AFRIROCK

PIONEERING PROGRESS :
THE FUTURE OF ROCK ENGINEERING

AGEMERA
Critical Raw Materials for a Resilient Europe

KGHM CUPRUM
CENTRUM BADAWCZO-ROZWOJOWE

Application of MEMS accelerometers for continuous near-field monitoring of mining-induced seismicity

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Project AGEMERA

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MUON SOLUTIONS

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TAL TECH

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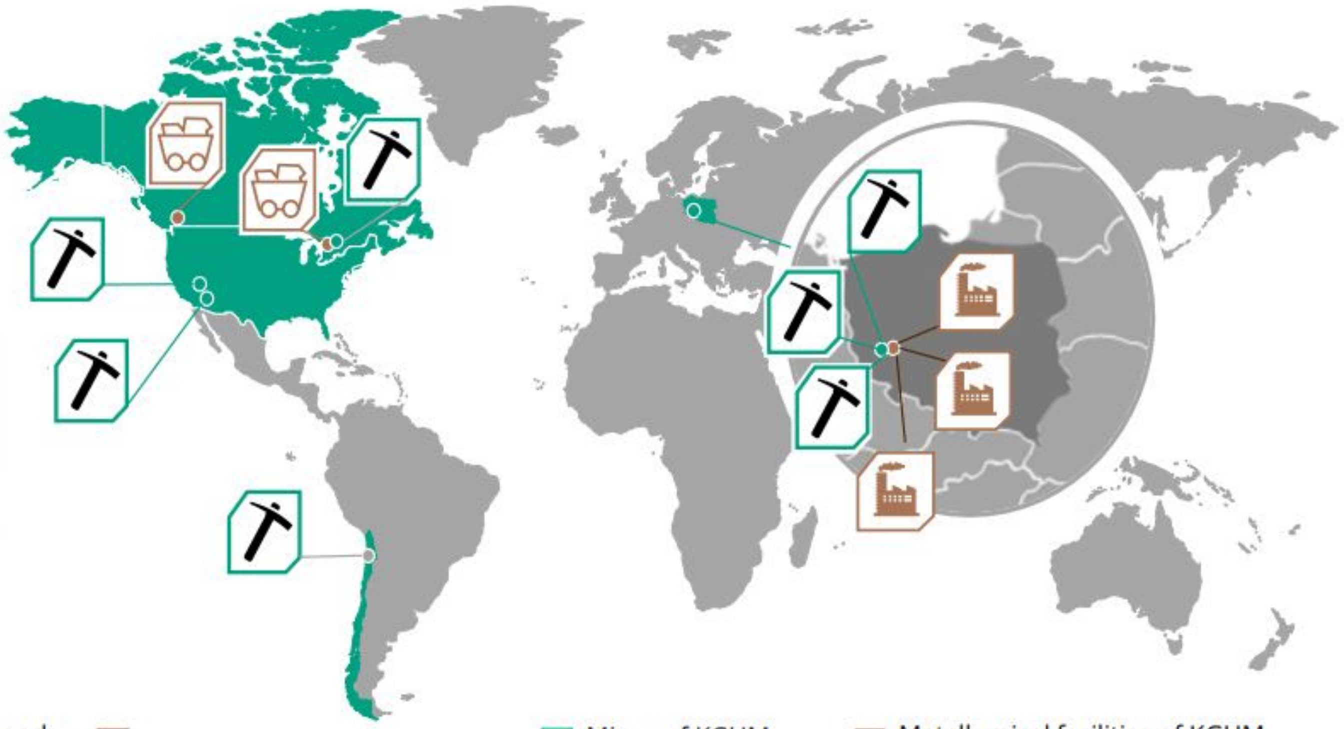
OPT/NET

KGHM: a top ten copper producer and a leading Polish exporter

The Group has a global reach and plays a significant role on the global copper and silver markets



Legend: Mining projects of KGHM | Mines of KGHM | Metallurgical facilities of KGHM

Eighth largest mining copper producer

Second largest silver producer

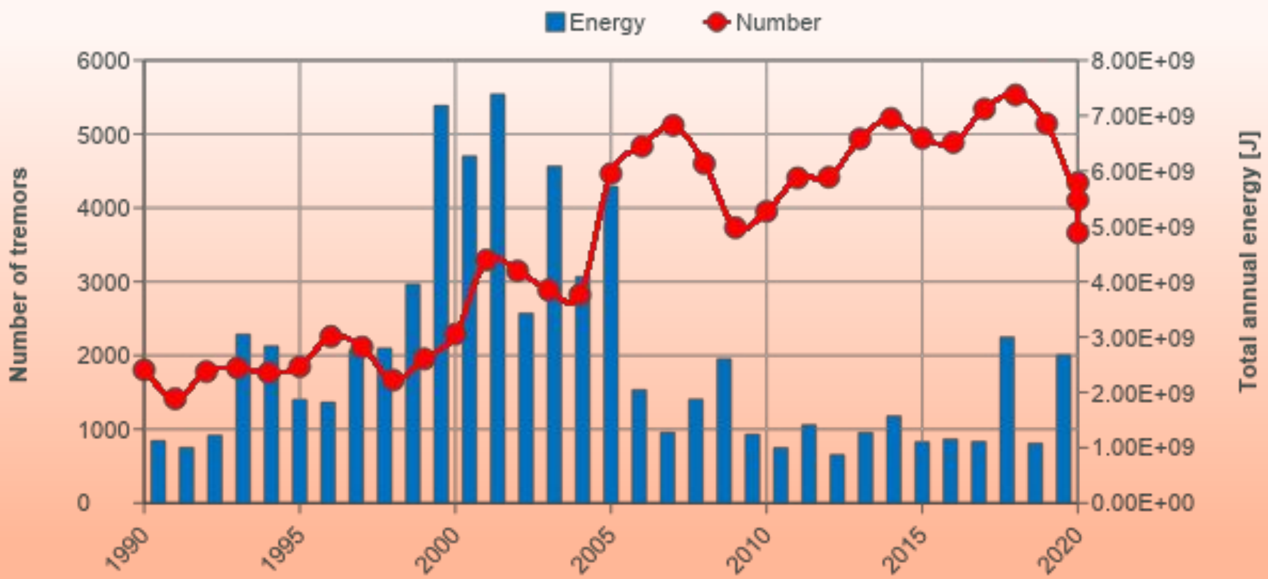
Source: Kitco 2023, World Silver Survey 2024

