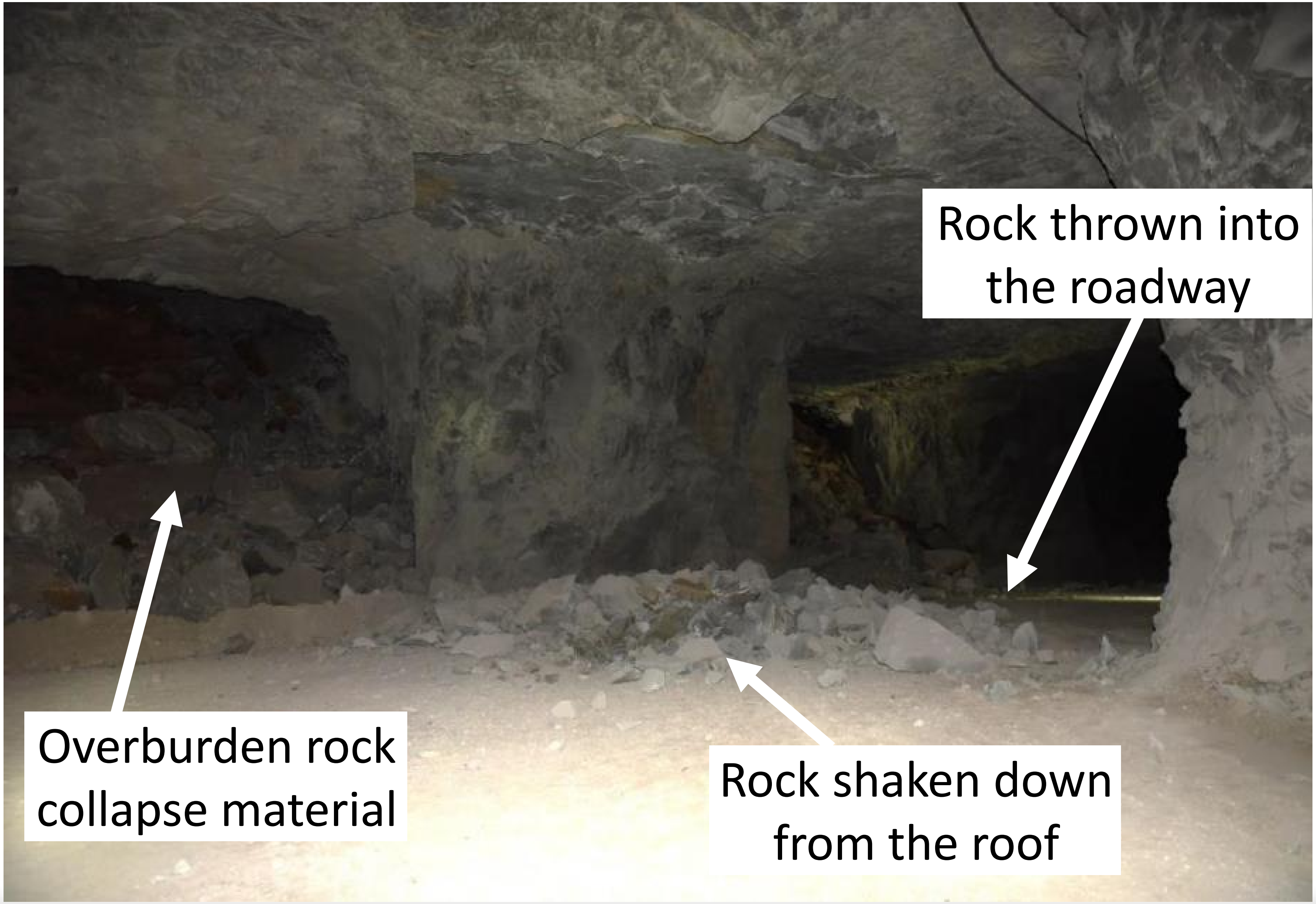
U.S. Department of Labor
MSHA
Mine Safety & Health Administration

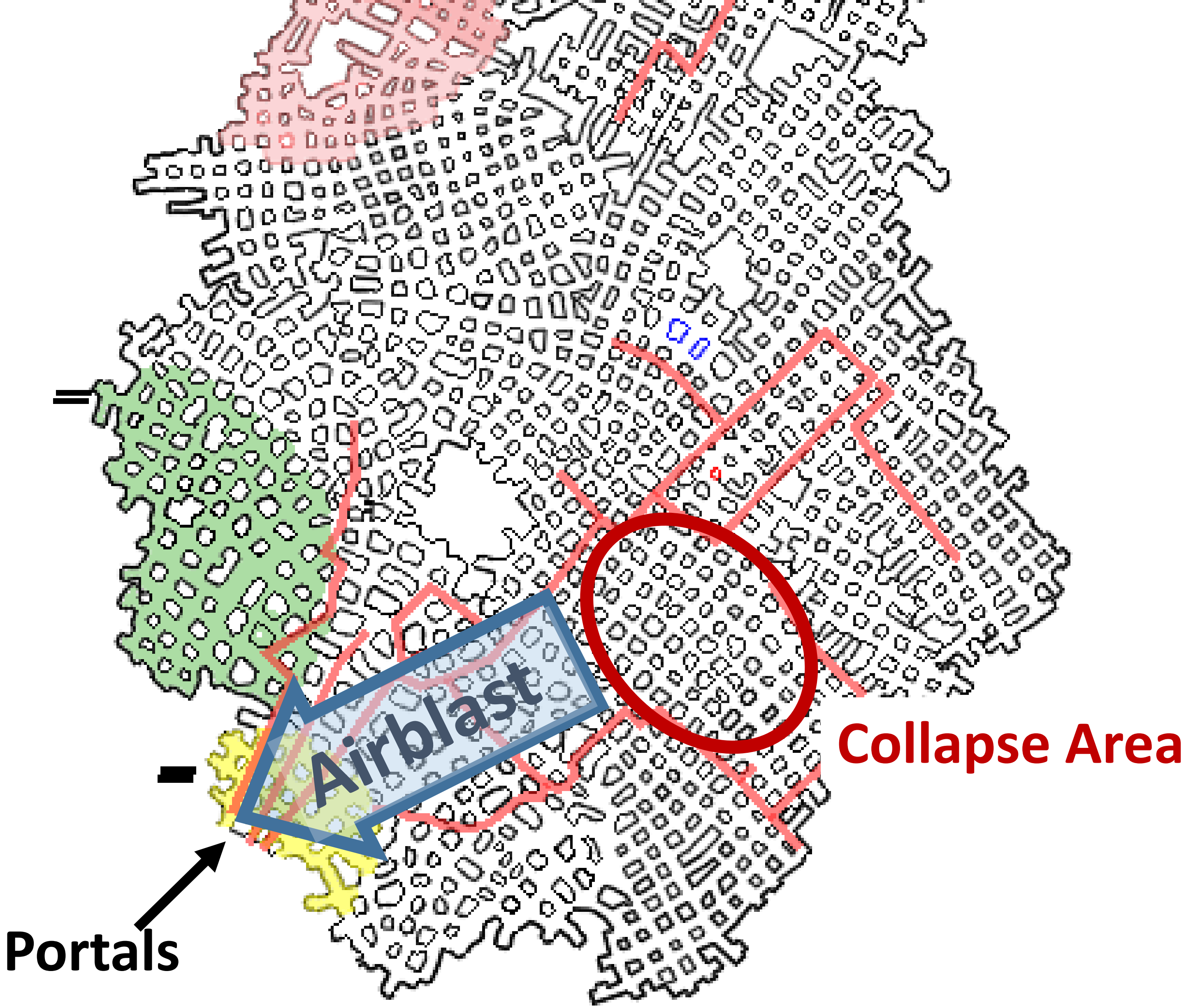
Assessing Pillar Collapse and Airblast Hazards in Underground Stone Mines

