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Original Research Article

ROCK MASS PRECONDITIONING METHODS IN UNDERGROUND MINES AND WAYS OF ITS EVALUATION – STATE-OF-THE-ART

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A b s t r a c t

Currently, the most serious problem associated with underground mining of deposits is geomechanical hazard, which significantly disrupts the production process and exposes the mining crew to a threat to life and health. As recent achievements in the field of minimizing geomechanical hazards show, rock mass preconditioning is the most effective way to prevent the risk of rock bursts and mining-induced seismic activity in underground mines. In principle, rock mass preconditioning involves reducing rock mass strength parameters by the controlled creation in the fractured zones by introducing an external force inside the rock mass. Most often, this can be achieved using hydrofracturing or blasting. This paper is focused on the description of the current State-of-The-Art in rock mass preconditioning methods which are applied to improve the efficiency of ore extraction in underground mines. Selected ways of rockmass preconditioning evaluation has been analysed and future ways of development in the scope of active rock mass preconditioning has been described.

Keywords: rock mass preconditioning, hydrofracturing, destress blasting, underground mine, geomechanical hazards

1. INTRODUCTION

In geomechanics, rock mass preconditioning is a method aimed at weakening the strength parameters of rocks, e.g. by forcing them to crack, in order to reduce their potential to accumulate elastic energy and thus reduce the risk of seismic activity and rock burst occurrence. According to Córdova et al. [1] rock preconditioning is essentially the treatment of the rock mass with an appropriate dynamic process to aim at generating cracks and fractures by activation of the local rock structure with existing discontinuities network or by creation of new zones of cracks and fractures (Fig. 1). The primary goal of this process is to decrease strength parameters of the rock mass. According to recent research works three main ways of preconditioning the rock mass may be highlighted:

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- Preconditioning with hydraulic fracturing (HF) – this method was commonly used in the oil industry. It assumes a fluid injection to the rockmass with a suitable pressure level what will starts process of fractures creation and their propagation in rock mass [2 - 4]. Creating fractures should be opening in the direction of the minimum principal stress direction σ3, therefore boreholes have to be oriented in the plane of principal stresses σ1 and σ2 [5]. As was highlighted in Córdova et al. [1] usage of this technique has led to a significant reduction of the seismic hazard in subjected sites.
- Preconditioning with explosives – this method is commonly described also as rock mass destressing or destress blasting and consists in forcing the formation of a network of cracks by initiating a charge or group of charges of explosives at specific time intervals [6]. The primary assumption of this method is to conduct blasting in confined conditions to maximise the energy transfer to rock mass. In case of torpedo blasting, deep holes ensure that there are no open faces. In terms of short holes (for example in room and pillar mining) one open face is allowed due to technological requirements [7]. Creating new fissures and reduction of the strength parameters of the rock mass is the primary objective of this method. To increase the resulting damage in the rock mass, blasting parameters like initiation points and firing pattern can be chosen to amplify blast-induced seismic effect [8].
- Mixed preconditioning: In exceptional cases, it is also possible to use a hybrid method including HF and destressing by blasting activities in order to improve the fragmentation of the rock mass that with simultaneous ensuring of high extraction and productivity rates. The method of mixed preconditioning was described, among others, in the work of Catalan et al. [9].

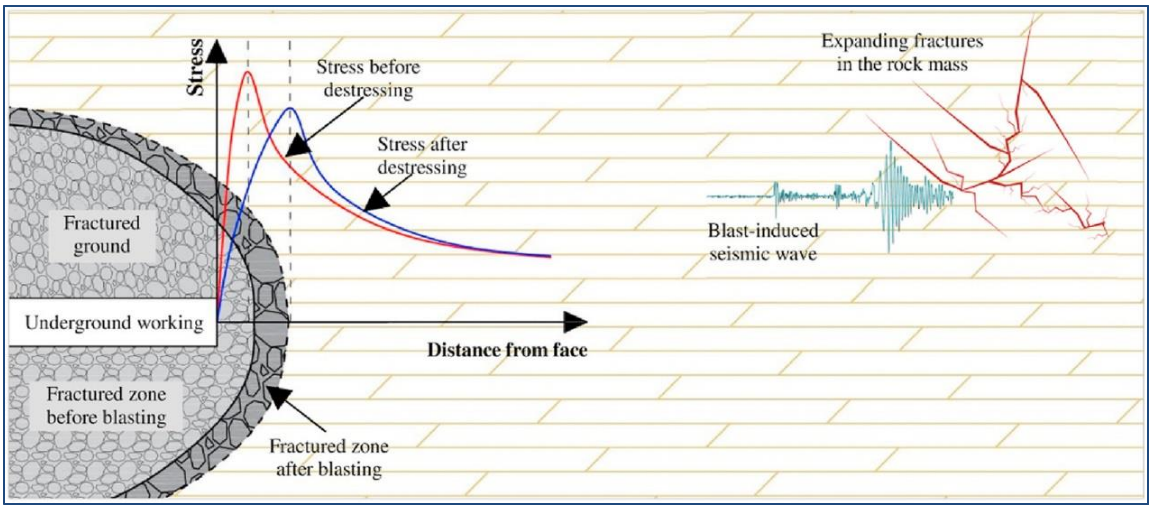

Fig. 1. Basic assumptions of rockmass destressing [6]

Regardless of applied preconditioning methods at least one of two results are observed, namely rock's fractures and seismic vibrations which can occurs separately or together. The main purpose of rock preconditioning is to decrease stress concentration in the vicinity of production area by means of creation of fracture zone in the rock mass [10 -12]. In case of blasting method, which is more energetic, thus more distant zone can be affected. Induced, by blasting works, seismic vibrations may also reduce friction of joint planes what can caused development of existing discontinuities structures or creates new one even in relatively far zones (Fig. 1 – right) [13]. In other words principal aim of rock mass preconditioning is reduction of strength parameters of the rock mass and thus limited energy that can be accumulated by the rock.

2. TECHNOLOGY ROCK MASS PRECONDITIONING FORMULAE

2.1. Directed hydro fracturing

The method of HF rock mass preconditioning was developed already in 1947 but it waited almost fifty years to be tested and implemented to the mining industry. Applying high pressure in a previously drilled hole causes inducing of tensile cracks and thus hydraulic fractures are formed [14]. As it was pointed out in Karkocha [15] effective HF should reduce strength rock parameters and limit rock burst hazard. It needs application of hydraulic fracturing to create significant range of fractured zone. However, achieving this effect requires drilling a significant number of longer holes, preferably reaching the high-strength rock layers. Research presented in Myszkowski et al. [16] and Myszkowski [17 - 19] indicates that the range of HF-induced discontinuities in the rock mass may be up to 25 meters around the fracturing well. Which is a highly satisfactory result, exceeding preconditioning associated with, for example, standard mining blasting. One of the best developed hydrofracturing methods is the so-called Directional Hydraulic Fracturing (DHF) of the Roof. The essence of this technology is to create cracks in the rock in the immediate surroundings of the drilling hole (Fig. 2), dividing the rock layers into blocks of specific dimensions and shapes [20]. This is possible by making a transverse wedge-shaped disc-shaped cut out (Fig. 3).