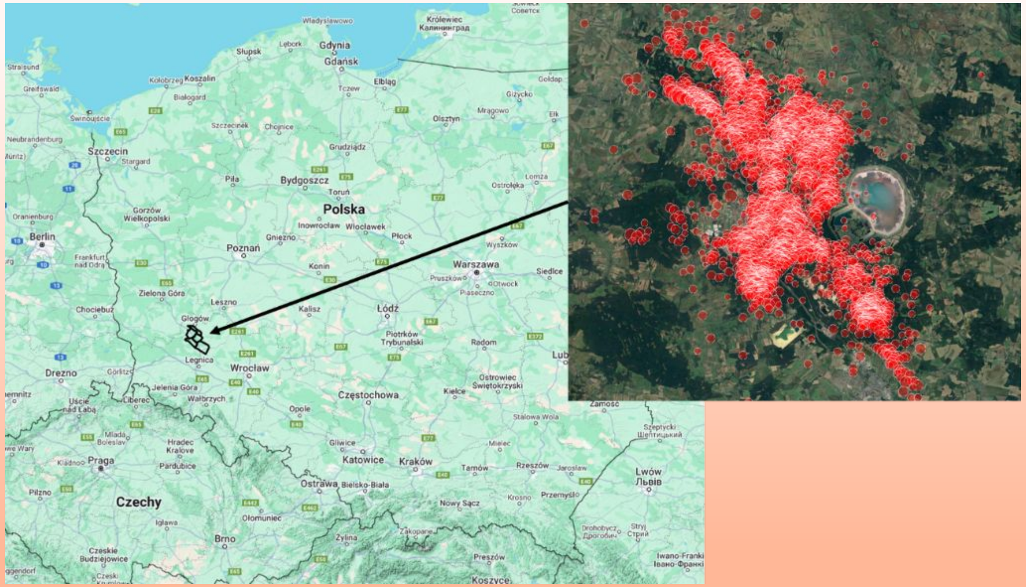
Other KGHM Group products:

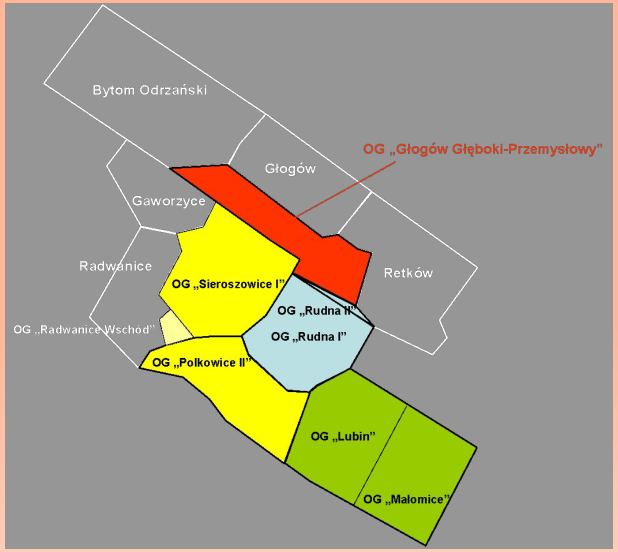
- Molybdenum
- Lead
- Nickel
- Gold
- Palladium
- Platinum
- Rhenium
- Sulphuric acid
- Selenium
- Copper sulphate
- Nickel sulphate

Geology	Mining		Metallurgy	
Exploration and evaluation	Ore extraction	Ore enrichment	Smelting and refining	Downstream processing