Pillars are blocks of rock left to support the overlying strata. A **pillar collapse** is when an array of pillars fail suddenly. Pillar collapses can occur with very little warning, and can affect miners far away from the collapse.


Rock thrown into the roadway
Overburden rock collapse material
Rock shaken down from the roof

The total collapse of the overburden typically causes a subsidence feature (sinkhole) on the surface.

An ***airblast*** is a rapid displacement of large quantities of air, often under pressure, caused by a fall of ground in a constrained underground environment.



Miners located in high-velocity air pathways are at most risk.

During the years 2015-2021, five major pillar collapses occurred at four underground stone mines.

These events resulted in three injuries and numerous near-misses.

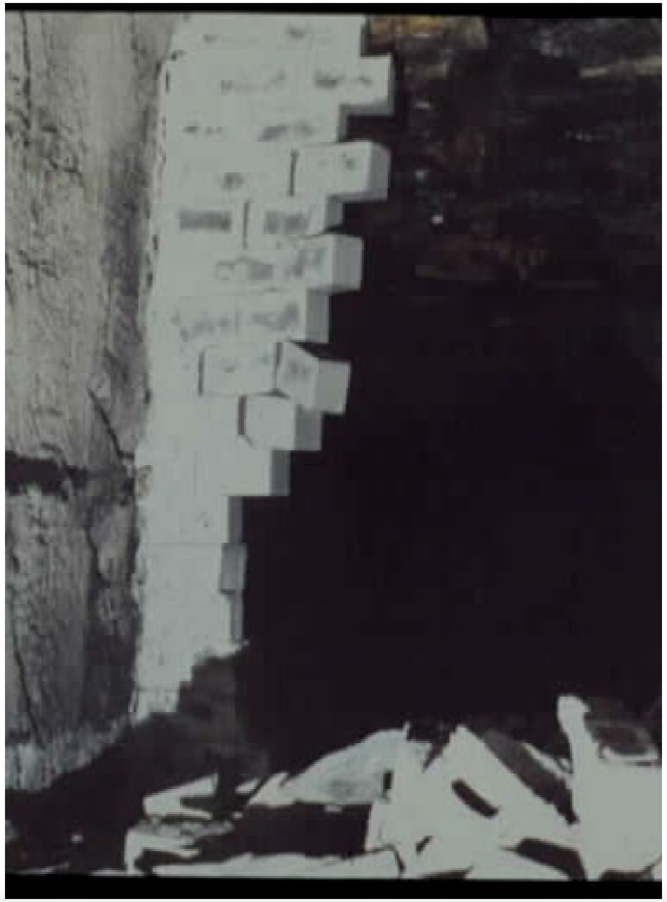
Similar events have occurred in previous years in marble mines and in lead/zinc mines.

It is not possible to predict when, or even whether, a particular array of pillars will collapse.

However, experience has shown that certain factors are associated with an increased likelihood of a pillar collapse.

