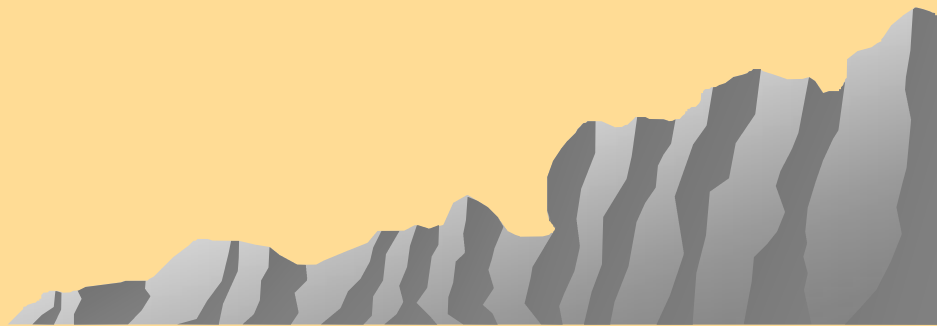
Ground Control In Quarries

DMME

Division of Mineral Mining

AR Training

Updated 2012



Objectives

- How highwall hazards are created
- How to recognize highwall hazards
- How to remediate highwall hazards

The Ultimate Objective….

No More Victims

- **Highwall hazards are created when workers are exposed to highwalls with the potential for failure.**

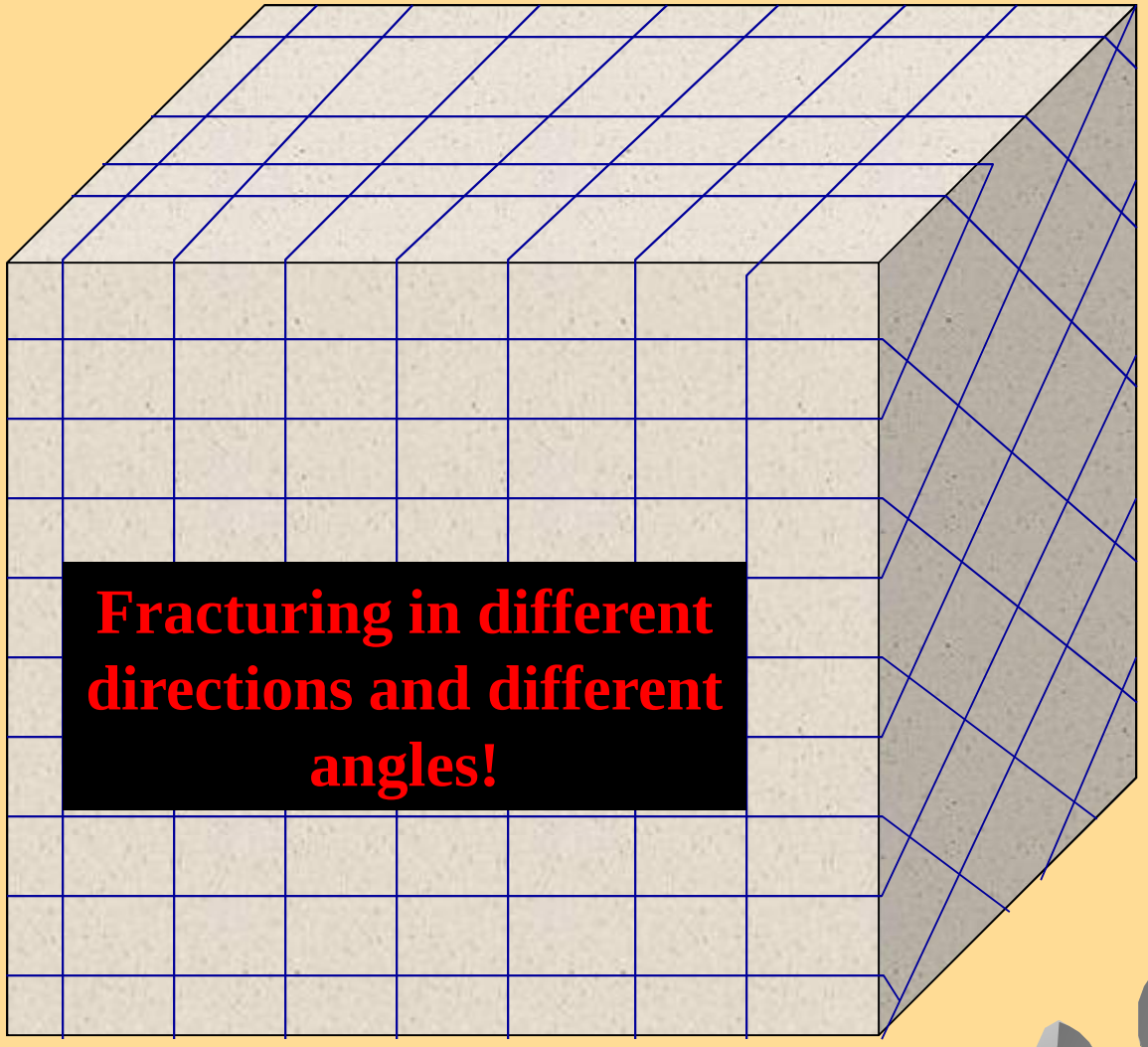
Highwall Composition (Intact Rock vs. Rock Mass)

- **Highwalls are composed of rock masses that consist of intact (solid) blocks of rock separated by structural (geological) discontinuities.**
- **The properties of a rock mass are not the same as the properties of the intact rock blocks.**
- **The properties of a rock mass include the properties of the intact rock and the properties of the discontinuities.**

Discontinuities

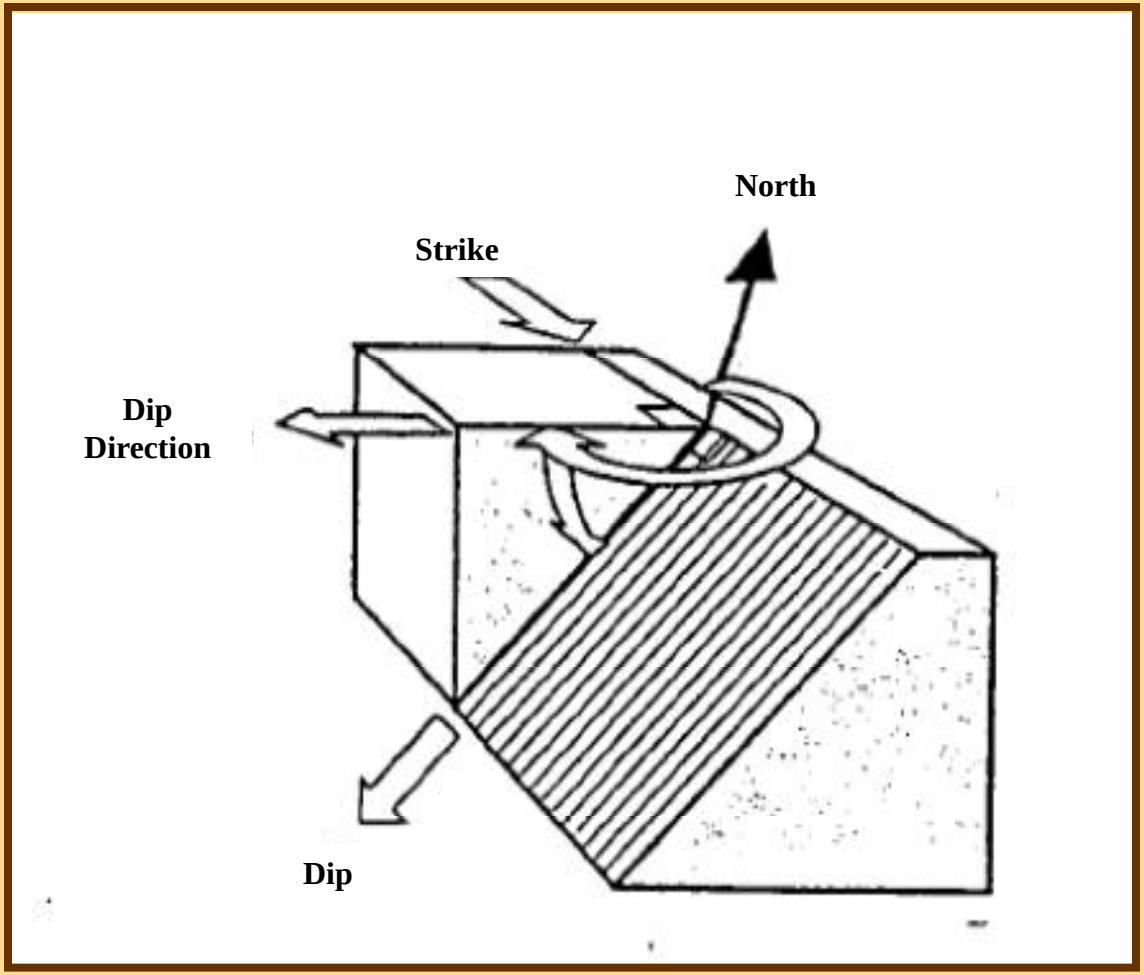
- A discontinuity is any disconnect or break in the continuity of the rock material.
- It is a structural weakness along which movement and possibly failure can occur.

Effect of Discontinuities on Rock Mass



Discontinuity Orientation

- **Dip – angle at which a discontinuity is included from the horizontal, measured normal to the direction of strike.**
- **Dip Direction – the bearing of the dip, measured perpendicular to the direction of the strike.**
- **Strike – the bearing of the outcrop of a discontinuity.**

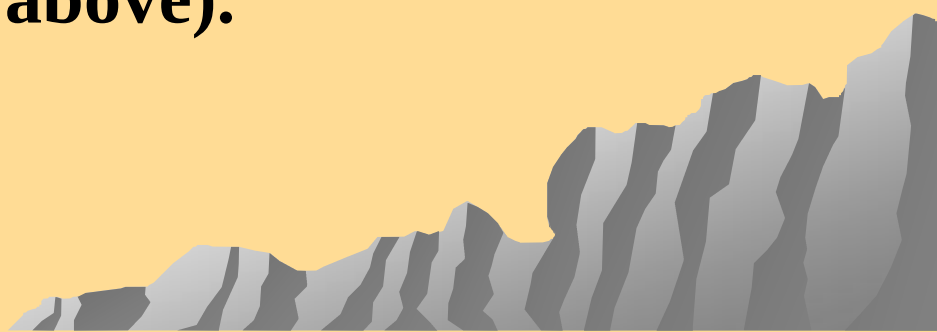


Orientation Diagram


Favorable Dip
Unfavorable Dip
How So?

Common Types of Discontinuities

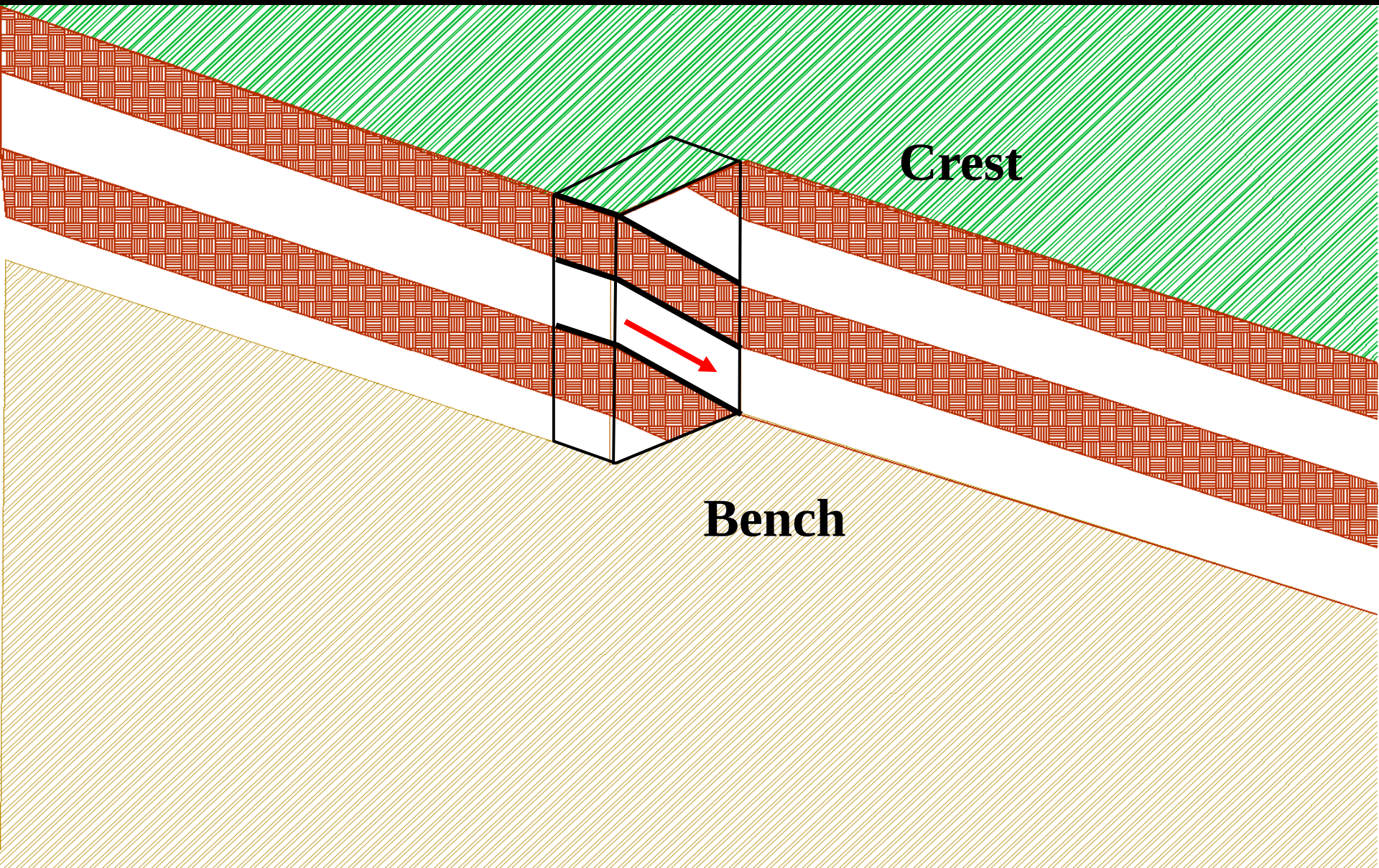
- **Bedding – a deposit layer or surface found in sedimentary rocks.**
- **Joint – a discontinuity along which no visible movement or slippage has occurred.**
- **Fault – a discontinuity along which movement or slippage has occurred.**
- **Fracture – a generic term applied to a variety of discontinuities (all of the above).**



