Highwall Stabilization and Ground Control – Portal Design

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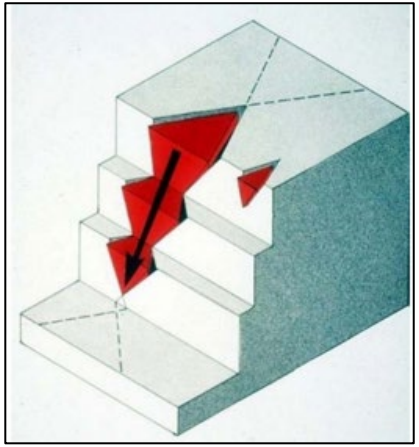
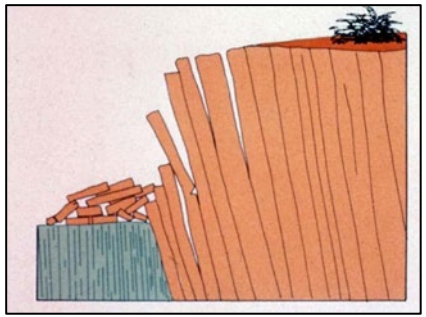
Topics

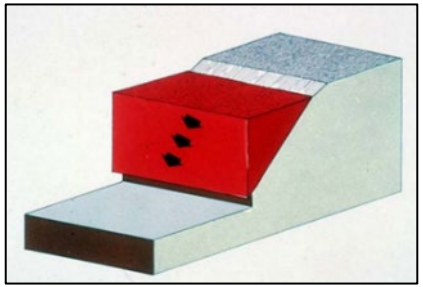
- Highwall Hazards
- Location planning for Final highwall AND Portals
- Data collection and analysis for Design
- Highwall stabilization solutions
- Portal Reinforcement

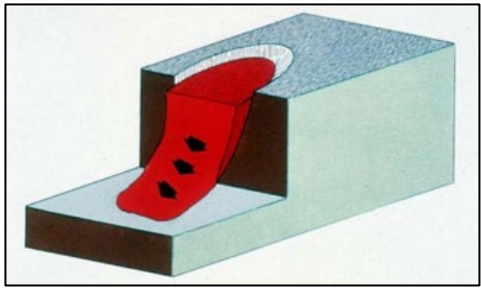
Highwall Hazards

- **Joint sets**
  - Discontinuity intersections can control pillar strength and highwall wedge instability; potential for toppling failure
- **Bedding planes**
  - Planar failure, roof control issues
- **Unconsolidated Material**
  - Circular failure of waste or overburden
- **Mud or Clay seams**
  - Weak bands impact face and pillars
- **Water / Ice**
  - Increased weight to face; freeze-thaw impacts to portals and final highwall; falling ice chunks







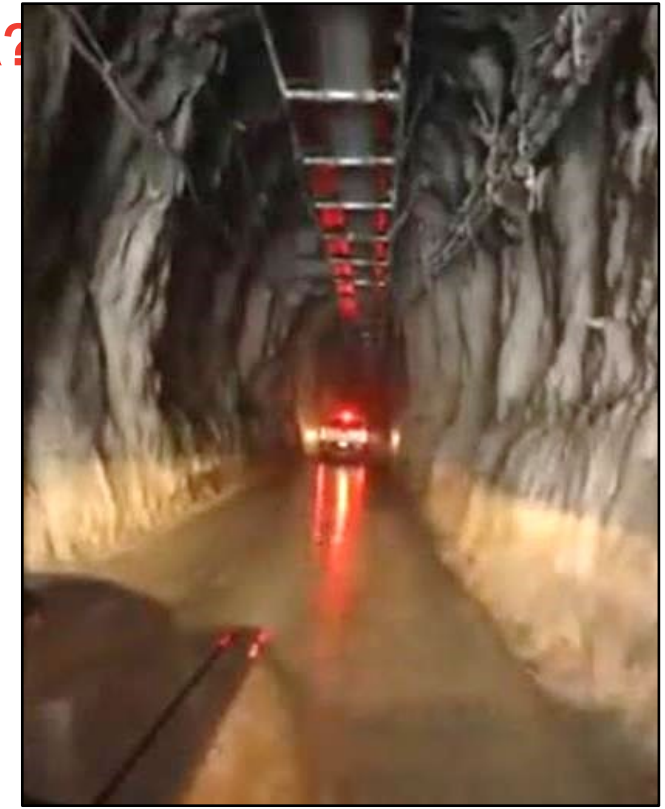


Final Highwall and Portal Location planning

- **111 active underground stone mines** (2023, MSHA)
- **Layouts are highly variable**
  - Fit to site topography, infrastructure, and geology
- **Access**
  - Adit, Decline, Shaft-only

