Czech Academy of Sciences

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Ústav geoniky – AV ČR

DESTRESS BLASTING AS A PROACTIVE MEASURE AGAINST ROCKBURSTS

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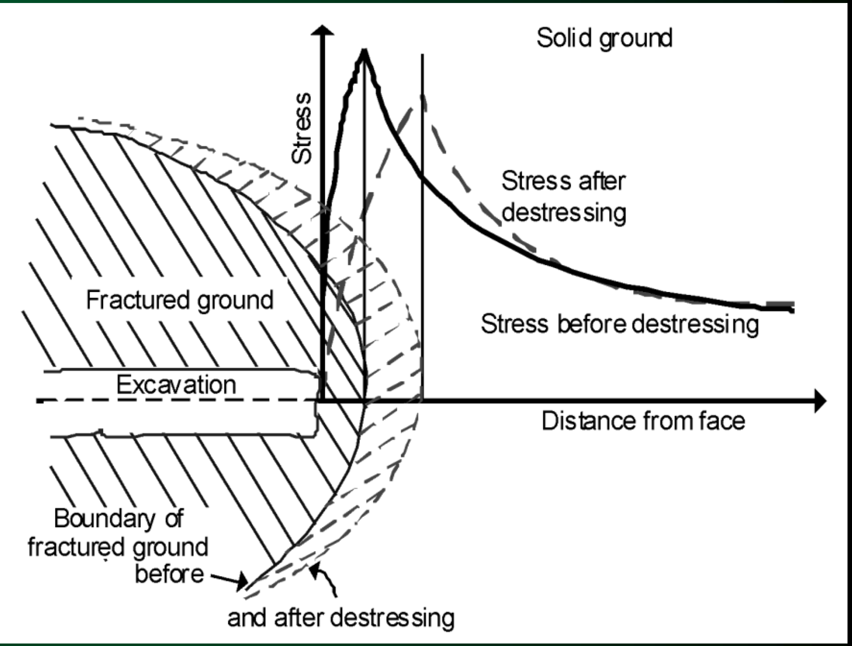
1. Introduction
2. Natural and mining conditions
3. Destress blasting as an active measure
4. Evaluation of stress release
5. Case studies
6. Rockbursts and destress blasting in underground constructions
7. Conclusions

INTRODUCTION

INTRODUCTION

- Main goals of destress blasting:
  - Desintegration of rock mass by means of explosion (without breaking into open spaces),
  - Redistribution of stress away from the working face (behind a preconditioned zone),
  - Destressing (without employees in underground workings).

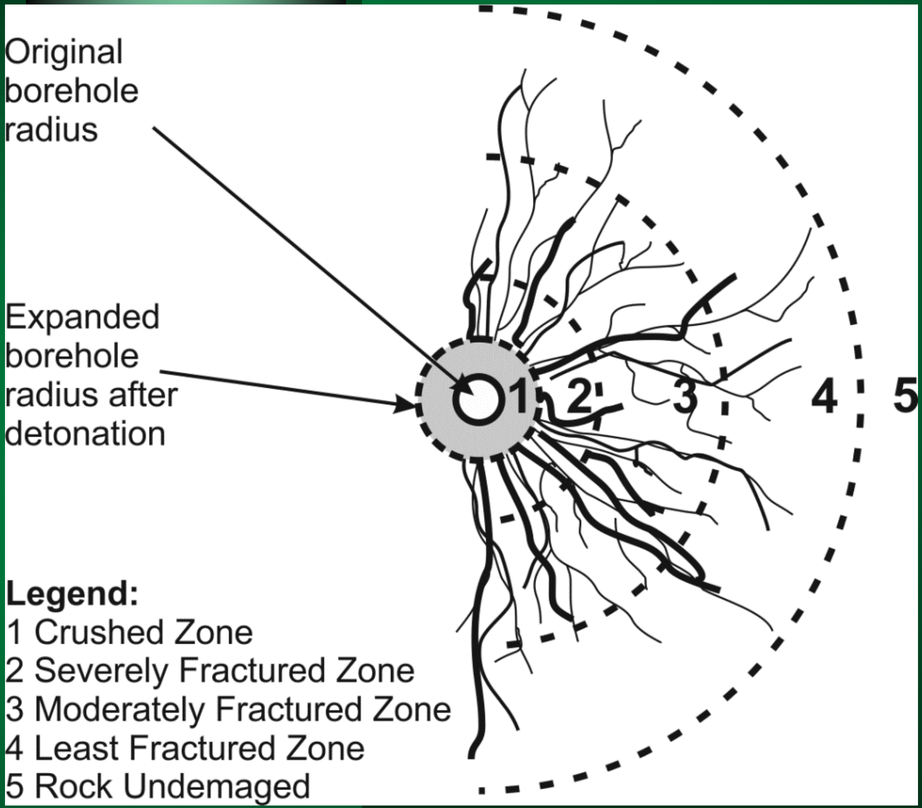


- Using of destress blasting is not so much common technique in hardcoal mining yet.
- State-of-the-Art Review:

Mitri, H, and Saharan, M.R., 2006. Destress blasting in hard rock mines-a state-of-the-art review, *CIM Bulletin*,Vol. 1, No. 109.

Konicek, P., Saharan, M. and Mitri, H. 2011. Destress Blasting in Coal Mining – State-of-the-Art Review. *Procedia Engineering*. 2011, vol. 26, s. 179-194.

DETONATION PRINCIPLES, ROCK FRACTURING:



According to PalRoy 2009

- Detonation – explosion of reactive material – greater speed than sonic velocity:
  - Shock wave
  - Chemical reaction – heat energy and high pressure gas
- Impact of stress in the shock front following pressure of gases after detonation.
- Crushing of rocks (near area of explosive charge) creation new fractures or reopening of existing fractures.
- Generation of elastic waves in rock mass in greater distance from explosive charge (possible stress release of rock mass)

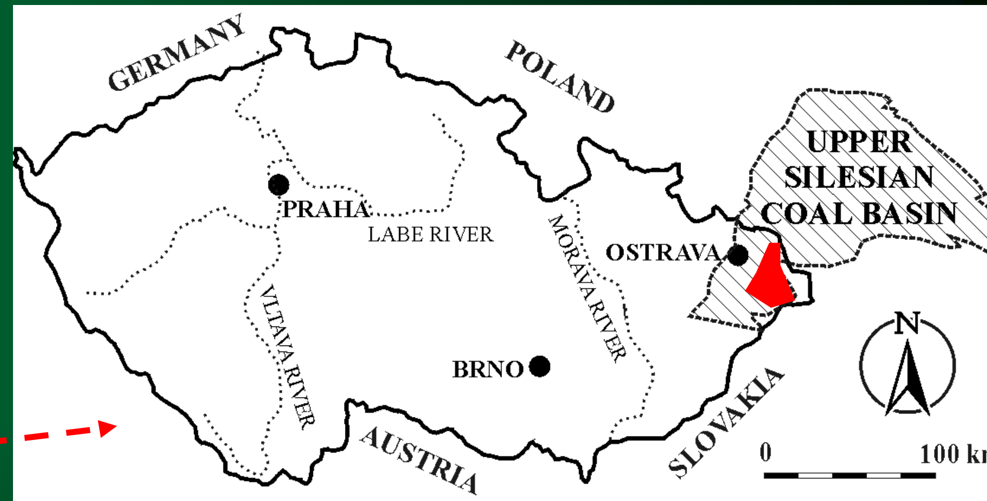
RANGE OF ROCK FRACTURING:

- Creation of new fractures and expansion of existing fractures – mainly in direction of maximal stress.
- With increasing depth (2000 m) → decreasing new fractures occurrence and reopening existing fractures ⇒ effect of high stress.
- Modulus of elasticity and tensile strength have insignificant role on fractures development in surroundings area of borehole.
- Modelling of explosives → emulsion types of explosives are more suitable for rigid and brittle rocks than ANFO types of explosives.
- Directional fracturing of rocks → technique of predispose notches ⇒ increasing of impact energy of explosives for more effective stress release ⇒ long fractures in different direction that direction of maximal stress.

STRESS RELEASE:

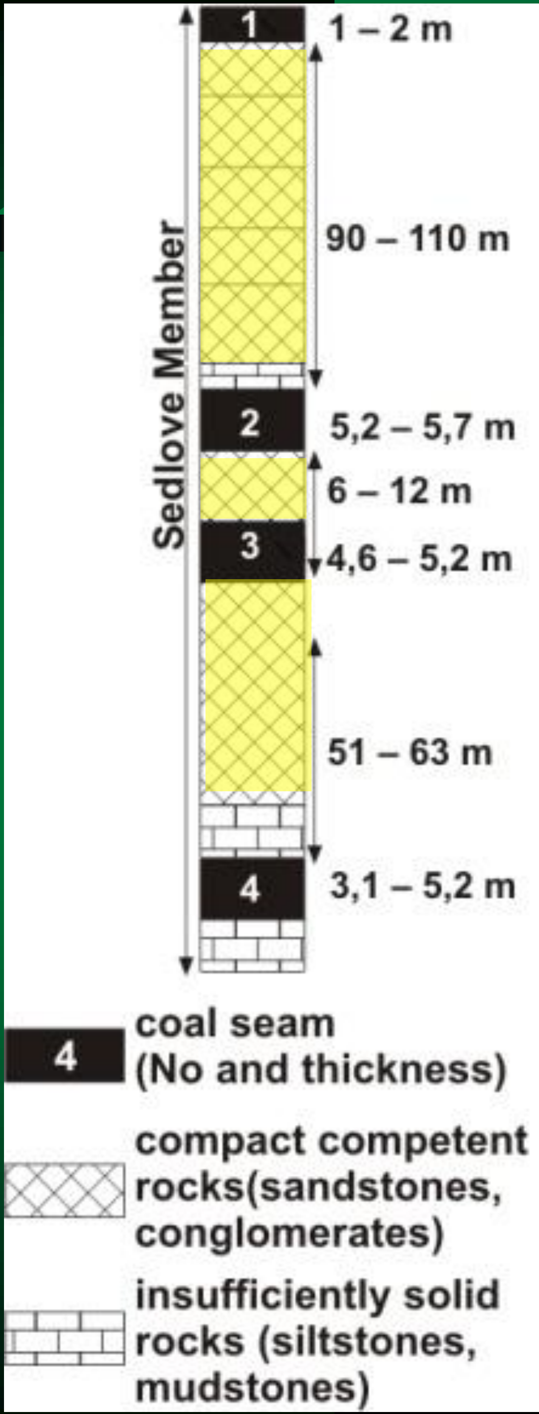
- Visual inspection of underground openings impacted by rockburst, which is an impact of stress release.
- Stress changes measurement.
- Geophysical methods.
- Due to engineers methods allow to evaluate of effect of stress release.
  - Destressability index (Andrieux and Hagigeorgiou 2008)
  - Seismic Effect (Konicek et al. 2013)

INTRODUCTION - LOCATION



Upper Silesian Coal Basin:

- Area : 7000 km^2 (78% – Poland
  22 % – Czech Republic
- Hardcoal deposit of Carboniferous age.
- Nowadays – exploitation mainly in Karvina Subbasin



SITE CONDITIONS

- Depth 800 –1200 m.
- Coal seams (thickness 3–10 m).
- Interbeds – compact competent rocks (conglomerates and sandstones) – more than 80 % share.