Bedding Relative To The Highwall Face

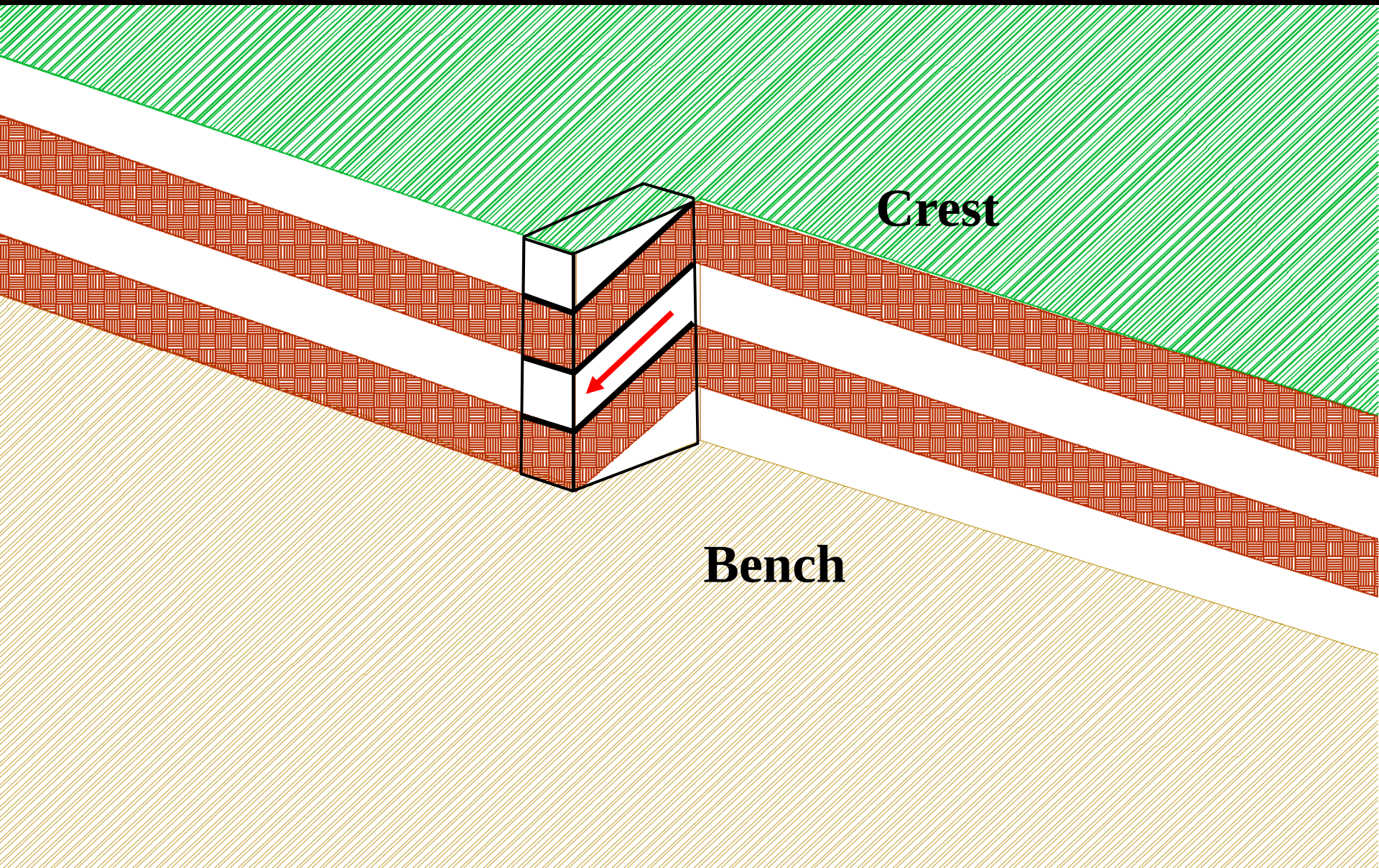
Favorable Orientation

(Beds Dipping Into Highwall)

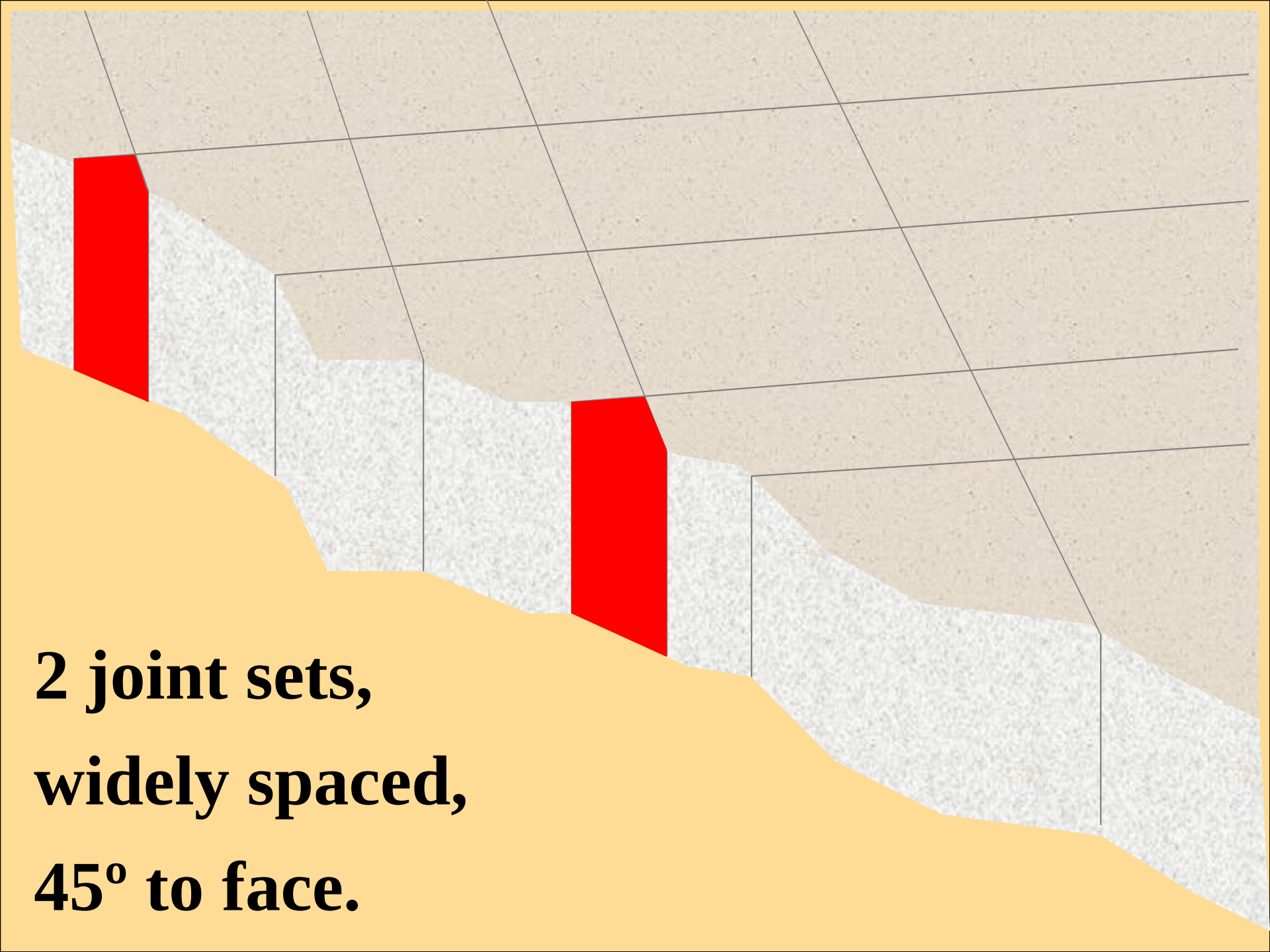


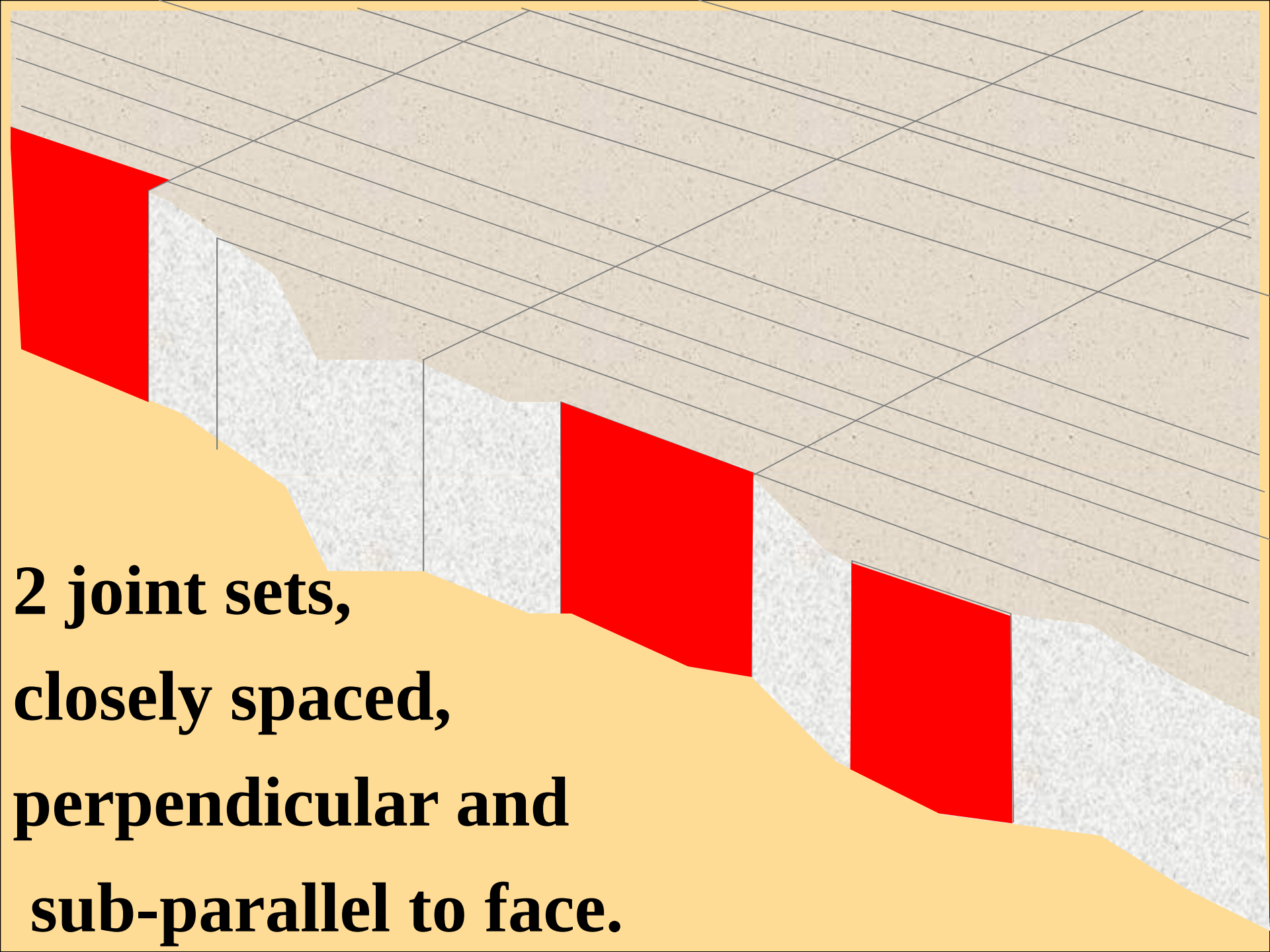
Unfavorable Orientation

(Beds Dipping Into Pit)



Joints Relative to the Highwall Face


2 joint sets,
widely spaced,
45º to face.



2 joint sets,

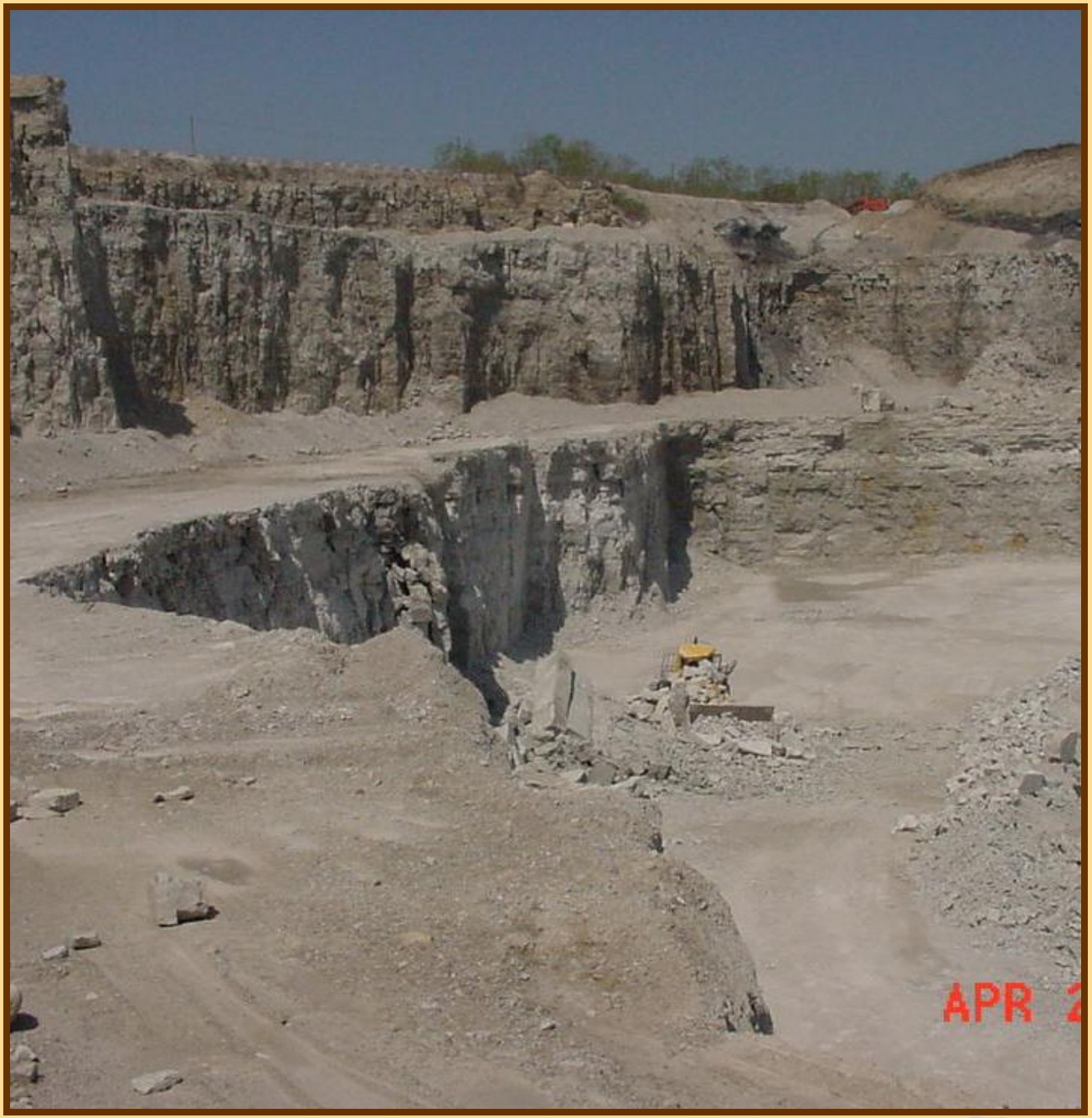
closely spaced,

perpendicular and

sub-parallel to face.