UNDERGROUND COPPER MINING IN POLAND







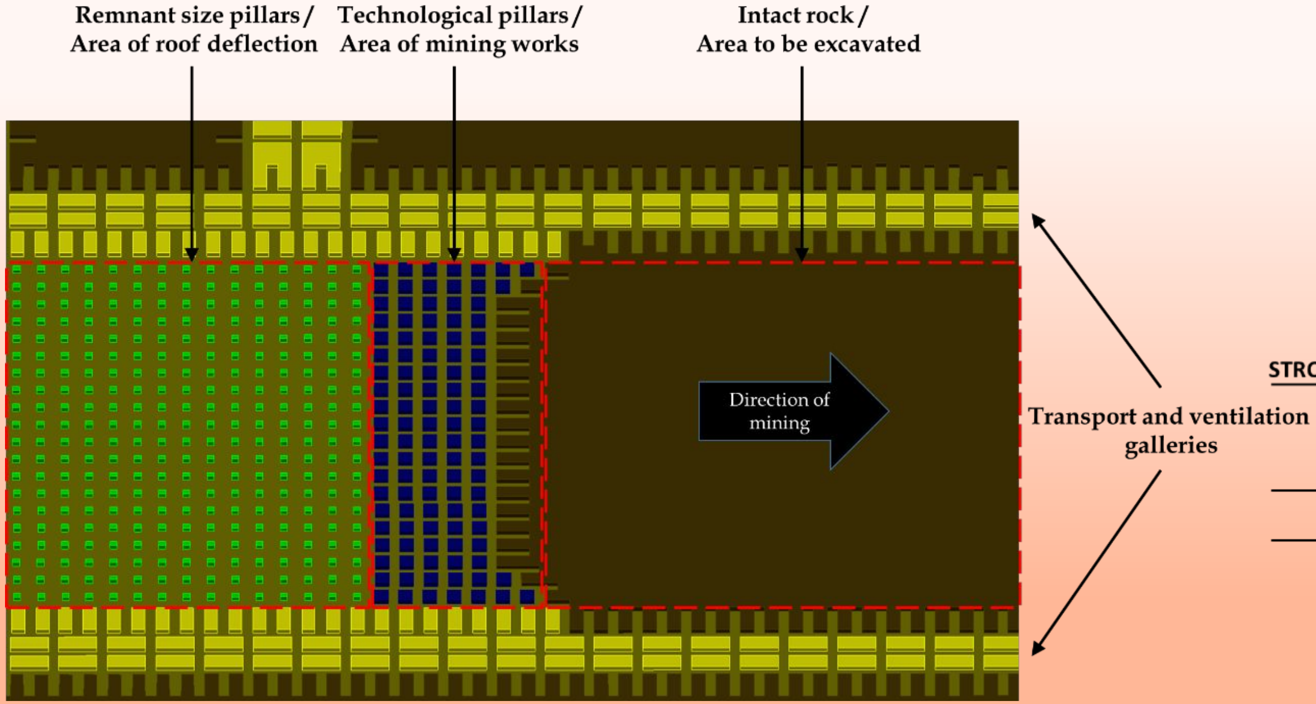
RUDNA MINE

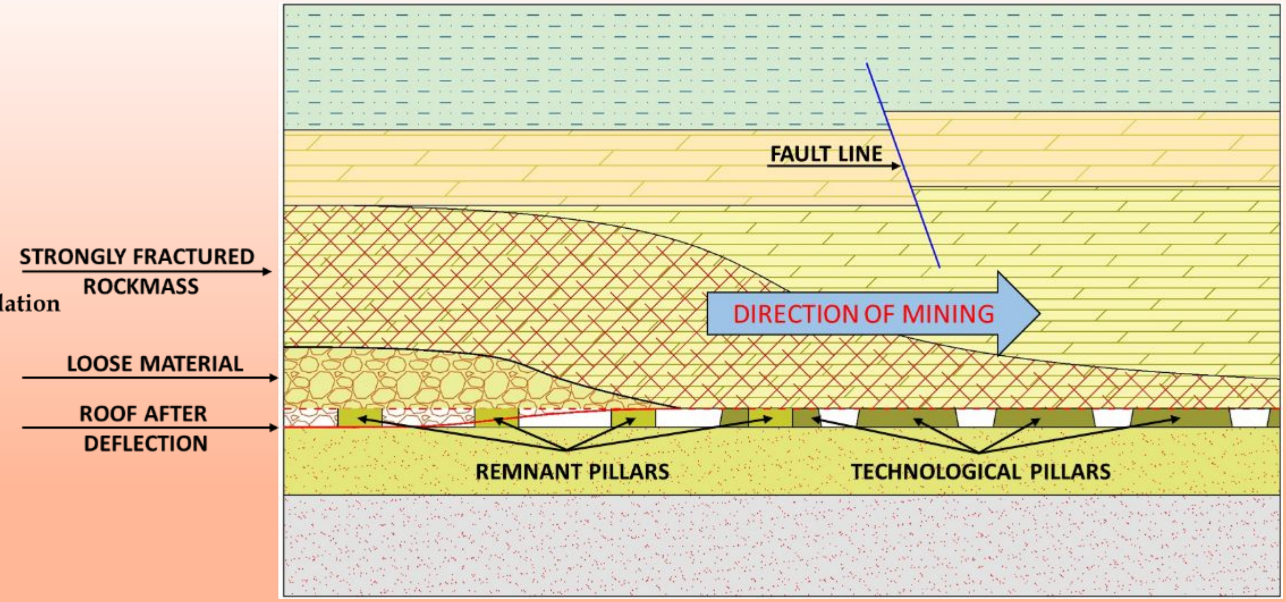
POLKOWICE-SIEROSZOWICE MINE

LUBIN MINE

Area of over 500 km^2 was excavated already

CAUSES OF SEISMIC ACTIVITY

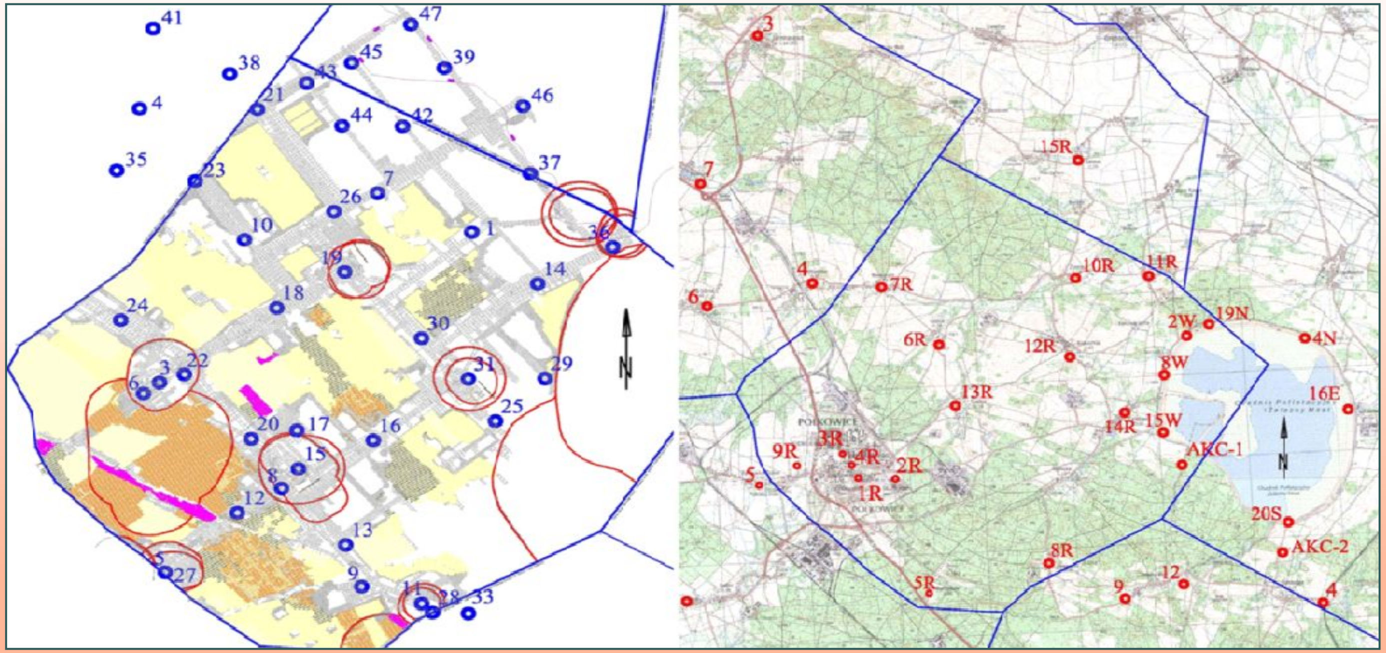




UNDERGROUND WORKINGS DESTRUCTION

1.2×10^7 J

SEISMIC MONITORING



Standard seismic monitoring systems offer high effectiveness in detecting and analyzing mining-induced seismic events; however, their implementation and maintenance are associated with significant costs. As a result, the design of seismic network coverage in underground mines is typically optimized to achieve a compromise between financial feasibility and the quality of data acquisition, ensuring sufficient resolution for hazard assessment while maintaining reasonable investment and operational expenses.

SEISMIC MONITORING IN LGOM

Why Monitor Mining-Induced Seismicity?

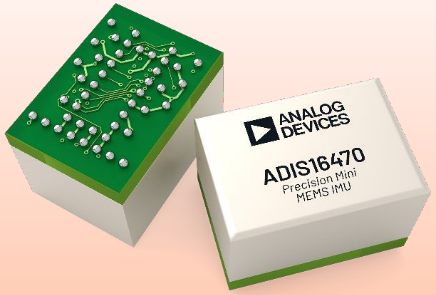
- **Safety:** Early detection reduces rockburst risk and protects workers.
- **Infrastructure protection:** Prevents damage to mine workings and support systems.
