NETWORKED MINE OBSERVATORIES— BENEFITS & CHALLENGES —

4TH INTERNATIONAL UNDERGROUND RESEARCH LABORATORY (URL) WORKSHOP

MONTRÉAL, CANADA

DAMIEN DUFF (CEMI)

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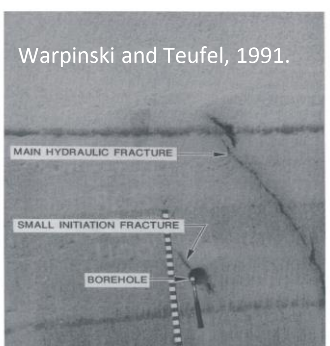
Laurentian University Université Laurentienne

FindMine DeepMine ValueMine ConstructMine SustainMine

Fostering Innovation, Implementing Excellence



Warpinski and Teufel, 1991.


Courtesy: G. Capes (2011)

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OUTLINE

CONTEXT

- Traditional monitoring in non-active mines versus “Living laboratories” in active mines
- The importance of rockmass behaviour change in response to mining
  - Reducing georisk
  - Reducing excavation vulnerability
  - Increasing mining intensity

CEMI’S FIELD MONITORING PROGRAM

- Hydro-Frac experiment focused on Vale mine
- SUMIT inter-university program focussed on Coleman mine
- NRS pillar monitoring at Glencore mine
- MODCC (Mining Observatory Data Control Centre) in collaboration with SNOLAB

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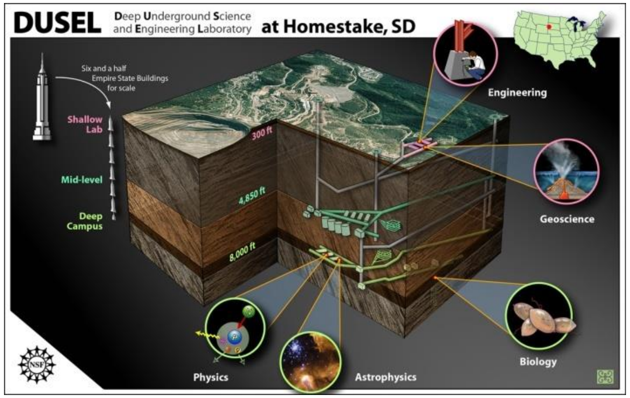
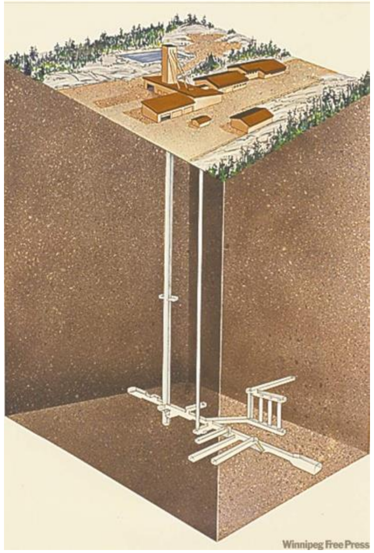
CONVENTIONAL URL'S – STEADY STRESS ENVIRONMENT



Dusel

Äspo



White Shell (Pinawa)

Location of the Grimsel Test Site (GTS) in Switzerland - (1) Grimsel Test Site, (2) Rätrichsbodensee, (3) Grimselsee and (4) Juchlistock

Grimsel

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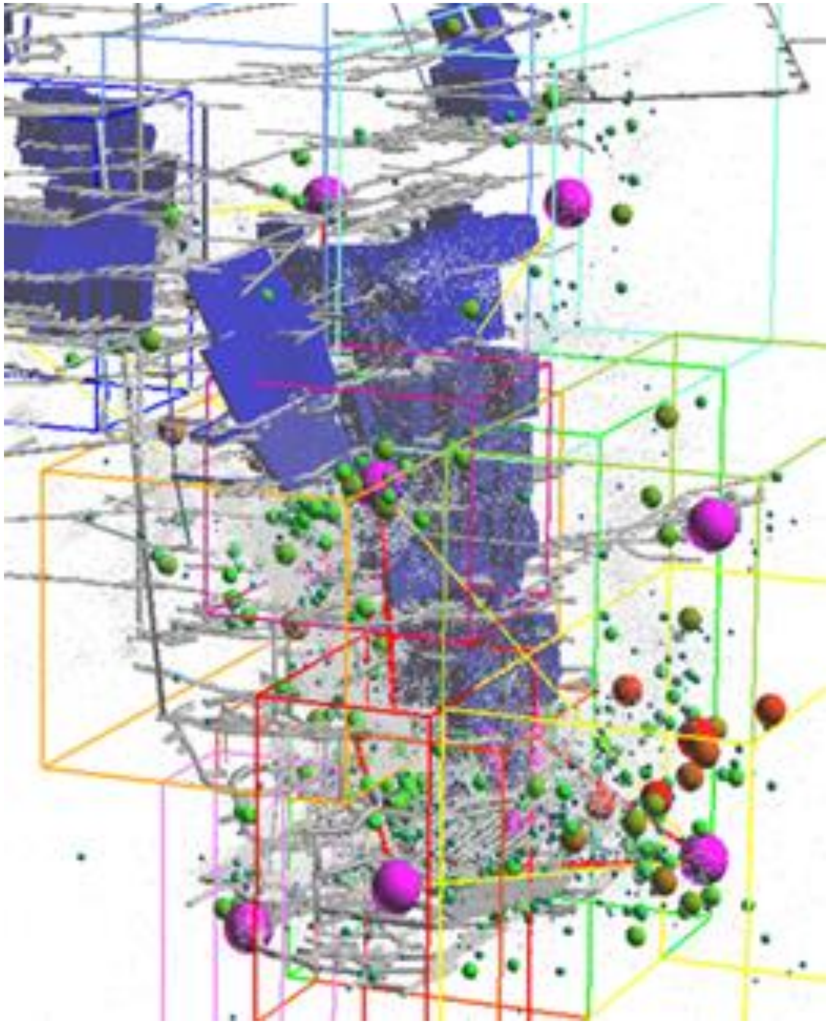
Sudbury's "Living Laboratories"

– IN CHANGING STRESS ENVIRONMENT –

- Producing mine
- all at deep or with >50% extraction → stressed
- many geotechnical challenges
- supportive management and workforce

THE IMPORTANCE OF AN ACTIVE MINE SITE



- Induced Seismicity
- Real world risks and risk mitigation requirements
- Traditional rock mass behaviour monitoring practices in effect
  - mostly microseismicity
- Opportunity to try new approaches
  - Gauge effectiveness in real world

Ground reaction concept (Fenner-Pacher curve 1960's)

