places, consists in inserting the needle into the charge and then tamping up the hole. Care is taken to draw out the needle a little as the tamping proceeds, so as to prevent too much force being required for its final withdrawal. The small hole left in this way serves for the insertion of a straw, rush, or series of small quills, filled with fine powder, which like the fuse reaches from the charge to the outside. A short squib which shoots a stream of sparks down the needle hole is also used occasionally. The straw or squib is lighted by some kind of slow match, made either by dipping a cotton strand in melted sulphur or soaking a piece of paper or a lucifer in the tallow of a candle; touch-paper also is used.

Dynamite, blasting gelatin, gun-cotton, and cotton-powder are fired by the detonation of a fulminating cap. A long copper cap containing fulminate of mercury is fastened into the safety-fuse by squeezing with a pair of nippers, and is then inserted into a small cartridge of the explosive (*primer*), and placed above the rest of the charge. Fig. 24 shows a hole charged with two dynamite cartridges, a primer with cap, and filled up with water as tamping. Sometimes gun-cotton is fired by a small charge of powder above it.

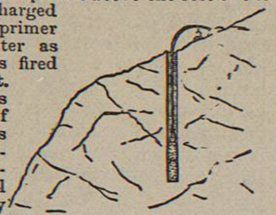


Fig. 24

Several substitutes for explosives have been tried with the object of getting rid of the flame, which is dangerous in collieries giving off fire-damp. Among these may be mentioned plugs of dry wood which swell when wetted, wedges worked by hydraulic pressure, cartridges containing compressed air at extremely high pressures, and lastly cartridges of compressed lime which expands when water is brought into it.

For the purpose of firing several holes simultaneously, Messrs Bickford, Smith, & Co., the original inventors and makers of the safety-fuse, have brought out a new fuse (fig. 25), the action of which will be easily understood from the figure. An ordinary fuse is fixed into a metal case called the igniter, from which a number of instantaneous fuses convey fire to as many separate holes. It is found in practice that this fuse answers very well.

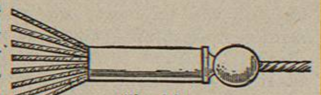


Fig. 25.

Charges may be readily fired singly or simultaneously with the aid of electricity, either of high tension obtained from a frictional, magneto-electric, or dynamo-electric machine, or of low tension from a galvanic battery. The former is preferred.

Fig. 26 shows a section of one of Brain's high-tension fuses. A is a cylindrical wooden case containing a paper cartridge B, with an electric igniting composition C at the bottom. Two copper wires D, D enclosed in gutta-percha E, E reach down to the composition, where they are about $\frac{1}{50}$ inch apart. A copper cap or detonator G is fixed on to the small end of the wooden case. The insulated wires D, D are long enough to reach beyond the bore-hole. The ends of the wires are scraped bare, and one wire of the first hole is twisted together with a wire of the next hole, and so on, and finally the two odd wires of the first and last hole are connected to the two wires of a single cable, or to two separate cables, extending to some place of safety to which the men can retreat. Here the two cable wires are connected by binding screws to a frictional electrical machine or dynamo exploder. A few turns of the handle charge a condenser, and by pressing a knob or by some other device the circuit is completed and the discharge effected. The electricity passes through the fuse wires making a spark at each break, and so firing the electric igniting composition. The flame flashes through the hole H, and ignites the fulminating mercury I, the detonation of which causes the explosion of the dynamite, blasting gelatin, or tonite surrounding the cap.

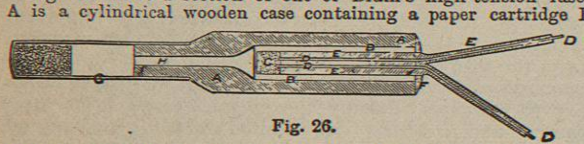


Fig. 26.

One great advantage of electric firing is that the miner can retire to a perfectly safe place before attempting to explode the charge. This is important in sinking shafts, where the means of escape are less easy than in levels. A second advantage is that there is no danger of a "hang fire," an occasional source of accidents with the ordinary safety-fuse.

One of the greatest improvements in the art of mining during the last few years has been the introduction of machinery for boring holes for blasting; most of the machines imitate percussive boring by hand, but a few rotary machines are also in use. A percussive drill or perforator consists of a cylinder with a piston to which the drill is fastened. Compressed air is made to act alternately on each side of the piston, and in this manner the drill receives its reciprocating motion. Various arrangements have been adopted for securing the automatic rotation of the drill. In some cases also the advance forward of the machine, as the hole is deepened, is also effected automatically; but in many of the best drills this work is left to the man in charge. It is impossible within the limits of this article to describe the various drills now in use, or even to make a complete enumeration of them.

The following, in alphabetical order, are the names of some of the best-known drills:—Barrow, Beaumont, Burleigh, Champion, Cornish, Cranston, Darlington, Desideratum, Dœring, Dubois and François, Dynamic, Eclipse, Excelsior, Ferroux, Frohlich, Ingersoll, Laxey, Mackean, Osterkampf, Rand, Roanhead, Sandycroft, Schram. An account of two of the simplest, the Barrow and the Darlington drills, will be sufficient to give a general idea of the construction of these machines.