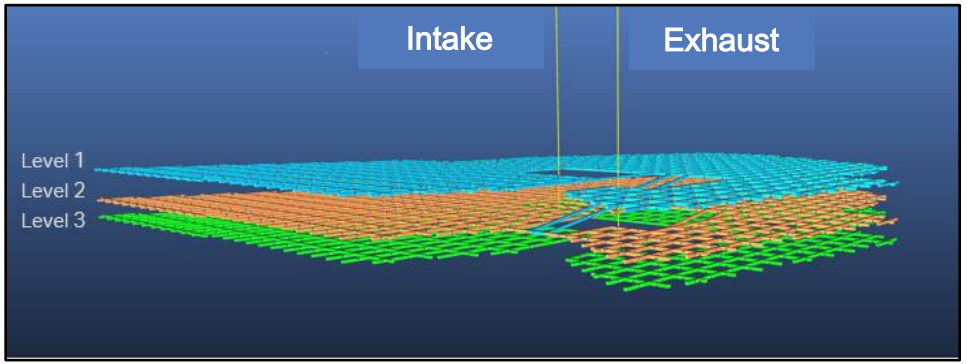
Final Highwall and Portal Location planning

- **mining interval defined by chemistry or strata?**
  - Multi-level mining; heading only; benching
- **What does the geology allow?**
  - Roof and floor selection to minimize ground control costs
  - Pillar sizing and orientation
  - Bench Face Angle
- **Equipment to be used?**
  - Maneuvering room and reach
  - Ease of access and maintenance
- **Is the Underground mine viable/profitable?**
  - Life of the mine, any post-mine use
  - Expected production rate



Final Highwall AND Portal Location planning

- **Planning for A good site and wide benches saves money**
  - Easy to inspect and maintain
  - Easy to work from to install support
  - Avoid higher cost stabilization measures (rockfall fences, face grouting and bolting, additional layback)
- **Save on operating costs**
  - Ventilation simulation to determine appropriate sizing of shafts and entries
  - Water management design

