the Renaissance. Early in the century there arose a taste for older models. As, for their writing and afterwards for their printing, they went back to the 11th and 12th centuries for their standards. so they adopted again the interlacing designs of the Lombardic school for their ornament, and produced beautiful borders of twining patterns relieved by colour; or they took natural objects for their models, and painted borders of delicate flowers made still more brilliant with clustering stars of gold. Later, they drew from the ancient classical designs inspiration for the wonderful borders of arabesques, medallions, griffins, human forms, antique objects, &c., which they brought to such perfection early in the next century. Their miniatures rose to the rank of exquisitely finished pictures, and were executed by some of the best artists working under the patronage of such great houses as those of Sforza and Medici.

Here then, having advanced to the threshold of the domain of modern painting, we leave these two great schools of miniaturists in possession of the west of Europe. The Flemings had the wider field; they were wanderers from home; and their works are scattered through many lands, from England in the north to Spain in the south. But Italian art had greater inherent strength, and will always hold the first rank. To instance a few of the more famous MSS. of this closing period of miniature painting, the Breviary of Isabella the Catholic in the British Museum, is a masterpiece of Flemish art produced in Spain; the Grimani Breviary at Venice is another fine example of the same school. Some beautiful Italian miniatures (executed for Leo X. and others) were in the collection lately sold by the duke of Hamilton. The earl of Ashburnham possesses a most delicately illuminated Book of Hours written for Lorenzo dei Medici by the famous scribe Sinibaldo in 1485, as well as a MS. to which Perugino and his contemporaries contributed paintings. And in one MS., a Book of Hours belonging to Mr Malcolm of Poltalloch, are gathered some of the best miniatures of both schools, viz., a series of exquisite paintings by Milanese artists supplemented by later ones of the finest Flemish type. (E. M. T.)

MINIMS. See FRANCIS (ST) OF PAOLA, vol. ix. p. 695.

MINING

THE art of mining consists of those processes by which useful minerals are obtained from the earth's crust. This definition is wider than what is popularly known as mining, for it includes not only underground excavations but also open workings; at the same time it excludes underground workings which are simply used for passages, such as railway tunnels and sewers, and galleries for military purposes. We must remark also that the word "mine," or its equivalent in other languages, varies in signification in different countries on account of legal enactments or decisions which define it. Thus, in France and Belgium, the workings for mineral are classified by the law of 1810, according to the nature of the substance wrought, into *mines, minières, et carrières*. In the United Kingdom, on the contrary, it is the nature of the excavation which decides the question for certain legislative purposes, and the term mine is restricted to workings which are carried on underground by artificial light. The consequence is that what is merely an underground stone quarry in France becomes a true mine in England, whilst the open workings for iron ore, such as exist in Northamptonshire, would be true mines under the French law. It is necessary, therefore, in an article on mining, to go beyond the English legal definition of a mine, and include the methods of working minerals in excavations open to daylight as well as in those which are purely subterranean. Furthermore, as it is customary for the miner to cleanse his ore to a greater or less extent before selling it to the smelter, we shall treat, under the head of mining, those processes which are commonly known as the dressing or mechanical preparation of ores; and, finally, a few remarks will be made concerning legislation affecting mines in the United Kingdom, accidents in mines, and the production of the useful minerals in various parts of the globe.

The subject therefore will be dealt with as follows:—

1. Manner in which the useful minerals occur in the earth's crust, viz., tabular deposits and masses; faults or dislocations.
2. Prospecting, or search for mineral.
3. Boring with rods and ropes; diamond drill.
4. Breaking ground; tools employed; blasting by various methods; machine drills; driving levels and sinking shafts.
5. Principles of employment of mining labour.
6. Means of securing excavations by timber or masonry.
7. Exploitation, or the working away of strata or veins.
8. Carriage or transport of minerals through underground roads.
9. Winding, or raising in the shafts, with the machinery and apparatus required.
10. Drainage of mines, adit-levels, pumps, pumping engines.
11. Ventilation and lighting of mines.
12. Means of descending into and ascending from mines.
13. Dressing or mechanical preparation of minerals.
14. Recent legislation affecting mines in the United Kingdom.
15. Accidents in mines.
16. Useful minerals produced in various parts of the globe.

