Anvendt Bergmekanikk – 10/01/2018

PRAKTISKE EKSEMPLER FRA ANVENDT BERGMEKANIKK I GRUVEINDUSTRIEN

Nghia Trinh – SINTEF Byggforsk

Presentation content

1. SINTEF in mining industry
2. Activities at Rana Gruber
3. Activities at a high stress mine
4. SINTEF philosophy

SINTEF in mining industry

Skaland Graphite	Norway
Franzefoss Miljøkalk As	Norway
Sala Mineral	Sweden
Norcem	Norway
Boliden Mineral	Sweden
Glærum Kalksteinsbrudd	Norway
Store Norske Coal	Norway Spitsbergen
Naas Kalkstein	Norway
Norcalsitt	Norway
Rana Gruber	Norway
Industrimineraler	Norway
North Cape Minerals	Norway
Hustad Group	Norway
Hammerfall	Norway
IMM-EU research	Italy
Brønnøy Kalk AS	Norway

Lundhs Labrador	Norway
Björka Mineral	Sweden
Grong Gruber	Norway
J. Grønseth	Norway
Nikkel & Olivin	Norway
Skaland Grafit	Norway
Sydvaranger	Norway
Fauskemarmor	Norway
Norwegian Talc	Norway
Gudvangen Stein	Norway
Norstone	Norway
Folldal Verk	Norway
Falkhammar Magn	Norway
Fosdalen Mining	Norway
Bleikvassli Mines	Norway
Dannemora Mine	Sweden
Orkla Mining	Norway

Gränges	Sweden
Elkem Skorovas	Norway
Elkem Tana	Norway
Sulitjelma Mining	Norway
Minnor Minerals	Norway
Greenex Mines	Greenland
Titania Mines	Norway
Arna Knuseverk	Norway
Rautarukki OY	Finland
Rødsand Mining	Norway
Franzefoss	Norway
Røros Copper	Norway
Rio Tinto Mines	Spain
LKAB	Sweden
Coricancha and Contonga	Peru

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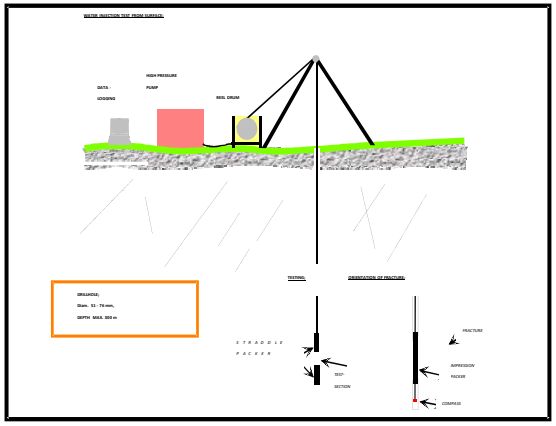
SINTEF in mining industry

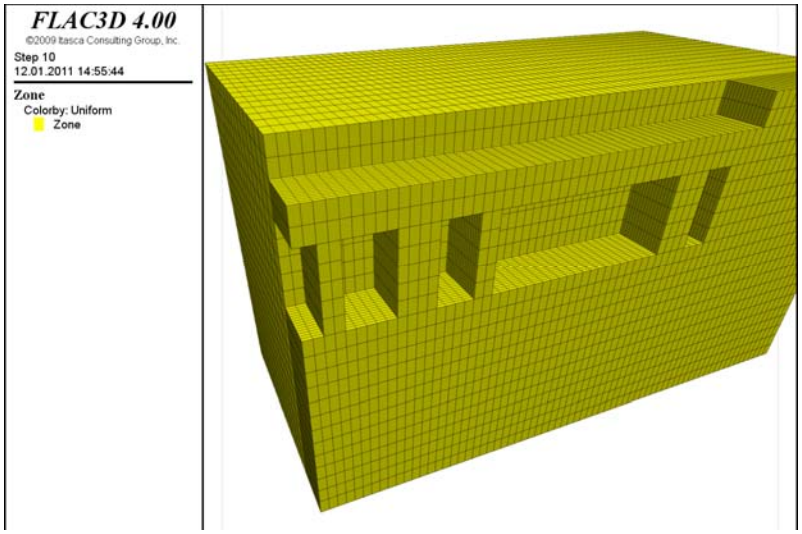
Typical activities for a mining project (open pit and underground) may consist:

- Stress measurement hydraulic fracturing, 2D and/or 3D with self development method;
- Deformation, stress, and groundwater monitoring;
- Laboratory tests rock properties;
- Numerical modelling in combination with measurement and monitoring to provide a reliable tool for planning;

- Engineering geological mapping;
- A projects are normally followed for many years.

SINTEF in mining industry





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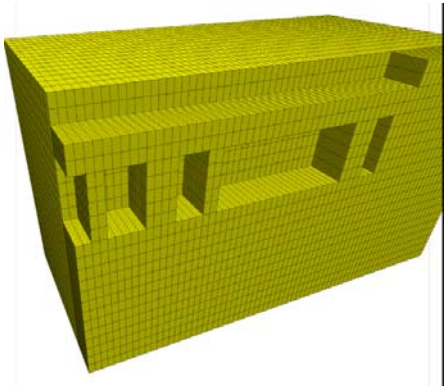
SINTEF in mining industry

✓In-situ rock stress measurements (2D and 3D)
✓Rock laboratory tests

✓Numerical modelling of different mining alternatives



✓Installation of the monitoring: extensometers and stress sensor
✓Following up

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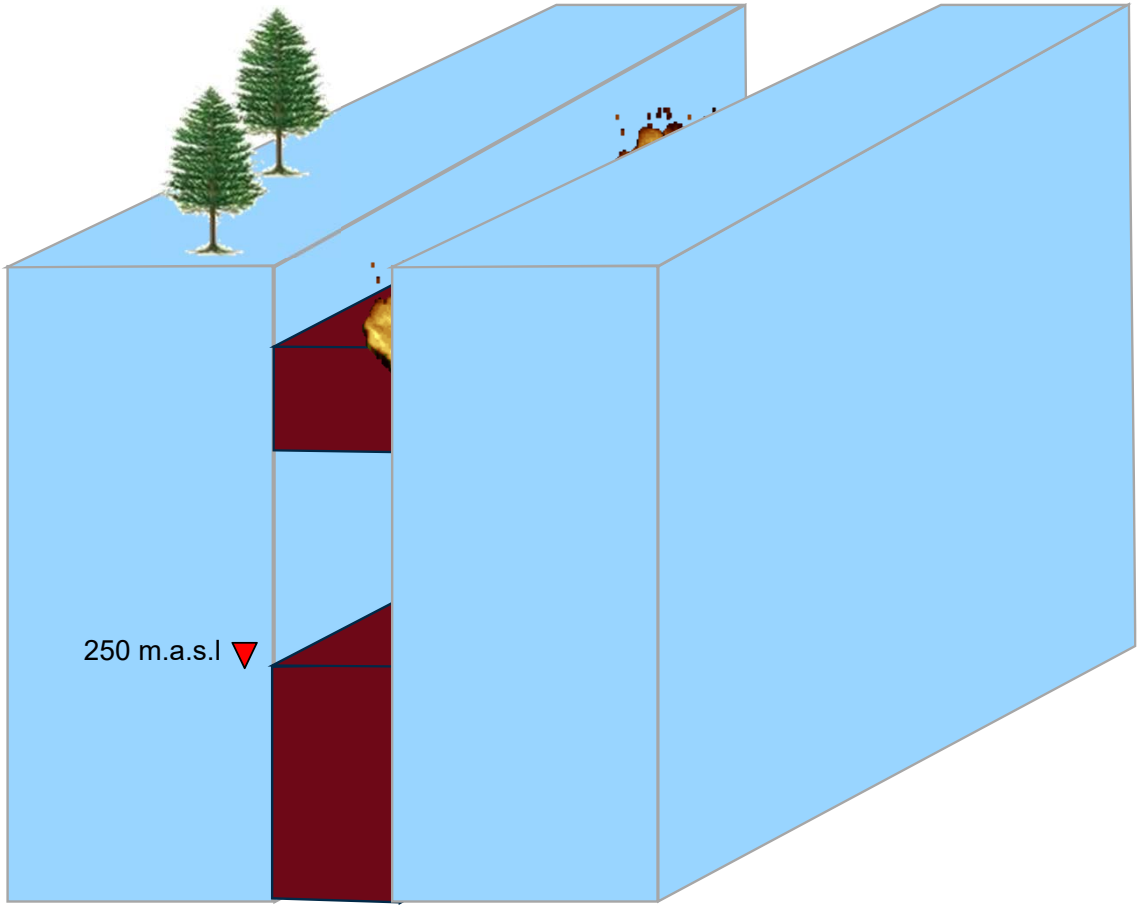
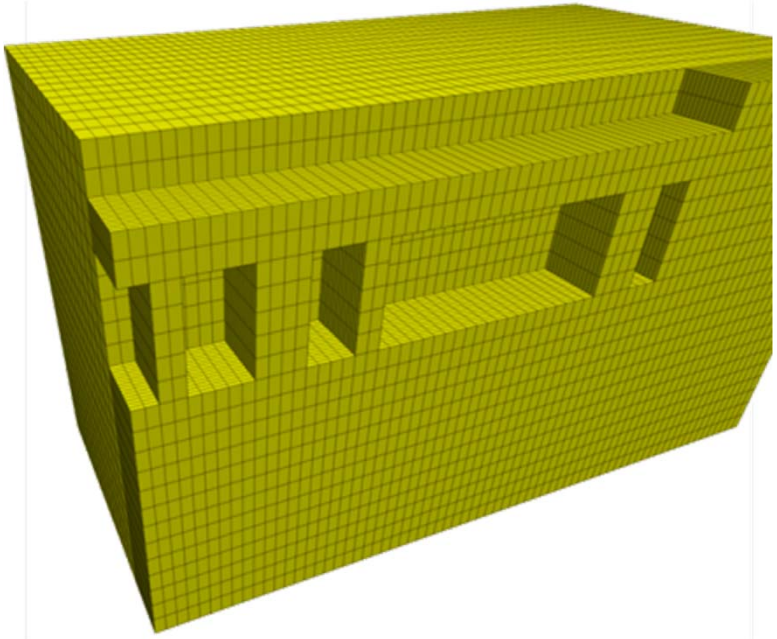
Activities at Rana mine

Application at Rana mine

- A major challenge in this mine is very high horizontal stresses
- Verify with the current situation
- The previous mining method is sublevel stoping => Vertical and horizontal pillars are existed;
- Before the sub-level caving can start, the pillars need to be removed => Check stability of the footwall;





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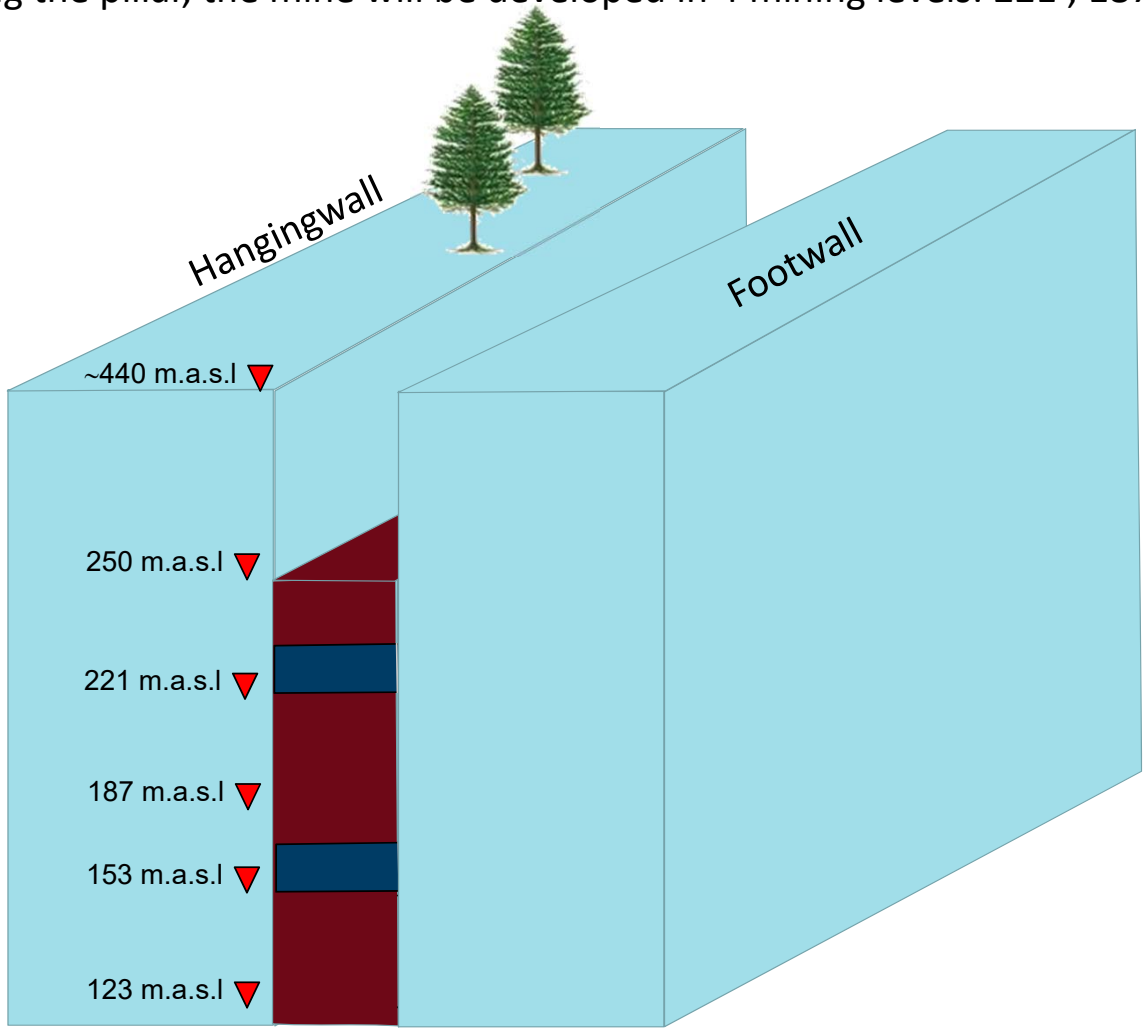
Application at Rana mine