MASSIVE PILLAR COLLAPSES

Stopping destroyed by airblast

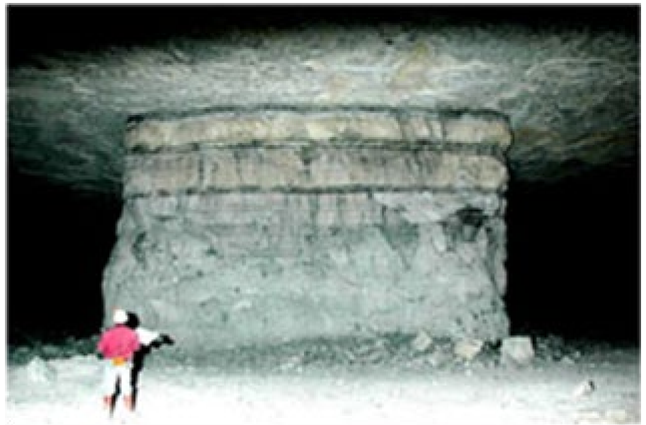


Large collapse area

Pillar Design for Underground Stone Mines

S-PILLAR

Software for Stone Mine Pillar Design



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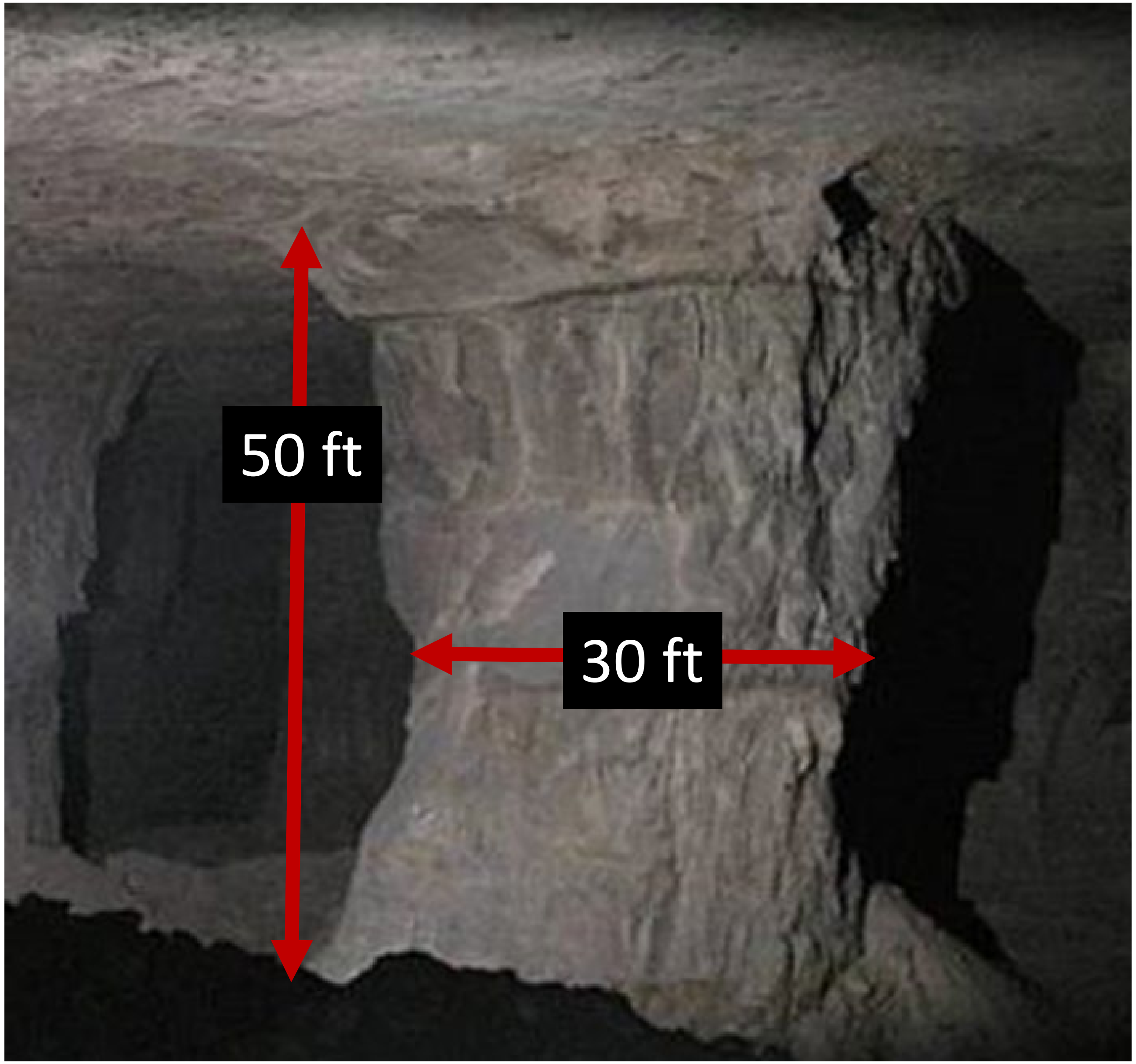
NIOSH

Proper pillar design is a necessary first step for new workings.

NIOSH developed the S-Pillar program in 2010 and it is widely known in the industry.



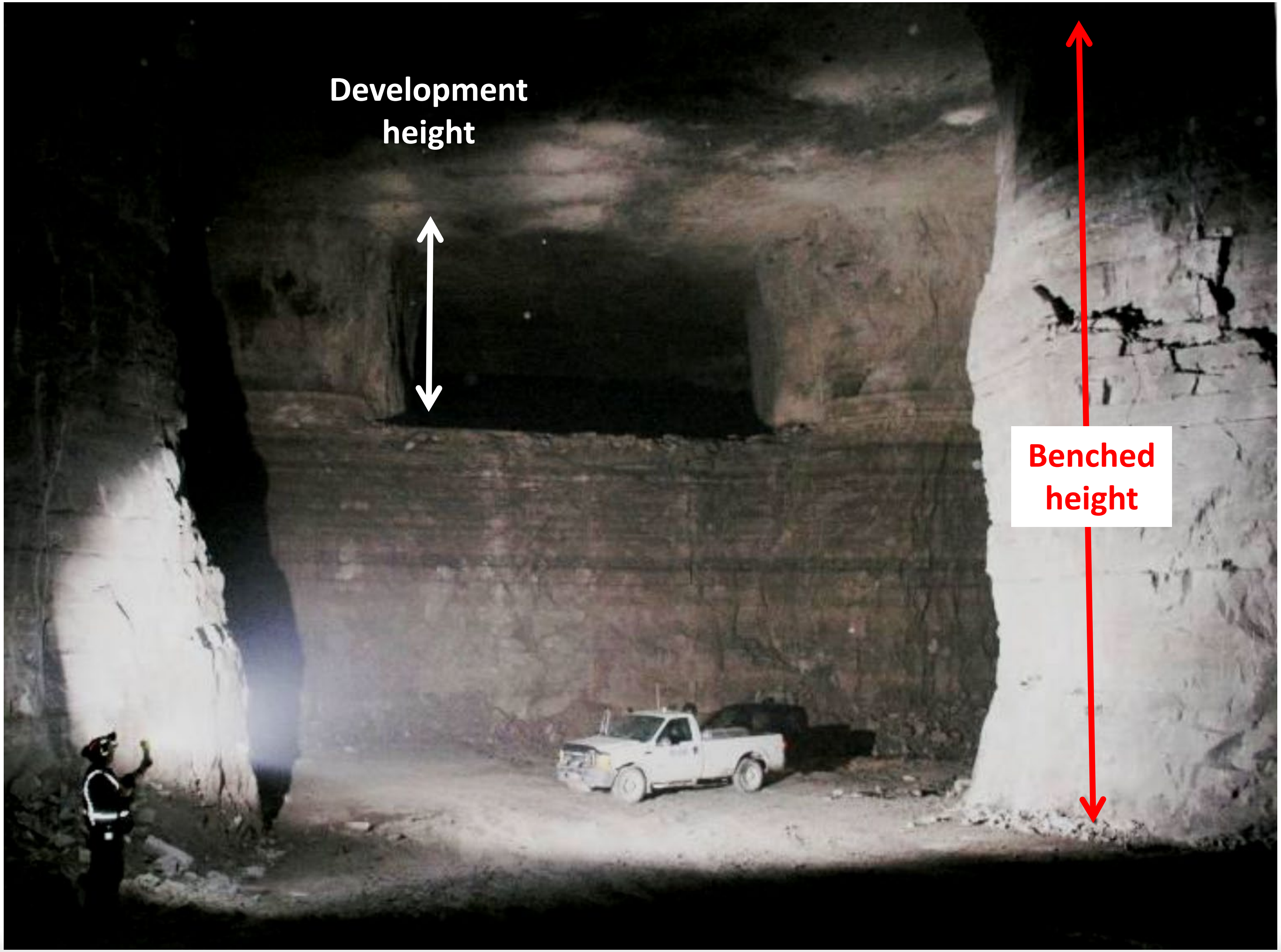
Slender Pillars, with width-to-height ratios less than 0.8, are at risk of collapse.