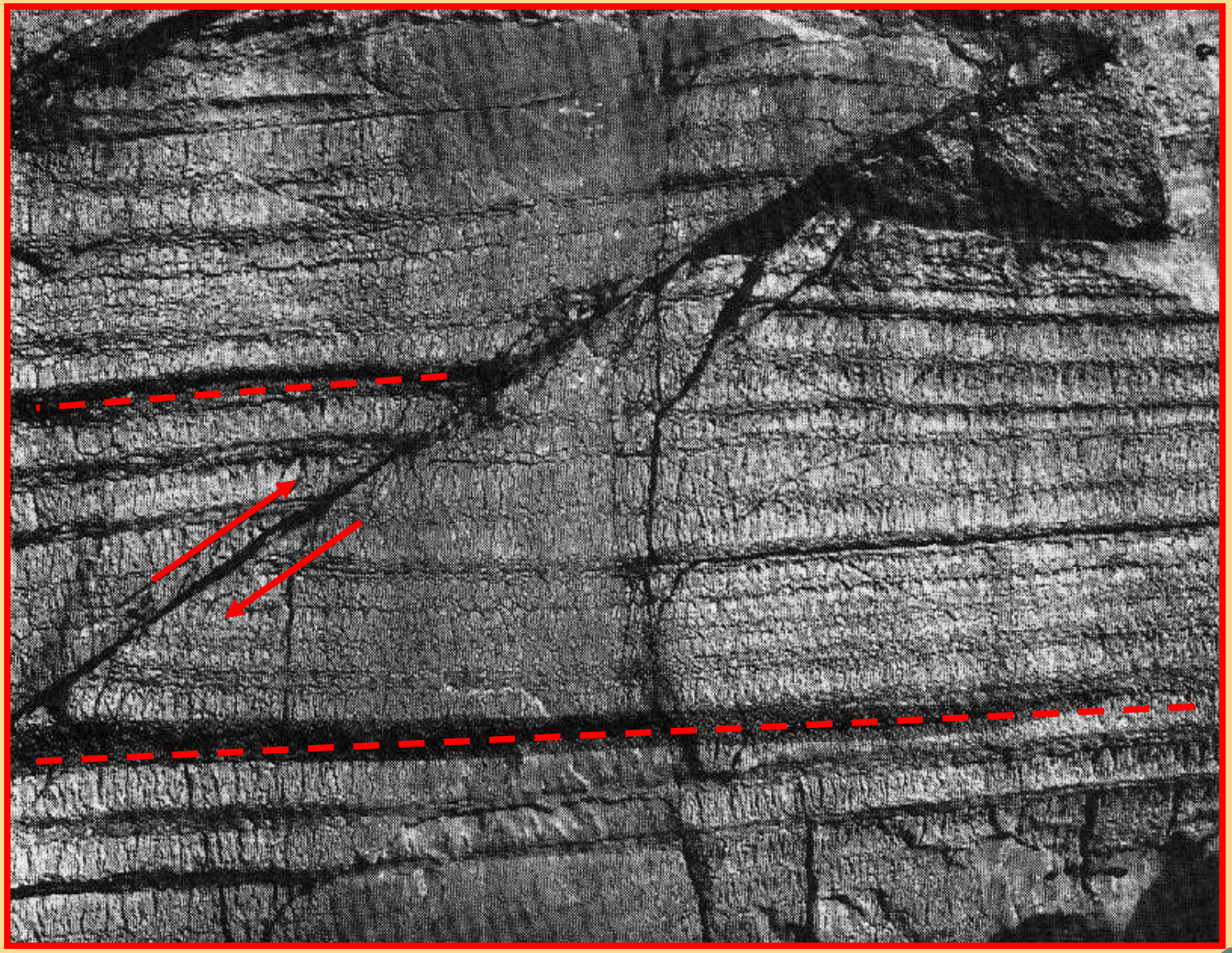
Structure Parallel To The Face

Previous Scene, Different Angle



Wider View

Look closely at the walls and rock structure.



Thrust Fault

Fractured Highwall

Pick out the worst spots

Tip:

There are not many good spots!

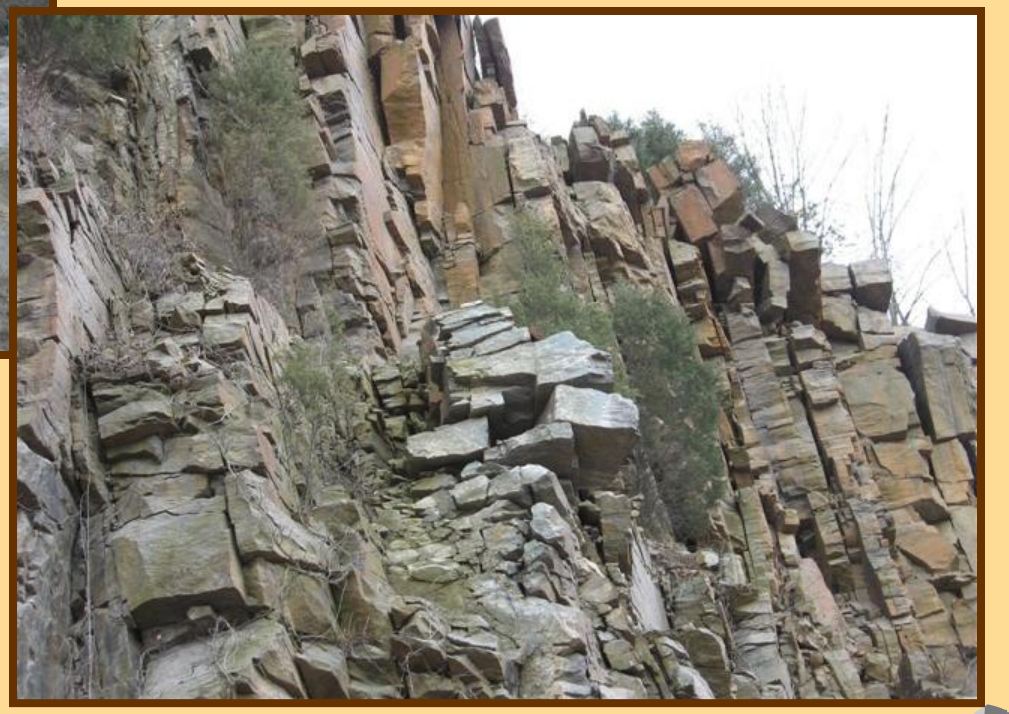
Fractured Highwall

Note areas where material has fallen out under and/or around material still on the wall.

Note areas where material leans into the quarry.

Note areas with wide fractures and a lot of small pieces.

Someone Complained!!



What would be wrong with carrying out drilling operations under this highwall?

Maybe someone should have complained!!

Points to Remember

- Discontinuities can occur at any orientation and spacing.
- The way in which discontinuities intersect each other and the highwall face contribute to the failure potential and the damage potential.
- Knowledge of discontinuity properties in the mine environment allows for anticipation, and often the prediction, of hazards.
- Hazards can be reduced or eliminated with good pit layout design.

Some Factors That Contribute To Highwall Instability

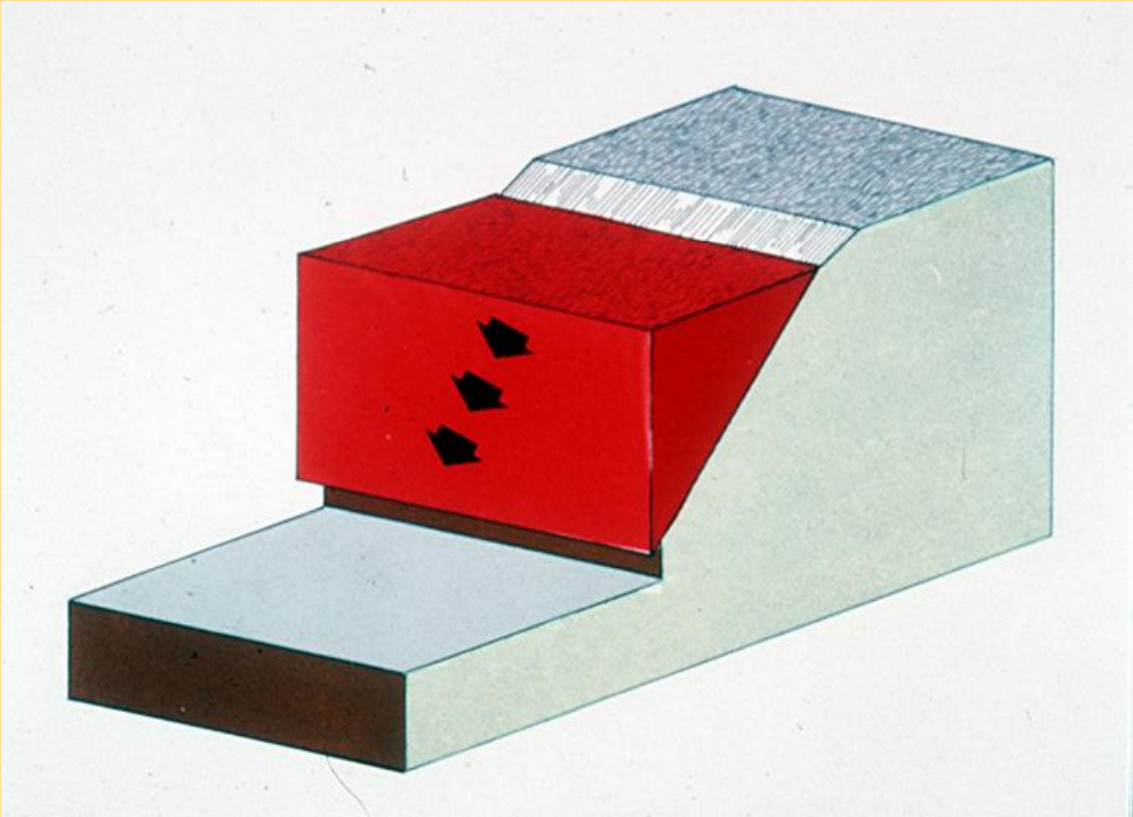
- Rock Mass Properties (strength, structure, etc.); Highwall Geometry (angles, heights, etc.); Face Orientation
- Precipitation (rain, snow)
- Ground Water
- Freeze – Thaw Cycles
- Equipment Vibrations and Blasting
- Soil Decomposition
- Burrowing Animals, Tree Roots
- Wind

Rock Mass Failure Modes

- Planar
- Wedge
- Toppling
- Circular

Planar (Plane) Failures

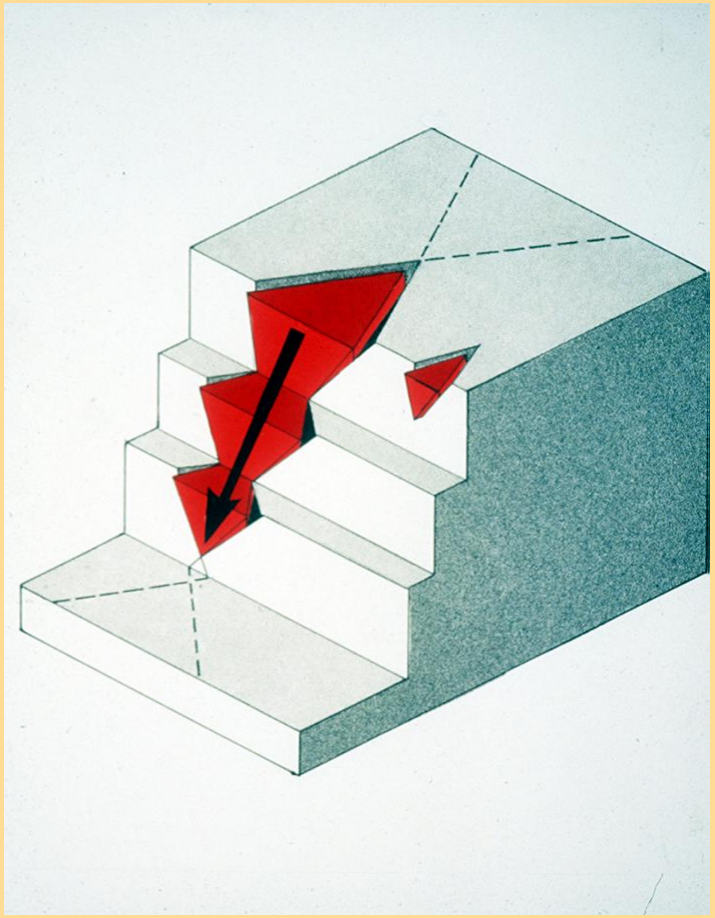
Involve sliding movement along a single discontinuity surface; however, additional discontinuities typically define the lateral extent of the failures.

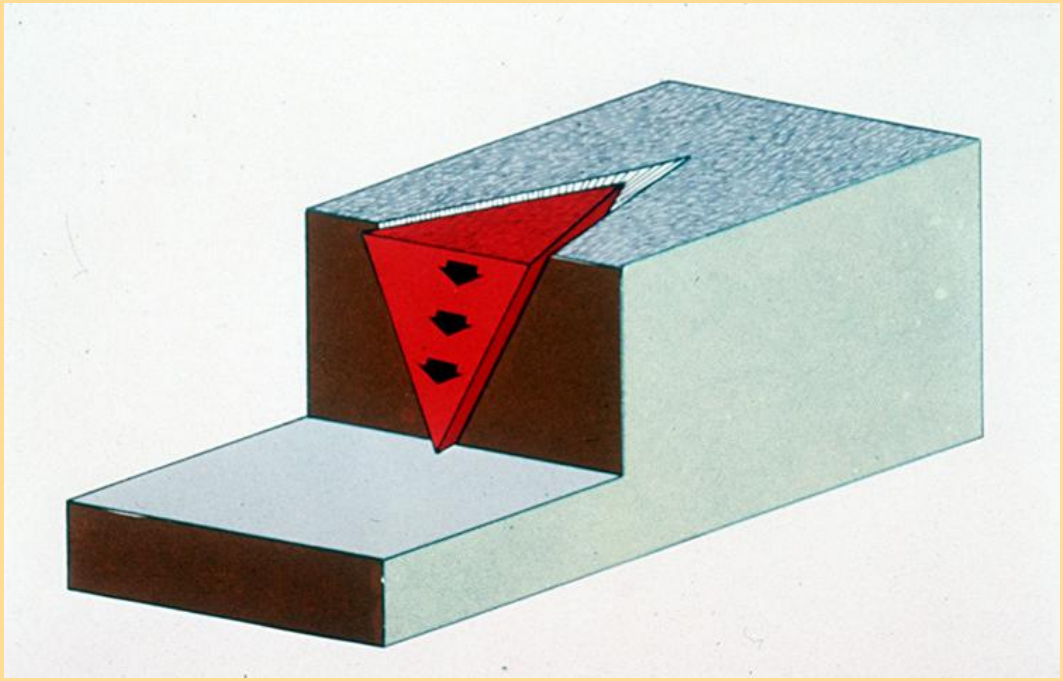


Planar Failure

Wedge Failures

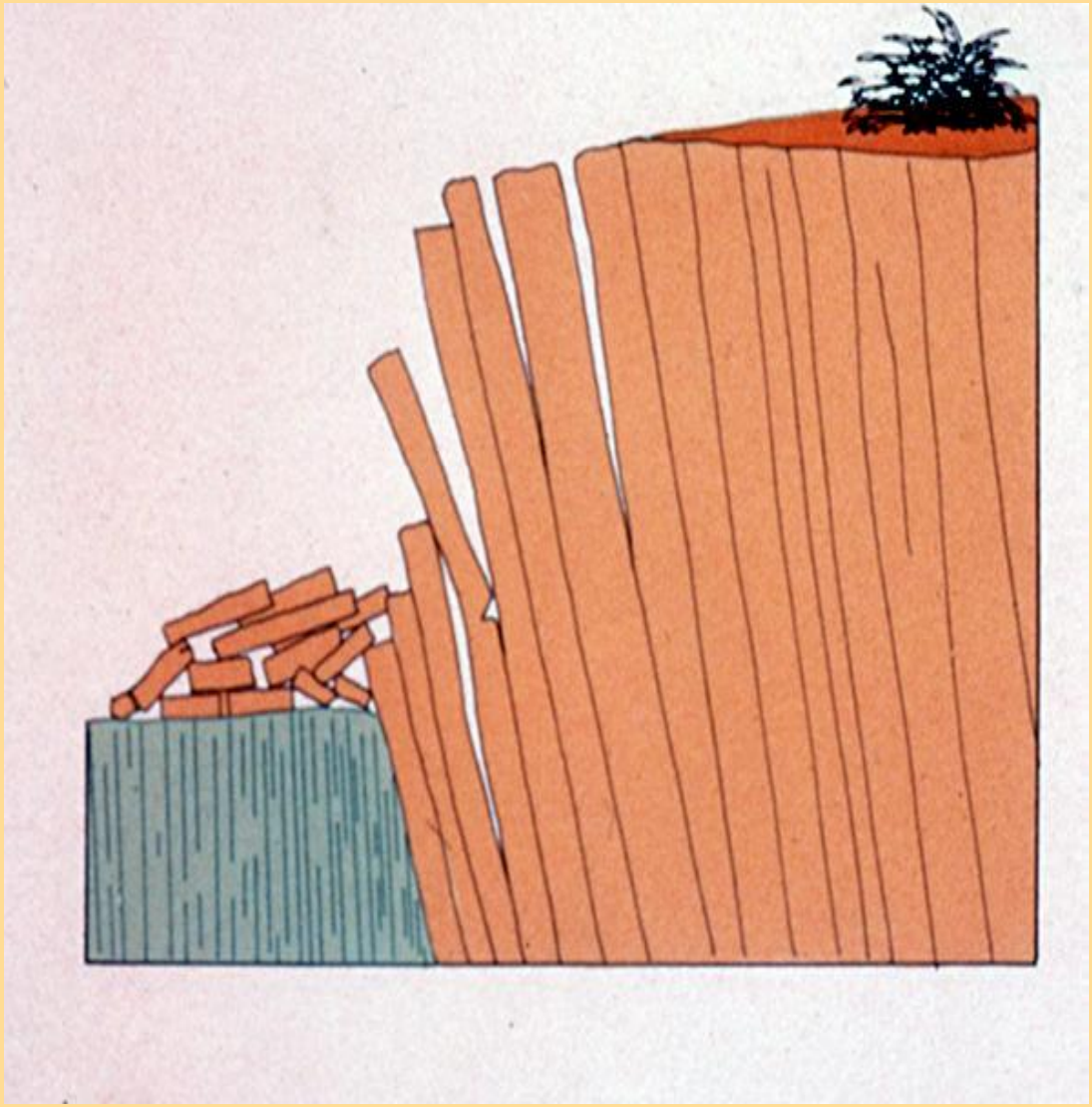
Involve sliding movement along two discontinuity surfaces that intersect at an angle forming a wedge shaped block in the highwall face.