	UCS (MPa)	RQD (%)
Coal	10–30	–
Mudstone	35–65	–
Siltstone	40–150	60–90
Sandstone	50–170	70–90
Conglomerate	40–140	70–90

MINING CONDITIONS

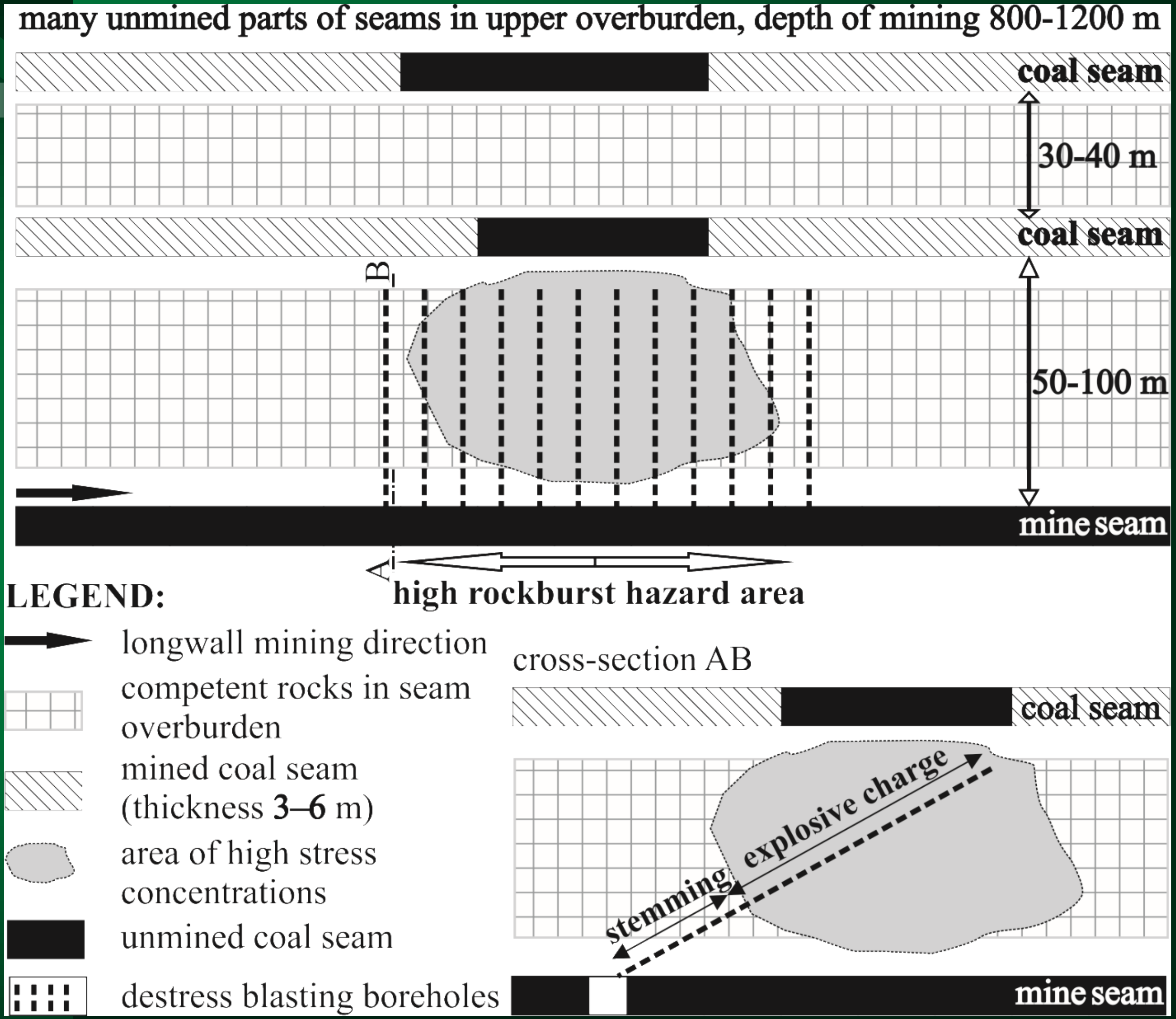
- Long–term mining (more than 200 years).
- Mined out tens seams in carboniferous rock mass.
- Used mining method – longwall mining.
- Occurrence of many abandoned pillars in seams.
- Sometimes disrespecting natural (geological) boundaries (abandoned pillars).
- Sometimes improper time sequences of mining (e.g. between neighbouring colliery claims).

Induced stress field is anisotropic and non uniform!

HISTORY OF DESTRESS BLASTING

- Destress blasting application from 1980's (the first destress rock blasting in 1973),
- In the beginning – using charges hundreds kg,
- In nowadays are using charges about thousands kg,
- Progressive improvement:
  - Technology of drilling,
  - Technology of blasting
  - Evaluation of range of fracturing from blasted, boreholes,
  - Evaluation of stress release,
- Increase of application – due to increasing occurrence of competent rocks in connection with deep mining.

CONCEPTION MODEL



Disintegration of the rock mass for better caving.

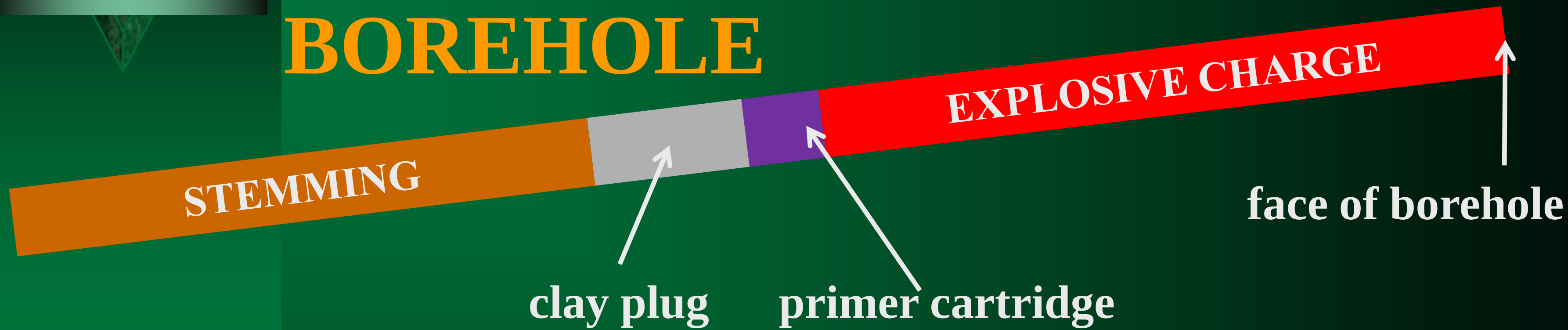
Stress release of the rock mass.

SPECIFICATIONS

General technical conditions for carrying out the destress rock blasting:

- Boreholes diameter of 75 – 105 mm drilled usually from the gateways.
- Inclination of boreholes up to 30°.
- Length of boreholes up to 100 m (sometimes up to 120 m).
- Spacing of parallel boreholes 5–12 m (according to the purpose).
- Pneumatic charging of explosives into boreholes in cartridges.
- Use of rock gelatine explosives (Perunit and Danubit types).
- Blasting without delay in one-time level.
- Blasting charges from 400 kg up to 4780 kg.
- Up to now applied more than 3000 destress rock blastings.

BLASTING TECHNOLOGY SCHEME OF BLASTING BOREHOLE



Parameter	Minimum	Maximum	Average
Length of borehole [m]	30	120	70
Length of charge [m]	15	100	44
Percentage of charge [%]	45	85	70
Stage charge [kg]	400	4781	1660
Loading density diam. 76 [$kg.m^{-1}$]	3.0	6.5	4.8
Loading density diam. 95 [$kg.m^{-1}$]	5.1	12.0	8.5

PNEUMATIC LOADING OF EXPLOSIVES

EVALUATION OF STRESS RELEASE

- Evaluation of seismological monitoring data – registered seismic energy and data of destress rock blasting (weight of explosive charge).
- Calculation of seismic effect (SE) of destress rock blasting.
- Put SE into the practice in the 1990th of the last century (application about 20 years). Verification of methodology in 2009 and 2016.

EVALUATION OF EFFECTIVENESS

Calculation of seismic effect (SE):

$$SE = \frac{E_{OKC}}{K_{OKC} \cdot Q}$$

Registered seismic energy

Equivalent of seismic energy corresponding to the size of the detonated charge weight

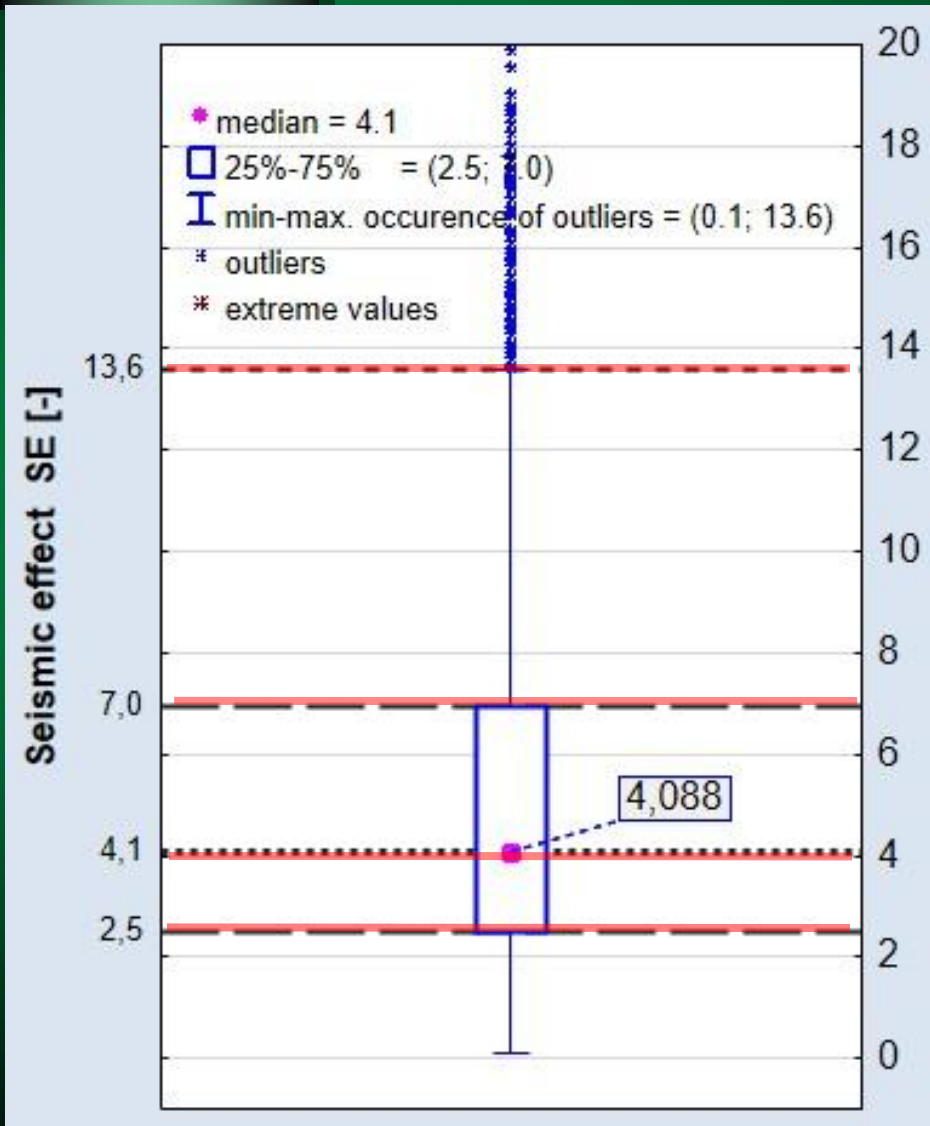
Where:

E_{OKC} – local (Ostrava-Karvina Coalfield – OKC) seismic energy of seismic event corresponding of destress blasting from seismological monitoring [J]

Q – weight of explosive charge [kg]

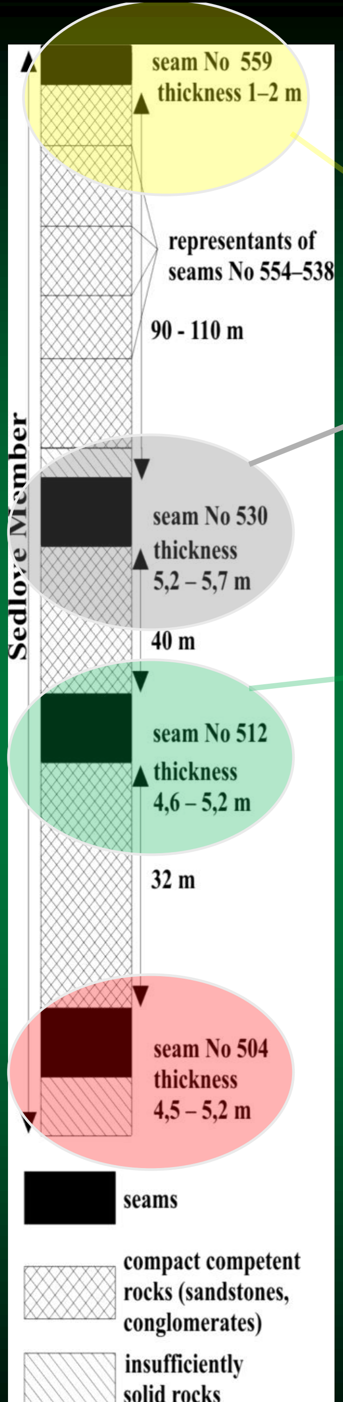
K_{OKC} combined coefficient which characterized by natural and mining conditions in OKC (K_{OKC} = 1.86). More details in Konicek et. al 2013 and Konicek 2016.

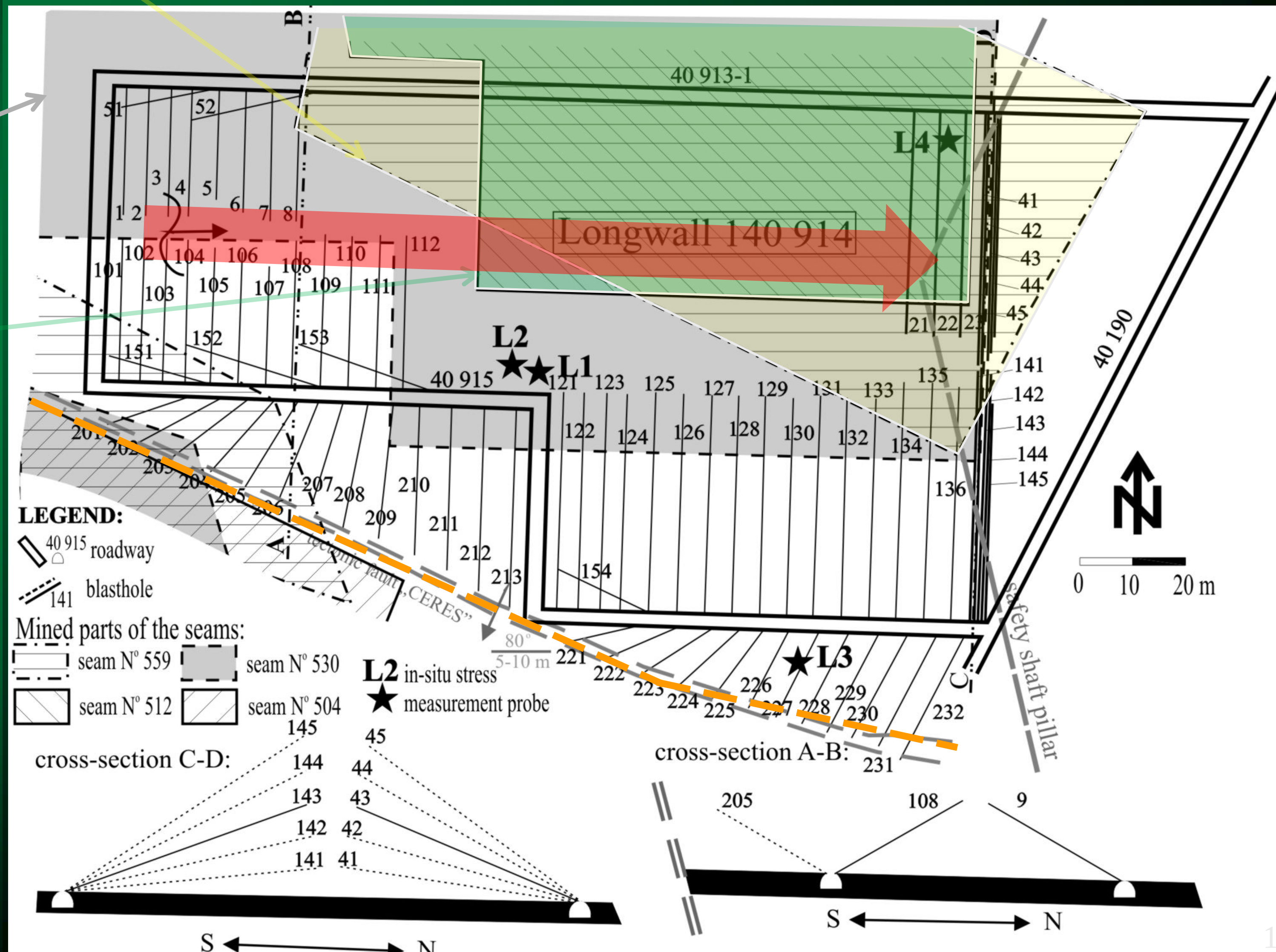
EVALUATION OF SEISMIC EFFECT (STRESS RELEASE)



Seismic effect (E_{OKR})	Evaluation of seismic effect
SE < 2.5	Insignificant
2.5≤SE<4.1	Good
4.1≤SE<7.0	Very good
7.0≤SE<13.6	Extremely good
SE ≥ 13.6	Excellent

LONGWALL NO 140 914 (LAZY COLLIERY)





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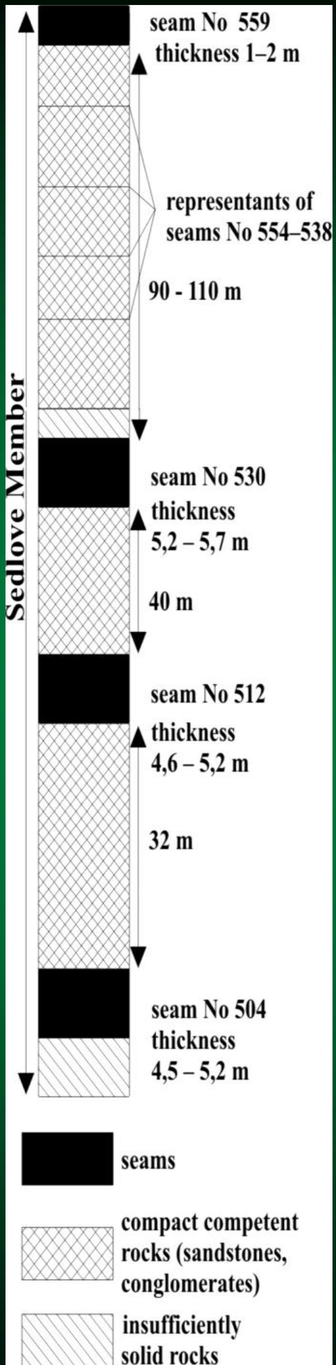
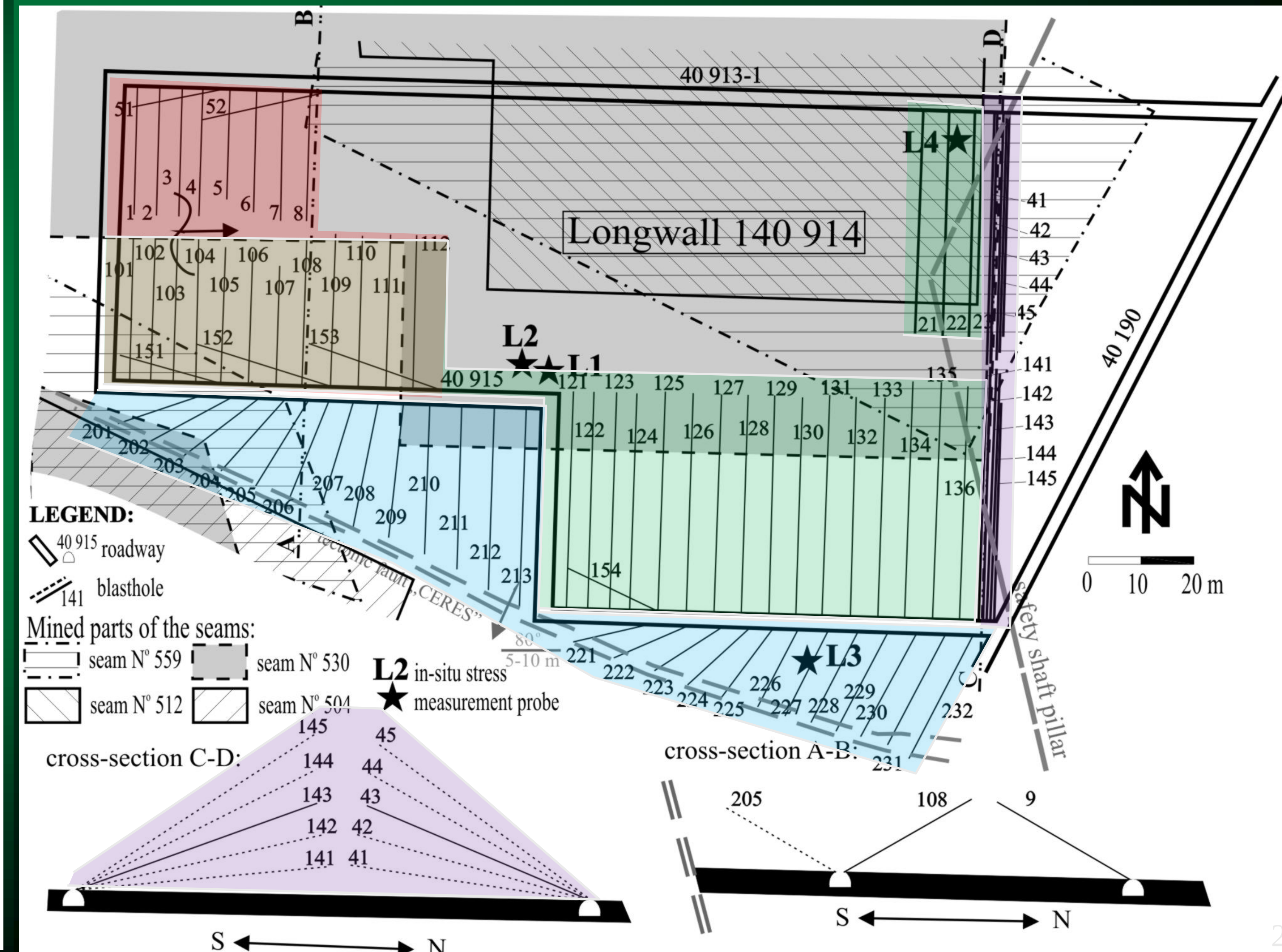
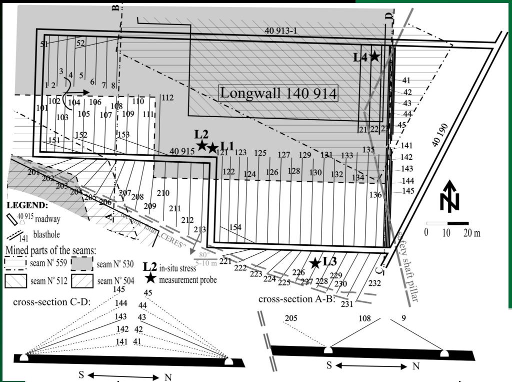


