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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

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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.

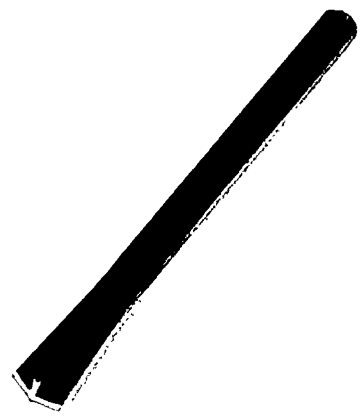
Hand drilling is an effective method for maintaining forest trails.

Description of Tools

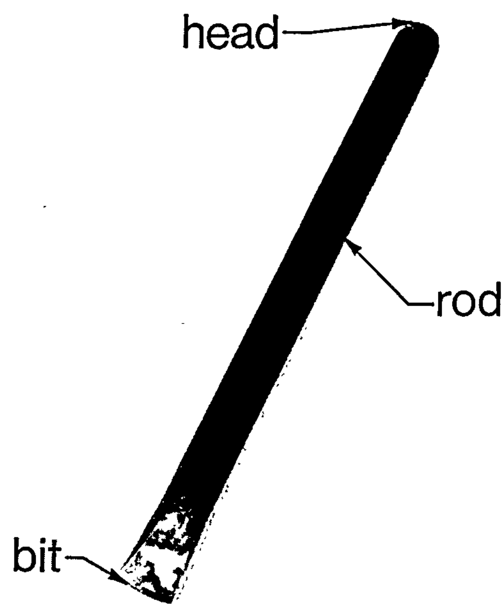
Hand Drilling Steel

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



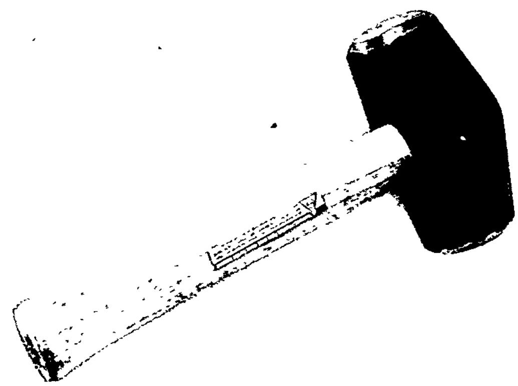
Straight pattern bit

*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

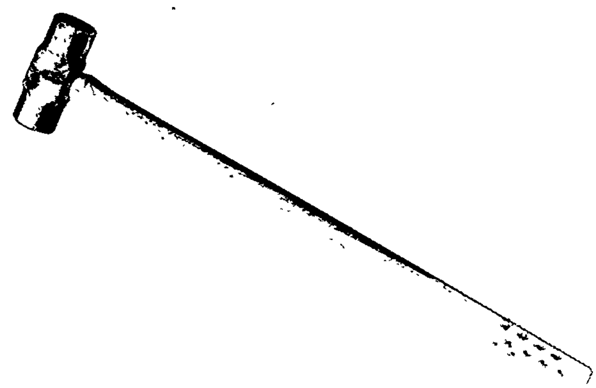
Nomenclature

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

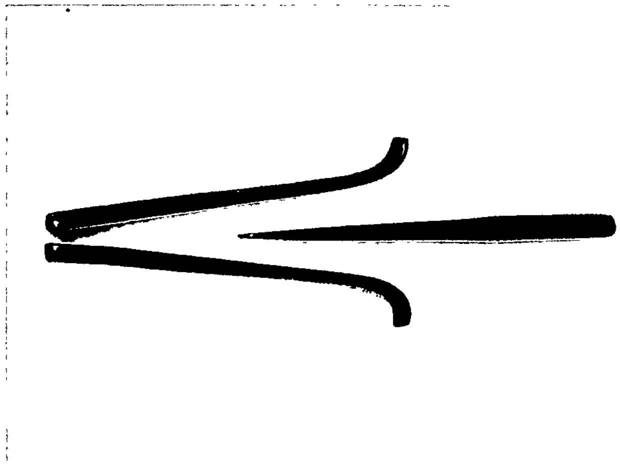


Double jack

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.

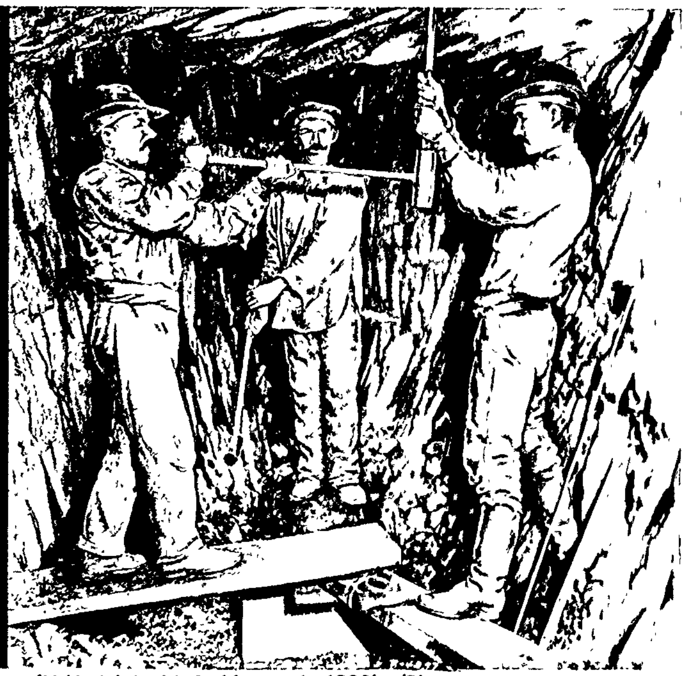
Gun powder was first used to break rock during the Middle Ages. In 1683 a Saxon named Hemming Hutman used a drill forged of wrought iron with an inset bit of tempered steel to hammer holes in the rock at critical points. The charges placed in the holes broke the rock more effectively than those laid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

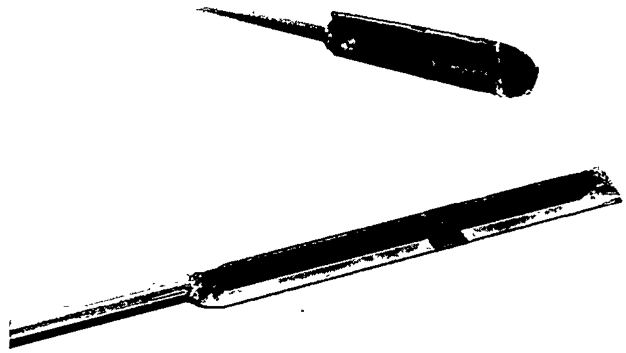
After each stroke, turn the drill about 1/8-revolution; this is called 'shaking' the steel. Drill steel is usually octagonal in shape, so turn the steel so the next flat side faces you. There is a slight recoil of the steel after each blow, and it is after the recoil that shaking is performed. Lift the 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.

