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PIONEERING PROGRESS : THE FUTURE OF ROCK ENGINEERING

Seismic-based live tracking of underground fires and cooling period response –

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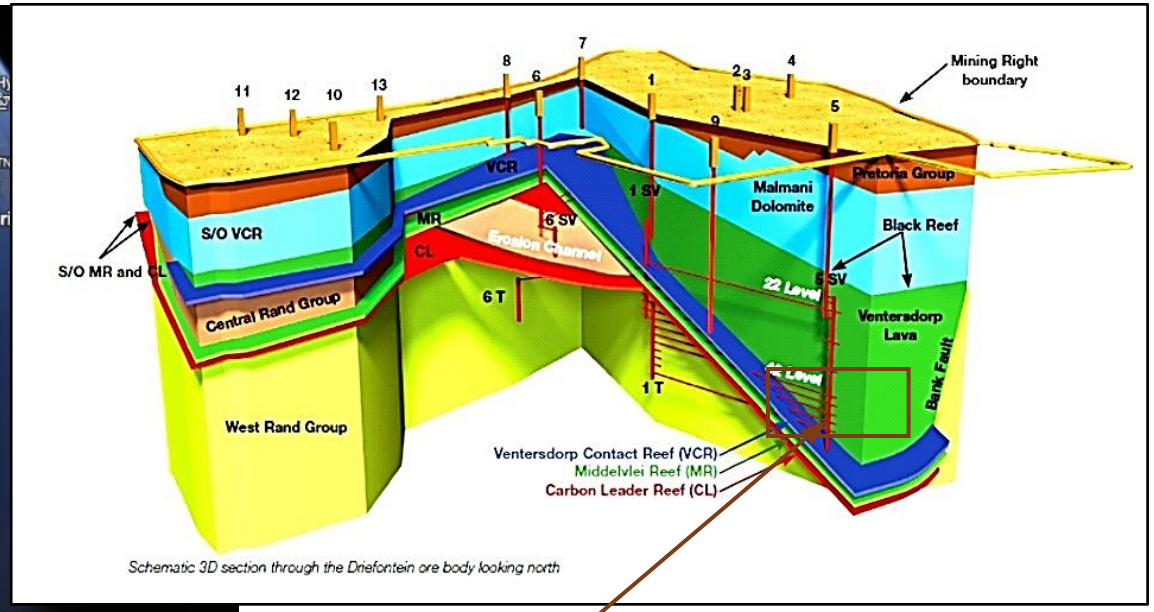
It all starts somewhere…



Sited at 3200km below surface on 44 level in Carbon leader stope.

A Fire 3.2 km Below the Surface: What Happened?

It was July 12, 2023. A spark underground went untreated by contractors busy with rehabilitation of pipe sets. By midnight, temperatures exceeded 1000°C, CO levels soared to 12,000 ppm, and the rate of seismic activity loading onto structures was set in motion by the heat distribution.

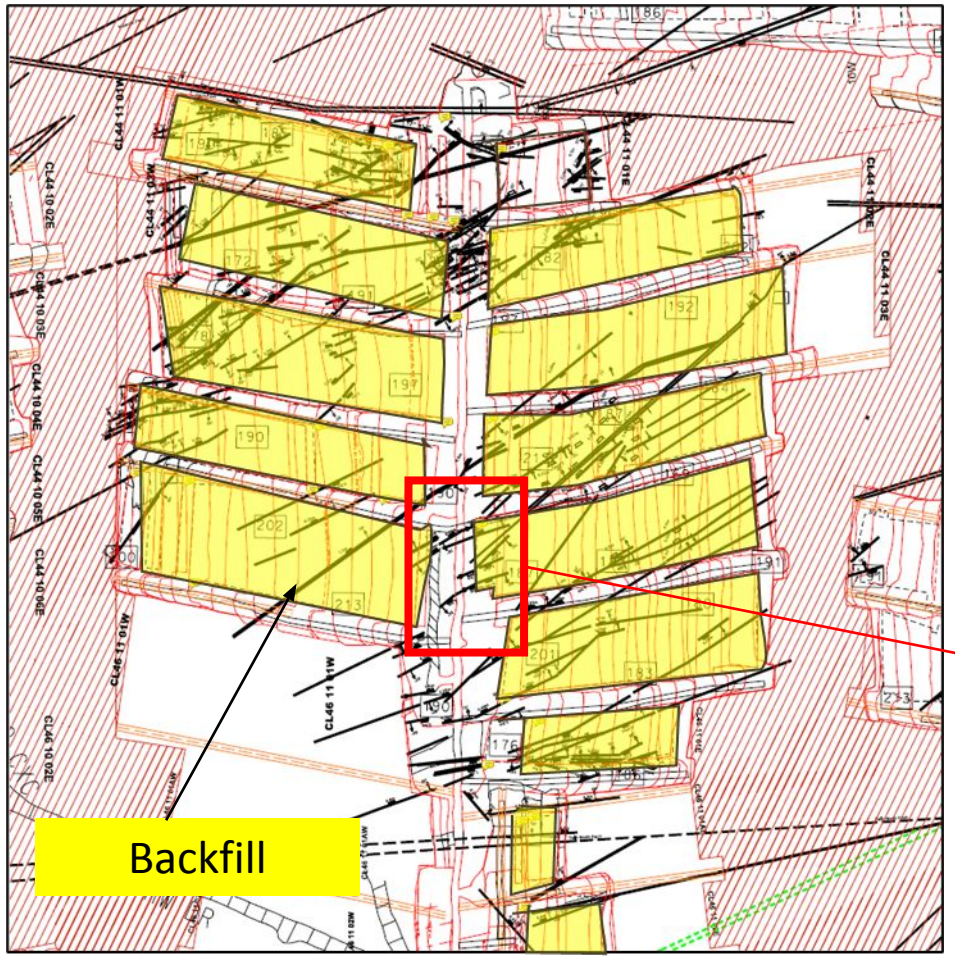
At 00h39 of the fateful shift, the last of the 31 employees were safely retrieved by MRS (proto brigades men) with one miner who sadly lost his life at 25m from the refuge bay because he did not don his self-rescuer.

Why underground fires are a game changer

Underground mining environments present several specific fire hazards that make fire incidents particularly dangerous:

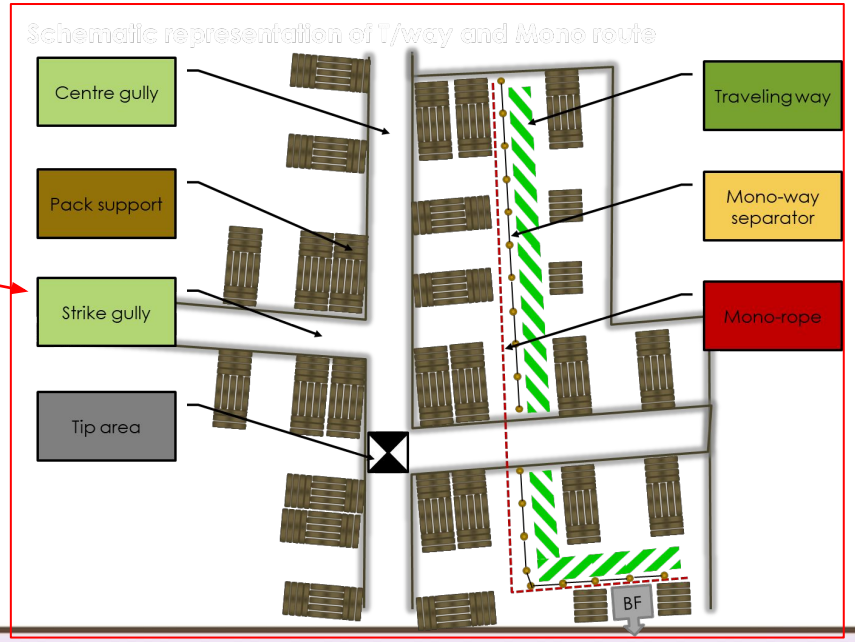
- Flammable Materials
- Limited Ventilation
- Explosive Atmosphere
- Difficult Emergency Access
- Hot-Work Risks
- Fire Detection Challenges
- Limited Escape Routes