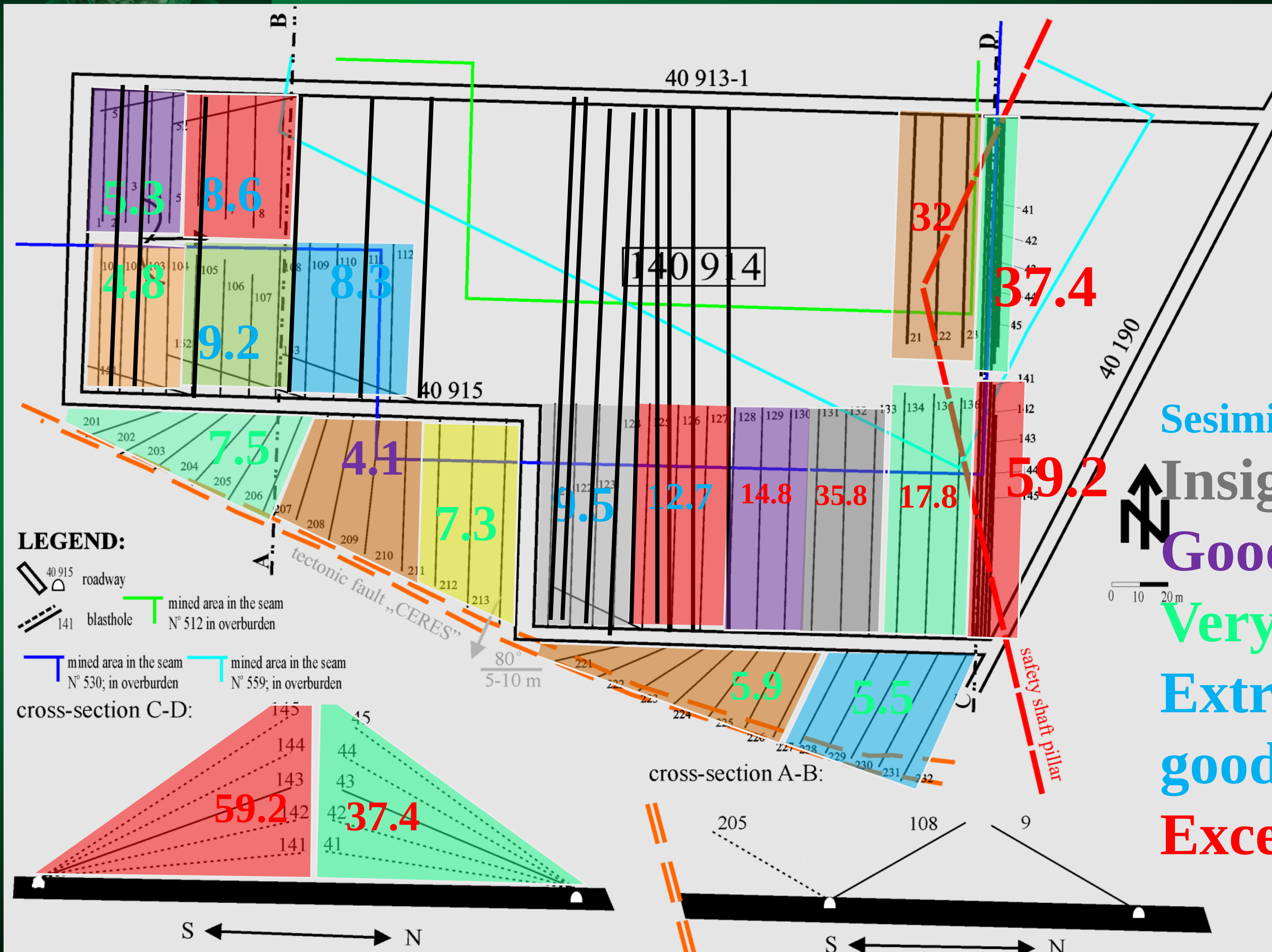




PARAMETERS OF DESTRESS BLASTING

stage	date and time	numbers of boreholes	explosive charge [kg]	registered seismic energy [J]	seismic effect (SE) [J.kg^{-1}]	evaluation of SE
1	16.7.2006; 16:23:06	1-4, 51	1625	1.61E+04	5.3	very good
2	23.7.2006; 16:32:19	101-104, 151	1550	1.39E+04	4.8	very good
3	29.10.2009; 17:20:58	201-206	1725	2.40E+04	7.5	very good
4	12.11.2006; 16:17:17	5-8, 52	2000	3.19E+04	8.6	extremely good
5	19.11.2006; 16:27:38	105-108, 152	1775	3.03E+04	9.2	extremely good
6	3.12.2006; 16:28:51	109-112, 153	2150	3.31E+04	8.3	extremely good
7	17.12.2006; 16:51:27	207-210	1700	1.29E+04	4.1	good
8	14.1.2007; 16:14:05	211. 212, 213	1850	2.50E+04	7.3	very good
9	4.2.2007; 17:33:04	121-124, 154	2500	4.40E+04	9.5	extremely good
10	8.3.2007; 16:31:07	125. 126, 127	2125	5.00E+04	12.7	extremely good
11	11.3.2007; 17:50:30	221-227	1635	1.80E+04	5.9	very good
12	18.3.2007; 17:16:42	41-45	3450	2.40E+05	37.4	Excellent
13	25.3.2007; 17:34:01	141-145	3450	3.80E+05	59.2	Excellent
14	15.4.2007; 16:17:53	128-130	2250	6.20E+04	14.8	Excellent
15	29.4.2007; 22:41:06	131-133	2250	1.50E+05	35.8	Excellent
16	1.5.2007; 17:49:46	228-232	1850	1.90E+04	5.5	very good
17	6.5.2007; 21:48:46	134-136	2350	7.80E+04	17.8	Excellent
18	13.5.2007; 22:06:34	21-23	2350	1.40E+05	32.0	Excellent

ANIMATION OF LOGWALL ADVANCE



Sesimic effect:

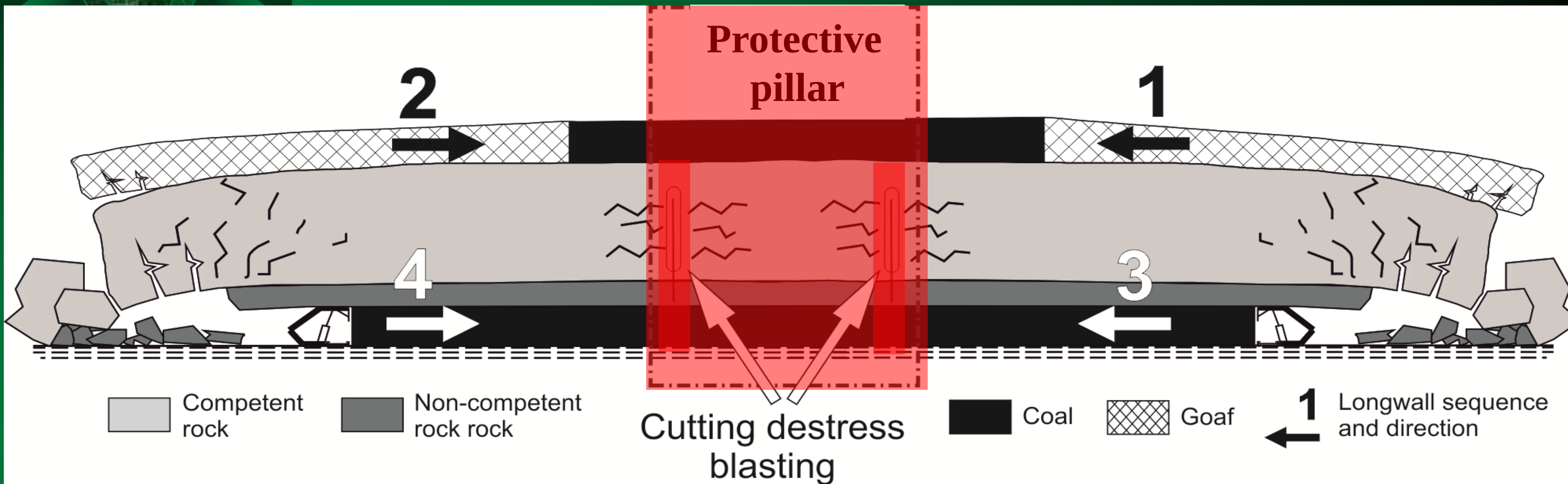
Insignificant

Good

Very good

Extremely good

Excellent



Main goals:

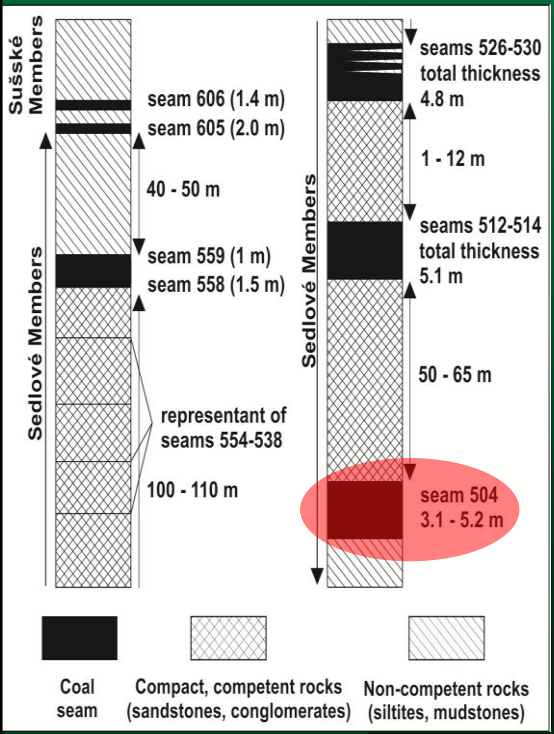
- ❑ **Create a physical separation between the deformed mining areas and the non-deformed safety pillar area and this way decrease the impact of additional stress induced inside the safety pillar area.**
- ❑ **Stress release without employees in underground openings.**