In this photo, the w/h ratio is 30/50 = 0.6.

Limestone is a very strong rock.

However, it often contains joints or other geologic features.

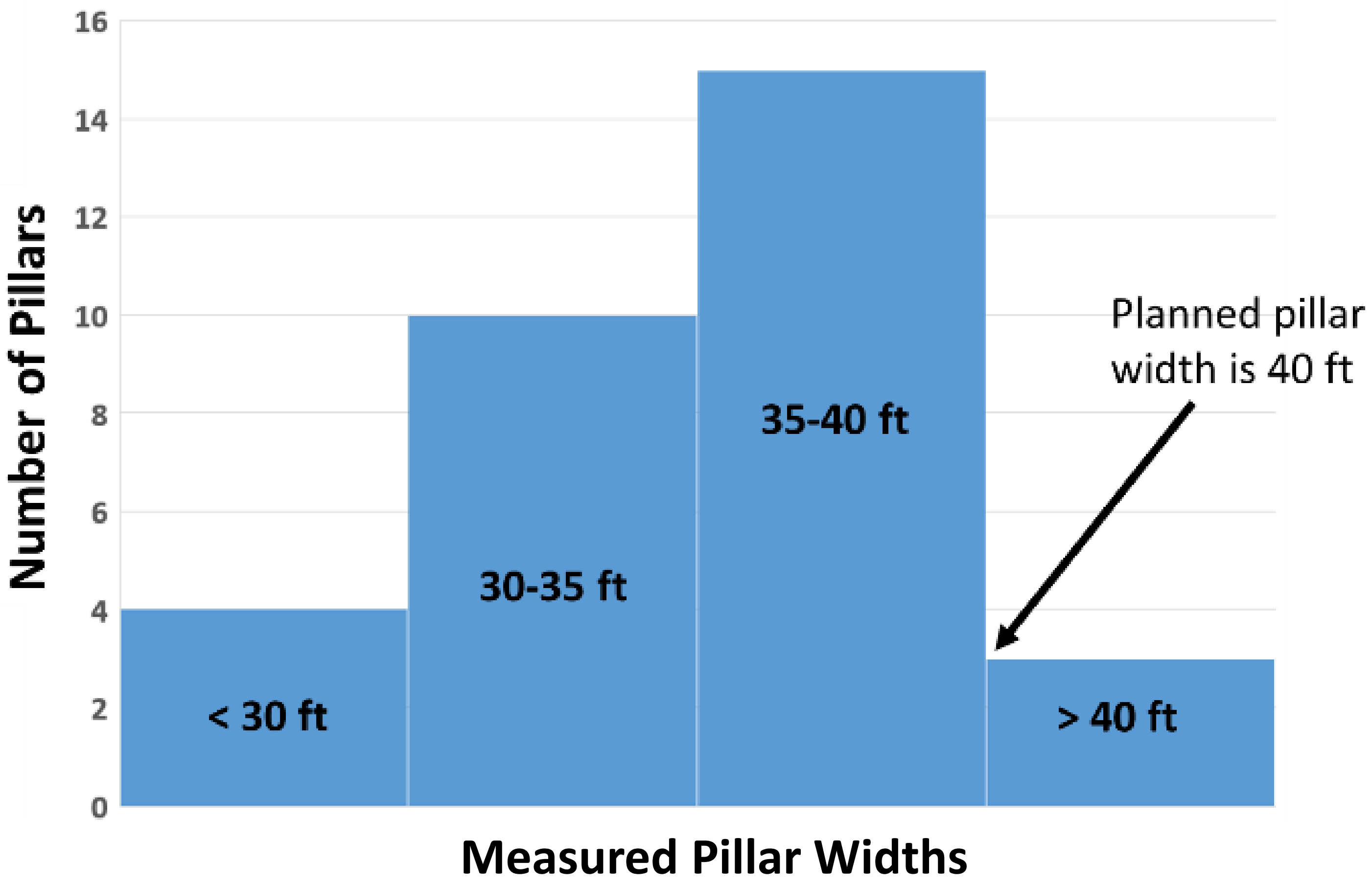
These can greatly reduce the strength of a slender pillar, particularly when they "daylight" on both sides of the pillar.

