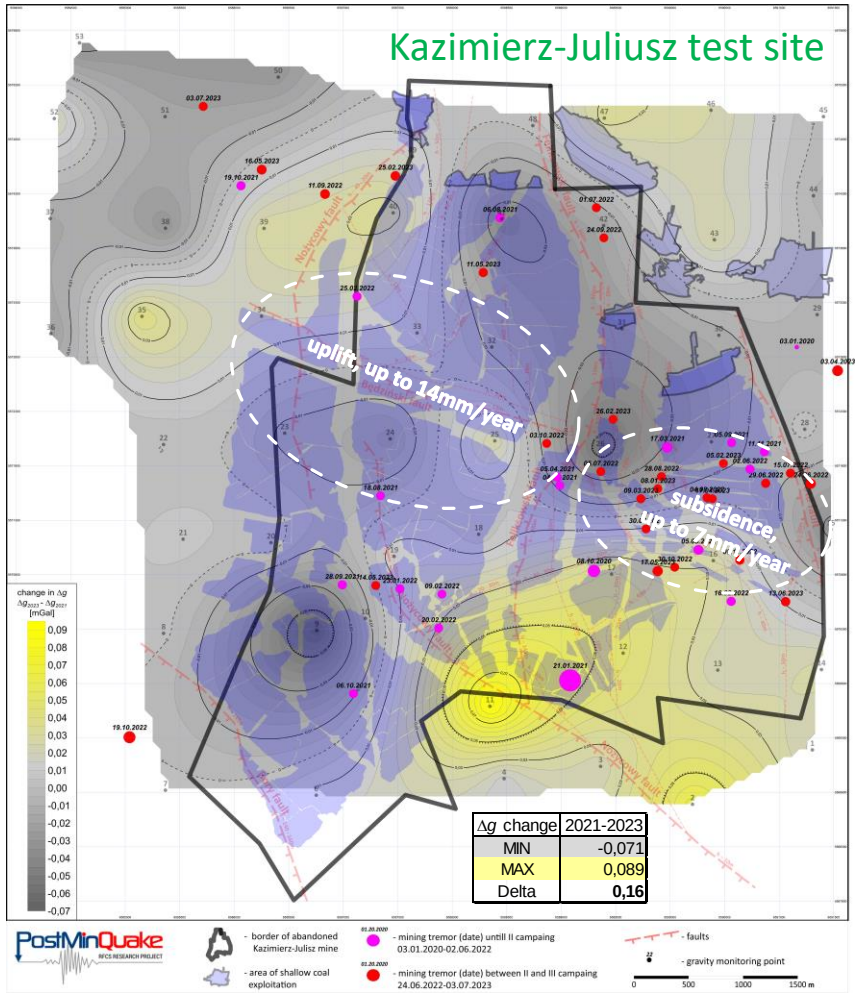

2021-2023

Conclusions - Continuous gravity measurements

- Continuous gravity measurements have been introduced relatively recently to study and monitor the seismic activity induced by mining and post-mining, and at present, remains in a development phase.
- Similar to seismological observations, the possibility to detect (post)mining earthquakes in continuous gravity recordings depends on the earthquake magnitude and its distance to the gravimetric station.
- Based on the experience collected from the gravity monitoring in the Upper Silesian Coal Basin, we recommend using this method as a supplement to seismological monitoring. The deployment of one gravity measuring station in the area of the former mine during flooding seems to be sufficient for an integrated seismo-gravimetric monitoring.

Conclusions - Periodic gravity measurements

- Periodic gravity measurements provide spatial information about the location of regions where the gravity changes are anomalous. Differential maps created from measurement data obtained at different times allow for mapping areas where the processes of lowering or increasing of the average density occur.
- As shown in the examples (EPOS-PL, PMQ Kazimierz-Juliusz), the measurement of periodic changes of g and Δg gives good and verifiable results. Differential maps allow for regionalization of areas where rock mass movements cause density changes leading to tremors, while other methods cannot. As added value the recorded changes in g make possible to comment on the change in the stress state.
- At the moment, it can only be said whether the tremor occurred in the stress accumulation zone or in the relaxation zone for the duration of a given series of measurements. In order for the picture to be more complete, the measurement series should be more frequent and observations should be made until the mine is completely flooded (then the tremors data base would also be much richer and better correlations could be obtained).

Thank you

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