
Geology



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The module is an example of the technical assistance the Federal government furnishes States to assist them in meeting the requirements of the Surface Mining Control and Reclamation Act of 1977, upon which their State surface coal-mine regulating programs are based. In particular, the module was requested and will be used by the Sheridan District Office, Wyoming Department of Environmental Quality, Land Quality Division.

A word of caution: please note that **this module is not intended to stand alone, nor is it a self-training type module.** Rather, **the information the module provides MUST BE SUPPLEMENTED** by information given by a certified blasting instructor.

DISCLAIMER

The technologies described in the module are for information purposes only. The mention herein, of the technologies, companies, or any brand names, does not constitute endorsement by the U.S. Department of the Interior's Office of Surface Mining.

Geology

This module presents information regarding fundamental rock properties and the geologic structures encountered during blasting operations. Geology can vary widely and has a great impact on drilling and blasting efficiencies.

A blaster should understand the properties of the different types of rock he or she intends to blast. Typically, rock “properties” are described in terms of composition and structural characteristics.

The methods selected to drill blastholes, the type and placement of explosives, the layout of blastholes or the drilling pattern, and the type of initiation system all are greatly influenced by rock type and structural geology.



Highwall cut showing horizontal bedding planes cut by inclined joints that offset beds in the limestone.

Rock Classification and Properties

Rock Classification

Rocks are classified according to three types:

- sedimentary,
- igneous, and
- metamorphic.

Rock Properties

Strength.—A rock's strength is defined as the maximum load it can bear at the point of failure,



which is when the rock fractures and can no longer support a load.

Some rocks near the ground surface are exposed to weathering processes that chemically break down the minerals and reduce rock strength. Deeper in the earth, the rock may not be chemically altered and will have a higher strength. The type and amount of explosives needed to fracture surface rock and subsurface rock may be very different. Stronger, more competent rock requires an explosive with high energy output, higher density, and generally higher cost.

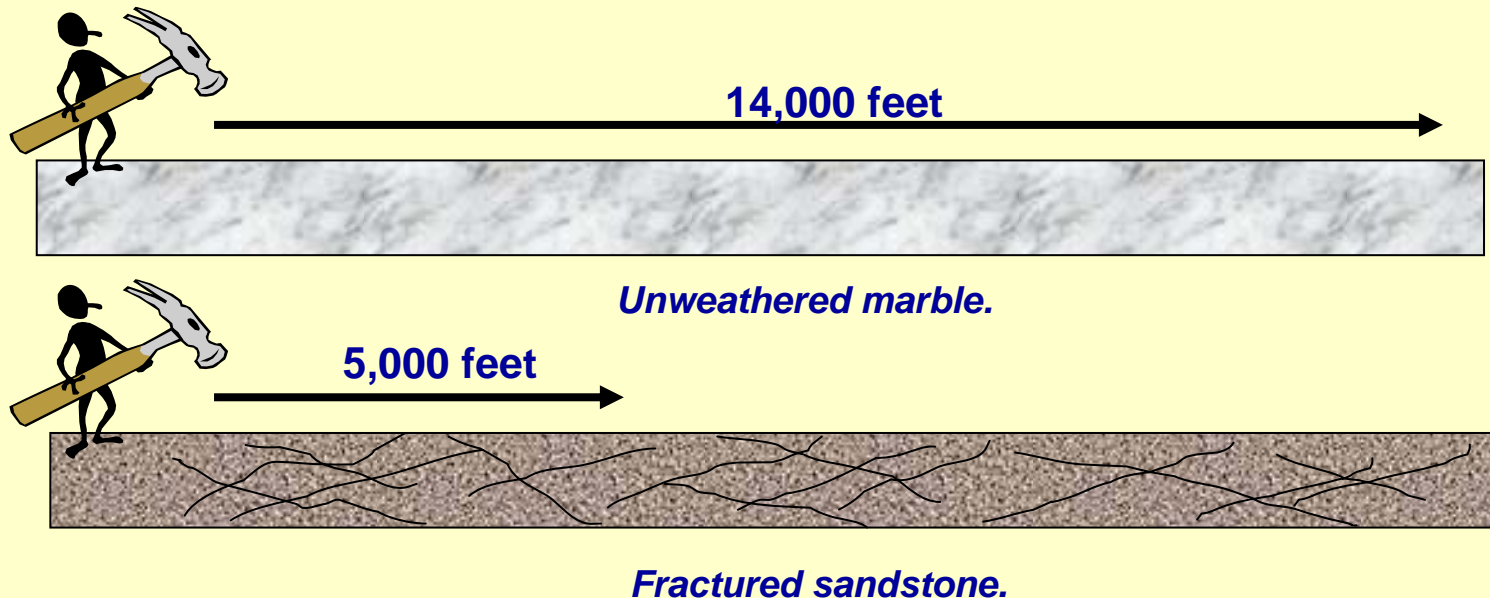
Bulk density.—The bulk density of a rock is defined as the specific gravity of the rock or the ratio of the rock mass to water at a constant volume. Density is a function of the minerals present in the rock, as well the ratio of solid mineral grains to open pores such as small voids and micro-fractures. In general, the greater the rock density, the higher the explosive energy needed to break the rock.

Rock Properties

Sonic-wave speed.—The sonic-wave speed of a rock is defined as the speed of sound in the rock or the velocity of a compression wave traveling in it.