Support load depends on support type and installation sequence

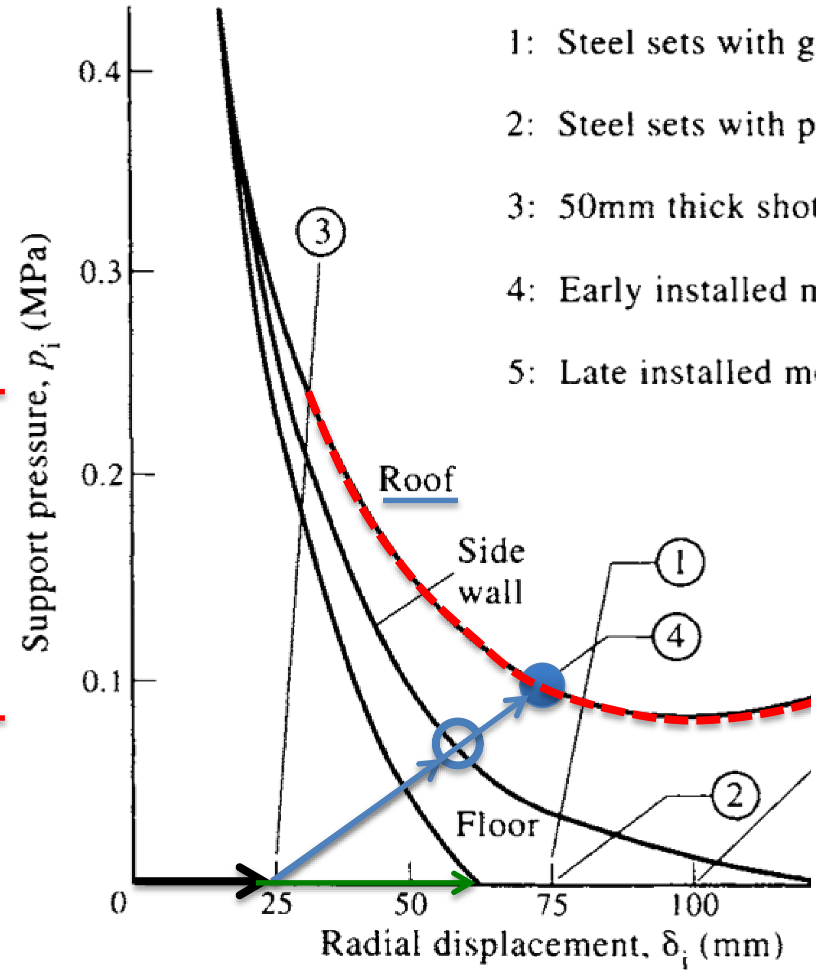
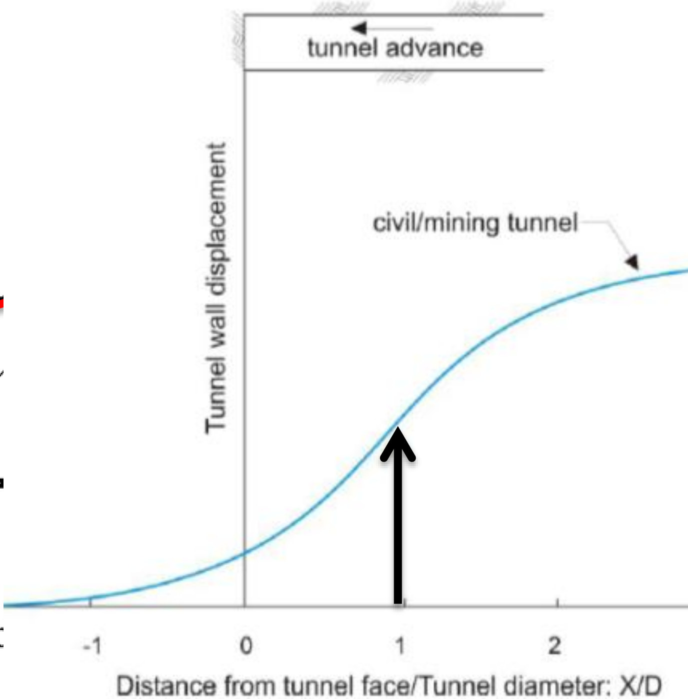
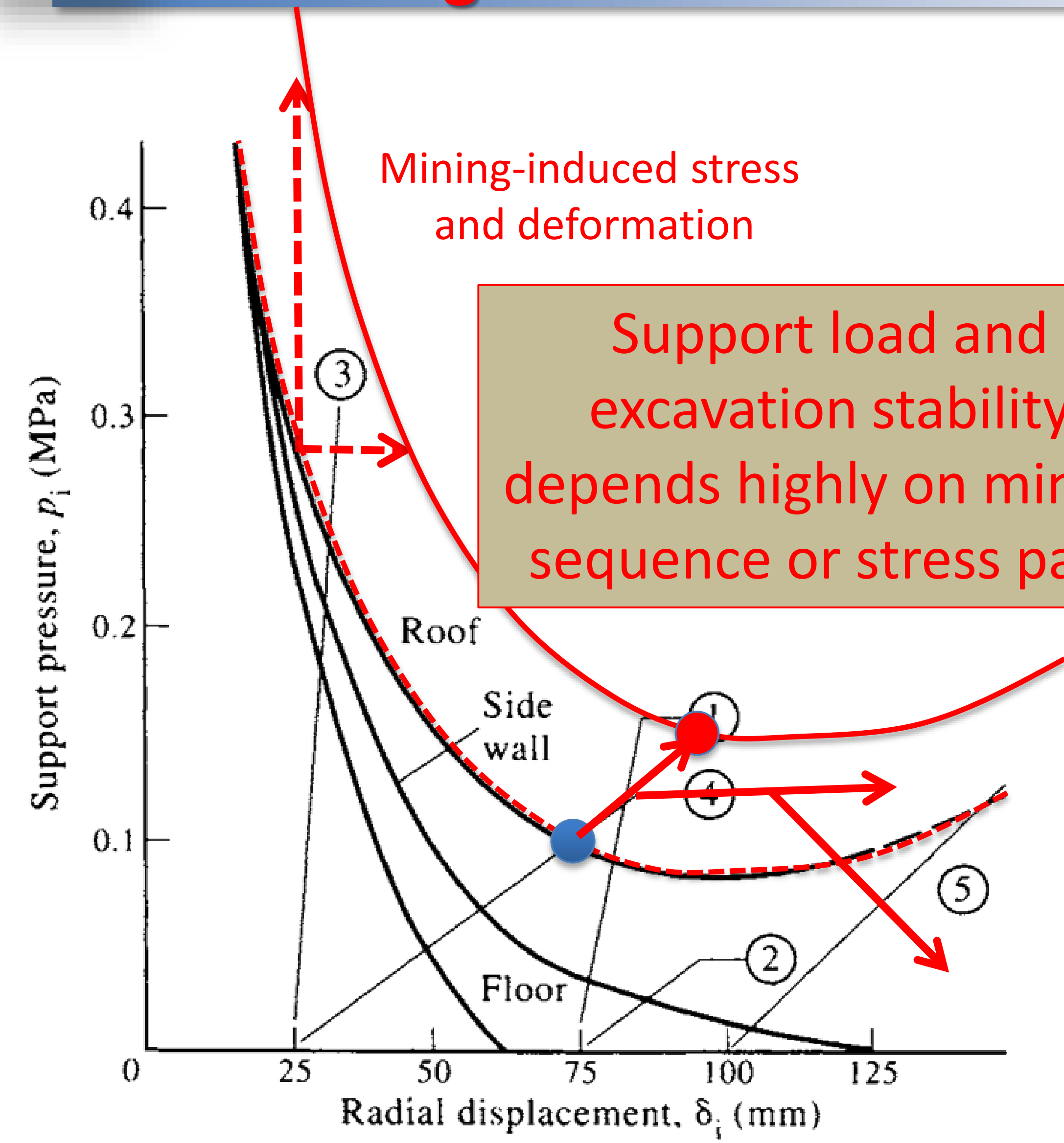


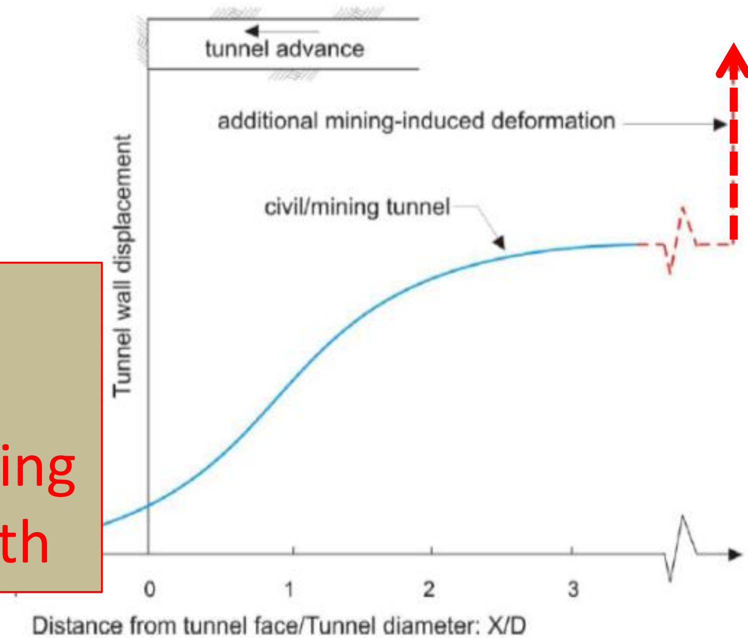
Figure 20.28 Available support lines and grounc
Brown, 1985, and Hoek and Brown, 1980).



Conceptual support design with **mining-induced stress change** or deformation



Support load and excavation stability depends highly on mining sequence or stress path



- Increasing ER
- Cave loading

Support – Deep mining

Basic Requirements:

- *In situ* stress
- Geometry
- Rock mass strength or failure criteria
  - to predict depth of failure
- Rock mass bulking factor
  - Mining induced convergence or rock / support straining

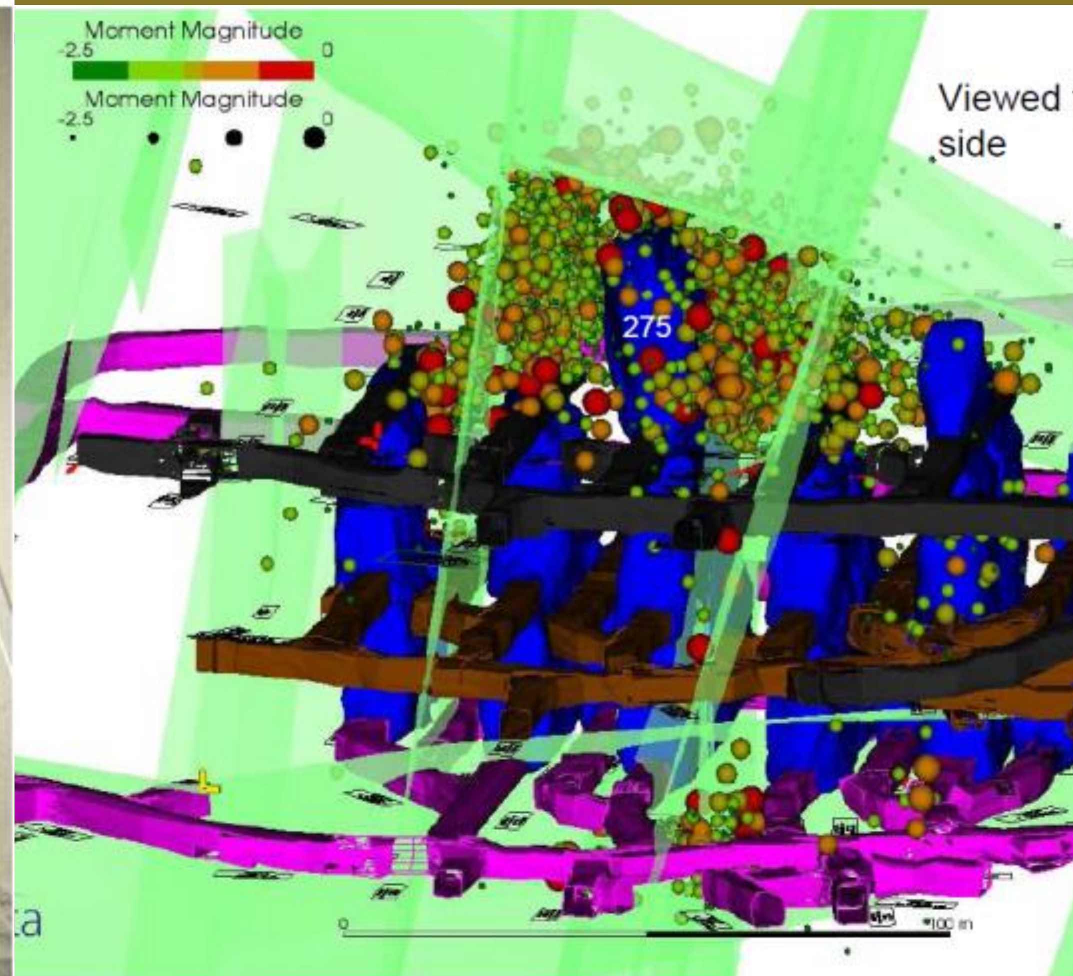
Extraction level Failure – North Parkes E48