1. *Manner in which the Useful Minerals Occur.*—The repositories of the useful minerals may be classified according to their shape as (A) tabular deposits, and (B) masses.

A. *Tabular Deposits.*—These are deposits which have a more or less flattened or sheet-like form. They may be divided, according to their origin, into (1) beds or strata, and (2) mineral veins or lodes.

Stratified deposits.

(1) *Beds.*—Geology teaches us that a large proportion of the rocks met with at the surface of the earth consist of substances arranged in distinct layers, owing to the fact that these rocks have been formed at the bottom of seas, lakes, or rivers by the gradual deposition of sediment, by precipitation from solutions, and by the growth or accumulation of animal and vegetable organisms. If any one of these layers consists of a useful mineral, or contains enough to make it valuable, we say that we have a deposit in the form of a bed, stratum, or seam. Of course the most important of all bedded or stratified deposits is coal, but, in addition, we have beds of anthracite, lignite, iron ore, especially in the Oolitic rocks, cupriferous shale, lead-bearing sandstone, silver-bearing sandstone, diamond-, gold-, and tin-bearing gravels, to say nothing of sulphur, rock-salt, clays, various kinds of stone, such as limestone and gypsum, oil-shale, alum-shale, and slate.

The characteristic feature of a bed is that it is a member of a series of stratified rocks; the layer above it is called the *roof* of the deposit, and the one below it is the *floor*. Its *thickness* is the distance from the roof to the floor at right angles to the planes of stratification; its *dip* is the inclination downwards measured from the horizontal; its *strike* is the direction of a horizontal line drawn in the middle plane.

The thickness of beds that are worked varies within very wide limits. Whilst the thickness of certain workable beds of coal is only 1 foot, and that of the Mansfeld cupriferous shale only 10 to 20 inches, we find on the other hand one of the beds of lead-bearing sandstone at Mechernich no less than 85 feet thick, and beds of slate far exceeding that thickness. It must not be supposed, however, that the thickness of a bed necessarily remains uniform. Occasionally this is the case over a very large area; but frequently the thickness varies, and the bed may dwindle away gradually, or increase in size, or become divided into two owing to the appearance of a parting of valueless rock. Fig. 1 shows beds of shale, limestone, iron ore, and sandstone. Any one of these beds may be valuable enough to be worked.

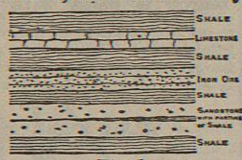

Fig. 1.

Mineral veins.

(2) *Mineral Veins or Lodes.*—Veins or lodes are tabular or sheet-like deposits of mineral which have been formed since the rocks by which they are surrounded; they differ, therefore, by their subsequent origin from beds, which, as just stated, are of contemporaneous origin with the enclosing rocks (although of course cases occur in which the deposit is lying unconformably upon very much older strata, or is covered unconformably by very much younger strata). It is necessary to explain that the term "vein" in this definition is used in a more restricted sense than is sometimes customary among miners, who speak of *veins* of coal, clay-ironstone, and slate, which geologically are true beds. They see a band of valuable mineral or rock, and, careless of its origin, call it metaphorically a vein or seam. On the other hand, the definition is broader than that which prevails among some geologists, who would confine the term vein to deposits occupying spaces formed by fissures.

The term "lode" was defined in 1877 by Mr Justice Field in the celebrated Eureka *v.* Richmond case as follows:—"We are of opinion, therefore, that the term, as used in the Acts of Congress, is applicable to any zone or belt of mineralized rock lying within boundaries clearly separating it from the neighbouring rocks." This interpretation seems suitable for the peculiar mining tenure of the United States, where the discoverer of a vein or lode can obtain a mining claim of 500 yards in length along the lode. It protects the prospector, whose object is to obtain a secure title, the mode of origin of the deposit being a matter of small importance to him so long as it is worth working. In many cases also it would be impossible to decide upon the mode of origin until workings had progressed considerably, and even then there would be room for disputes.

No doubt a very large number of mineral veins are simply the contents of fissures; others are bands of rock impregnated with ore adjacent to fissures or planes of separation; others, again, have been formed by the more or less complete replacement of the constituents of the original rock by particles of ore.