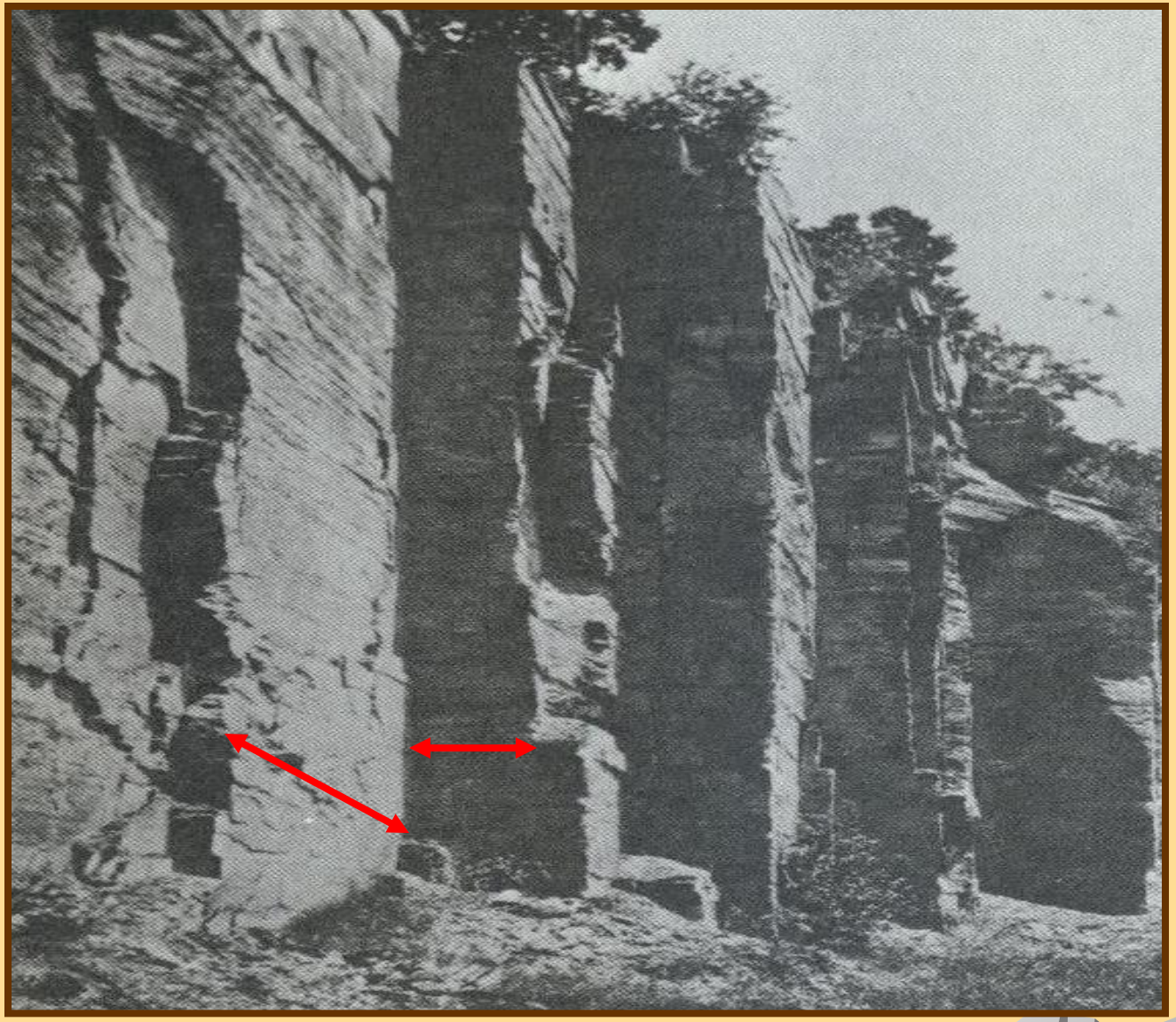
Wedge Formation

Toppling Failures



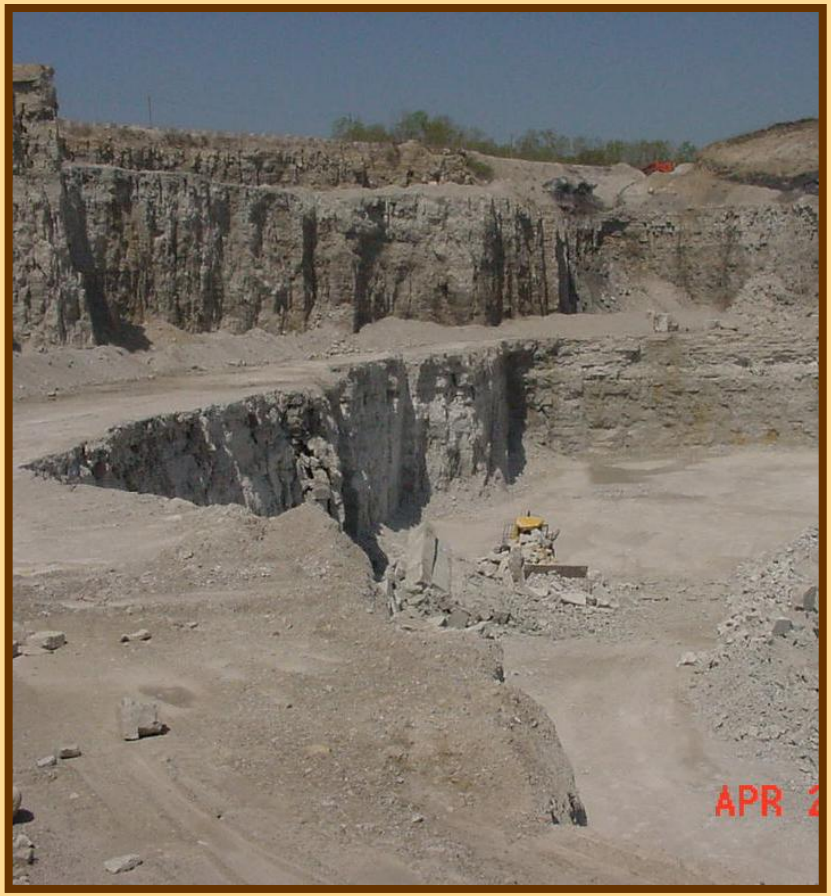
Involve buckling or rotational movement around the base of a slab or column formed by steeply dipping discontinuities oriented parallel or sub-parallel to the highwall face.

Two Sets of Vertical Joints

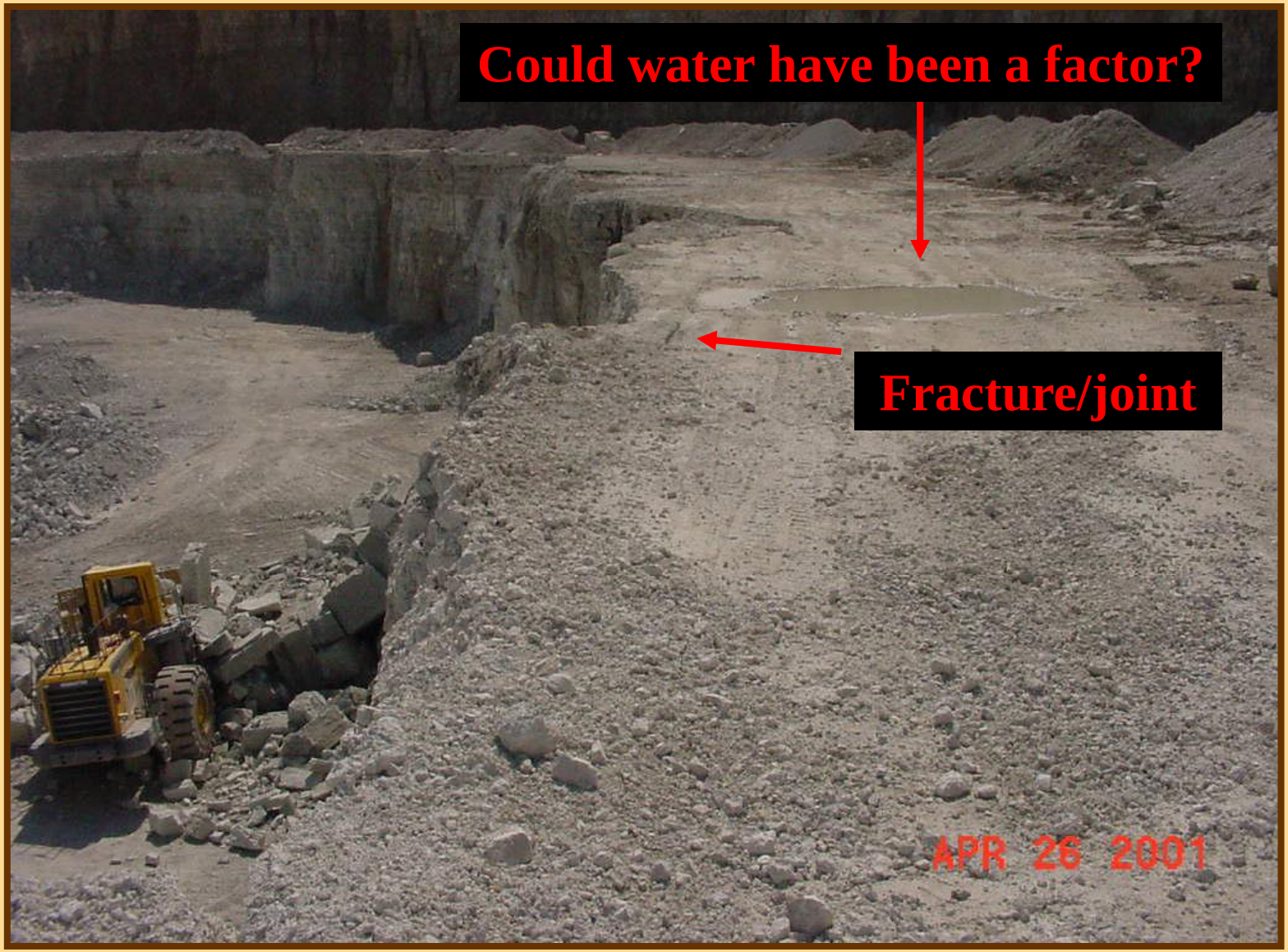


The dangers this situation presents are well illustrated on the next slide.

Toppling Failure



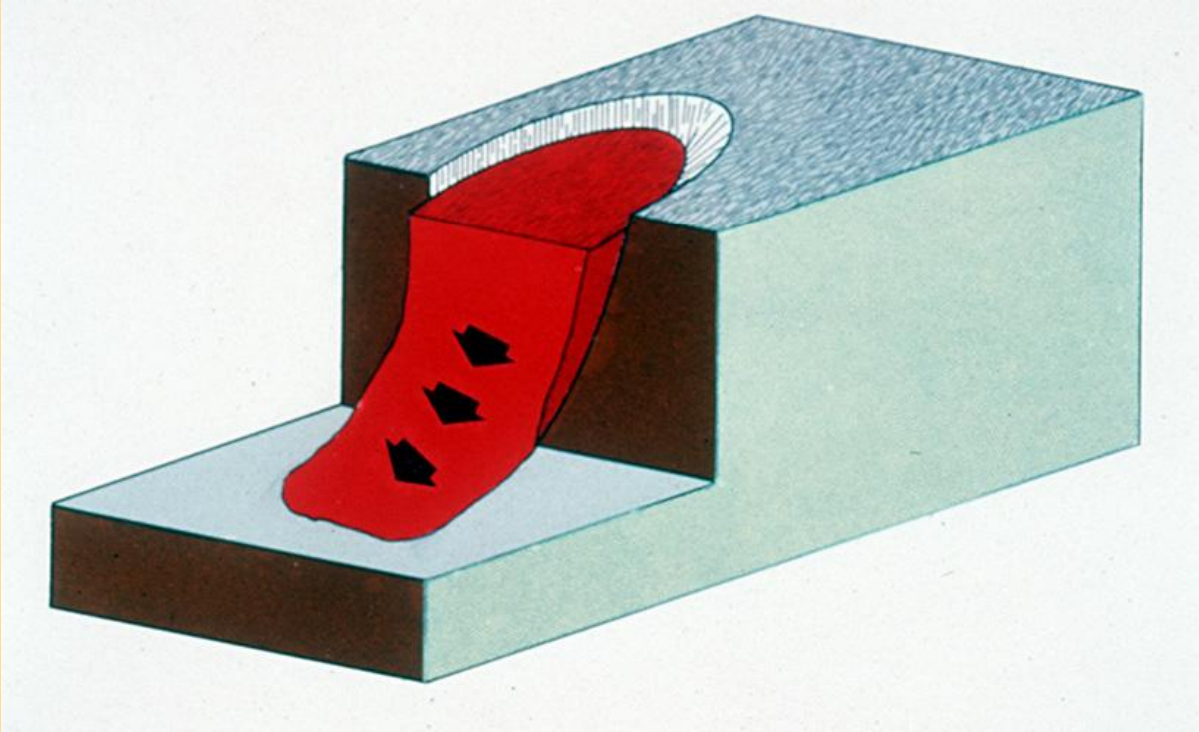
We saw this earlier, however, the next slide is a different view.



Toppling Failure

Circular Failure

Involves rotational and sliding movement along a failure surface that occurs along numerous discontinuities and often approximates the arc of a circle.