The difference backfill makes in support design



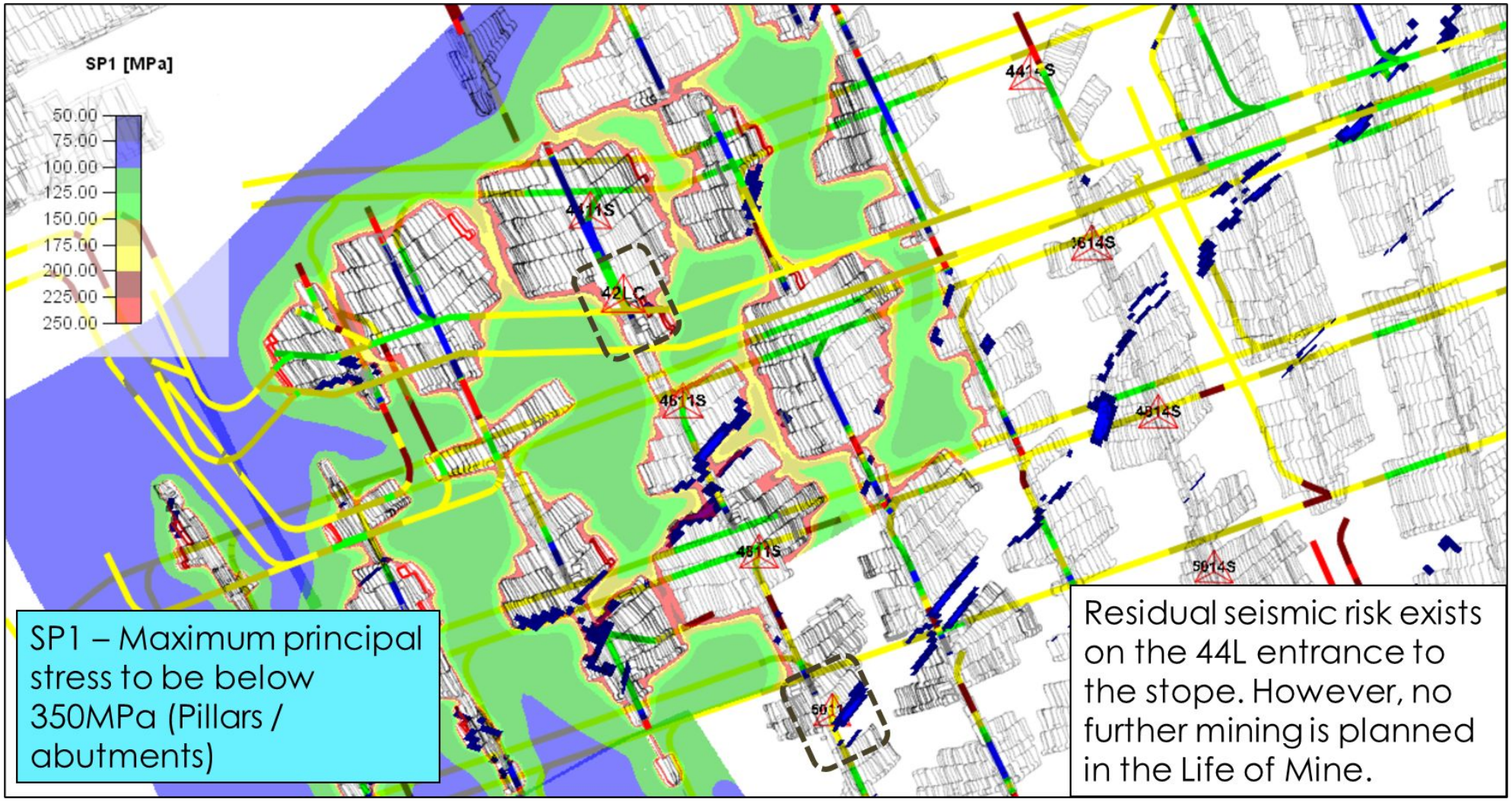
Closure rate with backfill placement

- Closure rate is theoretically the same with and without packs. The shaft has a historically low closure rate of ±150mm in 12 months versus the normal 300mm/m anticipated in ultra deep level mining.
- Packs are not designed to impact regional closure.
- Analysis of backfill installation is in line with the minimum design of 60% (23 300m² backfill out of total 39 105m² mined) to control regional closure (empirical design at 50%)



- Typical pack placement along the center raise and strike gullies

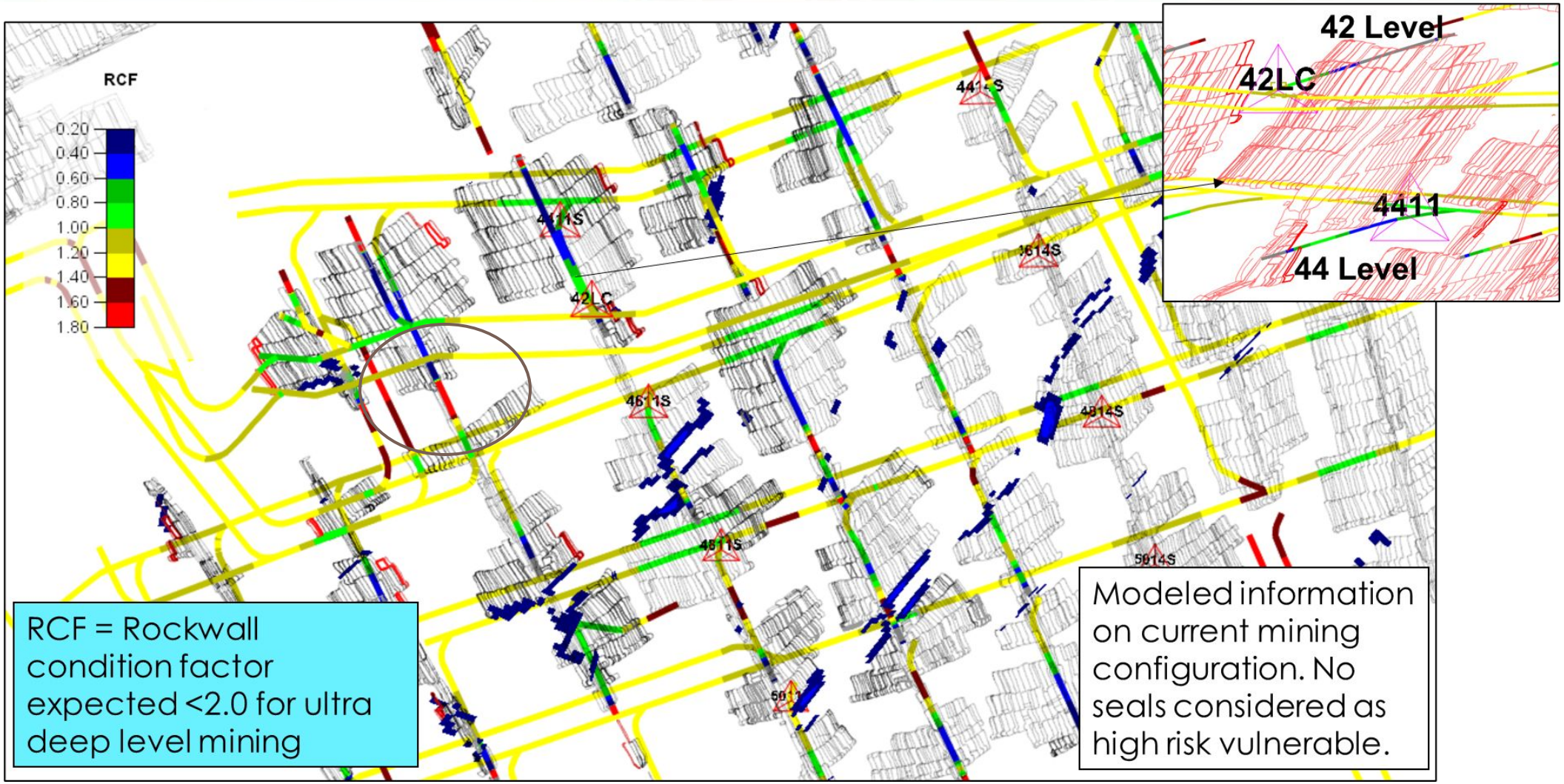
Seal exposure to potential seismic sources