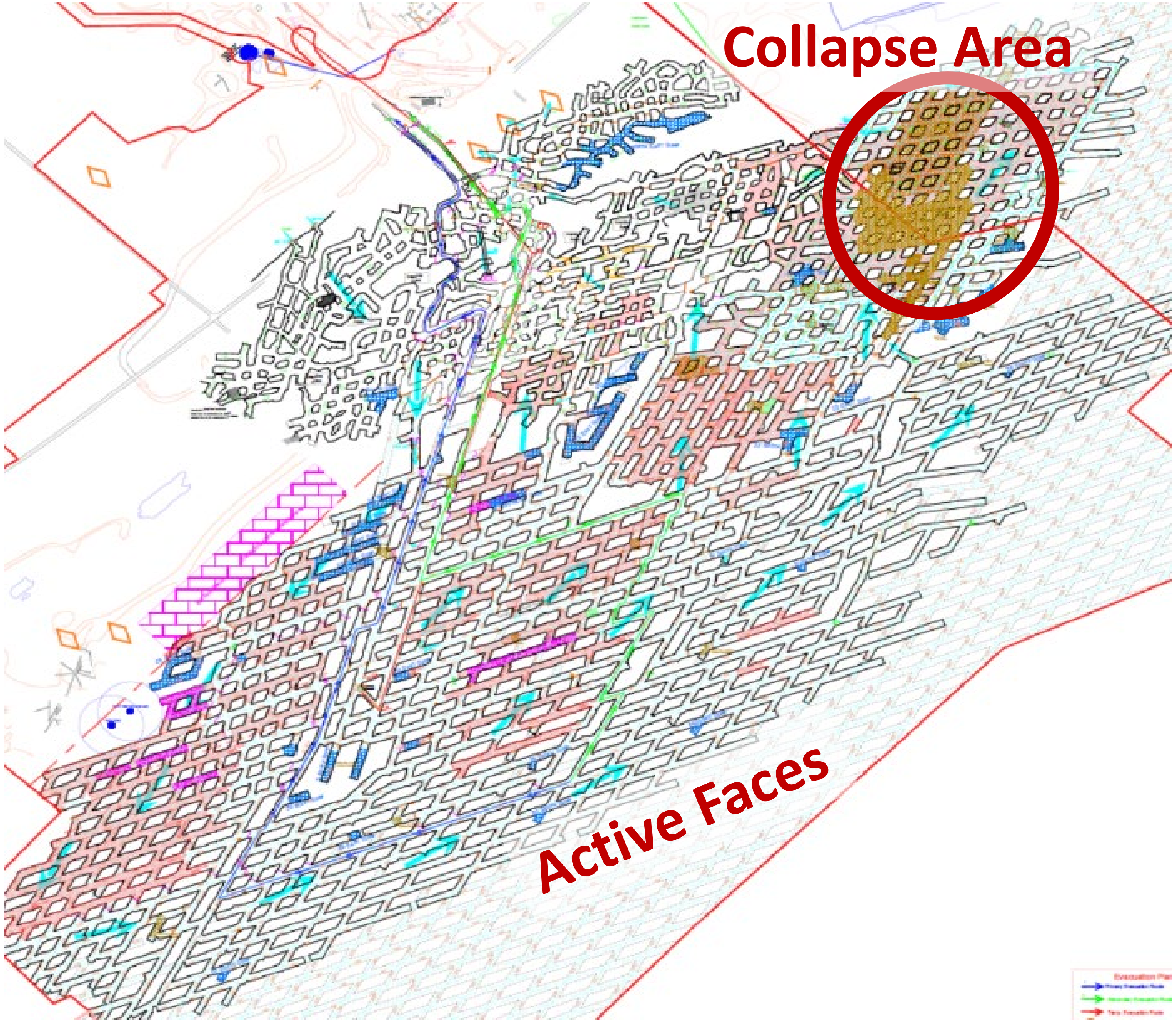


Benching

Mining the floor increases the pillar height.

Poor mining practices (blasting, surveying) can result in undersized pillars





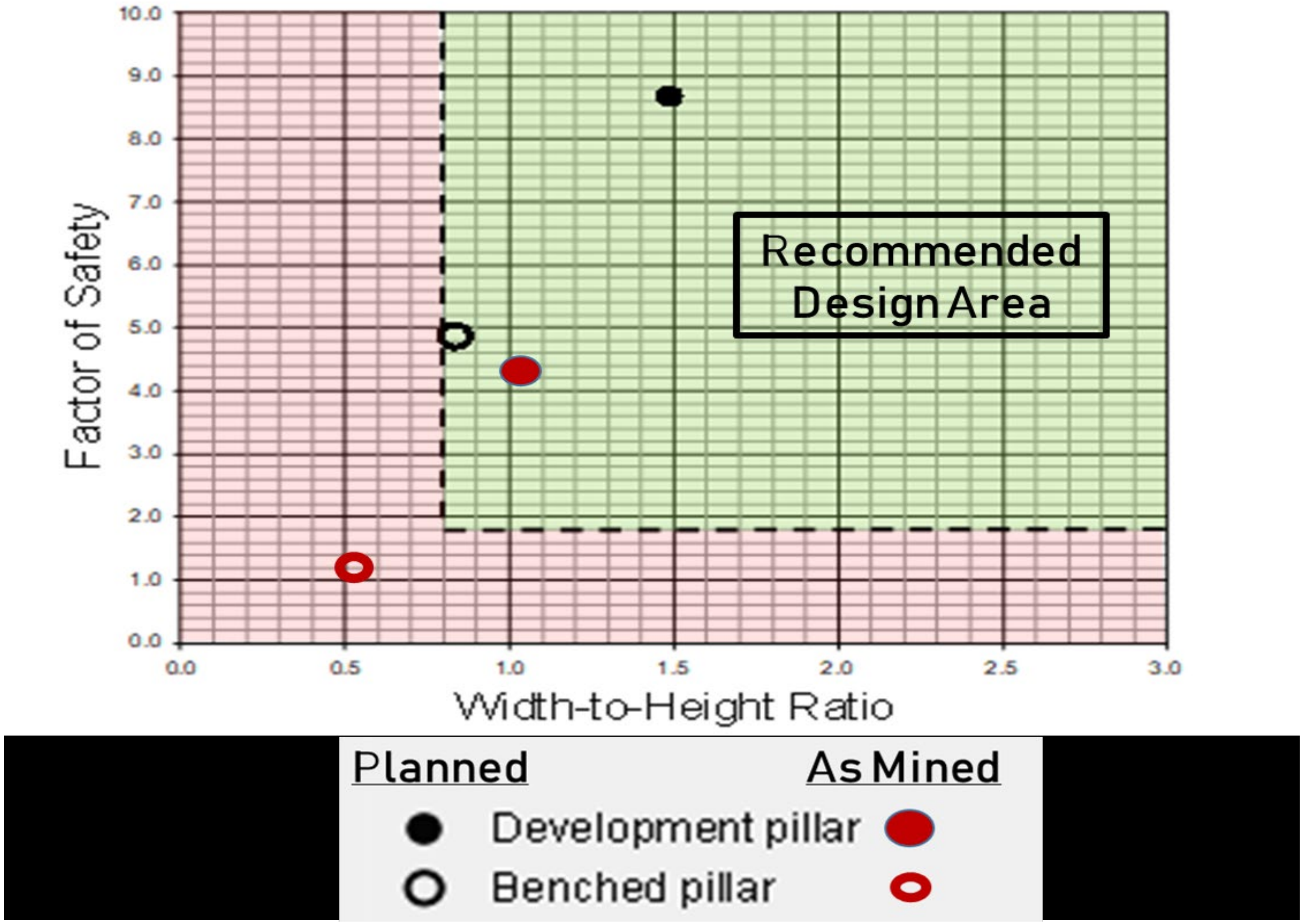
Many active underground stone mines contain “legacy” areas where pillars, particularly in benched areas, may be prone to collapse.

Mine operators should assess the risk of pillar collapse in these areas.

Risk Assessment requires rating the ***likelihood*** and the ***consequences*** of an unwanted event. The greatest risk is when both the likelihood and the consequences are high.