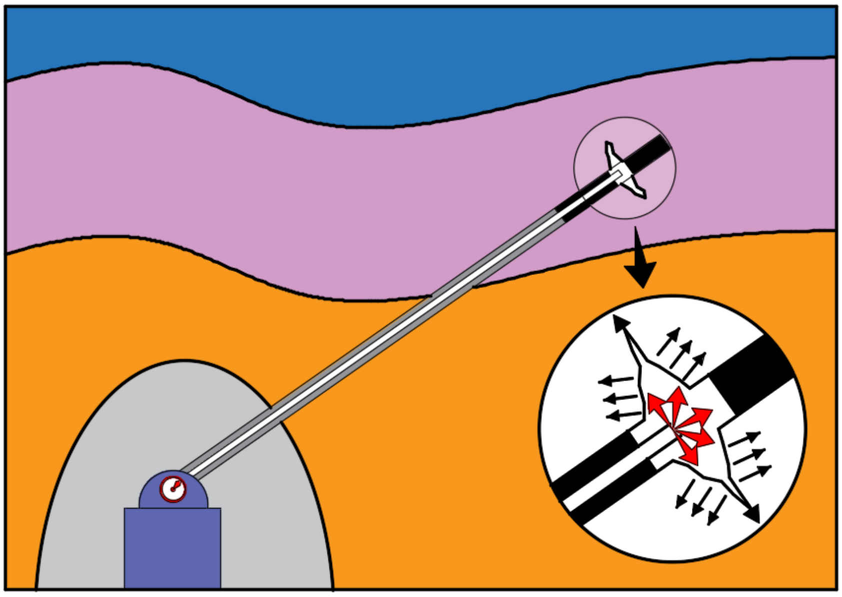

Fig. 2. The essence of the hydraulic fracturing method [21]

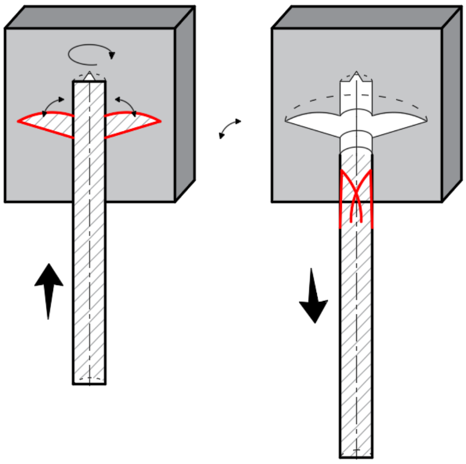

Fig. 3. Device for making transverse wedge-shaped in rock mass (a) sealant placed in the prepared hole before fracturing (b) [21]

The orientation of the cut is always closely related to the direction of the drill hole and is perpendicular to the axis of the hole. Then, in the area of the cut, the liquid is injected under high pressure, which forces the creation and propagation of discontinuities around the hole.

As a result, the fragmentation of the rock mass caused by directed fracturing methods reduces its stiffness and enables its faster deformation in the area of mining works, which ultimately results in:

- reduction of seismic activity,
- reduction of dynamic pressures,
- triggering a controlled roof collapse (within liquidation zones),
- intensive degassing of the rock mass.

Ultimately, based on many studies and experiences in the field of rock mass preconditioning, it should be noted that DHF is a very effective method from the perspective of mitigation of rock burst hazards, however, due to the technology of work, it may disturb the mining process, e.g. by periodically stopping works related to the exploitation and transport of mined material. Additionally, the impact of DHF on the workability of rocks in mining operations has not been considered so far. Analyses in this area would enrich knowledge in terms of not only the impact on the level of safety but also the profitability of mining by reducing mining resistance in selected parts of the mine.

2.2. Torpedo blasting

Rock mass preconditioning may be realised with the use of so-called torpedo blasting. Such a way of rock mass fracturing may be applied both in roof layers and in floor stratum. Torpedo blasting in the roof is aimed at disintegrating the rock medium and involves firing a significant charge of explosives in long blast holes reaching the overstressed roof layers. Examples of rock mass preconditioning with the use of torpedo blasting have been presented in papers [22 - 23]. The firing of the explosive charge causes the propagation of waves that travel over long distances. The magnitude and reach of seismic waves depend mainly on the elasticity of the rock medium, the distance and location of the explosive charge and the size of this charge [24]. Torpedoing blasting in most cases is performed in strong and elastic layers of the roof. An example of destress blasting utilised in one of the Polish coal mines has been presented in Fig. 4.

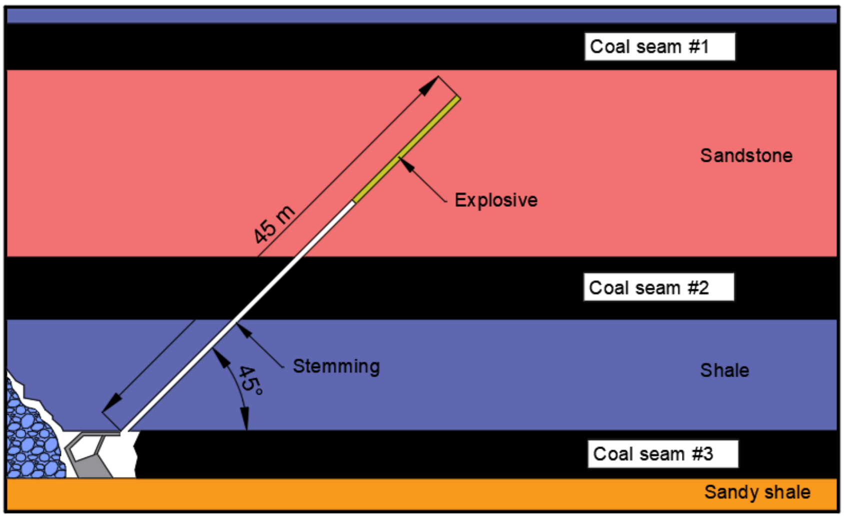

Fig. 4. Scheme of destress blasting in one of Polish hard coal mines [22]

Torpedo blasting, in exceptional cases, can also be used at the level of the deposit in a horizontal arrangement (Fig. 5). In this approach large charge of explosives is detonated in direct vicinity of roof rocks. A rock layers affected in this way should be characterised by a steep nature of fractures. The friction occurring on the surface of these cracks, resulting from numerous irregularities and interlockings, stops the vertical downward movement of rock blocks above the goafs/backfilling area. Immediately after detonation of the explosives, the rock block slips against the force of friction, which results in a rock burst in the excavation when mining crew is in safe place. This method was used successfully in Polish copper mines.