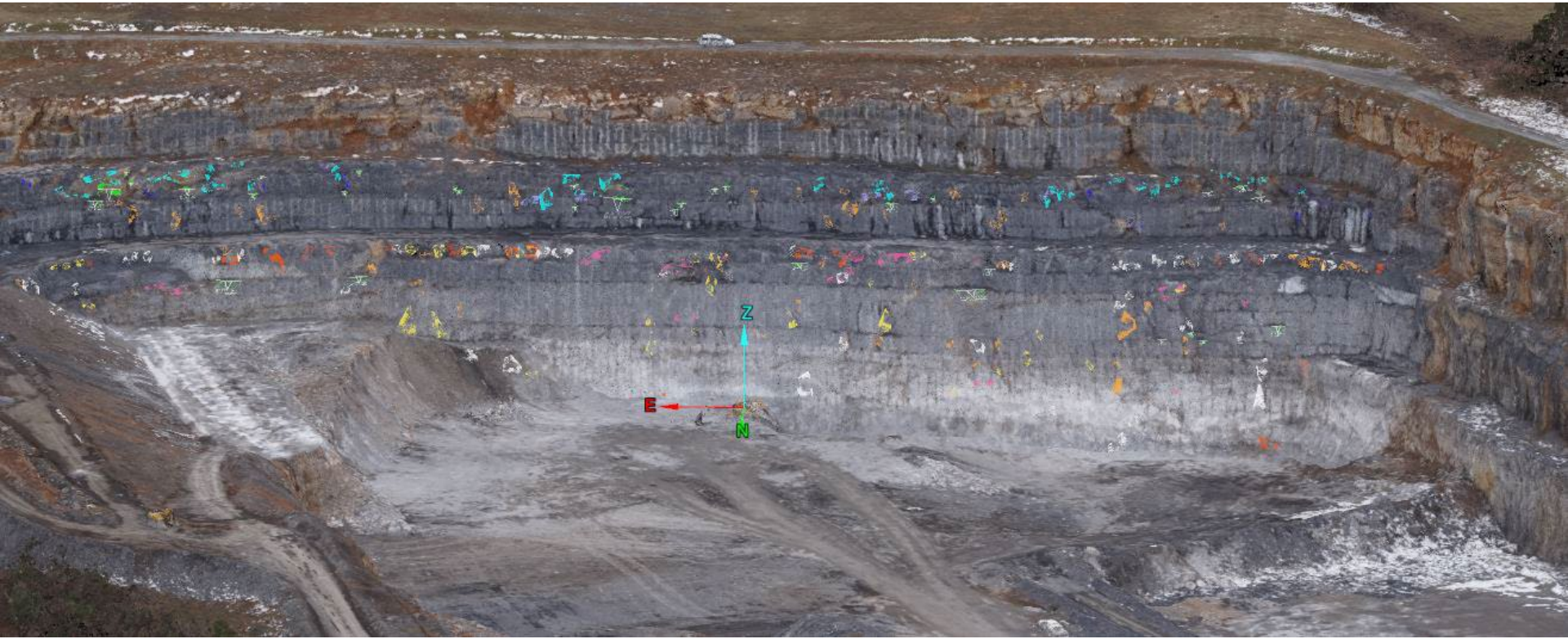


Data Collection and Analysis for Design

- **Data collection**
  - Existing mine infrastructure (utilities, material transport)
  - Geology: corehole drilling to characterize the rock mass
    - Lithology, Rock strength testing, Geotechnical logging, Chemistry / attribute analysis
  - Topography
    - Drone point clouds can be used for joint mapping, 3D modeling
  - Equipment fleet and Production targets
  - Site-specific needs
    - Water, Neighbors, Permit limits, State and MSHA regulations

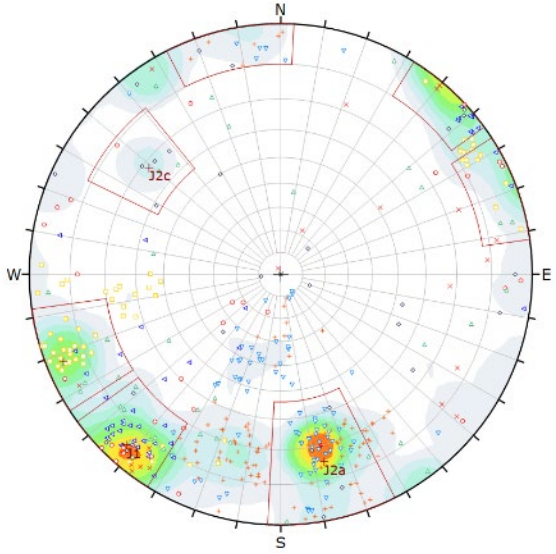
- **This information is also used for Underground mine layout and pillar sizin**

Data Collection and Analysis – Point Cloud Joint Mapping



Data Collection and Analysis for Design

- **Experience**
  - Rules of thumb can be overly conservative / misleading
- **Geologic investigation and 3d Modeling**
- **Rock mass classification**
  - Itasca models
    - FLAC - 2D and 3D geotechnical analysis
    - 3DEC – 2D and 3D jointed rock masses
  - Rocscience Models
    - RS2 – 2D geotechnical analysis
    - SWedge and UnWedge – ground support design of wedge structure
    - DIPS – slope orientation analysis
    - Slope stability and bench design for open pits



Stereonet Plot Example

Underground Layout / Pillar Design

- **rock properties**
  - Discontinuities dipping between 30 and 70 deg have the greatest impact on strength
  - Joint mapping more than just one wall prevents data bias
- **Benching**
  - More vertical height, more risk of continuous discontinuities being exposed

Highwall Stabilization Solutions

› ROCKFALL PROTECTION BARRIERS

- Protection from falling rock or debris
- When space is limited and a runout zone for falling rocks is not feasible

Highwall stabilization solutions

- **Wire mesh drape**
  - Chain link difficult to work with and limited strength
  - Wire mesh rolls with no vertical stretch (Geobrugg, Maccaferri, etc.)
    - Efficient installation
    - Conforms to highwall shape
    - Corrosion protection (galvanized)
    - Can be shotcreted over