The more competent the rock (with less weathering and greater density), the higher the speed of a compression wave traveling in it and the greater the explosive energy needed to break the rock.

The illustration below compares the typical *distance* it might take for a sound wave, generated by the impact of a heavy hammer or an explosive detonation, to travel in *1 second* inside solid marble (top) and highly weathered and fractured sandstone (bottom).



Field Exercise: Dynamic Rock-Loading Using a Hammer

The next time you go into the field, carry a heavy hand-held hammer with you. Make sure you wear safety glasses and protective clothing.

Select small, solid rocks (about 6 inches in size) of various types and degrees of weathering. Give each a good whack with the hammer. How does it feel and sound?

Striking a competent rock that is not easily broken will create a high-pitched “ping,” and the sound will ring for a short time. The hammer will recoil quickly and might even bounce off the rock surface.

Look closely at the impact surface of a competent rock. Is it still smooth and unmarked or have you created dust particles of crushed rock? How much “damage” have you created on the surface?

On the other hand, striking a highly weathered and weak rock may impart a dull, shallow “thud” and result in fracturing. The rock may have a preexisting flaw or small fractures that are not visible to the eye. Impacting the rock may cause the fracture to open, resulting in fragmented pieces.

Examine the fractured surfaces. Are they fresh and unaltered or are they stained with iron oxides (brownish-rust color), indicating weathering? Scratch the fractured surface with a pocket knife. Is it soft and coated with fine clays or other materials that are easily removed, or is it hard to scratch?

Just like the variation in responses to a hammer impact, the rock response to explosives can vary greatly. Understanding the energy required to fracture a given rock with explosives is key to efficient blasting.

Large-Scale Rock Properties



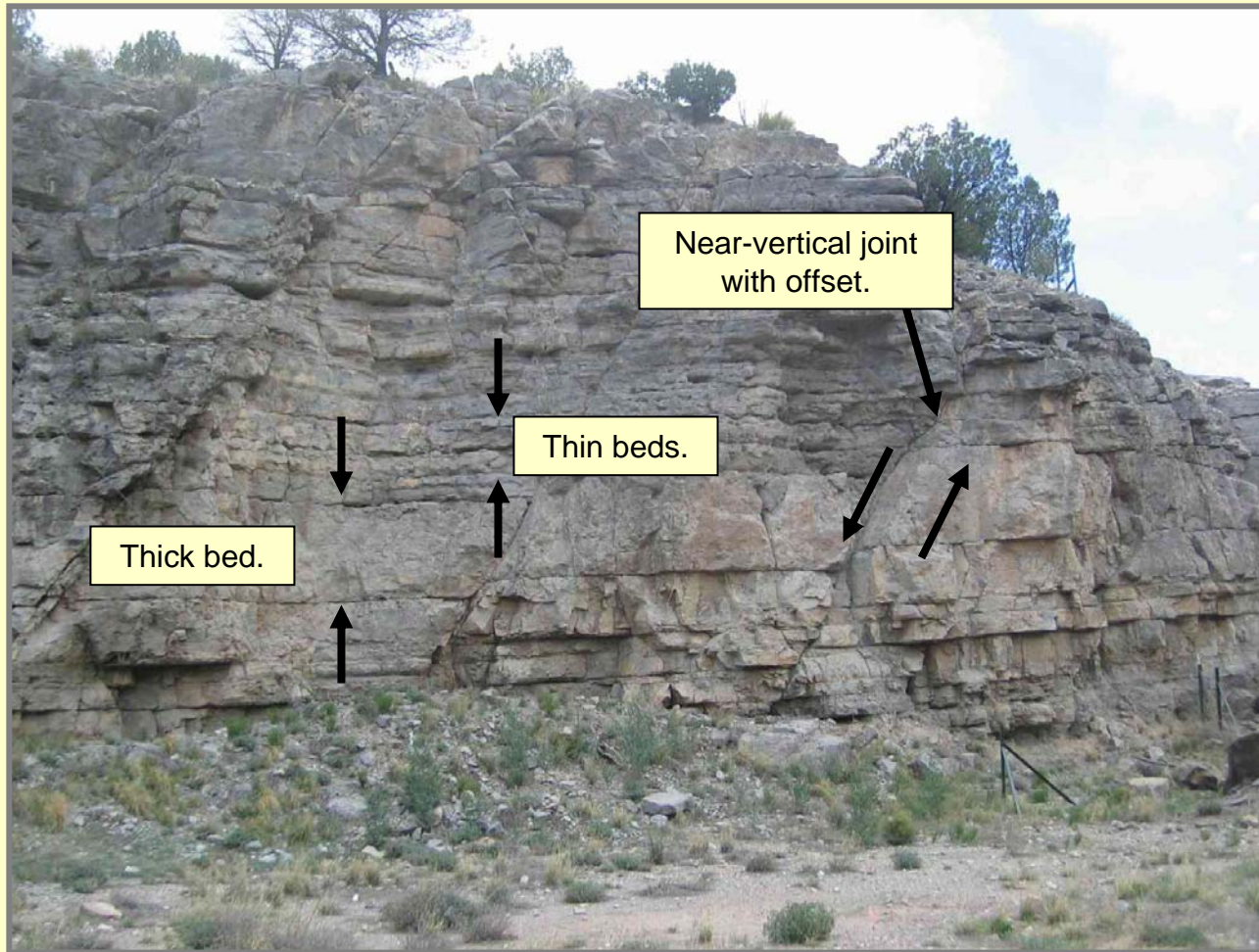
We often differentiate between the small-scale and the large-scale properties of rock. The small-scale properties are those that can be seen in a small rock specimen through a geologist's hand lens or with the naked eye. These are the properties that, in part, give the rock its strength, density, sound velocity, permeability (or ability for water to flow through the pores), and other attributes.