- **Seismic risk assessment:** Informs decisions on mining sequences.
- **Data collected:** Event location, magnitude, energy release, source mechanism, stress changes.
- **Real-time alerts:** Enables early warnings and emergency response.
- **Model calibration:** Validates geomechanical and hazard models.

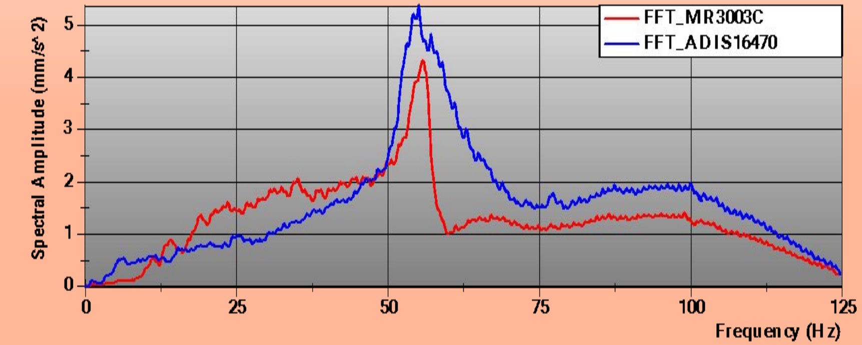
Why Increase Seismic Network Density?

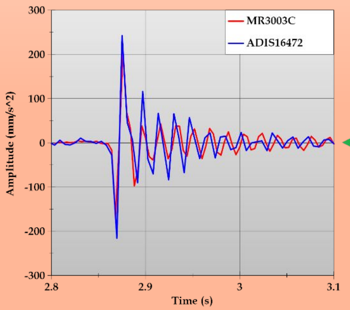
- **Higher resolution:** Better event location and source analysis.
- **Lower detection threshold:** Looking for small precursors to major events.
- **Improved hazard zoning:** Supports safer and more efficient mining.
- **Supports automation:** Essential for deep and remote-controlled operations.

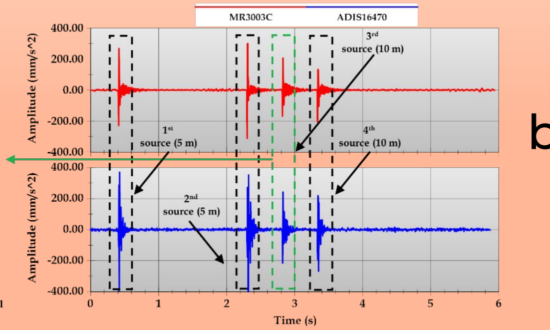
LOW-COST SOLUTIONS FOR MONITORING MINING-INDUCED SEISMICITY

Parameter	Unit	ADIS16470	ADXL355	MR3003C	Willmore MK III
Resolution	Bit	32	20	24	12
Number of recording components	-	3-axial (X,Y,Z)	3-axial (X,Y,Z)	3-axial (X,Y,Z)	1-axial (vertical)
Sampling (set up during measurement)	Hz	250	500	250	500
Measuring range	g or mm	±40 g	±2 g	±4 g	± 2 mm
Operating temperature	°C	-25 to +85	−40 to +125	-20 to +70	-40 to +50