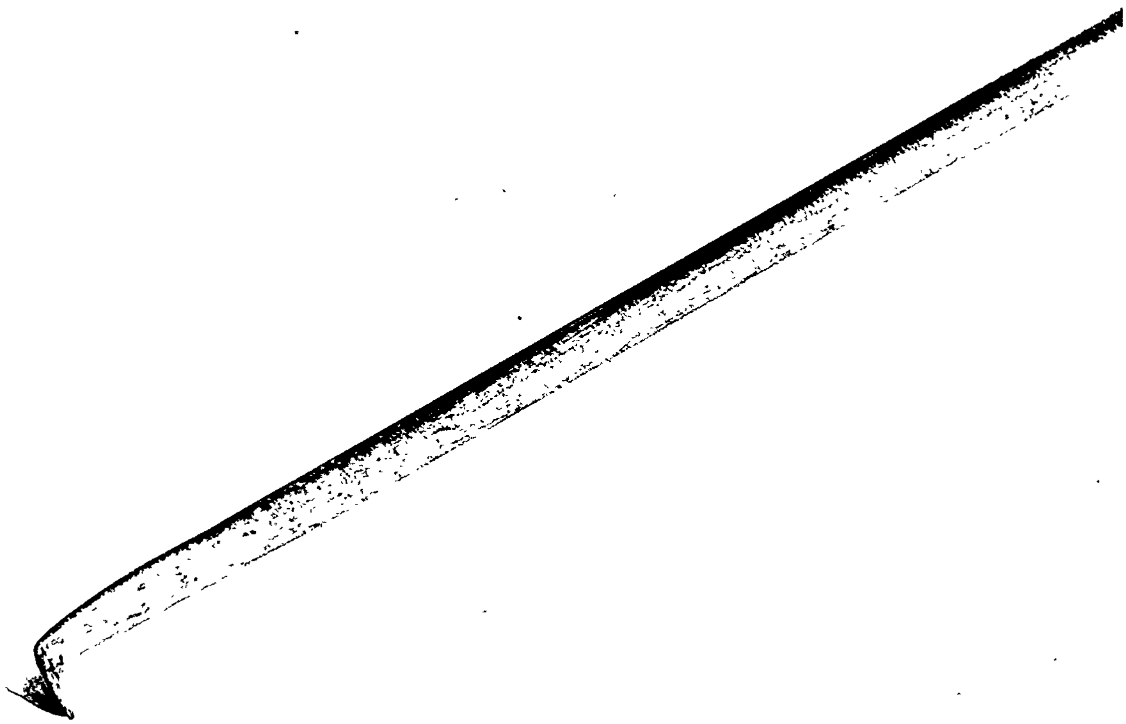
5. Regularly add small amounts of water to minimize dust from drilling and keep the drill steel cool and the temper intact. This keeps particles in 'down' holes in solution so they won't hinder the progress of the drill. Water creates a mud that sticks to the steel and is withdrawn from the hole with 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.

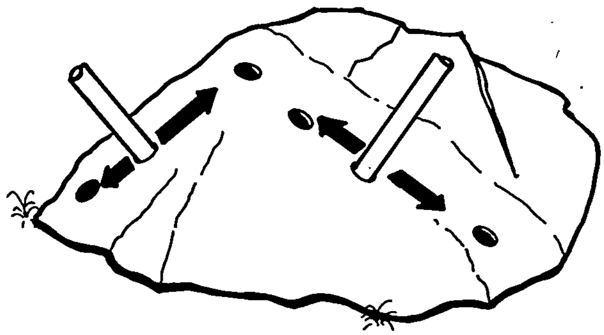


Our version of the miner's powderspoon had a 30 inch handle and a 6 inch spoon.

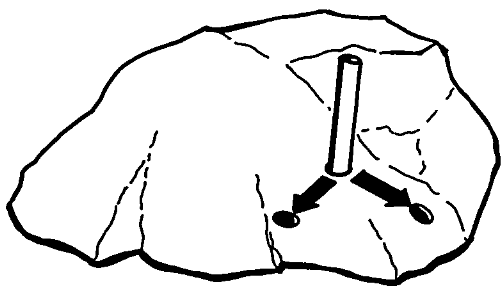


The aluminum spoon we made had a 22 inch handle and a 5/8 inch spoon.

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).



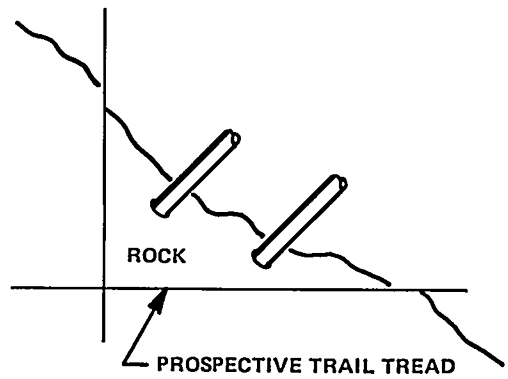
A. Drilled holes are perpendicular to the surface being worked. If wedge and feathers are used in this instance they will be less likely to be unduly stressed, because the compression forces of the rock are more evenly distributed on them. This rock will probably be split into chunks that will allow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