Just as important to rock breakage using explosives are the large-scale (or field-scale) properties of rock. These include the rock's:

- Bedding planes,
- Joints and faults,
- Stratigraphy (or the variation in different rock materials with depth),
- Hydraulic properties,
- Mud or clay seams, and
- Open voids.

These large-scale features often control the performance of explosives and the size of the blasted rock particles (termed fragmentation), as well as the direction and distance of rock movement during the blast. If explosives are loaded within zones of weakness—bedding planes, mud or clay seams, joints and faults—, the chances of flyrock and excessive airblast will increase.

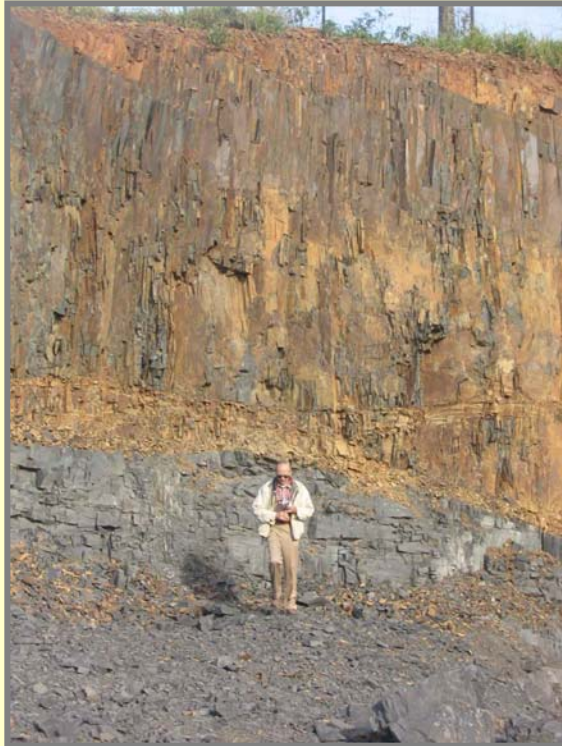
Large-Scale Rock Properties



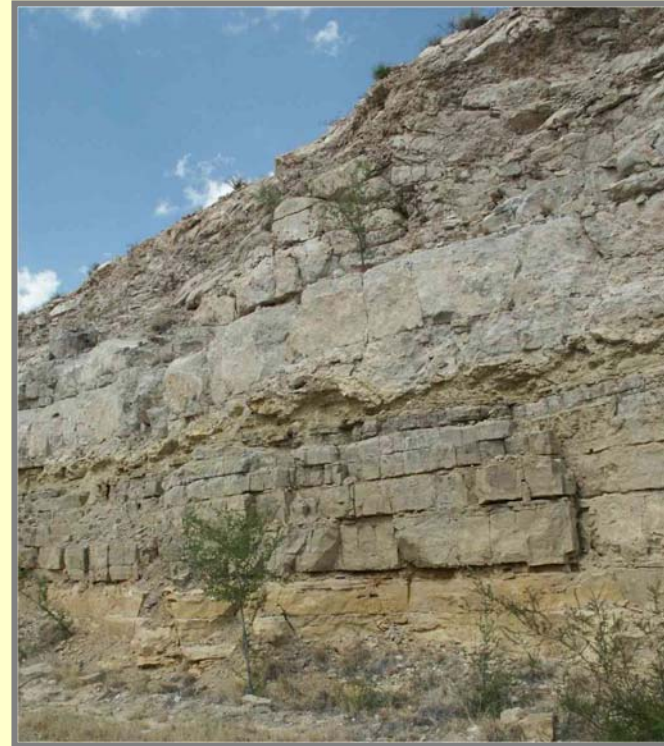
Photograph showing the difference between bedding plane and joints.

Large-Scale Rock Properties

The number of fractures per linear foot along a rock face and the spacing between fractures (either vertical joints or bedding planes) are important in projecting what the size distribution of fragments and the explosive-energy distribution within the rock mass will be. Widely spaced structures will reduce “blastability” (a function of the number of fracture planes over a given distance and the spacing between them), resulting in coarser fragmentation.

