HEALTH SAFETY ENVIRONMENTAL TECHNICAL

Rock Mechanics Research at the Lucky Friday Mine

CIM, May, 2015

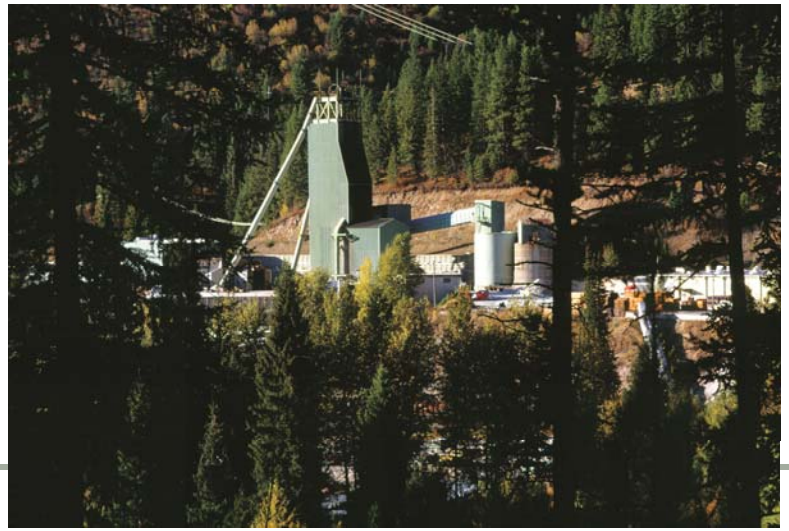
Hecla MINING COMPANY

Objective

- Describe the rock mechanics challenges of deep mining at Hecla's Lucky Friday Mine
- Discuss the seismicity and ground control mitigation strategies employed at the mine, particularly the stress shadowing approach for pillar destressing and deformable ground support for control of large deformations
- Provide a progress report on implementation of these strategies since the mine was re-opened in 2013