Circular Failure - Before

Circular Failure - After

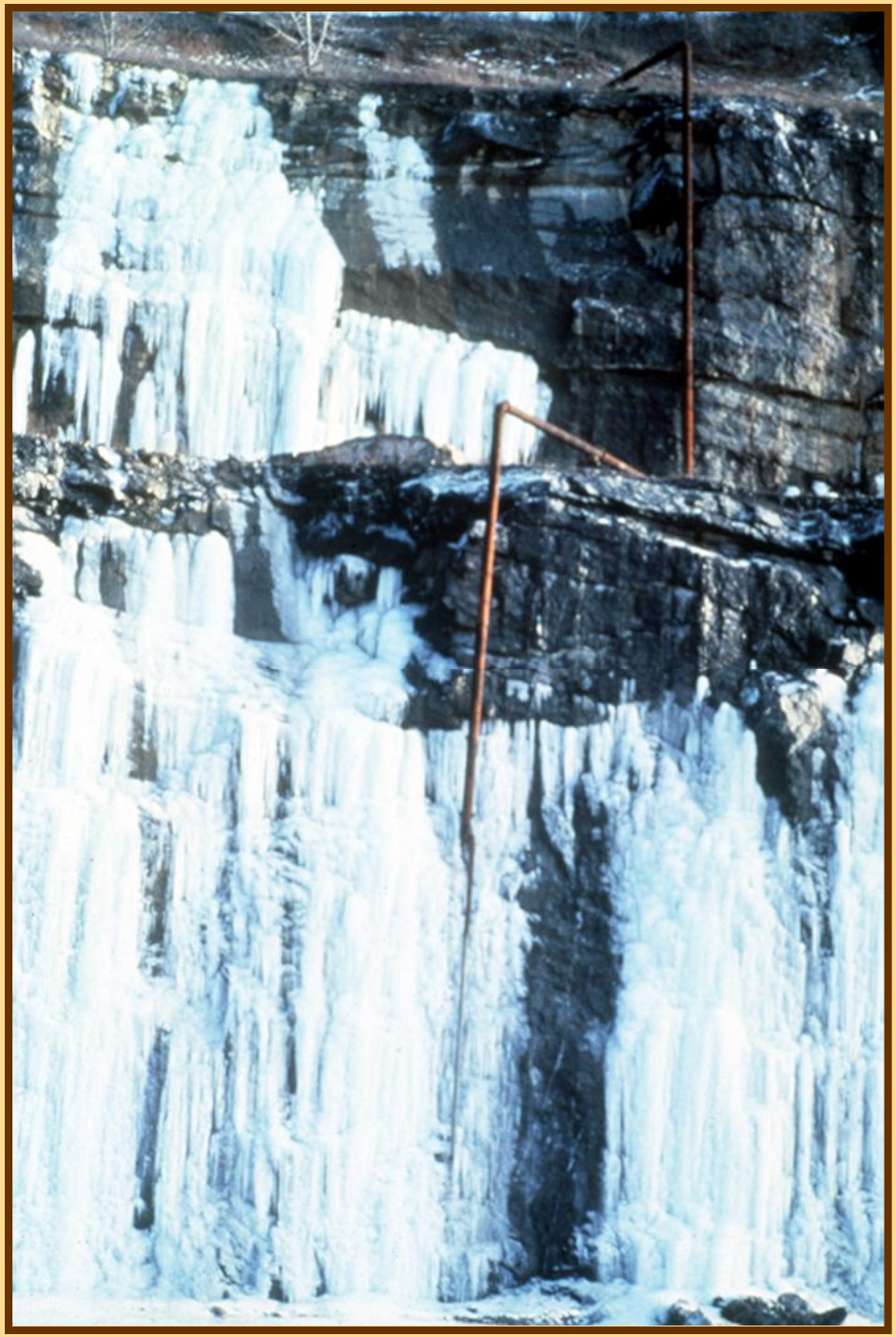
Water Seepage

Seepage is often a contributing factor to highwall failures.

<u>Effects of Seepage:</u>

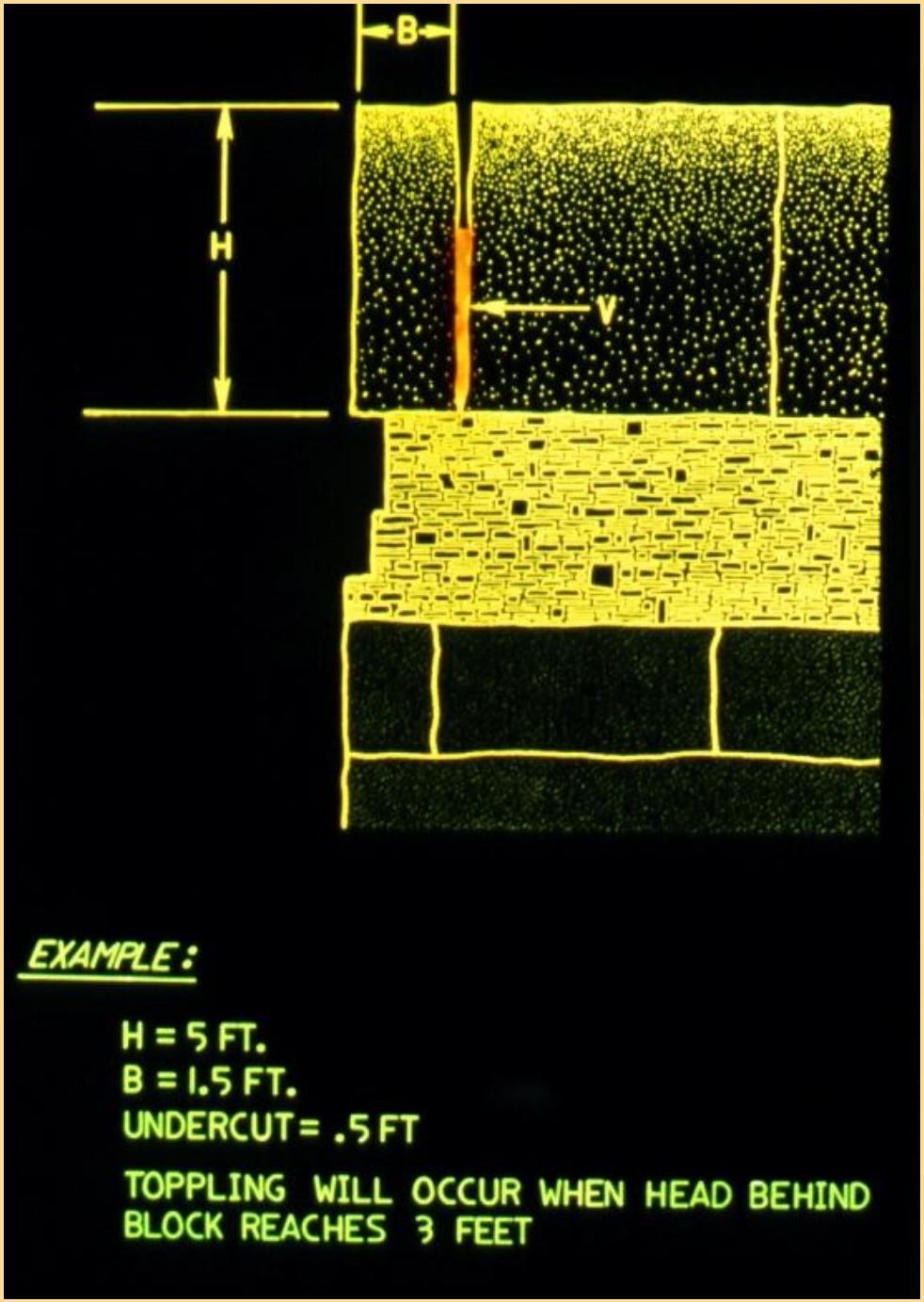
- **Creates driving force in joints**
- **Erodes supporting material**
- **Reduces strength of soil/rock**
- **Adds weight to the potential sliding mass**

Seepage on Highwall Face



Ice Is A Common Sight On Highwalls In The Winter

- Ice can cause freeze/thaw damage, restrict water flow to increase pressure and increase the weight of sliding masses.



The Effect Of Water

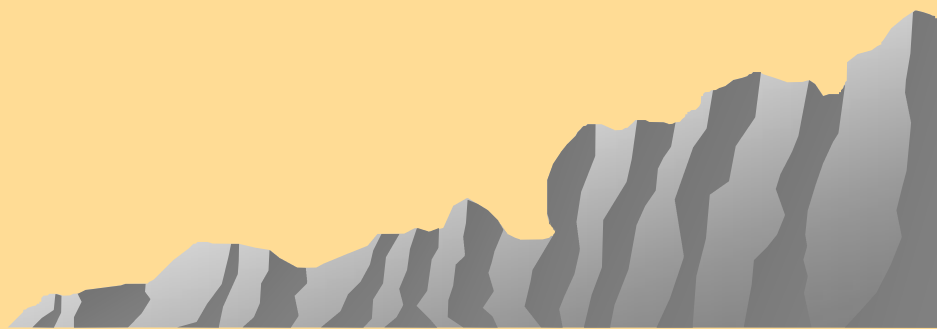
Study the diagram:

- **Note the structure, dimensions and how little it takes to move blocks.**
- **Think about what a common occurrence this is, or could be, in <u>your</u> quarry.**

Eliminating Highwall Hazards

- **Recognizing The Hazard - through a better understanding of highwall geometry, highwall composition, and highwall failure modes.**

- **Remediation Of The Hazard – through the application of protective measures intended to either prevent exposure or prevent failure.**



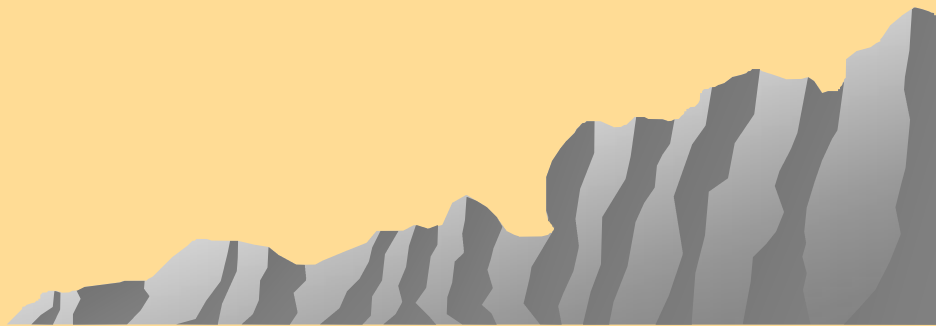
Recognizing the Hazard

What is a highwall failure?

- A highwall failure is generally the unintended loss of material from a highwall.
- Basically two types of highwall failures:
  - Rock Mass Failures – involves a relatively large amount of material on a large portion of a highwall. Material and structure are controlling factors.
  - Rock Falls – involves a small number of individual rocks on a small portion of a highwall.
- Volume of material involved and exposure contributes to the hazard.

Signs of Potential Stability Problems

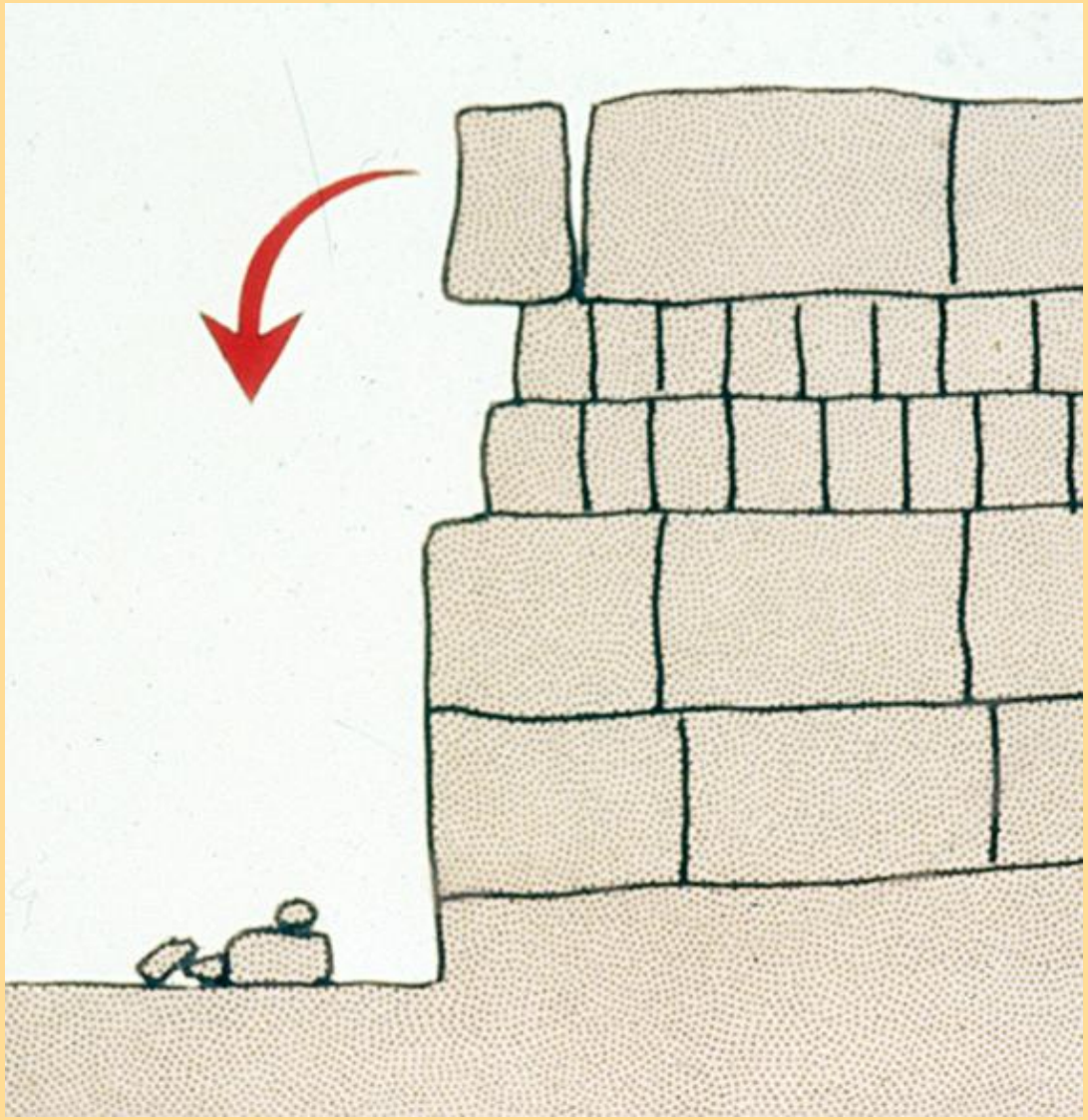
- Cracks behind the highwall crest
- Vertical displacement of the highwall crest
- Vertical cracks through the highwall face
- Fallen rock or fines piles at the highwall toe
- Bulging at the highwall toe
- Active raveling



Highly Fractured Rock Mass

Rock Mass Failures

Rock Falls



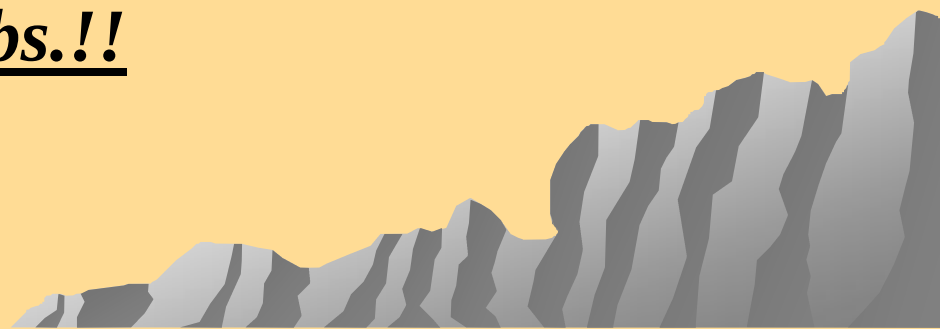
Intact blocks of rock on a fractured highwall are susceptible to falling since they are unconfined and usually not well supported.