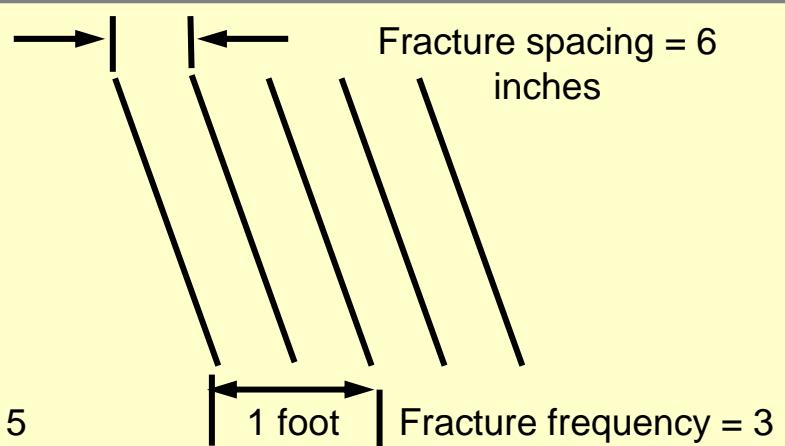
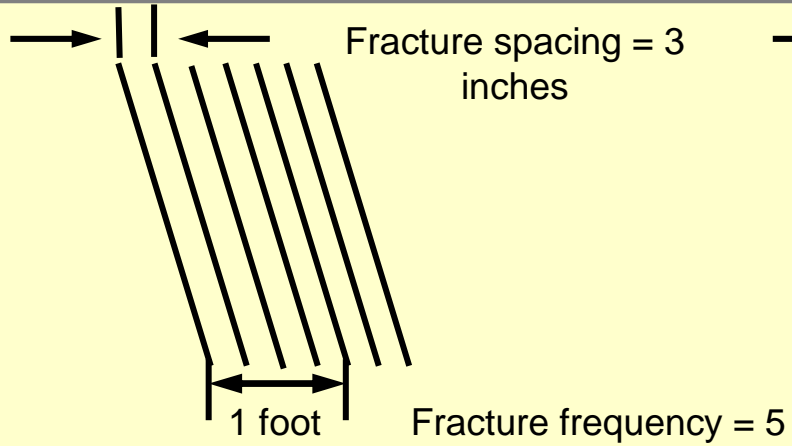
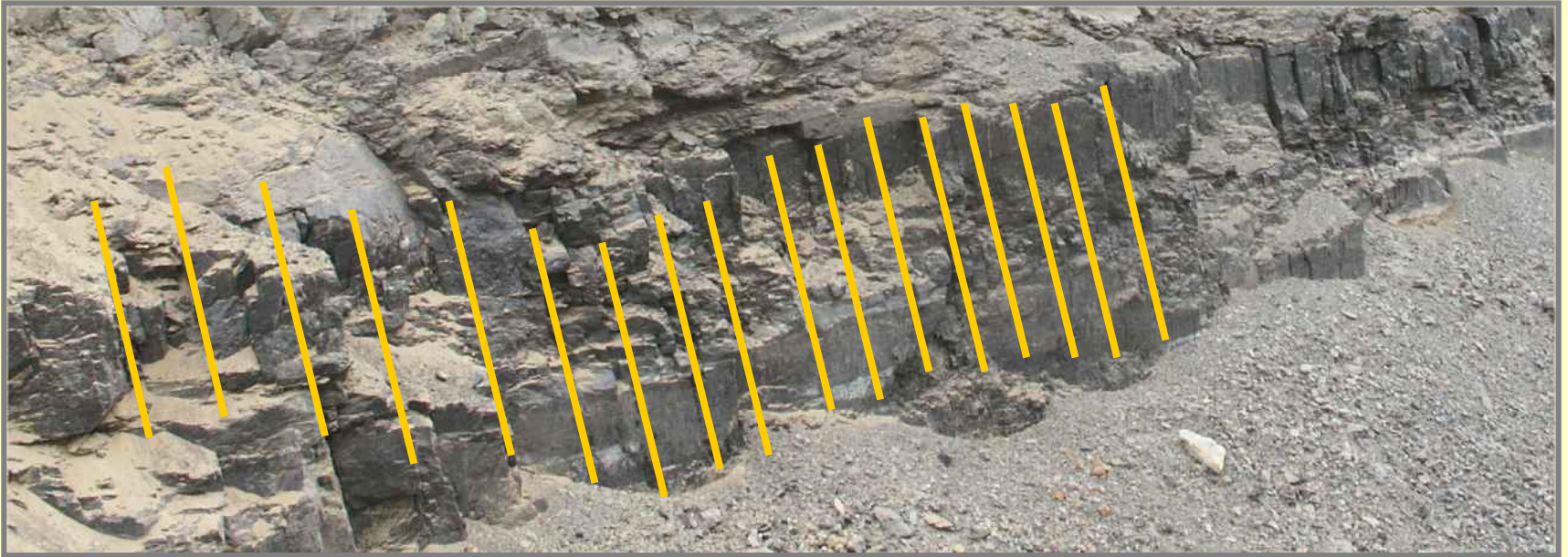


Photograph showing strong vertical jointing in a basalt flow.



