Stone Mine Pillar Stability and Design

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Outline

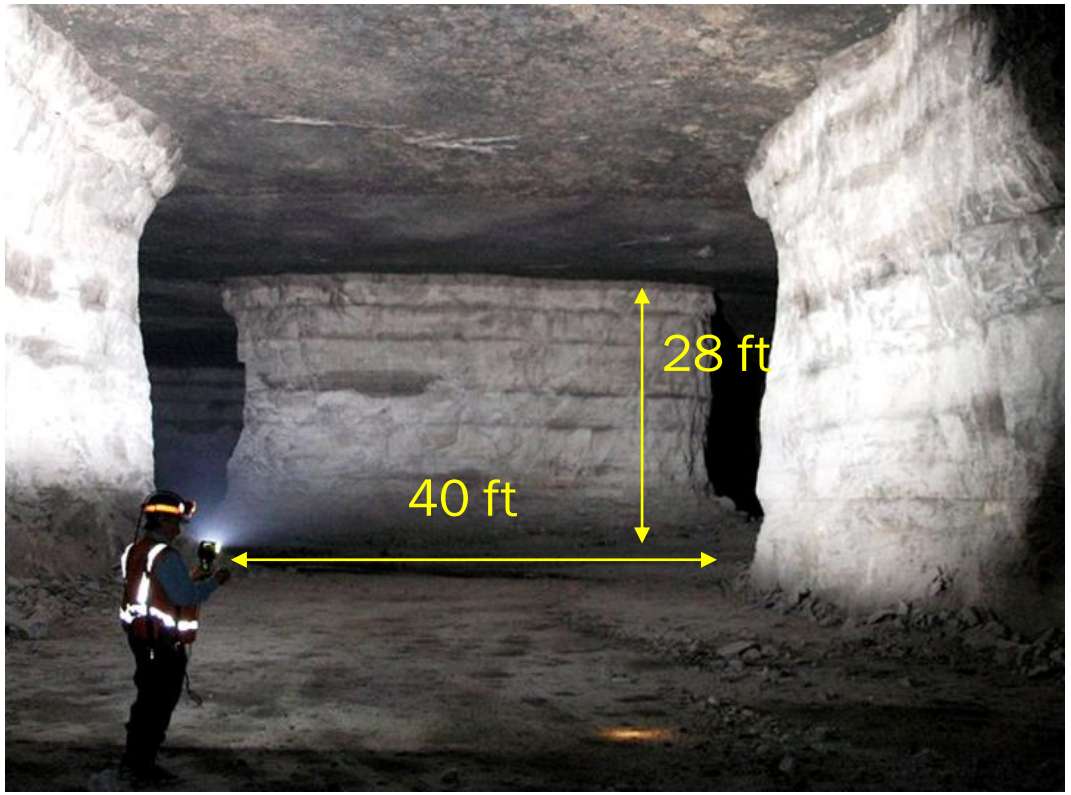
1. Pillars and pillar failure in stone mines

2. The S-Pillar program to design and assess pillar stability

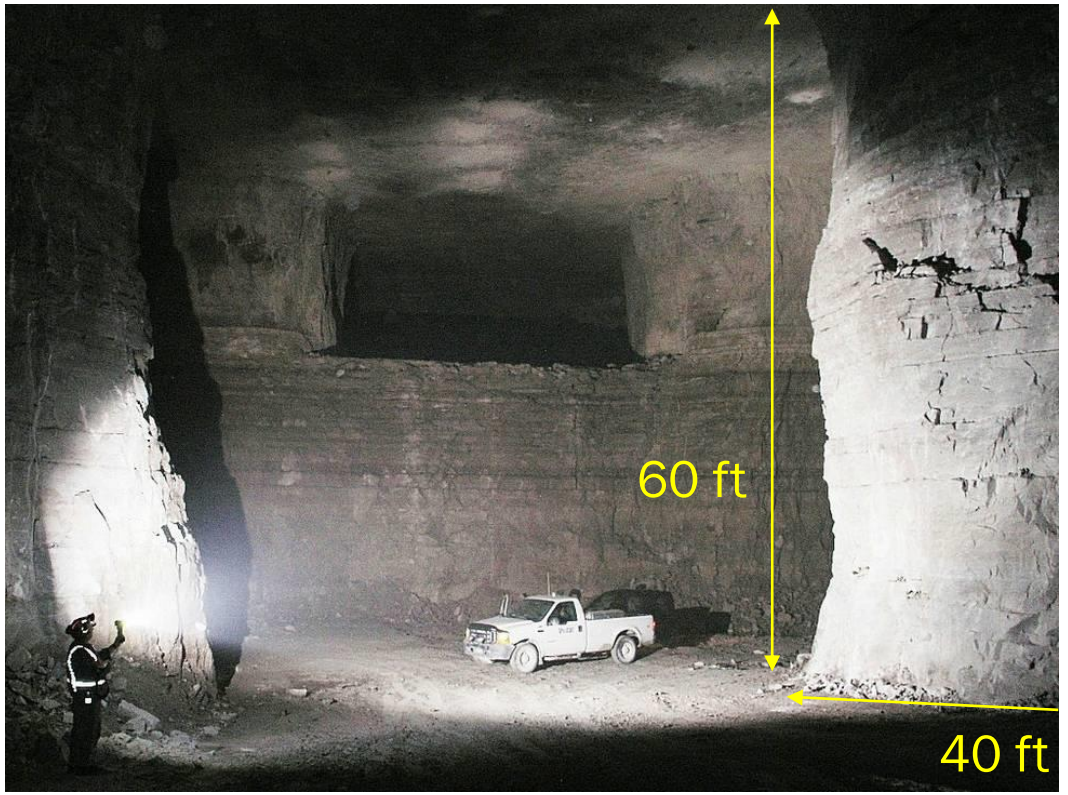
1. Pillars and pillar failure in stone mines
   - A look at stone mine pillars
   - Signs of potential overloading
   - Geologic factors that weaken pillars

Bench mining in stone mines produces tall narrow pillars

First mining 28 ft high



Floor benching to 60 ft

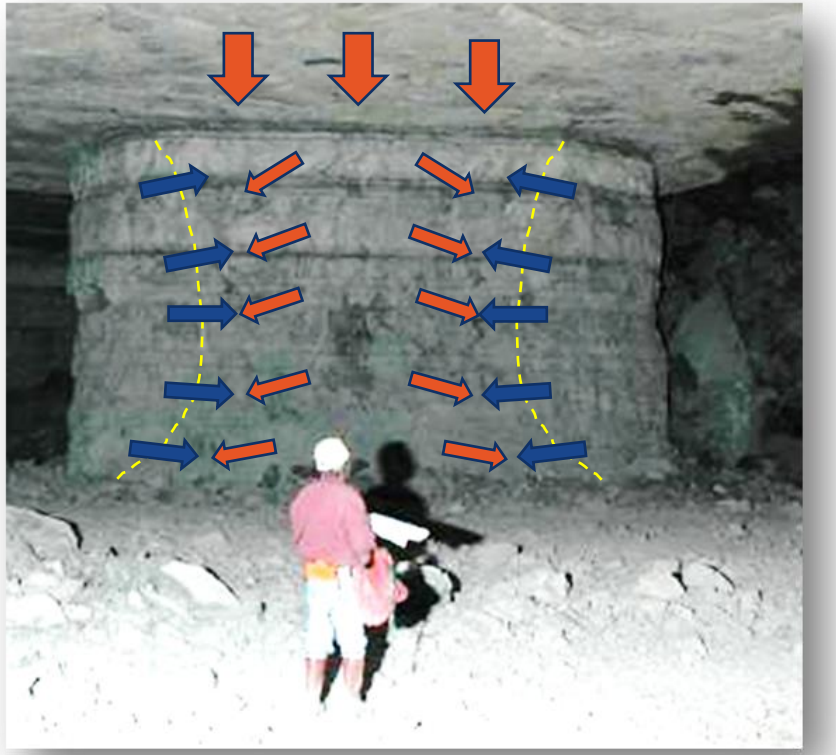


During benching pillar height is increased but width remains the same

Tall narrow pillars:

1) Weaker because lack of confined core

Too tall to develop confined core

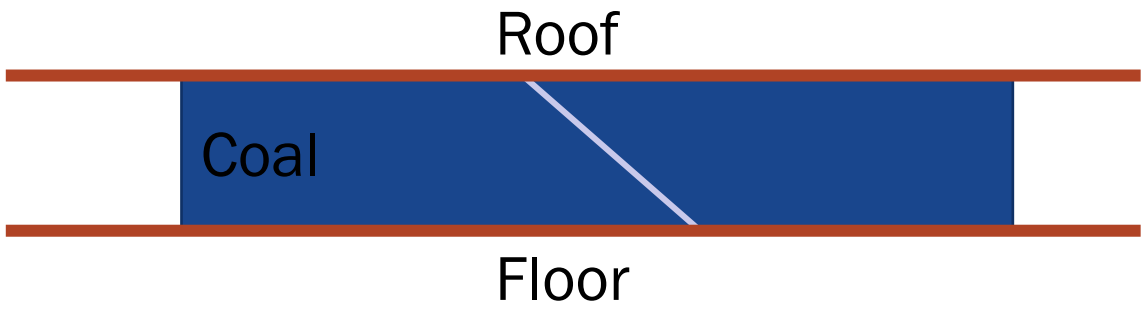


Outer material resists and strengthens inner core

Tall narrow pillars:

2) High impact of slips and joints

Slip has major impact on pillar strength



Slip has little impact on pillar strength

Tall narrow pillars:

3) Can fail suddenly with air blast as roof collapses

Air blasts associated with three recent pillar collapse events in USA

Edge of collapsed area near portal – mine in PA

1. Pillars and pillar failure in stone mines
   - A look at stone mine pillars
   - Signs of potential pillar overloading
   - Geologic factors that weaken pillars

Signs of potential pillar overloading

Rib slabbing and spalling continues long after initial mining

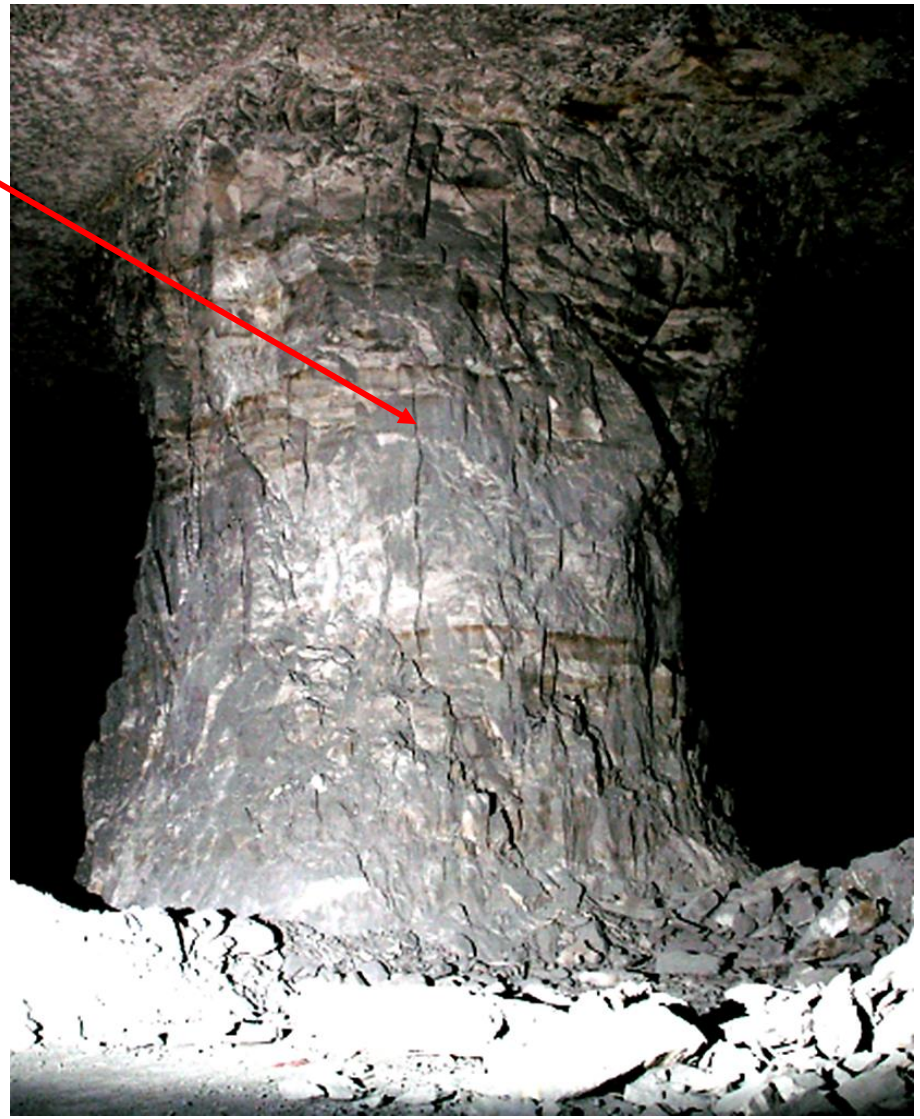
Signs of potential pillar overloading

Overloaded pillar is “hour-glassing”