"The Barrow drill (fig. 27) consists essentially of a gun-metal cylinder C about 2 feet in length and 4 inches in diameter, in which works a cast-steel piston-rod D, fitted with two pistons G, about 12 inches apart, mid-way between which is the tappet, or boss, G′. In a valve-box on the top of the cylinder is placed the oscillating slide-valve H (shown separately), hinged at M, which is worked by the reciprocation of the tappet G′ coming in contact with its lower edges, which for this purpose are formed with two slopes at each end, as shown. It has ports corresponding with openings in the slide-valve face for admitting the fresh steam or compressed air from the inlet pipe I (fig. 28) to the ports *j* at each end of the cylinder, and for letting the spent or exhaust air or steam escape by the exhaust pipe J. This simple arrangement constitutes the whole valve gear of the machine.

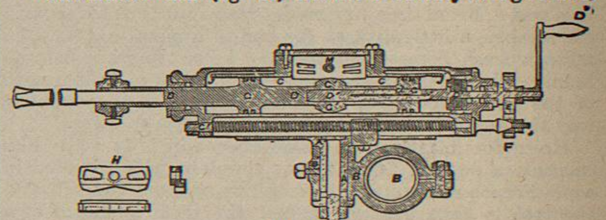


Fig. 27.

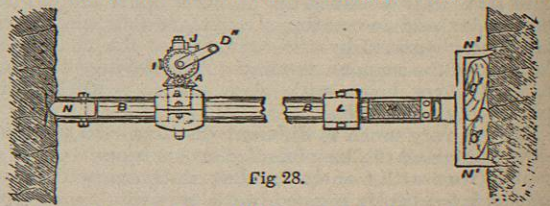
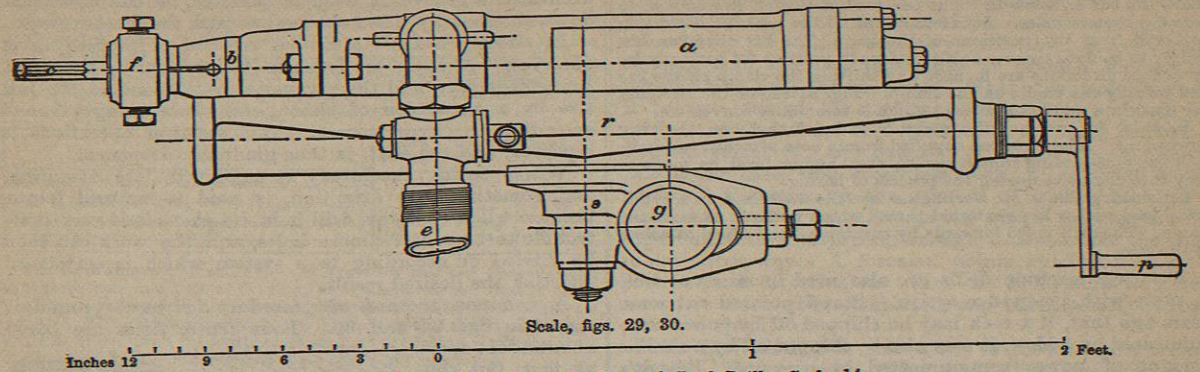


Fig 28.

"The borer is inserted into a hole formed in the fore end of the piston rod, and is fixed therein by means of a screw. Its rotation is effected by hand, by means of the handle D″, turning a spindle D′, which is so fitted by means of the cotter *d*, made fast in the piston DG, and fitting in a slot in the spindle D′, that the latter can slide in the piston DG, but when turned by the handle causes the piston to turn with it. The spindle D′ has a pinion E gearing into the pinion F, on the adjusting and feeding screw C′, so that when the piston D is turned by means of the handle D″ the cylinder C is simultaneously pushed along the bed-plate A. These pinions can be easily disconnected by loosening the nut *f*, and thus the piston and the adjusting screw can be turned independently of one another when required.

"The borers used are respectively 1¼ inches, 1⅛ inches, and 1 inch in diameter, the length of the stroke 4 inches, and the maximum number of blows about three hundred per minute. The air is brought down about 400 fathoms from surface, at a pressure of 50 to 55 lb to the square inch, in wrought-iron pipes 2 inches in diameter in the shaft, and 1½ inches in the level, and admitted through a flexible tube into the inlet I on the left-hand side of the cylinder. The cost of the pipes is rather under 7d. a foot, or about 3s. 3d. per fathom. The air is compressed at the surface by a 14-inch compressor, worked by a 12-inch horizontal engine, capable, however, of working two machine drills. The gross weight of the machine. including the bed-plate and gudgeon, is about 115 lb."

The method of fixing the machine for work is as follows:—"The bed-plate A of the machine is formed with a gudgeon A′ which fits into, and can be adjusted to any position in, a socket formed in or on a clamp B′, which can be fixed on any part of the wrought-iron bar or column B, thus forming a universal joint. This bar or column can be placed in position either horizontally or vertically, as may be most convenient, but is generally placed across the level, against the sides of which it is secured by means of the clamp L, and adjusting screw M, and claws N and N′. If necessary, wooden wedges O, O′ are driven in between the claws and the wall to make it still firmer. The weight of the bar is about 120 lb."[1]



Scale, figs. 29, 30.

Fig. 29.—Side Elevation of Darlington's Rock-Drill.—Scale $\frac{14}{100}$.

