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Hand Drilling and Breaking Rock

for Wilderness Trail Maintenance

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Hand Drilling and Breaking Rock

for Wilderness Trail Maintenance

by

Dale Mrkich
Forestry Technician

Jerry Oltman
Project Leader

ED&T
Hand Drilling and Breaking Rock

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Courtesy of the University of Montana Mansfield Library Archives.

Introduction

Percussive or hammer drilling is most often used to drill rock. In Forest Service trail work, gasoline-powered hammer drilling is common. Hand drilling is sometimes necessary however, because machines cannot be used. This manual describes elementary tools and techniques for hand drilling rock.

Although hand drilling is slow work, it is a safe and simple way to prepare rocks for breaking with explosives, wedge and feather sets or expansion chemicals, or to accept anchor bolts. The driller drives the steel by methodical hammering and turning. When the hammer strikes the head of the steel, the bit is forced against the rock. After each blow of the hammer, the driller turns the steel slightly and strikes it again. With each blow the bit chips small amounts of rock that collect in the hole as "drilling dust." The driller removes the dust by adding water to the hole, which creates a mud that sticks to the sides of the steel. To clear the mud, the driller removes the steel and raps it against the rock. The procedure is continued until the hole is deep enough; longer steel is substituted as the hole lengthens.

The steel is manipulated with one hand while the other hand hammers (single jacking), or the steel is manipulated by two hands while another person hammers (double jacking). This manual describes correct techniques, discusses proper tool maintenance, and includes sources of tools and a bibliography.

Although hand drilling is not commonly used in the Forest Service, it can effectively remove rock from trails and does observe the Chief's directive to resurrect, develop, and utilize primitive skills in wilderness management. Hand drilling skills have been all but forgotten; we hope to preserve them with this manual.

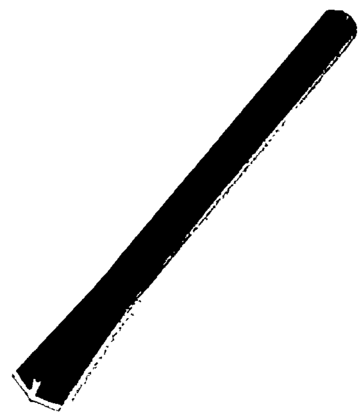
No cost comparisons have been made between hand drilling and gasoline-powered drilling. Initial tool costs are much less for hand drilling, however, and the techniques can be learned by unskilled or low salary employees. Since gasoline-powered drills are prohibited in wilderness, hand drilling allows wilderness managers to maintain trails without violating wilderness guidelines.

Hand drilling is an effective method for maintaining forest trails.