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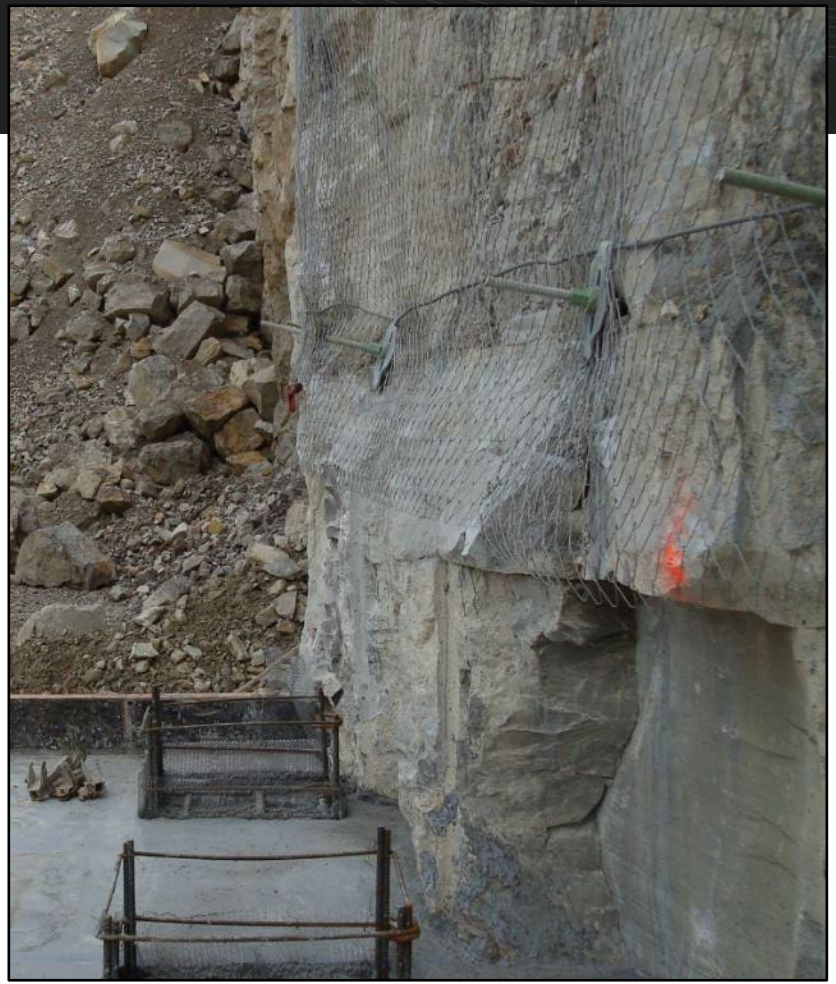

Portal Reinforcement

- Generally, portals require more reinforcement than the rest of the underground mine
- High risk of instability (>80%) if first roof beam less than 10% of span
- Welded wire mesh panels and bolting
  - Galvanized corrosion protection
- Shotcrete
- Brow and rib straps/support
- Portal canopies