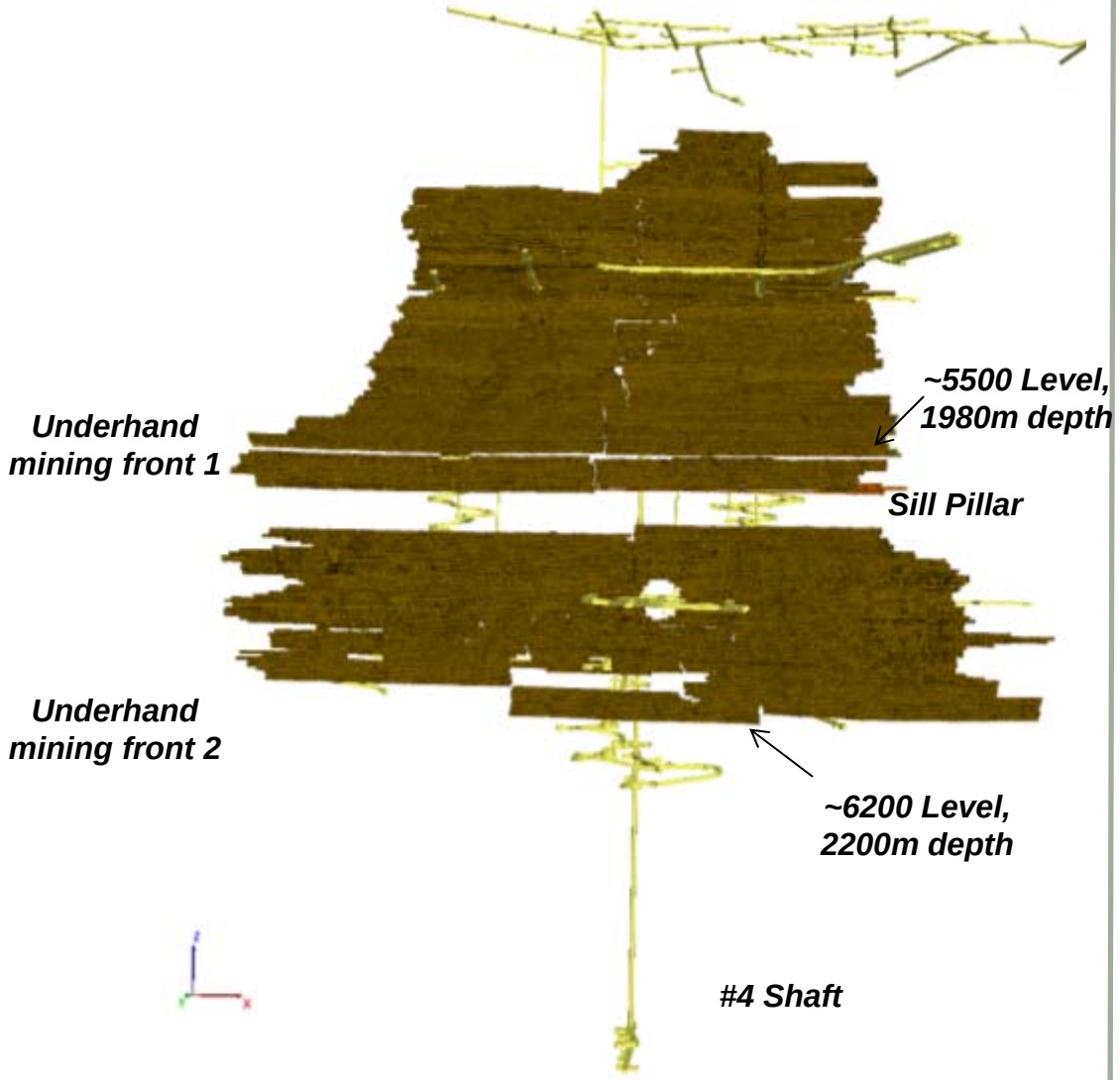
Lucky Friday Mine

- Mine production startup – 1942
- Narrow (average 3m), vertical silver, lead, zinc veins
- Annual production about 3.5 mm oz silver. More than 150 mm ounces of silver produced to date
- Current deepest stopes at ~7300' (2200m) depth, resource identified to >9000' (2750m) depth
- Underhand cut and fill mining method
  - Average stoping width ~3m
  - Typical footwall ramp access with slotting to vein every 50'.
  - Single boom jumbos, 2.5 yd LHDs, 20 ton trucks
  - Paste fill (8% binder of 75% slag/25% cement)
- Production rate 900 to 1000 tpd from average of 7 stopes



Mine Layout

- Primary vein is 30 Vein with 5 stopes. 2 to 3 additional stopes on parallel footwall veins. All vertical dip.
- Average strike length of orebody is 2500’ to 3000’ (750 to 900m)
- Two primary underhand mining fronts, one down from 5500 level, one down from 5900 level
- Sill pillar created below 5500 mining front