convergence continued
after under-cutting was complete

24th August 2010

10th September 2010

DEEP MINING - Dynamic loading challenge

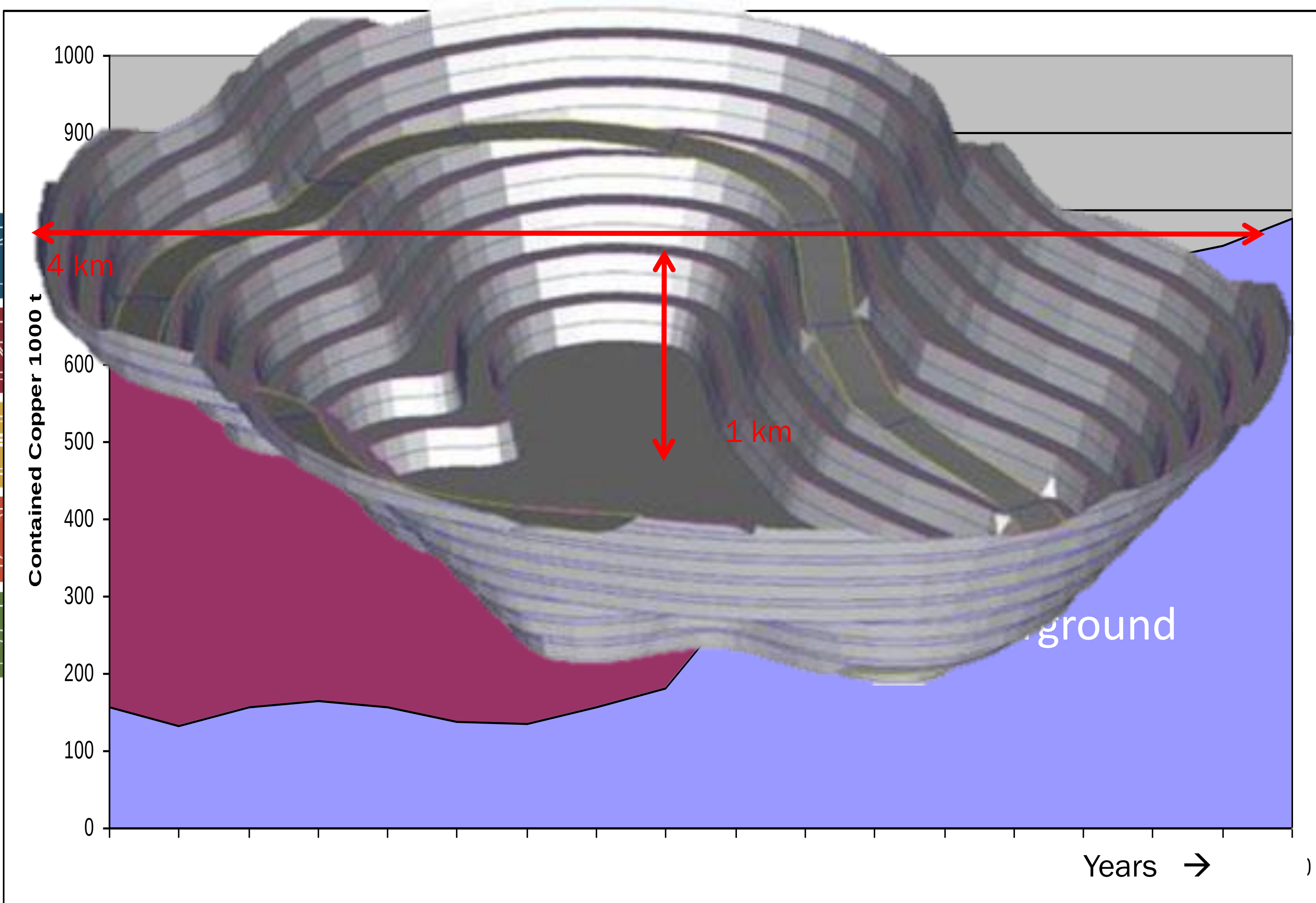


er 23, 2011 (day of final blast 1445-275) to November 24, 2011
major faults in the area shown

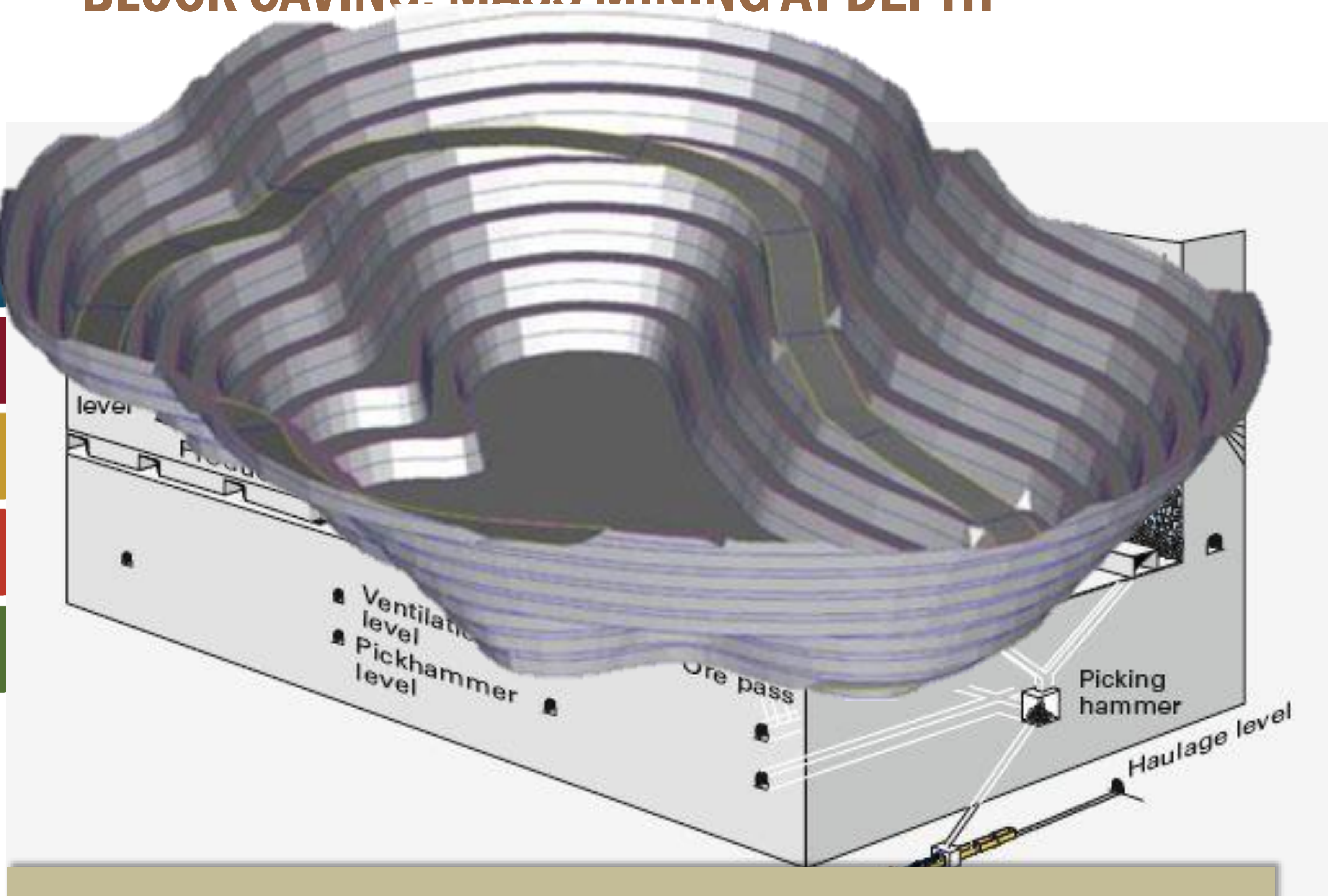
Courtesy B. Simser (Xstrata Nickel)