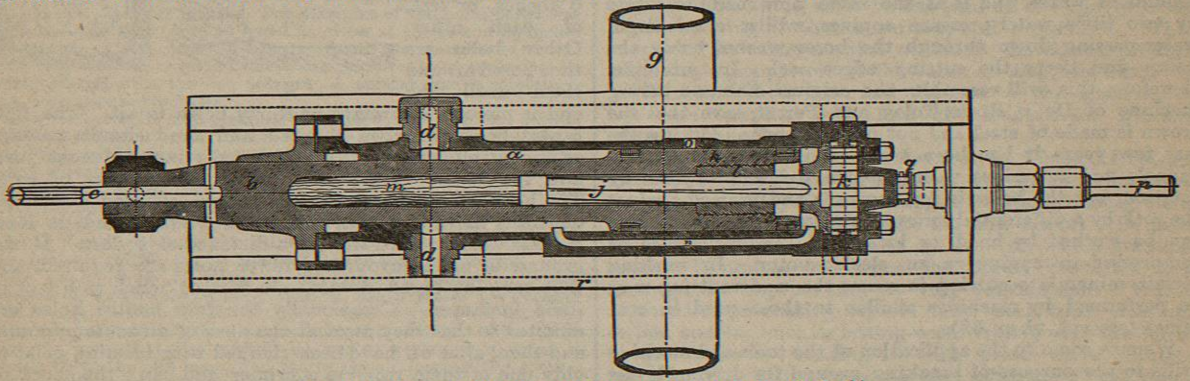


Fig. 30.—Horizontal Section of Darlington's Rock-Drill.—Scale $\frac{14}{100}$.

Air-compressing plant of greater size has now been erected at Dolcoath mine, to which the above description refers. At Snailbeach mine in Shropshire they have two air-compressors of 18 inches diameter and 5 feet stroke; the air-main is at first 9 inches in diameter, then 6 inches, whilst 2-inch gas-pipe is used in the levels.

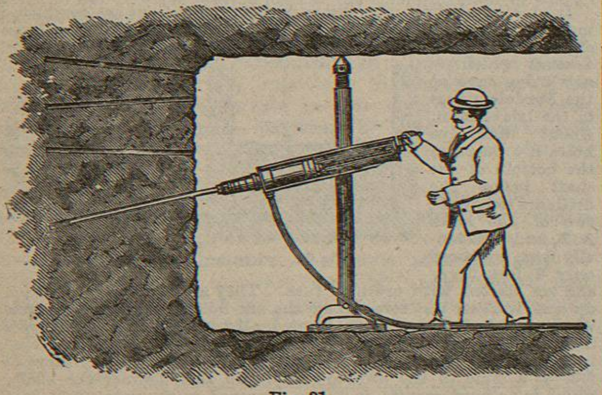


Fig. 31.

A rock-drill which has done, and is doing, excellent work is that of Mr John Darlington. Its construction will be understood by referring to figs. 29, 30, and 31; *a* is the cylinder, *b* the piston rod, *c* the borer; *d*, *d* are two openings for bringing in compressed air, either of which may be used according to the position of the drill; *e* is the inlet hose with a stopcock, *f* drill-holder, *g* stretcher bar, *h* piston, *j* rifled bar for turning piston and drill, *k* ratchet wheel attached to rifled bar, *l* rifled nut fixed in the piston head, *m* wood for lessening weight of piston rod and blocking space, *n* portway for allowing the compressed air to pass to the top of the piston and give the blow, *o* exhaust portway. The action of the drill is as follows. The compressed air is always acting on the underside of the piston, and when the upper side of the piston communicates with the outer atmosphere the piston moves rapidly backwards and uncovers the portway *n*. The compressed air rushes through and presses against the upper side of the piston, which has a greater area than the lower side, the difference being equal to the area of the piston rod. The piston is driven rapidly downwards and the drill strikes its blow. At the same time it uncovers the exhaust port *o* and then the constant pressure on the annular area on the underside of the piston produces the return stroke. The number of blows per minute is from six hundred to eight hundred. The rotation of the drill is effected by the rifled bar. On the down-stroke of the piston the bar with its ratchet wheel is free to turn under a couple of pawls, and consequently the piston moves straight whilst the bar and ratchet wheel turn. When the up-stroke is being made the ratchet wheel is held by the pawls and the piston is forced to make part of a revolution. As the hole is deepened the cylinder is advanced forwards by turning the handle *p*; this works an endless screw *g*

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[1] *Proc. Mining Institute of Cornwall*, vol. i., 1877. p. 12.

passing through a nut attached to the cylinder; *r* is the cradle carrying the feed-screw and supporting the cylinder. It is centred on the clamp *s*. As this clamp can be fixed in any position on the bar, and as the cradle can be turned on the clamp, it is evident that holes can be bored in any direction.

In driving a level with the Darlington drill it is usual to fix the stretcher bar horizontally across the level so as to command the upper part of the face: holes can then be bored with the cradle above the bar or below it. The bar is then shifted low enough to bore the bottom holes. It is found that all the necessary holes can be bored from two positions of the bar. The bar therefore has simply to be fixed twice; the alterations in position for boring holes in various directions are managed by shifting the clamp on the bar and turning the cradle on the clamp. Fig. 31 shows the stretcher bar fixed in a vertical position, which is sometimes convenient.

In order to clear out the sludge from holes that are "looking downwards," a jet of water, supplied from a hose attached to a half-inch gas-pipe leading from a cistern at a higher level, is made to play into the holes during the process of boring.

For sinking shafts Mr Darlington has the drill fixed in a cylindrical case with a large external thread which works in a nut on the clamp. The drill is fed forwards by turning a hand-wheel attached to the case.

Rotating drills.