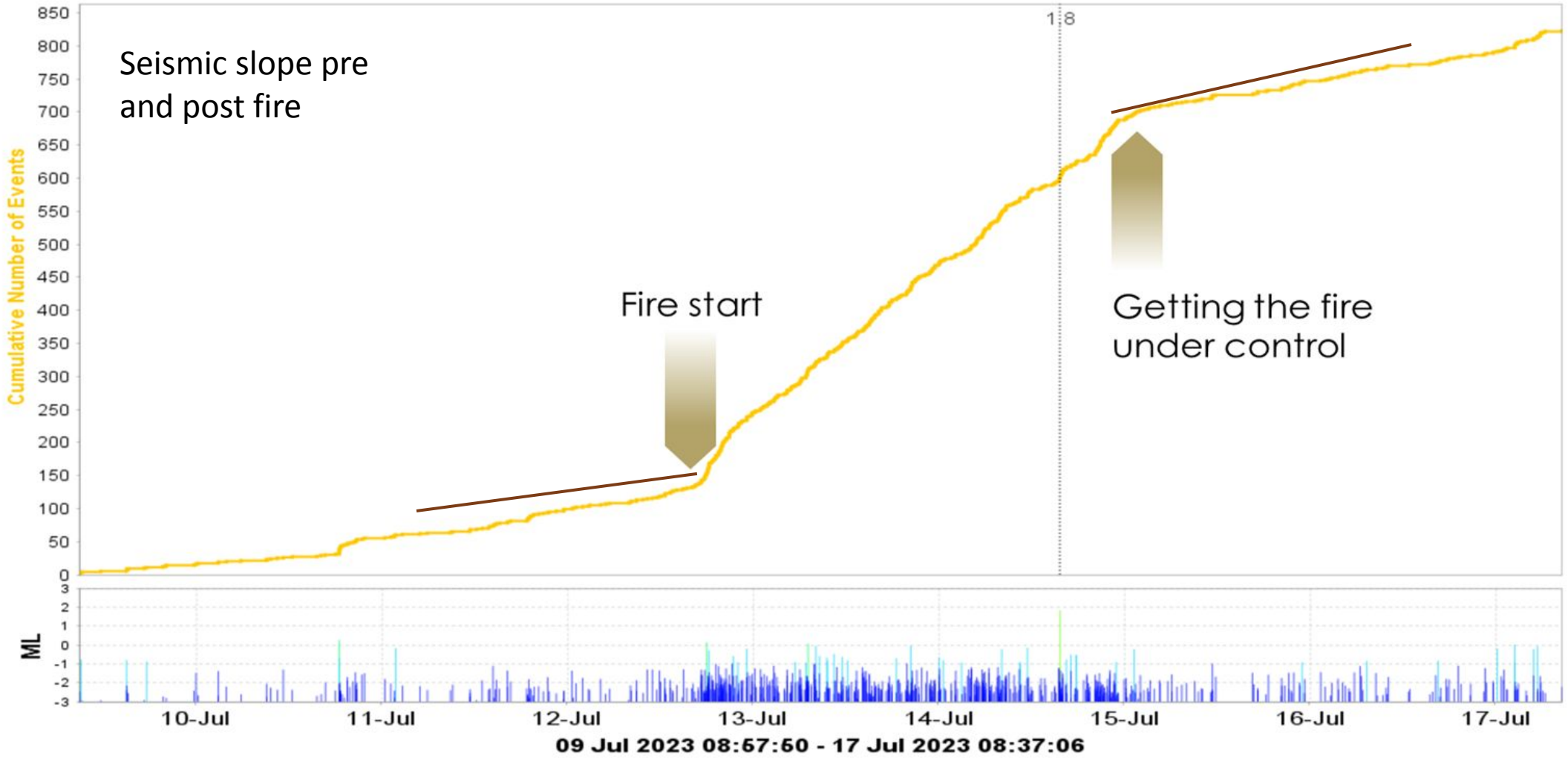
SP1 – Maximum principal stress to be below 350MPa (Pillars / abutments)

Residual seismic risk exists on the 44L entrance to the stope. However, no further mining is planned in the Life of Mine.