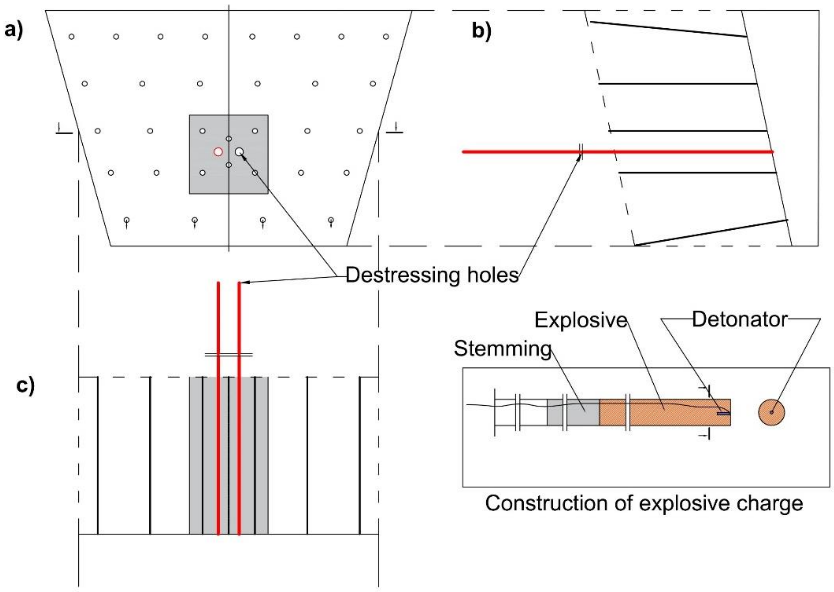

Fig. 5. Scheme of horizontal destress blasting in one of the Polish copper mines

Depending on the exploitation system used and the local geological arrangement of rocks, torpedo blasting can also be carried out in the floor layers (Fig. 6). Floor preconditioning is usually performed when there is a zone of stress concentration in the footwall layer. Performing such blasting causes the stresses to be released by destroying the structure of the floor, and moves the stress concentration area deeper into the rock mass. This method involves the simultaneous firing of explosive charges in holes drilled in the bottom of the excavation. In the case of Polish copper mines, the blast holes are made at an angle of 60–70°, their length is approximately 1.5 m and their diameter is from 40 to 50 mm. The distance between the holes is from 1.5 to 2.0 m. On the one hand, this approach is intended to minimise the potential of the rock mass to create floor bursts. On the other hand, in the case of systems with roof deflection, causing cracks in the floor layers facilitates the process of tightening the excavations and, as a result, minimises the potential for accumulating seismic energy in the pillars and roof layers.

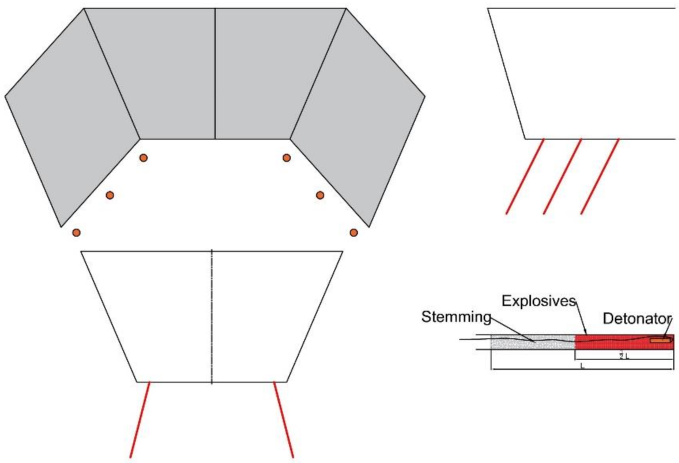

Fig. 6. Scheme of floor destress blasting in one of the Polish copper mines

2.3. Face preconditioning

In exceptional cases, it is possible to apply a comprehensive approach by simultaneous pre-conditioning of the roof, the bed level and the bottom of the workings (Fig. 7). Such a platform can effectively help to distance the stress zone from the exploitation front [25-29] while facilitating the process of roof deflection. However, this type of method should only be used in workings drilled into hard rock. Otherwise, such an approach could have a negative impact on ground control issues [30]. This approach is called face destress and taking into account the impact on the immediate vicinity of the work front, it can be assumed that this preconditioning method may have a positive impact not only on geomechanical safety but also on mining efficiency by "softening" the deposit being excavated.

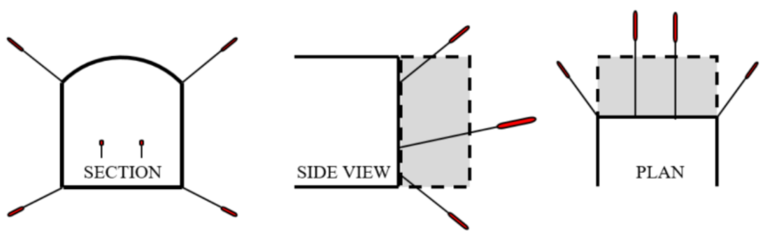

Fig. 7. Face destress blast design in hard rock [31]

2.4. Multiface destress blasting

Multiface destress blasting is a method used mainly in room and pillar mining systems and involves the simultaneous detonation of several to several dozen mining faces in order to maximize the area that is simultaneously affected by mining, and to improve the seismic effect by the amplification of seismic waves propagating from individual faces (Fig. 8).

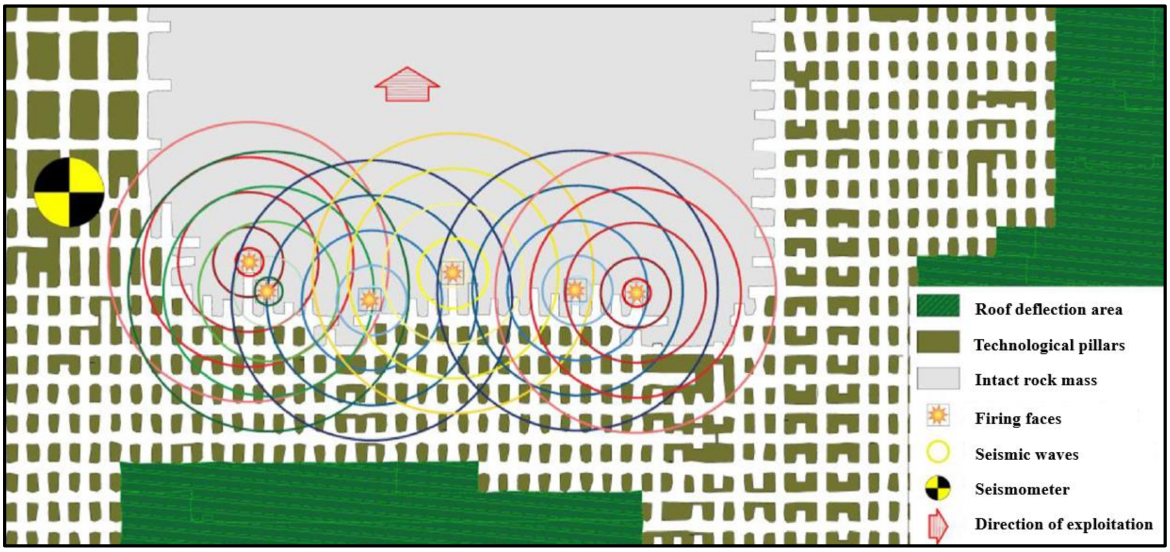

Fig. 8. Scheme of multiface destress blasting [8]

In the case of multiface destress blasting, rock mass preconditioning is performed using standard production holes. Changes are mainly made to D&B patterns by modifying the type of cut, maximizing the delay charge, and modifying the delay sequence (Fig. 9).