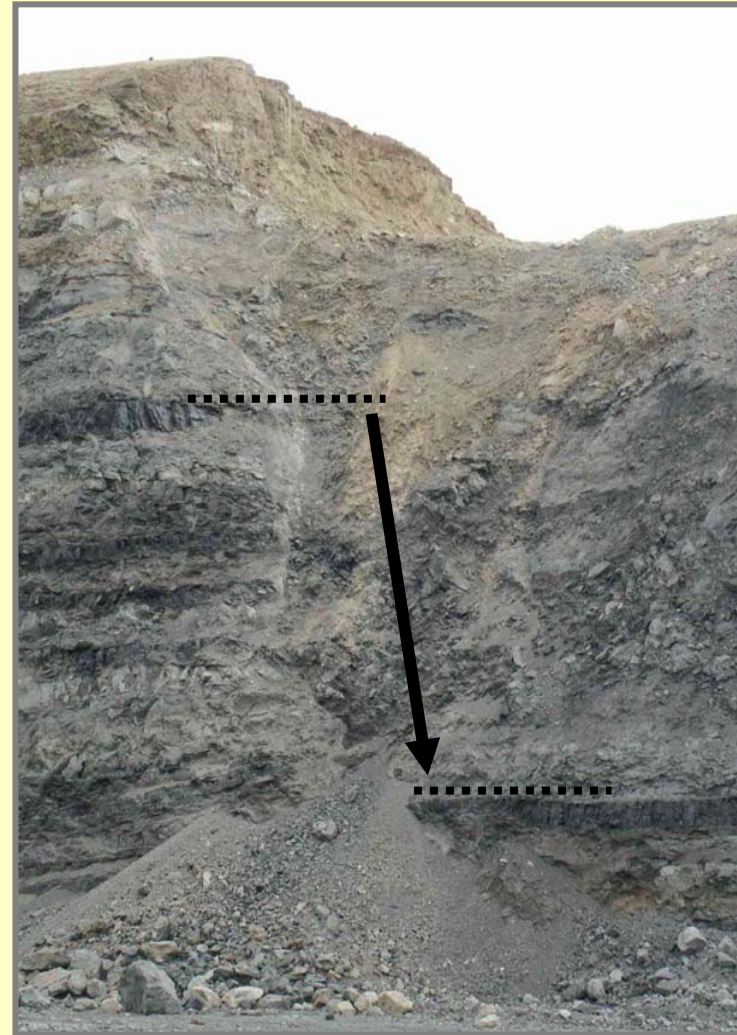
Photograph showing variations in thickness of limestone beds in a highway cut.

Large-Scale Rock Properties



Large-Scale Rock Properties

A large structural feature, such as the fault to the right, shows over 30 feet vertical displacement. In many cases, the variation in geological properties on either side of a fault can be dramatic. Lateral changes in geology, in particular any changes in rock strength or zones of weakness, require accommodation, usually amounting to modifications to the manner in which explosives are loaded into the displaced rock.



Large-Scale Rock Properties

Open joints that result from intense and deep weathering in a rock mass may cause a disruption in explosive-energy distribution. This may lead to a number of adverse consequences, such as the venting of explosive gases, airblast, flyrock, and the creation of large boulders in the muckpile.



Large-Scale Rock Properties



Photograph showing gas venting through fractures in the face.

Large-Scale Rock Properties

The uniformly spaced bedding and jointing at this quarry allows for a uniform distribution of explosive energy.

As a consequence, the fragmented rock resulting from a blast (shown in this photograph to the far right) is uniform in size.



Large-Scale Rock Properties



The blast (left) in the tight, far corner at this site produced large boulders from the caprock. Explosive energy lost through widely spaced, weathered joints (showing iron-stained) merely loosened the caprock in place. The caprock remained on top of the muckpile, as the finer fragmented material was kicked out beneath. A second shot along the bench (right) showed more uniform fragmentation from tight, unweathered joints. Explosive energy was well contained.

Large-Scale Rock Properties



Composite photograph showing typical fragmentation distribution from a well-timed coal-casting shot.

Large-Scale Rock Properties



Mixed geology like that shown to the left occurs when materials of very different strengths exist within the vertical strata.

In this highway cut, bedded limestone (1) is shown overlying unconsolidated soils (2) that grade down to a weak limestone (3).

Note the oxidized red (iron-colored) staining on the rock, indicating an active water channel along an open joint.

Such jointing poses a challenge to the process of loading explosives, because very little energy is needed to break and displace the material near the joint.

Large-Scale Rock Properties

The hydraulic properties of a rock are also important and contribute to the varying degrees of moisture that can develop in blastholes that are drilled into it.

Water can seep long distances through joints or faults, between bedding planes (as shown to the right), or within a coal seam.

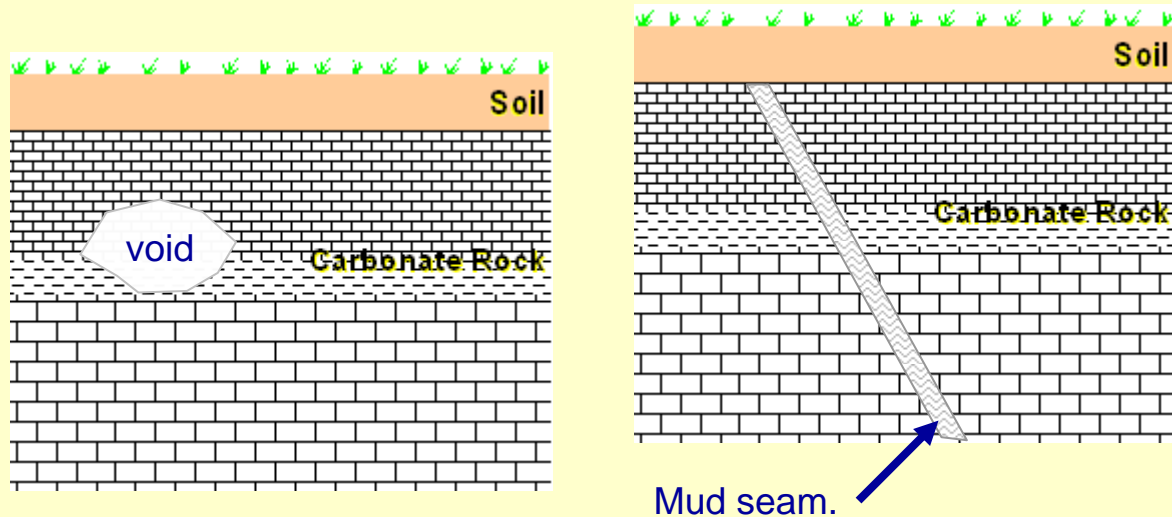
The amount of moisture or free-standing water in blastholes is an important consideration in the selection of explosives and hole-loading practices.