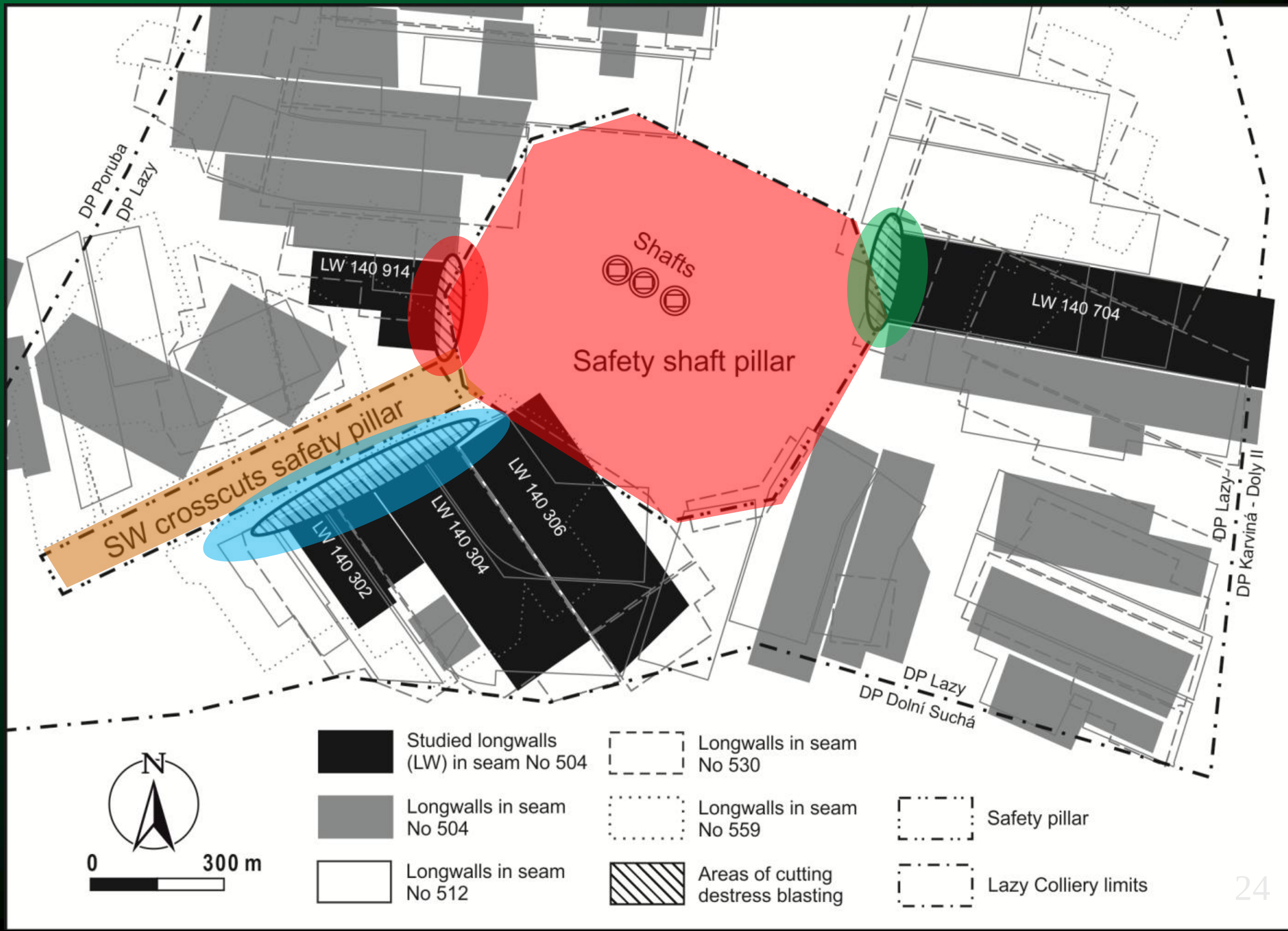
CUTTING DESTRESS BLASTING

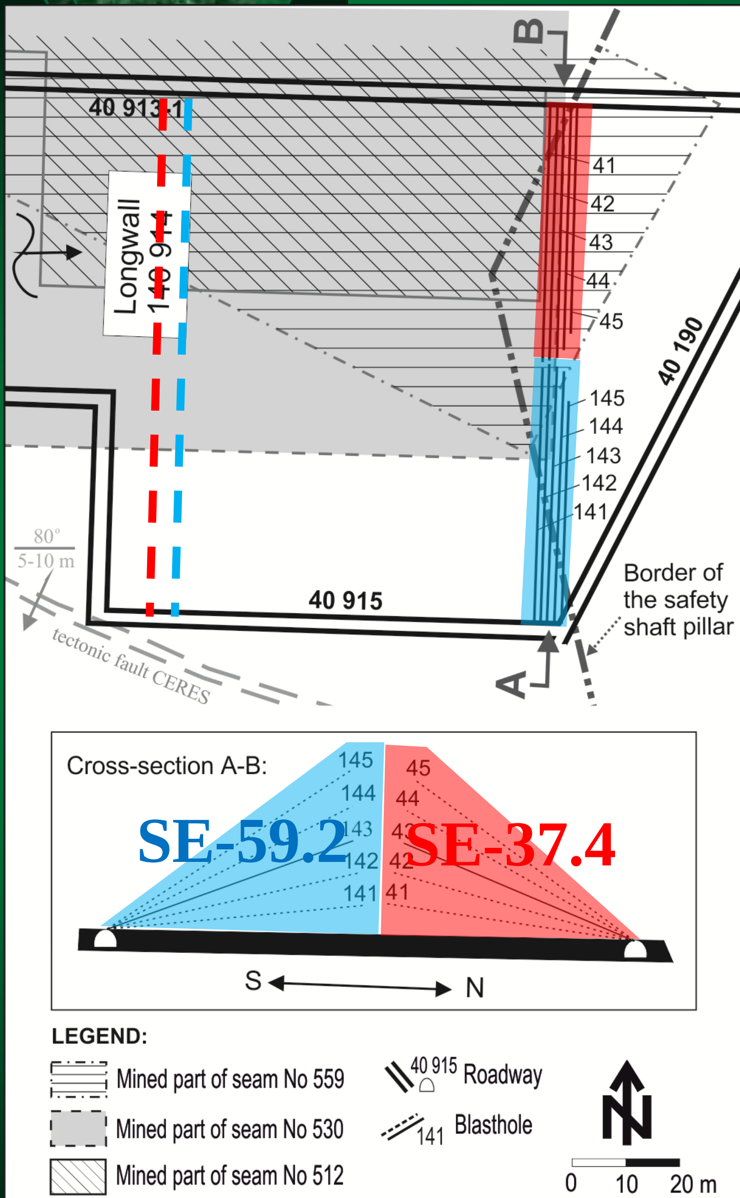
Case No. 1: longwall 140 914

Case No. 2: longwall 140 704

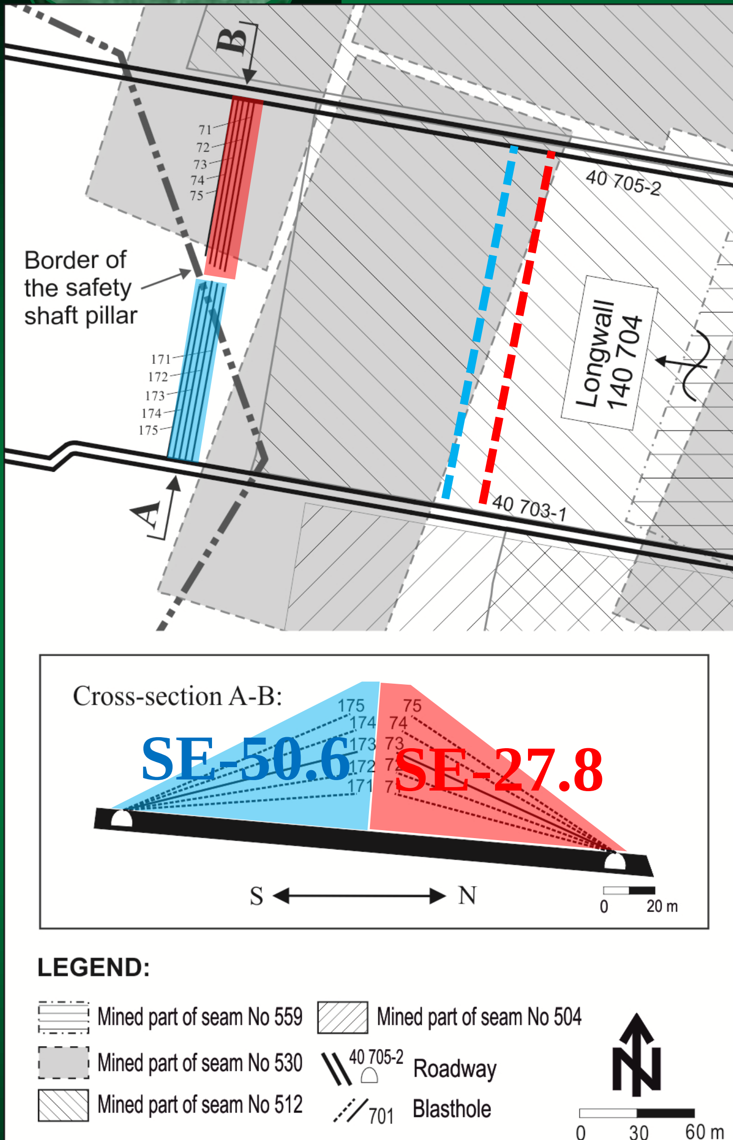
Case No. 3: longwalls near the SW crosscuts safety pillar