January 1, 2011 to November 28, 2011
Showing the most of the major faults (oblique fault also a significant player but removed from snapshot for clarity)

CHALLENGES IN DEEP MINING

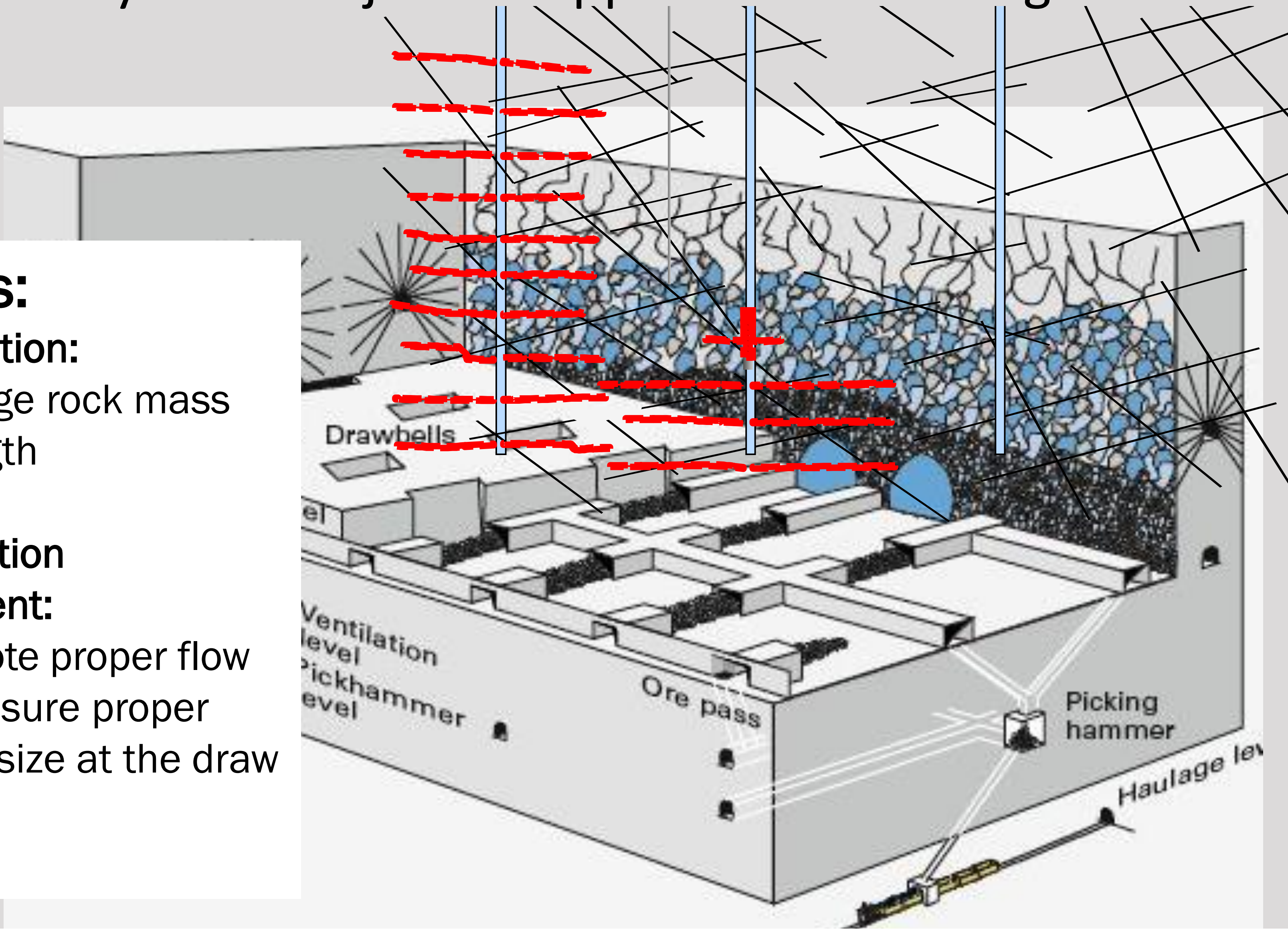


BLOCK CAVING: MASS MINING AT DEPTH



Maintain same level of production

Current hydraulic injection application in mining



Objectives:

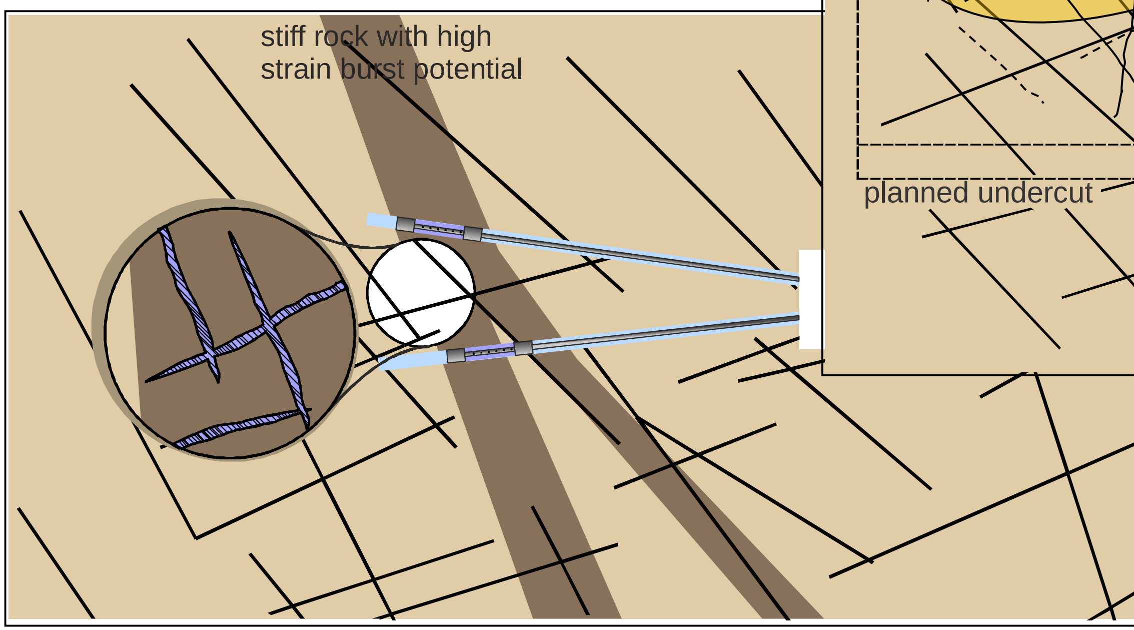
- **Cave induction:**
  → Manage rock mass strength

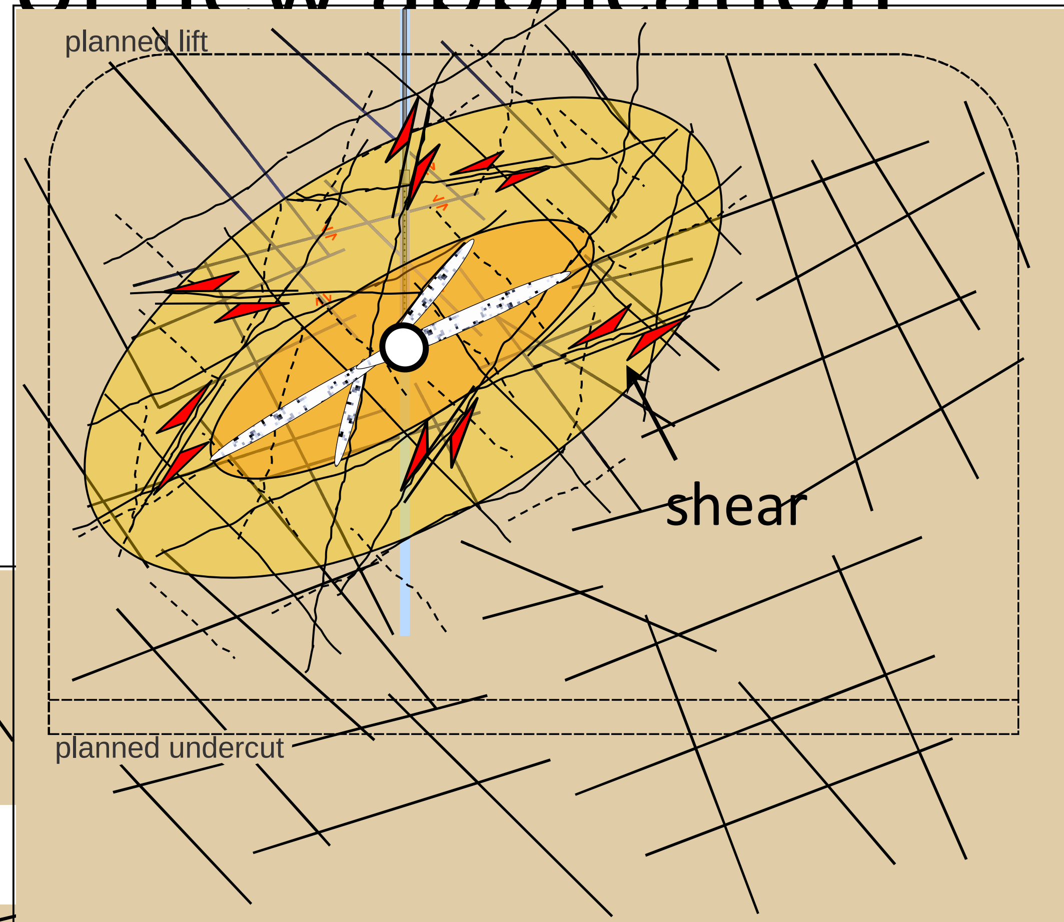
- **Fragmentation management:**
  → Promote proper flow and insure proper block size at the draw points