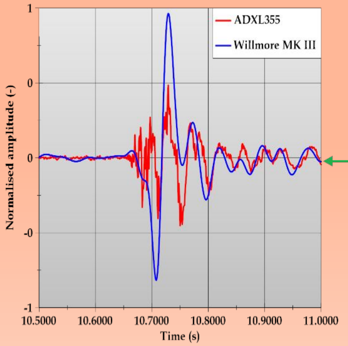


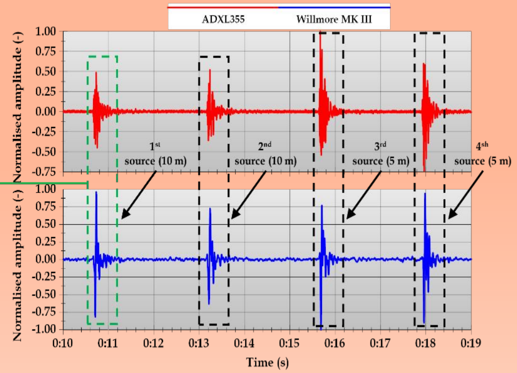






Surface tests – 10 hammer blows ADIS16472 MEMS-IMU vs. MR3003C

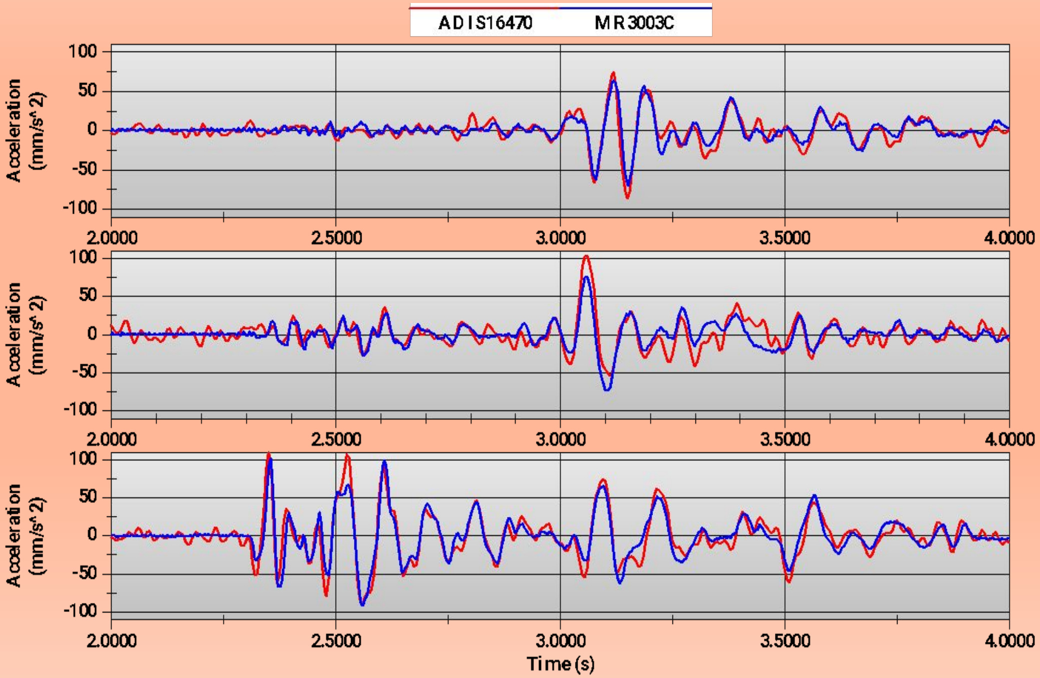


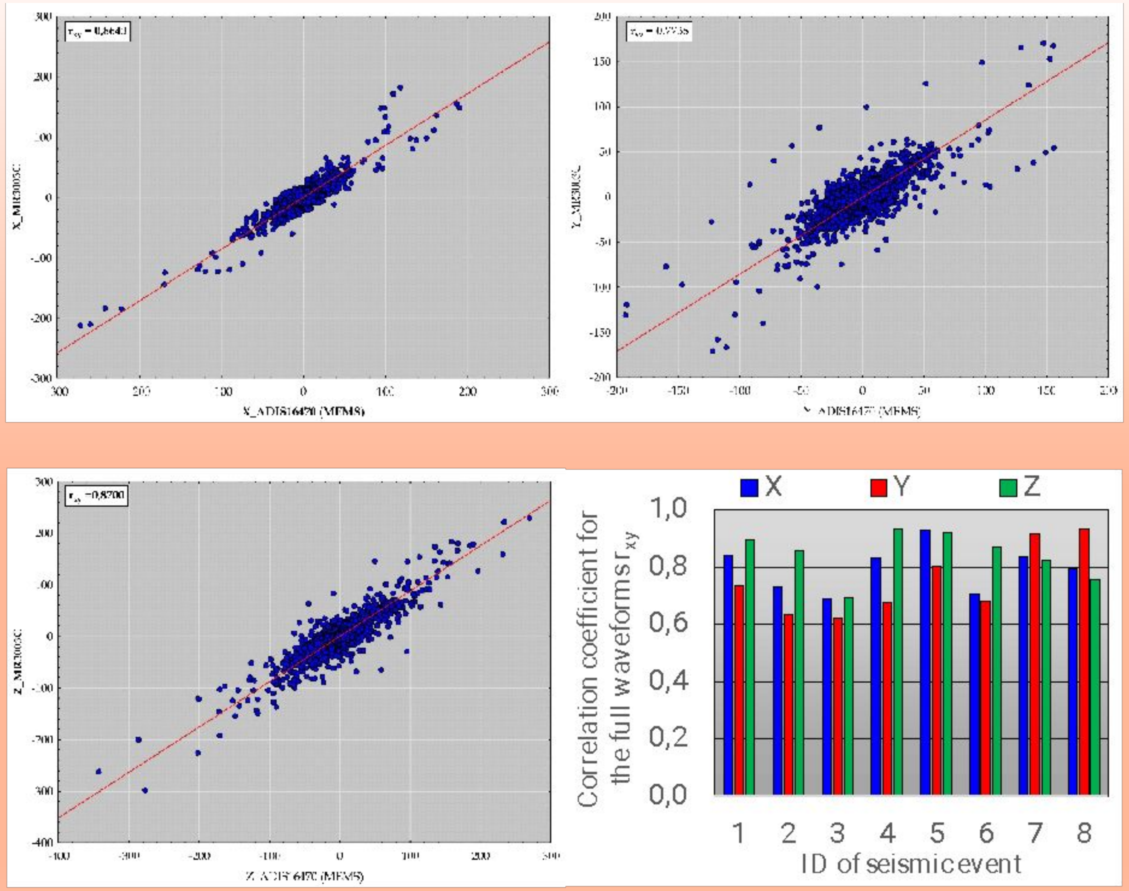


Underground tests – 10 hammer blows ADXL355 vs. Willmore MK III

SURFACE TESTS –
Near field seismic monitoring

ID of seismic event.	Date	Time	Energy [J]	Magnitude
1	19 September 2023	10:10:01	5,4E+05	2,3
2	22 September 2023	19:34:31	1,2E+05	2,0
3	28 September 2023	03:45:28	1,7E+05	2,1
4	12 October 2023	03:01:16	2,2E+05	2,1
5	13 October 2023	14:44:40	1,4E+06	2,5
6	17 October 2023	12:04:51	1,7E+05	2,1
7	17 November 2023	20:38:57	2,0E+05	2,1
8	18 November 2023	03:04:12	2,3E+05	2,1