Seal vulnerability based on RCF on tunnels



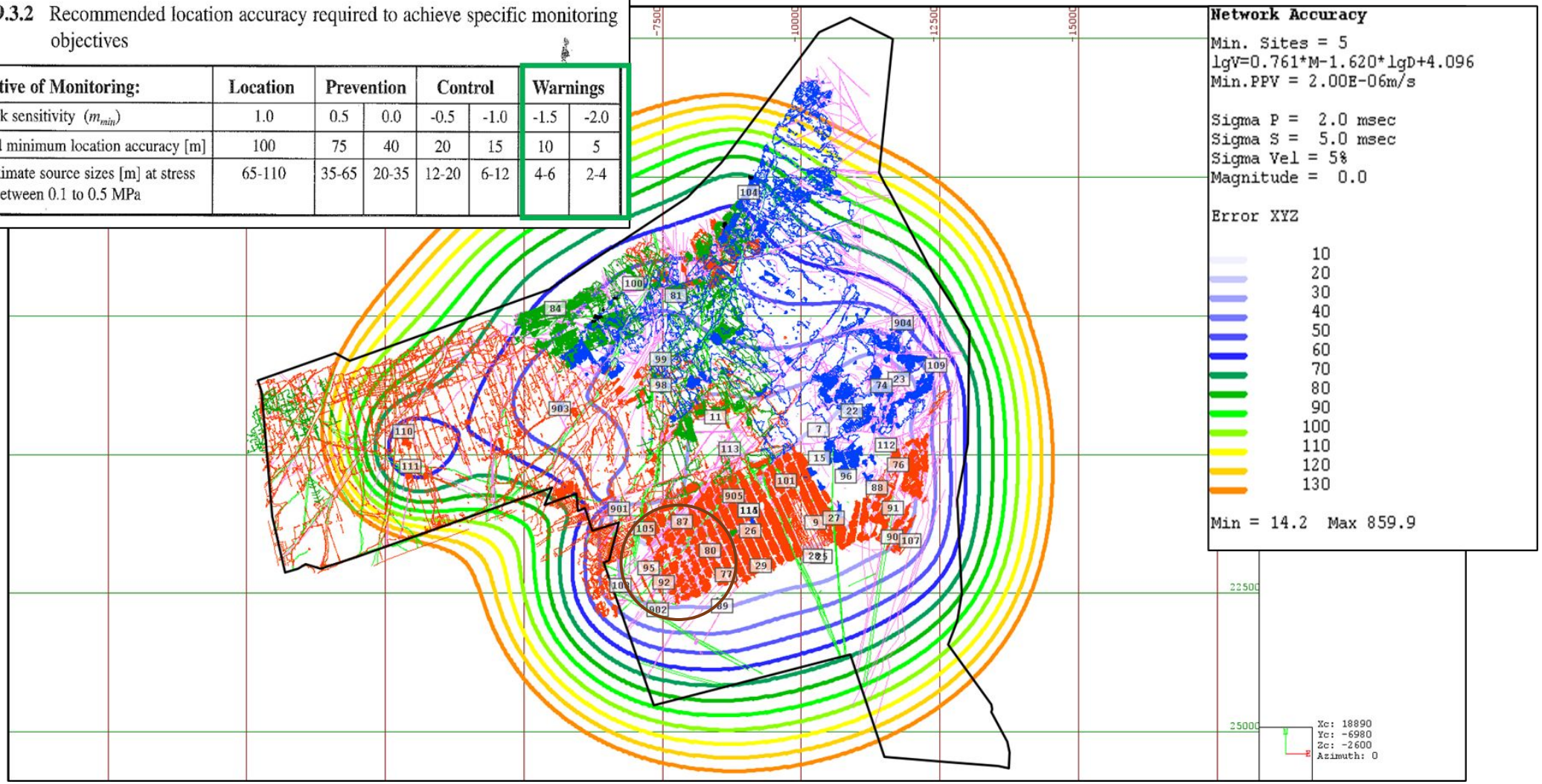
Seismic response profile



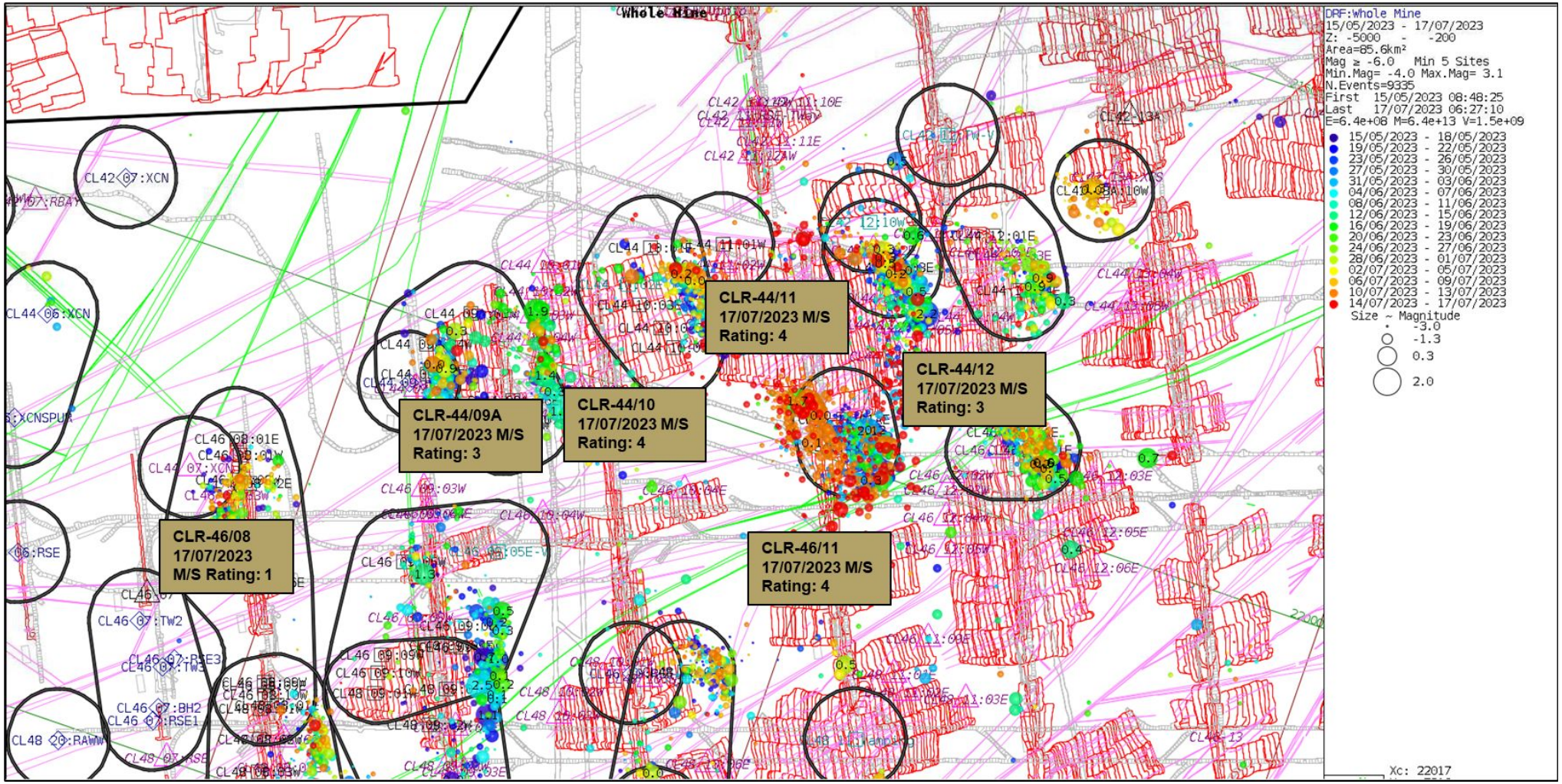
Network sensitivity site

Table 9.3.2 Recommended location accuracy required to achieve specific monitoring objectives

Objective of Monitoring:	Location	Prevention		Control		Warnings	
Network sensitivity (m_{min})	1.0	0.5	0.0	-0.5	-1.0	-1.5	-2.0
Desired minimum location accuracy [m]	100	75	40	20	15	10	5
Approximate source sizes [m] at stress drops between 0.1 to 0.5 MPa	65-110	35-65	20-35	12-20	6-12	4-6	2-4