Energy of a Rock Fall

- **The ANSI (American National Standards Institute) hardhat standard (ANSI Z89.1) stipulates that an 8 lb. steel ball dropped a distance of 5 feet must result in a hardhat deflection of less than 0.5 in.**

- **The kinetic energy of the steel ball in this standard is 40 ft.-lbs.**

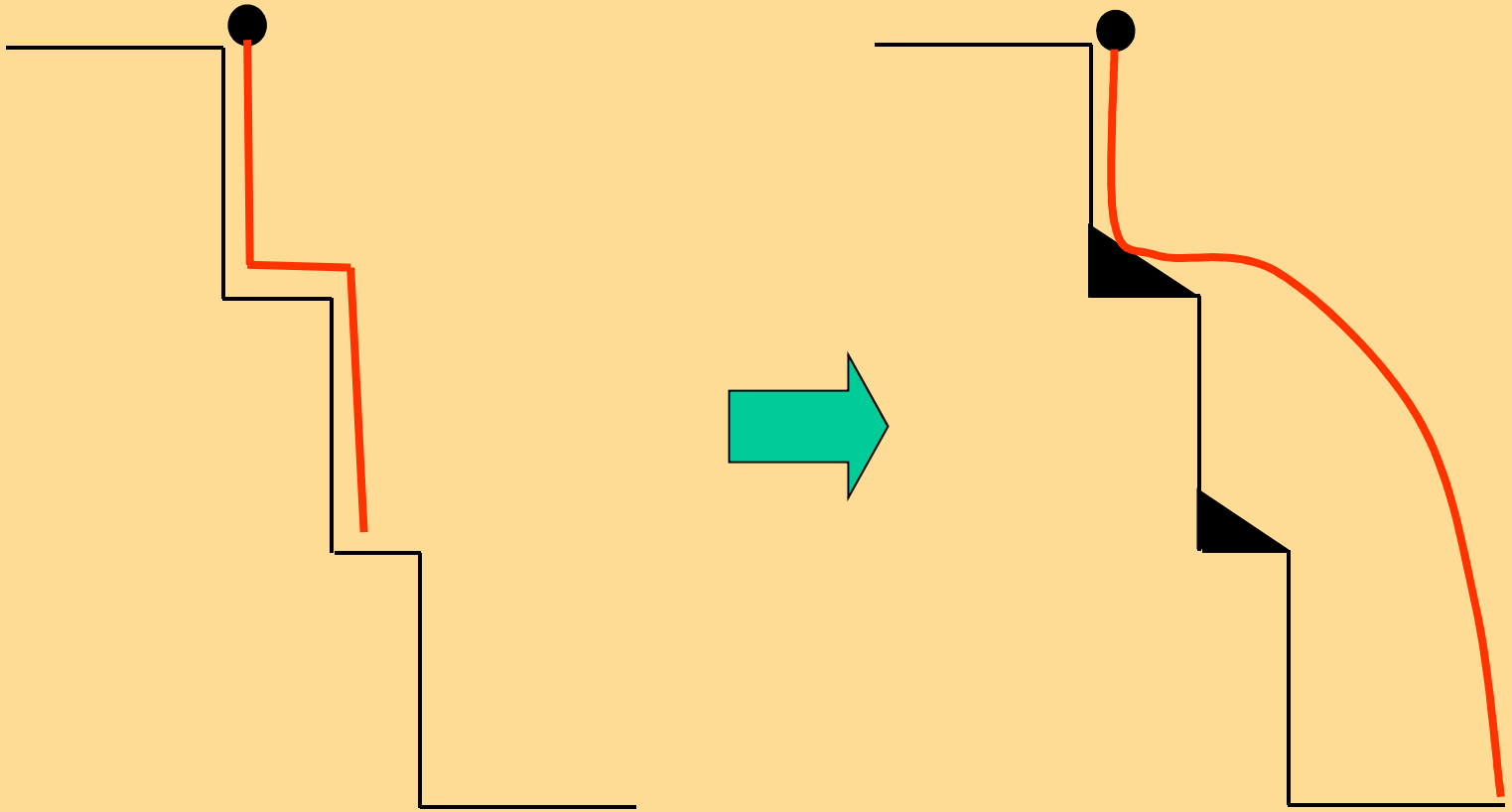
- ***For comparison, a 3 in. cube of rock falling 50 feet has a kinetic energy of 125 ft.-lbs.!!***



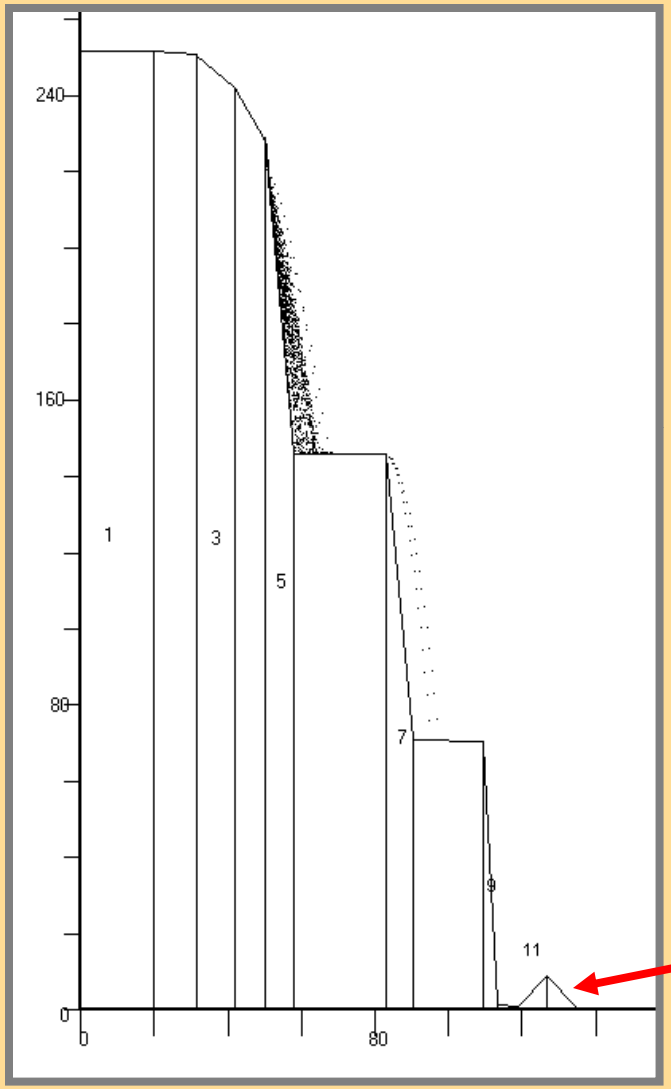
Look at the wall beyond the rock fall, then, look at the planes/dips behind the fall.

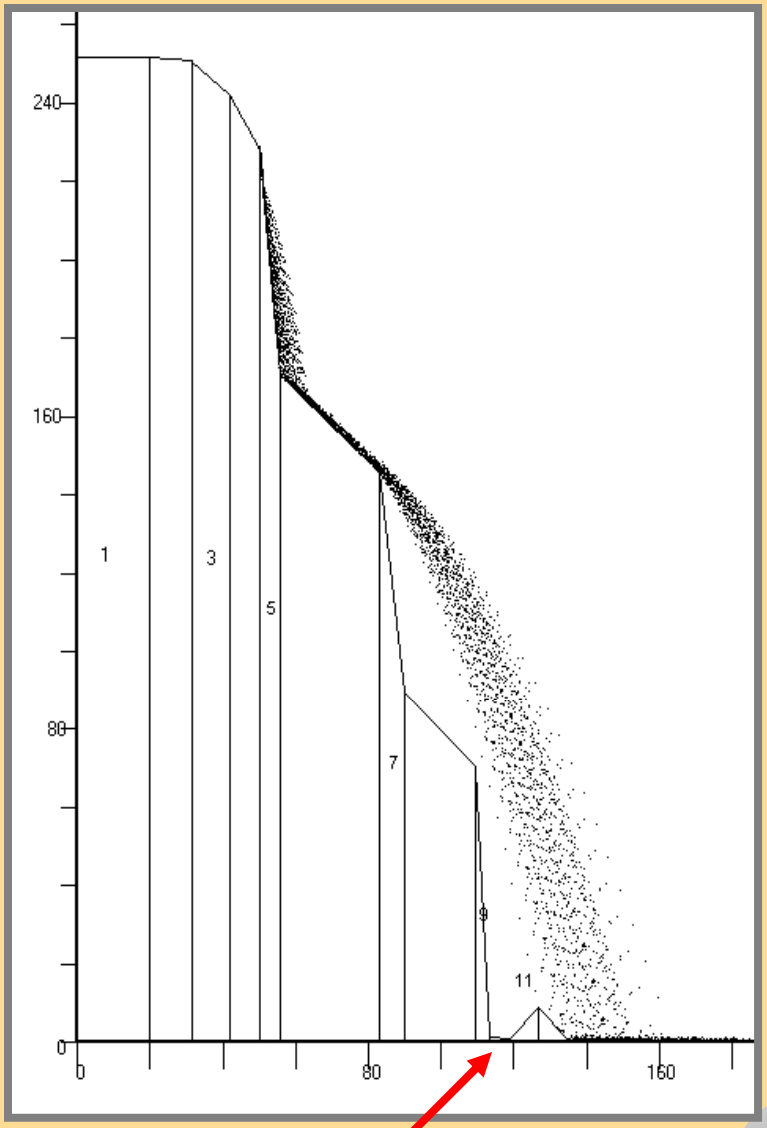
Highwall Geometry

The Problem of Full Benches



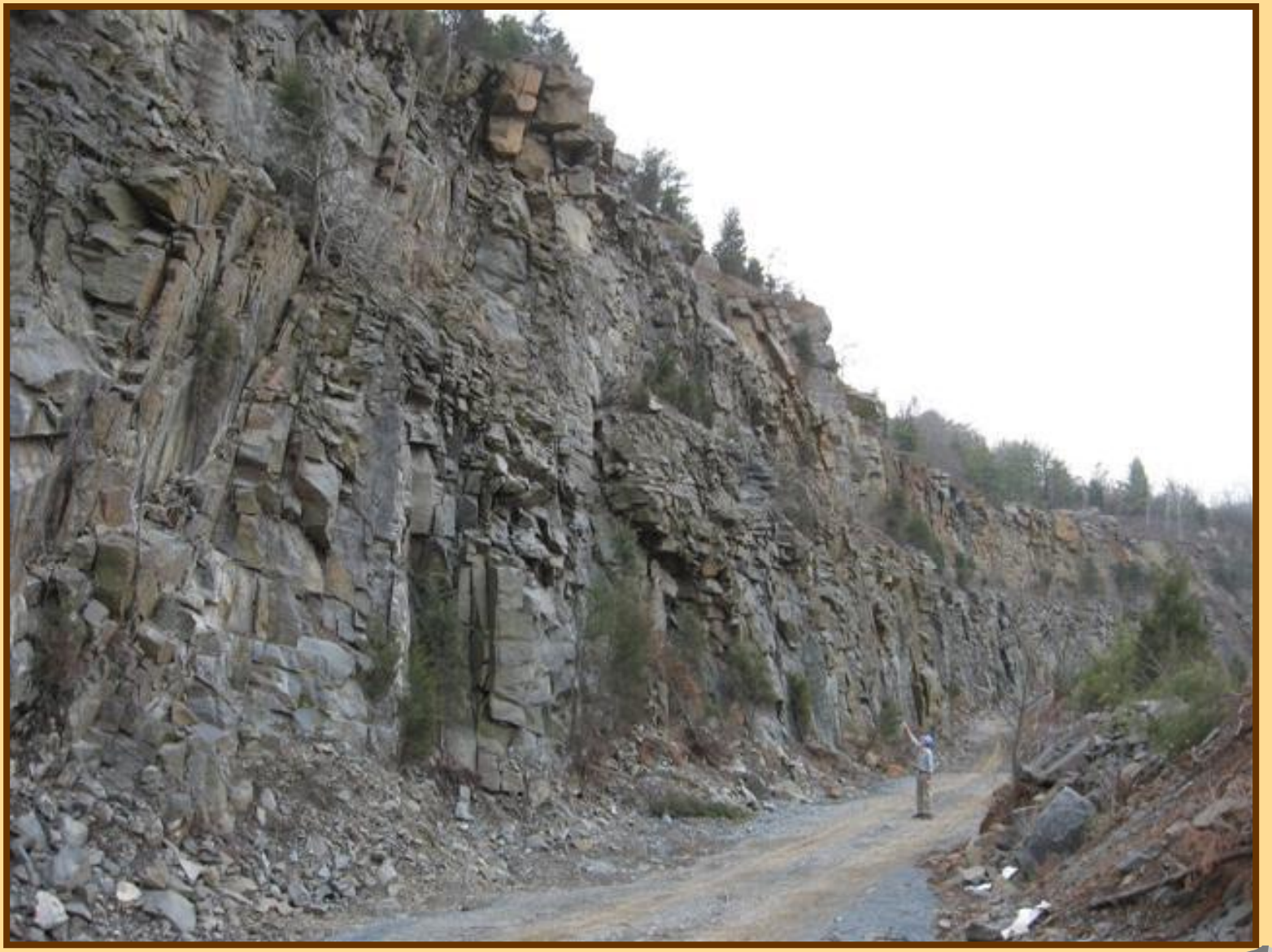
Another View





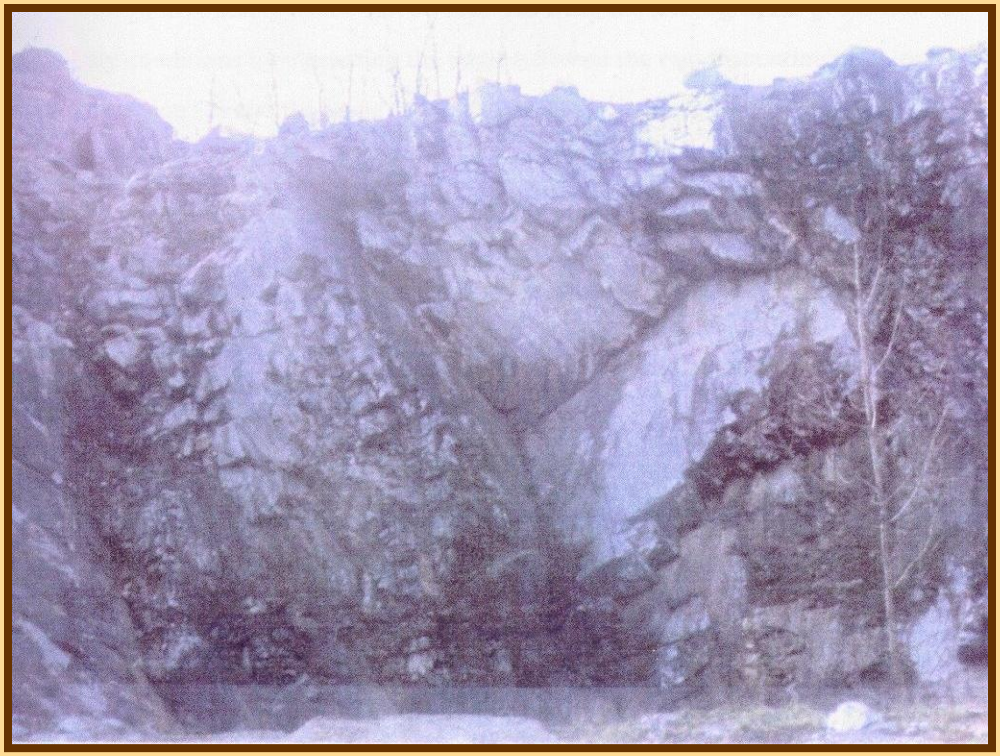
Catch berm/ditch

What's the problem here?



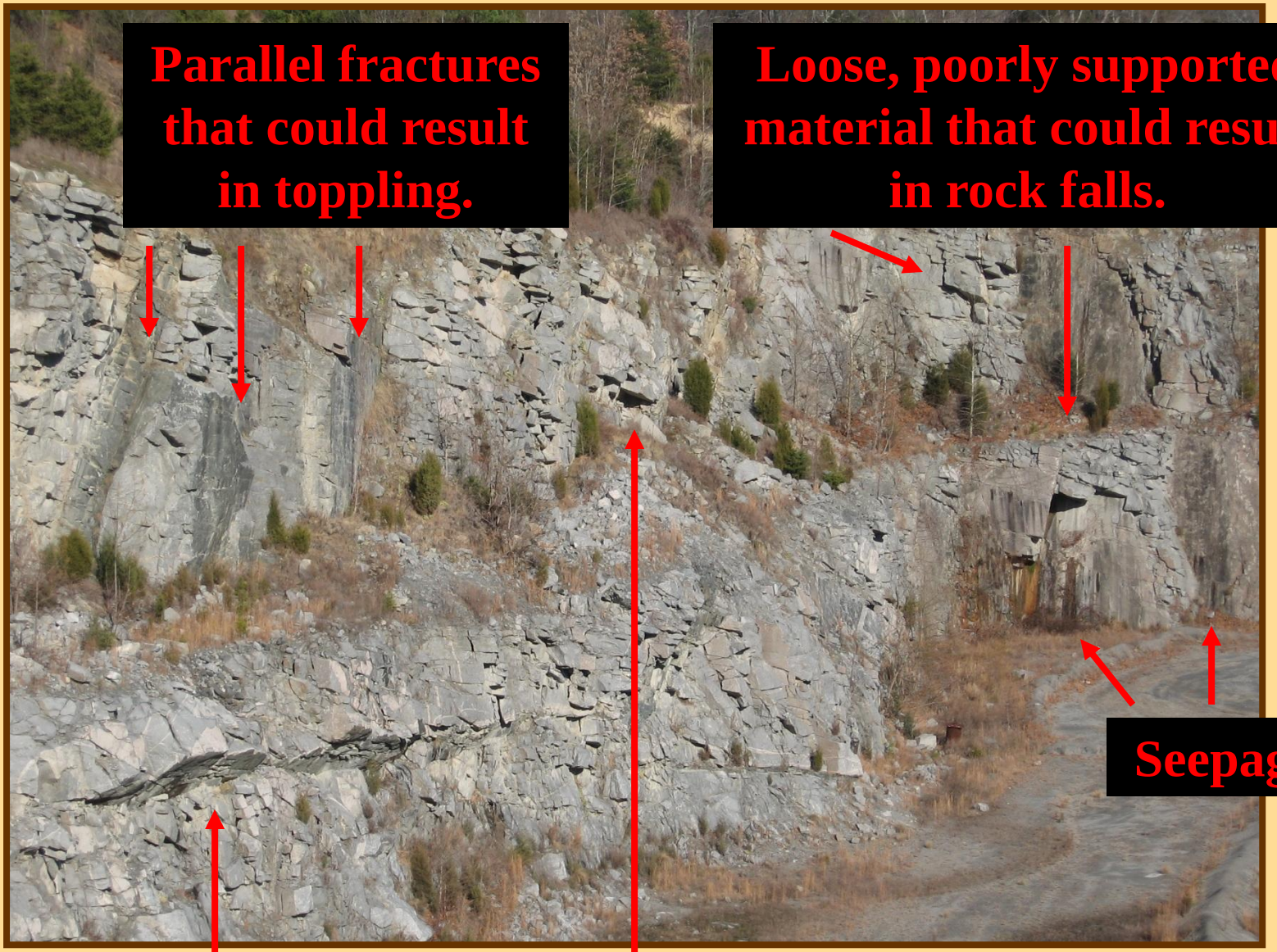
Evaluate this wall along with the inspector. What rock structures and hazards do you see?