Scatterplots of data recorded in X (top-left), Y (top-right), Z (bottom left) directions and correlation calculated for full waveform of each analysed seismic event (bottom right)

UNDERGROUND TESTS – AUTONOMOUS ACTIVE TOMOGRAPHY

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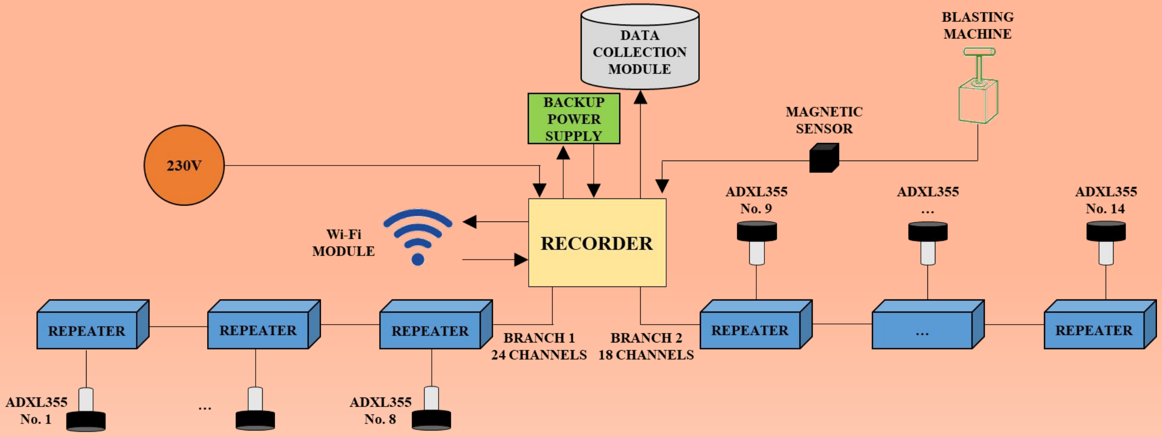
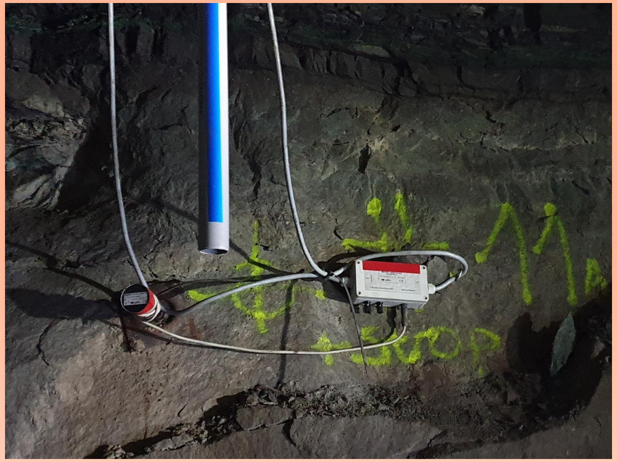
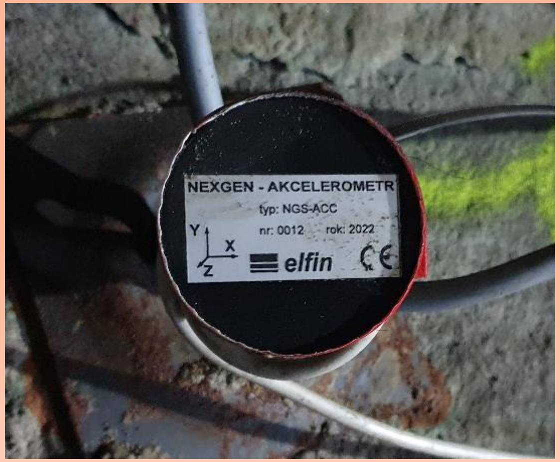
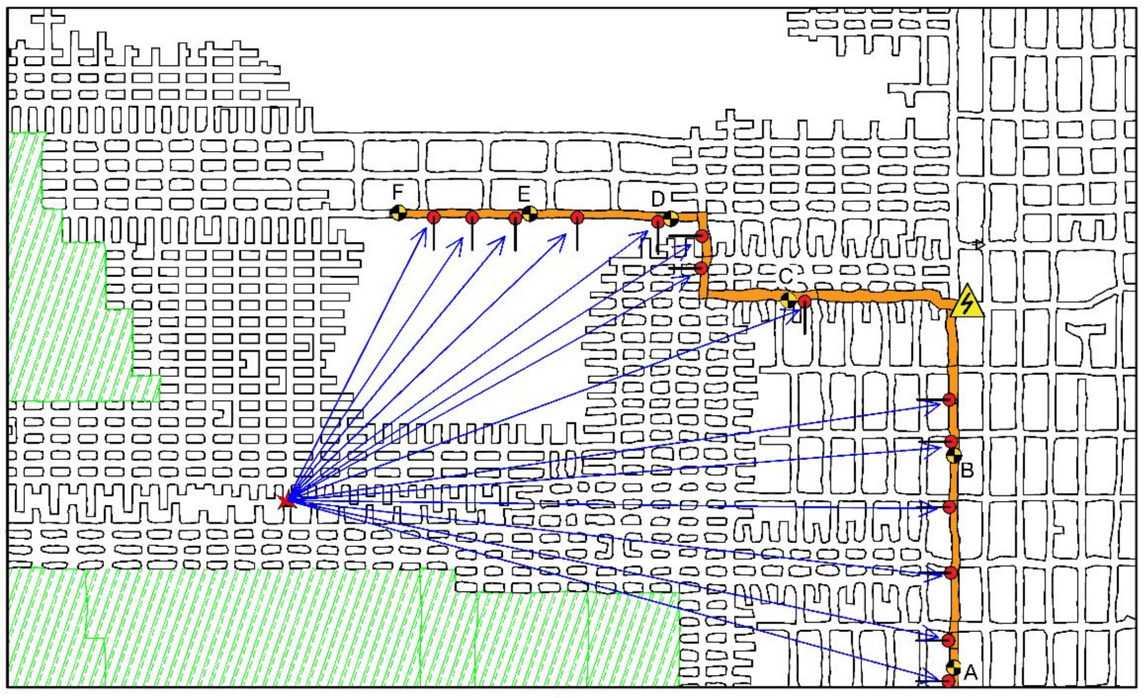
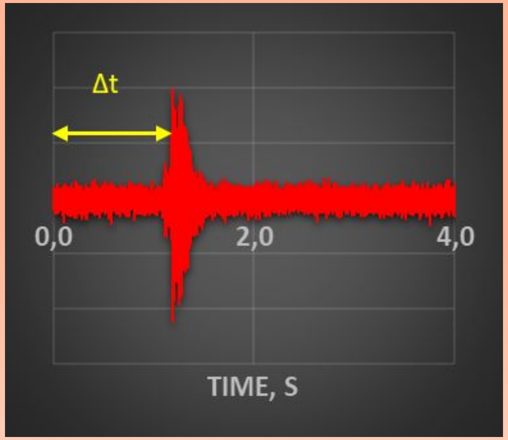