After removing the pillar, the mine will be developed in 4 mining levels: 221 ; 187 ; 153 ; 123



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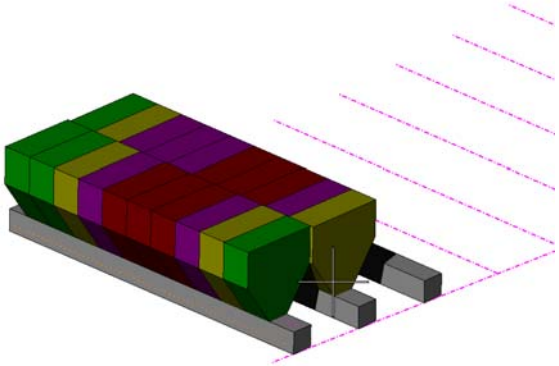
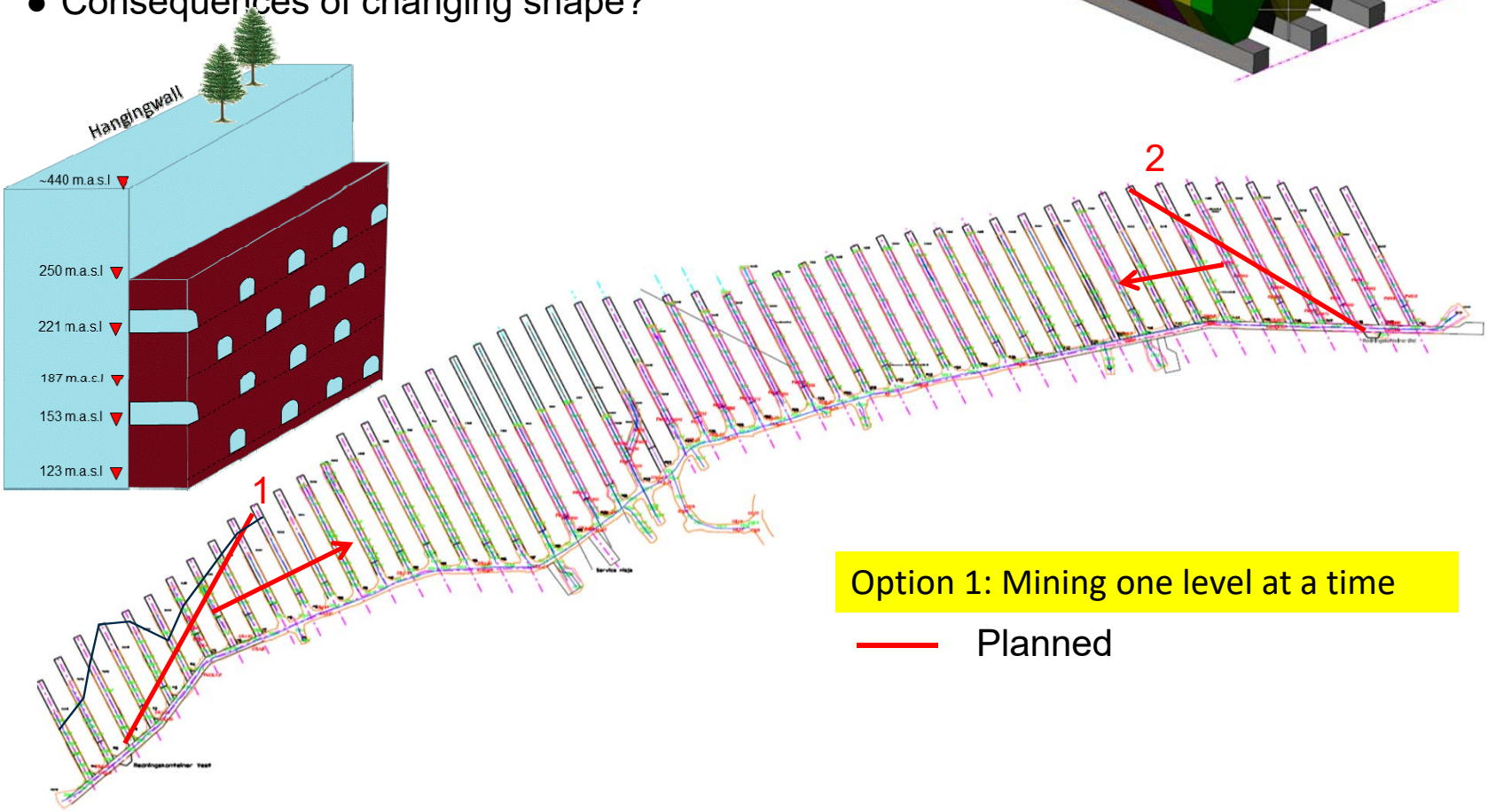
Application at Rana mine

- Consequences of uneven caving front?
- Optimum distance between drifts?
- Consequences of changing shape?



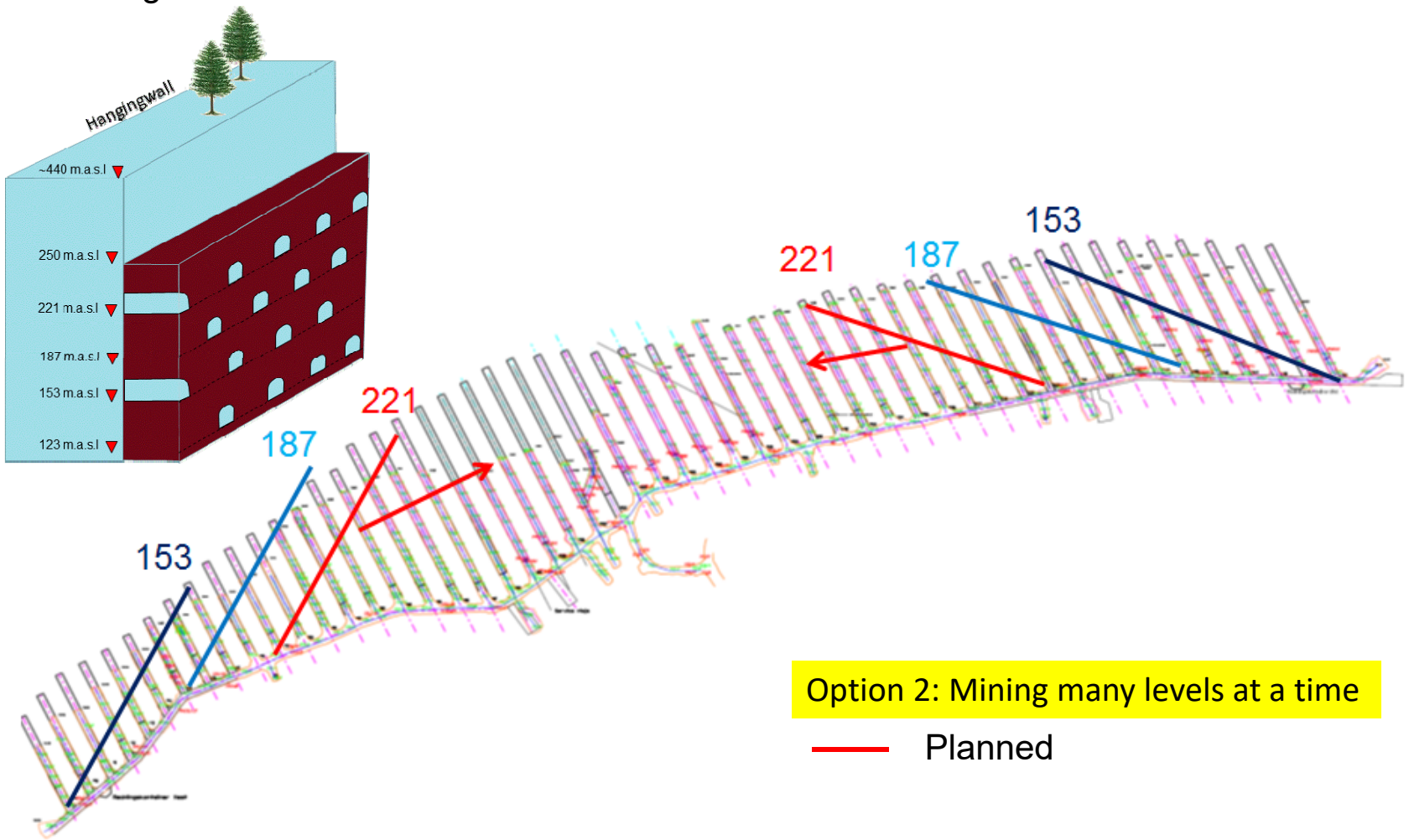


Option 1: Mining one level at a time

Planned

Application at Rana mine

- Mining all level:



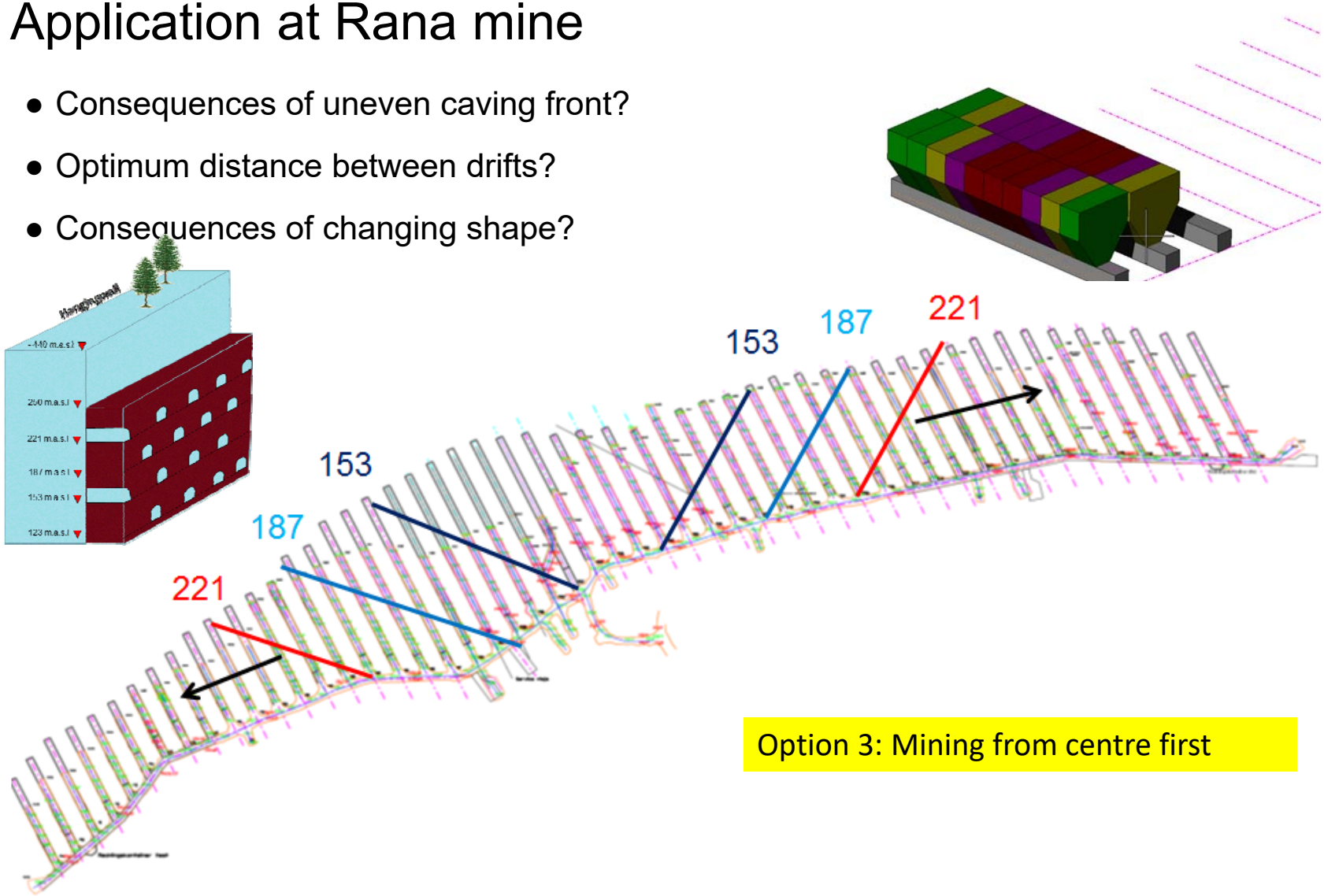
Option 2: Mining many levels at a time

Planned

SINTEF

Application at Rana mine

- Consequences of uneven caving front?
- Optimum distance between drifts?
- Consequences of changing shape?