Fractures running somewhat parallel to wall and some leaning toward quarry. Toppling?



Evaluate these areas for structure type and hazards

Carefully evaluate this area.



Dip running away from the quarry. Favorable.

Dip running into quarry. Unfavorable.

What are the dangers here? What precautions need to be taken?

Before moving back into the <u>inactive</u> area, what should be done to ensure the safety of the walls and benches?

What key areas need to be watched here? What should these operators be trained to look for?

How safe are these operators and their equipment?

Who is responsible?

Remediating The Hazards

Highwall Stabilization And Protection Measures

Stabilization Measures

Reinforcement:

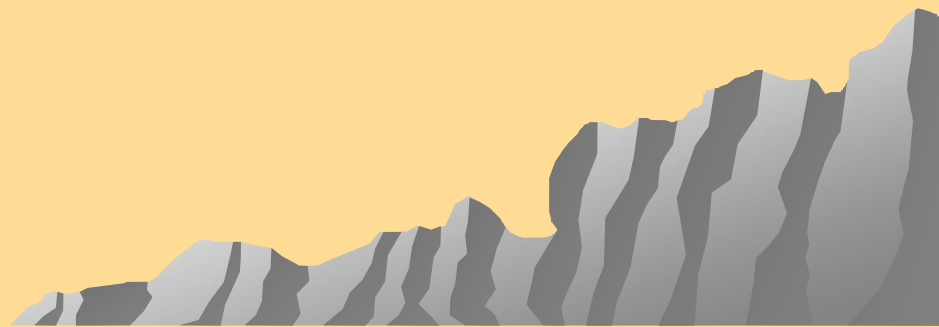
- Rock Bolting
- Dowels
- Shotcrete
- Buttresses
- Drainage

Rock Removal:

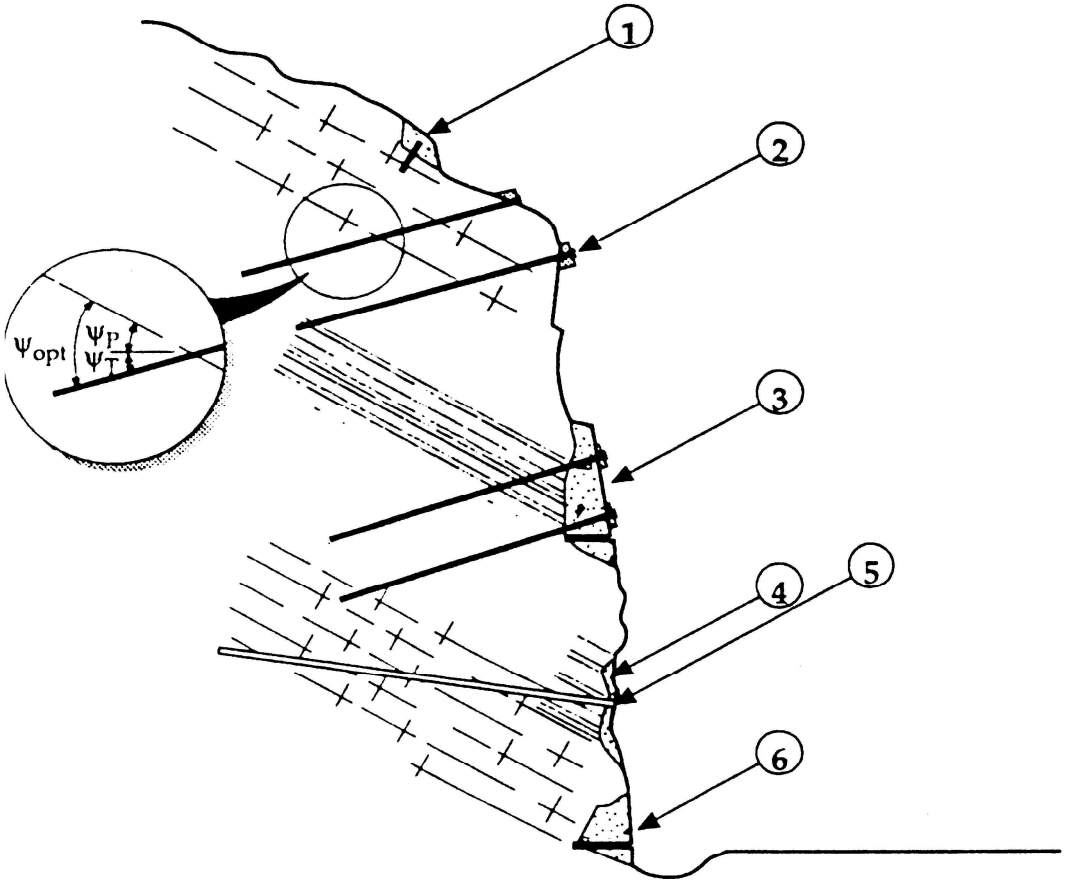
- Re-sloping
- Trimming/Pre-splitting
- Scaling

Protection Measures

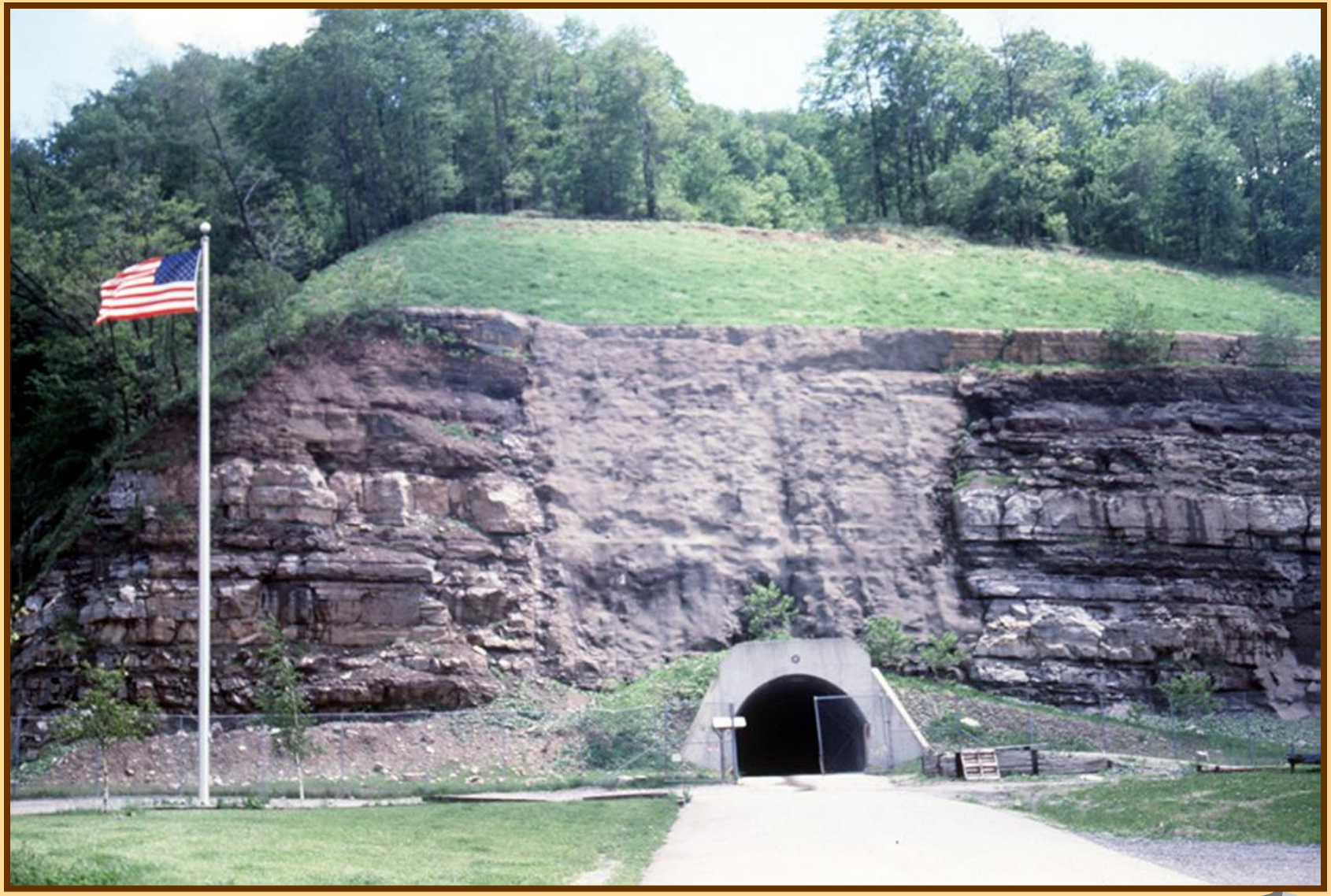
- Ditches
- Berms
- Wire Mesh
- Catch Fences
- Equipment Positioning
- Monitoring



Rock Reinforcement Methods For Highwall Stabilization



1. Reinforced concrete dowel to prevent loosening of slab at crest
2. Tensioned rock anchors to secure sliding failure along crest
3. Tieback wall to prevent sliding failure on fault zone
4. Shotcrete to prevent raveling of zone of fractured rock
5. Drain hole to reduce water pressure within slope
6. Concrete buttress to support rock above cavity

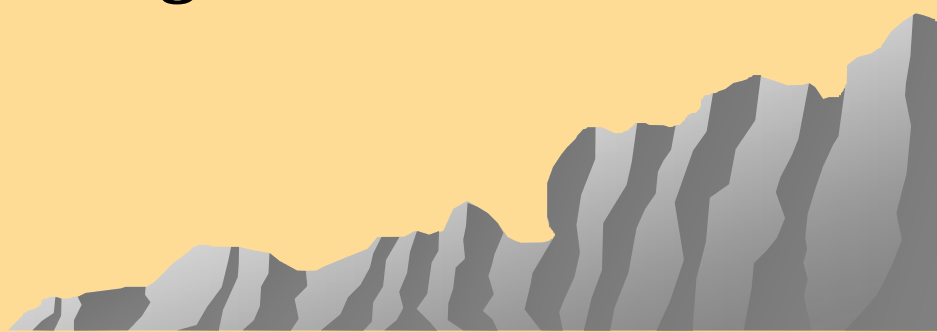


Shotcrete Face

Drainage

If a water problem is expected, defensive measures can be taken:

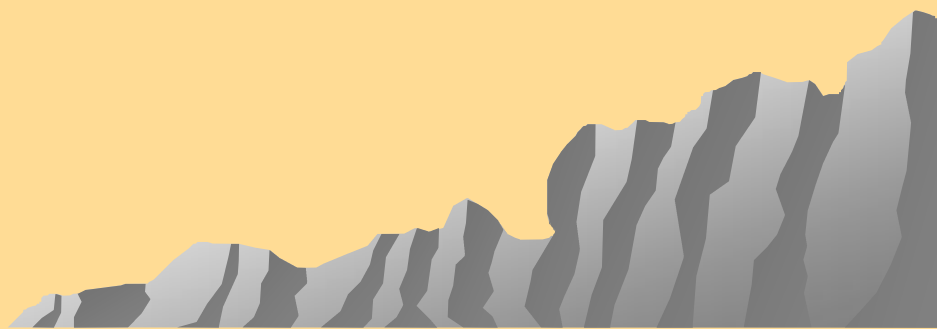
- **Grouting to prevent infiltration**
- **Diversion ditches above the highwall to prevent surface runoff**
- **Vertical wells behind the highwall crest**
- **Horizontal drains in the highwall face**



Rock Removal

- **The goal of rock removal is to remove potentially loose/dangerous rocks from the face of the highwall.**

- **Rock removal is preferred over rock reinforcement when a stable face can be achieved.**



Pre-Splitting Highwall

Mechanical Scaling

- Mechanical scaling is generally considered to be scaling by heavy equipment.
- It is the method generally used in our part of the country.
- It may not be very selective and will generally only remove excessively loose material.
- It may also cause damage to the highwall, creating more loose material in the process.
- Dragging the face of the highwall with a chain or similar object is marginally effective at best.

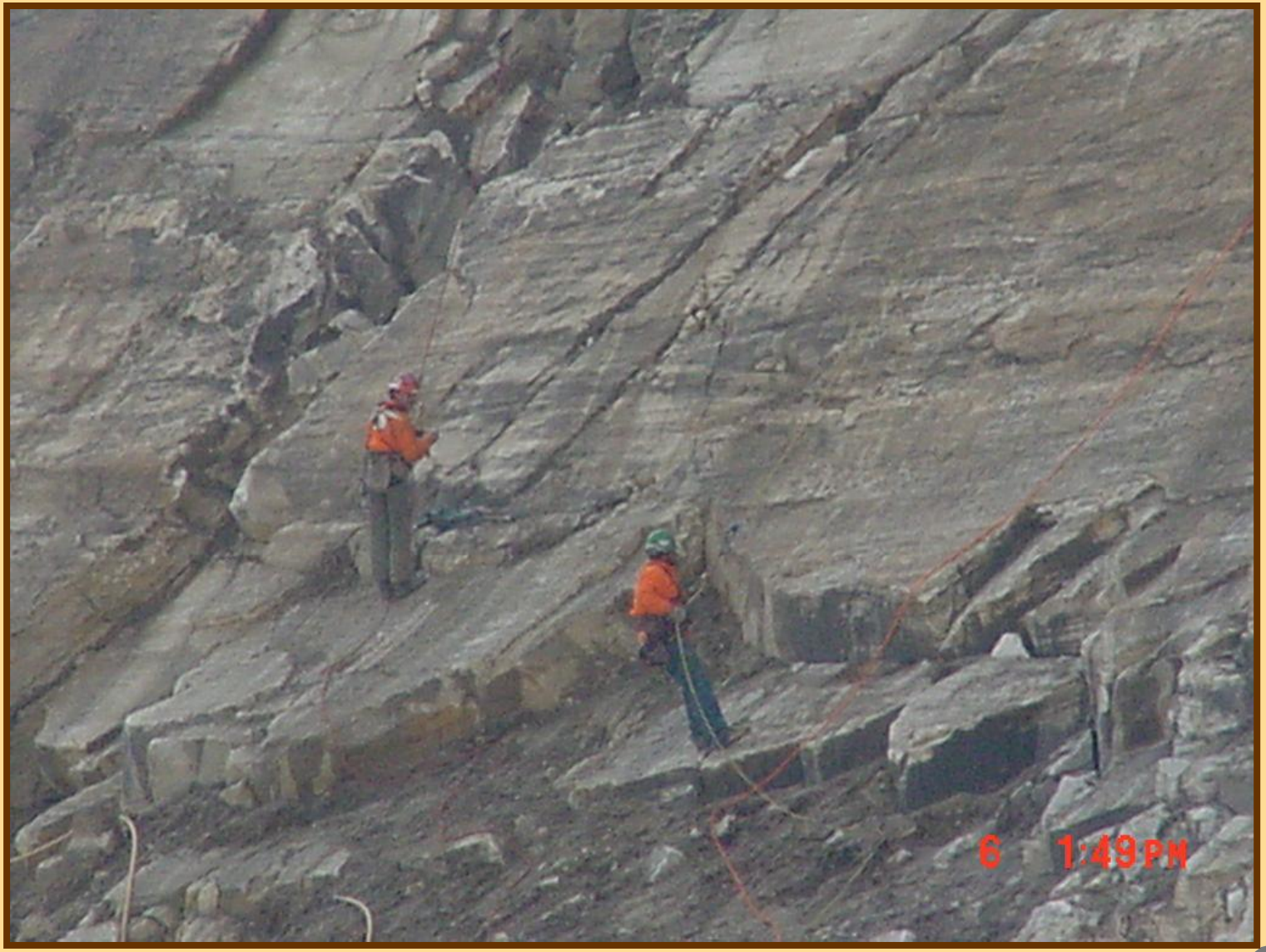
Dragging the Face

Scaling With A Crane

Scaling With An Excavator

Manual Scaling

- Manual scaling is generally considered to be scaling with hand tools.
- It is very selective and can be very effective with trained scalers.
- It can be labor and time intensive depending on the condition of the face and, therefore, costly.
- The positioning of personnel and equipment must be carefully considered.
- Rarely done in this part of the country and only in extreme cases. However, the practice is growing here.