		Likelihood of Occurrence		
		High value	Medium value	Low Value
Consequence	High Value	High risk		
	Medium Value		Moderate risk	
	Low Value			Low Risk

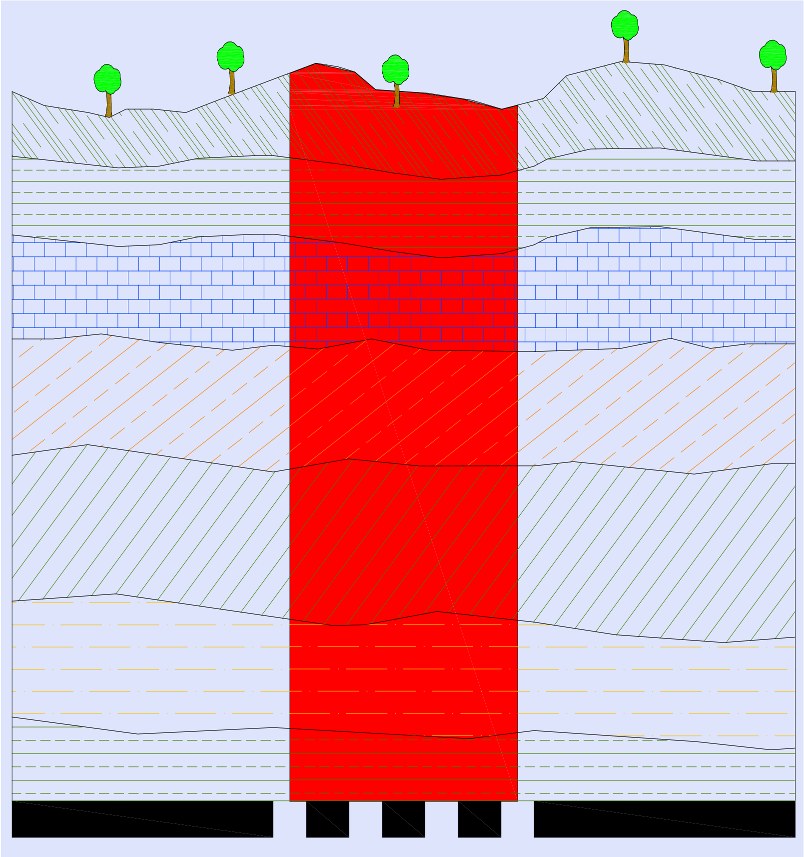
Source: Iannacchione, *Varley, and Brady (2008). The application of major hazard risk assessment (MHRA) to eliminate multiple fatality occurrences in the US mineral industry. NIOSH IC 9508.*

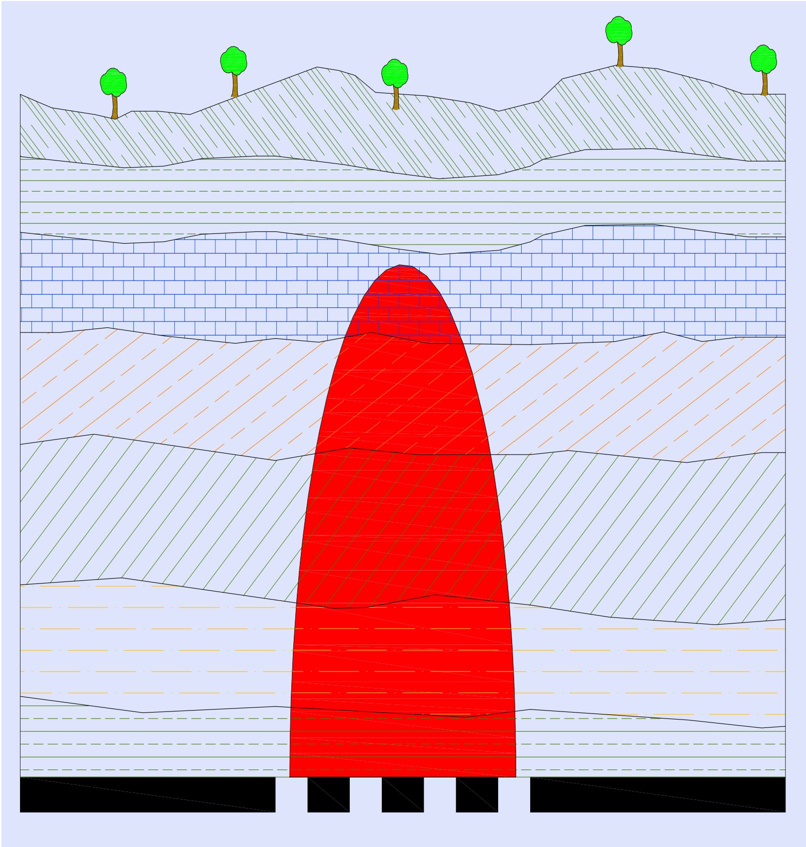


Factors contributing to the likelihood of pillar collapse

A pillar design method, like S-Pillar, is the primary tool for evaluating the likelihood of a pillar collapse.

The pillar's width-to-height ***ratio*** is an essential part of the pillar stability analysis.