Large-Scale Rock Properties

Voids, or solution cavities, in certain types of rock such as limestone occur when rain-water-carrying mild acids from the atmosphere seep into the ground surface. Slowly, over many years, this acid dissolves the lime or carbonate rock-forming cavities it encounters. Such cavities can range from a few feet up to tens of feet in diameter.

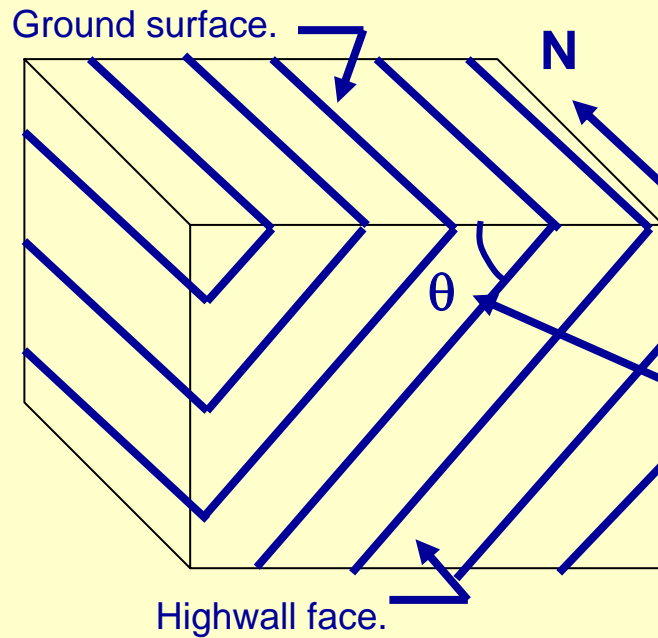
Mud seams, fault “gouge,” or gravel channels appear in many types of rocks. These features often represent widely spaced separations in the rock that are filled with weak, unconsolidated clays, gravels, and sands.



Every effort should be made to detect voids and seams during blasthole drilling. These features can greatly disrupt the confinement of explosive energy. If explosives are loaded into large voids or through seams and wide fault zones, the lack of confinement can contribute to flyrock, excessive airblast, and over-size fragmentation.

Large-Scale Rock Properties

The manner in which joints intersect the highwall or free face of an open pit or excavation will determine the stability of the remaining walls after a blast.



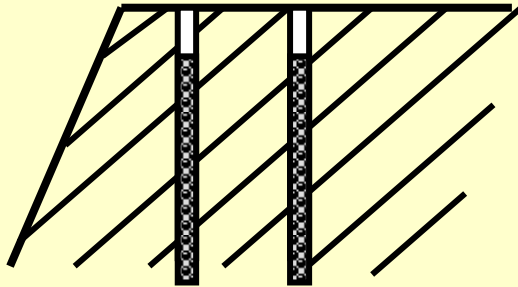
Joints generally come in “sets.” One-half of a set is shown to the left. Joints are characterized by:

Strikes.—The strike of a joint is its orientation as observed from the ground surface; the strike of the joints to the left is due north.

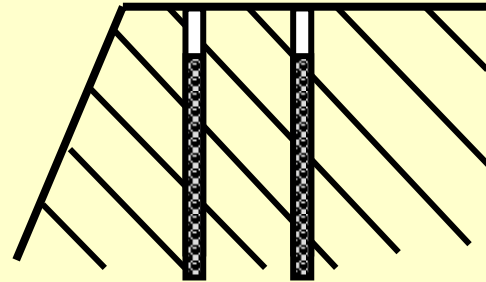
Dips.—The dip of a joint is its inclination as observed on a vertical plane “cut” through the earth perpendicular to the strike (shown to the left as angle θ).

Large-Scale Rock Properties

Dipping joints frequently cause (1) stability problems and (2) difficulty in breaking the burden toe.