Option 3: Mining from centre first

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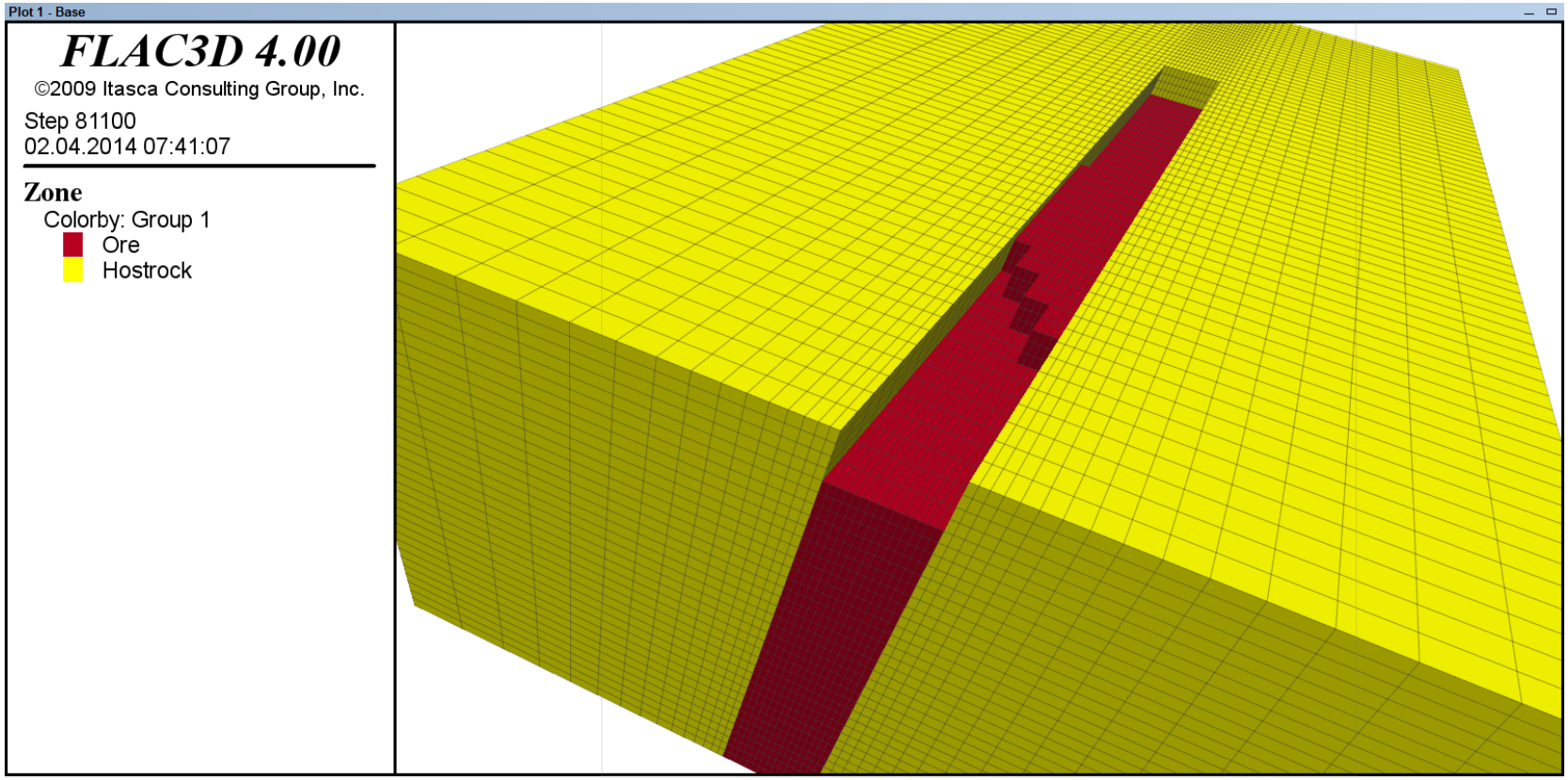
Application at Rana mine

- A 3D-model was established with proper simplification;
- Different mining alternatives were tested to find advantages and disadvantages.



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Application at Rana mine

- Stress monitoring: using 2D-long-term-door-stopper

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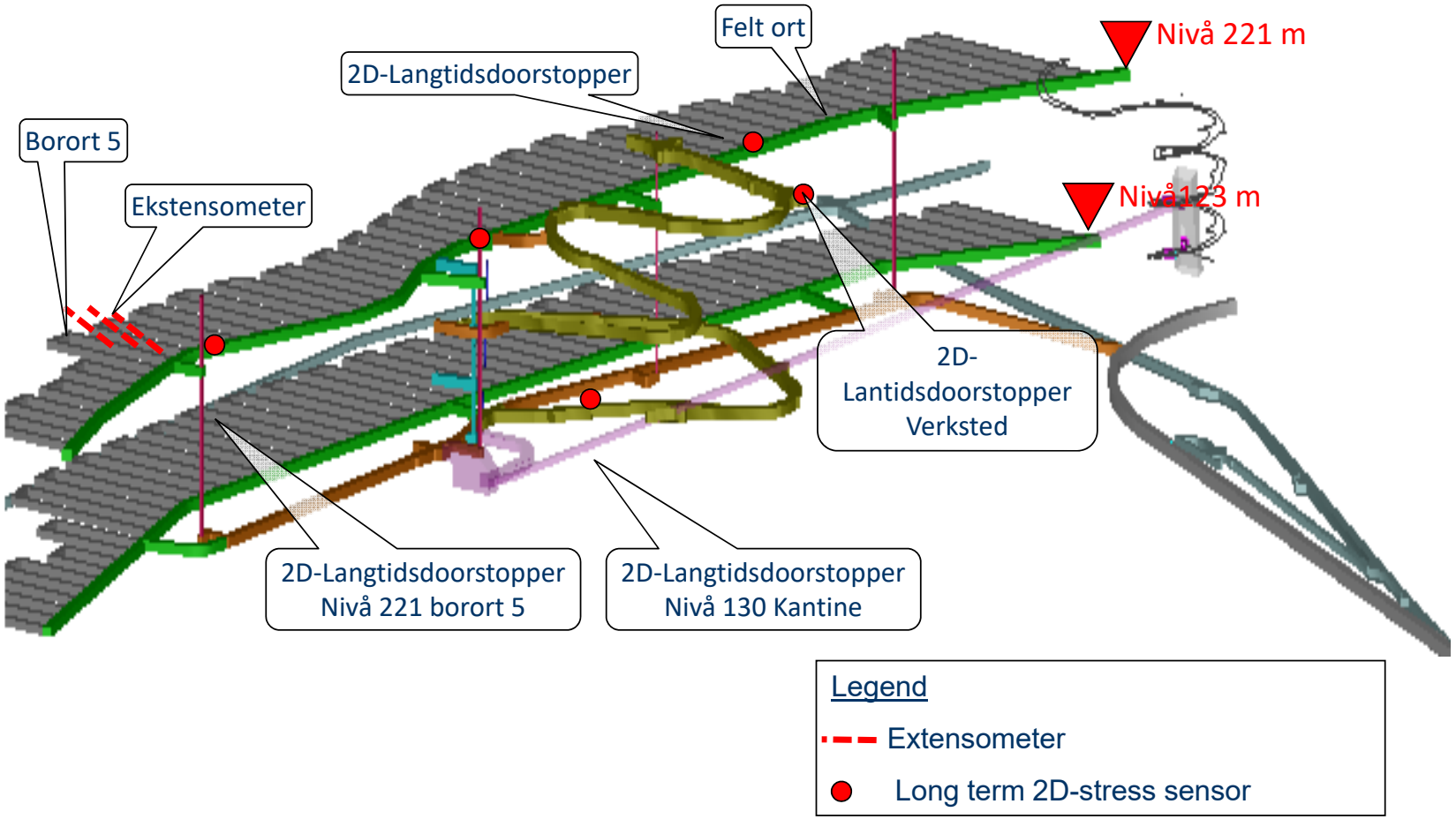
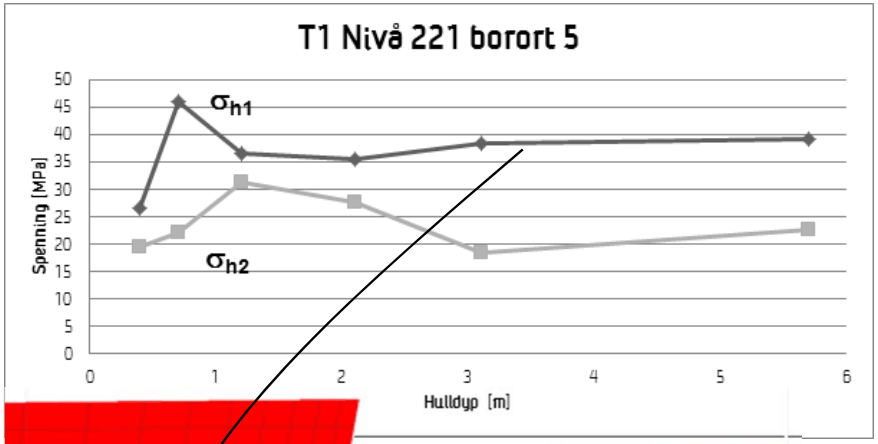
Application at Rana mine

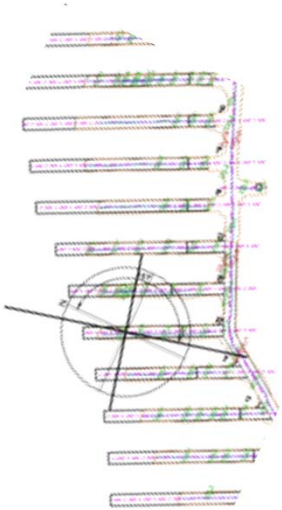
- Installed equipment for monitoring and verification:

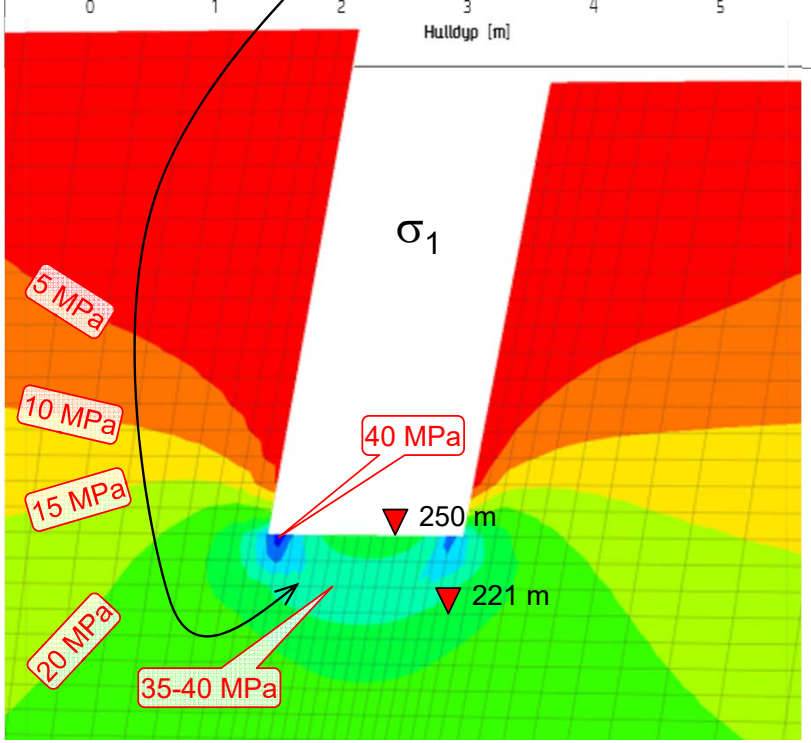


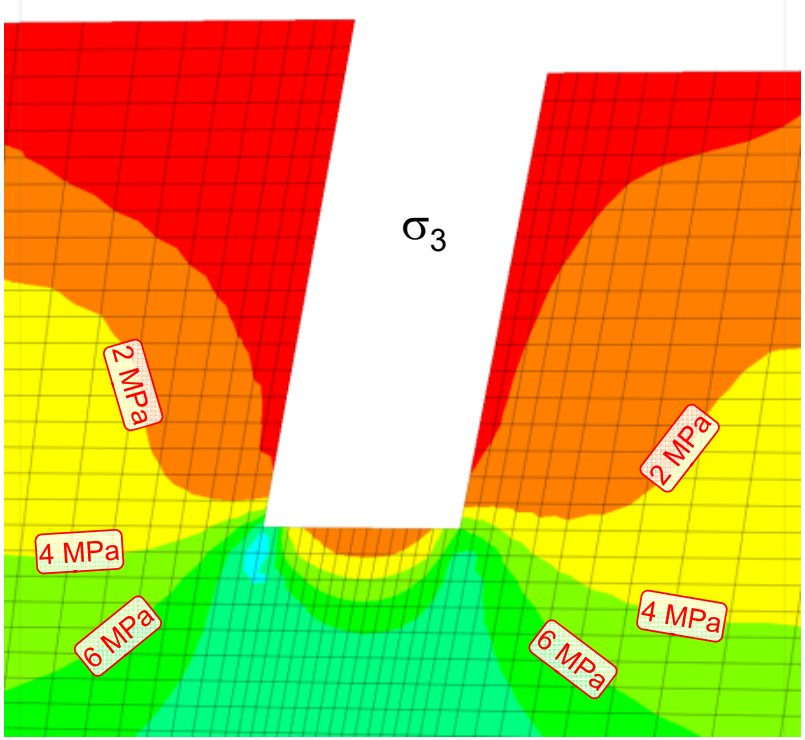
Application at Rana mine

- Case 1: Result of the SINTEF's measurement - verification:



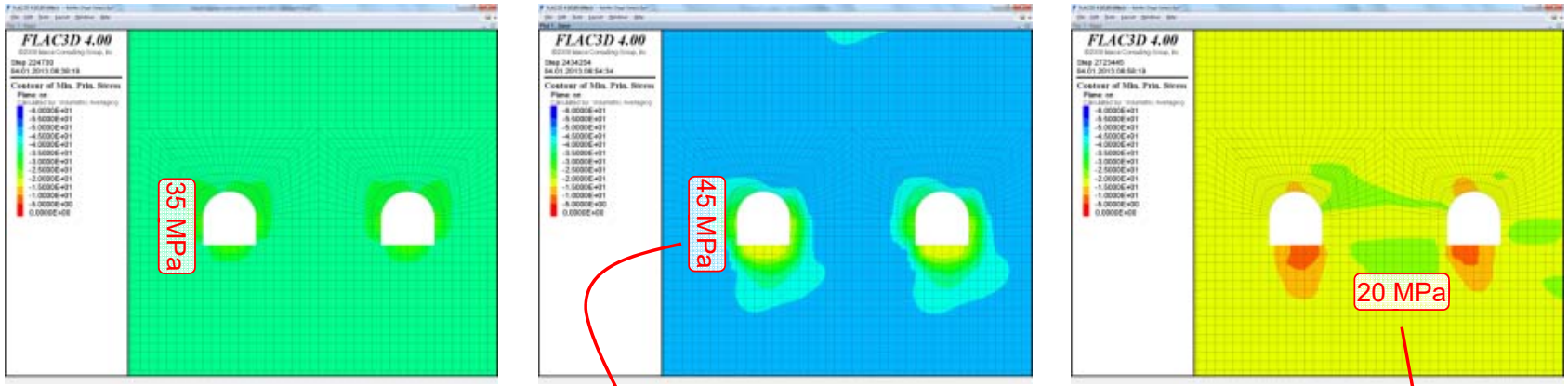


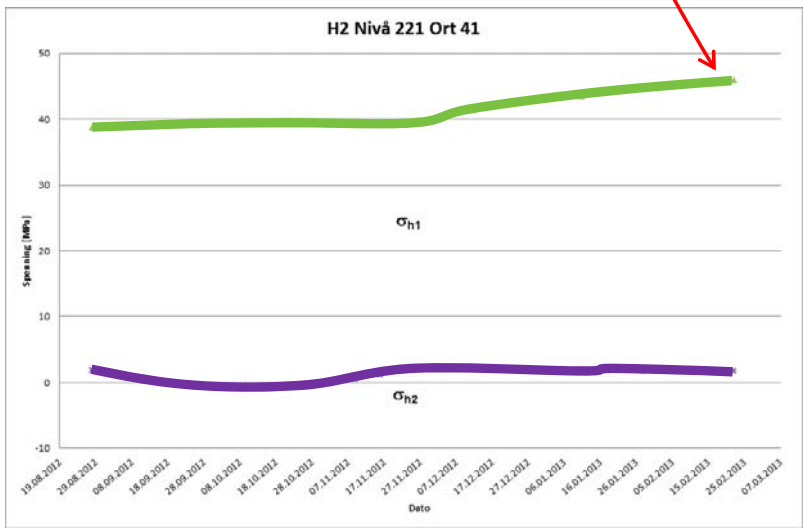


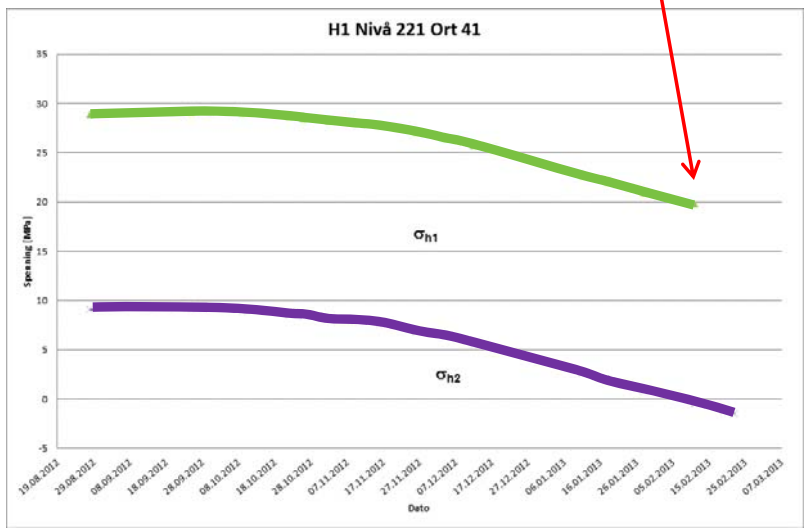


Application at Rana mine

- Stress in a pillar and verification:







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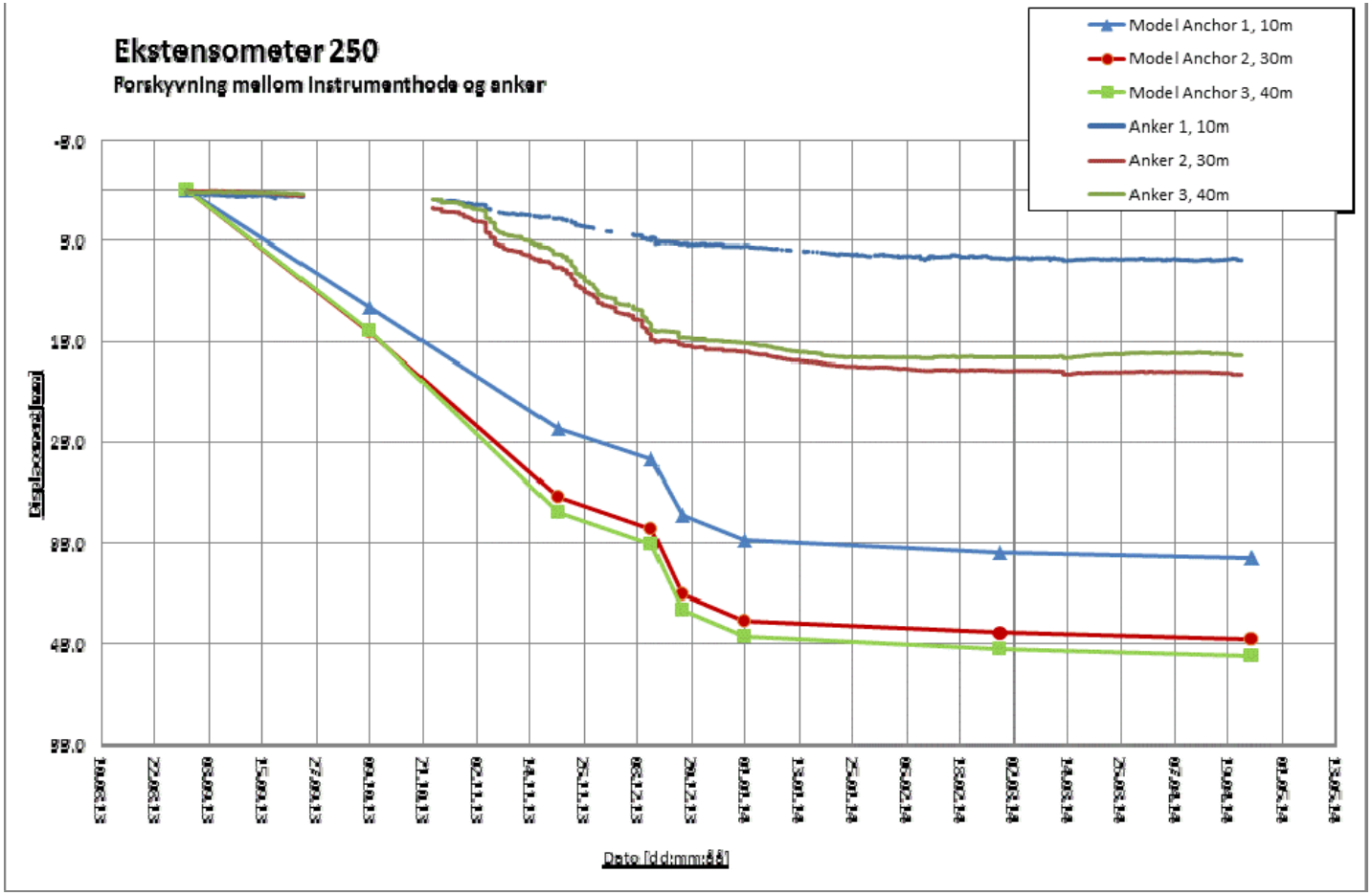
Application at Rana mine

- Recorded displacement in the extensometer 250 vs numerical model:



Application at Rana mine

Summary activities in Rana mine:

1. Many stress measurements and laboratory tests have been carried out by SINTEF over the years (since 1977). A good rock mechanics database was created from this;

2. Different models (2D, 3D-simplified, and 3D-total model) was established based on the need and complexity of the issues to be studied;

3. Stress monitoring and displacement monitoring equipment have been installed at key locations for monitor the safety of the mine, and also providing information for calibration and verification of the numerical model, so that the model becomes a reliable tool for planning.

Activities at a high stress mine

What is a "high stress" situation?

"High stress" does not always mean "negative"

- "High stress" can be utilised in this mine to make a large span room;
- To make this possible, it is necessary to know the stress orientation and magnitude…;
- One should also note that geological structural (faults, fold,..) may affect the orientation and magnitude of in-situ stress locally.

But, yes, "high stress" gives some challenges

Some rock falls

Some rock falls

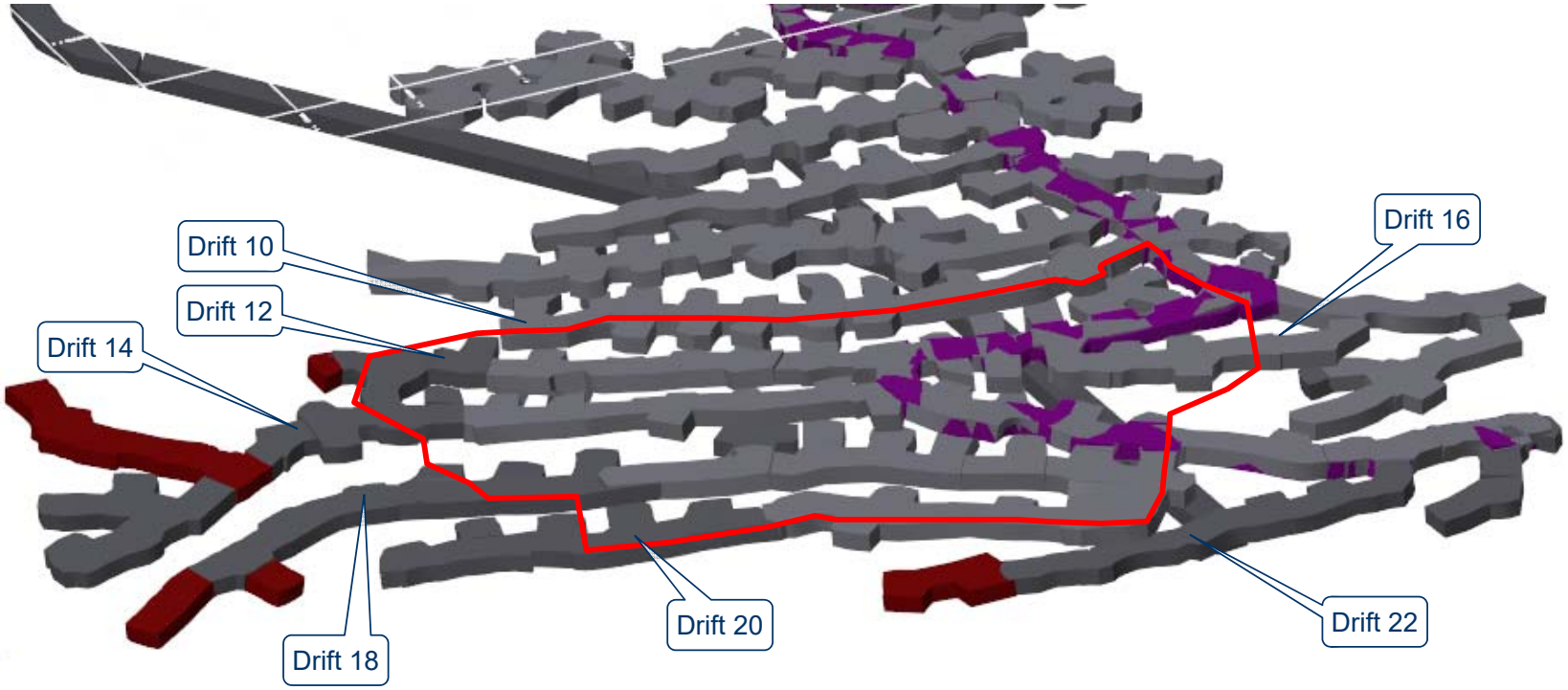
Very tough questions

Presentation

1. Mapping area
2. "Generally Stable" pillars
3. "Minor/Medium Slabbing" pillars
4. "Unstable" pillars
5. Thin wall – a hidden danger
6. "Next" rock fall
7. Rock support – bolt performance
8. Comments for this mine
9. "Tripod" over the years

1. Mapping area

- Location for the mapping is within the red marked area;
- A total of 41 pillars was mapped;
- Mapped pillars were divided into 3 groups: "Green", "Yellow" and "Red" based on observed condition



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2. "Generally Stable" pillars – Green Group

- Typical pillars without instability concern:

"*Generally Stable*" group: pillars in this group are in overall showing a stable situation:

- Very minor slabbing, local fractures, or few individual unfavourable joints are observed;
- Slabbing, fractures, and joints are local, no risk of further development that could lead to a gradual, progressive failure.
- No systematic rock support is required except spot bolting needed to keep the pillar supporting the roof of the mine in a long term.