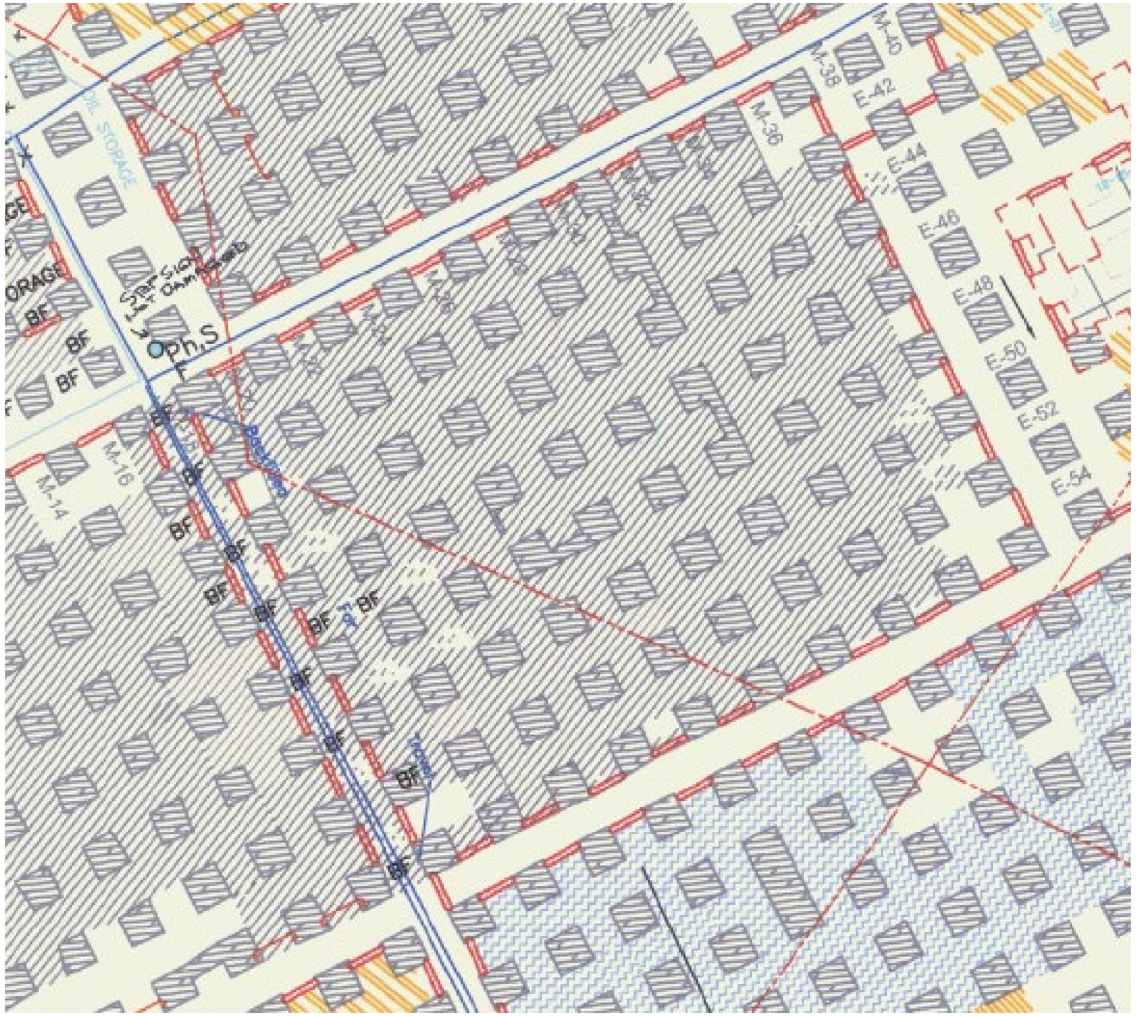




Tributary Area Loading

Pressure Arch Loading

Many pillar design methods assume the pillars carry tributary area loading. Where the panels are deep or narrow, and the overburden strong, the actual loading may be less due to pressure arch behavior.



A larger pillar array is more likely to collapse because there is less pressure arch potential, and it will also cause a greater airblast.

Major geologic features, like faults or karst, can reduce pillar strength or weaken the overburden.

Weak bands or soft floor can cause rib slabbing and reduce pillar strength.

Consequences of a Pillar Collapse

Miners working in the area of a pillar collapse would likely be killed. In one recent instance, miners were engaged in benching operations just days before a pillar collapse.

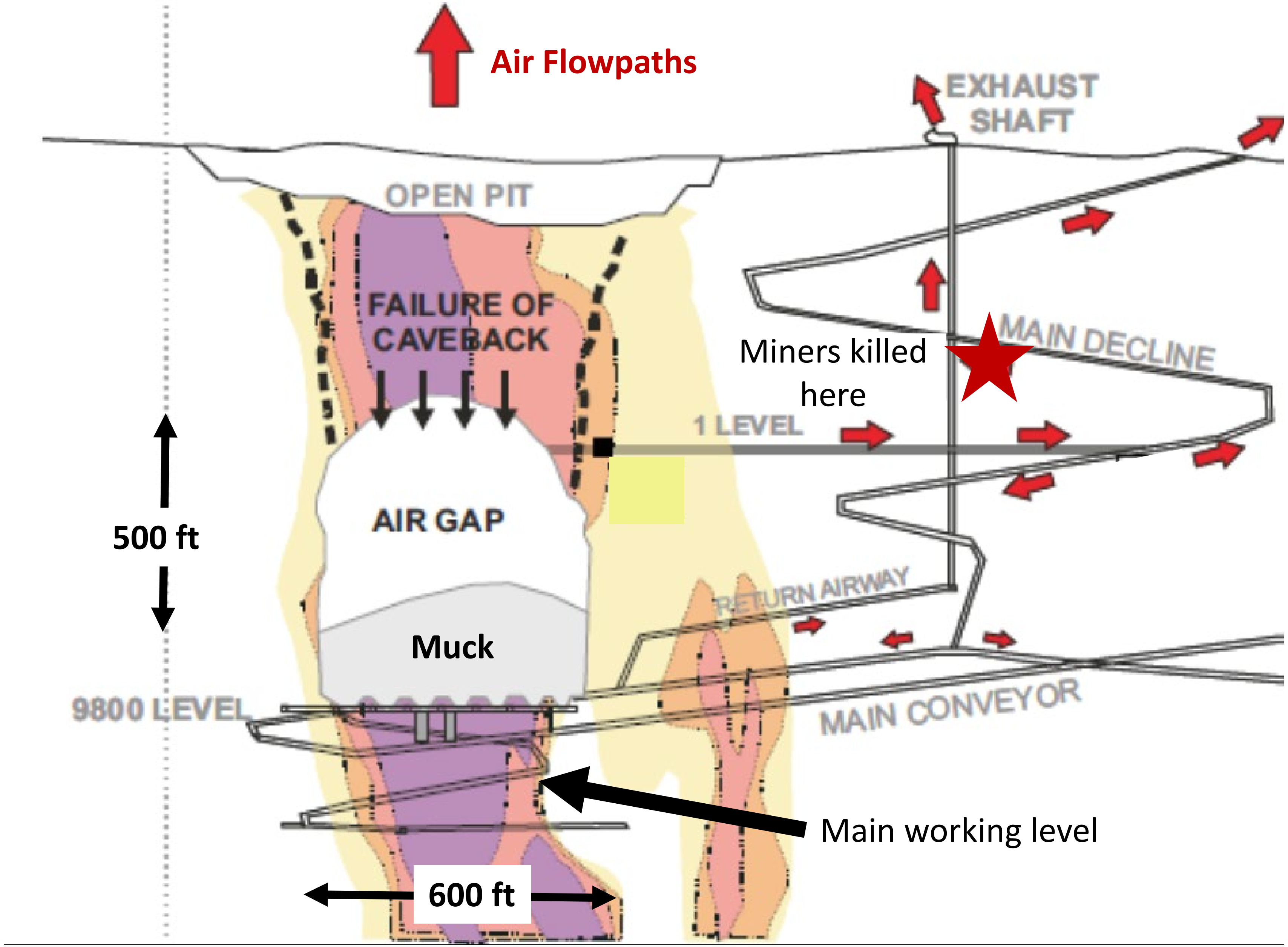
Miners working nearby a collapse, or traveling in an adjacent haulroad, could be killed or injured by falling rock or extremely high air velocities.

Miners located at some distance from the collapse can be at risk if they are working or traveling in high velocity air pathways.