Signs of potential pillar overloading

Open fractures develop

Spalling of fractured materials results in rounded shape



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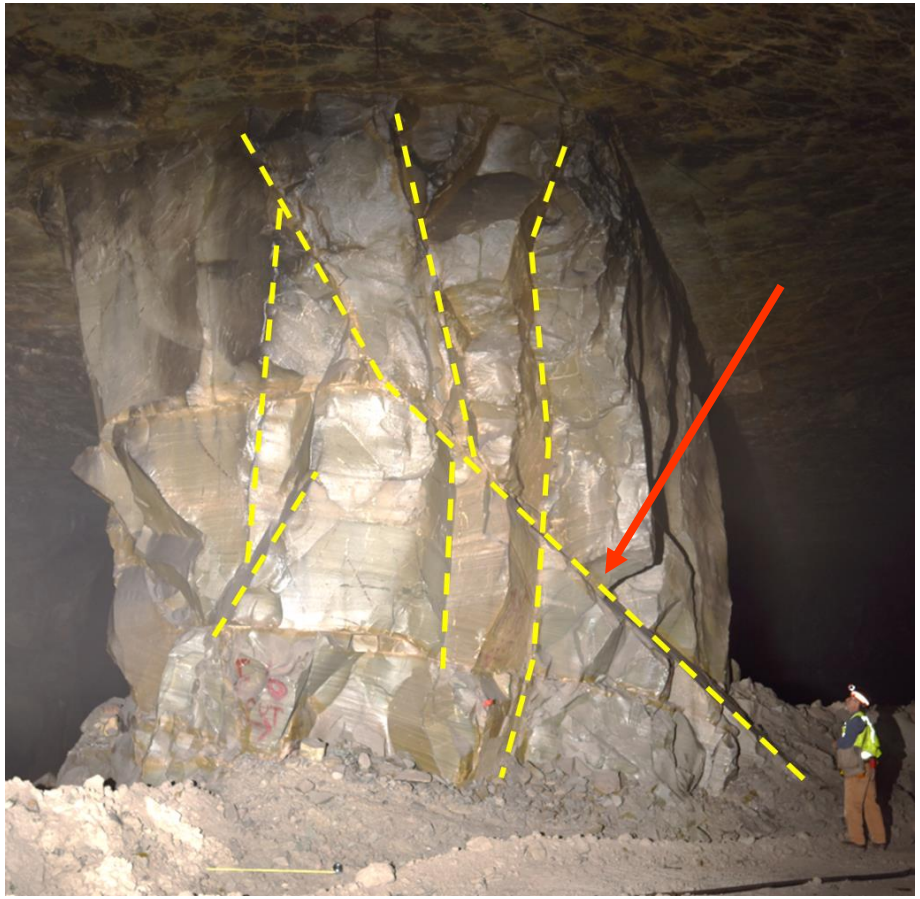
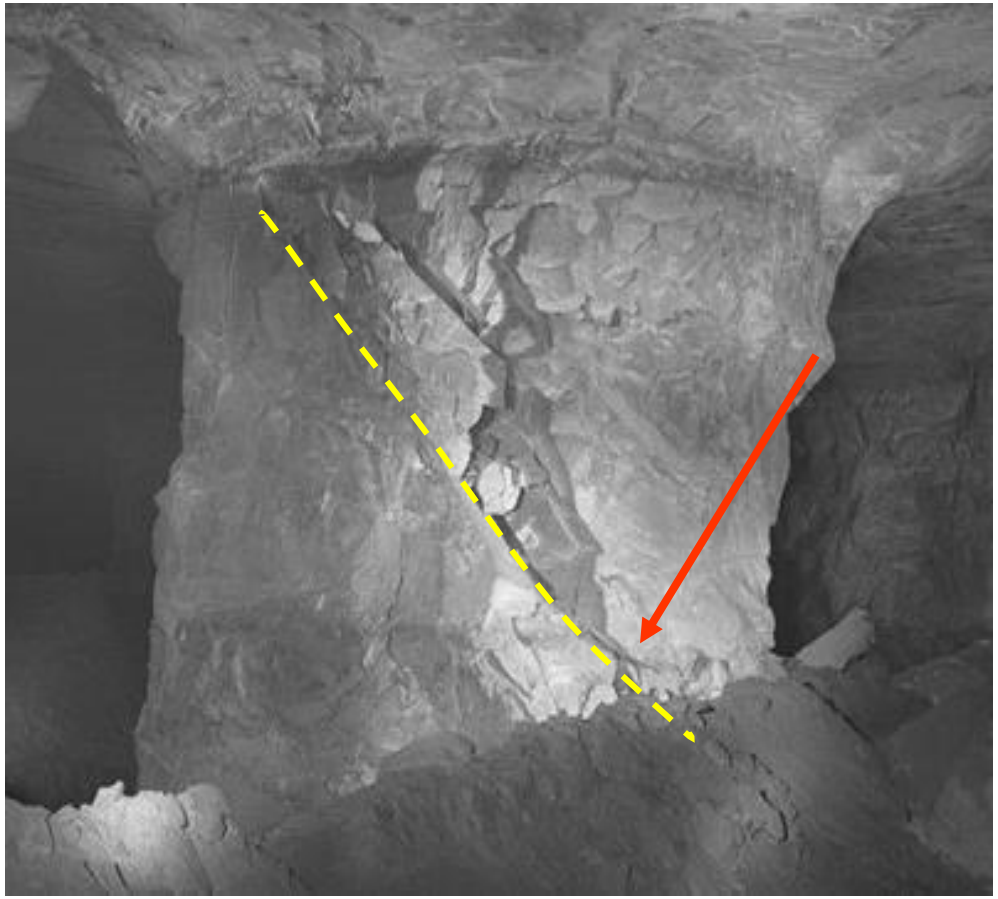
Geologic factors that weaken pillars

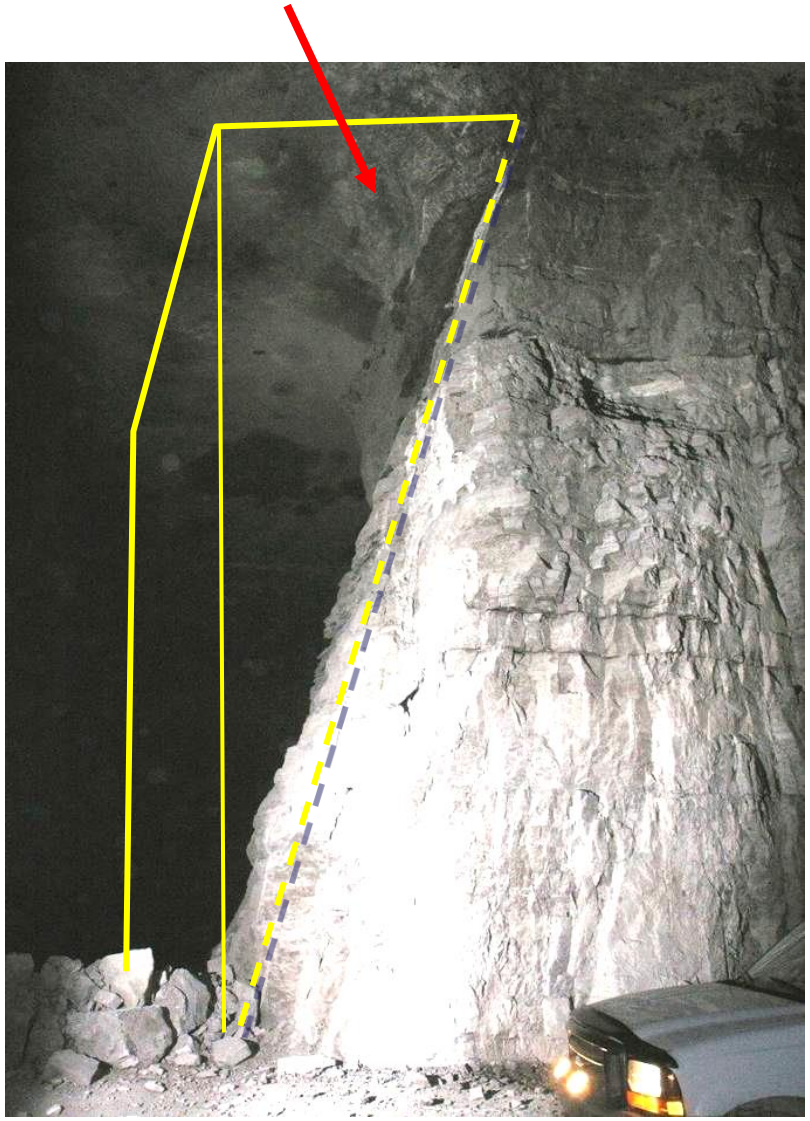
Through-going angular joints provide sliding surface