3. "Minor/Medium Slabbing" pillars – Yellow Group

- Typical pillars with instability concern (10-12/05):

"*Minor/Medium Slabbing*" group: pillars in this group expose an uncertain stability situation:

- Significant fractures are observed. The fractures may lead to a potentially unstable situation in the pillar and rock support is required in a long term;
- Rock slabbing appears in various degree from a noticeable to a significant area of the pillar:
- Working directly under the area is not recommended. Additional rock support measures is be required before working directly under an area with minor/medium slabbing;

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3. "Minor/Medium Slabbing" pillars – Yellow Group

- Typical pillars with instability concern (14-18/05):

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4. "Unstable" pillars – Red Group

- Typical pillars serious instability problem (10-12/09):

"*Unstable*" group: pillars in this group expose an unstable situation.
The following descriptors have been used for pillars in this group:

- Rock slabbing occurs in a very large part of the pillar. The slabbing leads to a progressive destabilisation and the pillar will eventually collapse;
- Rock fall may take place uncontrolled;
- Working directly under "Unstable Pillar" area is prohibited;

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4. "Unstable" pillars – Red Group

- Typical pillars serious instability problem (12-14/02):

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4. "Unstable" pillars – Red Group

- Typical pillars serious instability problem (12-14/06):

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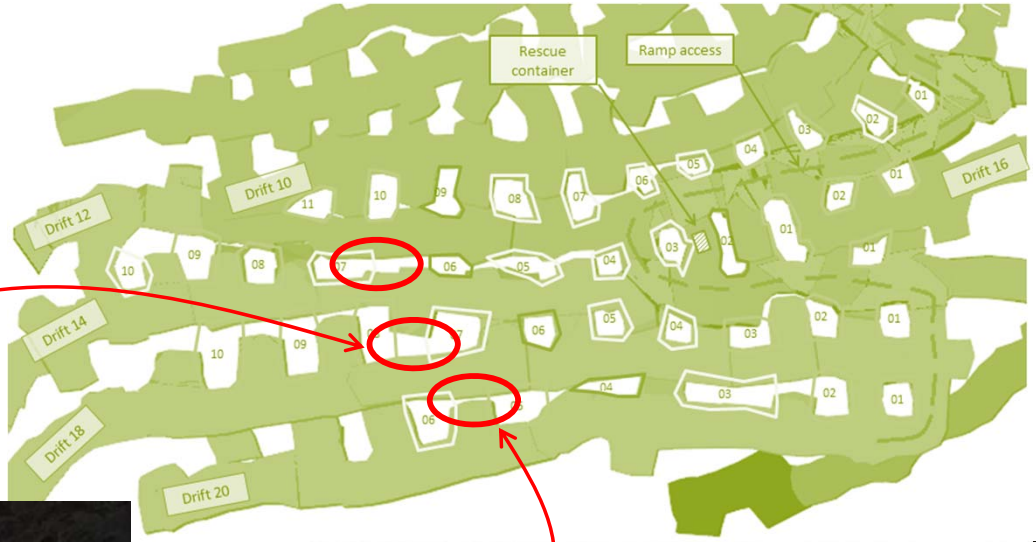
5. Thin wall – a hidden danger

- Thin wall and its apparent condition:



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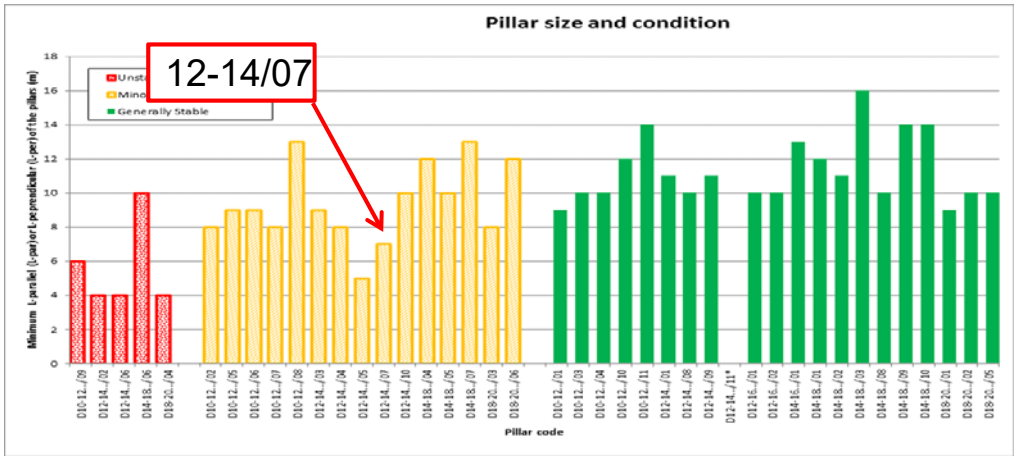
6. "Next" rock fall

- Location with risk of the "next" rock fall:



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6. "Next" rock fall

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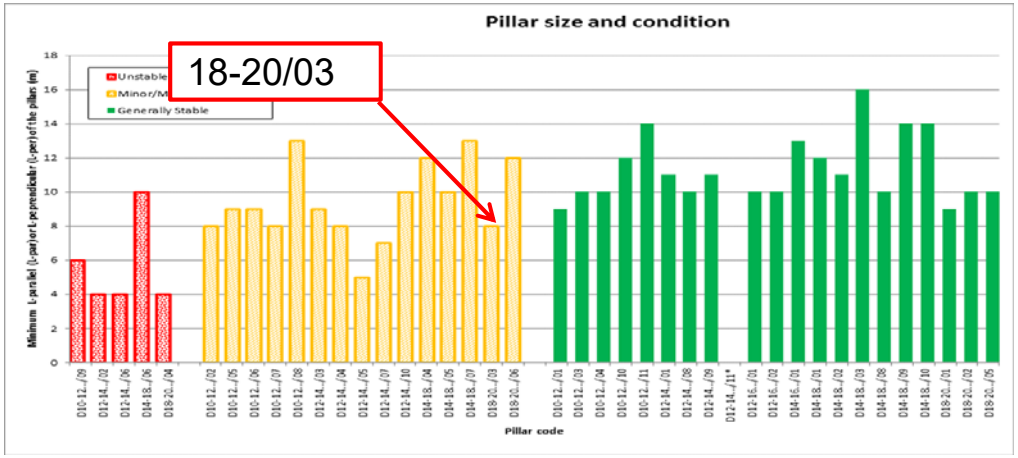

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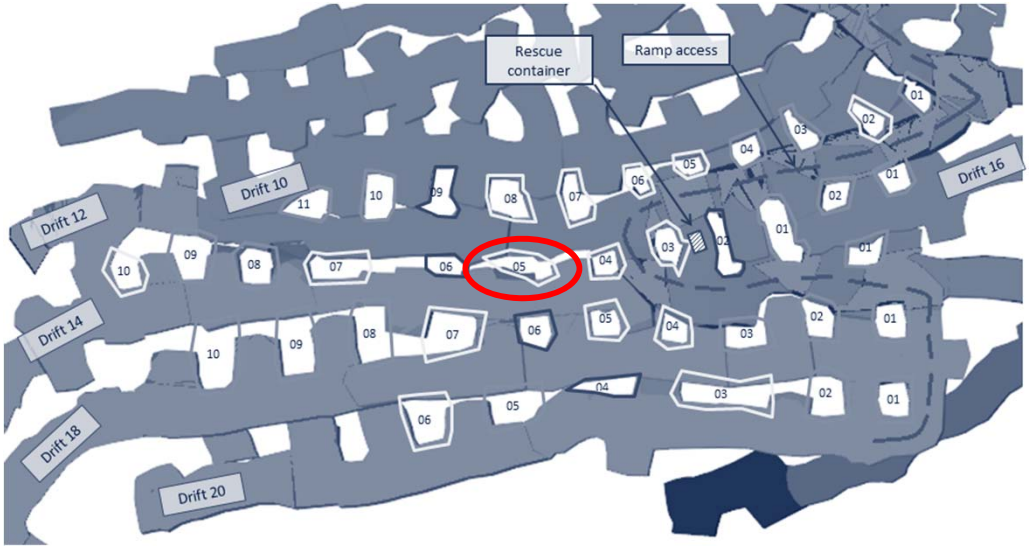
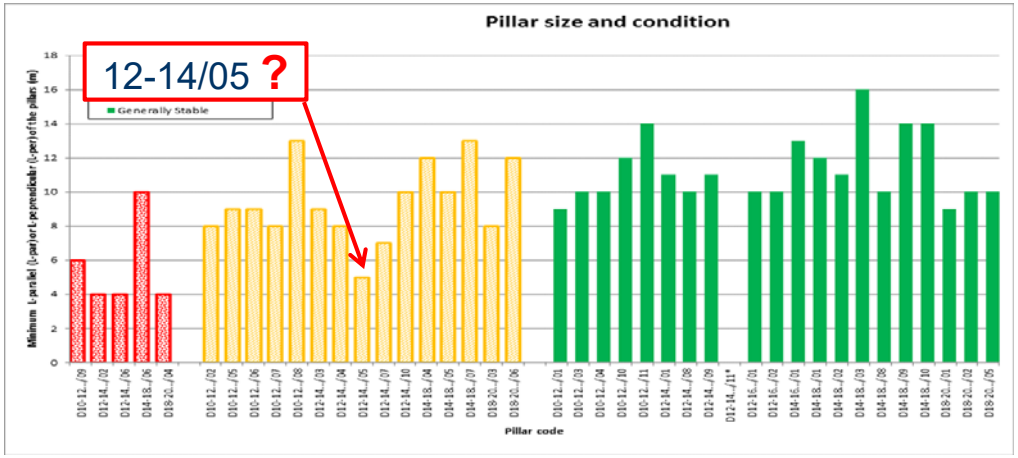
6. "Next" rock fall

- Location with risk of the "next" rock fall:

- 12-14/05 in the "Yellow" group, whereas *L-per* is only 4 m????
- With this small *L-per* it is expected a severe instability condition in the pillar. Why it appears as on in "Yellow" group??

- One explanation for the better stability situation than expected could be that the shape of this pillar is complicated. The measurement we made may not be accurate enough to capture the real situation;
- The pillar shows an useful information that the "Medium slabbing" area appears at the part with smaller *L-per*.





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7. Rock support – bolt performance

- Bolt in a high stress condition:

7. Rock support – bolt performance

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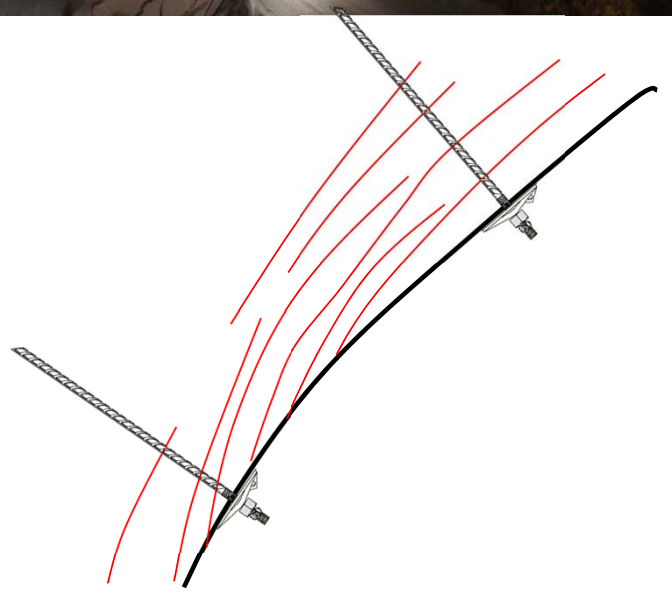

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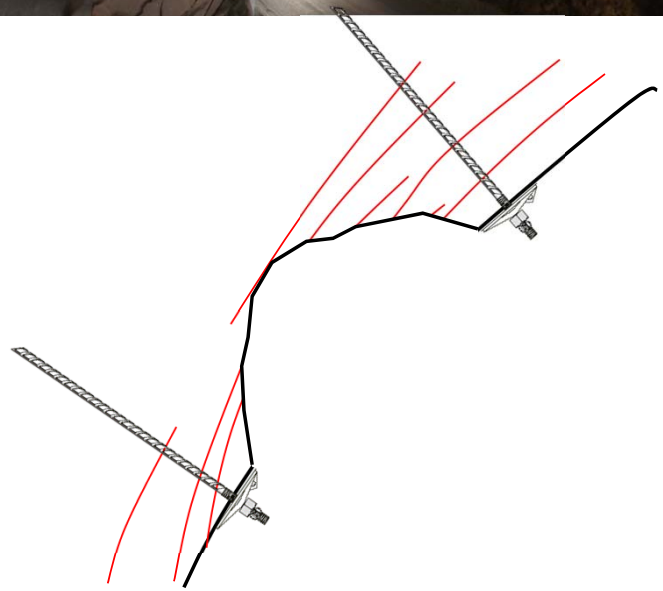
7. Rock support – bolt performance

- Bolt in a high stress condition:



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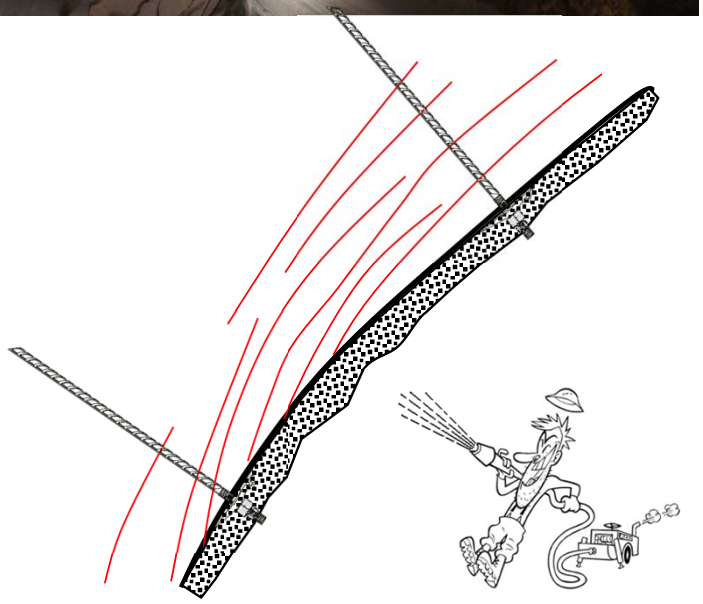
7. Rock support – bolt performance