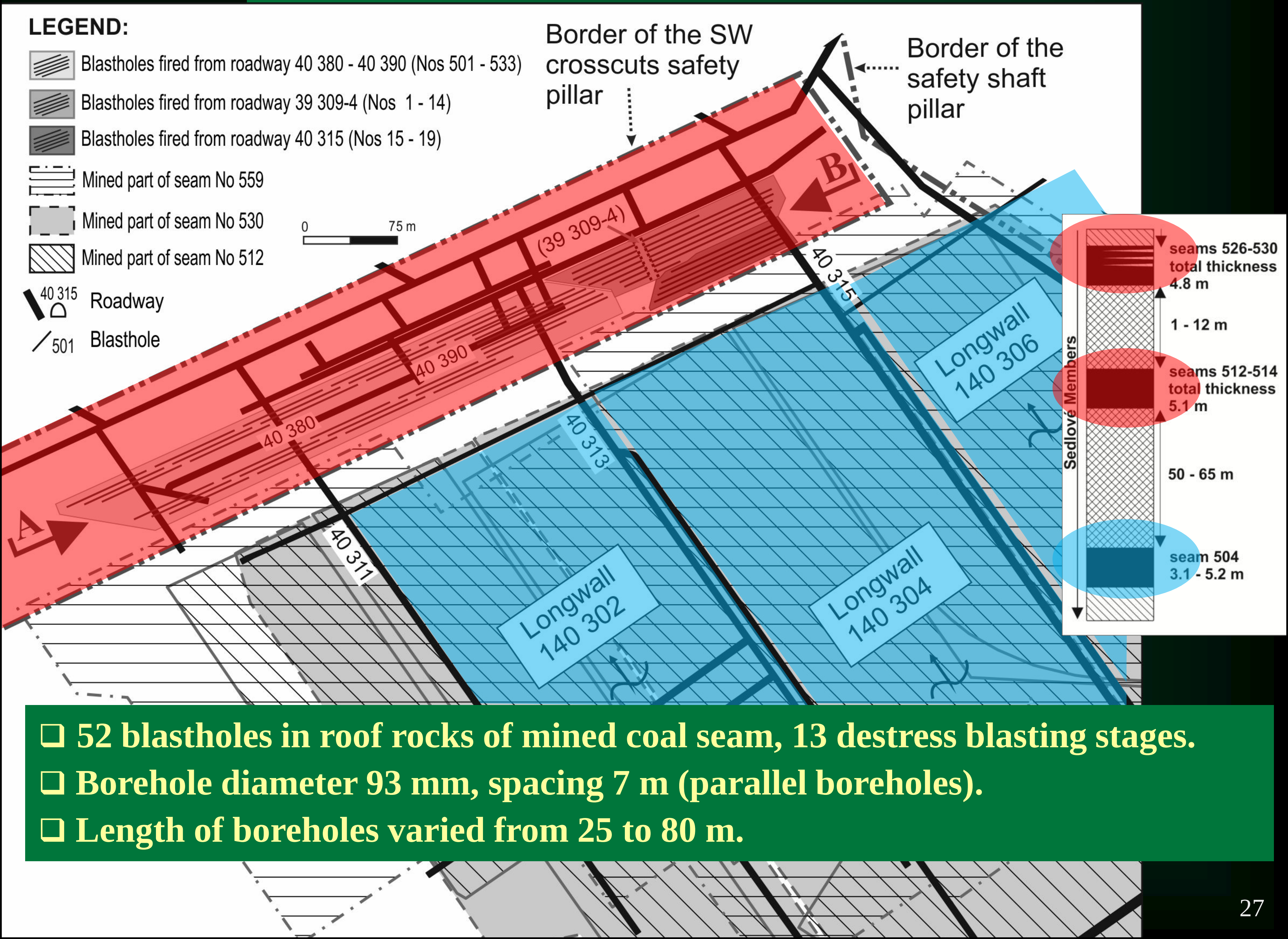




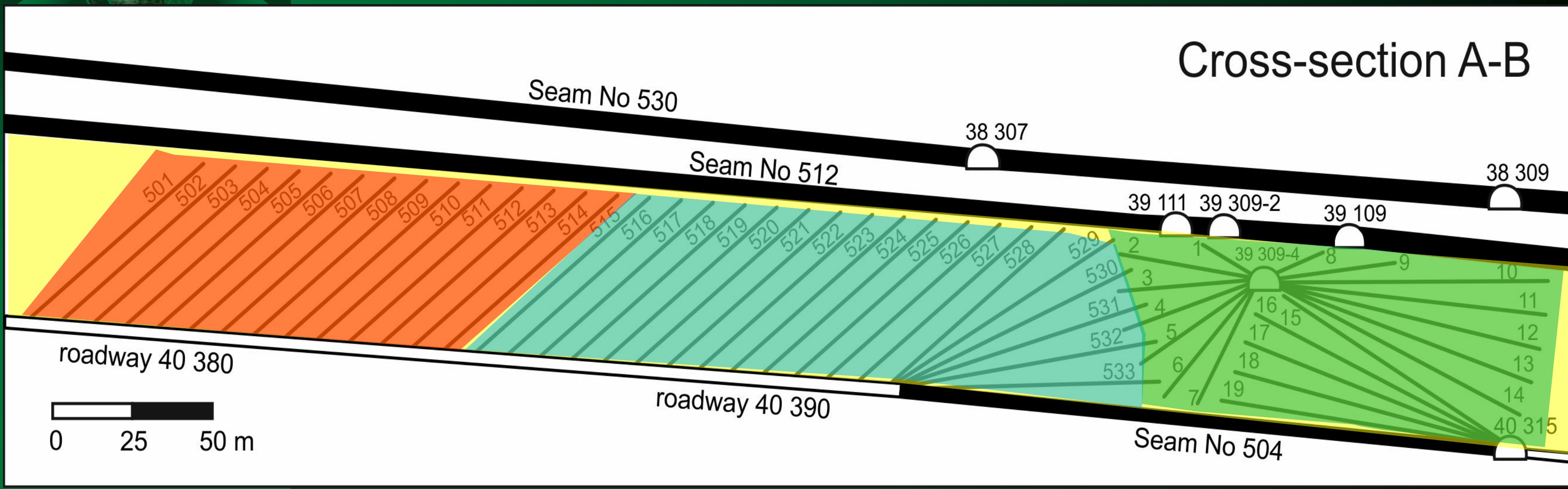
- 2 funs of borehole in the same vertical plane.
- Borehole diam. 93 mm
- Length of borehole 93 – 100 m.
- Borehole inclination 4º to 35º (upwards).
- 2 stages of destress blasting.
- Pneumatic loading explosives in cartridges.
- % of the loaded lengths: 67-80%.
- Charge from 595 to 780 kg per blasthole (according to length and position).
- Length of stemming (sand) 20 – 30 m.
- Firing without time delay (electric detonator).
- Stage 12–boreholes 41-45 (3450 kg explosive), 158 m from longwall face, released energy 2.4 E+05 J, SE 37.4.
- Stage 13–boreholes 141-145 (3450 kg explosive), 152 m from longwall face, released energy 3.8 E+05, SE 59.2.



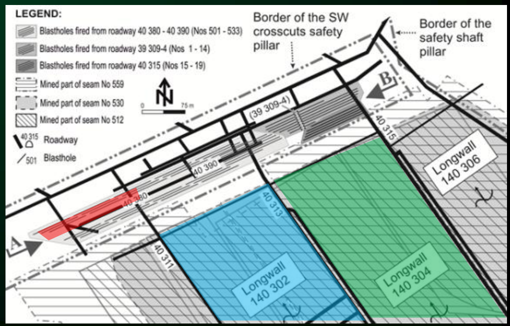
- ❑2 funs of borehole in the same vertical plane.
- ❑Borehole diam. 95 mm.
- ❑Length of borehole 93 – 100 m.
- ❑Borehole inclination 4º to 34º (upwards).
- ❑2 stages of destress blasting.
- ❑Pneumatic loading explosives in cartridges.
- ❑ % of the loaded lengths:50-80%.
- ❑ Charge from 415 to 700 kg per blasthole (according to length and position).
- ❑ Length of stemming (sand) 20 - 46 m.
- ❑ Firing without time delay (electric detonator).
- ❑Stage 19–boreholes 71-75 (2900 kg explosives) 168 m from longwall face, released energy 1.5 E+05 J, SE 27.8.
- ❑Stage 20–boreholes 171-175 (2975 kg explosives), 132 m from longwall face, released energy 2.8 E+05, SE 50.6.



- ❑ **52 blastholes in roof rocks of mined coal seam, 13 destress blasting stages.**
- ❑ **Borehole diameter 93 mm, spacing 7 m (parallel boreholes).**
- ❑ **Length of boreholes varied from 25 to 80 m.**



- Charge from 415 to 700 kg per blasthole (according to length and position).
- Length of charges varied form 18 to 60 m.
- Length of stemming (sand) 7- 20 m.
- Firing without time delay (electric detonator).
- Pneumatic loading explosives in cartridges.
- Stage charge range from 1130 to 2760 kg.

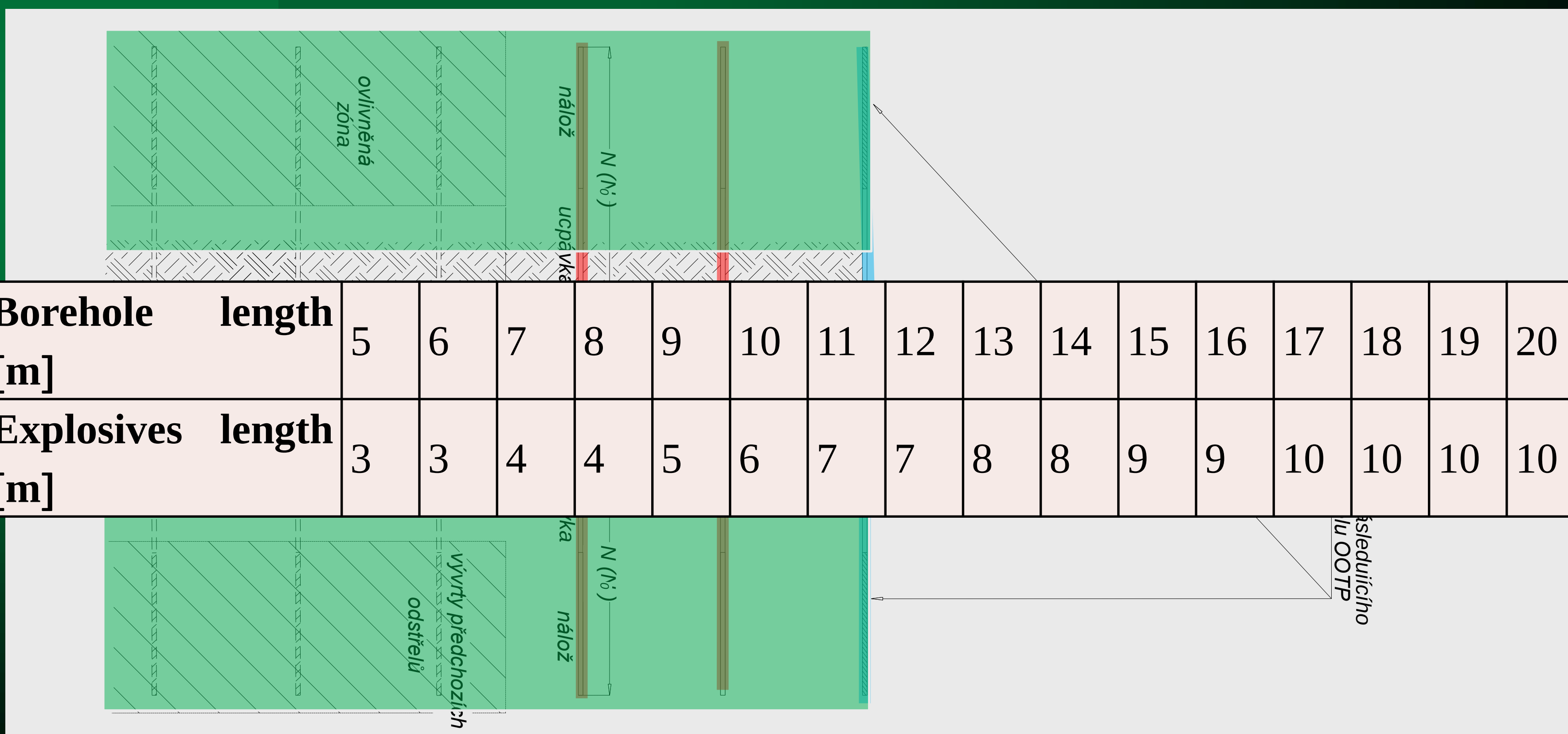


Stage	Blasthole number (-)	Explosive charge (kg)	Released seismic energy (J)	SE (Jkg^{-1})	Seismic effect evaluation (-)
1	501-504	1560	1.70E+04	5.9	Very good
2	516-519	1656	1.50E+04	4.9	Very good
3	505-508	1656	1.50E+04	4.9	Very good
4	520-523	1656	1.20E+04	3.9	Good
5	512-515	1688	2.10E+04	6.7	Very good
6	509-511	1130	1.30E+04	6.2	Very good
7	524-527	1728	2.30E+04	7.2	Extremely good
8	1.7	1488	2.30E+04	8.3	Extremely good
9	12.14	1275	7.60E+03	3.2	Good
10	8.11	1296	1.50E+04	6.2	Very good
11	528-530	1344	1.10E+04	4.4	Very good
12	531-533	1506	1.00E+04	3.6	Good
13	15-19	2760	2.00E+04	3.9	Good

Example – preconditioning for roadway driving:

Length to face: N=7 to12 m (safety area according to methodology) + planned face advance.