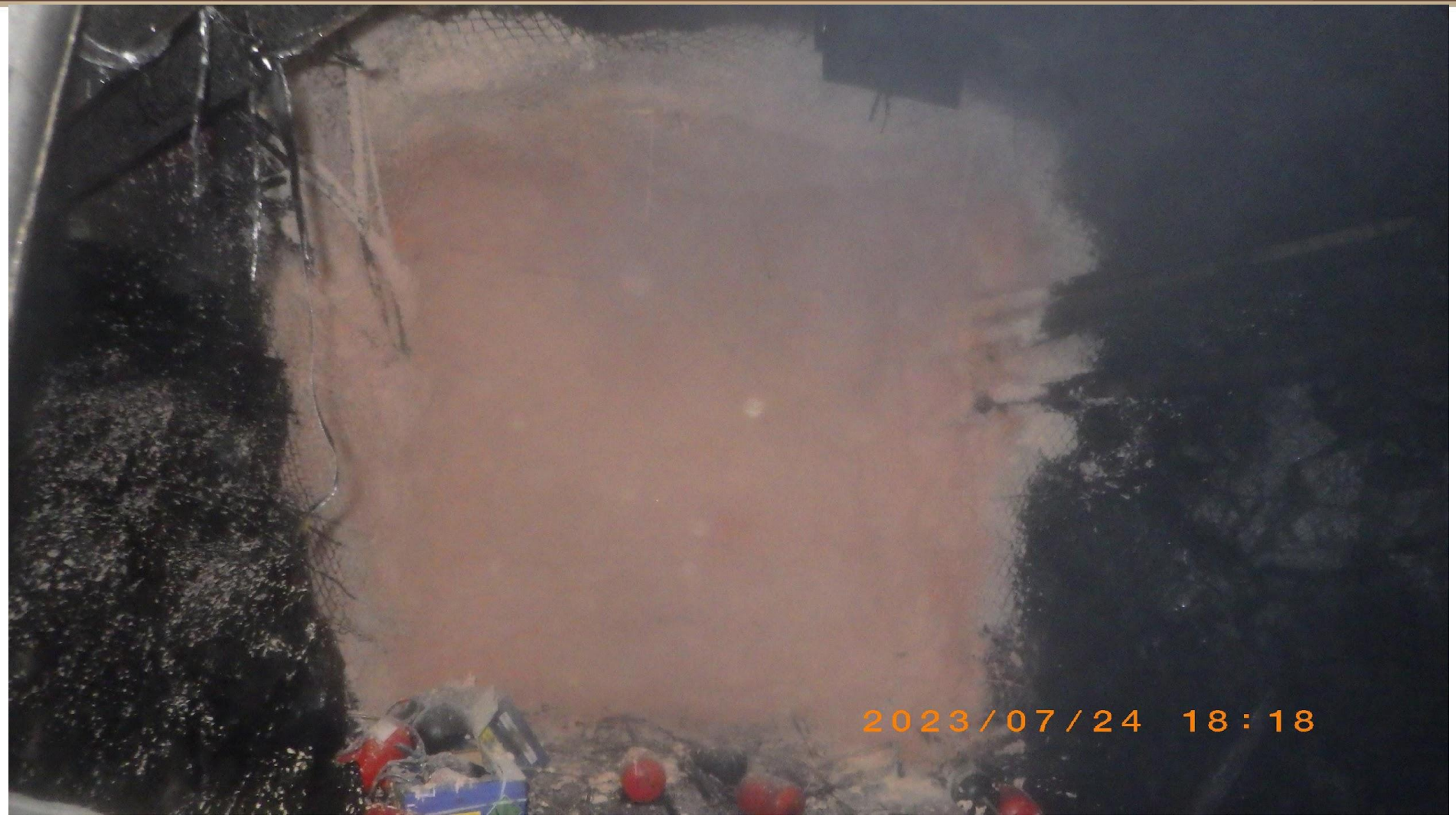


Daily seismic ratings (pre-seal construction)

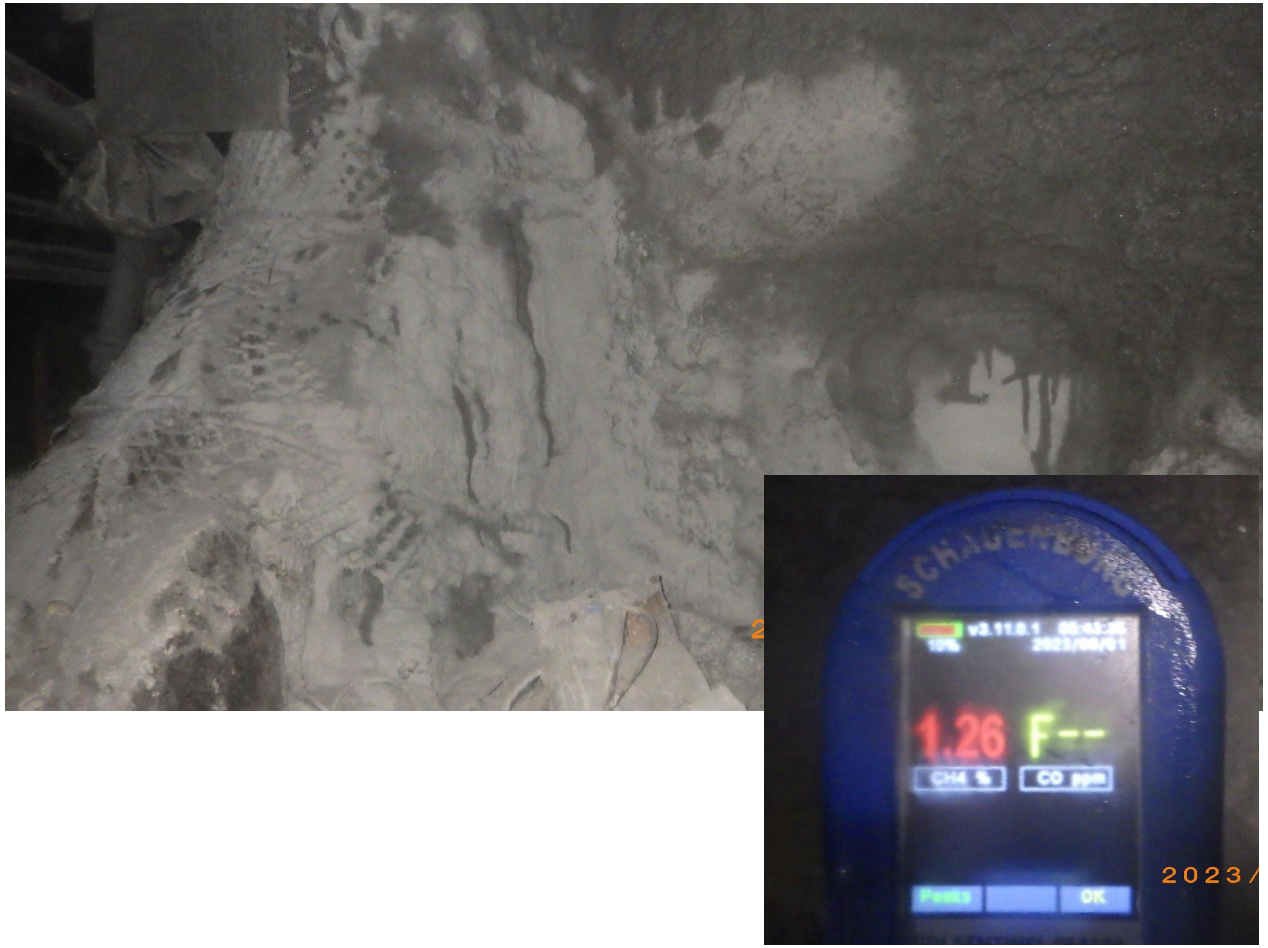


It’s smoking…..typical of a chimney!