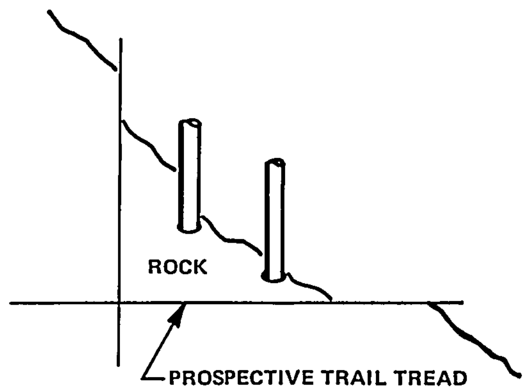
B. The drilled hole is not perpendicular to the surface being worked. Splitting will be both less predictable and less efficient in this situation. Be aware also that when you work the wedge into the hole it will be more prone to bending or breaking because the compression forces are distributed unevenly. 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

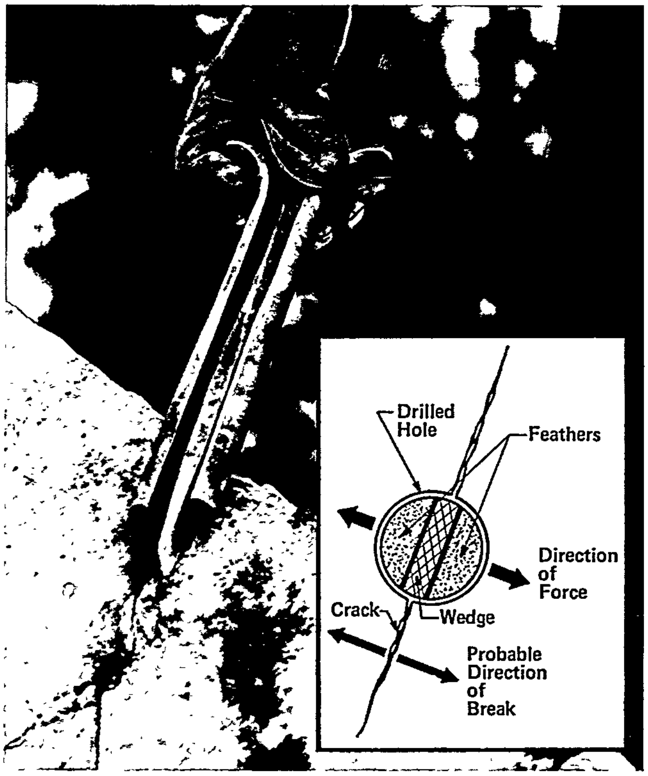
1. *Sandstone*—Sedimentary rock, usually quartz sand, cemented by silica, iron oxide, or calcium carbonate.
2. *Limestone*—Sedimentary rock that is formed by the accumulation of organic remains consisting mainly of calcium carbonate.
3. *Marble*—Metamorphic limestone that has been crystallized by a pronounced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

Wedges (Plugs) and Feathers

Wedges and feathers are tools designed to split rock when driven into a drilled hole or natural crack. The wedge fits in the hole between two feathers whose flat sides form a guide that prevents the wedge from jamming as it is driven into the hole. Use wedge and feathers as follows: Position the feathers in the hole so the flat sides of the wedge will be parallel to the line along which the break will occur. Drive the wedge into the slot between the feathers until the rock cracks, or until it sticks in the rock. Then tap the wedge lightly back and forth along the inside edges of the feathers until it is freed. Remove the wedge and, if necessary, begin again. Proceed slowly to allow the tools time to do their work.



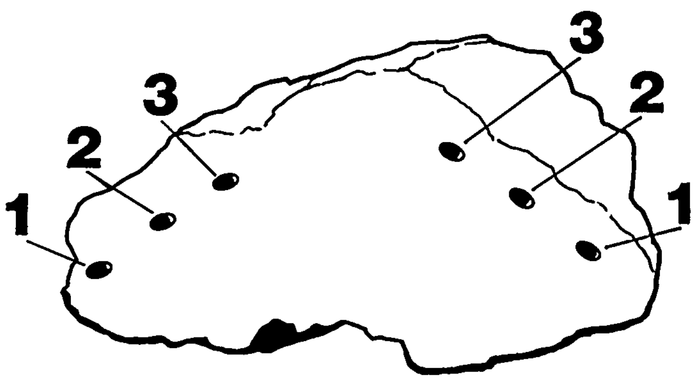
Correctly placing the wedge and feathers.

To be effective, wedges and feathers must be correctly sized. The diameter of the wedge rod and feathers at the point where the rod meets the feathers must exceed the diameter of the hole. Driving the wedge between the feathers forces them against the sides of the hole and splits the rock.

Avoid unnecessary stresses on wedges and feathers by drilling holes as straight as possible. Straight holes help keep wedges and feathers from binding or jamming in the hole.

Miscellaneous Tips

Drilling and splitting a large rock not free to move when split calls for additional care. If a hole is placed in the middle of the rock, one side may shift and jam, bend, or break the steel or the feathers and wedge. Similarly, splitting a rock that is supported only at the ends can shear tools if it breaks and slides suddenly. In instances like these, start holes from an open edge and work toward the middle. A hole drilled near the side of a large rock 18 to 24 inches from an edge will indicate how you should proceed.