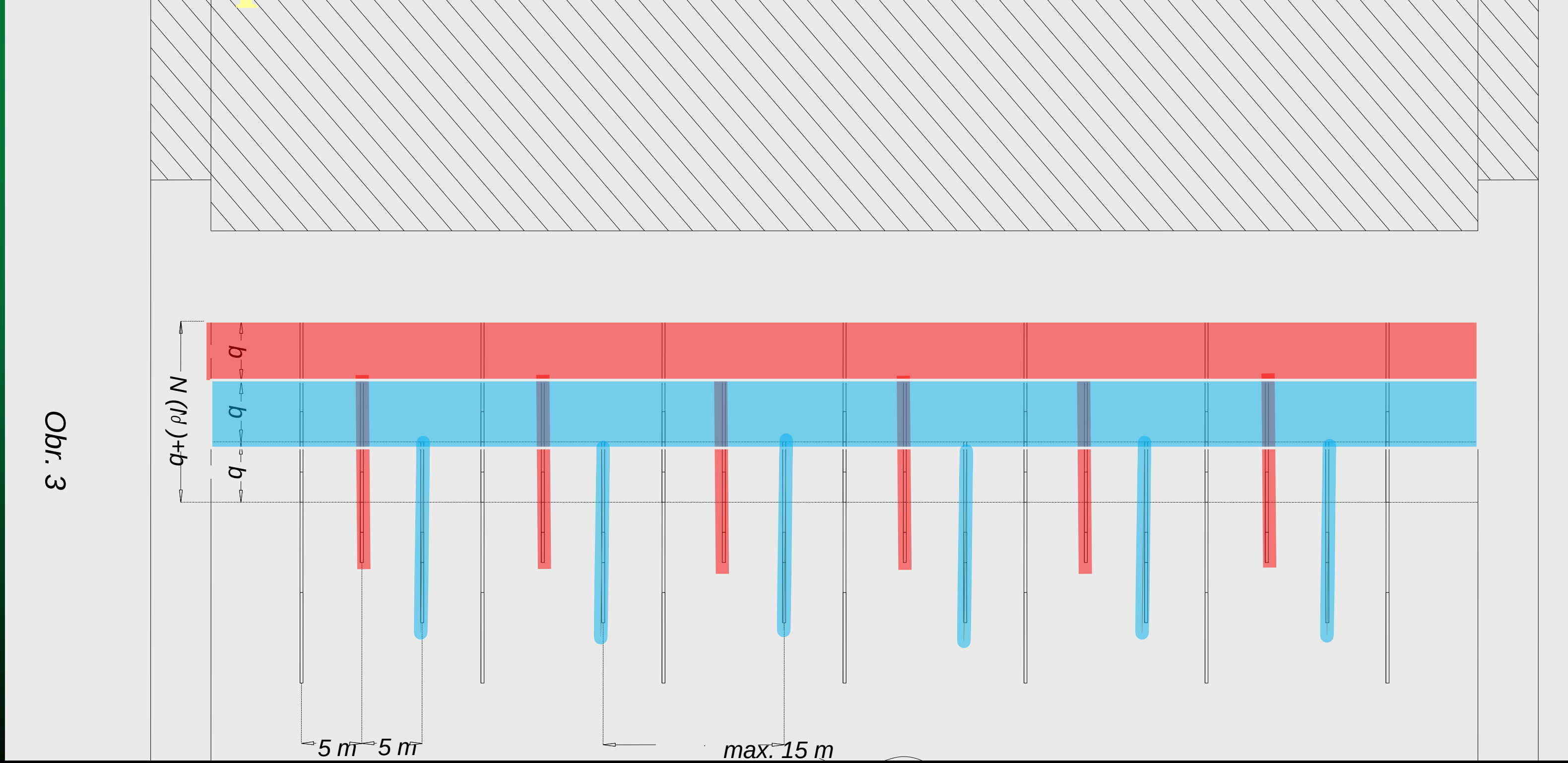
Length to ribs: N=7 to 12 m (safety area according to methodology), spacing max. 5 m.



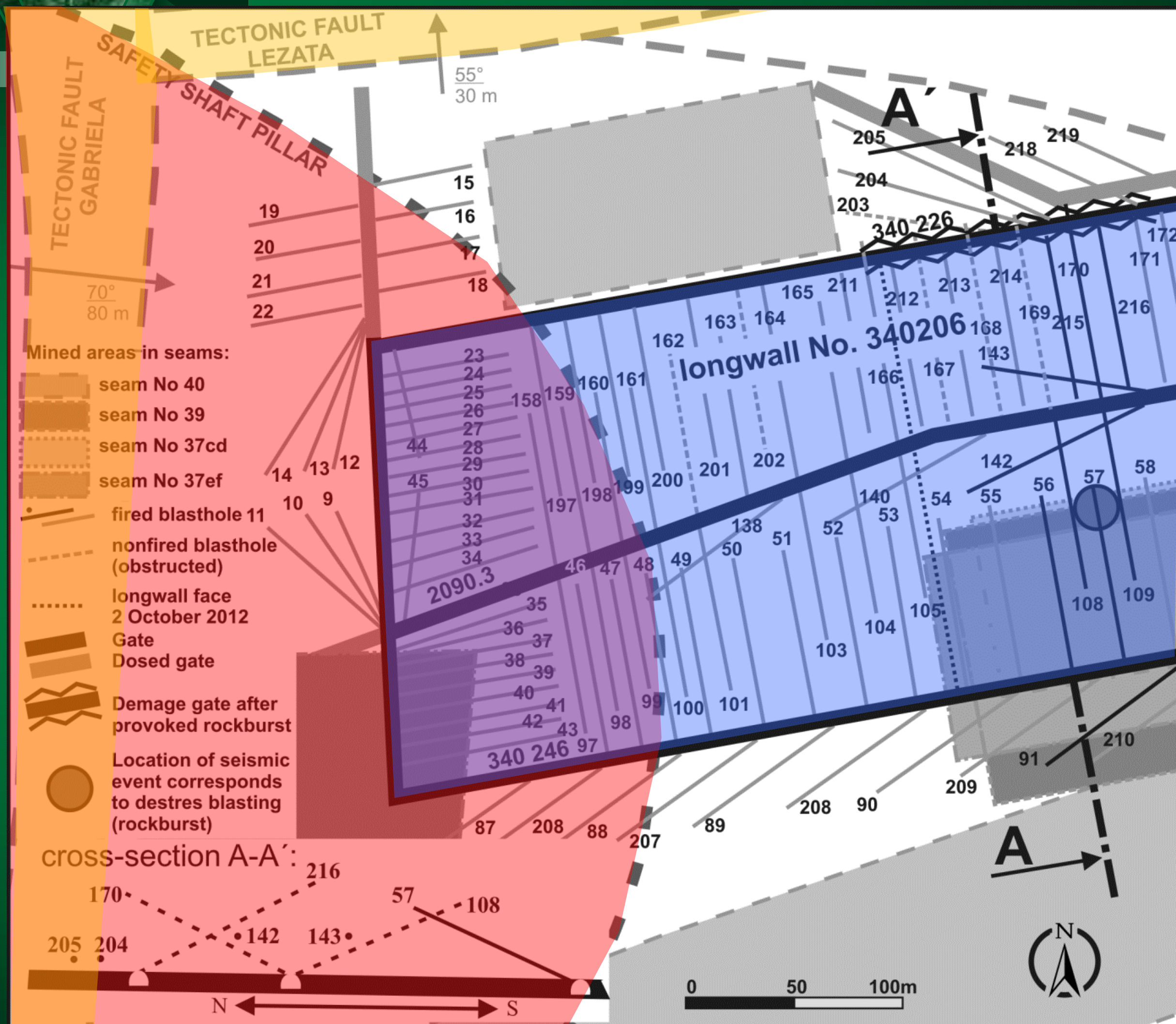
Borehole length [m]	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Explosives length [m]	3	3	4	4	5	6	7	7	8	8	9	9	10	10	10	10

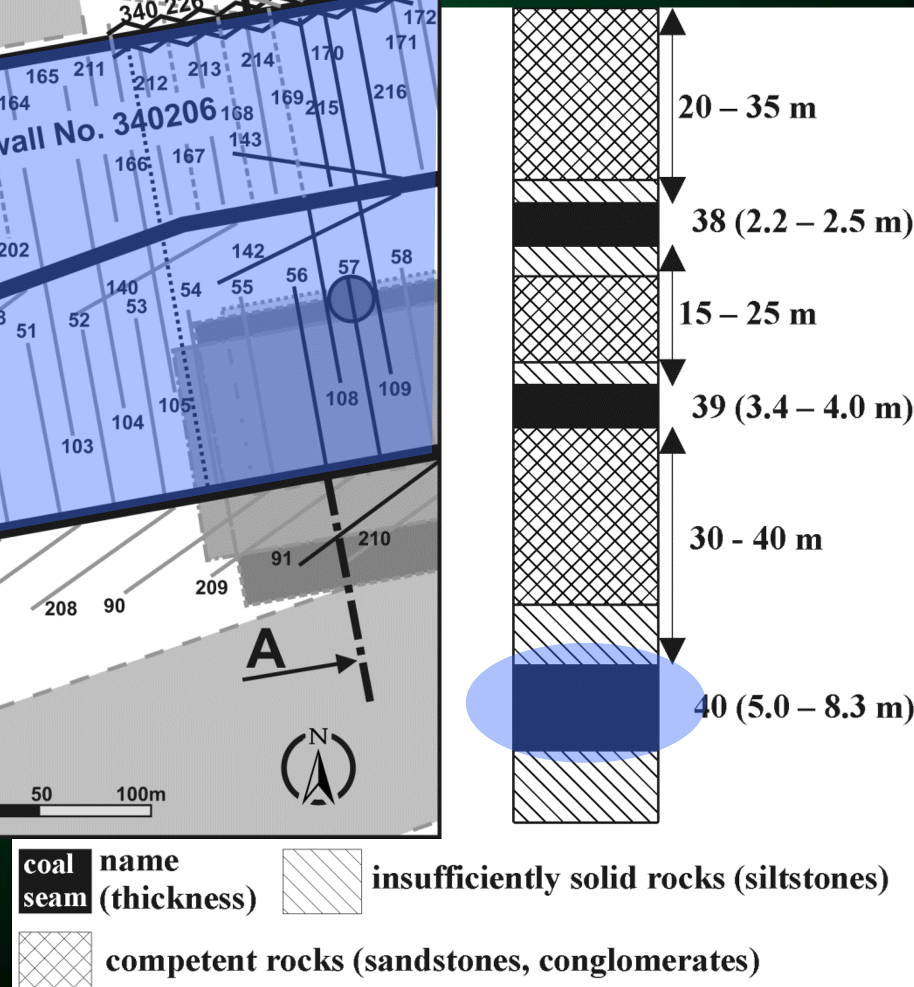
Example – preconditioning for longwall mining:

Length to face: N=7 to 12 m (safety area according to methodology) + planned face advance; general spacing max. 5 m., spacing in the same row max. 15 m, do not drilling holes in the same place!