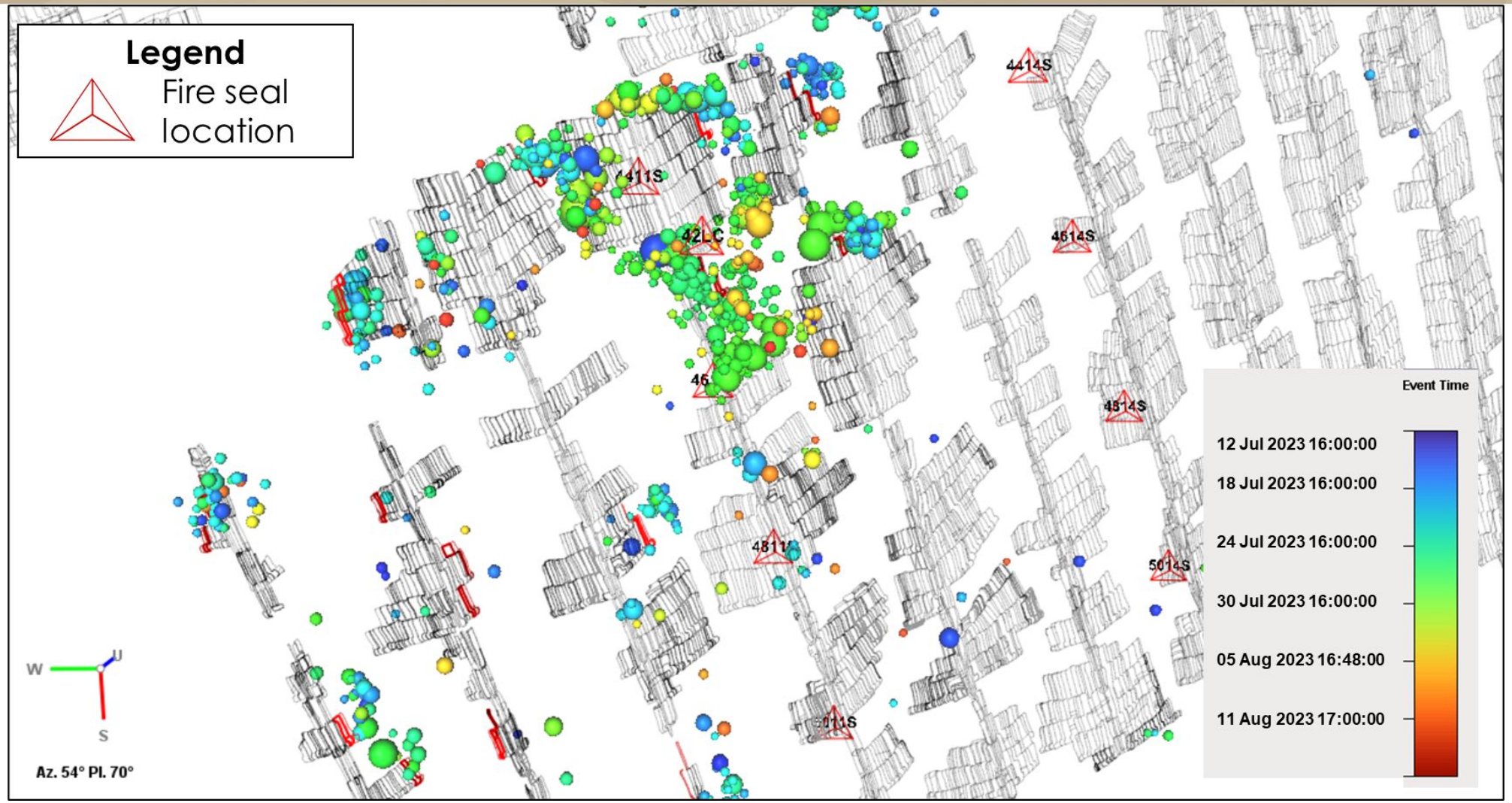
Sealing started of the top and bottom entrances along the 11 line



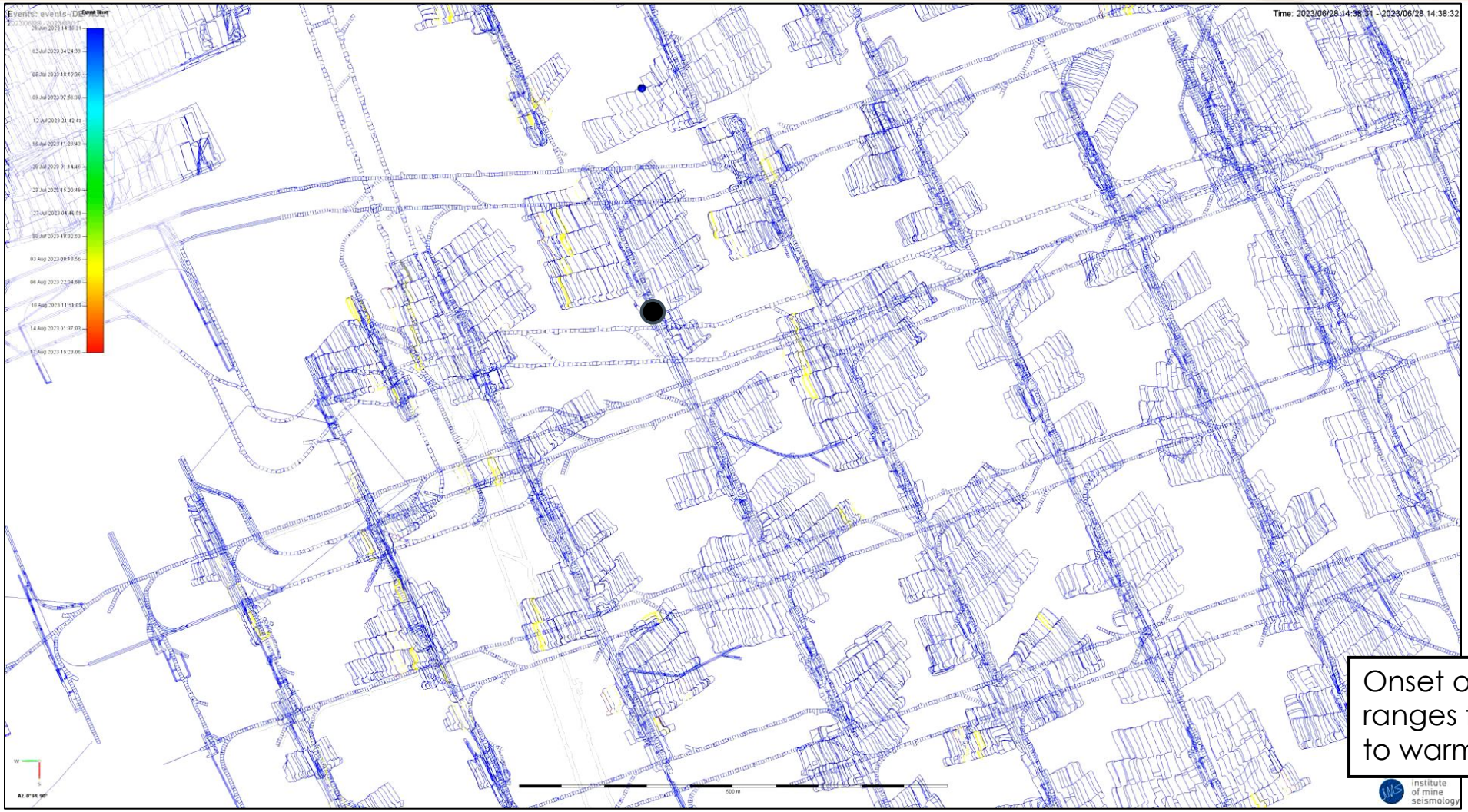
TSL was applied at the entrances and fractured rock