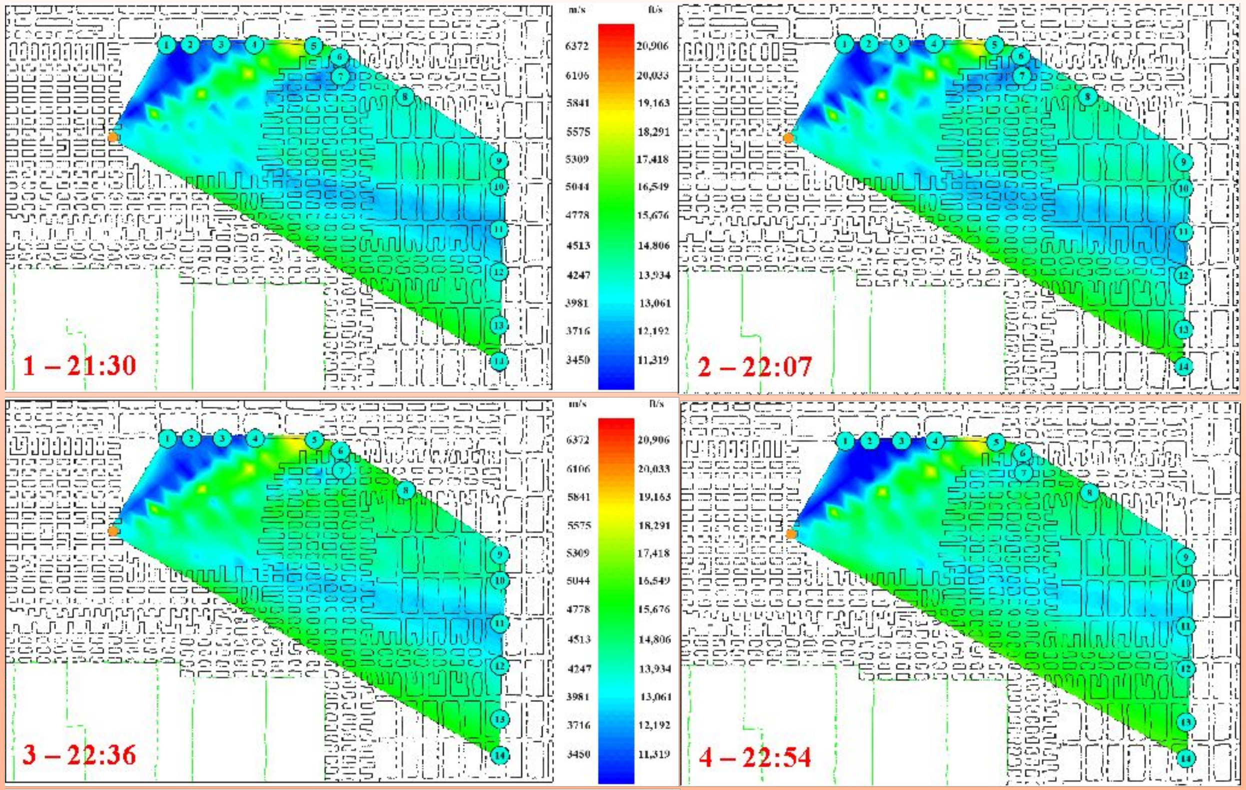


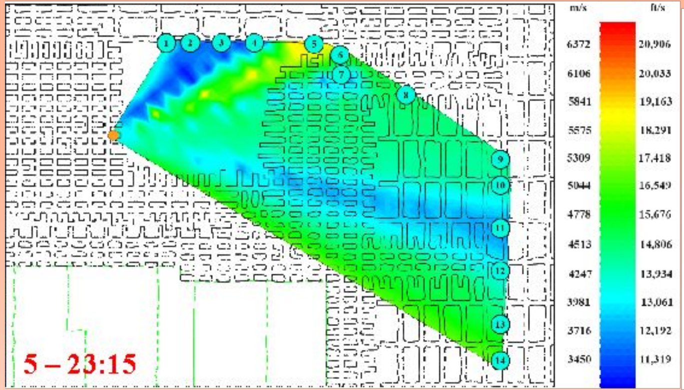


UNDERGROUND TESTS – AUTONOMOUS ACTIVE TOMOGRAPHY









The average value of the seismic velocity difference between the individual tests at subsequent accelerometers

1- 1.37%	8- 0.46%
2- 5.49%	9- 0.99%
3- 0.88%	10- 0.34%
4- 1.24%	11- 0.55%
5- 0.55%	12- 0.51%
6- 4.16%	13- 1.16%
7- 5.49%	14- 1.62%