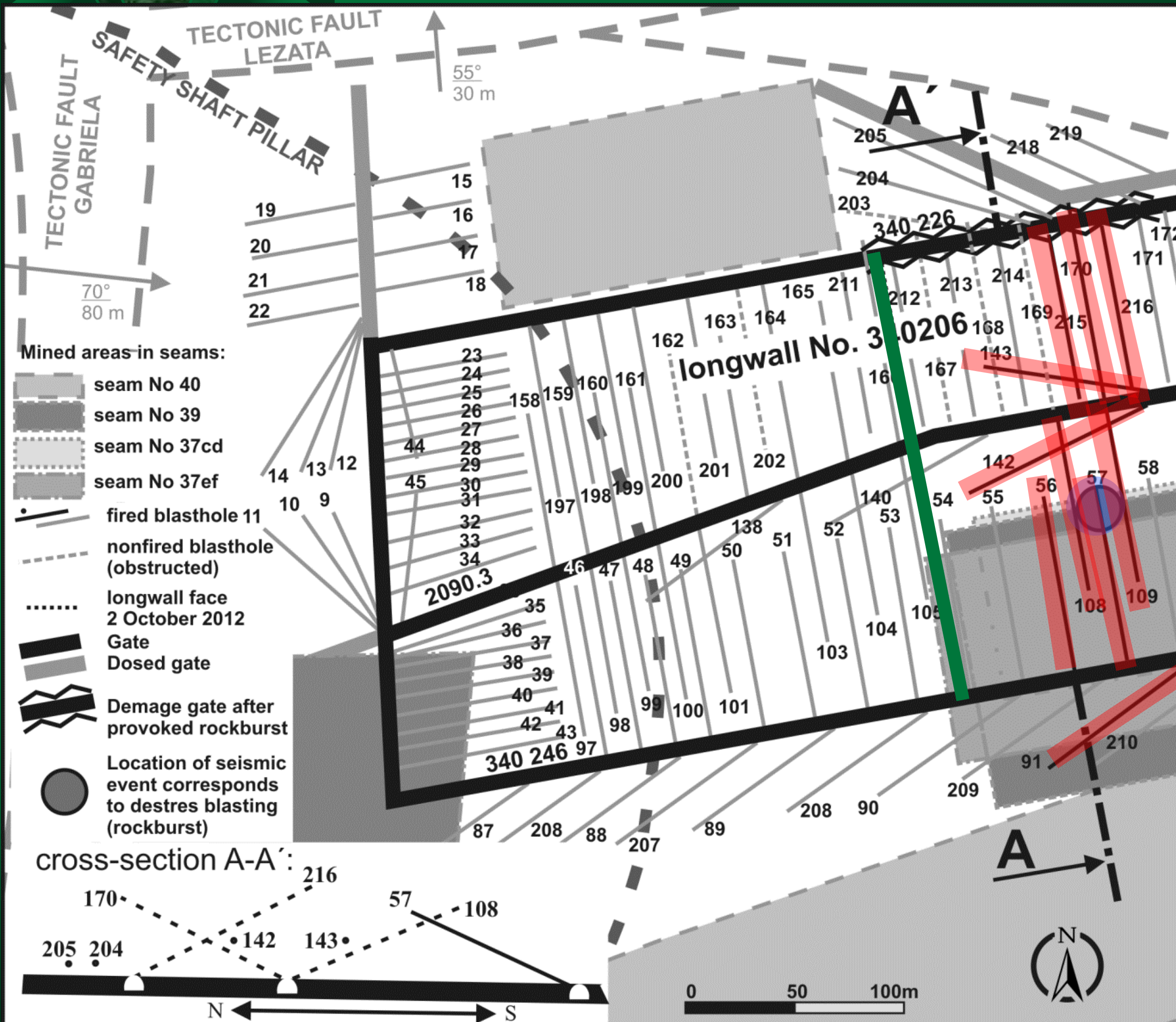


PROVOKED ROCKBURST



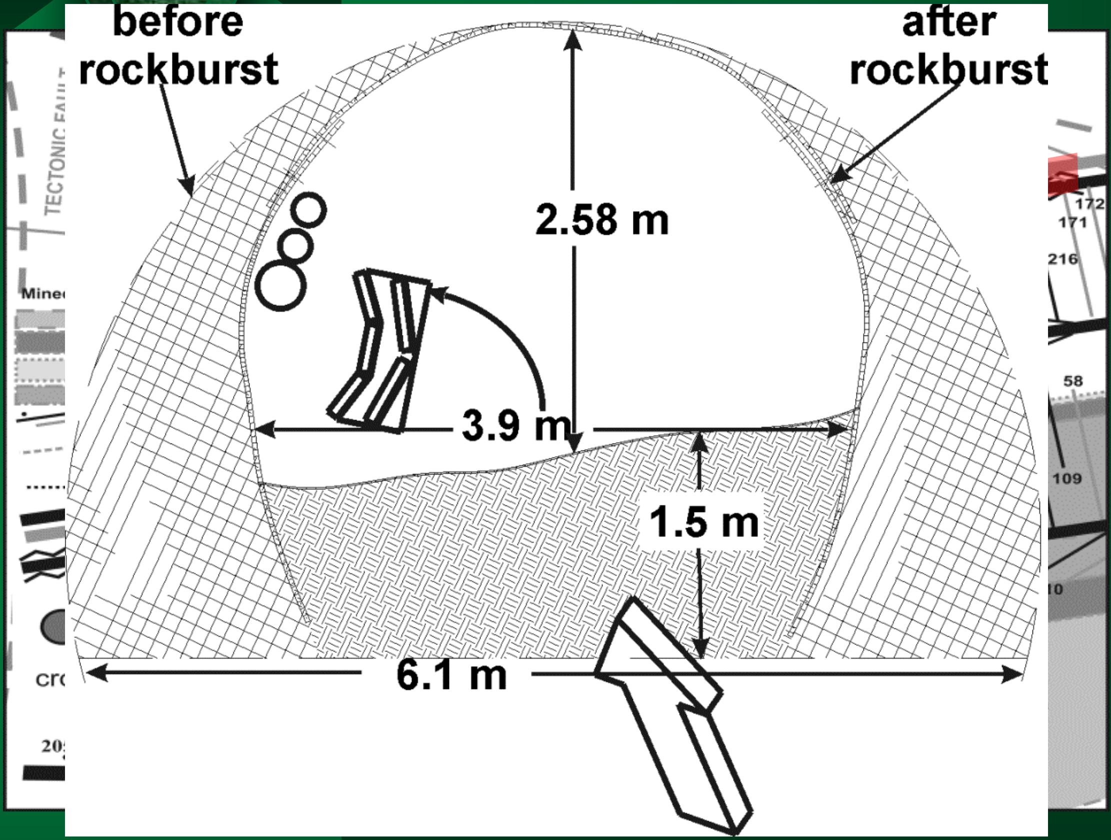


PROVOKED ROCKBURST – STAGE 13



- Boreholes Nos.215,216,108,109, 170,142,143,56,57,91
- Borehole explosive charge 250-576 kg
- Stage explosive charge 3700 kg
- Average load length of borehole – 68%
- Distance from longwall face 50 m
- Registered sesimic energy – 9.7E+06
- Calculated seismic effect (success of stress release) -1409

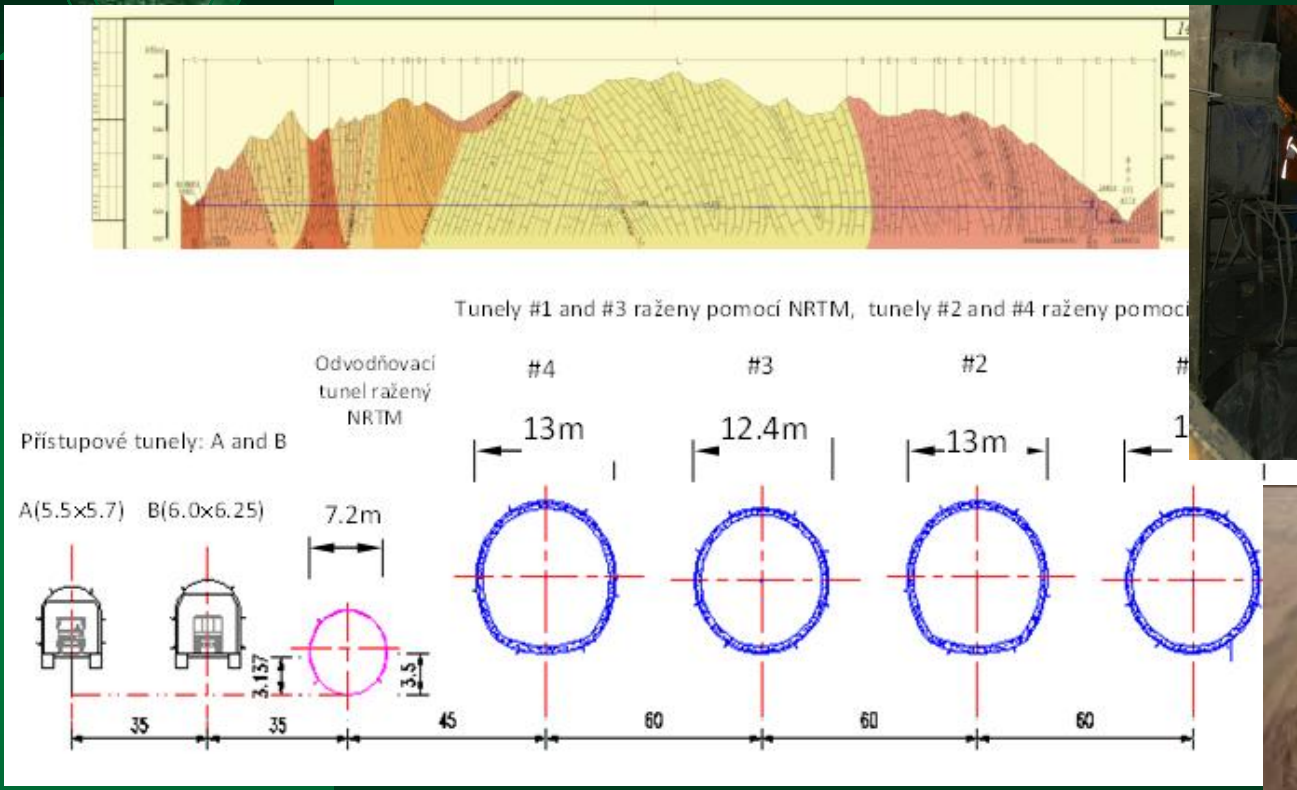
ROCKBURST IMPACT IN MAINGATE



- Length of deformation - 131 m.
- Bottom swelling up to 3.5 m.
- Deformation of steel arch.
- Broken hydraulic probes.
- Yeild of steel arches up to 0.6 m.
- Damage to conveyor belt and scatter of facilities.

→More details in FRAGBLAST conference proceedings

ROCKBURSTS IN DEEP TUNNELS:



- Tunnels for hydropower station Jinping II (China)
- Depth 1500 – 2525 m (limestones a ultrabasic dykes – UCS 80 – 114 MPa; E – 25 – 40 GPa, great horizontal stress!)
- Recorded rockbursts during driving ⇒ design modification – seismic monitoring, rockburst measures – destress blasting.

ROCKBURSTS IN DEEP TUNNELS:

ISRM

International Society for Rock Mechanics

19th ISRM Online Lecture

10 a.m. GMT – 26th September 2017

"Rockbursts at deep tunnels"

by

Professor Xia-Ting Feng

ISRM President 2011-2015

CONCLUSIONS

- Destress blasting in longwall mining are used for relatively long time.
- Experiences with application of this technique in difficult natural and mining conditions are very good.
- Many longwalls influenced by destress blasting have been mined with minimum rockburst problems.
- Seismic Effect methodology was verified and its regularly used as a part of rockburst prevention. Technique was successfully tested in different regions too (Poland).
- In some specific conditions rockburst can be provoked.
- Experiences from underground mining can be inspiration for rockburst prevention in deep tunnels.
- Also this technique similarly like another rockburst control techniques has its own limits, because nature is powerful.

THANK YOU VERY MUCH FOR YOUR ATTENTION!

Czech Academy of Sciences

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