Seismic response to fire and seals location

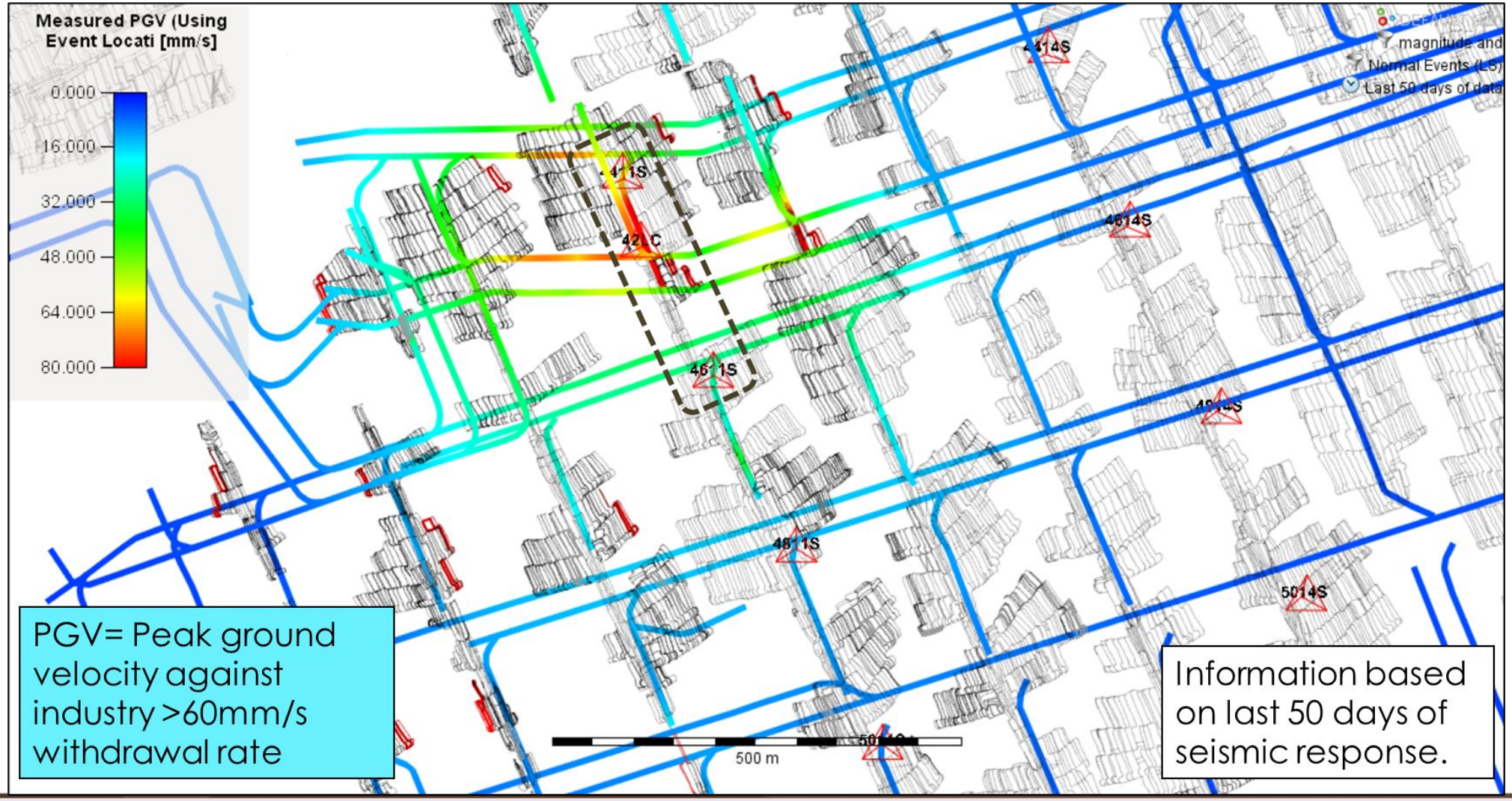


From Spark to Seismic Swell



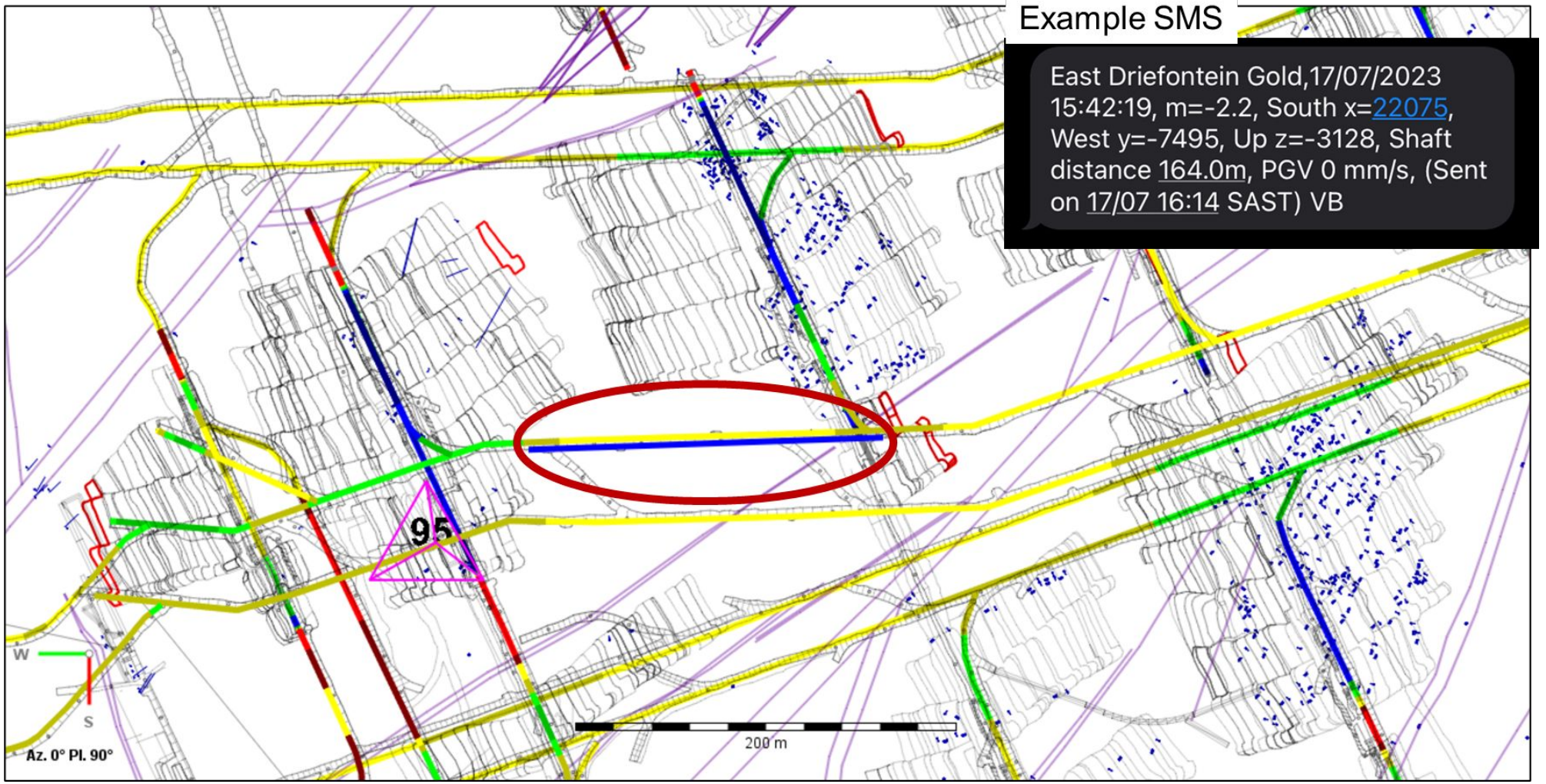
Onset of response ranges from cooler to warmer colors