Geologic factors that weaken pillars

Angular joint causes rib collapse and significant reduction in pillar width

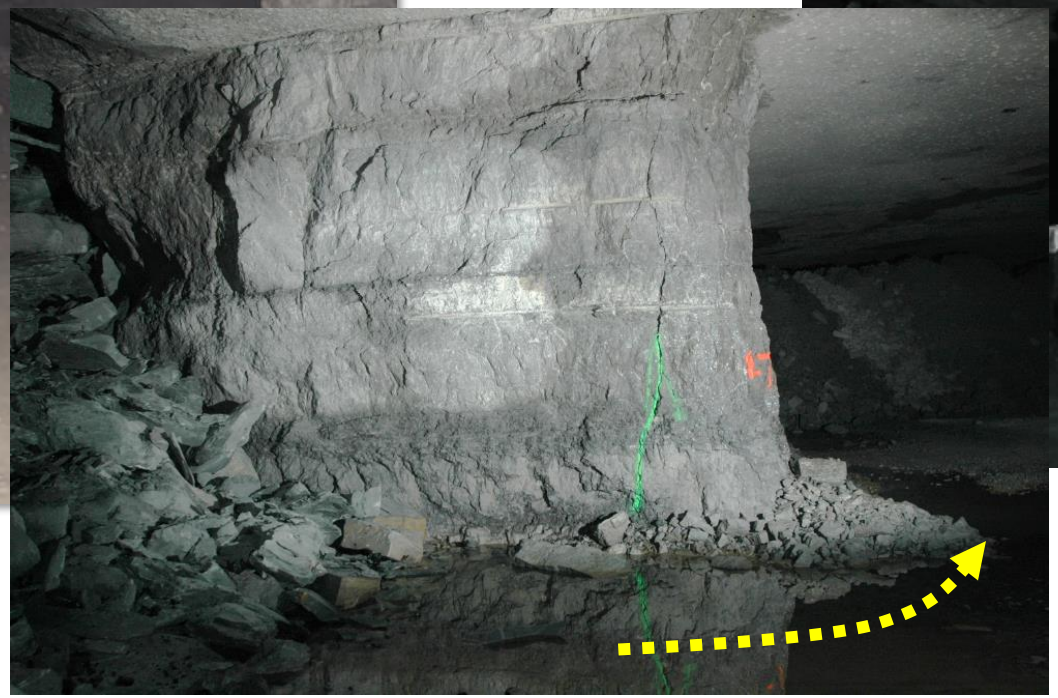


Geologic factors that weaken pillars

Thin soft/clayey weak bands extrude and result in progressive slabbing of pillar ribs

Geologic factors that weaken pillars

1) Soft floor weakened by flooding – pillar punching, and extrusion produces open tension cracks in pillar



Geologic factors that weaken pillars

2) Pillars sagging into soft floor – roof breaks-up, caving to surface

Summary

1) **Limestone mine pillars are narrow and tall:**
   Increased height after benching weakens pillars, sensitive to joints & slips, potential violent failure

2) **Signs of pillar overloading are:**
   Continued rib spalling, hourglass, rounded shape

3) **Geologic factors that weaken pillars:**
   Large angled joints, soft clayey bands, weak floor with moisture

2. The S-Pillar program to assess or design pillars

- S-Pillar program what does it do?
- S-Pillar Inputs and results
- Safety factor and design limits
- Design example
- When is S-Pillar applicable?

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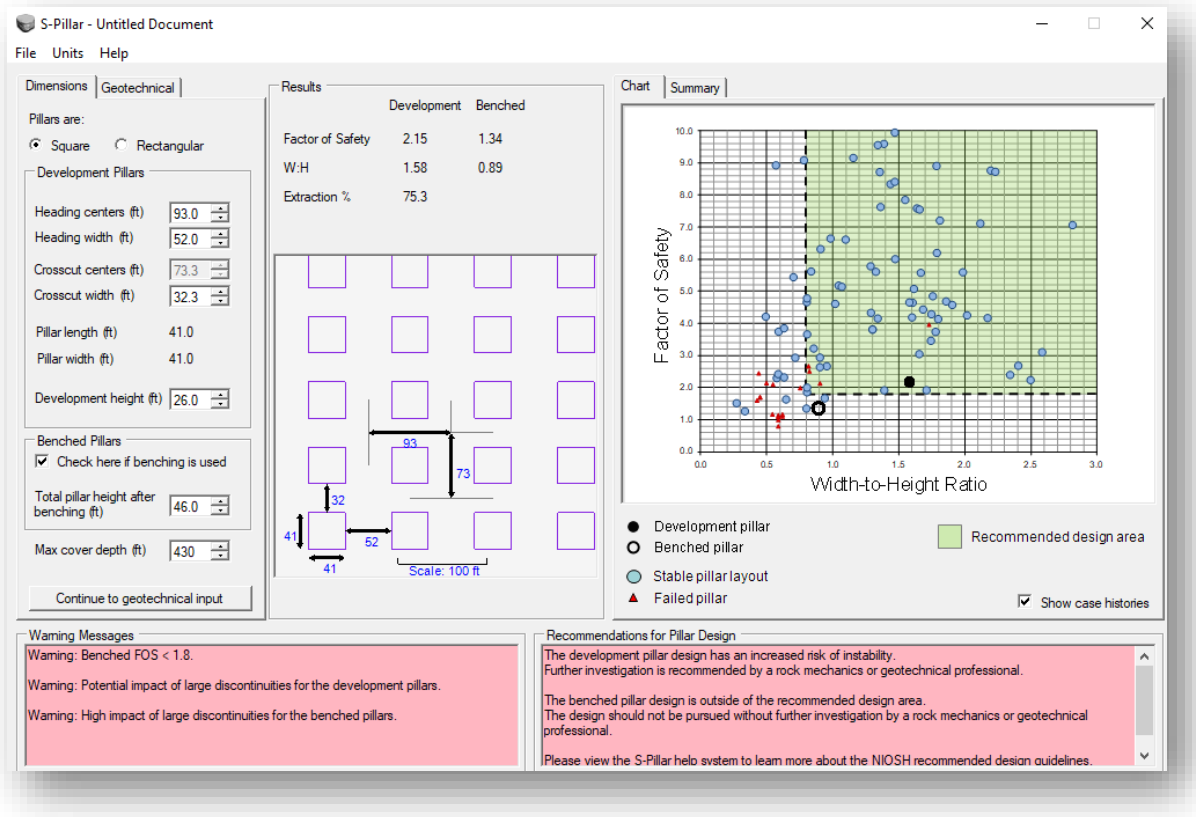
The S-Pillar program application