Tech Support Study of Airblasts in Underground Mines Worldwide

- 40 documented airblasts
- Coal, trona, potash, copper/gold, lead/zinc
- Pillar Collapses
- Caving Events (longwalls, room and pillar, block caving)

Northparkes Mine Disaster (1999)



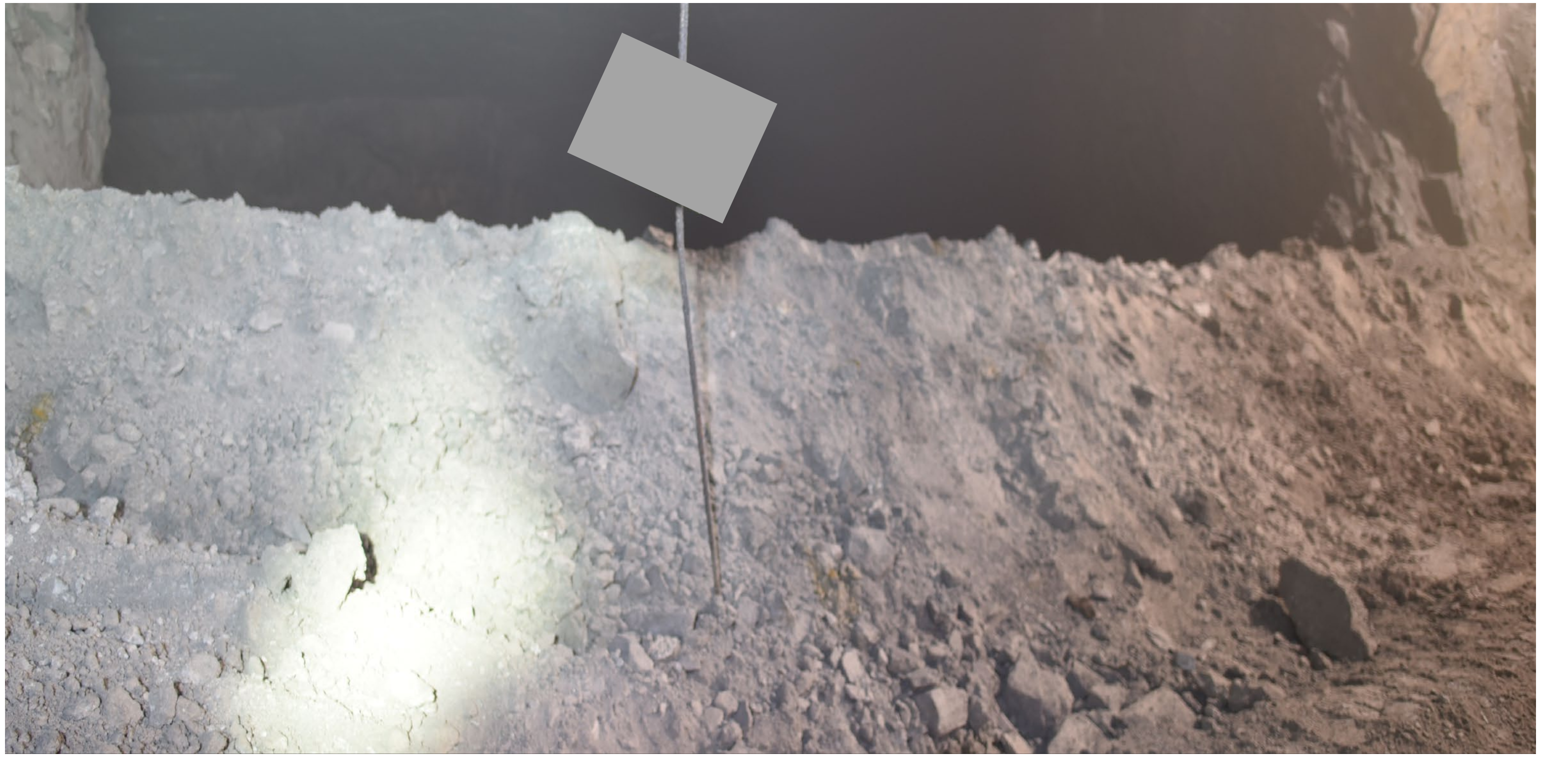
- 10 million tons fell 500 feet
- 4 Miners killed
- 57 other miners unhurt

Miners can also be harmed if fans or other ventilation controls are damaged by an airblast, or if egress from the mine is blocked.

Miners working in front of the portals, or on the surface, could also be harmed by a pillar collapse.

Control techniques that can reduce the risk from pillar collapse

1. Relocate travelways and other mine infrastructure to areas of lower risk.



2. Construct bulkheads or rock barriers to redirect airblast away from miners.

3. Airblast relief openings can provide a direct ventilation pathway that does not expose miners to the hazard.

4. Backfill?

5. Underground observations and monitoring

The Pillar Collapse Likelihood Matrix. The top two parameters are most important. A “high” value for a parameter correlates with a greater likelihood of collapse.

	Low	Moderate	High
Pillar Stability	Meets all applicable design criteria		Does not meet applicable design criteria
Width-to-height ratio (average)	w/h>1.0	0.8<w/h<1.0	w/h<0.8
Pillar Dimension Variability	All pillars approximately equal sized	A few pillars smaller than average	Many pillars smaller than the average
Pressure Arch Potential	Strong overburden/Deep cover/Narrow pillar array	Moderate strength overburden/Moderate cover/Moderate pillar array width	Weak overburden/Shallow cover/Wide pillar array
Size of Benched Area	Small	Moderate	Large
Major Geologic Features (Faults, karst)	None	If a fault, karst, or other major geologic feature is present, assess its potential contribution to the collapse likelihood	
Soft Floor	None	Possible, but minimal evidence of pillar distress	Thick weak floor causing pillar dilation
Weak Bands in the Pillars	None	Possible, but minimal evidence of pillar distress	Thick, weak band causing pillar dilation

The Pillar Collapse Consequences Matrix helps evaluate the hazards at different locations in the mine, and the potential exposure of miners.

Location of miners	Conditions/Hazards	Consequence if miners are present	Number of miners exposed	How often are miners exposed
Working within collapse area, engaged in active mining/benching operations	Massive rock fall, no warning	Death		
Working or traveling in roadways directly adjacent to collapse area	High air velocities, flying debris, small rock falls	Death or severe injury		
Working or traveling directly above a collapse area	Sudden development of a surface sinkhole	Death or severe injury		
Working or traveling in high velocity air pathways leading from collapse area to portals	Diminishing air velocities depending on number of pathways and distance from collapse	Injury		
Other locations in the mine	Damage to ventilation controls or egress routes	Indirect hazards		