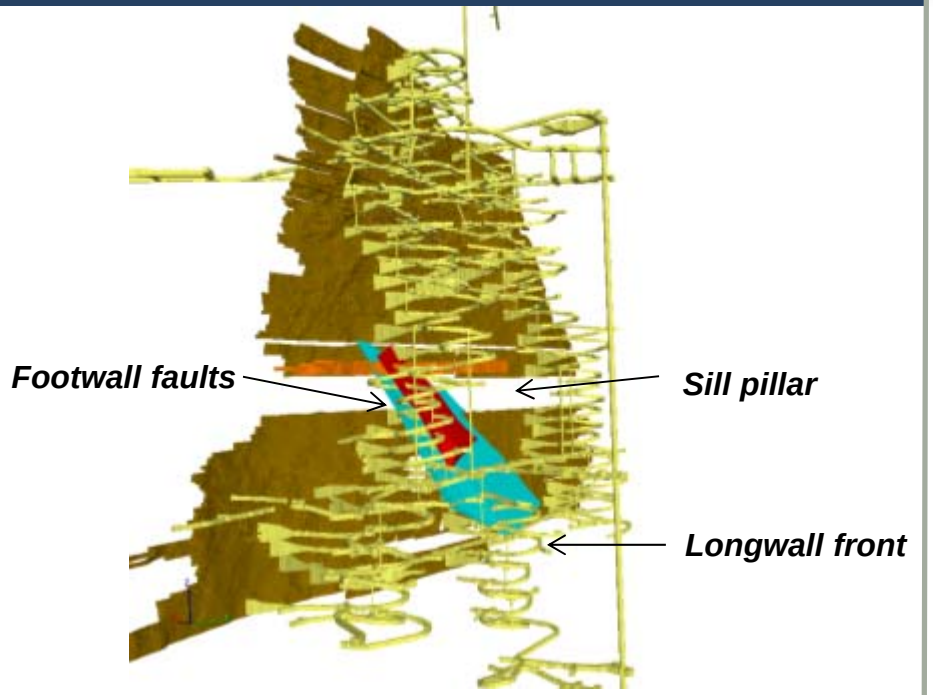
Rock Mechanics Challenges

➢ Seismicity

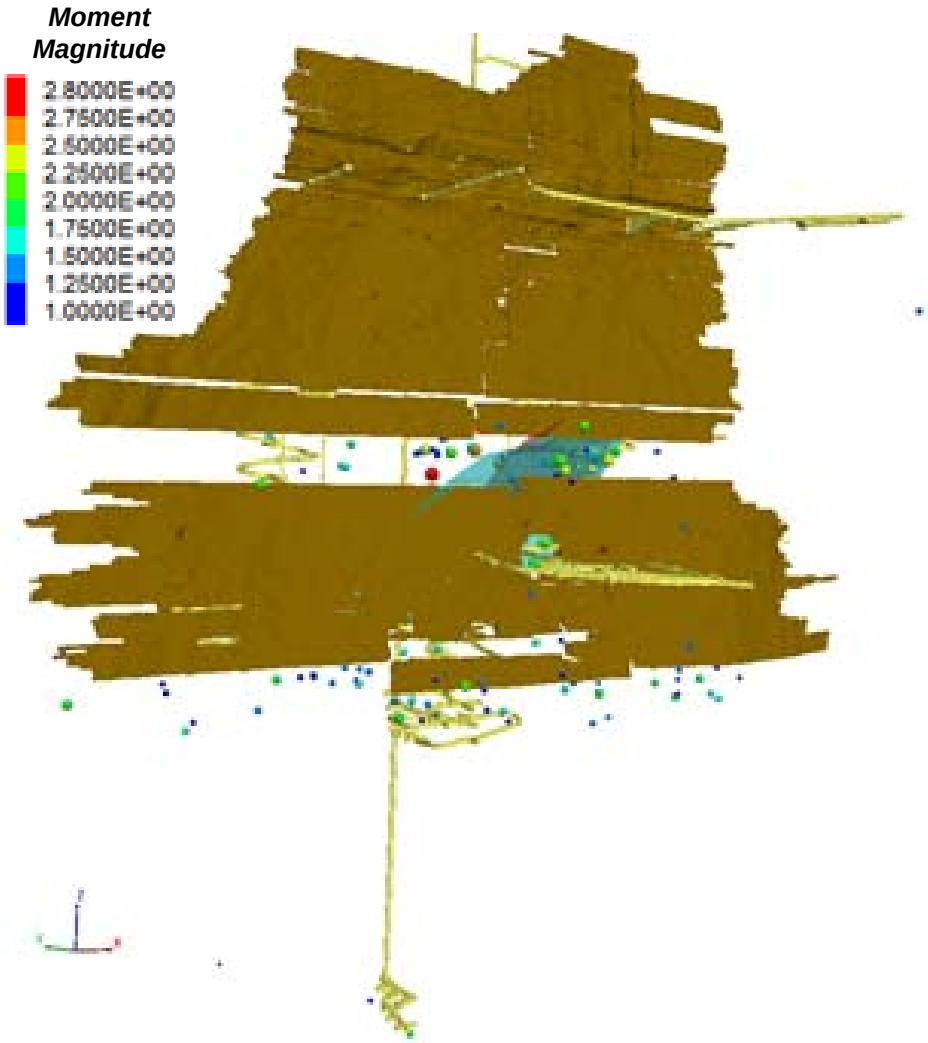
- Strain bursting associated with pillars and longwall front
- Fault slip