Scalers Supported By Ropes

Protection Measures Most Commonly Used In Mining

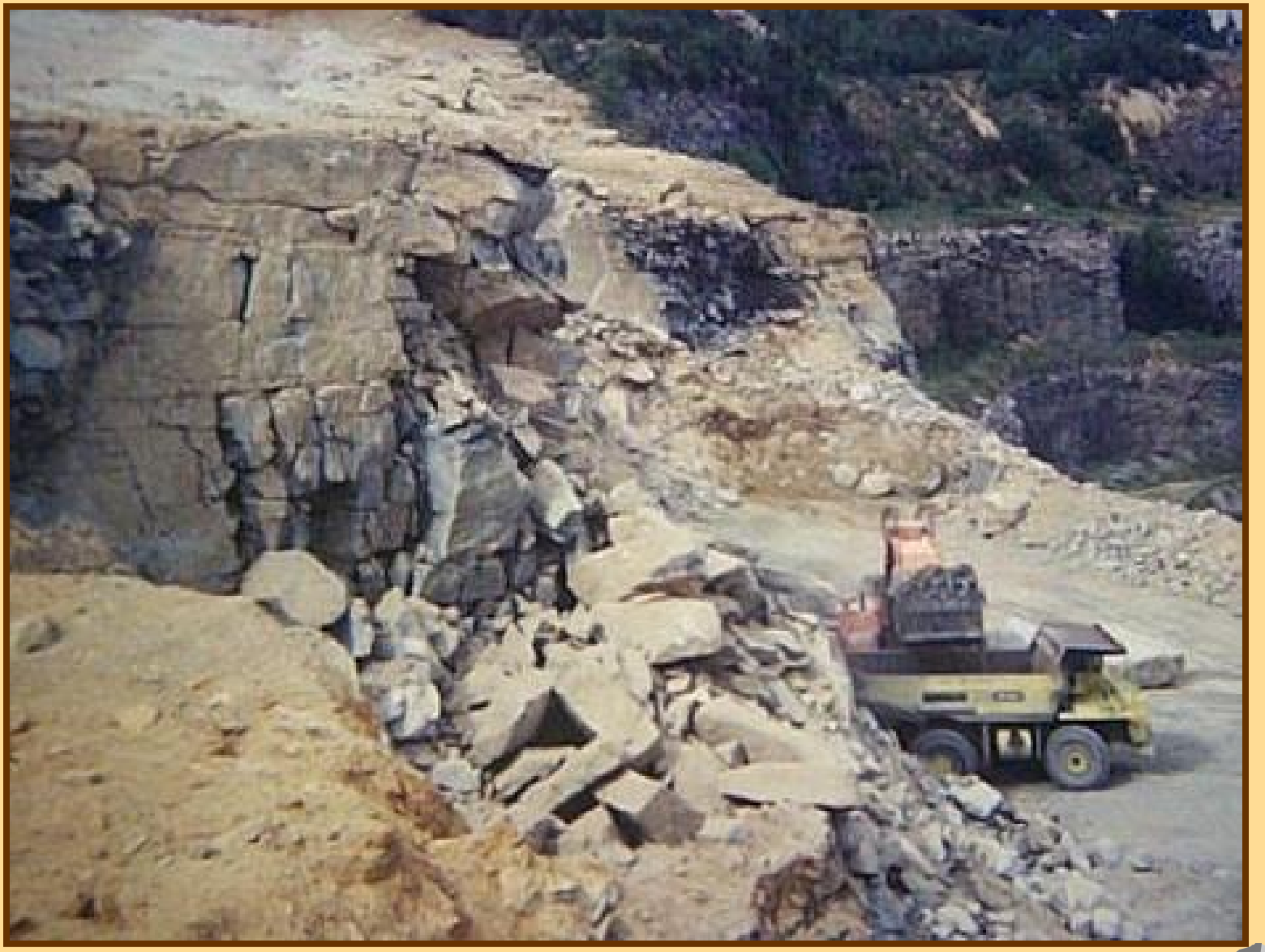
- Examination
- Restrict Access
- Equipment Positioning
- Benches
- Berms, Ditches
- Instrument Monitoring, Computer Modeling

Examination Of Ground Conditions

- A critical first step in protection.
- A key element in pre-shift, pre-operational and work area inspections.
- Regular, thorough examinations help identify potentially hazardous areas and developing conditions.
- Highwalls and benches should be examined from all possible angles.
- Particular attention should be paid to the toe and crest areas.

Does anything need to be done here?

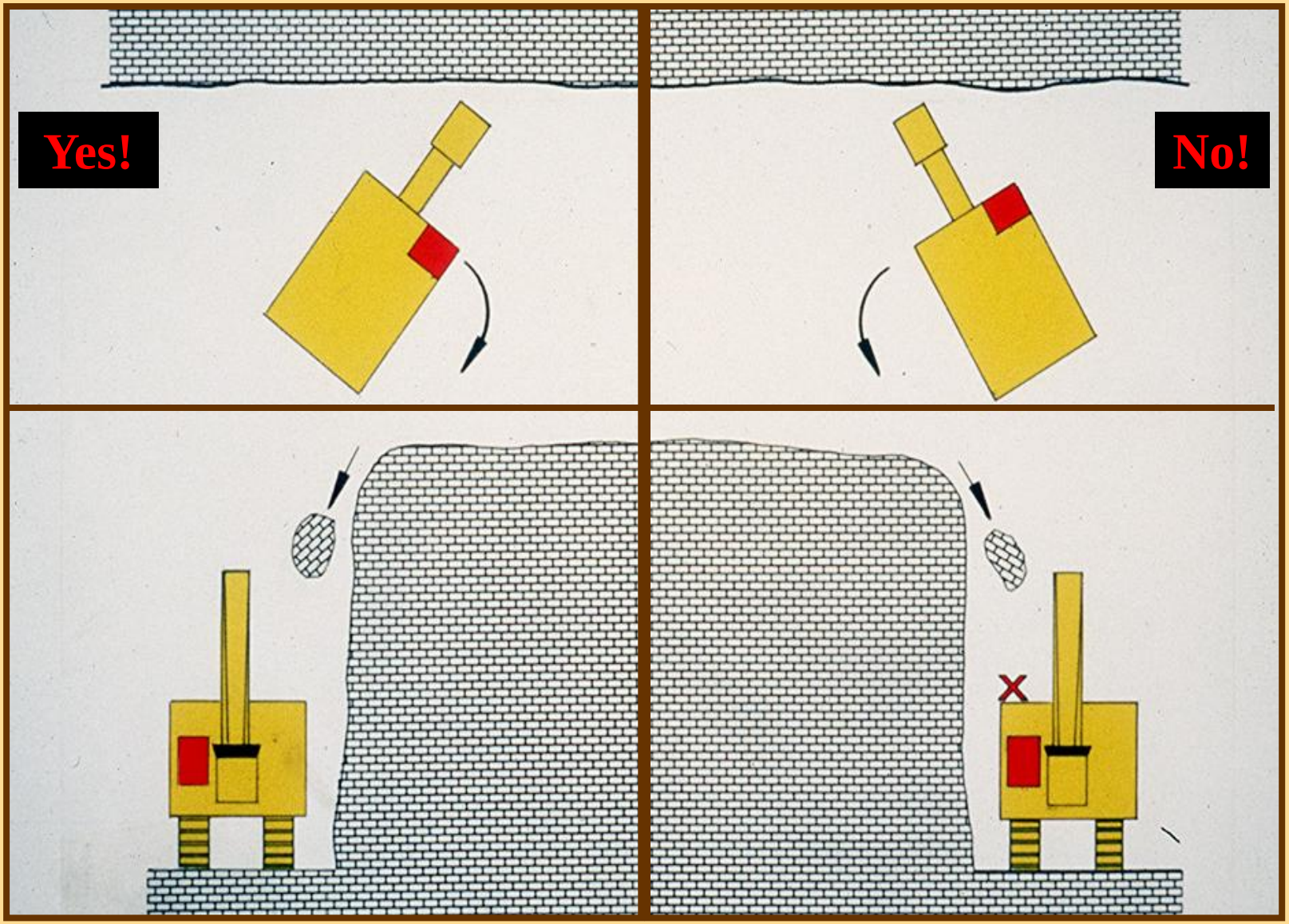
What would make this situation safer?



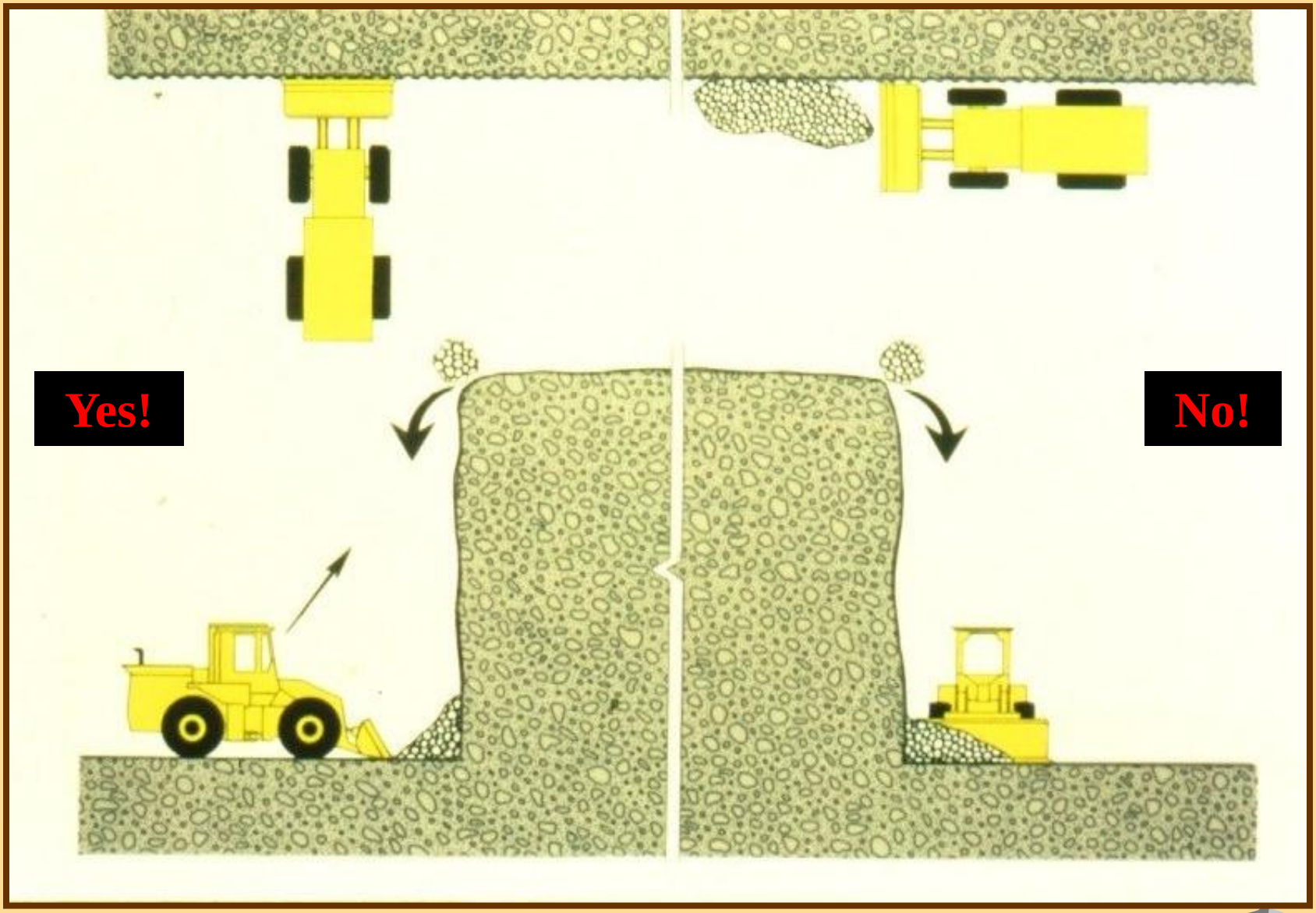
Who is responsible for finding and removing this hazard?

Warning Signs And Barriers To Restrict Access

- Barriers should be adequate to mark the area
- Signs should indicate the hazard



Equipment Positioning



Keep cabs away from highwalls!

Benches

Evaluate these operations

Berms

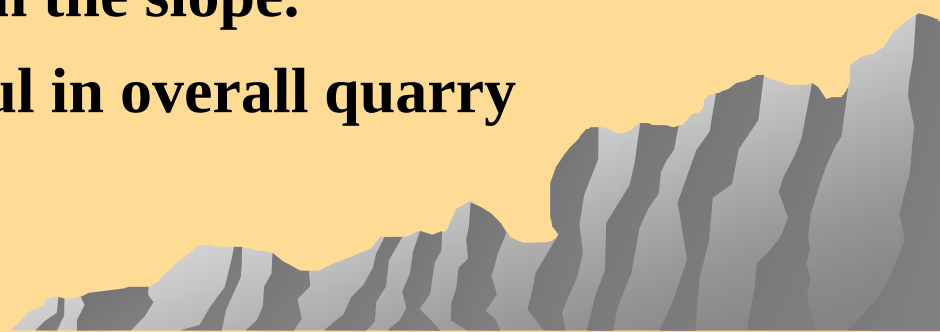
- Berms can effectively be used to control rock fall hazards.
- Berms create a catch basin to contain falling material.
- Berms are also an effective barrier to keep personnel out of an area.
- Berms must be properly sized and located.
- Berms must be maintained.

Berm is containing material, <u>but</u>, will need maintenance soon to remain effective!

Highwall Instrument Monitoring, Computer Modeling

Monitoring the highwall with the aid of instruments and using computer modeling to predict highwall performance is helpful in extremely unstable areas.

- **Provides advance notice of instability allowing for the timely evacuation of personnel.**
- **Provides information on the extent and rate of failure to help identify appropriate remedial measures; modify the mining plan, or redesign the slope.**
- **Provides information useful in overall quarry development.**



Does Anyone Want To Take This Miner's Place?

Ground control issues aren't just in the quarry!!

Stockpile faces shall be trimmed to prevent hazards to personnel.