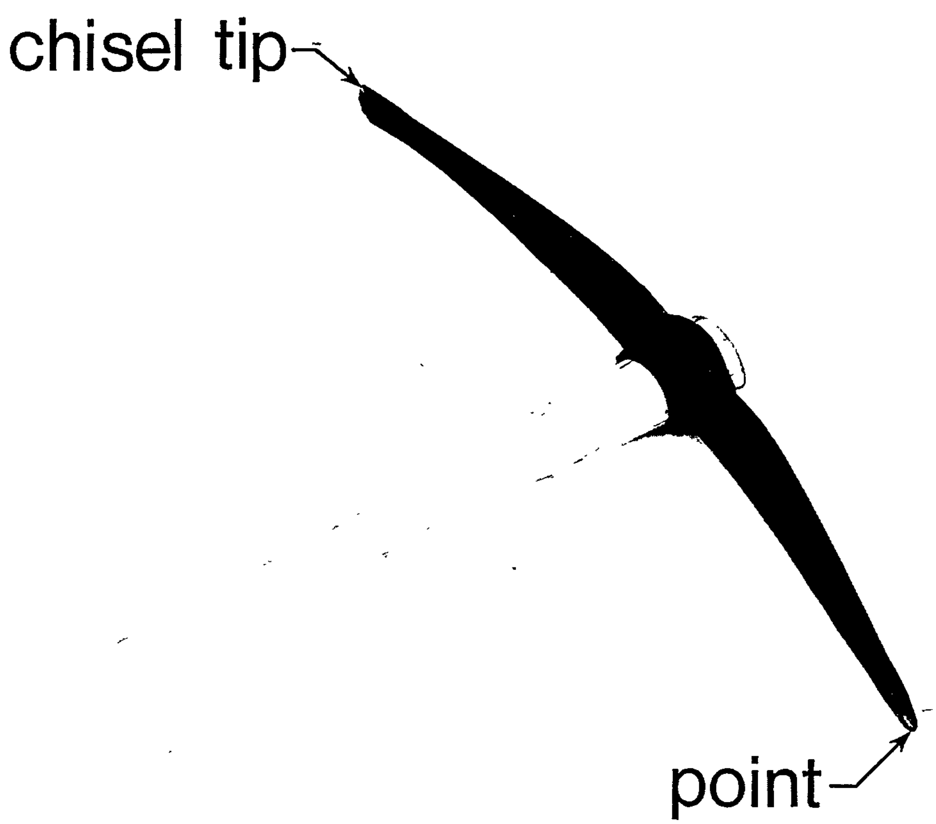
Holes drilled in these lateral locations will be less likely to jam steel or wedges and feathers than one drilled in the middle.

Picking

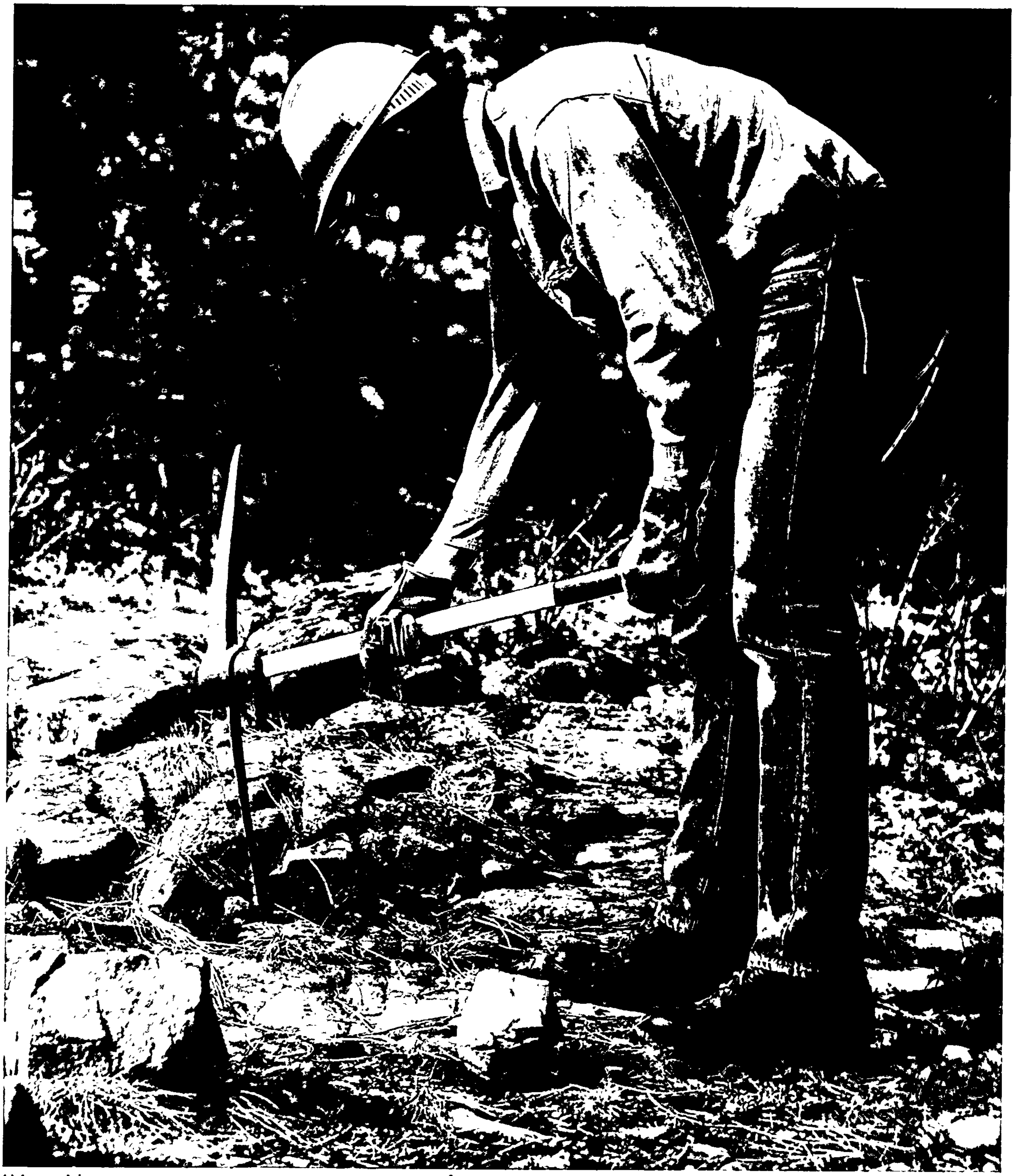
Pick heads have a pointed tip for exposing and enlarging points of natural weakness in rocks. Many times soft and medium hard rock can be broken with a pick so that no drilling is required.

When using a pick, be careful to maintain control of the head at all times. Avoid raising the pick overhead while swinging. This wastes energy needed for sustained operation, sacrifices accurate placement of the tip, and creates a safety hazard for the operator and others. The narrow heavy pick head cannot be easily controlled or directed from these heights.

Avoid using the pick as a prying tool; use crowbars instead. If picking or prying a natural seam does not split the rock, use a drilling steel or a wedge and feathers in the hole. Always wear safety glasses or goggles when picking to guard against flying chips of rock.