Veins may occur in igneous or in sedimentary rocks, and in the latter they frequently cut across the planes of stratification.

Like a bed, a vein has its dip and strike; but, as the dip of veins is generally great, the inclination is usually measured from the vertical, and is then spoken of as the *underlie* or *hade*. The bounding planes of a vein are called the *walls* or *cheeks*, and they are frequently smooth and striated, showing that one side must have slid against the other. The upper wall is known as the *hanging wall*, the lower one as the *foot wall*. The width of a vein is measured at right angles to the walls.

A typical example of a fissure-vein is shown in fig. 2, representing a lead lode in slate at Wheal Mary Ann mine[1] in Cornwall. It is evident that a fissure in the surrounding slate has here been filled up by the successive deposition of bands of mineral on both sides.

A large proportion of the contents of a lode may consist of fragments of the walls that have fallen into the original fissure, and these are often tightly cemented together by minerals that have been introduced subsequently. The horizontal section of part of the Comstock lode[2] (Plate IV.) shows much "country" rock enclosed within the walls.

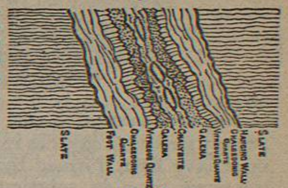

Fig. 2.

Where a lode consists of rock impregnated with ore, the mineralized part may fade away gradually into the surrounding rock (*country*) without there being any distinct wall, as shown in fig. 3, which is an illustration taken from the Great Flat Lode[3] near Redruth in Cornwall.

The celebrated Ruby Hill deposit in the Eureka district, Nevada, is a mineralized zone of dolomitic limestone varying in width from a few inches to 450 feet, and having a mean width of 250 feet. It contains numerous irregular ore-bodies, which consist mainly of highly ferruginous carbonate of lead, rich in silver and gold. This mineralized limestone band, long called a lode by miners, has been determined by the decision just mentioned to be a lode in the eyes of the law.

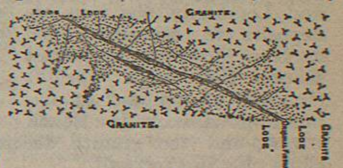

Fig. 3.

Veins often continue for a great distance along their strike. The Van lode in Montgomeryshire is known for a length of 9 miles, whilst the Great Quartz Vein in California has been traced for a distance of no less than 80 miles. Veins are of less uniform productiveness than beds, and are rarely worth working throughout. Rich portions alternate with poor or worthless portions. The rich parts have received various names according to the forms they assume: fig. 4 represents a longitudinal section along the strike (*course*) of a lode, and the stippled parts are ore-bodies; B, B, B are *bunches*; A is a large bunch or *course of ore*; when an ore-body forms a sort of continuous column we have a *shoot*, and ore-bodies which on being excavated leave chimney-like openings are called *pipes* (fig. 4, C). In the United States the Spanish word *bonanza*, literally meaning "fair weather" or "prosperity," is frequently used for a rich body of ore.

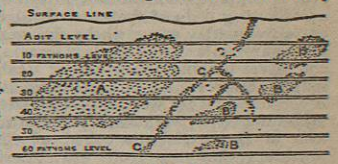

Fig. 4.

The richness of veins is dependent in many cases upon the nature of the adjacent rock (*country*), upon the underlie, and upon the strike, variations in any one of these three elements being often sufficient to cause a decided change of productiveness.

Various theories have been formed concerning the origin of mineral veins. Some geologists suppose that the minerals now constituting the veins have been dissolved out of the adjacent rocks and re-deposited in the vein cavity; others, on the contrary, believe that the ores have been brought up from great depths by mineral springs. In all probability both theories are correct, some lodes having been formed by the former process and some by the latter; and, furthermore, other lodes appear to owe their origin to a gradual substitution of valuable minerals in the place of some of the constituents of a worthless rock. One of the most important contributions to the science of ore-deposits of late years has been the discovery by Professor F. Sandberger of small quantities of silver, lead, copper, nickel, cobalt, bismuth, arsenic, antimony, and tin in silicates, such as olivine, augite, hornblende, and mica, which are constituents of igneous rocks. He therefore regards these rocks as the sources from which lodes have derived their riches.