Rotating machine drills are also used in mines as well as those with percussive action. Stapff pointed out some years ago that, if a rock may be chipped off by power communicated by a blow, it may also be chipped off by a similar amount of power communicated by pressure. Brandt's rotatory boring-machine consists of a hollow borer which has a steel crown with cutting edges screwed on. The tool is kept tight against the rock by the pressure of a column of water, and is at the same time made to rotate by two little water-pressure engines, whilst a stream of water passing down through the borer washes away the débris and keeps the cutting edges cool. In principle, therefore, this drill resembles the original diamond boring machine of De la Roche-Tolay and Perret, save that the crown is made of steel and not of diamonds. During the last few years it has been tried with success in railway tunnels and in mines. Jarolimek's drill[1] acts also by rotation, but the borer is fed forwards and pressed against the rock by a differential screw arrangement. The machine can be worked by hand, or by a little water-pressure or compressed-air engine or an electro-motor. In working certain minerals occurring in seams the undercutting may be performed by machines similar to those used in coal mines (see vol. vi. p. 68).

We now come to the application of the tools and machine drills to the purpose of breaking ground for driving levels and sinking shafts.

Driving levels.

A level or drift is a more or less horizontal passage or tunnel, whilst a shaft is a pit either vertical or inclined. In driving a level by hand labour in hard ground, the first thing the miner has to do is to take out a cut, *i.e.*, blast out a preliminary opening in the "end" or "forebreast." The position of this cut is determined by the joints, which the miner studies carefully so as to obtain the greatest advantage from these natural planes of division. Thus fig. 32 shows a case in which, owing to joints, it was advisable to begin with a hole No. 1, and then bore and blast 2, 3, and 4 one after the other. The miner as a rule does not plan the position of any hole until the previous one has done its work; in fact he regulates the position and depth of each hole by the particular circumstances of the case. Though a vein and its walls may be hard, there is occasionally a soft layer of clay (DD, DD, fig. 33) along one wall (*dig*, Cornwall; *gouge*, United States). The miner then works this away with the pick, and, having excavated a groove as deep as possible, he can now blast down the lode by side holes and so push the level forward

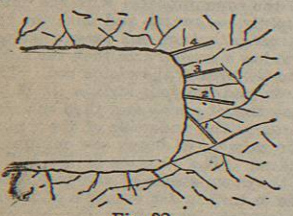

Fig. 32.

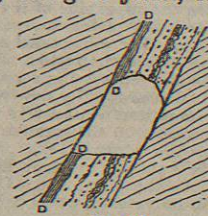

Fig. 33.

In sinking a shaft a similar method of proceeding is observed. A little pit (*sink*) is blasted out in the most convenient part, and the excavation is widened to the full size by a succession of blasts, each hole being planned according to circumstances. This series of operations is repeated, and the shaft is thus gradually deepened.

Where boring machinery is employed, less attention, and sometimes no attention, is paid to natural joints, because when once the drill is in its place it is very little trouble to bore a few more holes, and the work can then be carried on according to a system which is certain of effecting the desired result.

Driving levels with machine drills.

A common method of procedure for hard ground is shown in figs. 34 and 35. Four centre holes are bored about a foot apart at first, but converging till at a depth of 3 feet they are within 6 inches, or less, of each other. Other holes are then bored around them until the end is pierced by twenty or thirty holes in all. The four centre holes are then charged and fired simultaneously, either by electricity or by Bickford's instantaneous fuse, and the result is the removal of a large core of rock. The holes round the opening are then charged and fired, generally in volleys of several holes at a time, and the level is thus carried forward for a distance of 3 feet. If the ground is more favourable fewer holes are required, and they may be bored deeper,—in fact as much as 6 feet in some instances. Occasionally the four centre holes are directed so that they meet at the apex of an acute pyramid, and then, after all have been charged with blasting gelatin, only one of them receives a primer and cap; the shock of the explosion of one charge fires the other three adjacent charges simultaneously. The preliminary opening is not necessarily made in the centre of a level, and sometimes it is blasted out in the bottom or one side.

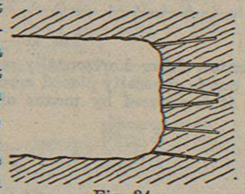

Fig. 34.

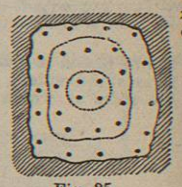

Fig. 35.

In sinking shafts by boring machinery operations are conducted much in the same way as in levels, save of course that the holes are directed downwards. Figs. 36 and 37 are a section and plan of a shaft which is now being sunk at the Foxdale mines in the Isle of Man. About forty-five holes are bored in the bottom of the shaft before the drills are removed; two of the holes A, B, and occasionally four, are bored only 4 feet deep, and are blasted with ordinary fuse. They serve simply to smash up and weaken the core; then the six holes nearest the centre, which are 8 feet deep, are blasted all together with Bickford's instantaneous fuse, and the result is the removal of a large core leaving a deep *sink*. The remaining holes are fired in volleys of four at a time in the ordinary way. In this manner the shaft, which is in hard granite, is being deepened at the rate of 3½ or 4 fathoms a month. Tonite is the explosive used.

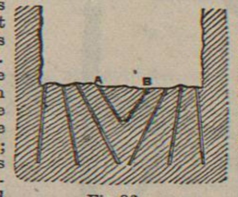

Fig 36.

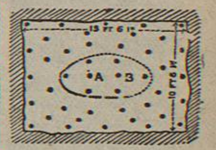

Fig. 37.