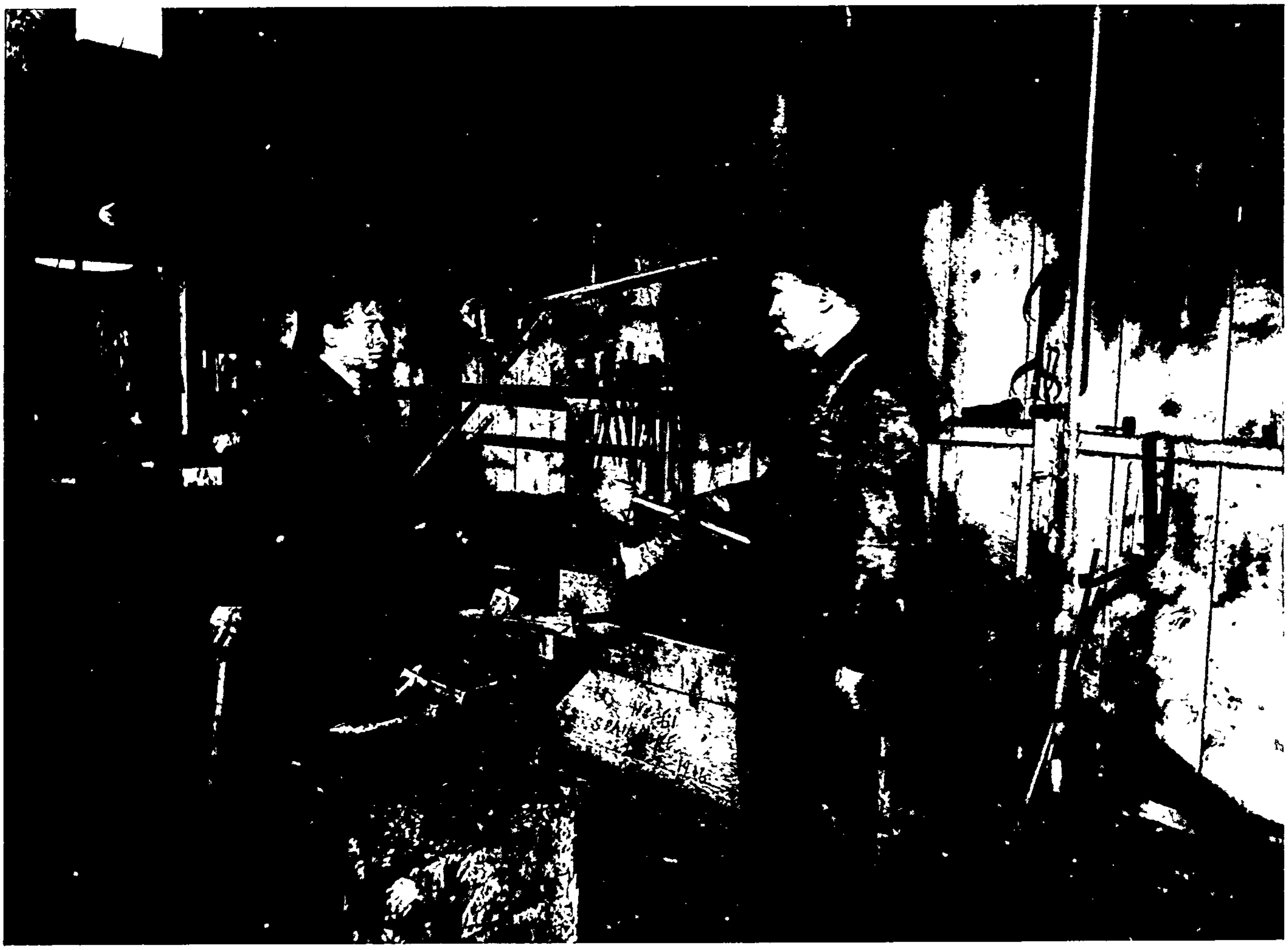
Picks are effective tools for breaking rock.



Using a pick.

Maintenance

Conscientious tool maintenance is essential to safe drilling and increases tool life. Drilling steel must be sharp and tools must be reconditioned periodically. Pick heads must be kept sharp, hammer faces smooth, and handles sturdy Wedges and feathers should be carefully protected.



Courtesy of the University of Montana Mansfield Library Archives.

Drilling Steel

Sharpening

Make sure that your steel is straight. Bent steel is nearly impossible to use effectively and a poorly placed blow could glance and cause an injury. Keep the steel sharp. Sharp steel helps you work safely and efficiently.

Use a double cut file or grinder to redress steel that is not badly worn. Maintain existing edge bevels as much as possible. In the field file the heads smooth and cutting edges sharp. Use a completed hole as a holder. Insert the steel upside down and brace it with your knee or foot. Your partner may also hold the steel while you file. Always wear gloves when sharpening or holding.

When using a grinder, remember to avoid excessive heating of the steel that could draw temper and soften the bit. Be aware that forged tools are harder on the outside than they are at their core. Careless or excessive grinding or filing can expose the core and cause premature dulling.

One worker may hold the steel while the other files.

Using a hole as a holder.

Reconditioning and Tempering

The facilities and expertise of a blacksmith will almost certainly be required to completely recondition dull drilling steel. Here is an historical account describing how a blacksmith worked:

> "Drills are sharpened, first by forging to the right shape and to give a sharp edge; this edge, however, by many smiths is not hammered sufficiently sharp, and they use either a file or a grindstone to give the required edge. The point is then heated to a glowing red and dipped in cold water for a few seconds to harden the steel; the edge is then rubbed on sand to clean it. The smith examines for the colour, and dips at a pale straw colour to make it hard, or at a dark blue, which makes it a little tougher. If, after the first cooling, there is not sufficient heat in the drill for these colours to show on the edge, it must be reheated in the fire. When the drill is dipped for tempering, it may remain in the water till cold. The exact colour at which steel has to be dipped varies with the quality of the steel, and also, no doubt, with the nature of the work, but a little practice will soon show." (Lupton, 1906).

Special variations in the temper and length of steel were sometimes required to drill particularly hard rock.