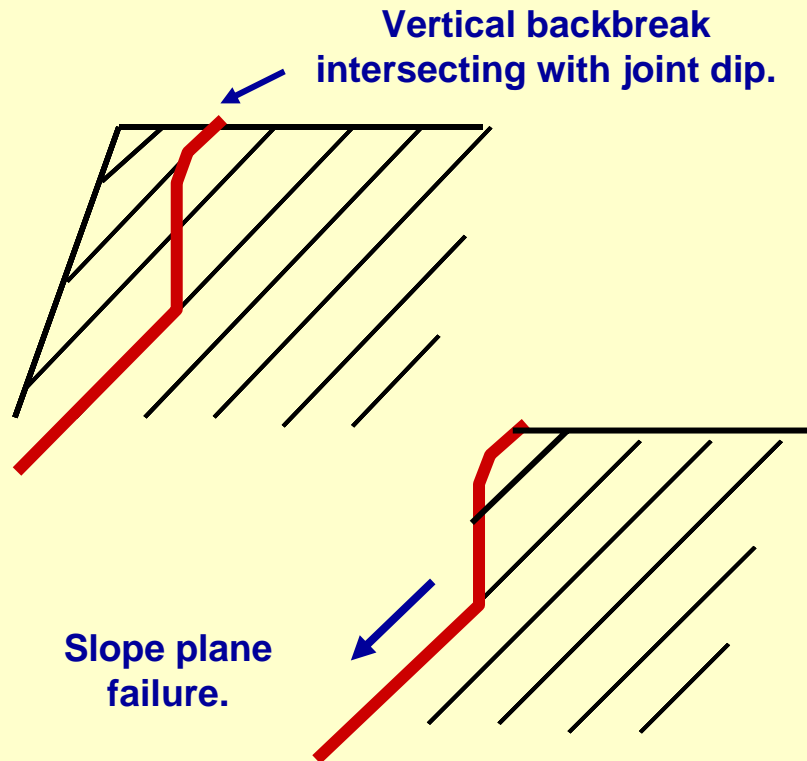


Dipping joints could create unstable highwall; excessive backbreak may lead to plane failure, as well as surface and slope failure into the working areas.



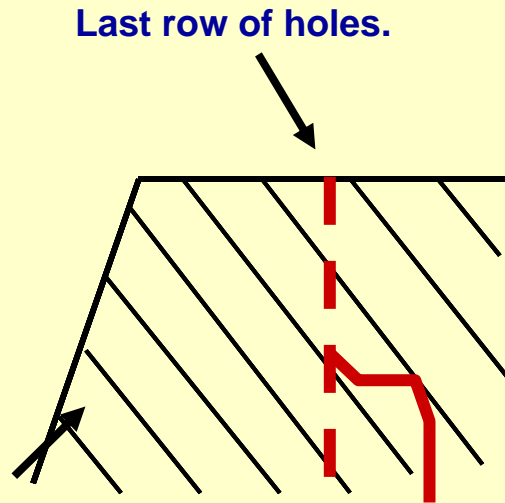
Overhanging rock may result from overloading the toe region.

Large-Scale Rock Properties



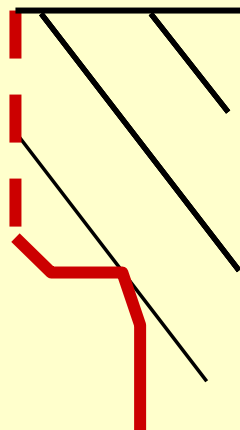
Plane failure involves large rock-mass movement and can be very dangerous to employees and equipment working below the face.

Large-Scale Rock Properties



An overloaded toe that causes
excess rock damage or
"overcut" * * *

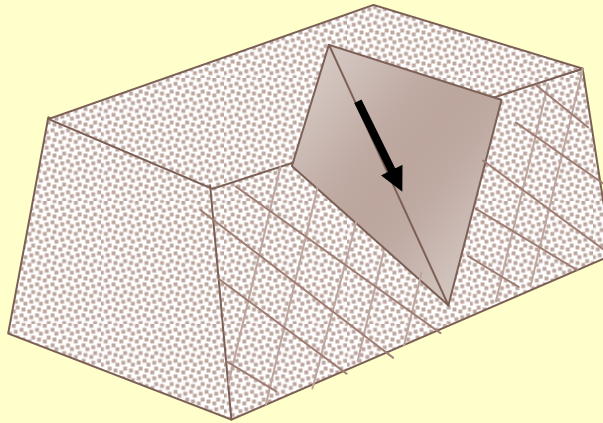
* * * can lead to this unsafe
overhang situation.



Photograph showing overhang.