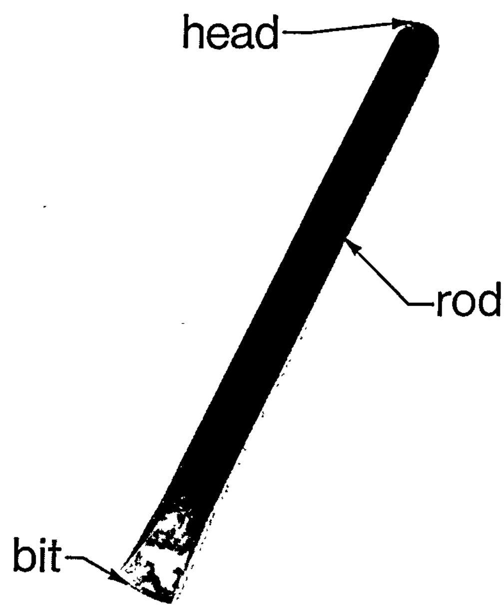
Description of Tools

Hand Drilling Steel

	Nomenclature
Rod	The rod is high carbon octagonal steel bar, 3/4 to 7/8 inches wide. Length may vary from 10 inches to several feet.
Bit	The bit is the sharpened end of the rod.
Bit Gage	The cutting edge is flared on 7/8 inch steel to a length of 1¼ inches.* Other thicknesses of rod have similarly proportioned cutting edges.
Effective length	The effective length is the length of the steel that is available for drilling, the total length less the shank or hand hold area.
Shank	The shank is the area near the head where the driller or holder grips the steel.
Head	The head is the end of the rod opposite the cutting edge, and receives the blow of the hammer.
Plastic caps	These are convenient for protecting sharpened cutting edges during transportation and storage. The top cap also keeps ragged edges from snagging other items.
Cutting edge angle	This angle must be precisely maintained during sharpening and reconditioning so the cutting edge remains in the center of the rod.
Bits	
Star Pattern	Two perpendicular cutting edges, flared and raised slightly, intersect at the center of the bit. These are common on modern drilling steel.
Straight Pattern	These have a single flared, slightly raised, cutting edge. They are old style bits, and may be found in second hand or antique stores.



Star pattern bit



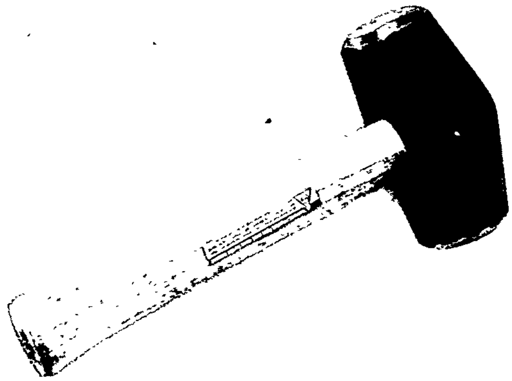
Straight pattern bit

*We have not arbitrarily chosen this size rod. Water gels approved for Forest Service blasting are packaged in polyester cartridges. The length of these varies, but the smallest available diameter package is 1 inch. A 1¼ inch hole is the minimum size that could easily accept that package.

Hand Drilling Hammers

Nomenclature

Head	The double face hammer head is made of heat-treated, high carbon steel.
Striking faces	The two striking faces should have beveled edges and should be heat treated.
Handle	Wood handles are usually made of hickory. They should have a tight, knot-free grain that runs parallel to the wedge slot. Other handles are made of fiberglass, or are a forged extension of the head.
Single jack	These are also called 'club' or hand drilling hammers. Handles are commonly 10 inches long, and heads weigh either 3 or 4 pounds. The short handle is uniquely suited to hand drilling because it resists breaking better than longer ones, and it facilitates accuracy by requiring the hand to be close to the head.
Engineer's hammer	These are also called long handle single jacks. They come with a 14-inch handle attached to a 3- or 4-pound head, and work well for the drilling technique we call modified double jacking.
Double jack	These large driving sledges have 36-inch handles and 6- or 8-pound heads. Because their use requires considerable expertise from both the driller and holder, we recommend that you use single jacking or modified double jacking until safety and proficiency with the double jack can be assured.



Single jack

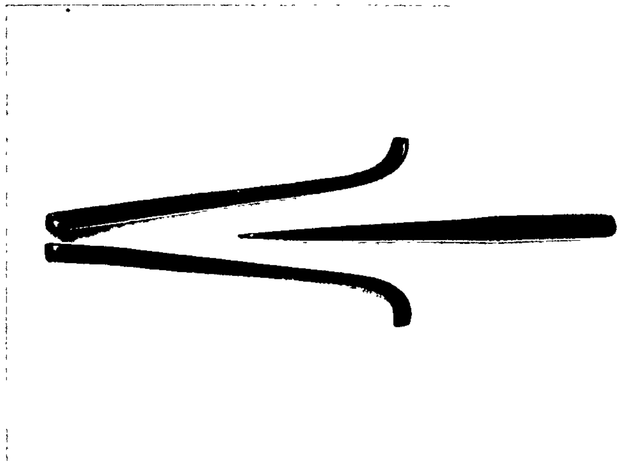
Engineer's hammer

Double jack

Wedge and Feathers

Nomenclature

Wedge	This is a heat-treated steel rod that is generally the same diameter as the drilling steel.
Blade	Wedges have a pointed, flattened blade opposite a head that receives the blow of the hammer.
Feathers	These are half round pieces of forged steel with a curved top, blunt bottom, and a flat inside edge running their entire length.