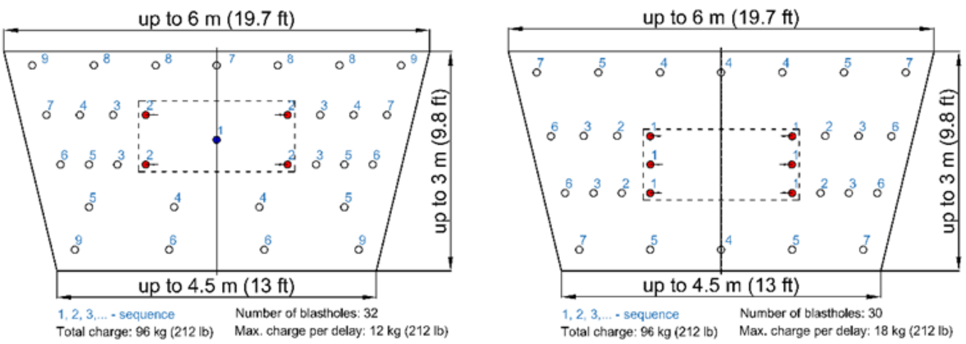

Fig. 9. Example of D&B pattern before (left) and after (right) modification

Detonation of large amounts of explosives in blast holes makes it possible to precondition the rock mass both in the close surroundings of the location of explosives and in zones distant from the place of work by inducing high-amplitude seismic waves [6]. As shown in research [6 - 8], appropriate modifications of D&B patterns make it possible to increase the seismic effect several times (Fig. 10) without affecting the operating costs. The advantage of preconditioning the rock mass with multiface blasting is the possibility of combining high mining efficiency and minimising geomechanical hazards while having no negative impact on the continuity of exploitation. Taking into account the technologies of multiface destress blasting, it is obvious that the maximum pre-conditioning effect is generated in the immediate vicinity of the mining front. Therefore, it is worth analysing how preconditioning of the rock mass using multiface destress blasting affects the efficiency of rock mining. Some case studies in this subject can be found in articles [6-8].

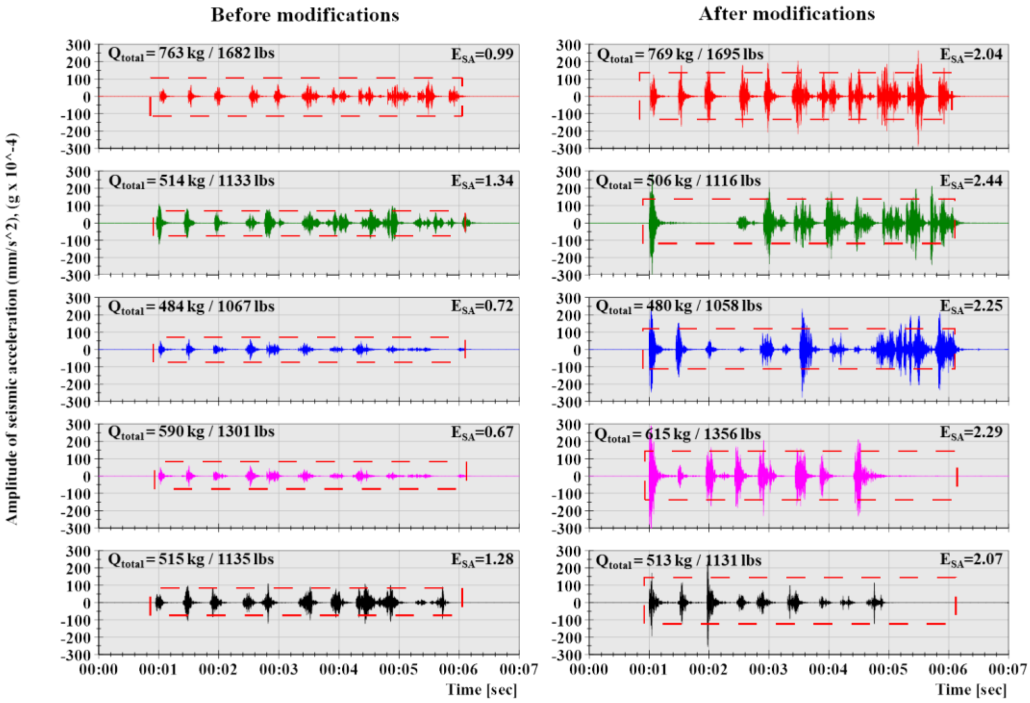

Fig. 10. Comparison of seismic waves generated by destress blasting before modifications (left) and after modifications (right)

2.5. Mixed methods of controlled blasting and hydraulic fracturing

Attempts were also made to simultaneously precondition the rock mass using both hydraulic methods and those based on the use of explosives. In study [32] connection of these two methods were described. Controlled blasting, which additional pressurise water in dynamic way induce in the borehole surrounding hydraulic fracturing, which causes grows of cracks both in range and numbers. As Huang et al. [33] pointed out, this method may be applied as follows:

i. Hole's drilling for hydraulic fracturing.
ii. Loading holes with water-proof explosives (e.g. bulk emulsion).
iii. Closing tightly borehole by cement plug.
iv. Water injection (water has to pressurized with proper pressure value).
v. Explosives' detonation (additional dynamic pressuring of water).
vi. Pulse or cycled injection of water.

Scheme presented in Fig. 11 shows water pressure blasting technique.

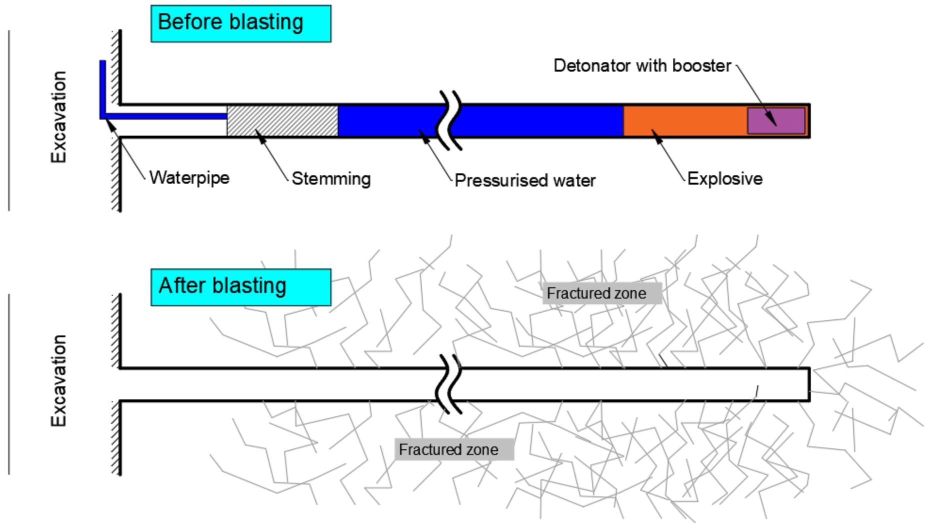

Fig. 11. Scheme of blasthole in water pressure blasting method [15, 32]

Another promising method of rockmass preconditioning is a concept of combination of two methods: 1# hydraulic fracturing in down-holes and 2# confined blasting in up-holes. These methods are employed before cave's initiation and affected volume of the mining block [34]. This concept of preconditioning which was presented by Catalan et al. [9] is shown in Fig. 12.