Development of new application

- Stress and stiffness change management

- Mitigate strainburst risk





- Minimize damage from induced seismicity and bursting on foot print

Mining Objectives

1. Permit stress management → enhanced safety /reduce risk
2. Rockmass (pre-)conditioning to help control → fragmentation
3. Control strainburst potential → mechanized excavation
4. Control energy release from instability mechanisms → fault–slip → Modify "mine system stiffness" to change stored energy in brittle structures → risk management
5. Develop ground characterization techniques → design

and much more ...

- Improve support design,
- stress determination by ... ment inversion,
- velocity models
- ground motio

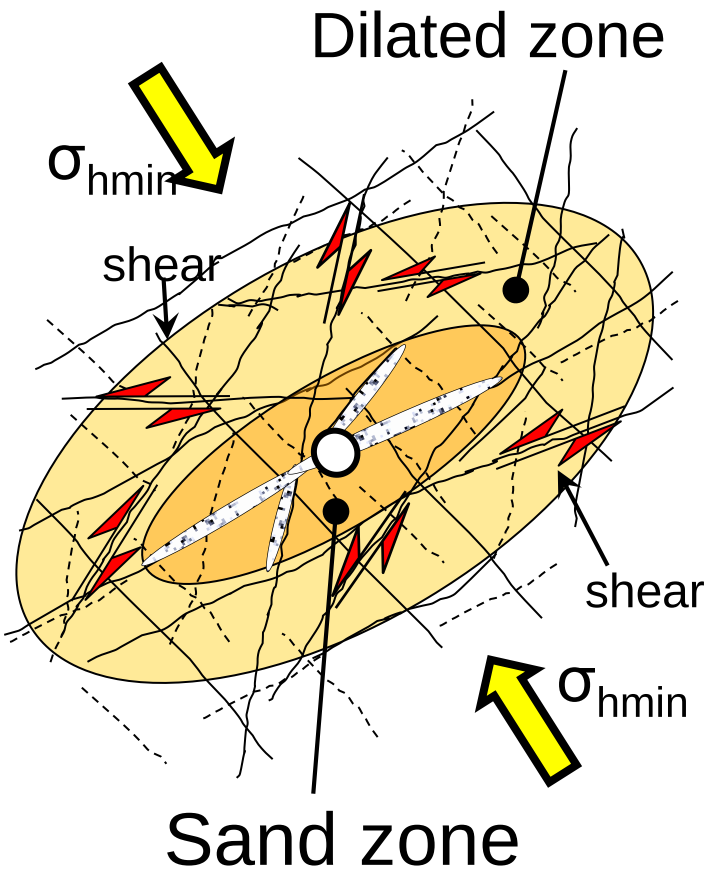
Safety
& Productivity enhancement

Oil & Gas objectives

1. Improve our knowledge of processes at play during hydraulic *fracturing in tight formation*

2. *Calibrate geophysical proxy* (e.g. micro-seismicity) for hydraulic fractures processes tracking

3 *Calibrate numerical models* for hydraulic fracturing and hydraulic stimulation simulation;



The Industry Participants

Mining Companies

- Vale
- Rio Tinto
- Newcrest Mining Limited

Oil & Gas Companies

- Nexen
- ConocoPhillips
- Shell

The Technical Team

CEMI Centre for Excellence in Mining Innovation

University of Calgary

University of Waterloo

University of Alberta

Mirarco Mining Innovation

Duff

Kaiser

Eaton

Dusseault

Van der Baan

Schmitt

Pakalnis

ITASCA™

The Mining BLNCE Network

UDMN
ULTRA DEEP MINING NETWORK

$46 million business-driven national network, founded and funded by members of the mining and oil & gas industries, Small to medium sized enterprises (SMEs), industry agencies, research facilities and academia

Canada

Network
Centres of
Excellence

Theme – 1 Rock Stress Risk Reduction

UDMN
ULTRA DEEP MINING NETWORK

Non-Conventional Stress (& strain) Measurement

- Seismic Stress Inversion
- Ambient Noise Analysis
- Mobile Convergence Monitoring
- Active Seismic Monitoring

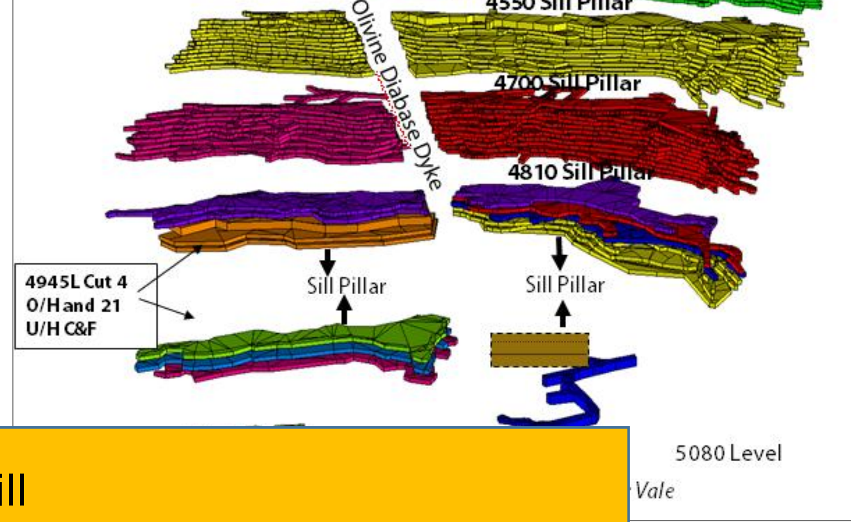
Assess Geotechnical Hazard

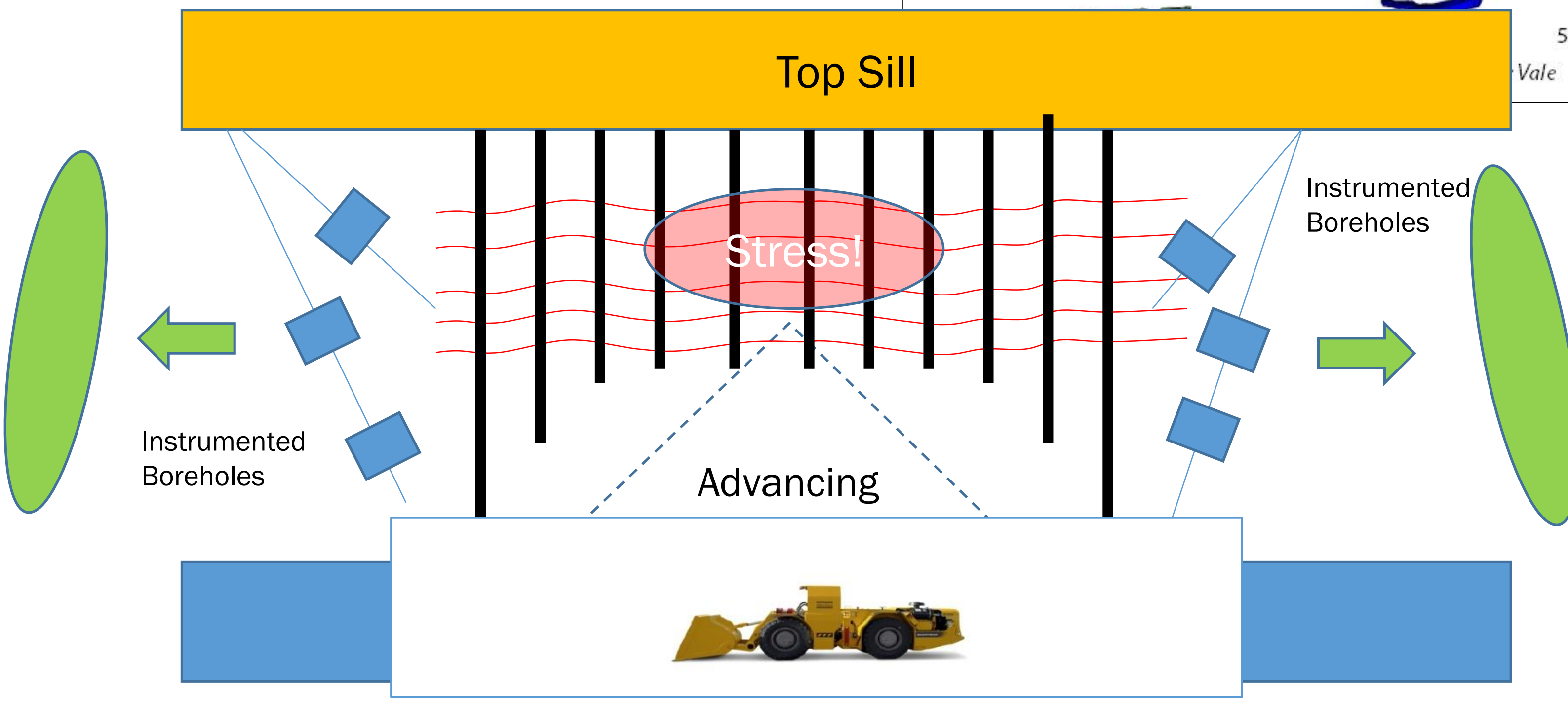
- Real-time assessment
- Measurement while drilling (MWD)
- Open geotechnical data networks