Wedge and feathers

The Problem

A proposed trail may cross a rock face or, after prolonged trail use, hazardous points of solid rock often protrude into the tread. A trail is built in rock by cutting some rock away to form a ledge or by removing the rock entirely. Sometimes rocks may be chipped flat with a pick.

Hand drilling helps remove rock three ways: (1) A rock may be split into chunks of manageable size by steel drilled into a natural seam; (2) If the steel in the seam does not split the rock by itself, the hole may be fitted with the wedge and feathers. The wedge is driven between the feathers with a hammer until the rock breaks; (3) Finally a hole may be used to prepare a rock for blasting. In general, the larger the rocks, the more likely you will use explosives to move them.

Although most large rocks are moved with explosives, we will not discuss the safe and effective use of explosives in this manual. For this information we recommend the Forest Service *Blasters Handbook*.[1] Explosives are most efficient, however, when used in drilled holes.

There are several considerations that make hand drilling a preferable alternative to other drilling. Gasoline-powered rock drills are expensive, and trail operations often do not have enough drilling work to justify costly equipment. Moreover these machines are noisy, heavy to backpack into remote areas, and tedious to use when they are there. Ferrying in gasoline-powered drills and supplies must usually be coordinated with a packer. And since motorized equipment is prohibited in wilderness, permission to use power drills must be secured in advance.

In short, many small drilling jobs are delayed because of economic, logistical, or policy considerations. Personnel trained to use hand drilling equipment could accomplish these small drilling jobs economcially without violating the spirit of the 1964 Wilderness Act.

History

The building blocks for the Egyptian pyramids and obelisks were obtained by using hammers and wooden wedges to extract large sections of stone in carefully measured shapes and sizes. The wedges had a hole in the middle for holding and carrying.

Miners from the time of the Roman Empire though the Middle Ages often applied a "fire setting" system to break rock. A rock face was exposed to intense heat followed by a quick dousing with water. The sudden cooling caused the rock to crack and split along natural seams. Sometimes a suspended wooden ram with a hard stone ball on its front was used to open a hole in the center of a rock face, and the face was chipped into it radially.

Gun powder was first used to break rock during the Middle Ages. In 1683 a Saxon named Hemming Hutman used a drill forged of wrought iron with an inset bit of tempered steel to hammer holes in the rock at critical points. The charges placed in the holes broke the rock more effectively than those laid on or near it.

The early history of our country contains many accounts of legendary 'hammer and steel' drillers who were experts at both single and double jacking. Single jacking involved an individual holding and turning the steel with one hand while hitting the steel with a small hammer held in the other hand.

Single jack drilling, circa 1850. *(Photo reprinted courtesy of Compressed Air Magazine.)*

[1] U.S. Department of Agriculture Forest Service. 1980. Blaster's Handbook. FSH 7109.51, 146 p. Washington, D.C.

'Down hole' double jacking, early 1800's.

'Up hole' double jacking, early 1800's. *(Photos reprinted courtesy of Compressed Air Magazine.)*

Ambidexterity was very helpful for the single jack driller because he could work longer by shifting the hammer from one hand to the other to distribute the work. In double jacking one or two drillers hit a drilling steel with large sledge hammers while a holder turned the steel slightly after each blow. As the hole deepened, the holder substituted longer steels in a way that did not interrupt the driller's disciplined rhythm.