Modern hand drilling steel has similar forging requirements. In the reconditioning process it is important for the blacksmith to be able to control the hardness of steel by tempering. In general, the harder the steel, that is, the more cohesive the particles of metal, the more resistant the tool will be to wear. If the steel is made too hard, however, it may become brittle and break during use.

Standards for the hardness of tempered steel have been established that guide smiths to the correct hardness for a tool based on its usual range of applications. Hardness is measured by pressing on tempered surfaces with specific shapes under a known pressure. The amount of pressure that the tempered metal is able to withstand before an indentation is made becomes a measure of its hardness. The best known measures of hardness of tempered steel for tools are Rockwell and Brinell hardness. Rockwell hardness tests measure the indentation of a diamond cone (Rc), or a steel ball of a specified diameter (Rb), on a tempered surface. Brinell hardness tests measure only with a ball (HB) (see chart p. 26).

The steel on the tool's surface is slightly harder than the steel in the middle. This is because during the quench the particles on the surface are more radically affected; they are more cohesive than those in the middle or slightly beneath the surface. The key to tempering is to retain the desired toughness at the center of the tool. The softer core assures a strong tool, while the hard exterior provides the cutting edge or protective shield.

Complete Reconditioning

Here is a description of a modern tool reconditioning process:

Forging

1. Heat the point to a yellow color (1800 to 1900°F/982 to 1038°C), for the length necessary to forge. Be careful not to heat too far back on the steel; this is the most common cause of premature breaking after reconditioning. Do not attempt to forge below a cherry red color, (1450°F/790°C) (see chart p. 26).

2. Rework tools only to their original design.

3. After forging allow the tool to cool to room temperature.

Hardening

1. Reheat the point to a cherry red color 1½ to 2 inches back from the cutting edge, making sure to overlap the forging depth.

Quenching

1. Quench in water, or in a brine or oil solution. Maintain the quench at a temperature of 75 to 100°F/24 to 38°C, to achieve Rockwell hardness (Rc) 60 to 65, Brinell hardness (HB) 600 to 652.

Tempering

1. Withdraw the tool from the quench with sufficient heat remaining in it to draw the temper. A shade of brown or dark yellow is best.

2. Rub the point clean with emery.

3. When a light straw color appears, (430°F/222°C), complete the quench.

4. If drawing facilities are available, reheat to 425°F/218°C, and hold for 1 hour to achieve Rc 56 to 60, HB 555 to 600.

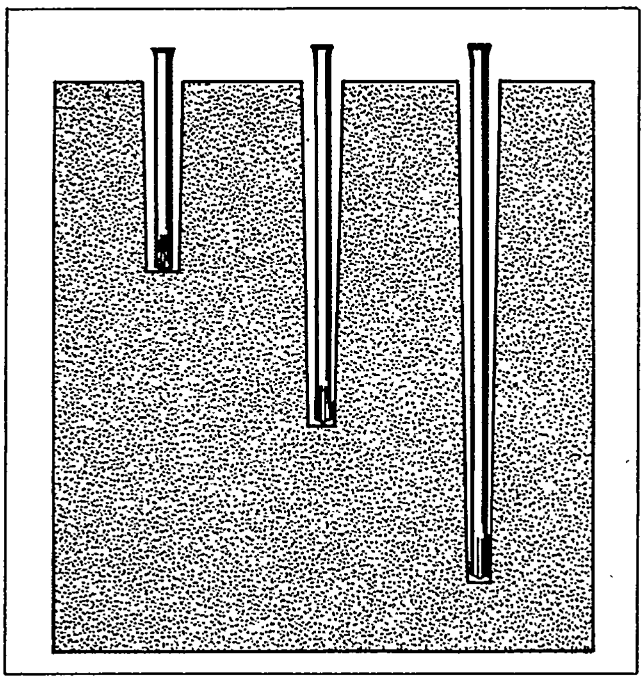
Miscellaneous Tips

1. Temperatures will vary among types of tool steel.

2. This operation should be undertaken only by or under the close supervision of an experienced blacksmith who knows the specific requirements of the steel he uses.

3. Wear adequate protective clothing, including eye protection and gloves, at all times.

If your drilling steel includes short 'starters' and longer 'seconds', the smith should make the cutting bits diminish slightly in width as the rods increase in length. This is necessary to prevent jamming when a new length of steel is started in the hole. A drilled hole gradually decreases in diameter as the tool wears. The bore-hole is not a true cylinder, but the frustum of an elongated cone. If the head of the steel becomes mushroomed from extended use, it should be reshaped by the blacksmith during reconditioning.



The bore-hole is not a true cylinder, but the frustum of an elongated cone.

Defective Steel and Prolonged Safe Use

Although drilling steel is designed to perform in demanding applications, few products are subjected to more stress in service. Hand-hammered percussion tools for drilling and wedging must endure the same punishment as the rock being worked, so some failures may be expected.

Defective steel is likely to fail early on due to the severe stresses from the blows of the hammer, although some break after considerable service without having been defective. To insure long life and safe use of drilling steel, avoid these common causes of premature failure:

1. Using steel for an unintended purpose. Prying with the steel, for example, will bend it and render it unsafe and ineffective.

2. Allowing steel to overheat in service. This will draw temper and cause cutting edges to soften and dull.

3. Failing to keep the steel sharp. This causes extra stress on the rod.

4. Redressing steel inadequately or improperly. Tools improperly forged and rehardened or excessively filed will dull quickly, mushroom prematurely, and break before giving a full measure of service.

Drilling Hammers

Using hammers with cracked handles, loose heads, or chipped faces is a safety hazard as well as a reflection of poor maintenance. Examine handles to insure that they are tight on heads and free of cracks. If handles have been poorly maintained or neglected, take time to repair or replace them before beginning a drilling job.

Striking faces should be smooth and evenly worn. Drilling hammers have hard tempered faces designed to strike softer drilling steel heads. The head of the steel mushrooms and the hammer face remains smooth. If a hammer face becomes pitted or chipped, however, carefully grind it smooth. Work slowly to avoid damaging the shallow temper of the face. Discard badly worn hammers. Some hammers have faces tempered soft to mushroom with use. These allow workers to safely hammer hard metals without the hammer face chipping. Mushroomed hammer heads can also be reconditioned by a blacksmith.