Modify Rock Mass Behaviour

- Hydraulic Fracturing
- Enhanced pre-conditioning design approach

BLOCK-SCALE (MIRARCO)





Vale Sill Pillar
Cut and Fill Mining
Longitudinal Projection

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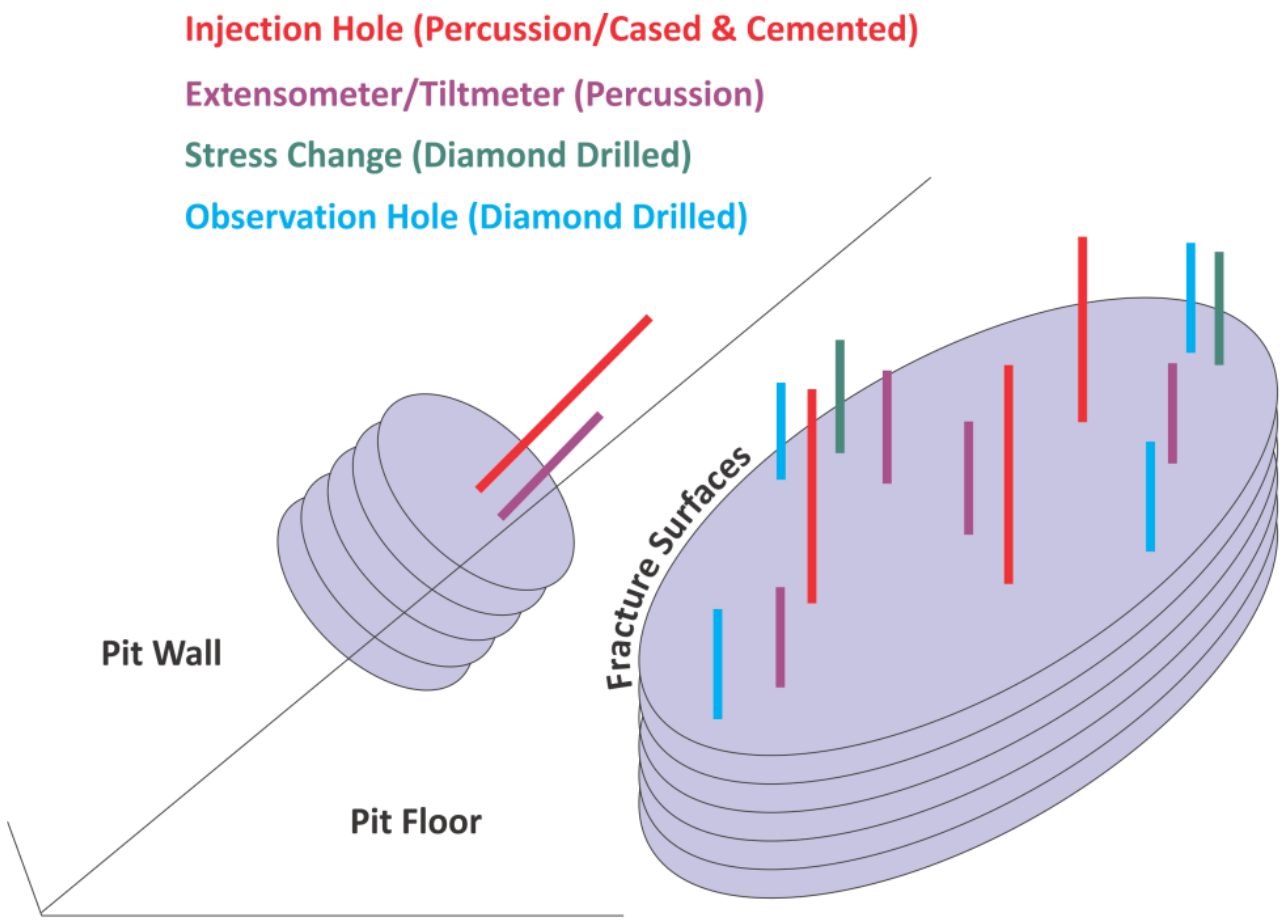
Approach

1. Conduct surface trial in pit bottom
   – Refine equipment and procedures based on modelling and performance.
2. Execute HF treatment underground (stress shedding demonstration)
3. Finalize service model
4. Implementation of new mining methods