Since every mechanical advantage gained by drillers was considered desirable, hand drilling was generally abandoned as soon as pneumatic drills were developed. Still some hand drilling methods were retained by prospectors for small budget rock work. Drilling and breaking rock with hand tools is discussed in Forest Service manuals up to 1923, and in prospecting handbooks as recently as 1943.

Some of the older techniques are not applicable today. For example, we consider double jacking unsafe for inexperienced drillers. Since most of today's hand drilling will be done by beginners, we suggest you use either single jacking or modified double jacking, a technique we developed. Both of these methods are safe, effective, and readily learned.

A prospector single jacking, circa 1910. *(Photo reprinted courtesy of Compressed Air Magazine.)*

Technique

Every section of rock has its own character, and experience and common sense will help determine the most effective method of dealing with it. Take time to carefully evaluate the rock's structure. Consider whether the rock is solid or 'seamy', stratified horizontally or vertically, or is igneous, sedimentary, or metamorphic before deciding where and how to attack it. Work with, not against, the rock.

The importance of properly planning the hole in advance, that is, deciding where and how deep to place it, cannot be overemphasized. Rock usually splits to the first horizontal seam below the drill bit or tip of the wedge. Proper placement will help assure that the rock will break at the proper angle and in the right place while using the least time and energy. Using the shortest steel necessary will also save time and energy.

Courtesy of the University of Montana Mansfield Library Archives.

Drilling

Always wear safety equipment, including safety glasses or goggles and gloves, when drilling.

1. A special, short-handled hammer called a single jack is used for one-handed drilling. Hammer heads weigh either 3 or 4 pounds, and handles are 10 inches long. The short handle helps you place blows accurately.

A long-handled single jack, an engineer's hammer with a 14-inch handle and a 3- or 4-pound head, for example, can be used for two-handed drilling with another worker holding the steel. The proximity of both hands to the steel required by the handle assures that accuracy and safety are not sacrificed. We call this technique modified double jacking.

2. The driller will be kneeling on one or both knees, or sitting. If modified double jacking is used, the holder should position himself across the steel from the driller, and wear gloves on both hands.

Assume a comfortable position and change positions and tasks regularly to help minimize stiffness in legs, arms, and back. Knee pads could be an asset.

Single jack driller at work.

Modified double jacking team at work.

3. Grasp the hammer firmly and hit the steel squarely. When collaring (starting) a hole, work deliberately and slowly, placing each blow carefully. Although a drill hole is usually started with a drilling steel, it can also be started by chipping slightly with a pick. In the beginning dust and rock chips are difficult to minimize. Be patient when collaring; a hammering rhythm is much easier to maintain after the hole has been started.

Establish your rhythm as soon as possible. Drilling with a regular rhythm will be more productive than driving the steel with powerful strokes in sporadic bursts of effort. Hard hitting causes you to tire quickly and experience cramping prematurely. It also causes the steel to stick in the hole. Take frequent rests to prevent cramps, and do not ignore signs of fatigue. Let the tools and gravity do the work.

Any rest that can be afforded your 'hammer-holding' hand while single jacking will help conserve your energy. A wrist thong may be attached to the end of the handle to help drill at unusual or difficult angles. The thong is looped around your wrist and lets you rest your grip a moment after each stroke. On the backstoke the fingers may be opened and the grip relaxed, allowing the handle to swing free but restrained from dropping by the thong. At the end of the backstroke the fingers close around the handle to prepare for the next swing.

Old time miner using a single jack equipped with wrist thong, early 1800's.

4. A hole is drilled because rock is chipped by the concussion of the bit from the blow of the hammer. Grip the steel firmly but not tightly during each blow. Hand drilling produces very little shock in the 'steel-holding' hand. The holder in a modified double jacking operation will also find that only a small amount of shock is transmitted from the blow of the hammer. Always wear gloves while holding, in case of a glancing blow.