Sundry machines have been invented and used for driving levels without blasting. Some cut up the face into small chips which can

easily be removed, but they have not made their way at present into ordinary mining. The Bosseyeuse of MM. Dubois and François acts on a different principle. It is a strong machine worked by compressed air. It first of all drills holes 4 inches in diameter by percussion; a striking head is then substituted for the drill, and wedges, on the principle of the plug and feathers, are inserted into the holes; and powerful blows with the striking head wedge off the rock in lumps. This machine is being used with success in Belgium for driving levels and crosscuts in fiery mines.

Some comparative experiments between hand-labour, a percussive drill, and a rotatory drill have lately been made in one of the Freiberg mines,[1] and the results are of much interest and importance. The actual figures are as follows, the cost including, in the case of the machines, interest, depreciation, and cost of repairs, and cost of steam-power, supposing water-power not available:—

	Hand-boring.	Schram's Drill.	Brandt's Drill.
Distance driven per week (in metres)	0·95	4·5	5·0
Cost in marks per metre driven....................	120 to 123·5	77·4 to 85·25	74·34
Wages realized by the miners, in marks, per 8 hours shift	1·85 to 2·05	3·48 to 3·66	3·76

The advantages of machine work are very marked indeed both as regards rate and cost of driving, and wages earned by the men. Brandt's rotatory drill did its work cheaper and faster than Schram's machine; but nothing is said in the original notice of the advantage of a machine driven by compressed air for ventilating workings such as advanced headings in which these drills are employed.

Brandt's machine was worked with water at a pressure of 83½ atmospheres, of which 56·6 atmospheres were obtained by pressure pumps provided with an accumulator, and 26·9 atmospheres by natural fall, owing to the working level being 277 metres below the pumps. The water was conveyed to the machine in iron pipes of 1½ inches diameter inside. The diameter of the holes bored was 2¾ inches, and they could be bored in gneiss at the rate of 1½ inches per minute. The stretcher bar on which the machine is carried is hollow, and has a piston which can be forced out by hydraulic pressure so as to fix the bar firmly. A similar bar is sometimes used with percussive drills.[2]

As a method of breaking ground the ancient process of fire-setting requires to be mentioned. Before blasting was known it was largely employed, but its use is now confined to a few places on the Continent where the rocks are exceedingly hard and where wood is abundant and cheap. Piles of wood are heaped up against the face of the workings and set on fire. On returning to the working place two or three days afterwards, when the rocks have cooled a little, it is found that the ground has split and flaked off, and that much has been loosened which can be removed by the pick and wedge.

We finally come to water as an agent for removing rocks. Streams of water were formerly used in South Wales for working beds of clay ironstone at the outcrop. The water washed away the clay and shale and left the clean nodules of ironstone. The china clay of Cornwall is also worked by water: a stream of water is turned on to the soft mass, and the workman loosens the ground with a pick; the water carries off the particles of decomposed rock in suspension to regular settling pits. Water under pressure has rendered vast services to the miner in working auriferous alluvia. The system is described and figured at p. 746 of vol. x., so it is unnecessary here to enter into details. In the special case of salt-mines recourse may be had to the solvent action of water, directed by suitable jets, for making excavations.

Modes of paying miners.

5. *Principles of Employment of Mining Labour.*—As a large proportion of the expenditure in mining is for actual manual labour, it is very important that means should be taken to prevent any waste in this department. Three principles are in vogue—payment by time, by work done either measured or weighed, and by the value of the ore extracted.

The overseers, called captains in many metal mines, are naturally paid by the month, and where strict supervision can be exercised, such as is possible at the surface, on the dressing-floors for instance, the same principle may be adopted; but when men are working underground, and often in small gangs of only two or three persons at some distance apart, piecework of some kind is more economical and satisfactory in every way.

In driving levels and sinking shafts it is usual for the men to work at a certain price per running yard or fathom The agents have to see that the excavation, whether shaft or level, is maintained of the full dimensions agreed upon, and preserved in the proper direction. At the end of a certain time, generally a month, the work is measured by the agent. From the gross amount obtained by multiplying the price by the number of fathoms driven or sunk it is necessary to deduct the cost of the materials supplied to the men by the mining company, such as explosives, steel, candles, &c., and the remainder is divided among the persons who took the contract. When the useful mineral is being obtained the men may be paid at so much per cubic yard or fathom excavated, or at so much per ton of mineral extracted; the overseer of course has to see, in this latter case, that worthless rock is not sent to the surface. Payment by the number of inches bored is a method in use in some countries, where the men are not experienced or enterprising enough to undertake the work in any other way. A foreman points out to the men the position and direction in which the holes must be bored, measures them when completed, and subsequently charges and fires them.

The third method is that which is known as the tribute system. The miner working on tribute is allowed to speculate upon the value of the ore in a certain working area assigned to him and called his *pitch*. He gives the mining company all the ore he extracts at a certain proportion of its value, after he has paid all the cost of breaking it, hoisting it to the surface, and dressing it. Thus, supposing he takes a pitch at 5s. in the £, and produces marketable copper ore of the value of £50, his share will be 50 × 5s. = £12, 10s., less the cost of the materials he has been supplied with, and all expenses for winding, dressing, sampling, &c.

Timbering.

6. *Means of Securing Excavations by Timber, Iron, and Masonry.*—The following kinds of timber are those most frequently employed for securing excavations underground: oak, larch, pitch pine, spruce fir, and acacia. In many mines the timber is attacked by dry rot, which gradually renders it useless, and when the timber has often to be renewed the expense may be very considerable. Various methods of preventing dry rot have been tried with more or less success, such as letting water trickle over the timber in the mine or treating it with preservative solutions beforehand. Brine, creosote, and solutions of chloride of zinc, sulphate of zinc, sulphate of copper, and sulphate of iron increase the duration of timber. It was found by experiments carried on at Commentry during a long series of years that one of the best plans was to soak the timber for twenty-four hours in a strong solution of sulphate of iron. The total cost was only ½d. per yard of prop, whilst the timber lasted eleven times as long as when this simple treatment was omitted.