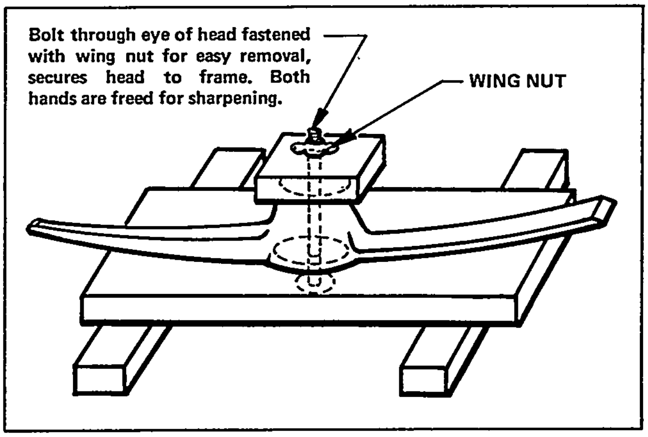
Wedges and Feathers

Wedge and feather sets should generally be treated like drilling steel. Avoid using wedges alone to break rock. Wedge tips are not tempered hard enough to start holes. Hammer wedges primarily on the heads, and avoid striking feathers as much as possible. Remember also that wedge and feathers break rock with friction and stress, so overheating can occur.

Picks

When sharpening picks grind the tips to a point 1/8-inch square. This will make a sharp, effective point that is strong enough to resist breaking. Before sharpening secure the head in a vise or special jig. Sharpen with an electric grinder or a 10-inch mill bastard file. Badly damaged picks can also be reforged by a blacksmith.

An oval-tapered eye and handle allow pick heads to tighten when swung, while remaining removable for sharpening, transporting, and handle replacement. A small screw in the handle just below the head will further fasten heads to handles.



Pick secured for sharpening without a vise.

Drilling Steel

1. Senter Tool Service, Portland, Oreg., manufactures hand drilling steel and others tools to individual specifications. The steels are generally one-piece units with a sharpened edge for drilling and a head for receiving the blow of the hammer. The cutting edges can be made in various styles, although star pattern bits are most common. The steels can also be made with removable bits if a rod of greater than 1-3/8 inches is ordered. The latter may be larger than necessary for most trail work, but detachable bits may be preferred in some situations. Senter Tool Service maintains a complete blacksmith shop, so all types of steel can be returned to them for reconditioning. Used steel that is sometimes available in second-hand stores can also be reconditioned there. In addition they will manufacture hammers to your specifications, along with a large variety of other hand tools not commonly found on the market.

2. Local blacksmith shops are usually equipped to manufacture and recondition drilling steel, and although they may not routinely fill orders for hand tools, they are often willing to help.

Courtesy of the University of Montana Mansfield Library Archives.

Drilling Hammers

General Services Administration
(branch office)

Local hardware stores

Senter Tool Service, Inc.
5413 NE Columbia Blvd.
Portland, Oreg. 97218
(503) 381-1151

Stanley Tools
(Div. of Stanley Works)
Box 1800
New Britain, Conn. 06050
(203) 225-5111

True Temper Corp.
1623 Euclid Ave.
Cleveland, Ohio 44115
(216) 969-3366

Wedge and Feather Sets

ABEMA
Box 775
Norwalk, Conn. 06856
(203) 846-2003

Atlas-Copco Corp.
610 Industrial Ave.
Wayne, N.J. 07652
(201) 696-0554

Senter Tool Service, Inc.
5413 NE Columbia Blvd.
Portland, Oreg. 97218
(503) 281-1151

Picks

Ben Meadows Co.
Box 80549
Atlanta, Chamblee, Ga. 30366
(404) 455-0907

Easco Tools, Inc.
6721 Baymeadow Dr.
Glen Burnie, Md. 21061
(301) 760-2200

Forestry Suppliers, Inc.
Box 8397
Jackson, Miss. 39204
(601) 354-3565

Sears Roebuck and Co.
(local outlet)

Union Fork and Hoe Co.
500 Dublin Ave.
Columbia, Ohio 43216
(614) 228-1791

Warren Group
(Div. of Warren Tool Corp.)
Box 68
Hiram, Ohio 44234
(216) 569-3224

Woodings-Verona Tool Works
Box 126
Verona, Pa. 15147
(412) 828-7000

Conversion Tables

DECIMAL AND MILLIMETER EQUIVALENTS

Fraction	DECIMALS	MILLIMETERS	Fraction	DECIMALS	MILLIMETERS
1/64	0.015625	0.397	33/64	0.515625	13.097
1/32	.03125	0.794	17/32	.53125	13.494
3/64	.046875	1.191	35/64	.546875	13.891
1/16	.0625	1.588	9/16	.5625	14.288
5/64	.078125	1.984	37/64	.578125	14.684
3/32	.09375	2.381	19/32	.59375	15.081
7/64	.109375	2.778	39/64	.609375	15.478
1/8	.1250	3.175	5/8	.6250	15.875
9/64	.140625	3.572	41/64	.640625	16.272
5/32	.15625	3.969	21/32	.65625	16.669
11/64	.171875	4.366	43/64	.671875	17.066
3/16	.1875	4.763	11/16	.6875	17.463
13/64	.203125	5.159	45/64	.703125	17.859
7/32	.21875	5.556	23/32	.71875	18.256
15/64	.234375	5.953	47/64	.734375	18.653
1/4	.2500	6.350	3/4	.7500	19.050
17/64	.265625	6.747	49/64	.765625	19.447
9/32	.28125	7.144	25/32	.78125	19.844
19/64	.296875	7.541	51/64	.796875	20.241
5/16	.3125	7.938	13/16	.8125	20.638
21/64	.328125	8.334	53/64	.828125	21.034
11/32	.34375	8.731	27/32	.84375	21.431
23/64	.359375	9.128	55/64	.859375	21.828
3/8	.3750	9.525	7/8	.8750	22.225
25/64	.390625	9.922	57/64	.890625	22.622
13/32	.40625	10.319	29/32	.90625	23.019
27/64	.421875	10.716	59/64	.921875	23.416
7/16	.4375	11.113	15/16	.9375	23.813
29/64	.453125	11.509	61/64	.953125	24.209
15/32	.46875	11.906	31/32	.96875	24.606
31/64	.484375	12.303	63/64	.984375	25.003
1/2	.5000	12.700	1	1.000	25.400