- Calculates average loading, strength and safety factor of pillars in stone mines
- Used to assess stability of existing or planned stone mine pillars



Developed by NIOSH – free download:

https://www.cdc.gov/niosh/mining/works/coversheet1817.html

2. The S-Pillar program to design and evaluate stone pillars
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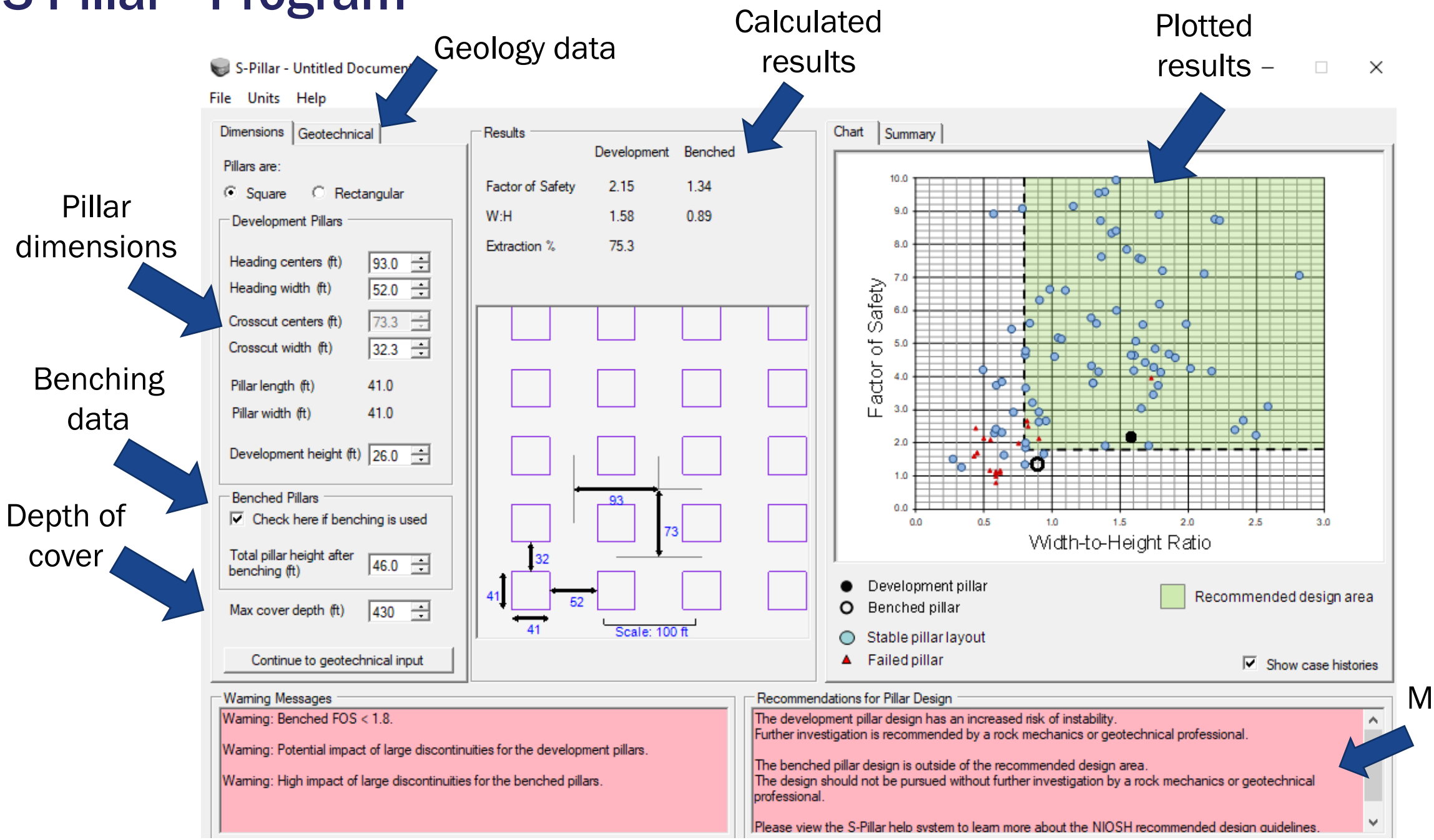
S-Pillar –Program



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Pillar strength, load and safety factor calculation

Strength

- Pillar strength calculated from rock strength, W:H ratio, presence of large slips/joints in pillars