Timber is used in various forms—either whole and merely sawn into lengths, or squared up, or sawn in half, or sawn into planks of various thicknesses.

Where the roof of a bed is weak it may be kept up by simple props; but in some coal-mines and clay-mines a better support is obtained by logs (*chocks*) laid two by two crosswise (fig. 38).

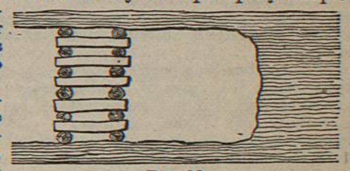

Fig. 38.

Though a level is an excavation of a very simple nature, the methods of timbering it vary considerably, because the parts requiring support may either be the roof alone, or the roof and one or two sides, or the roof, sides, and bottom.

If the roof only is weak, as is the case with a soft lode between two hard walls, a *cap* with a few boards resting on it (fig. 39) is sufficient to prevent falls. If one side is weak the cap must be

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[1] *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1881.

[1] *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen auf das Jahr* 1882, p. 18, and abstract in *Proc. Inst. Civ. Eng.*, vol. lxix., 1881–82, part iii. p. 51.

[2] *Annales des Mines*, ser. 8, ii., pl. 1, fig. 6, 1882.

supported by a side prop or *leg* (fig. 40), and very often by two legs. The forms of joint between the cap and leg are numerous (fig. 41), depending to a great extent upon the nature of the pressure, whether coming upon the top or sides. With round timber the top of the leg is sometimes hollowed as shown in fig. 42 A, but occasionally the joint is flat and a thick nail, or *nog*, is put in (fig. 42 B) to prevent the effects of side pressure, or, better, a piece of thick plank is nailed under the cap (fig. 43). Where the floor of a level is soft and weak, a sole-piece or *sill* becomes necessary, and, if the sides or roof are likely to fall in, a lining of poles or planks is used (fig. 43).

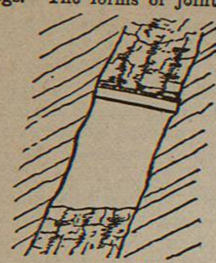

Fig. 39.

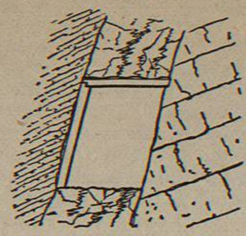

Fig. 40.

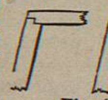

Fig. 41.

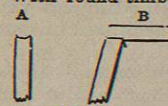

Fig. 42.

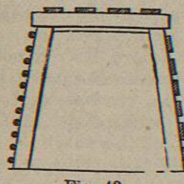

Fig. 43.

In some very heavy ground in the Comstock lode a special system of timbering is adopted (fig. 44).

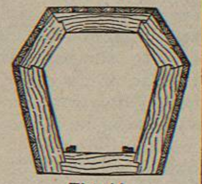

Fig. 44.

If the ground is loose, so that the roof or sides, or both, will run in unless immediately supported, the method of working called *spilling* or *poling* is pursued. It consists in supporting the weak parts by boards or poles kept in advance of the last frame set up. The poles or boards (*laths*) are driven forward by blows from a sledge, and the ground is then worked away with the pick; as soon as a sufficient advance has been made a new frame is set up to support the ends of the poles or boards and the process is repeated (figs. 45 and 46). In running ground it is necessary to have the laths fitting closely together, and the working face also must be supported by *breast-boards* kept in place by little struts resting against the frame. These are removed and advanced one by one after the laths in the roof and side have been driven beyond them.

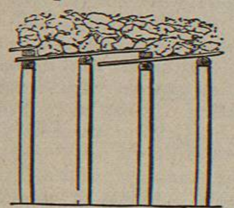

Fig. 45.

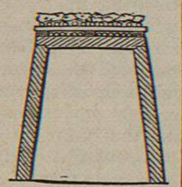

Fig. 46.

On account of the high price of timber, iron is sometimes employed in its place. One method in use in the Harz consists in bending a rail into the form shown in fig. 47 and making it support other rails laid longitudinally, against which flattish stones are placed; the vacant spaces are then filled with rubbish.

Masonry has long been used for supporting the sides of mining excavations. The materials necessary are stone, ordinary bricks, or slag-bricks, and they may be built up alone (*dry walling*) or with the aid of mortar or hydraulic cement. The bottom of a level is occasionally lined with concrete to carry a large stream of water, which otherwise might run into lower workings through cracks and crevices. Dry walling is not uncommon, and it may be combined with the use of timber (or iron) as shown in fig. 69, in which a level is maintained between two walls keeping back a mass of rubbish.

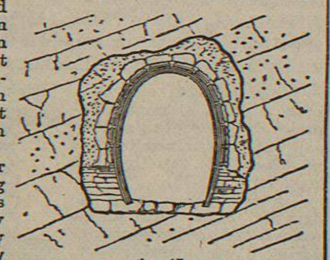

Fig. 47.

Figs. 48 and 49 show methods of securing a drift by arches when a lode has been removed.