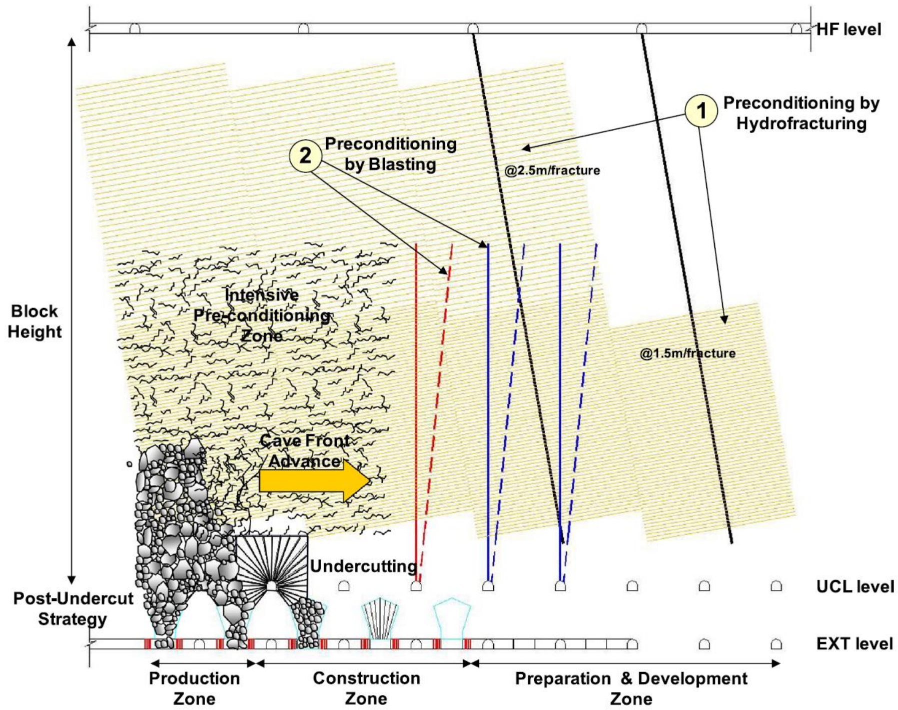

Fig. 12. Sequence to implement intensive preconditioning [9]

This technique can induce improved creation of new fractures and expand zone of existing ones. It also helps to increase efficiency of gas drainage e.g. methane. Still, joint preconditioning using blasting and hydraulic fracturing is a topic which should be further developed. A set of modelling and theoretical calculations, with taking fluid parameters like viscosity and pressure should be performed.

All described preconditioning methods in brief form is presented in Table 1.

Table 1. Summarized list of preconditioning methods with brief description

	Preconditioning methods		
No	**Name**	**Description**	**Advantages/disadvantages**
1.	Directed hydrofracturing	Creation of the fractured zone by pressurized liquid.	**A:** Effective mitigation of rockburst hazard. **D:** Large number of long holes is needed; potential disturbance of mining process.
2.	Torpedo blasting	Fracturing of the rock mass by means of detonation of explosives in long holes (especial in the roof layers)	**A:** Effective mitigation of rockburst hazard, triggering of seismic events. **D:** Potential disturbance of mining process, potential problem with ground control.
3.	Face destress blasting	Preconditioning of rock mass by means of explosives used in the face area	**A:** Effective mitigation of rockburst hazard (removing stress area from exploitation front). **D:** Potential negative impact on ground support.
4.	Multi-face destress blasting	Preconditioning of the rock mass by means of simultaneous blasting of many faces (method used in room and pillar mining method)	**A:** Effective mitigation of rockburst hazard in the short and long range from the face **D:** There is a need to prepare suitable mining front with many faces.
5.	Mixed methods	Preconditioning of rock mass by simultaneous using of hydraulic and explosives methods	**A:** Improving efficiency of rock preconditioning and limitation of rockburst hazard in the short and long range. **D:** More complicated, possible disturbance of mining process.

3. EVALUATION OF PRECONDITIONING EFFICACY

3.1. Laboratory tests

A well-preconditioned rock mass, due to extensive cracks, should be characterised by lower strength parameters. In this aspects commonplace tests which is applied to determine rock strength is uniaxial compressive strength, which is maximum value of axial compressive stress that standardised rock sample can withstand before failure. Such a test allows us to determine also the following parameters of the rock material: Poisson's ratio, elastic constants, Young's modulus [35]. Still, according to research presented by Catalan et al. [34] both hydraulic and blasting preconditioning had only a little impact on UCS values in the analysed area. As presented in Fig. 13, looking into the normally distributed data only small difference in UCS value can be seen, after summarised effect of confined blasting and hydraulic fracturing. Still, Catalan et al. [34] pointed out that this difference is insignificant from the practical point of view. Therefore it may be stated that analysing the effect of preconditioning based solely on UCS data may not be a sufficient way of evaluation.

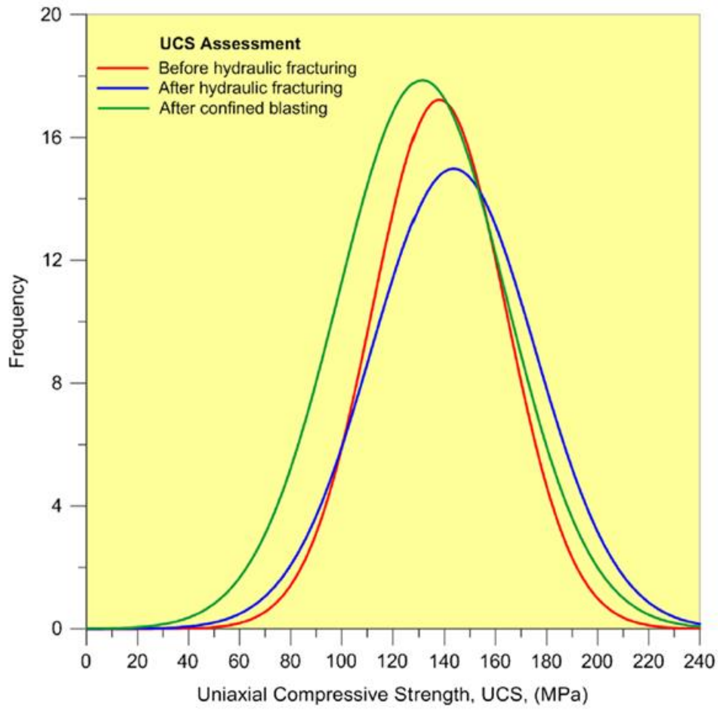

Fig. 13. Distribution of UCS after preconditioning process [34]

3.2. Monitoring

Acoustic emission monitoring (AE)

Brady & Brown [36], emphasized that before reaching the peak strength level, three phases of rock destruction must be achieved:
1st phase – process of crack closure,
2nd phase – increasing of elastic deformation up to reaching of axial stress (crack initiation and stable crack propagation process),
3rd phase – level of axial stress with unstable crack propagation and irrecoverable deformation. This process are finished when peak of UCS is reached.