How we tracked a fire using Seismic Data



In terms of PPV, no correlation was tested.
The PPV parameter was simply used as a risk management tool (without calibration) to indicate where risk of exposure to high calculated PPV (due to nearby seismic events) was experienced.
In the model the tunnel is not excavated and as such the PPV is in solid rock.

Monitoring of seal building site



Reading the fire's footprint in the Rock

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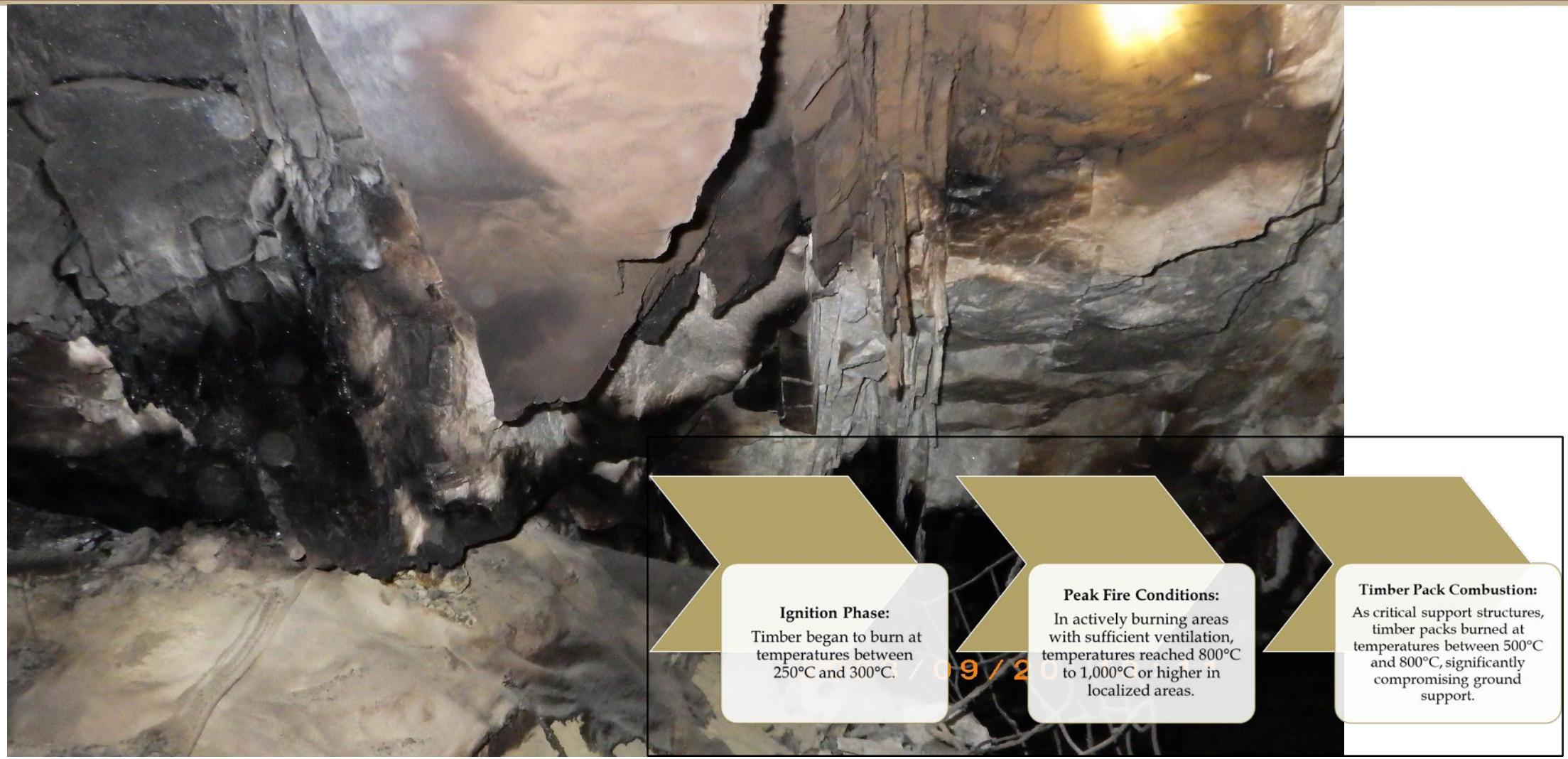
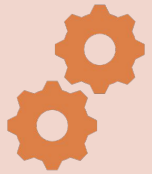


Monitoring enhancements

Monitoring system	***Potential improvement***
Integrated Monitoring	Develop systems that better integrate seismic, gas, and temperature monitoring for a more comprehensive assessment of fire conditions.
Automated Analysis	Implement advanced analytics to better correlate seismic patterns with fire progression and predict critical thresholds.
Mobile Monitoring	Equip emergency response teams with portable monitoring devices to enhance situational awareness during response operations (not available currently)
Decision Support Tools	Development of decision support systems that incorporate real-time monitoring data to guide response actions.

What have we learned?

- **Underground fires** can trigger **seismic activity** due to heat-induced changes in rock and geological structures.
- **Real-time monitoring** is essential for predicting fire behaviour and improving emergency responses.
- A **ground motion threshold** of **0.06 m/s Peak Particle Velocity (PPV)** is used to guide **evacuation decisions**.
- Combining **seismic, gas, and temperature data** provides the most accurate understanding of underground fire conditions.



Future research should focus on developing more integrated monitoring systems and automated analysis tools to further improve response capabilities, particularly in developing predictive models that can anticipate fire behaviour based on early seismic signatures.

These findings underscore the need for continuous innovation in fire monitoring systems to ensure operational safety in deep-level mining

THANK YOU