B. *Masses.*—These are deposits of mineral, often of irregular shapes, which cannot be distinctly recognized as beds or veins. Such, for instance, are the red hæmatite

[1] C. Le Neve Foster, "Remarks on the Lode at Wheal Mary Ann, Menheniot," *Trans. Roy. Geol. Soc. Cornwall*, vol. ix. p. 153.

[2] James D. Hague, in *United States Geological Exploration of the Fortieth Parallel*, vol. iii., "Mining Industry," Washington, 1870, Atlas, plate 11.

[3] C. Le Neve Foster, "On the Great Flat Lode south of Redruth and Camborne, and on some other Tin Deposits formed by the Alteration of Granite," *Quart. Jour. Geol. Soc.*, vol. xxxiv. p. 644.

deposits of the Ulverston district (fig. 5[1]) and the brown hæmatite deposits (*churns*) of the Forest of Dean, which

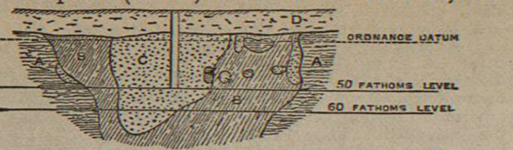

FIG. 5.—Vertical Section, Roanhead Mine. A, Mountain Limestone; B, red hæmatite; C, sand and clay; D, gravel. Scale $\frac{1}{3000}$.

occupy irregular cavities in the Mountain Limestone. These may have been formed by the percolation of water bringing down iron in solution from overlying Triassic rocks. Other examples of masses are the calamine deposits of Altenberg[2] (fig. 6), Sardinia, and Lombardy, the iron ore deposits in Missouri, such as Iron Mountain and Pilot Knob, the huge upright "necks" or "pipes" of diamantiferous rock in South Africa, and the granite decomposed *in situ* worked for china clay in Cornwall.

FIG. 6.—Vertical Section, Altenberg. B, slate; *d*, dolomite; C, calamine; L, clay.

Under this head also are included by most authors the so-called "stockworks" or "reticulated masses," names applied to masses of sedimentary or igneous rock which are penetrated by so many little mineral veins as to make the whole worth excavating.

It must be understood that we cannot expect nature to make distinct lines of demarcation between the different kinds of deposits. Though we may be able to see clearly that a seam of coal is contemporaneous with the enclosing rocks, and that a vein intersecting beds of shale and sandstone was formed subsequently, cases frequently occur where the origin of the mineral is uncertain. For example, we have the lead-bearing sandstone of Mechernich and the silver-bearing sandstone of Utah. The grains of sand are of sedimentary origin; but opinions differ as to whether the lead and silver respectively were deposited with the sand or were introduced subsequently by solutions percolating through the beds. In the case of the well-known bed of Cleveland ironstone, Dr Sorby considers that the iron was "derived partly from mechanical deposition and partly from subsequent chemical replacement of the originally deposited carbonate of lime."[3] Furthermore, a bed may be so folded and contracted as to lose its original sheet-like form in places and assume the shape of an irregular mass. This may happen even with a coal seam.[4]

All kinds of deposits are subject not only to irregularities of origin dependent upon their mode of formation but also to dislocations or shiftings known as faults, heaves, or throws.

We will take the case of a bed (fig. 7). AB is a seam which ends off suddenly at B, whilst the continuation is found at a lower level at CD. The bed was evidently once continuous; but a fracture took place along the line XY followed by a displacement. As a rule

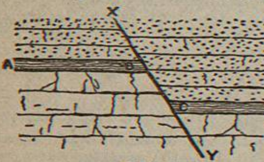

Fig. 7.