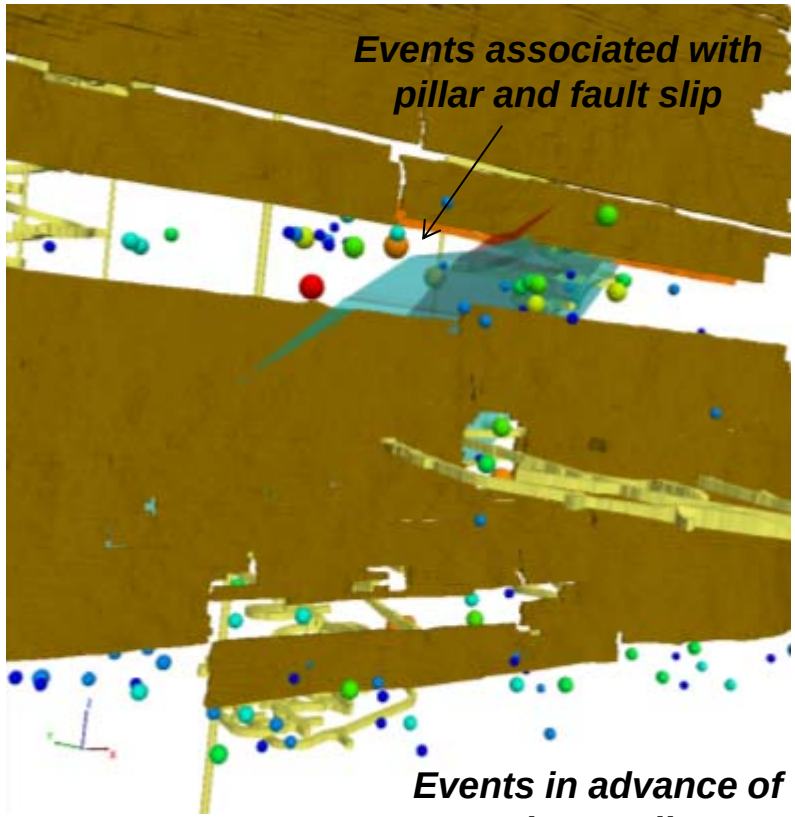
➢ Ground Deformation

- Large deformations due to buckling in thinly-bedded argillites
- Dynamic ground movement