Knowing the process one may observe that acoustic emission (AE) monitoring may be a suitable tool for observation the process of the brittle rock failure. AE can be correlated with failure process. This method has been often employed in engineering and rock mechanics in the identification of damage process of observed rock structures [37-41]. Correlating AE signals with the stress-strain diagram allows for estimation of the initial point of micro fractures development and propagation during a UCS test performance. Numerous research studies confirmed that AE is suitable way of monitoring crack behaviour and can be used with high degree of confidence [42 - 45].

Seismic velocities monitoring

Continuous high-accuracy seismic measurements may be used for monitoring of ground vibration level after each blasting operation [46]. On the other hand, it may be also used for monitoring of seismic wave propagation velocities which may be correlated with the rock burst risk [47, 48]. The aim of this method is to determine the propagation velocities of seismic waves between sources and receivers. The source is usually an explosive charge located in the blasthole, while the receiver is a special geophone probe, accelerometer or seismometer. As a result of the measurements, the map of seismic velocity distribution is created. It is assumed that proper rock mass preconditioning leads to changes in the seismic velocities within the given panel, so effective stress-release blasting or hydrofracturing should result in a decrease in seismic wave velocities [7].

As part of the EU-funded NEXGEN SIMS project, one of the most innovative, low-cost systems for continuous seismic tomography was developed, aimed at identifying the effectiveness of rock mass preconditioning through blasting. As demonstrated during the demonstration in in-situ conditions, the use of seismic systems enriched with appropriate computational algorithms and automated recorder excitation systems makes it possible to track the speed of propagation of seismic waves each time after the detonation of explosives, which in turn is the basis for determining whether preconditioning was effective or no.

An example of the use of the NEXGEN SIMS autonomous seismic measurement system in monitoring the effectiveness of preconditioning is shown in Fig. 14.

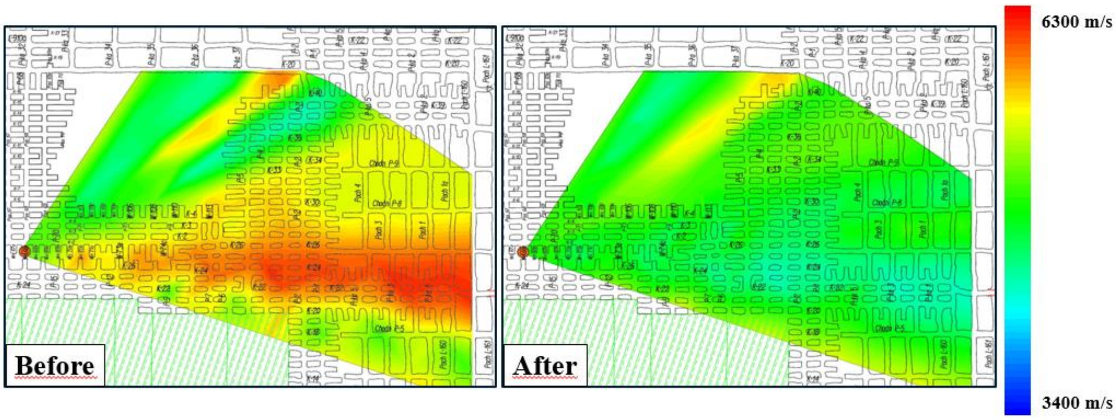

Fig. 14. Seismic velocity maps before (left) and after (right) destressing with modified D&B patterns

Seismic velocity maps confirm that properly conducted destress blasting may significantly change the stress state in the surroundings of the analysed mining panel. More information about NEXGEN SIMS project may be found under the link https://www.nexgensims.eu.

3.3. Numerical simulations

Sometimes, precise monitoring aimed at analysing the effectiveness of preconditioning cannot be used due to technological limitations or high costs of installation and maintenance of devices. In such a case, the effectiveness of preconditioning can be determined based on numerical simulations. Simulations can be conducted on a small scale (mining face) or on a macro scale (mining panel).

Based on current experience, it can be observed that the finite element method is most often used for large-scale 3D analyses. Although this method is a continuous method and does not enable the simulation of crack propagation, it is possible to determine the state of stress, e.g. before and after destress blasting, which may indirectly indicate the effectiveness of preconditioning (Fig. 15). Moreover, a well-validated numerical model can be a useful tool for the theoretical verification of various preconditioning scenarios, which reduces the costs of the work carried out (Fig. 16). An example of numerical modelling using focused 3D FEM is presented in the papers [49 - 51].

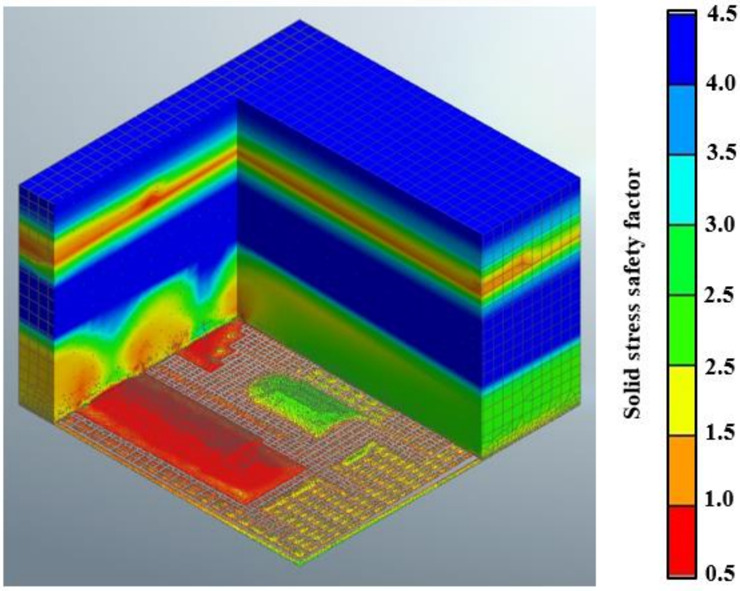

Fig. 15. View of a large-scale 3D numerical model

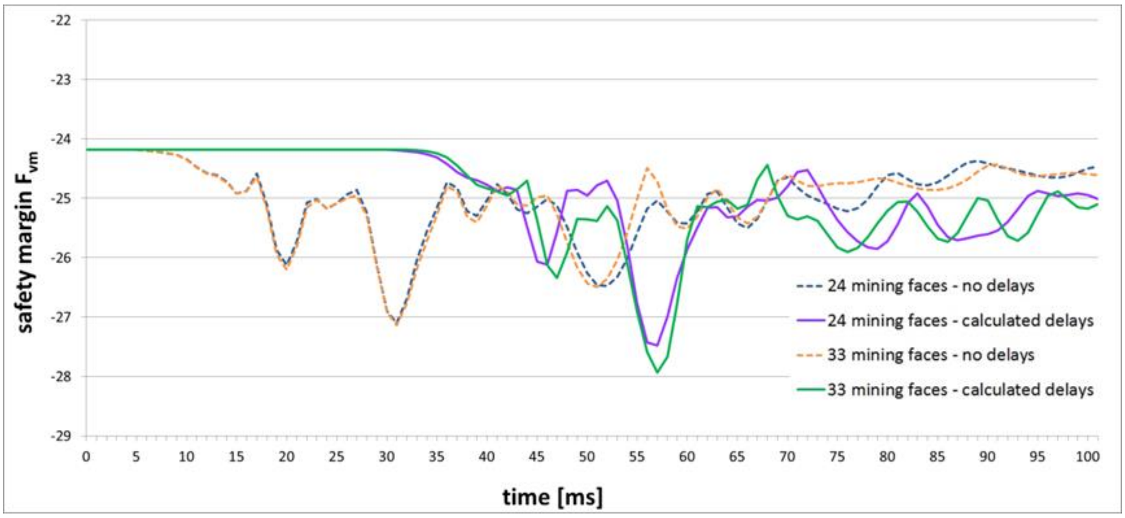

Fig. 16. Safety stock distribution for various multi-face destress blasting scenarios

Recently numerical methods to determine the effectiveness of rock mass preconditioning were used, among others, in the Sustainable Intelligent Mining Systems (SIMS) project co-financed under the Horizon 2020 program (SIMS, 2021) or the Baltic Sea Underground Innovation Network (BSUIN) project co-financed by the Interreg Baltic Sea Region program.