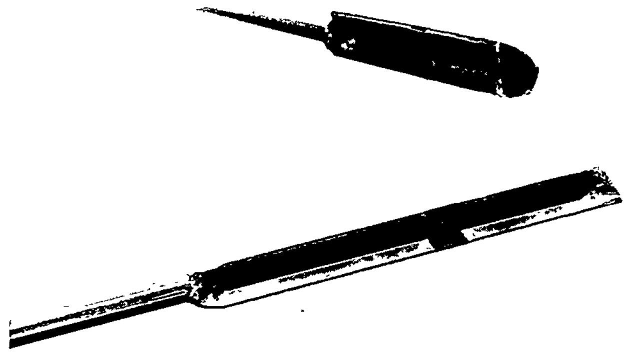
After each stroke, turn the drill about 1/8-revolution; this is called 'shaking' the steel. Drill steel is usually octagonal in shape, so turn the steel so the next flat side faces you. There is a slight recoil of the steel after each blow, and it is after the recoil that shaking is performed. Lift the steel slightly before turning. If the steel is not turned, the bit will sink straight into the cut and jam in the hole. When shaking, allow your grip to relax slightly after each rotation. Regain your grip before the next blow.

Difficulty in shaking the steel, especially in 'down' holes, indicates that the rock dust in the bottom interferes with the cutting edge of the bit against the rock. With two hands turning the steel, teams may go for longer periods before clearing cuttings from the hole. Water is helpful for removing cuttings from holes.

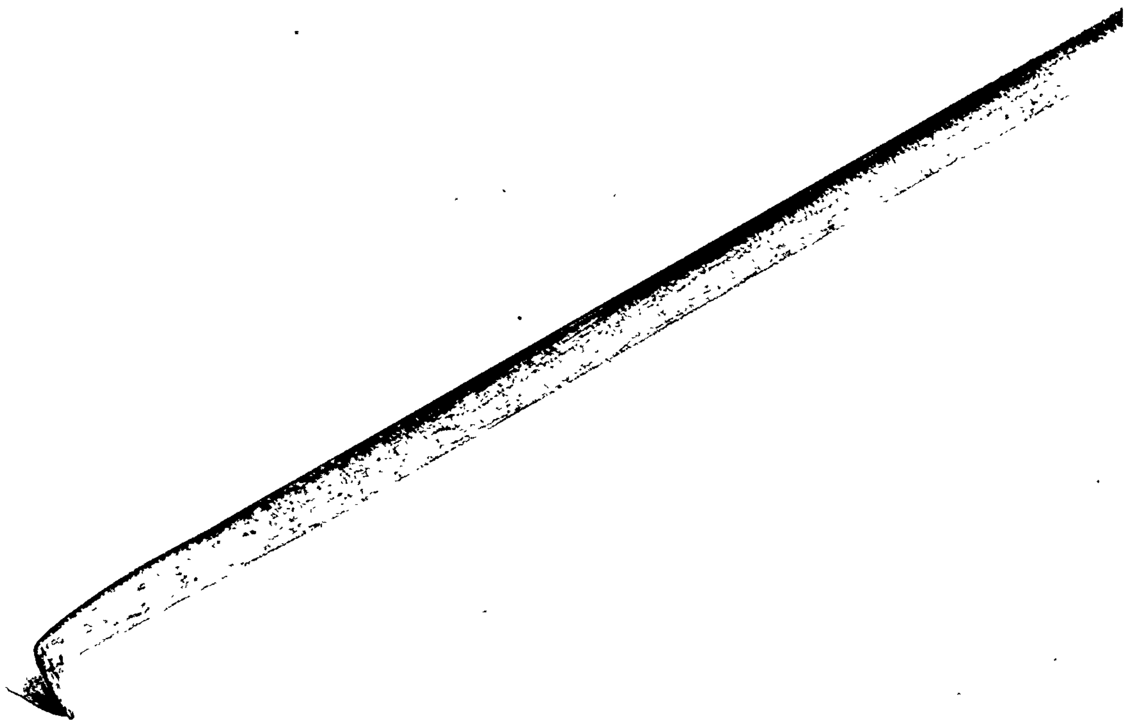
5. Regularly add small amounts of water to minimize dust from drilling and keep the drill steel cool and the temper intact. This keeps particles in 'down' holes in solution so they won't hinder the progress of the drill. Water creates a mud that sticks to the steel and is withdrawn from the hole with the steel. The adhering mud is removed by rapping the steel sharply against the rock. Holes are periodically flushed clean by bouncing the steel in the hole while adding water to create an agitating motion. The generous use of water allows the drilling action to force cuttings out of the hole as quickly as they are generated. Minimize unpleasant splashing by wrapping a small rag around the rod at the top of the hole. Keep the rag loose so shaking is not impeded.