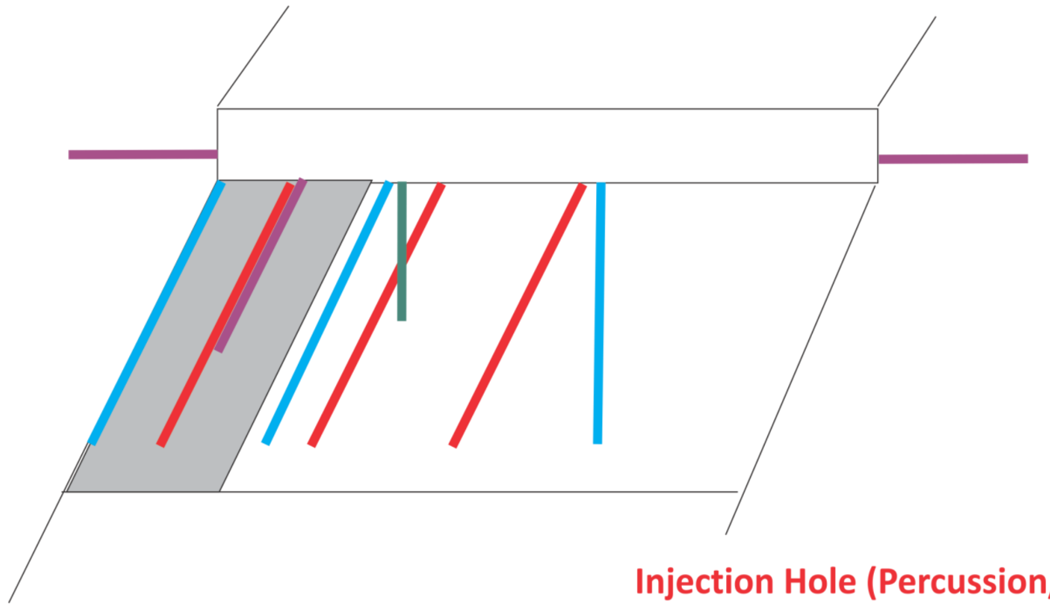
Surface Layout



16 Sensor Seismic Array to Envelop Test Volume (not shown)

Underground Layout

Dense microseismic array not shown



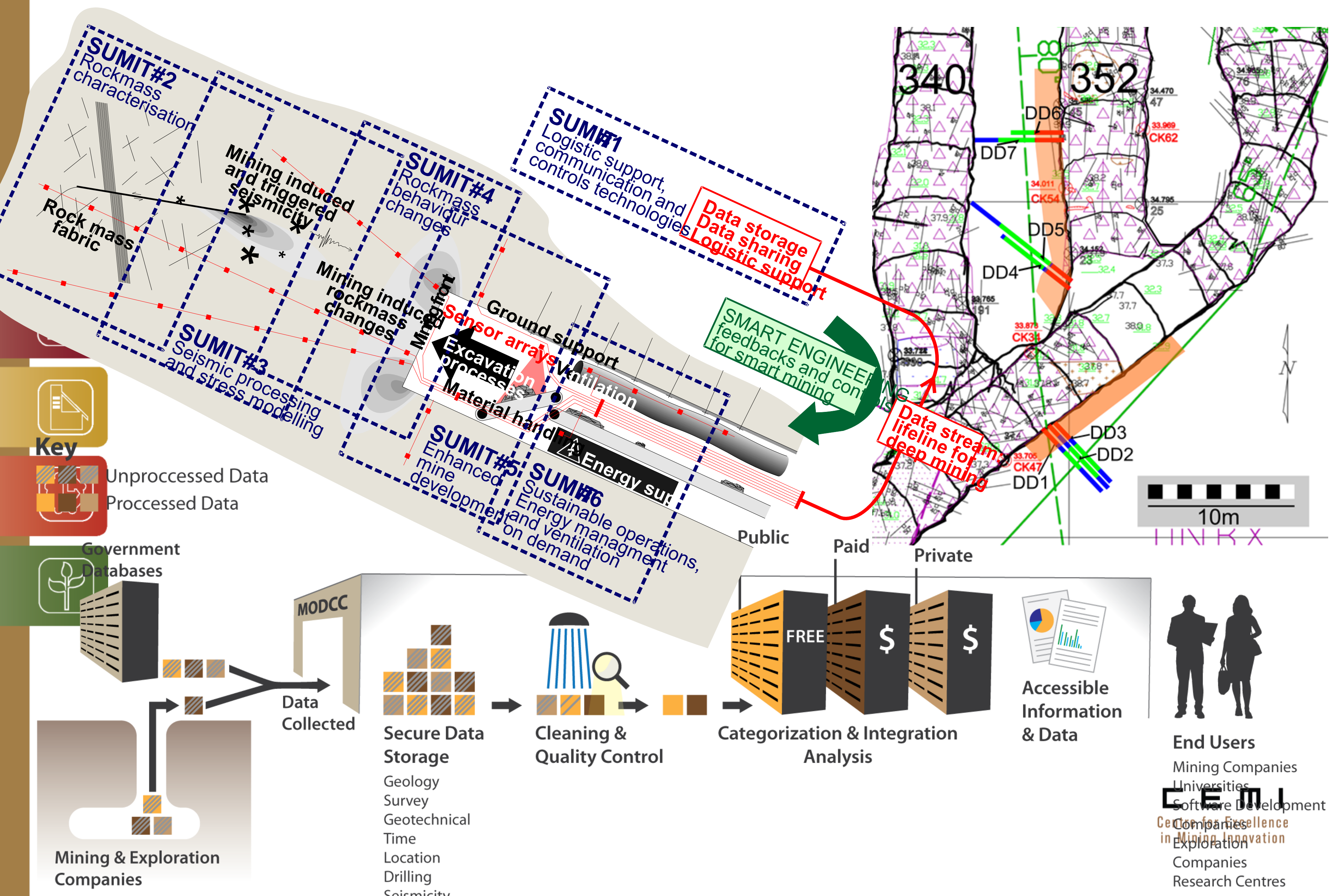
Injection Hole (Percussion/Cased & Cemented)

Extensometer/Tiltmeter (Percussion)

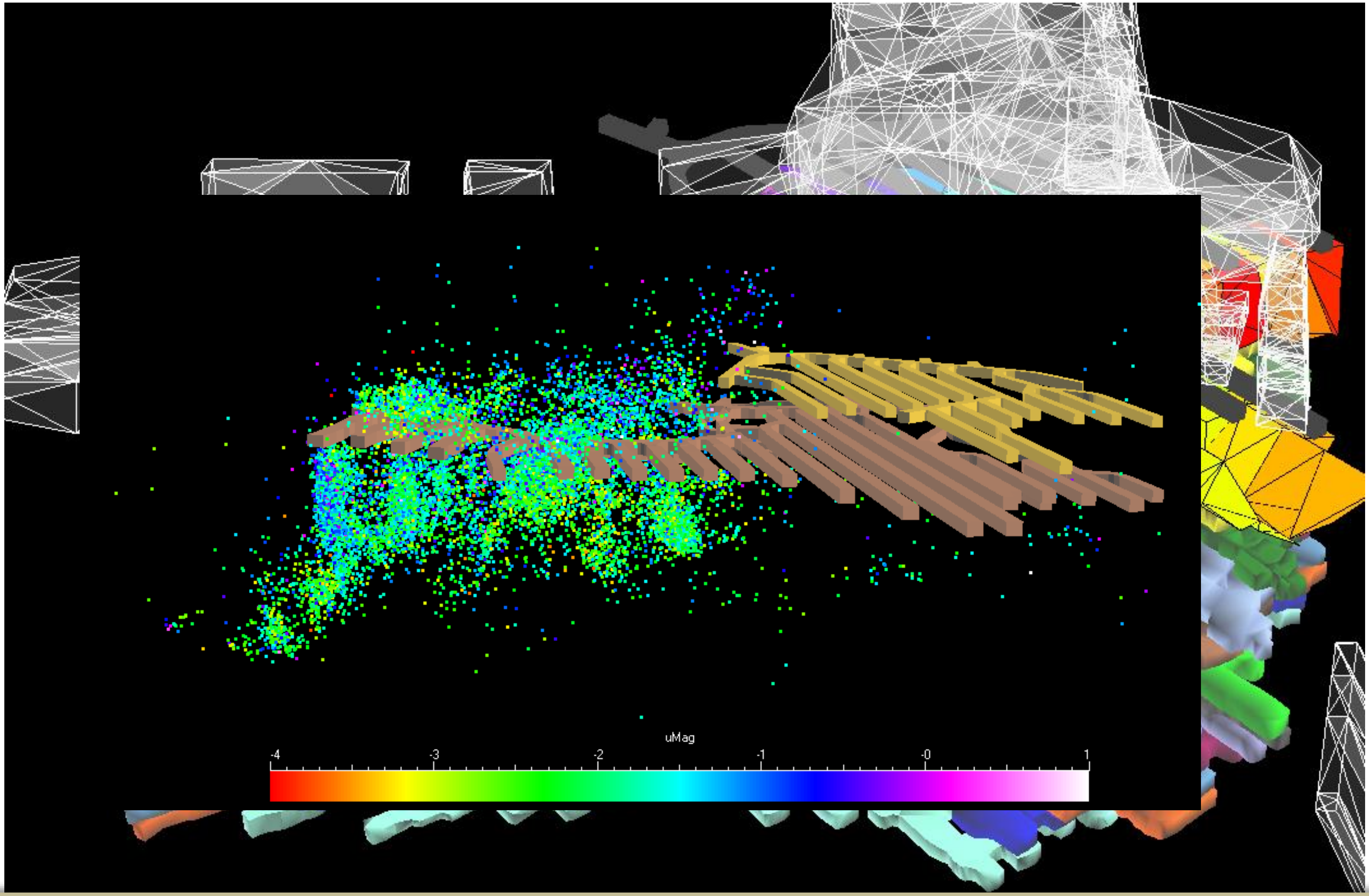
Stress Change (Diamond Drilled)

Observation Hole (Diamond Drilled)