The dynamic development of numerical methods in recent years has resulted in the development of new non-continuous and hybrid numerical codes that enable dynamic calculations of the rock cracking process caused by preconditioning of the rock mass. Using discontinuous methods (most often Finite-Discrete Element Method - FDEM or Discrete Element Method - DEM), it is possible to determine the impact of stress blasting [52-58] and hydrofracturing [59-62] on the range and density of cracks, which is a measurable indicator of the effectiveness of the work being carried out. An exemplary application of the FDEM method to simulate cracks after the detonation of blast holes is presented in Fig. 17 and 18, while Fig. 19 shows an exemplary diagram of the detonation of a series of blast holes.

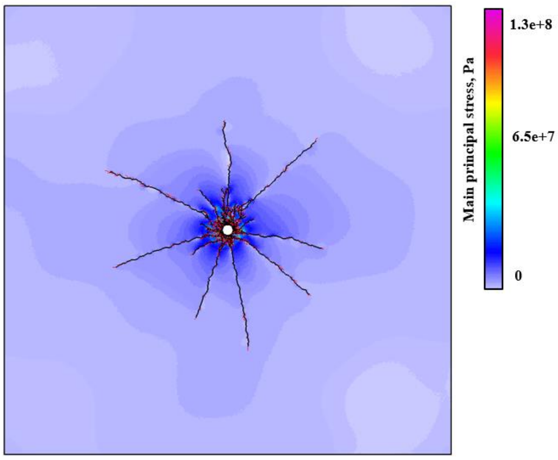

Fig. 17. Detonation of a blast hole with a diameter of 48 mm made in dolomite, using an explosive with a detonation velocity of 2,800 m/s

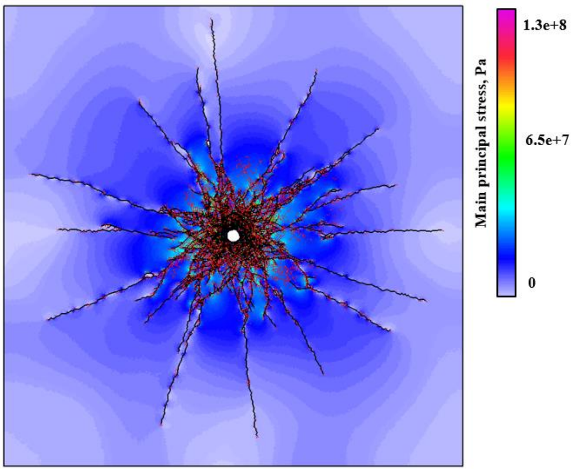

Fig. 18. Detonation of a blast hole with a diameter of 48 mm made in dolomite, using an explosive with a detonation velocity of 4,800 m/s

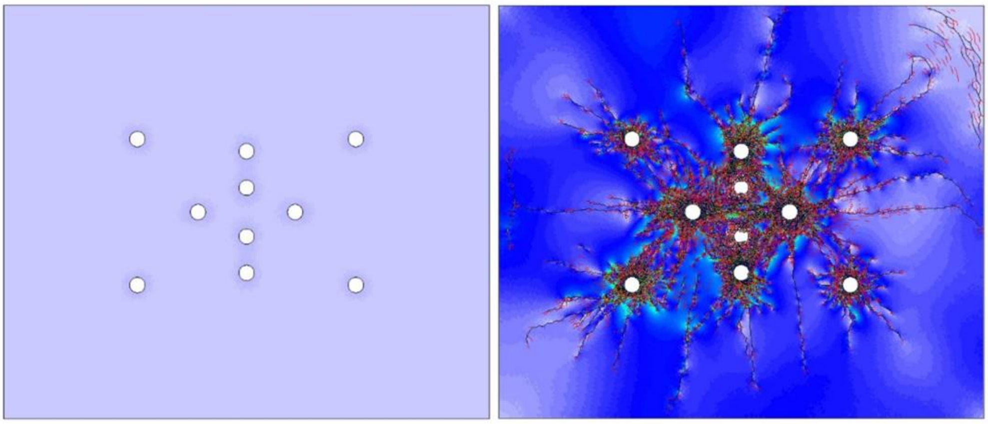

Fig. 19. Detonation of a series of blast holes with a diameter of 51 mm, made in dolomite. Condition before the start of detonation (left) and after detonation of all holes (right)

3.4. Tracking of seismicity level and location

The long-term distribution of seismic activity, especially in terms of energy may be an indicator of the rock mass preconditioning in a long perspective. Proper preconditioning may result in increase of low-energy events number, but at the same time should definitely turn into the decrease in number and magnitude of high-energy seismic events. Blasting and hydrofracturing generate cracks which may induce micro seismic events, but also prevent further energy accumulation in rock mass which decreases rock mass proneness to seismicity. An example of such evaluation has been well presented in the final reports of the NEXGEN-SIMS project.

According to research prepared by KGHM CUPRUM distribution of seismic activity in 2023 in one of the mining panels of Lubin underground copper mines, between January and April 2023, multi-face destress blasting was carried out with modified D&B and the use of electronic detonators (green dots in Fig. 20). According to the analysis, seismic activity in terms of energy gradually decreased from month to month and in May 2023, high-energy seismic events in the observed mining panel were almost completely eliminated. Due to the temporal lack of availability of people involved in the NEXGEN-SIMS project, in May 2023 the mine operator switched to using standard D&B patterns again. This resulted in a renewed accumulation of stresses and a sudden increase in the energy of seismic tremors in June 2023. After switching back to a modified D&B pattern, the seismic energy gradually decreased again until the complete elimination of high-energy tremors in December 2023.