Using water in a drilled hole.

Removing cuttings from deep holes may require more water than is readily available. In this case, small amounts of water may be used to create the mud, and a long-handled spoon can extract it. Oldtime miner's spoons were forged from various lengths of iron rod. They had a handle opposite a flattened, slightly curved end approximately ¾ inches wide and up to 6 inches long. These spoons were used for clearing holes of cuttings and for retrieving sticks of powder from misfired holes. The pointed tip on the handle end was used to thoroughly clean holes before loading and to pack explosives in the holes. Today similar soft metal "powder spoons", made of 3/8-inch iron rod in lengths up to 8 feet, are sometimes still used in underground mines. We made a 30-inch long version of the "powder spoon" for trail work. We also made a spoon from a piece of aluminum tubing ½-inch in diameter and about 22 inches long. We flattened and shaped one end so it had a flat edge roughly perpendicular to the rod handle. This spoon worked well for cleaning 1¼-inch holes up to 16 inches deep.

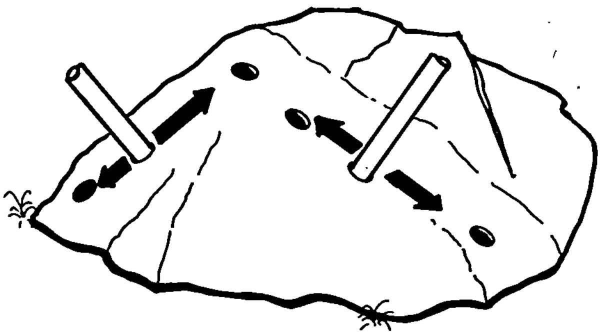


Our version of the miner's powderspoon had a 30 inch handle and a 6 inch spoon.

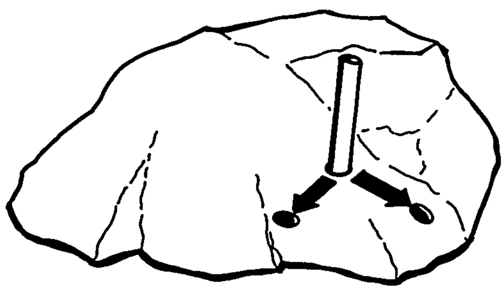


The aluminum spoon we made had a 22 inch handle and a 5/8 inch spoon.

6. Carefully select the points at which holes will be placed. Use natural points of weakness, and keep in mind your total breaking needs for the project. Evaluate the site and proceed accordingly. If you plan to remove a rock entirely, position the holes as perpendicular as possible to the largest face parallel to its strata (see A below). If the rock is to remain in place with only parts removed, a different technique is used (see B below).



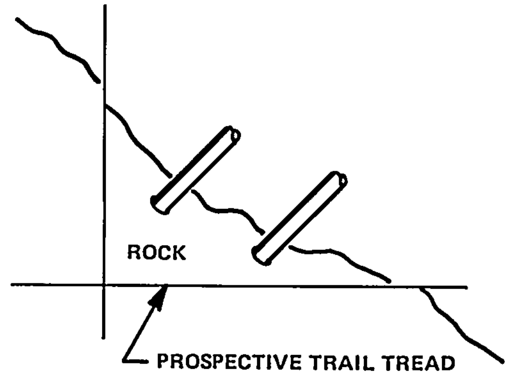
A. Drilled holes are perpendicular to the surface being worked. If wedge and feathers are used in this instance they will be less likely to be unduly stressed, because the compression forces of the rock are more evenly distributed on them. This rock will probably be split into chunks that will allow its complete removal. Arrows indicate probable direction of splitting.