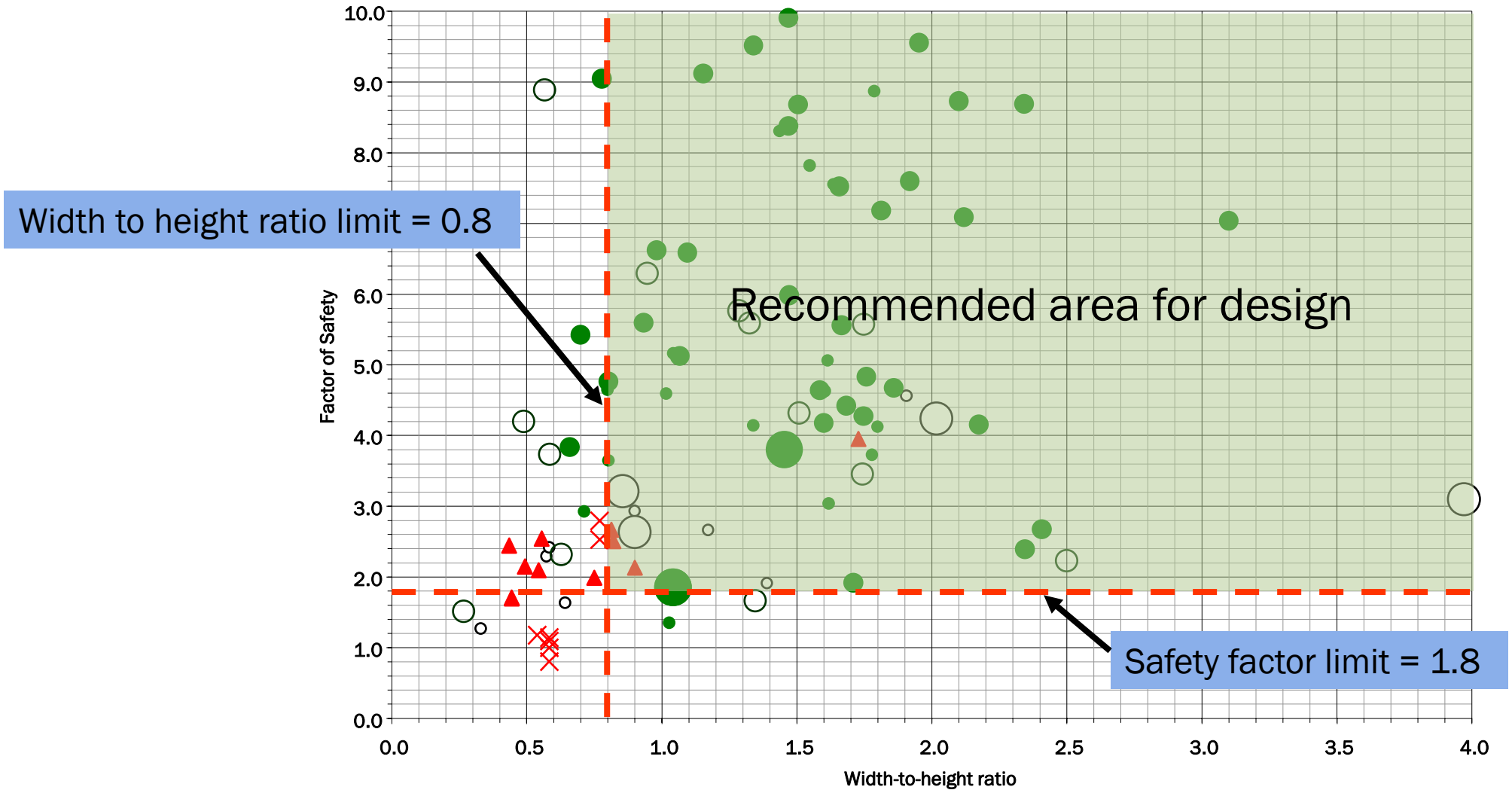
Loading

- Pillars carry full overburden weight to surface: tributary load

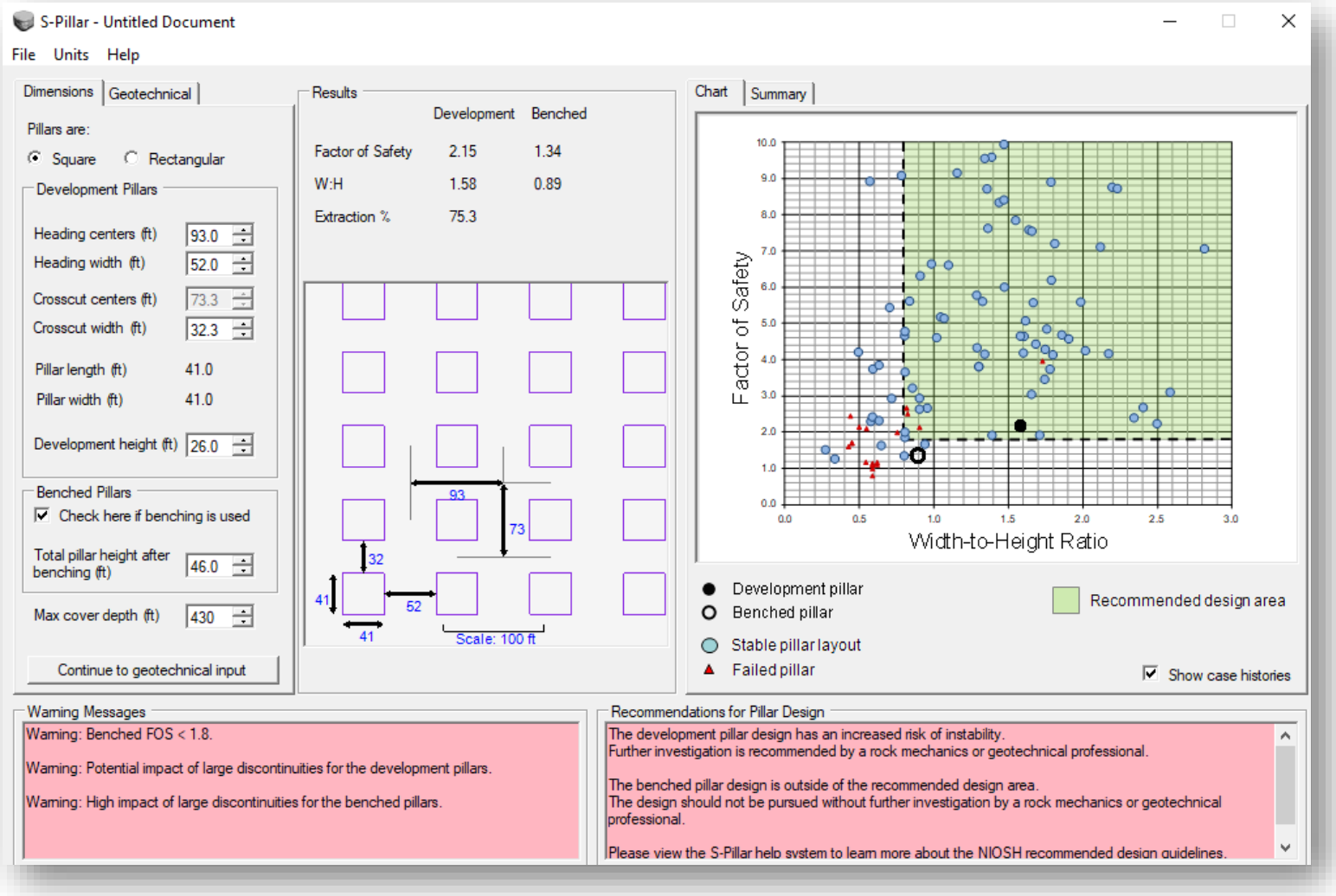
Safety Factor

- SF = $\frac{Strength}{Tributary\ Load}$
- If strength is twice the tributary load: SF = 2.0