Large-Scale Rock Properties

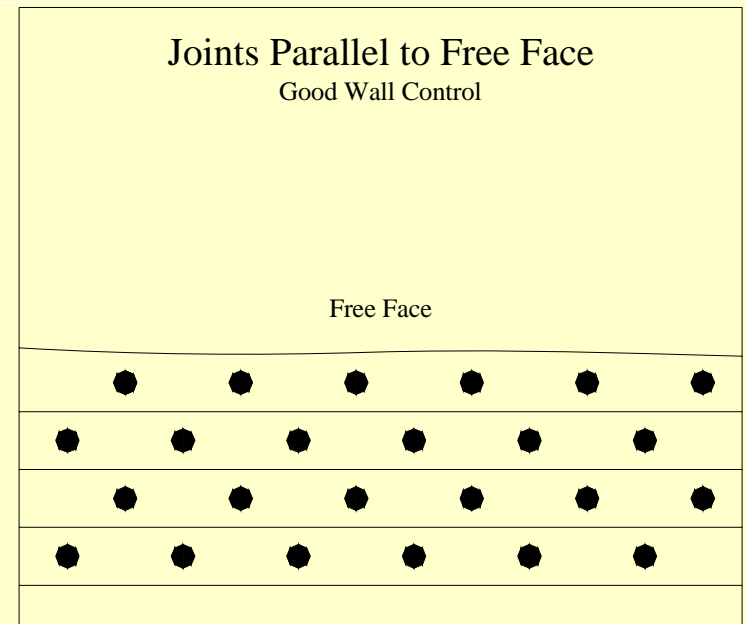
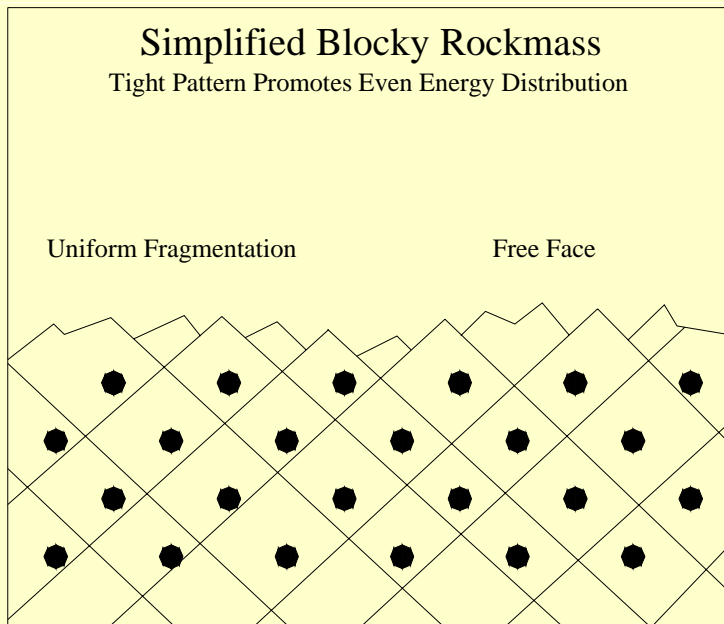
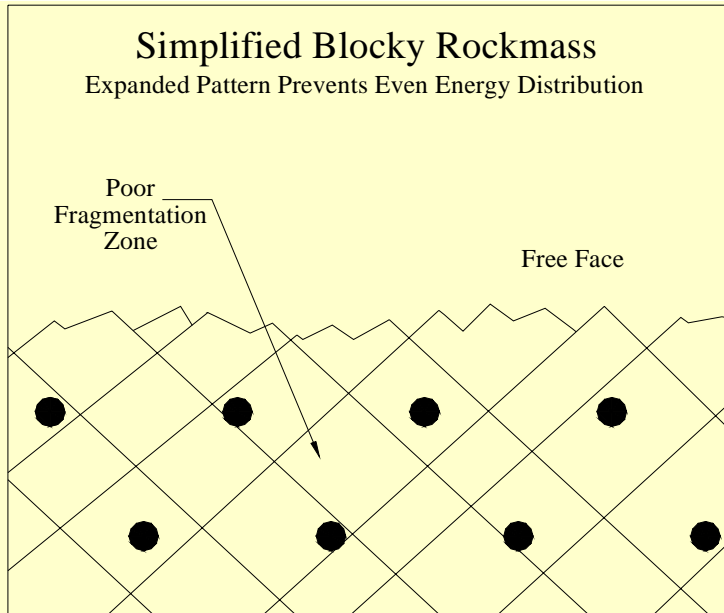
When joint sets intersect behind the highwall face, the intersection may form a line of potential slip (dipping into the working areas). Slip may occur if joints in the back wall are opened by blasting energy and excessive vibrations create high lateral forces.



Wedge failures can involve a large mass of rock material that may, as a consequence, be quite dangerous to workers below the face.



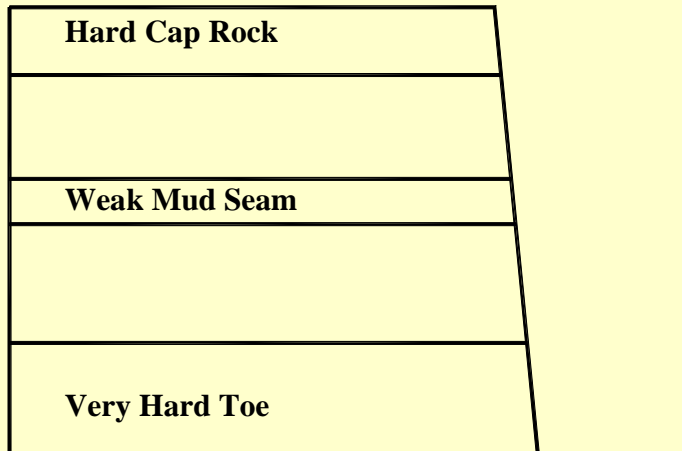
Large-Scale Rock Properties with Drilling



Large-Scale Rock Properties with Angle Drilling

Multiple geologic seams affect highwall stability. Angle drilling will allow weathering of softer rock at the natural angle of repose and help prevent undercutting of competent rock. Remember to deck holes as necessary to keep explosives in the competent materials.

Multiple Geologic Seams



Review Questions and Discussion

1. True or false: the strength and density of a rock, as well as its structural features (jointing and bedding), are important considerations when selecting the type of explosives needed to blast it.
2. The size of rock fragments that form during blasting is **not** affected by:
 - a. Rock strength
 - b. Explosives strength
 - c. Rock joint patterns
 - d. Tensile strength of detonating cord
3. List three situations that can lead to unstable highwalls after blasting.

Answers

1. True.
2. d. is correct.
3. Three situations that can create unstable highwalls following blasting are (1) backbreak intersecting joints dipping into the highwall face; (2) overhang or undercutting at the toe; and (3) wedge-type failure or slipping on two intersecting joints.