1 mm = .03937"

.001" = .0254 mm

MM	INCHES	MM	INCHES
.1	.0039	46	1.8110
.2	.0079	47	1.8504
.3	.0118	48	1.8898
.4	.0157	49	1.9291
.5	.0197	50	1.9685
.6	.0236	51	2.0079
.7	.0276	52	2.0472
.8	.0315	53	2.0866
.9	.0354	54	2.1260
1	.0394	55	2.1654
2	.0787	56	2.2047
3	.1181	57	2.2441
4	.1575	58	2.2835
5	.1969	59	2.3228
6	.2362	60	2.3622
7	.2756	61	2.4016
8	.3150	62	2.4409
9	.3543	63	2.4803
10	.3937	64	2.5197
11	.4331	65	2.5591
12	.4724	66	2.5984
13	.5118	67	2.6378
14	.5512	68	2.6772
15	.5906	69	2.7165
16	.6299	70	2.7559
17	.6693	71	2.7953
18	.7087	72	2.8346
19	.7480	73	2.8740
20	.7874	74	2.9134
21	.8268	75	2.9528
22	.8661	76	2.9921
23	.9055	77	3 0315
24	.9449	78	3.0709
25	.9843	79	3.1102
26	1.0236	80	3.1496
27	1.0630	81	3.1890
28	1.1024	82	3.2283
29	1.1417	83	3.2677
30	1.1811	84	3.3071
31	1.2205	85	3.3465
32	1.2598	86	3.3858
33	1.2992	87	3.4252
34	1.3386	88	3.4646
35	1.3780	89	3.5039
36	1.4173	90	3.5433
37	1.4567	91	3.5827
38	1.4961	92	3.6220
39	1.5354	93	3.6614
40	1.5748	94	3.7008
41	1.6142	95	3.7402
42	1.6535	96	3.7795
43	1.6929	97	3.8189
44	1.7323	98	3.8583
45	1.7717	99	3.8976
		100	3.9370

METRIC CONVERSION CHART

Symbol	When You Know	Multiply By	To Find	Symbol
in.	inches	25.4	millimeters	mm.
mm.	millimeters	.039	inches	in.
in.	inches	2.54	centimeters	cm.
cm.	centimeters	.394	inches	in.
ft.	feet	30.48	centimeters	cm.
cm.	centimeters	.033	feet	ft.
ft.	feet	.305	meters	m.
m.	meters	3.281	feet	ft.
yd.	yards	.914	meters	m.
m.	meters	1.094	yards	yd.
oz.	ounces	28.35	grams	g.
g.	grams	.035	ounces	oz.
lb.	pounds	.454	kilograms	kg.
kg.	kilograms	2.205	pounds	lb.

INCANDESCENT COLORS AND TEMPERATURES

COLOR	°F	°C
Black Red	990	533
Dark Blood Red	1050	565
Dark Cherry Red	1175	634
Medium Cherry Red	1250	676
Full Cherry Red	1375	745
Light Cherry	1550	843
Salmon	1650	899
Light Salmon	1725	940
Yellow	1825	995
Light Yellow	1975	1078
White	2220	1203

COLORS OF TEMPERING HEATS

COLOR	°F	°C
Light Straw	430	222
Straw	450	232
Dark Straw	470	244
Yellow Brown	490	255
Dark Brown	510	265
Brown Purple	520	271
Dark Purple	530	277
Bright Blue	550	288
Full Blue	560	293
Dark Blue	600	316

HARDNESS TESTING CONVERSION TABLE

Rockwell C 120 Cone 150 Kg	Brinell 3000 Kg 10MM Ball	Rockwell C 120 Cone 150 Kg	Brinell 3000 Kg 10 MM Ball
	156	32	302
	159	33	311
	163	34	321
	166	35	332
	170	36	340
	174	37	351
	179	39	364
	183	40	375
	187	41	387
	192	43	402
10	196	44	418
12	202	45	430
14	207	46	444
17	212	48	460
19	217	49	477
21	223	50	495
22	228	52	512
23	235	54	532
24	241	56	555
25	248	58	578
26	255	60	600
27	262	62	627
28	269	65	652
29	277	66	683
30	293	68	744
31	293	68	744

Bibliography

Mining Books

Foster, C. LeNeve. *A Textbook of Ore and Stone Mining* (Charles Griffing Co., Ltd.) 1901.

Ihlseng, M.C. *A Manual of Mining* (John Wiley and Sons, New York) 1901.

Lupton, Arnold. *Mining* (Longman's, Greene, & Co., London) 1906.

Young, George. *Elements of Mining* (McGraw-Hill, Inc., New York) 1946.

Young, Otis E. *Black Powder and Hand Steel* (University of Oklahoma Press, Norman, Oklahoma) 1975.

Young, Otis E. *Western Mining* (University of Oklahoma Press, Norman, Oklahoma) 1970.

Mining Handbooks

Atlas Copco Company. *Rock Drilling Manuals.* V.I "Theory and Technique" and V.II "Drill Steel Applications" (Atlas Copco Co., Wayne, N.J.) 1979.

Lock, C.G. Warnford. *Miner's Pocket-Book.* (Spon and Chamberlin, London and New York) 1896.

Von Bernewitz, M.W. *Handbook for Prospectors and Operators of Small Mines.* (McGraw-Hill, Inc., London and New York) 1943.

Trail Manuals that Reference Rock Work

Arthur, Guy B. *Construction of Trails* (CCC Project Training 7, Feb. 1937). (U.S. Dept. of Interior, Washington, D.C.)

Proudman, Robert D. *AMC Guide to Trail Building and Maintenance* (Appalachian Mountain Club, Pinkham Notch Camp, N.H.) 1977.

USDA-Forest Service. *Trail Construction on the National Forests 1915* (Washington, D.C.).

USDA-Forest Service. *Trail Construction on the National Forests 1923* (Washington, D.C.).

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