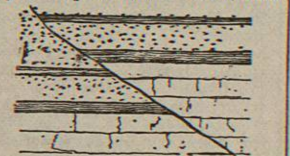

Fig. 8.

the portion of rock on the hanging-wall side of a fault appears to have slid downwards, but occasionally this is not so, and we have a reversed fault (fig. 8). It is very evident, in some cases, that the motion took place, not along the line of greatest dip, but in a diagonal direction, causing a displacement sideways as well as downwards. Nevertheless, where beds or veins are not horizontal, a mere shift along the line of dip is sufficient to cause an apparent heave sideways. This will be understood from fig. 9. Let AB and CD represent two portions of a lode dislocated by the fault EF. The point B′ corresponded originally with B, and the dislocation was caused by a simple sliding of B′ along the line of dip BB′. An instance of the complication caused by a succession of faults is shown in fig. 10.[5]

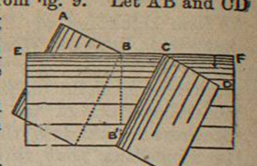

Fig. 9.

2. *Prospecting, or Search for Mineral.*—The object of the prospector is to discover valuable deposits of mineral. This search is beset with many difficulties: the outcrops of

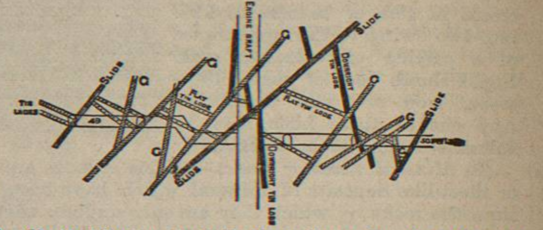

FIG. 10.—Vertical Section, Penhalls Mine, Cornwall. G, G, G, small veins called *gossans* in the St Agnes district.

mineral deposits are frequently hidden by soil; the nature of the deposit itself is generally entirely changed near the surface; and, in addition to this, the explorer may have to pursue his work in trackless forests far away from any settlements.

The prospector seeks for natural sections of the rocks, such as occur in cliffs or in river valleys and their tributary gullies and gorges; he examines the materials constituting the river-beds, often digging up and washing portions in a pan, in order to ascertain whether they contain traces of the heavy ores or metals. If, while prospecting in a valley, he discovers stones that have the appearance of having once belonged to veins, he endeavours to trace them to their source, and is perhaps rewarded by finding similar fragments, but less water-worn, as he goes up the stream; further on he may come upon large blocks of veinstuff lying about, and finally find the vein itself laid bare in a gorge, or at the bottom of a brook, or possibly projecting above the soil in the form of huge crags of quartz. Thus at the Great Western quicksilver mine in California the outcrop of the vein appears as a dike over 100 feet wide, and having precipitous sides in places 75 feet high.[6] Loose pieces of veinstuff found lying about are known in Cornwall as shoad-stones, and *shoading* is the term given to the process of tracking them to the parent lode.

The upper portion of a deposit is frequently much altered by atmospheric agencies, and bears little resemblance to the undecomposed bed or vein which will eventually be met with at a greater or lesser depth. The principal difference consists in the change of sulphides into oxides or oxidized compounds. Thus iron pyrites, which is such a common constituent of mineral veins, is converted into hydrated oxide of iron, and a vein originally consisting largely of iron pyrites and quartz now becomes a cindery mixture of quartz and ochre, known in Cornwall as *gossan*. This gossan, or *iron hat*, may often furnish important indications concerning the nature of the lode itself, because such minerals as pyromorphite or cerussite point to the existence of galena, whilst melaconite, cuprite, malachite, and azurite are the forerunners of chalcopyrite or copper glance. The gossan itself may contain a sufficient quantity of valuable ores to be worth working.

The seams containing native sulphur in Sicily often show no trace of that element immediately at the surface, as the sulphur-bearing limestone weathers into a soft white granular or pulverulent

[1] Fr. Moritz Wolff, "Beschreibung der Rotheisenerzlagerstätten von West Cumberland und North Lancashire," *Stahl und Eisen*, 2 Jahrgang, No. 12, plate vi.

[2] M. Braun, *Zeitschr. d. d. geol. Gesellsch.*, 1857, vol. ix.; and A. von Groddeck, *Die Lehre von den Lagerstätten der Erze*, Leipsic, 1879, p. 242.

[3] *Quart. Jour. Geol. Soc.*, vol. xxxv. (1879), p. 85, Anniversary Address of the President.

[4] J. Callon, *Lectures on Mining*, vol. i. p. 163, and Atlas, plate viii. fig. 44.