The timbering required for shafts varies according to the nature of the ground and the size of the excavation. A mere lining of planks set on their edges (fig. 50) suffices for small shafts, corner pieces being nailed to keep the successive frames together. In some of the salt-mines of Cheshire the shafts are lined with 4-inch planks united by mortice and tenon joints.

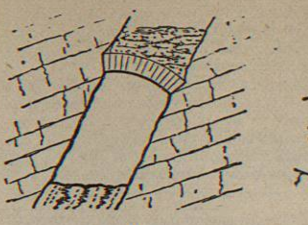

Fig. 48.

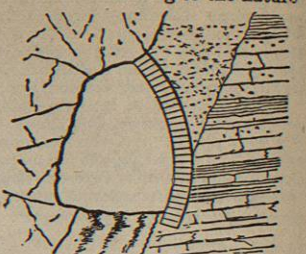

Fig. 49.

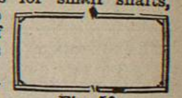

Fig. 50.

The usual method of securing shafts is by *sets* or *frames*. Each set consists of four pieces, two longer ones called *wall-plates* and two shorter ones called *end-pieces*. They are joined by simply halving the timber as shown in fig. 51. A more complicated joint (fig. 52) is often preferred. The separate frames are kept apart by corner pieces (*studdles*, Cornwall; *jogs*, Flintshire), and loose ground is prevented from falling in by boards or poles outside the frames.

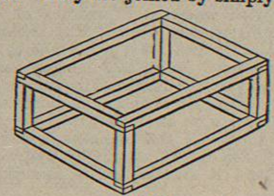

Fig. 51.

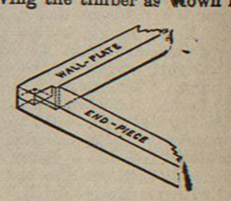

Fig. 52.

As shafts are frequently used for the several purposes of pumping, hoisting, and affording means of ingress and egress by ladders, it becomes necessary in such cases to divide them into compartments. Pieces of timber parallel to the end-pieces (*buntons* or *dividings*) are fixed across the shaft, and serve to stay the wall-plates and carry the guides as well as to support planks (*casing boards*) which are nailed to them so as to form a continuous partition or brattice. The magnificent timbering of some of the shafts on the Comstock lode is described by Mr James D. Hague as follows:[1]—"The timbering consists of framed sets or cribs of square timber, placed horizontally, 4 feet apart, and separated by uprights or posts introduced between them. Cross-timbers for the partitions between the compartments form a part of every set. The whole is covered on the outside by a lagging of 3-inch plank placed vertically." Figs. 53, 54, and 55, copied from Mr Hague's plates, illustrate this method of timbering. Fig. 53 is a plan of the shaft: "S, S are the longitudinal or sill-timbers, T, T the transverse end-timbers, P partition-timbers, *r* guide-rods between which the cage moves, *g* gains cut in the sill-timbers, to receive the ends of the posts. The sheathing or lagging is seen enclosing the whole frame." Fig. 54 is a transverse section through the partition P of fig. 53, "between the pumping compartment and the adjoining hoisting compartment, looking towards the latter. In this figure, G, G are the posts, S the sill-timbers, P the partition-timbers, the ends of which are framed with short tenons that are received in gains cut in the sill-timbers and the ends of the posts, *r* guide-rod, *l* lagging or sheathing." Fig. 55 is an end view of the frame shown in fig. 53. "The single piece T forms the end, while the double pieces P forming the partitions are seen beyond." "The outer timbers of each set, that is, the two sides and ends of the main frame, are 14 inches square; the posts, ten in number, four at the corners and two at each end of the three partitions, are of the same size. The dividing timbers, forming the partitions, are 12 inches square."

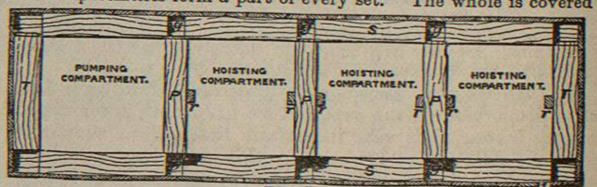

Fig. 53.

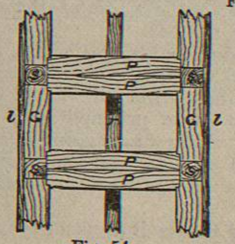

Fig. 54.

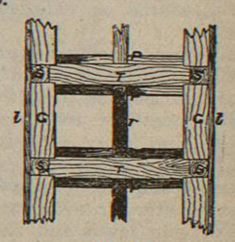

Fig. 55.

When ground is loose or running, recourse must be had to a *spilling* process like that described for levels. Strong balks of timber are fixed at the surface or in solid ground, and then the first frame is hung from these *bearers*, and each successive frame from the one above it. Iron bars with cotters may be used for suspending the sets; but on the Comstock lode each bolt is made in two parts with a tightening screw in the middle, and the sets can thus be kept very firmly together. The laths are driven in advance, in the manner explained in the case of levels, and a new frame is put in as soon as the excavation has been sufficiently deepened within the protecting sheath of boards. In very unstable ground it may be necessary to put in the frames touching each other, so that the shaft becomes encased in a solid box of timber, occasionally 14 inches thick.

Like levels, shafts may be lined with masonry or brickwork, and these have the advantage of being far more permanent than timber, and of requiring fewer repairs. This kind of shaft-lining is especially desirable in the loose ground near the surface; because, if the working is discontinued temporarily, the shaft still remains secure and available for use at any future time, whereas if timber is put in it often decays, the top of the shaft collapses, and much expense is incurred in the process of reopening it. The section of the shafts that are walled is generally circular as affording the best resistance to pressure; but elliptical walling is also met with. Another shape is like a rectangle, save that the sides, instead of being straight, form curves of large radius. The walling may be dry or with mortar, according to circumstances.