- Bolt in a high stress condition:

In a normal underground structure, it is best to use shotcrete in this situation, but not at this mine



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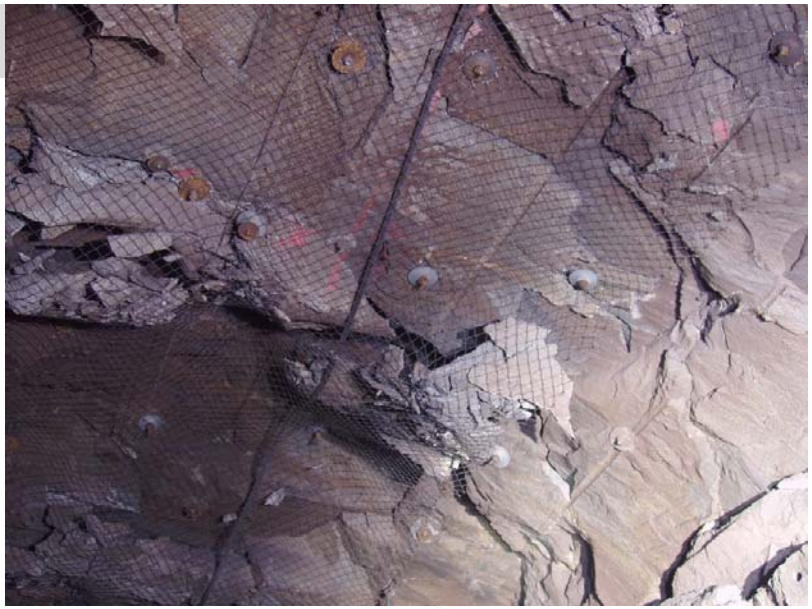
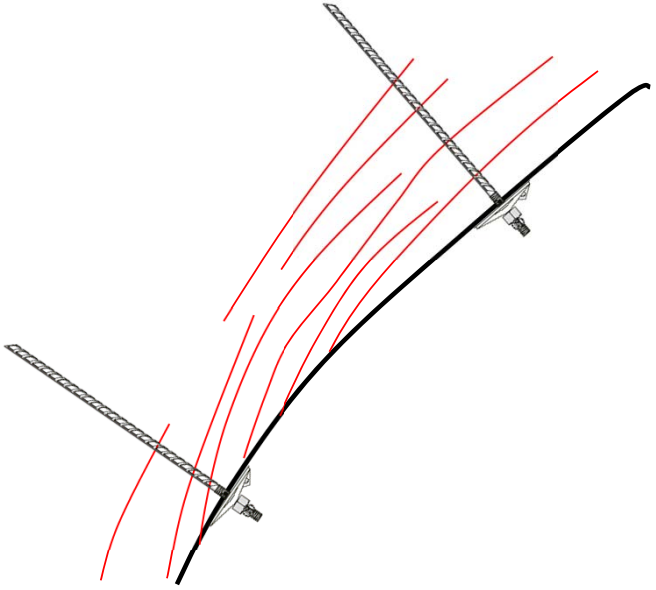


Steel mesh may be an alternative to provide a confinement.
….



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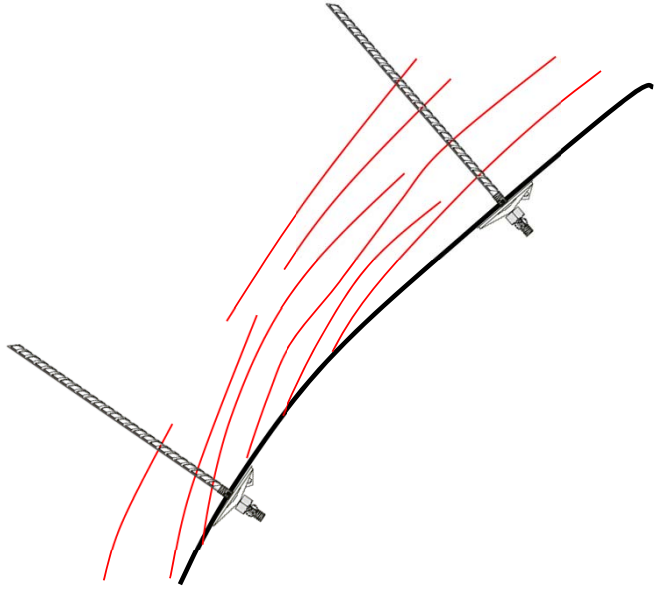
7. Rock support – bolt performance

- Bolt in a high stress condition:

Steel straps are not really suitable to provide a confinement.



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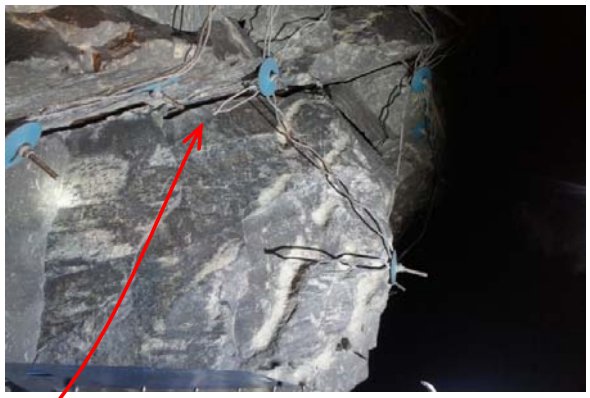
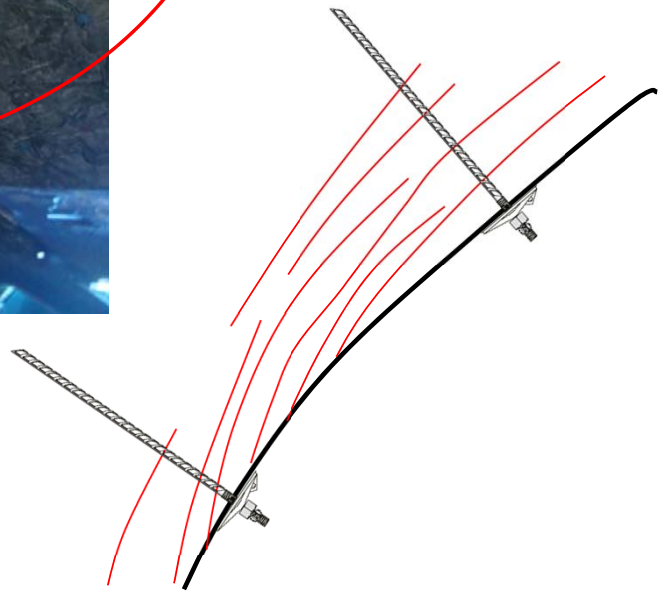
7. Rock support – bolt performance

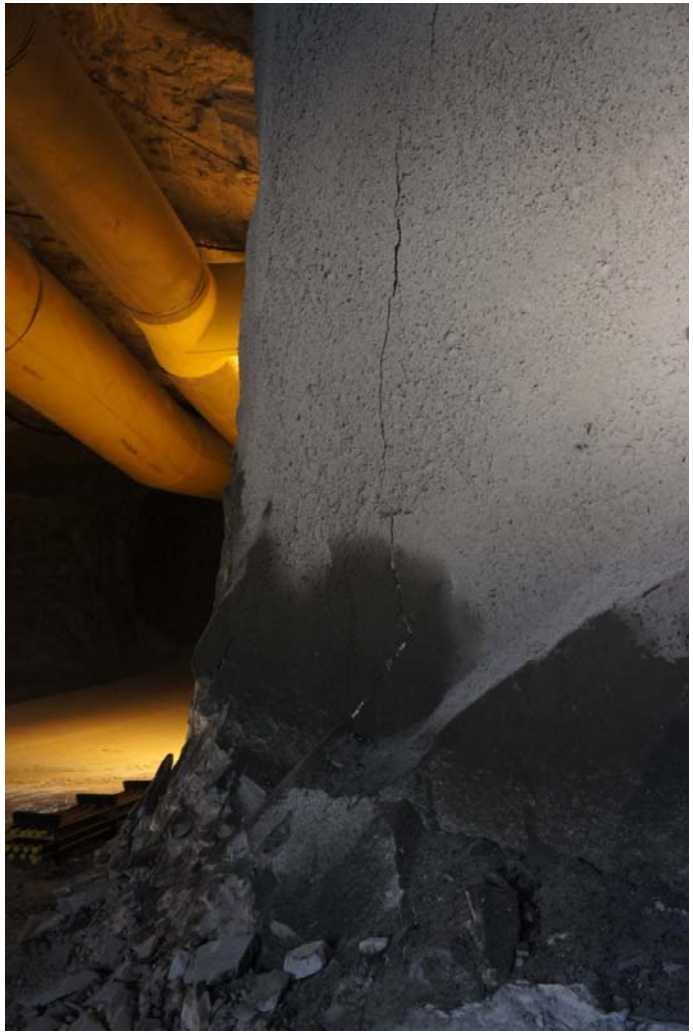
- Steel straps may be more suitable for supporting individual rock block:

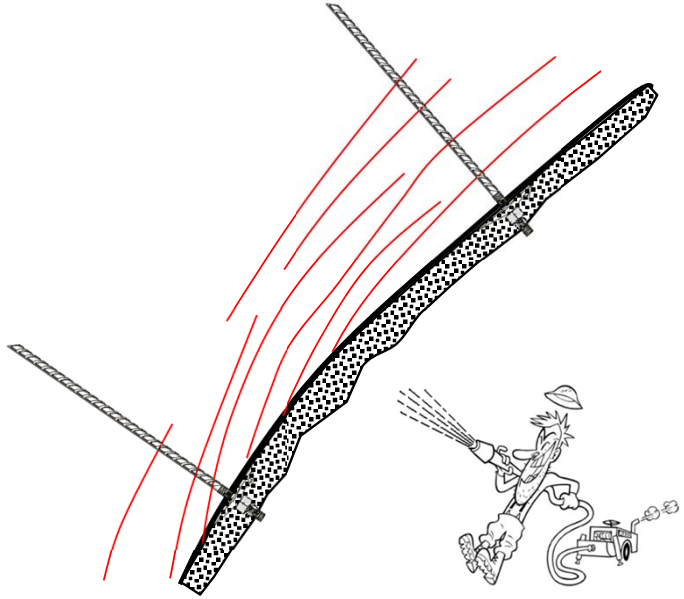




7. Rock support – bolt performance

- Thin shotcrete should be avoided:





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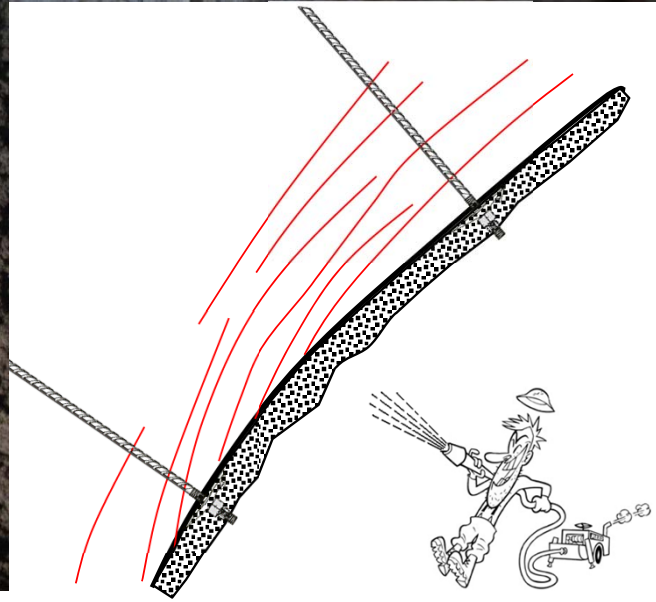

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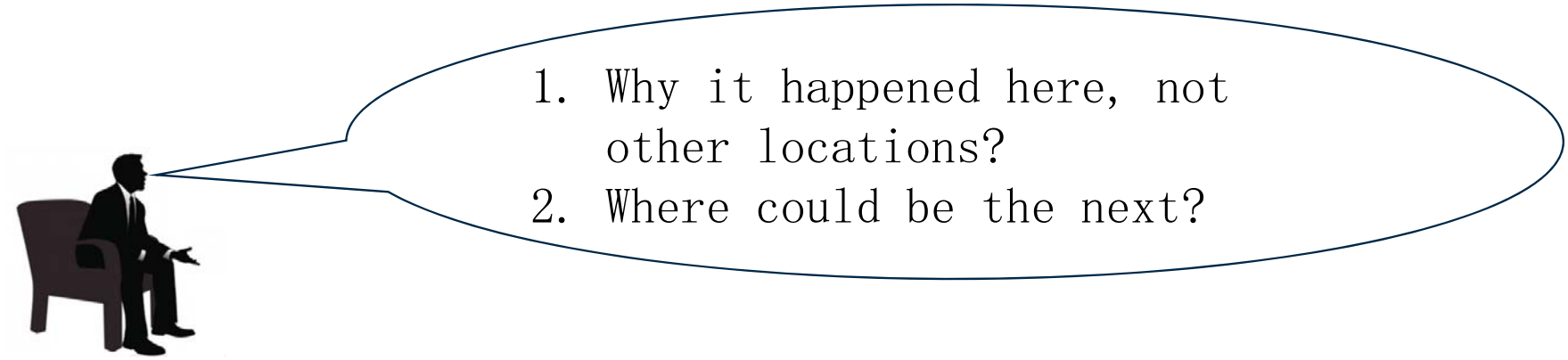
8. Comments for this mine