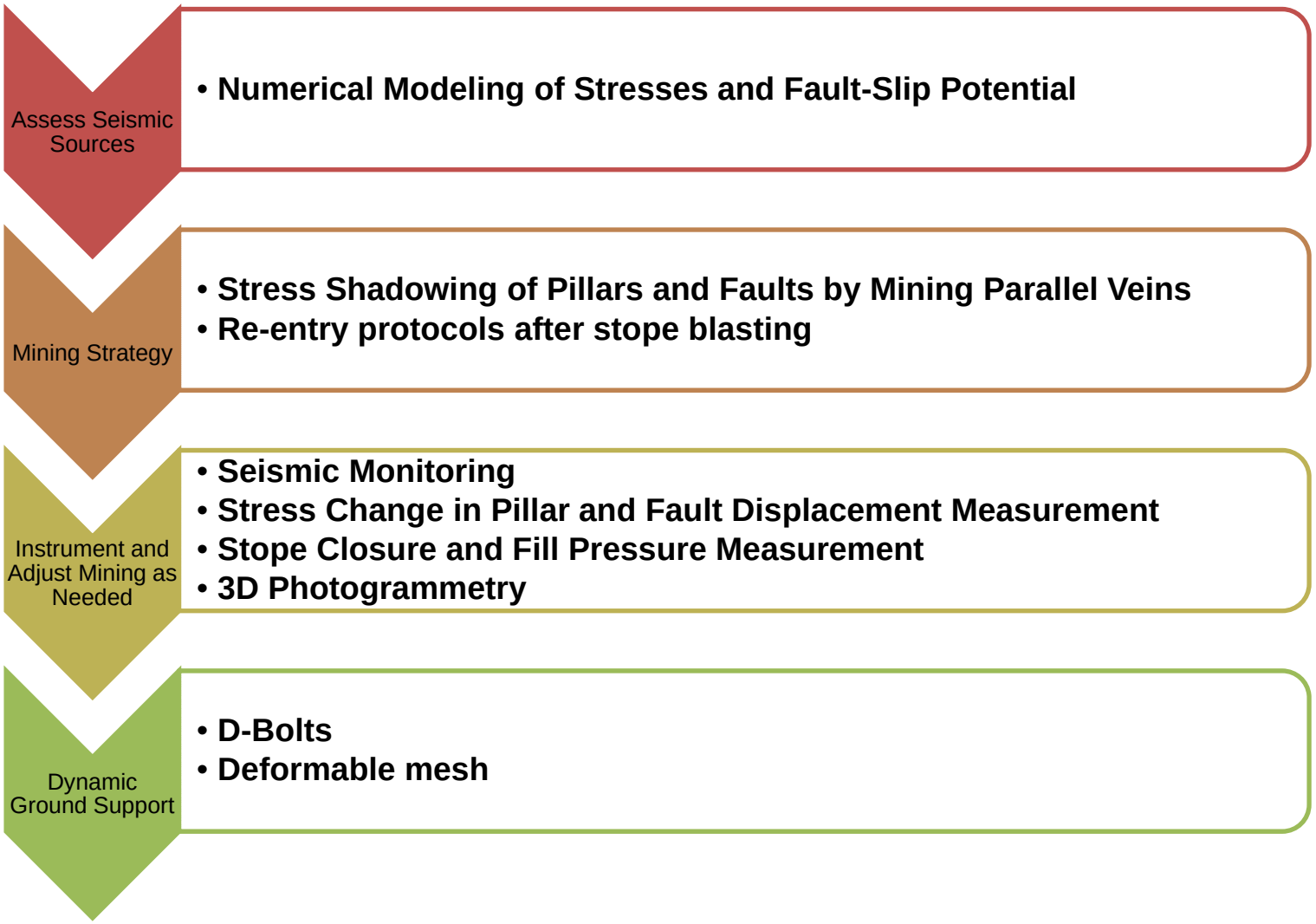


Seismic Events, 2007 to present





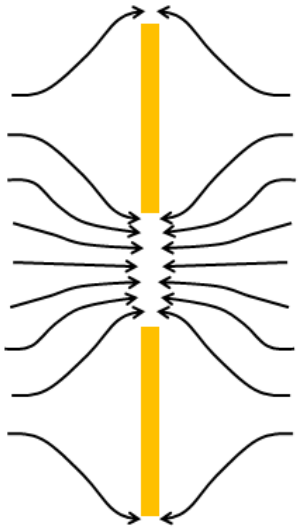
Seismicity Mitigation Strategy



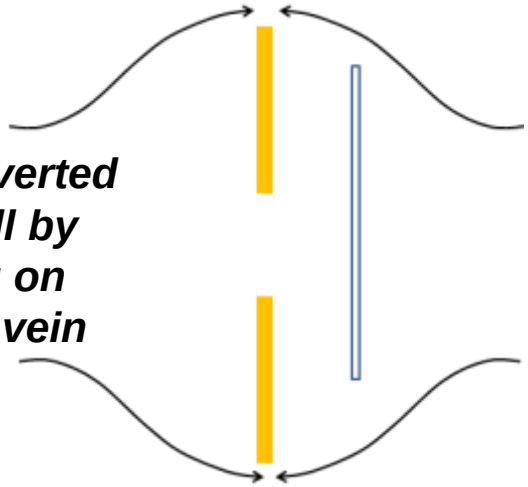
Stress-Shadowing Concept

- Gold Hunter vein "package" consists of multiple, parallel veins
- Advanced mining on one vein will divert stresses from adjacent veins/pillars
- Parallel vein should be far enough from pillar to minimize stress interaction of stope faces