The masonry is put in either in one length or in successive portions in descending order, and this is the usual plan. The shaft is sunk a certain depth, with temporary timbering if necessary, and when firm ground has been reached a bed is cut out round the shaft, and on this is placed a crib or curb AB (fig. 56)[1] consisting of segments of timber which form a ring. This serves for a foundation for the brickwork, which is built up to the surface; the temporary timbering is removed, and the space filled up with earth or concrete. Sinking is then resumed below the curb, and for a certain distance of a smaller diameter, so as to leave a bracket, or ledge, to support the first curb. On arriving, after a certain depth of sinking, at another firm bed, a second curb CD is put in and a portion of brickwork built up. When the ledge of rock is reached, it is carefully removed in small sections and the brickwork brought up to the first curb. This process is repeated till the shaft is completed, or reaches rock in which no masonry is requisite. If, owing to the nature of the ground, it is impossible at first to find a firm seat for the curbs, it becomes necessary to hang them by iron bolts from a strong bearing frame at the surface.

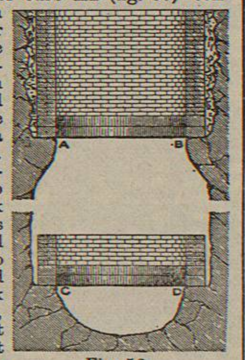

Fig. 56.

When shafts pass through very watery strata, it is most desirable to stop all influx into the mine for the purpose of saving the heavy expense of pumping. The manner in which this is effected by a watertight lining, known as tubbing, is described in the article COAL, vol. vi. p. 62, where will also be found an account of Triger's plan of sinking shafts with compressed air, and the very successful method of boring shafts through water-bearing ground invented by Messrs Kind & Chaudron.

7. *Exploitation, or Working Away of Veins, Beds, and Masses.*—We have described how shafts are sunk and levels driven, and we now come to the processes employed in removing the mineral.

The deposit must first of all be reached by a shaft, or, where the contour of the country permits it, by a level. In the case of a vein an exploratory shaft is often sunk on the course of the lode for 20 or 30 fathoms, and, if the indications found in a level driven out from this shaft warrant further prosecution of the mine, a first working shaft is sunk to intersect the lode at a depth of 100 fathoms or more from the surface. Crosscuts are then driven out at intervals of 10, 15, or 20 fathoms to reach the lode, as shown in fig. 57, which represents a section at right angles to the line of strike. Sometimes the main shafts are carried down all the way along the dip of the deposit, though perpendicular shafts have the advantages of quicker and cheaper winding and cheaper pumping, to say nothing of the possibility of utilizing the cages for the rapid descent and ascent of the miners. If an inclined shaft appears to be advisable, great care should be taken to sink it in a straight line. In either case levels are driven out along the strike of the lode as shown in the longitudinal section fig. 58, in the hopes of meeting with valuable ore-bodies such as are represented by the stippled portions of the figure. For the purpose of affording ventilation, and still further exploring the ground and working it, intermediate shafts, called *winzes* (Cornwall) or *sumps* (North Wales), are sunk in the lode.

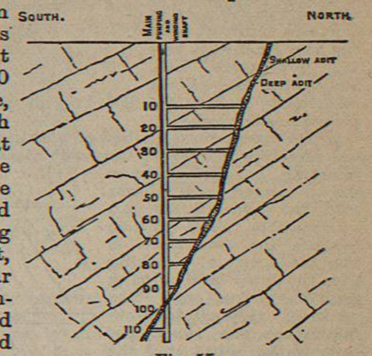

Fig. 57.

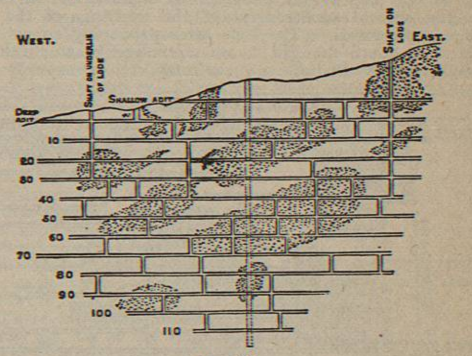

Fig. 58.

The actual mode of removing the lode itself depends a good deal upon circumstances, viz., its width, the nature of its contents, and the walls that enclose it; but the methods of working may generally be brought under one of two heads, viz., underhand stoping or overhand stoping. The word *stope* is equivalent to step, and the term stoping means working away any deposit in a series of steps. *Underhand* or *bottom stopes* are workings arranged like the steps of a staircase seen from above, whilst *overhand* or *back stopes* are like similar steps seen from underneath. Both methods have their advantages and disadvantages, and both are largely used.

We will first take underhand stoping, as this is the older method. In the old days the miner began in the floor of the level (fig. 59), and sank down a few feet, removing the part 1; he followed with 2, 3, 4, &c., until the excavation finally presented the appearance shown in fig. 60. Any valueless rock or mineral was deposited upon platforms of timber (*stulls*), and the ore was drawn up into the level

Fig. 59.

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[1] *United States Geological Exploration of the Fortieth Parallel*, vol. iii., "Mining Industry," p. 103.

[1] J. Callon, *Lectures on Mining*, vol. i., Atlas, plate xxviii.