Safety factor and design limits

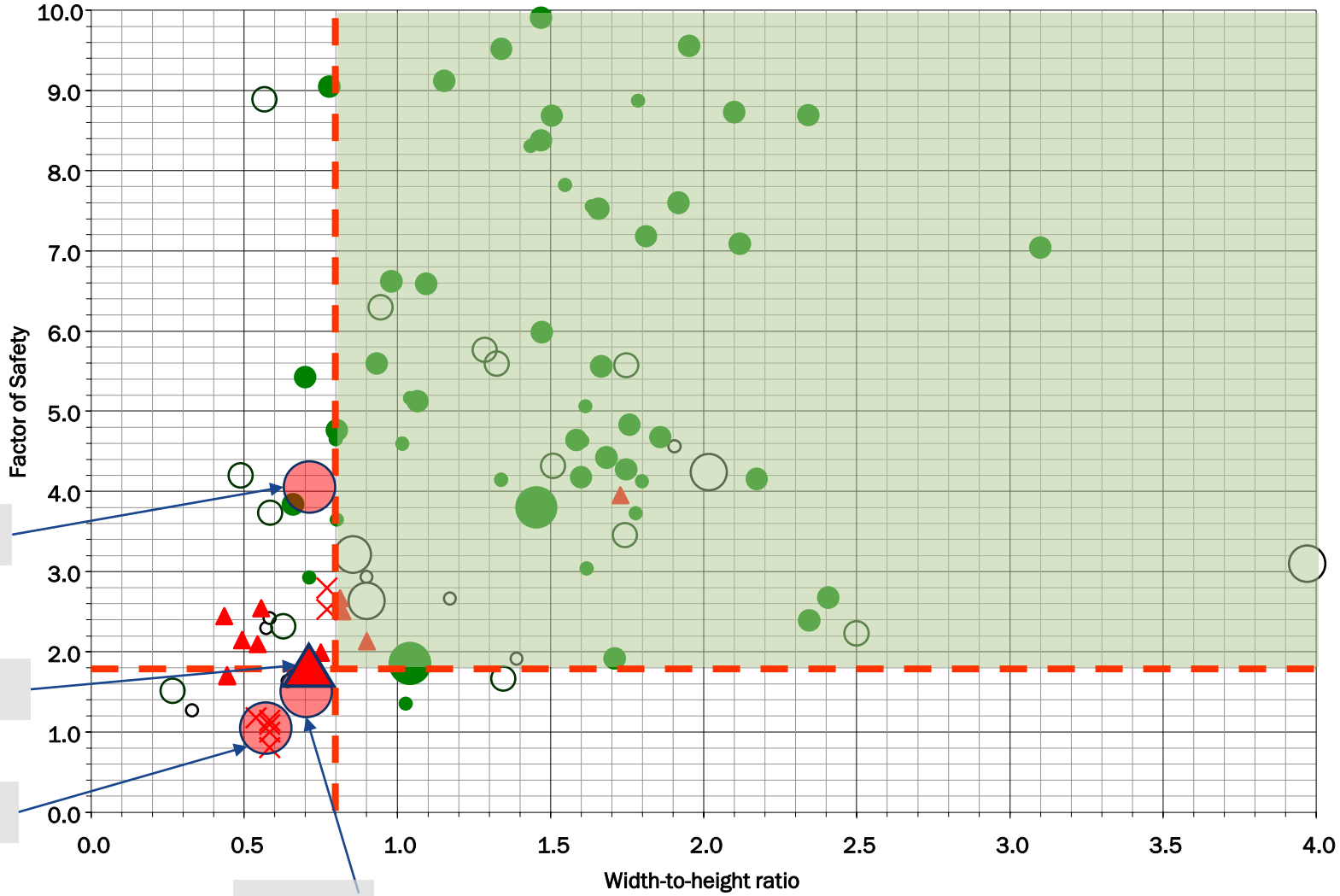


S-Pillar run through and help system



Safety factor and design limits

Recent collapsed cases - based on provisional information on pillar as-mined dimensions and geology



Mine A – average pillars

Mine A undersized pillars

Mine B

Mine C

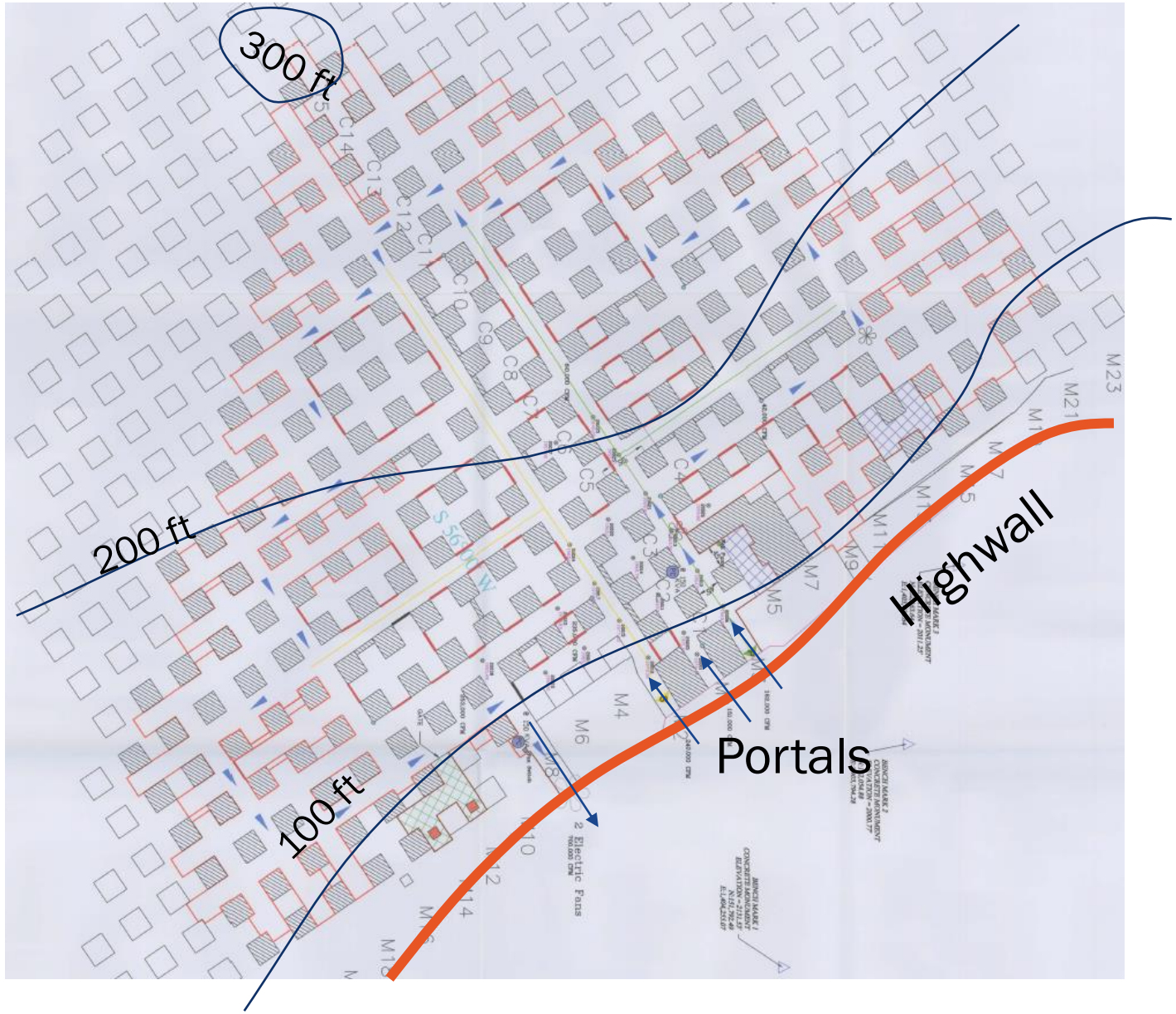
2. The S-Pillar program to assess or design pillars
   - Pillar strength, load, and safety factor
   - S-Pillar Layout and Inputs
   - Safety factor and design limits
   - Design example
   - When is S-Pillar applicable?