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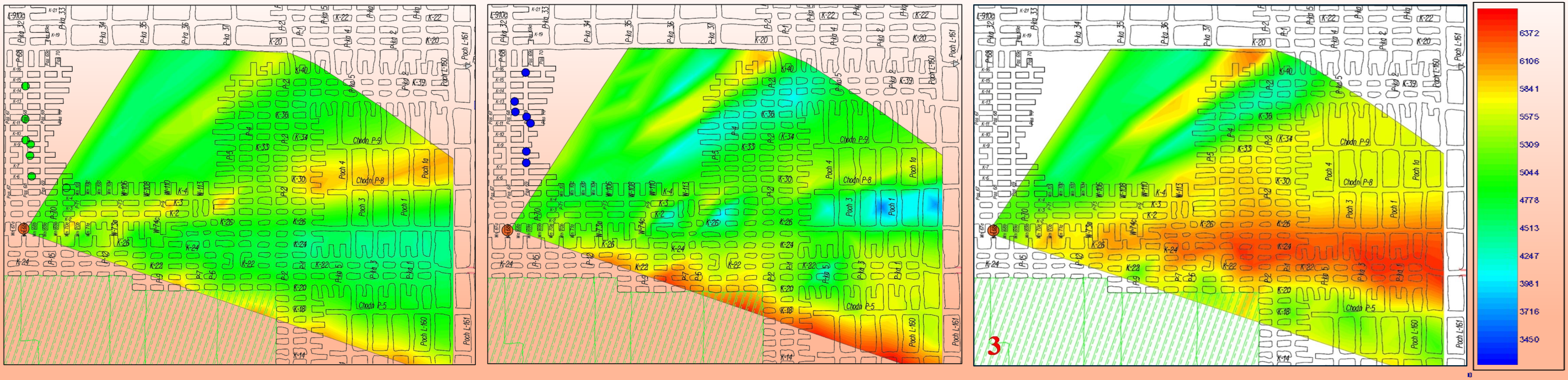
UNDERGROUND TESTS – AUTONOMOUS ACTIVE TOMOGRAPHY

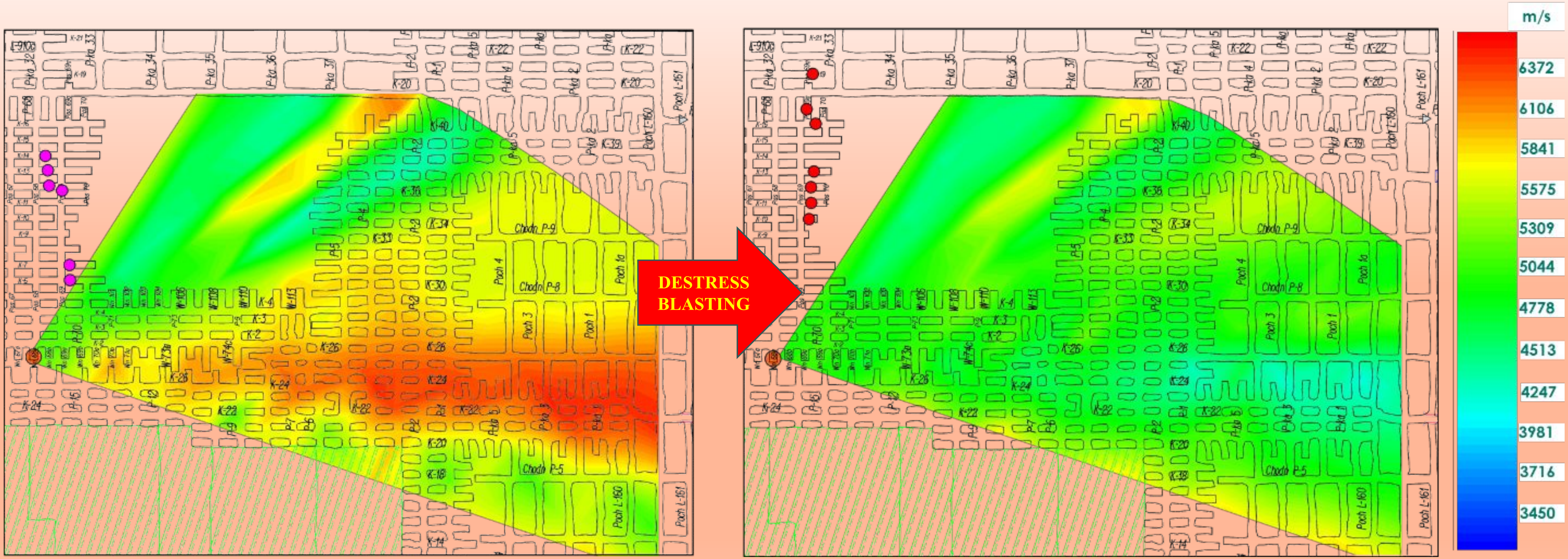


The possibility of conducting continuous seismic tomography with use of MEMS accelerometers enables ongoing assessment of the rock mass condition and is the basis for the implementation of constructive planning of preventive measures, such as destress blasting.

Figure above shows the distribution of seismic wave velocities in the analyzed area before and after destress blasting. As can be seen, information on the location of stress zones allows determining when and to what extent the rock destressing should be carried out.

UNDERGROUND TESTS –

AUTONOMOUS ACTIVE TOMOGRAPHY



SUMMARY

Discussion

- **Low-cost MEMS sensors** can significantly increase seismic network density without major cost impact.
- **Higher self-noise** of MEMS (ADXL355, ADIS16470) limits their use for low-energy or distant events.
- **Accuracy trade-off:** Reduced precision in P-wave arrival times affects event localization.
- **Potential in structural monitoring:** Dense arrays may detect instability zones via ambient noise—but feasibility needs testing due to MEMS self noise.
- **Operational benefits:** MEMS-based tomography system recorded underground machinery activity—enabled analysis of traffic volume, speed, and load state.
- **New insights:** Such data can support optimization of ore transport and haulage.

Conclusion

- Two MEMS-based systems (ADIS16470 for surface, ADXL355 for active tomography) were tested.
- MEMS-based systems showed **low cost, low power use, and measurement reliability**.
- MEMS sensors, though less precise than standard units, provide **useful seismic data**.
- Future work: wireless MEMS networks and tests for ambient-noise-based stability assessment.

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