[5] J. W. Pike, "On some remarkable *heaves* or *throws* in Penhalls Mine," *Quart. Jour. Geol. Soc.*, vol. xxii. p. 537.

[6] Luther Wagoner, "The Geology of the Quicksilver Mines of California," *Engineering and Mining Journal*, vol. xxxiv. p. 334.

variety of gypsum, called *briscale* by the miners, and considered by them as affording important indications concerning the bed itself.[1]

Other signs of mineral deposits are given by springs and by certain plants dependent upon the deposit or its associated minerals for part of their nourishment. The appearance of the so-called lode-lights may be explained by the production of phosphoretted hydrogen from the action of organic matter and water upon phosphates, which are so common in the upper parts of mineral veins; and one hears also of differences in the appearance of the vegetation along the line of the deposit, of places where snow will not lie in winter, and of vapours hanging over the ground. Though some writers refuse to put any value upon these indications, they should not be entirely overlooked, because the outcrop of a lode, of different nature and texture to the surrounding rocks, and which is generally a channel for water, may readily cause the phenomena just mentioned. Where the surface is cultivated and the natural springs are tapped by adit-levels or other mine-workings, these appearances cannot be looked for to any great extent. With one special mineral, magnetic iron, the position of the deposit may be traced out with some degree of accuracy with a dipping needle; this is used in Sweden.

After having acquired an idea of the position of a vein or seam by some of the surface indications just mentioned, it is necessary, before attacking it by shafts or levels, to obtain more certain data concerning it. In the case of mineral veins, trenches are dug at right angles to the supposed strike; and, when the upper part of the deposit has been cut in several places, its general course and dip can be determined sufficiently for the purpose of arranging the future workings. These trenches are called "costean pits"; in some cases, instead of a trench, a pit is sunk a short distance and a little tunnel driven out.

Where the mineral to be wrought occurs as a bed or mass, the process of boring is resorted to, and indeed this method is also applied in the case of veins, especially in the United States. Boring is a work of such importance that it deserves to be treated under a separate heading.

3. *Boring with Rods and Ropes—Diamond Drills.*—The object of boring is to reach a deposit by a small hole and ascertain its nature, its depth from the surface, thickness, dip, and strike. Bore-holes are also used for obtaining water, brine, and petroleum, which either rise to the surface or have to be pumped up from a certain depth, and finally for tapping water in old workings or for effecting ventilation. The methods of boring may be classified as follows:—(1) boring with the rod; (2) boring with the rope; (3) boring with the diamond drill.

In the first method tools for cutting and removing the rock are fixed to rods, which are lengthened as the hole increases in depth, and which are worked by hand or by machinery at the surface. Where the ground is soft, such as sand or clay, tools like augers can be employed; but in harder ground it becomes necessary to have recourse to percussion; various forms of chisel are used, the simplest being made of the shape shown in fig. 11.[2] The rods generally consist of bars of square iron, from 1 inch to 2 inches on the side. The length of each rod depends upon the height of the tower, derrick, or shears erected above the bore-hole, which should be an exact multiple of the individual parts. These are made in lengths of 15 to 30 or rarely 40 feet, and with a suitable tower it is possible to detach or attach two or three lengths at a time, instead of having to make or unmake every joint. The mode of connexion usually preferred is by a screw joint as shown in fig. 12; care is taken to have all the joints exactly alike, so that any two bars can be screwed together. In order to

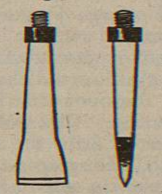
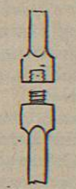

FIG. 11.—Chisels. Fig. 12.

diminish the weight of the rods, which becomes considerable in deep holes, wood has sometimes been employed. The rods are connected by male and female screws attached to the rods by sockets of sheet iron, or by a fork-like arrangement. At the surface a head is screwed to the uppermost rod by which the rods can be lifted, and they are turned by means of cross-bars called tillers.

When the depth is small the rods are lifted by hand and then allowed to drop, being turned slightly at each lift so that the cutting chisel may strike a new place each time. For greater depths a lever has to be employed, the rods being suspended at one end, whilst the other end can be pressed down by men using their hands or feet. The spring pole is another arrangement, in which the elasticity of a long pole is made use of for lifting the rod at each stroke. The length of the stroke can be maintained the same while the bore-hole is deepened by means of a screw in a swivel-head at the top of the rod.