Hypothetical mine – planning to mine and bench under 300 ft cover

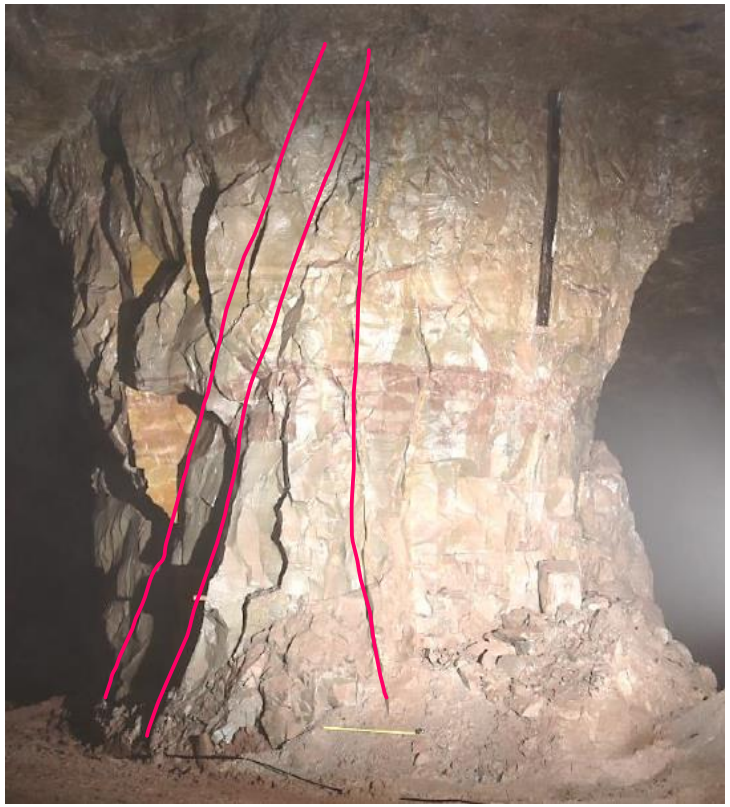
Heading centers: 80 x 80 ft
Entry widths: 40 ft
Development height: 25 ft
Bench 1 floor-cut; 15 ft
Bench 2 floor-cut: 15 ft

Rock formation: Vanport

No strength or other geologic data



Observation of existing pillars



Average dip: ?

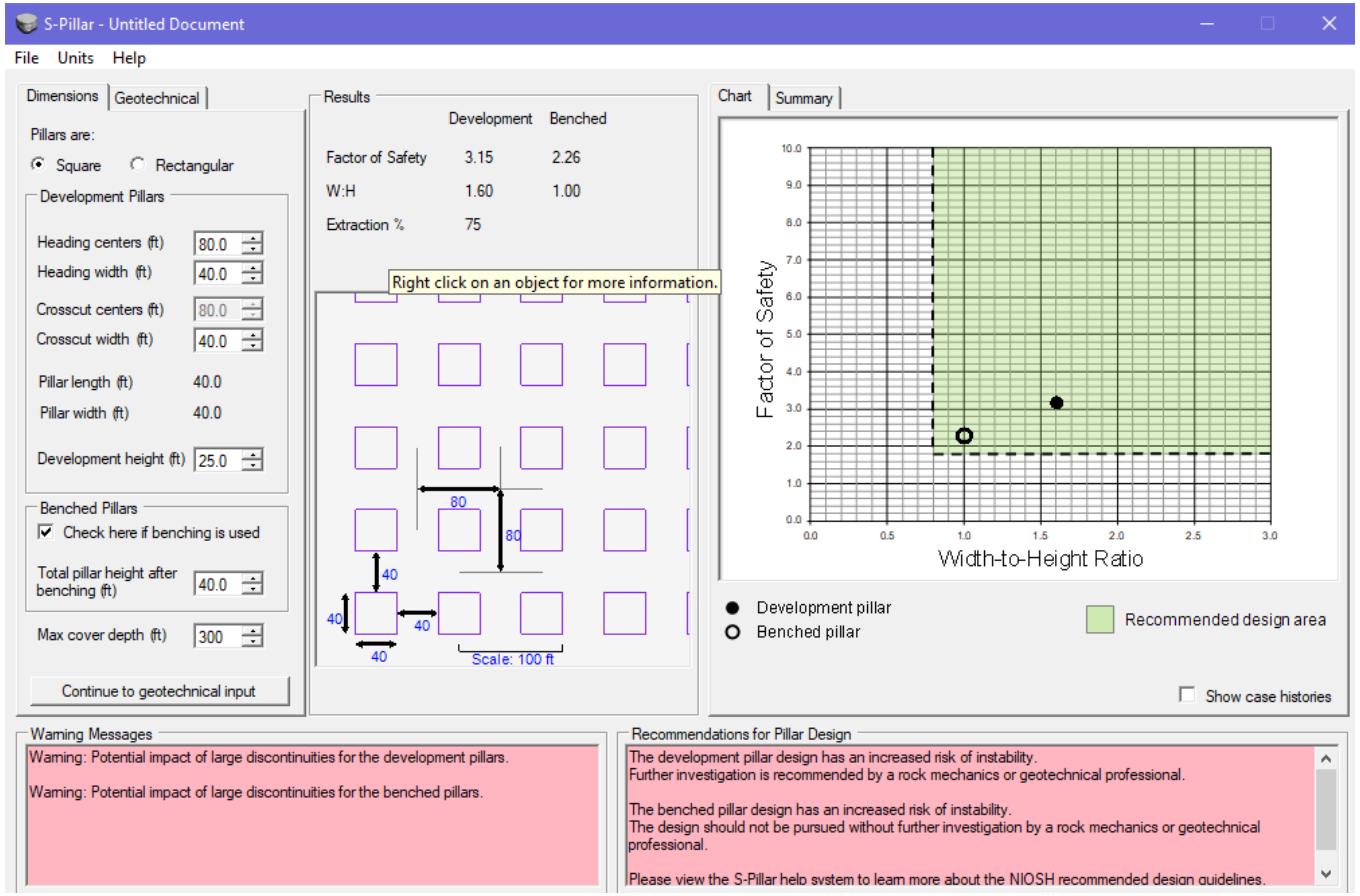
Average frequency per pillar: ?

S-Pillar Analysis:

Heading centers: 80 x 80 ft
Heading widths: 40 ft
Development height: 25 ft
Bench 1 floor cut; 15 ft
Bench 2 floor cut: 15 ft
Benching total heights:
1: 40 ft
2: 55 ft

Depth of cover: 300 ft

Rock formation: Vanport
Rock strength:
Large discontinuities:
Dip 45-75 deg Spacing: 2 to 4 per pillar



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When is S-Pillar applicable?

- Eastern/Midwestern US limestone mines
- Pillars are near horizontal (< 5° dip)
- Single level mining
- Strong limestone strata (6,000 psi)
- Weak clayey bands not be present in pillars
- Strong floor and roof, no punching

Summary

1) S-Pillar can be used to assess stability conditions of existing pillar layouts and to design new layouts
2) Careful observation needed to identify presence and spacing of large joints/slips/faults that can compromise pillar strength
3) Thin weak bands in pillars and soft floor not accounted for in S-Pillar but can have detrimental impact on pillar strength

This presentation presents only the highlights of stone pillar stability and design using S-Pillar.
For full information regarding this topic please review the help-system in S-Pillar and visit:
https://www.cdc.gov/niosh/mining/works/coversheet1817.html

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