OTHER LIVING LABORATORY INITIATIVES – SUMIT, NRS, MODCC



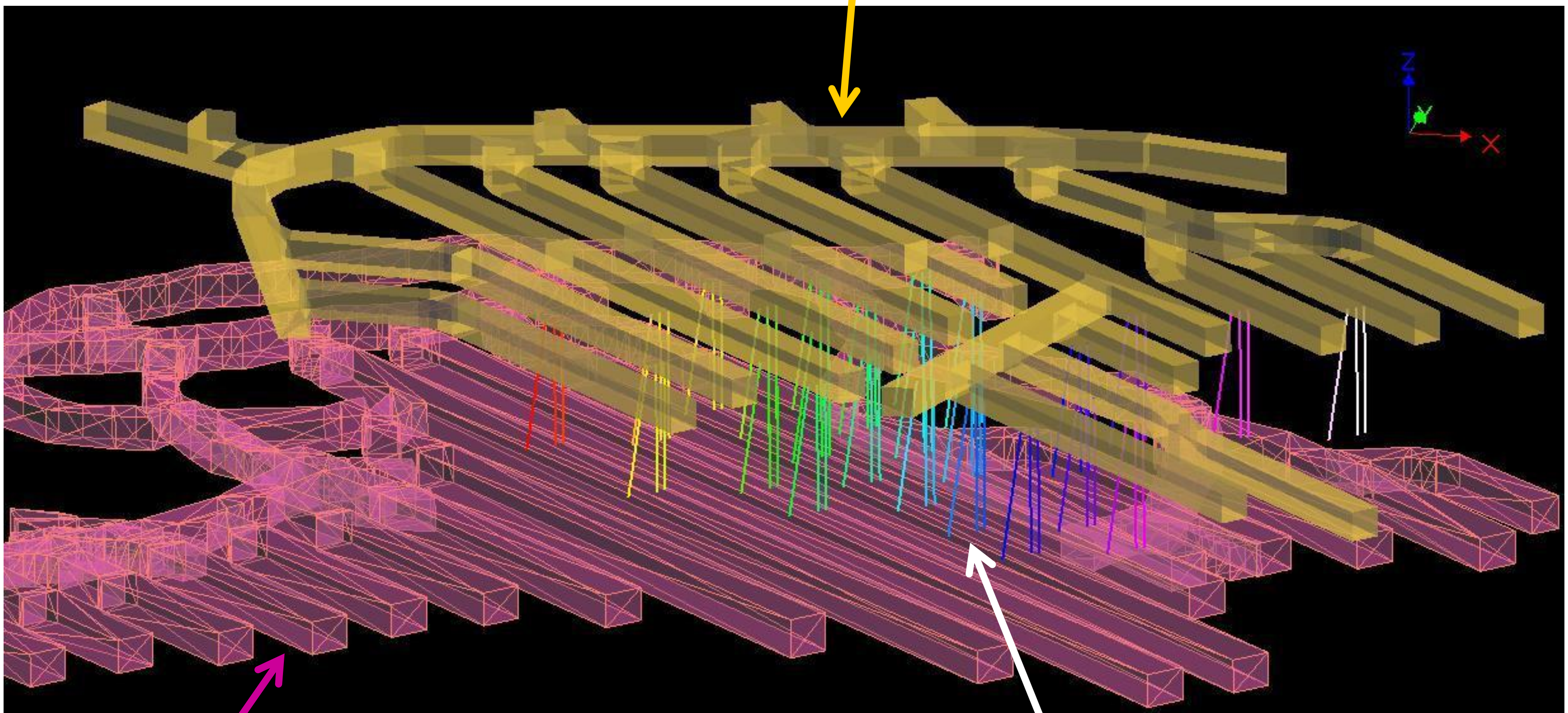
OTHER LIVING LABORATORY INITIATIVES



Differentially stressed sill pillar

Monitoring boreholes array

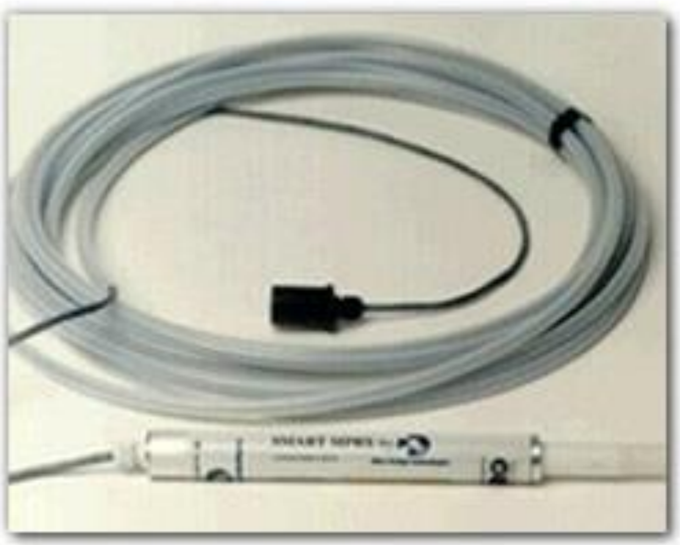
MOB1 crown top sill



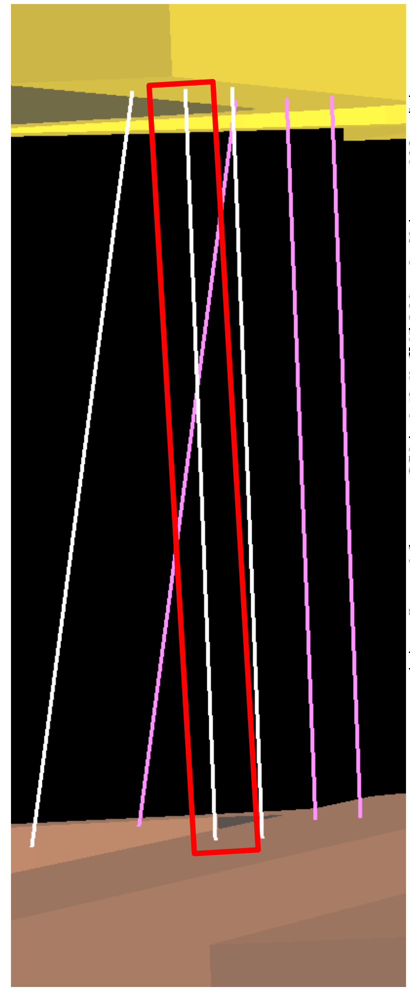
MOB1 crown bottom sill

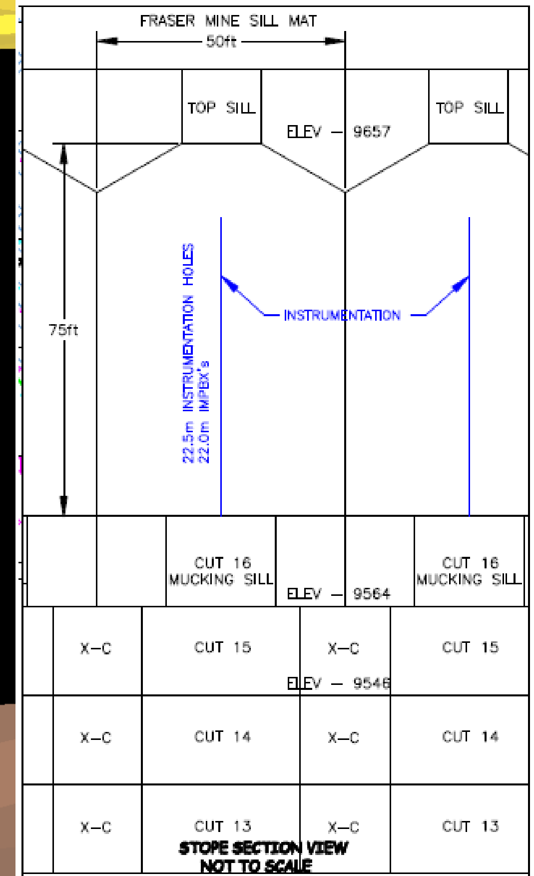
Monitoring boreholes array
(21 locations)

Deformation monitoring



Length:	up to 50 m
Diameter:	33 mm
Weight:	0.5 kg/m
Borehole diameter:	50 mm minimum
Transducer:	linear potentiometers
Stroke:	63.5, 127, 190.5, and 508 mm
Accuracy:	+/- 2% F.S.





NRS PILLAR STUDY

ADVANCING MINING FRONT

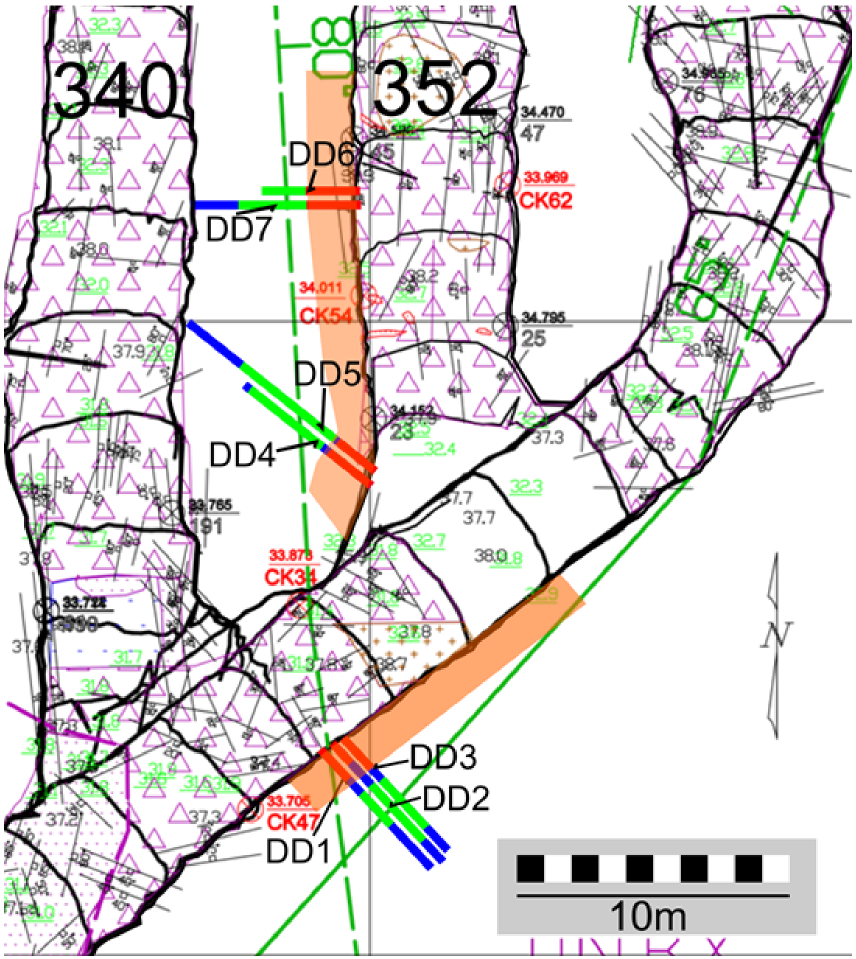


Figure 1 top view of test pillar configuration showing existing boreholes

Six objectives of this program:

1) damage characterisation of a narrow pillar that has been loaded and damaged by mining;
2) assessment of pillar response to further mining-induced loading;
3) determination of depth of failure behind the support to improve support design;
4) testing of innovative geophysical methods to define the depth of failure (the primary research goal of this monitoring program);
5) testing of hand-held laser scanning technology (ZEB1) for rapid detection of rock mass bulking; and
6) interpretation of measurements to derive practical implications for pillar and support design, to better assess the capacity of rib pillars for NRS, and to assist in the development of deformational controls in yielding pillars

MANAGING DATA!

CONCLUSIONS

NETWORKED APPROACH…

- comprising both cross sectoral industry and multi disciplinary research components

UNDERGROUND "LIVING LABORATORIES" AN ESSENTIAL ELEMENT

- experimentation under "real- world" conditions possible…
- leading to solutions with "buy-in" from industry
- Logistics can be difficult
  - Importance of experimental design
  - Minimum operational interference
  - Clear value propositions
  - TIMING IS EVERYTHING!

DATA MANAGEMENT NEEDED IN PARALLEL

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NETWORKED MINE OBSERVATORIES— BENEFITS & CHALLENGES —

Thank you!

FindMine

DeepMine

ValueMine

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