With deep holes, and especially those of large diameter, steam machinery has to be employed for working the rod; the engine may be direct-acting and stand immediately above the bore-hole, but a commoner arrangement is to employ a single-acting cylinder working a beam. Occasionally also the beam is actuated by a connecting-rod worked by a crank.

The actual boring machinery has now been described, and the mere boring appears to be a very simple matter, consisting only in lifting the rod a little and allowing it to drop, the rod being turned slightly before each stroke. Nevertheless the process of putting down a bore-hole is not so simple as it seems, for there are numerous indispensable accessory operations which take up much time. In the first place the débris have to be removed, and in order to effect this the rods must be drawn up, the swivel-head is disconnected and a cap screwed on. A length of rods is now drawn up by a hand or steam windlass and disconnected. It is well to have as many caps as there are lengths to be drawn up, and then each length can be suspended in the house. Sometimes a *grip* which catches the rod at the bulging joint is used instead of a cap. The next operation consists in lowering by means of a rope the *shell-pump* or *sludger*, which is a hollow cylinder with a clack or a ball-valve (fig. 13). It is worked up and down a little till it is filled, and it is then drawn up and emptied at the surface. The operation is repeated, if necessary, and the boring is resumed with the rod.

Fig. 13.

Occasionally a bore-hole has to be widened slightly with a tool called a *reamer*. Soft beds may have to be bored through with a *wimble*; and, unless the rocks are hard and firm, the hole has to be lined with a tube, generally of sheet-iron. Accidents may occur, causing an immense amount of trouble, such as the breaking of rods or chisel, and many ingenious implements have been devised for seizing the broken rod or the fragments of tools which prevent further progress with the work.

In boring at considerable depths, the weight of the rod becomes so great that much vibration ensues when the mass is suddenly arrested by the chisel striking against the bottom of the hole. Various devices have been contrived for overcoming this difficulty and producing a tool which will act independently of the rod. One of the best-known arrangements is the free-falling tool invented by Kind (fig. 14).[3] The head of the actual boring-rod is held by a click or grapple; when the main rod descends, the resistance of the water in the hole slightly stops the sliding disk D, the jaws J, J open, the head is disengaged, and the boring part falls and strikes the bottom without any injurious vibrations being communicated to the main rod. When this descends farther the head is caught again by the click. Special tools also are used for cutting an annular groove at the bottom of a bore-hole and breaking off the core, which is then brought up, with certain precautions, so as to show the nature and dip of the strata traversed.

Fig. 14.

In order to obviate the great loss of time which ensues from connecting and disconnecting long lengths of rods, recourse may be had to boring with the rope. In this method, known as the Chinese method, the chisel is worked by a rope in the same manner as the sludger already described. Messrs Mather and Platt of Manchester have long used with success, in many parts of England and various other countries, a system of boring by means of a flat hempen rope.

The most important modification of late years in the

[1] Lorenzo Parodi, *Sull' Estrazione dello Solfo in Sicilia*, 1873, pp. 7 and 24.

[2] Serlo, *Leitfaden zur Bergbaukunde*, Berlin, 1878, p. 59.

[3] J. Callon, *Lectures on Mining*, vol. i., Atlas, plate ix. fig. 52.

process of making bore-holes is the introduction of the diamond drill. The working part of the drill consists of the so-called crown, which is a short piece of tube made of cast steel, at one end of which a number of black diamonds are fastened into small cavities (fig. 15).

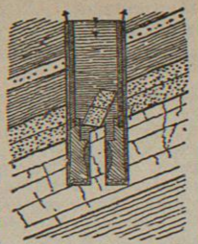

FIG. 15.—Diamond Drill.