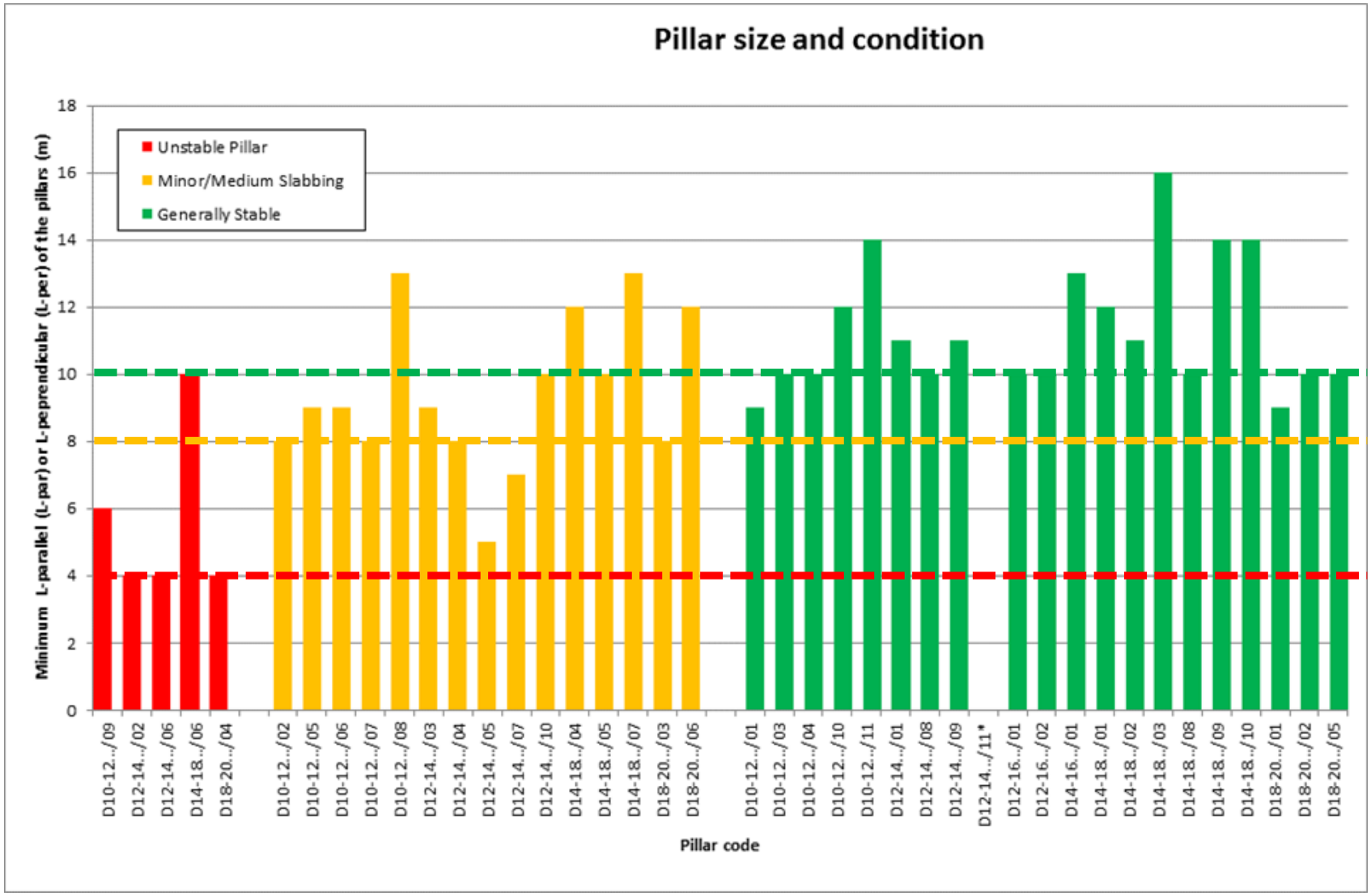


- Answer for question 1: Most likely the over-stressed in thin pillar is the reason for the rockfall in that particular location;

- Answer for question 2: Pillar 12-14/07 could be a next rock fall area - need more thoroughly measurement and observation;

- Pillar size in the new area can be designed at 12x12 m;
- Rock support should be improved;
- Blasting quality near the pillar should be improved;
- Thin rock wall is strongly NOT recommended;

8. Comments for this mine



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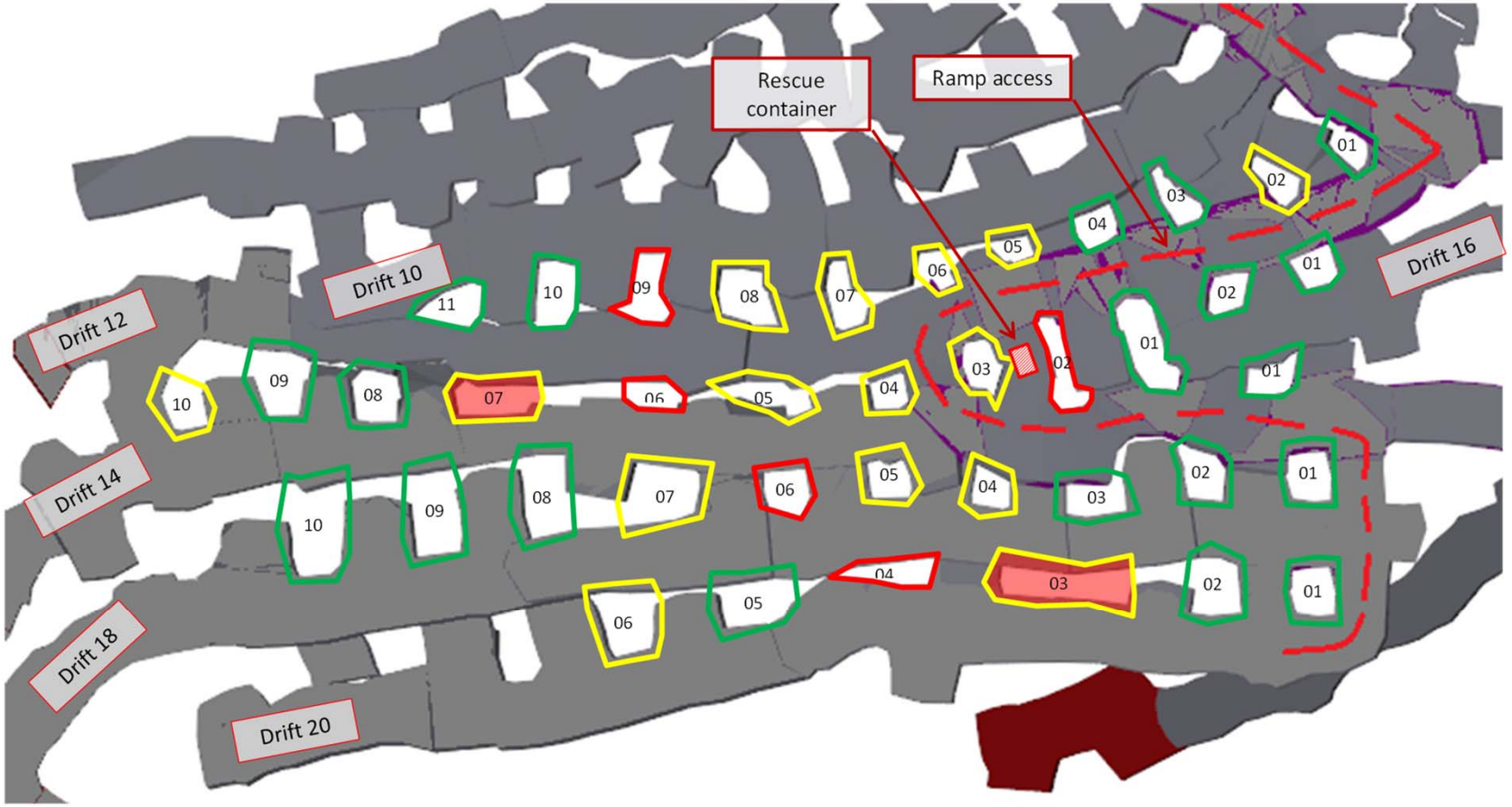
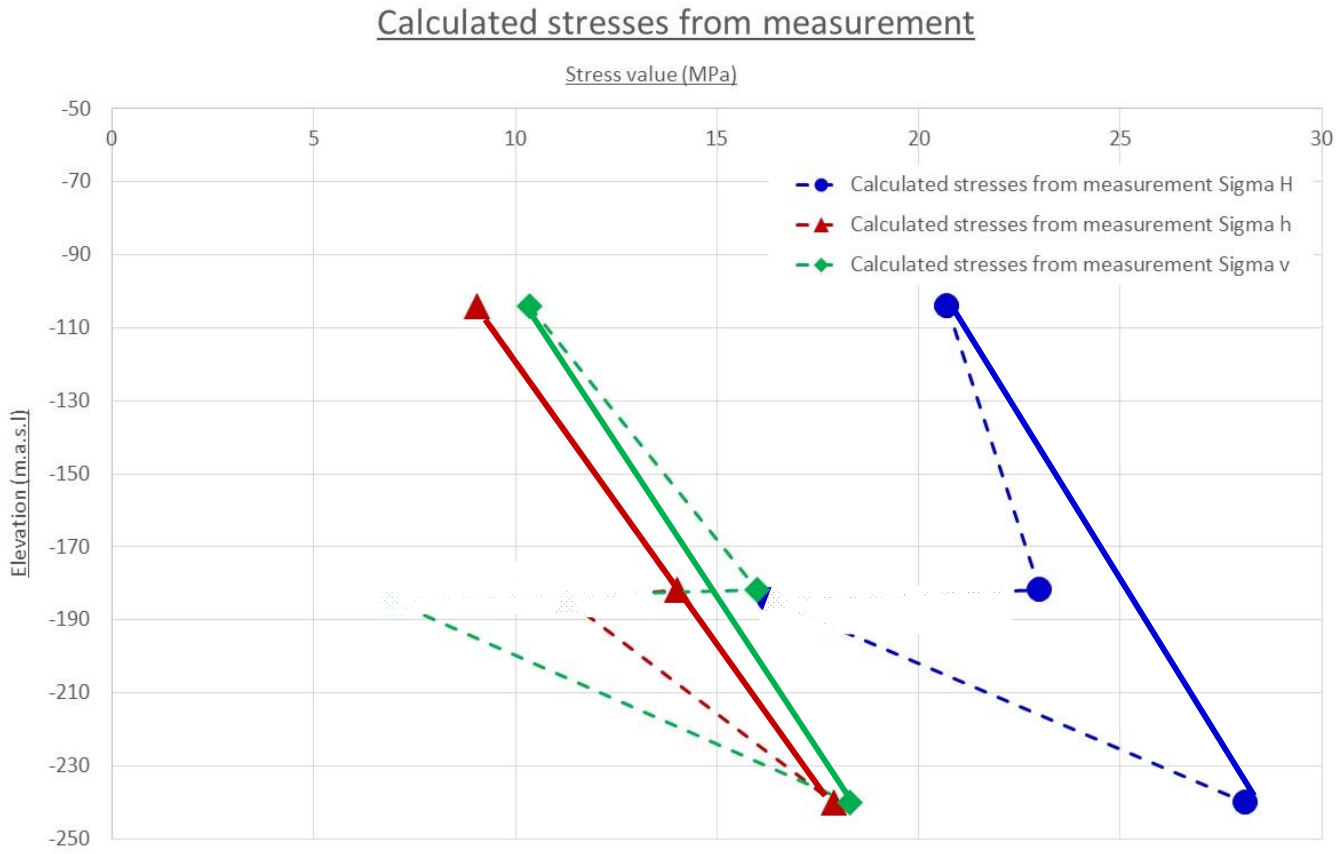


9. Activities over the years

- We carried out stress measurement to find in-situ stress;
- We carried out numerical model with stress measurement;
- We recommend to install stress monitoring equipment (Long Term Door Stopper Monitoring - LTDM) at some important locations.