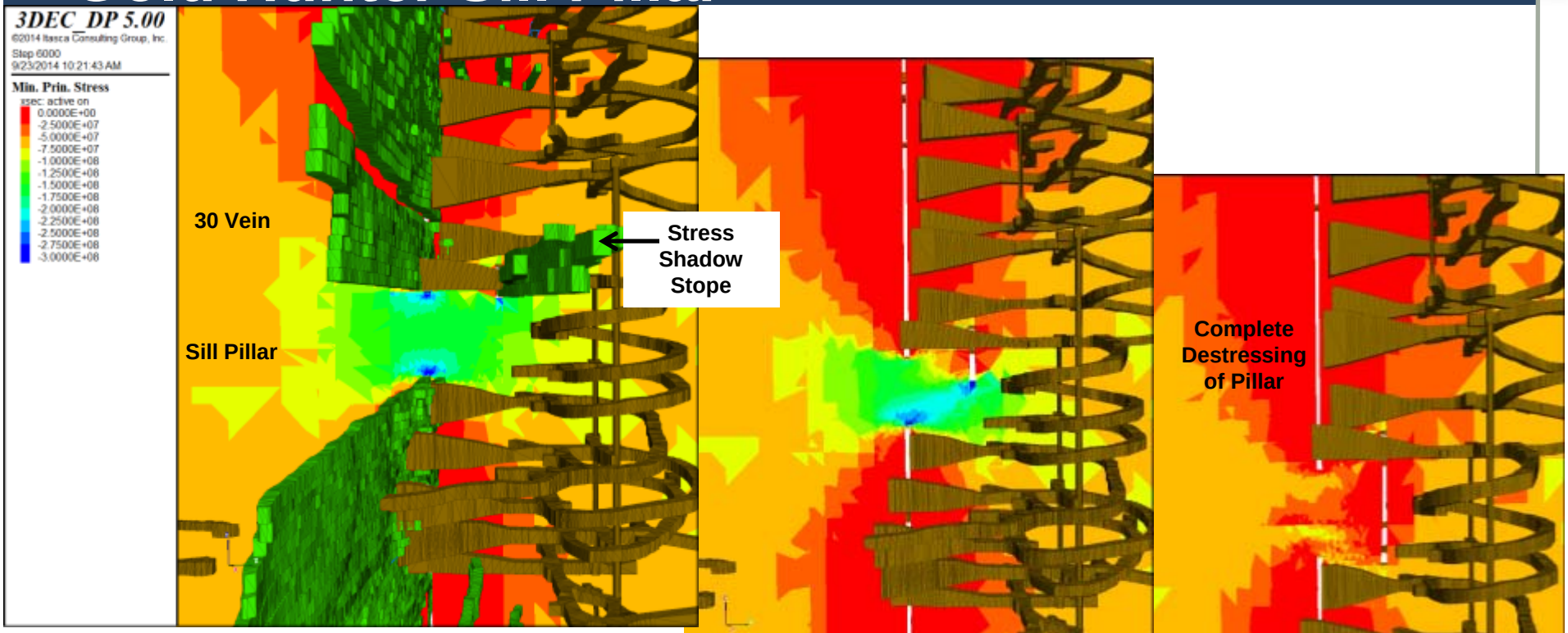
Stress concentration in sill pillar



Stress diverted from sill by mining on parallel vein



Numerical Modeling of Stress Shadowing – Gold Hunter Sill Pillar



Current State – Sill Pillar Below Underhand Stope on 30 Vein

Mining on Shadow Stope by CF Until Interaction of Stopes

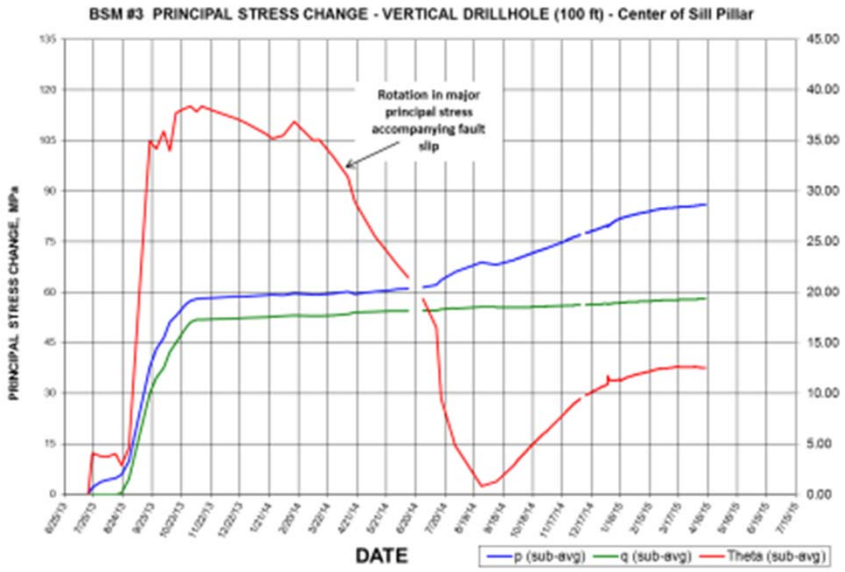
Final Extraction with LH Blast

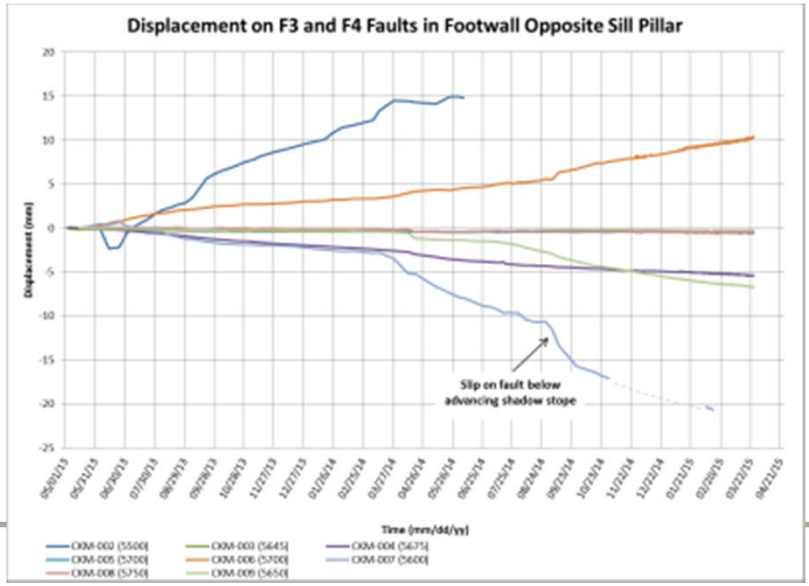
Instrumentation for Monitoring Shadow Stope

Biaxial Stress Change

Observations To Date as the Shadow Stope Advances

- As expected, an increase in stress in pillar as it arches around the shadow stope
- A rotation in the major principal stress to become vein-parallel as slip occurs on faults adjacent to sill pillar
- Increasing normal fault movement (approximately 10-20mm shear) in advance of the shadow stope
- Stope closure of about 75mm per cut, resulting in 2 to 3 MPa paste pressure
- As mining continues, expect to see destressing front developing