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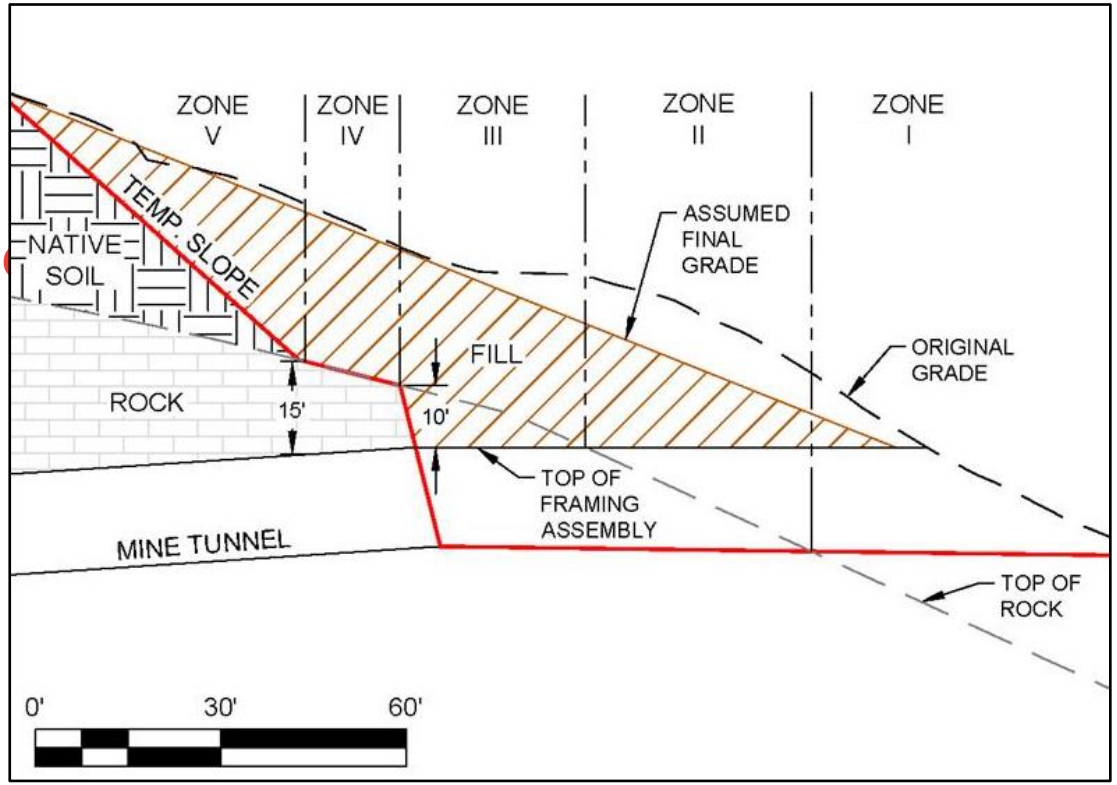
Portal Reinforcement

- **Portal Canopies**
  - Installed at mine openings after initial development
  - Impact resistance for falling ice or rock

Portal Reinforcement

- Soil load calculations
- Conceptual model
- Data-backed analysis to justify appropriate ground control

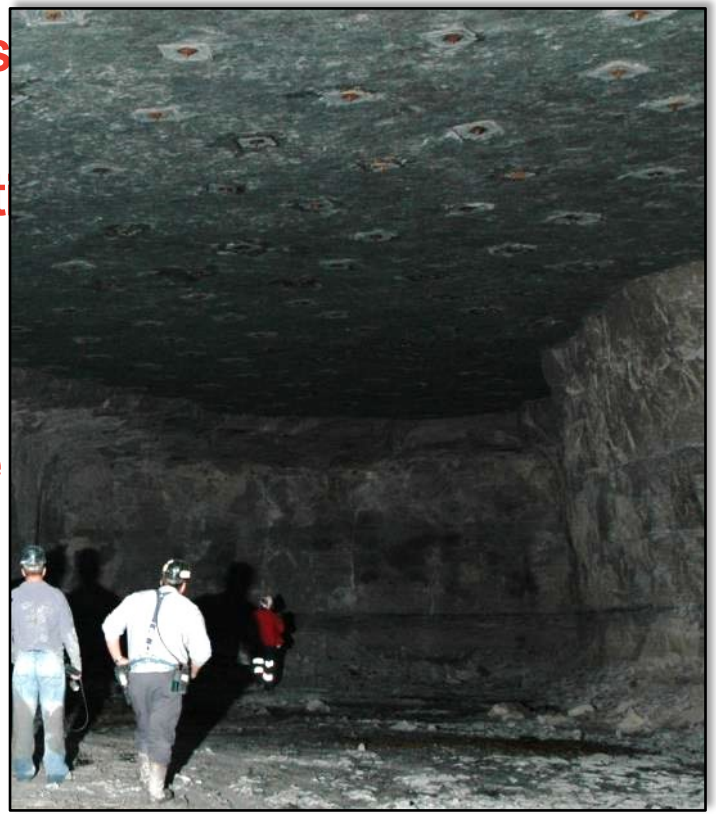


Portal Reinforcement

- Weak ground: more stabilization needed to pr
  collapse or convergence
- Geotech and civil / tunneling examples more a

In Conclusion

- **Planning and involving multiple disciplines**
  - Engineers, Operators, Geologists
- **Data Collection and analysis useful to just ground control needs**
  - Problem areas can be identified in advance
  - Planning leads to Capital &Operating cost savings
- **Support methodology must be compatible geologic conditions**
  - Monitor and verify support
- **Numerous support options are available**
  - Not all are cost effective



Questions?