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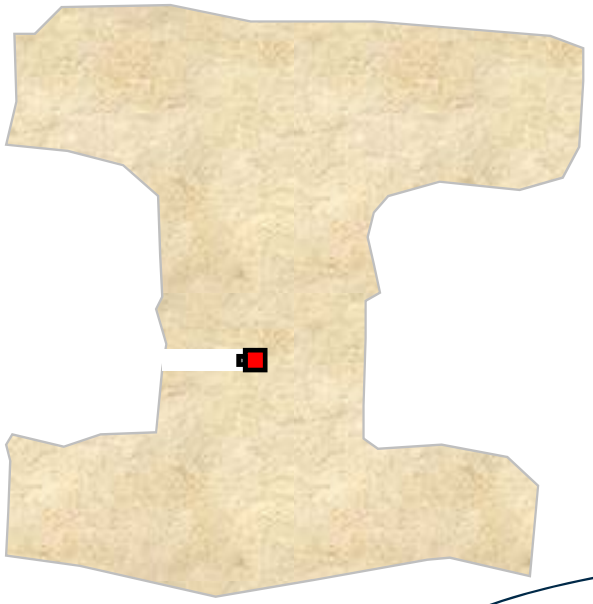
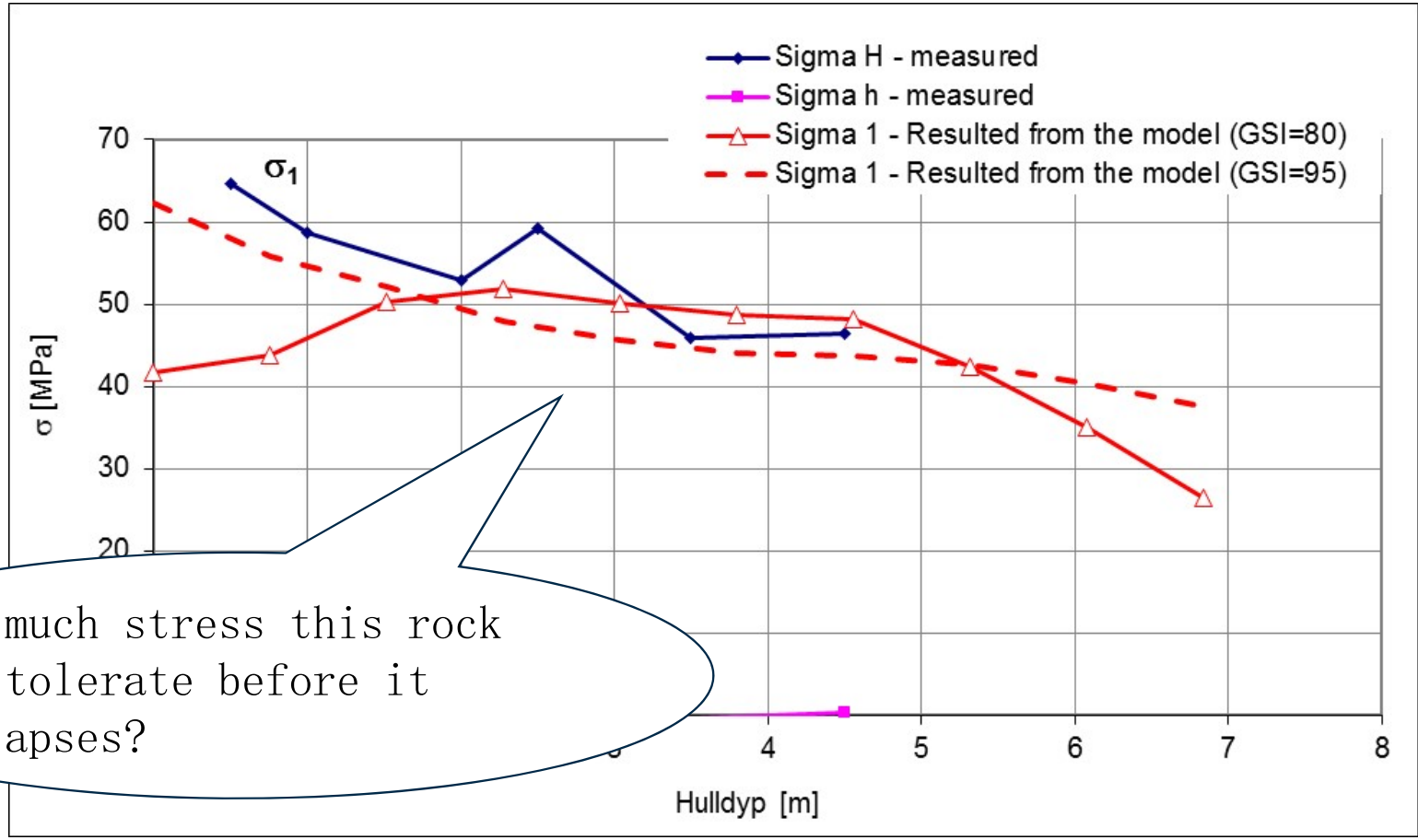
- We carried out numerical model with stress measurement;
- We recommend to install stress monitoring equipment (Long Term Door Stopper Monitoring - LTDM) at some important locations.





How much stress this rock can tolerate before it collapses?

9. Activities over the years

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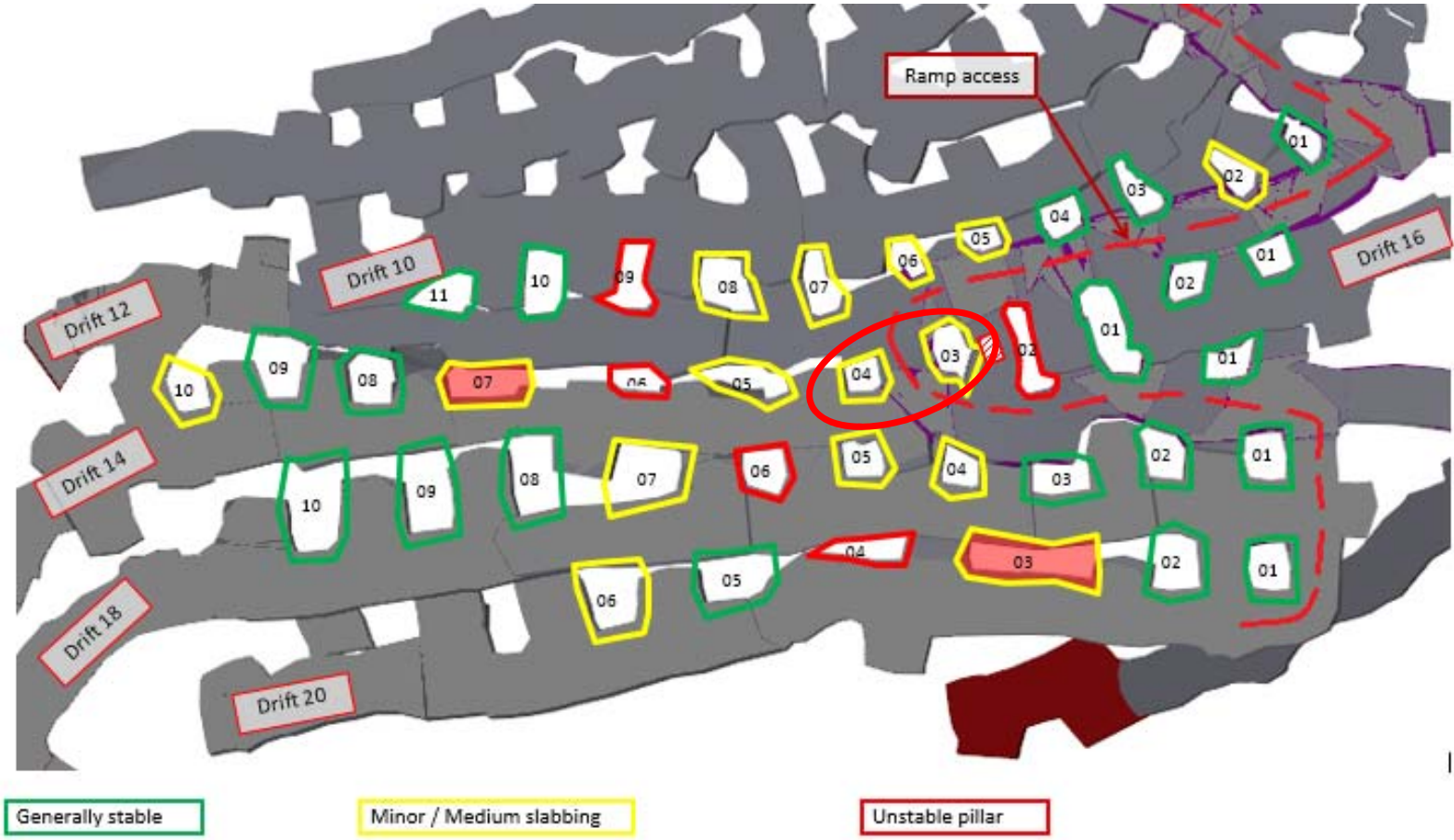


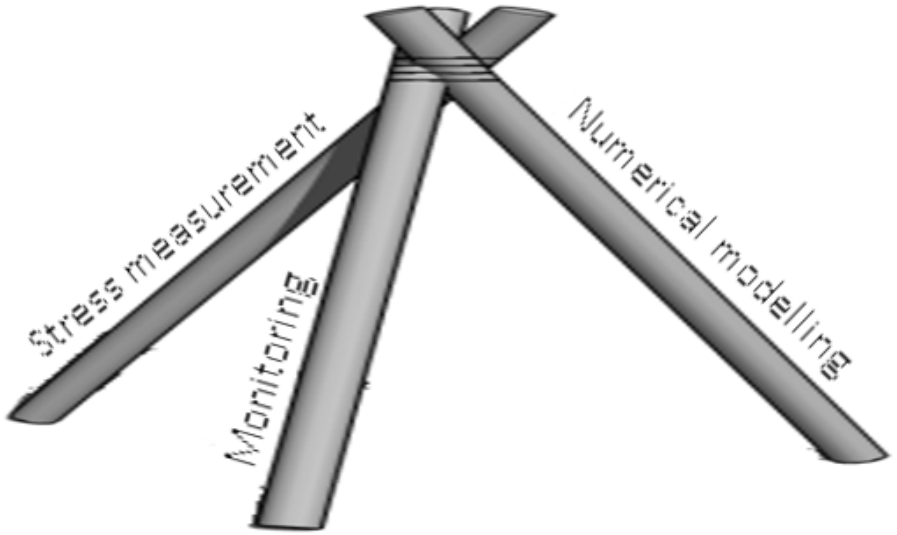
SINTEF philosophy

We believe that we can use a "tripod" of information to solve many rock mechanics challenges. The "Tripod" consists of:

- ✓In-situ rock stress measurements (2D and 3D)
- ✓Rock laboratory tests

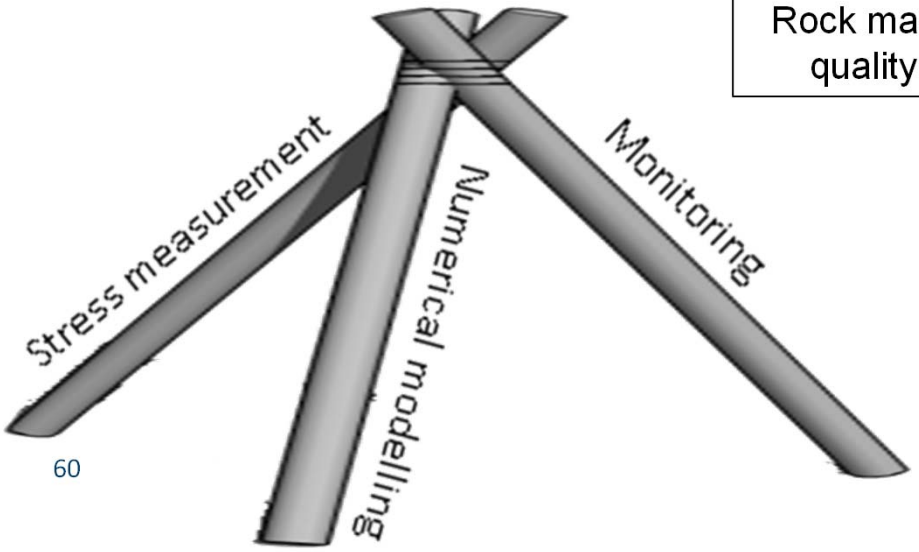
- ✓Numerical modelling
  - ✓2D
  - ✓3D

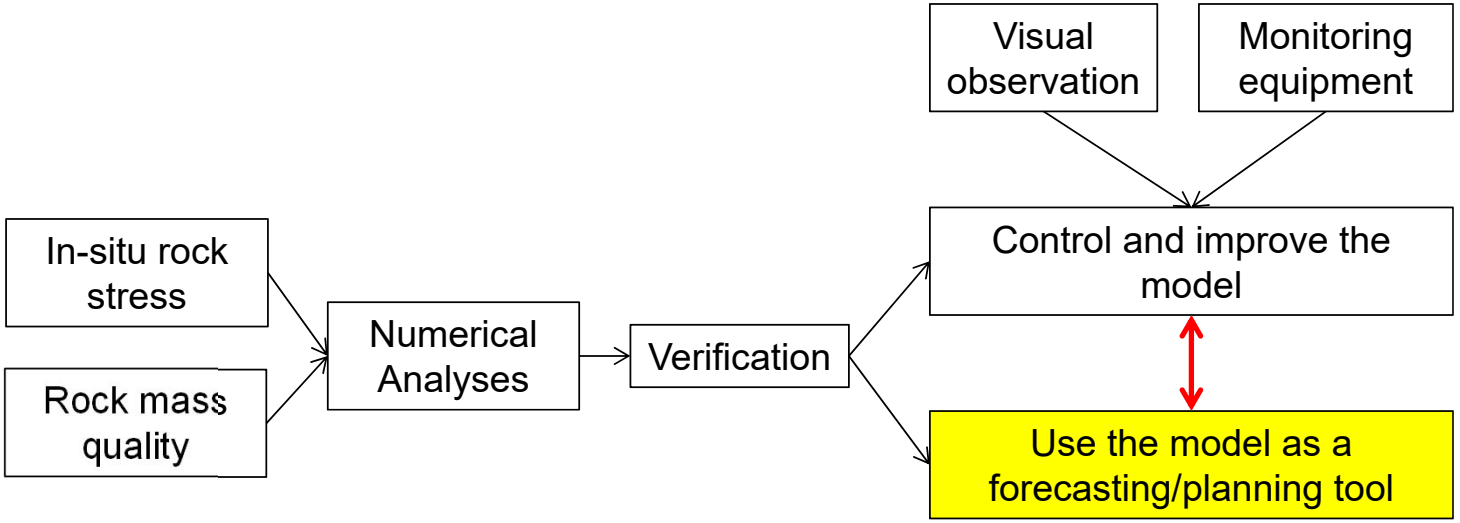
- ✓Installation of the monitoring: extensometers and stress sensor
- ✓Following up



SINTEF

SINTEF philosophy





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