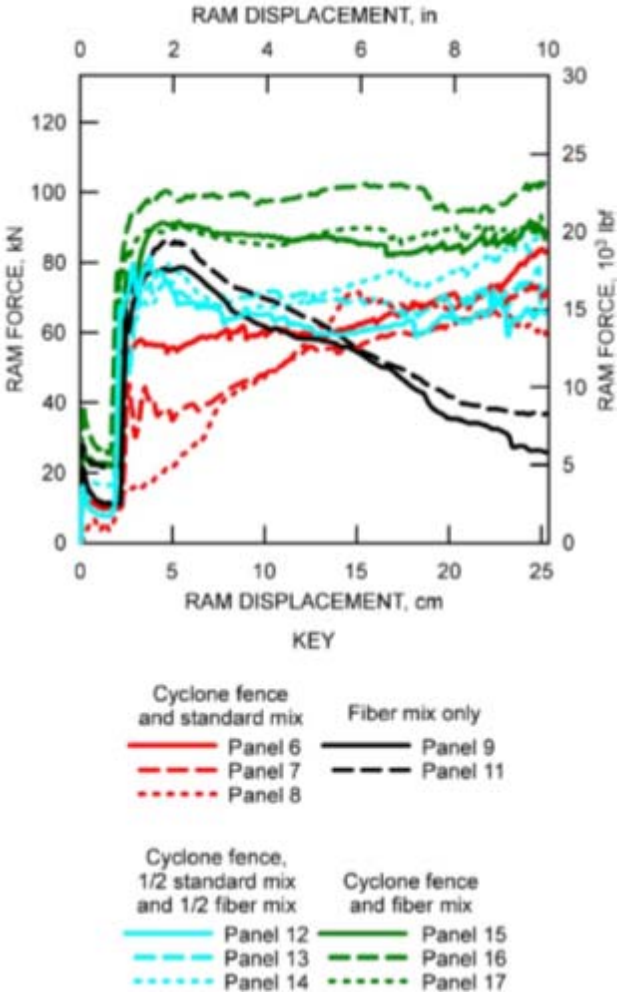


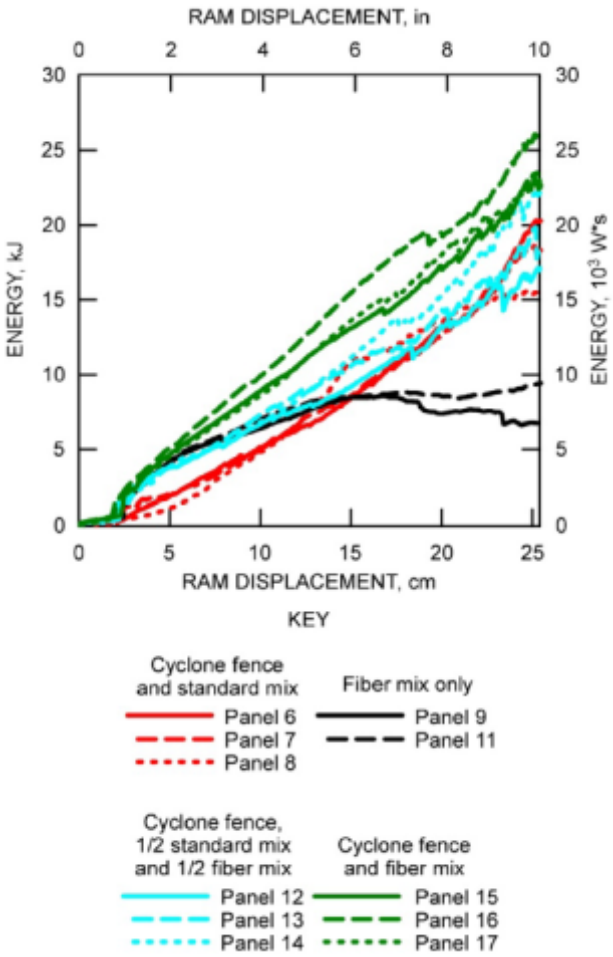


Ground Support Testing

- Current dynamic support method
  - D-Bolt high deformation grouted smooth bars on 4'x4' spacing
  - Chain link (50mm opening)
  - 100mm shotcrete
- Large deformation testing and energy dissipation of support system
  - Large-panel support system quasi-static load testing at NIOSH laboratory, Spokane, Washington
  - Support system shows elastic-plastic response with constant load capacity to over 25cm deformation
  - Testing indicates significant load capacity increase when using fiber in addition to mesh-reinforcement
- Field experience has shown positive results using D-Bolt and chain link support under seismic loading

Results of D-Bolt/Shotcrete/Chain Link Panel Testing





Note: Test results primarily show energy dissipation of the shotcrete/chain link as D-Bolts not failed.

Containment of Stope Sidewall Displaced by Seismic Event

- D-Bolts and chain link
- Approximately 1’-2’ of inward sidewall movement contained by support
- Example of stretched and broken D-Bolt

Summary

- Lucky Friday mine strategy for dealing with ground control issues includes:
  - Proactive stress shadow mining to strategically destress pillars created by multiple mining fronts
  - Use of deformable support elements with high energy dissipation capacity for dynamic and squeezing ground conditions
  - Numerical prediction and rock mass instrumentation to provide feedback for modification of design
- On-going project, results thus far as expected

Questions?

Thank You!