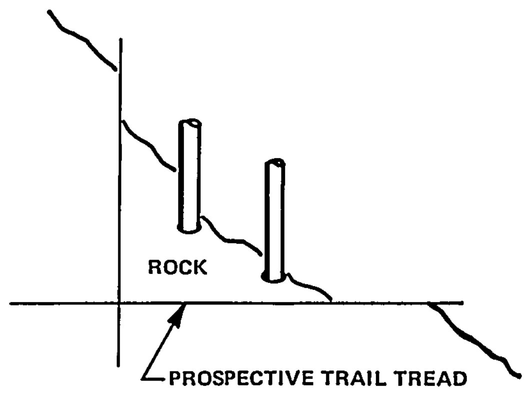
B. The drilled hole is not perpendicular to the surface being worked. Splitting will be both less predictable and less efficient in this situation. Be aware also that when you work the wedge into the hole it will be more prone to bending or breaking because the compression forces are distributed unevenly. You have already determined that only a section of the rock will be removed. That is what you can expect to happen here. Arrows indicate probable direction of splitting.

Drilled holes in rock.

The same principles can be applied if a prospective trail tread crosses a rock face.



A. If the rock looks and feels solid, drill to remove it completely.



B. If the rock is weathered, seamy, or soft, perhaps you can chip it flat.

Placing holes in trail tread.

Breaking Rock

Except when using explosives rock is split or broken by stressing it beyond its tensile strength. Rock is stronger in compression than in tension. For example, most rock will support a heavy load upon it, but can be pulled apart relatively easily. Moreover, different rocks have different tensile strengths; that is, some are easier to break than others. When breaking rock, stress it at points of natural weakness.

Seamy rock will usually break irregularly because it has no major points of natural weakness. Moreover, holes drilled in seamy rock sometimes slip because the layers shift both horizontally and vertically. This causes the steel to jam in the hole or a feather to be bound on one side against the wedge. You can best avoid this by carefully placing holes, by keeping them as straight as possible, and by attempting to determine in advance what will happen when the rock breaks. Sometimes, however, a new hole must be drilled to free a jammed steel or wedge and feather set. Be careful to avoid extra stresses on jammed tools while working to free them. A knowledge of rock types will also help you plan the job, procure tools, place the holes, and will indicate what to expect when drilling.

Rock Types

This manual offers no 'hard and fast' rules about hole spacing and drilling depth necessary to break specific types of rock. This information is best gained from experience, depending on what is encountered and what is required at a job site. The general categories of rock that follow give broad hints about what to expect when drilling them.

Soft Rock

1. *Shale*—Clay, mud, and silt that is consolidated into a finely laminated structure.
2. *Shist*—Crystalline rock with component minerals arranged in a roughly parallel manner.

Medium Hard Rock

1. *Sandstone*—Sedimentary rock, usually quartz sand, cemented by silica, iron oxide, or calcium carbonate.
2. *Limestone*—Sedimentary rock that is formed by the accumulation of organic remains consisting mainly of calcium carbonate.
3. *Marble*—Metamorphic limestone that has been crystallized by a pronounced change in heat, pressure, and water content.

Hard Rock

1. *Bluestone*—Bluish gray metamorphic rock similar to sandstone.
2. *Gneiss*—Laminated metamorphic rock similar to granite.
3. *Granite*—Naturally igneous rock formed of crystallized quartz and orthoclase.
4. *Basalt*—Dense igneous rock that consists of feldspar and various minerals.