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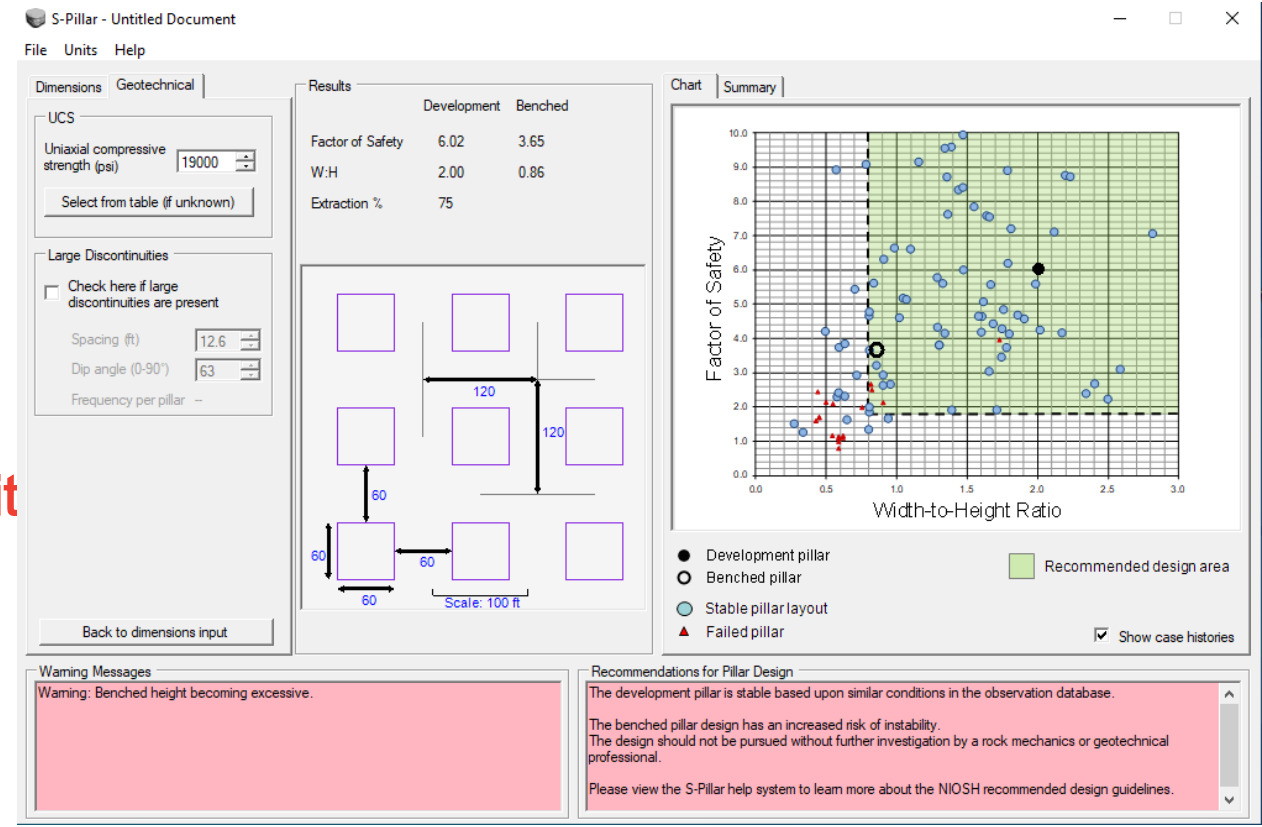
Appendix

Underground Layout / Pillar Design

- **S-Pillar Software (NIOSH)**
  - Roof beam and horizontal stress issues
- **Understand rock properties:**
  - Rock strength
  - Discontinuities
- **Suggested Design Crit**
  - Width / Height ratio > 0.8
  - Calculated Factor of Safety > 1.8



Underground Layout / Pillar Design

- SPillar Software (NIOSH)
- Identified Main stability issues:
  - Stability of bedded roof beams
  - High horizontal stress
- Limitations
  - Flat lying stone deposits in Eastern and Midwest US
  - Similar mining dimensions
  - Good quality rock mass (RMR > 60)
  - Weak clay bands should not be present