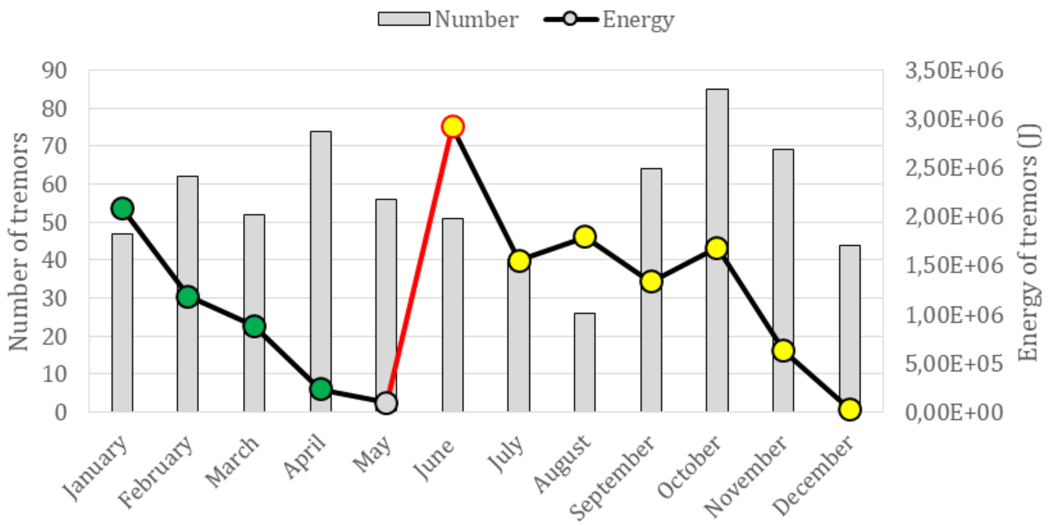

Fig. 20. Seismic activity in observed mining panel in 2023

As shown by the analysis, the use of modified blasting metrics and the use of a data-driven approach contributed largely to the reduction of seismic energy released in the monitored mining panel in the analysed period. As a result, seismicity in energy terms decreased by 95% in the period January-May 2023 and 97% in the period June-December 2023. Of course, it should be borne in mind that seismic activity is affected by many factors, such as the local geological condition, the exploitation system, extraction depth, etc., therefore it cannot be clearly stated that 100% of the effect obtained was achieved only by implementing modifications to multi-face blasting. However, based solely on data, this impact seems to be clear and research in this scope has to be proceeded further. On the other hand, when analysing the effectiveness of hydrofracturing hypocentral location of seismic events may be a useful tool for tracking the rock mass preconditioning process. During hydraulic fracturing, when water pressure tops rock strength, cracks are generated and microseismic events take place. Monitoring of acoustic emission allows to localise spatial position of these events and bring information on the cracking range and the effectiveness of hydraulic fracturing. The process of hydraulic fracturing can be tailored to condition by changing the viscosity of fluids used in the process [14], controlling the pressure and adding blasting-based destressing [33]).

3.5. In situ tests

In addition to continuous monitoring and numerical simulations, the effectiveness of preconditioning can also be estimated based on observations conducted in in-situ conditions and additional tests aimed at determining the degree of the rock mass destressing.

Ground penetrating radar surveys

Ground-penetrating radar (GPR) is a geophysical technique that utilises radar pulses in order to imagine the subsurface. This method allows for non-invasive exploration of underground solid medium like rocks by using electromagnetic radiation in the microwave band of the radio spectrum. GPR can detect reflected signals from structures beneath the surface. According to Toper et al. [63] ground penetrating radar (GPR) is a suitable method for determining the effect of preconditioning on the rock mass. The pulse of electromagnetic wave which is emitted by the GPR antenna subsequently is reflected by fracture planes, particularly if the fissures are open and the sides of the fractures are coated post-blasting fumes residues. As a result, the intensity and the depth of fracturing ahead of the mining face may be identified. Then the fracture pattern ahead of a face before and after preconditioning may be compared, which brings a general overview of preconditioning effectiveness. An example of a scan can be seen in Fig. 21.

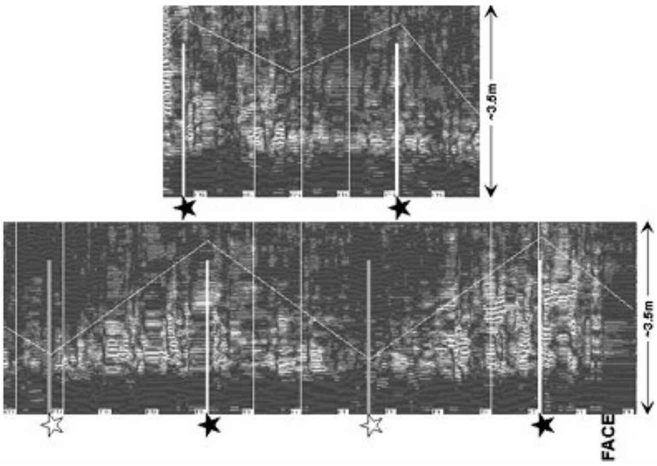

Fig. 21. GPR scan results with preconditioning holes (black stars) and proposed location of additional preconditioning holes (white stars) [63]

Face advance and drilling rates

Preconditioning at the deposit level, thanks to the reduction of the stress state in the rocks, should result in a reduction of mining resistance and, consequently, an increase in the progress of mining works. A parameter that can be easily measured is the drilling rate. As noted by Toper et al. [63], appropriate preconditioning of the rock mass with the use of explosives made it possible to increase the average face advance per blast by over 50%. The situation is similar in terms of drilling progress. The use of preconditioning using explosives allowed for an increase in drilling progress by 26 to 47%.

3.6. Digital twin technologies

It should be also stated that proper assessing effectiveness of preconditioning of the rock mass using different monitoring methods can be supported by 3D digital-twin for underground mines. Stream of data from monitoring systems mentioned before can be incorporated to developed reliable digital-twin for given mining area. This kind of systems are developed and implemented in real underground activities what helps to design and operate underground structures safe and effectively [64-67]. These kind of supporting systems are able to analysed rockmass in real time and might provide higher level of system integration with feedback loop. Eventually comprehensive system will probably help to operate the mine in real-time data-driven manner.

4. SUMMARY

Based on extensive research it may be stated that the preconditioning outcome of should be analysed in space and time. The preconditioning mechanism is aimed to transfer the stress ahead of the face resulting from induced deformations in the fracture area. Still, it may be assumed that proper fracturing of rock mass may actually modify the material properties of the rock and increase the effectiveness of drilling works by softening of rock material. Because the stress state changes continuously during the underground excavation process the preconditioning must be incorporated permanently into the production process in a well-planned and controlled manner. Considering that fact one may observe that there are some possibilities related to the implementation of preconditioning measures in regular mining operations. Properly destressed and well-fractured rockmass definitely will bring safer conditions in a deep underground environment and possibly will ease the excavation process by decreasing the energy required for drilling and crushing of rocks. Still, this approach has to be further developed. One of the main focuses of the PERSEPHONE project is to investigate the effect of rock preconditioning on the drilling/excavation process. This effect may be reflected as increasing energy efficiency, improving the drilling/excavation performance, or even extending the applicability of excavation machinery to harder and more challenging types of rocks.

It is assumed that the pre-conditioning process of rock may be achieved by means of mechanical/non-mechanical methods depending on the efficiency levels. The scope of this task would be to survey and compare the available technologies for this purpose and perform lab experiments complemented by theoretical/numerical modelling using simulation capabilities in order to prove the selected concepts. Moreover, preconditioning of the rockface, followed by efficient, accurate and strategic drilling would lead to significant reductions in the use of water and electricity at the mining front.

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