The crown is screwed on to wrought-iron pipes, which constitute the boring rod. Machinery at the surface causes the rod to rotate, and the result is the cutting of an annular groove at the bottom of the hole, leaving a core, which, breaking off from time to time, is caught by a little shoulder, and brought up to the surface with the rod. In places where it is not necessary to make any verification of the rocks traversed, the crown is arranged with diamonds in the centre also. The débris, in either case, are washed away by a stream of water, which is forced down the tube and flows up the sides of the hole. With this system a bore-hole can be deepened continuously at a speed altogether unattainable by the other methods, which require stoppages for cleaning out. It has the further advantage of making it possible to drill holes in any direction; and prospecting diamond drills are constantly used with much success inside many metal mines, especially in the United States.

Fig. 16[1] shows the Little Champion Rock-Drill, which is largely employed in the Lake Superior district for prospecting. It can be used above or below ground. Two inclined cylinders drive a horizontal crank shaft, which works bevel gear, causing the drill to revolve. At the same time a countershaft is likewise set in motion, and this effects the advance of the drill by gearing driving the feed-screw; as there are three kinds of gearing, the speed can be varied at pleasure. The feed-screw and its connexions are carried by a swivel-head, and this can be turned so as to drill holes at an angle. The drum shown above the cylinders is used for hoisting out the drill-rods by a rope. The rods are lap-welded iron tubes 1⅝ inches in diameter, fitted with a bayonet joint.

Another light portable prospecting drill for underground work is

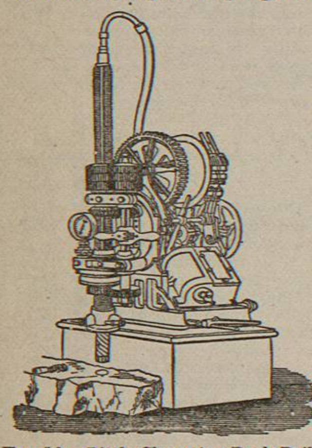

FIG. 16.—Little Champion Rock-Drill.

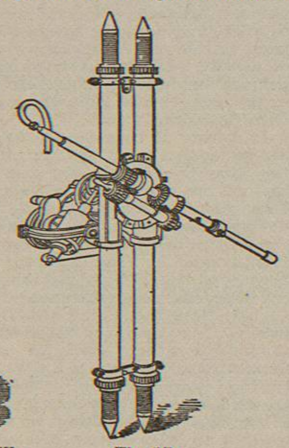

Fig. 17.

represented in fig. 17.[2] It is intended for drilling holes 1¼ inches in diameter to a depth of 150 feet. The cores which it yields are ⅞ inch in diameter. It has double oscillating cylinders 3½ inches in diameter with 3½ inches stroke, which are run up to a speed of 800 revolutions. The drill can be set to bore in any direction by turning the swivel-head on which it is carried.

The larger rock-drill used by the American Diamond Rock Boring Company for putting down holes to a depth of 2000 feet consists of a 20 horse-power boiler with two oscillating 6-inch cylinders and the necessary gearing for working the drill, all mounted upon a carriage, so that the whole machine is readily moved from place to place. The feed is effected by gearing or by hydraulic pressure; a 2⅜-inch crown is employed, leaving a 2-inch core. Each separate drill-rod is 10 feet long. The total weight of the machine is about 4 tons.

[1] *Engineering and Mining Jour.*, vol. xxxiii. p. 119.
[2] *Ibid.*, vol. xxxiii. p. 273.

4. *Breaking Ground — Tools Employed — Blasting by Various Methods — Machine Drills — Driving Levels and Sinking Shafts.*—The kind of ground in which mining excavations have to be carried on varies within the widest limits, from loose quicksands to rocks which are so hard that the best steel tools will scarcely touch them.

Loose ground can be removed with the shovel; but in the special case of peat sharp spades are employed, which cut through the fibres and furnish lumps or sods of convenient form for drying and subsequent use as fuel. What is called *fair*, *soft*, or easy ground, such as clay, shale, decomposed clay-slate, and chalk, requires the use of the pick and the shovel. The pick is a tool of very variable form, according to the material operated on. Thus there are the navvy's pick, the single-pointed pick with a striking head at the other end called the poll-pick (fig. 18), and numerous varieties of the double-pointed pick (fig. 19), the special tool of the collier, but also largely used in metal mining. When the ground, though harder, is nevertheless "jointy," or traversed by many natural fissures, the wedge comes into play. The Cornish tool known as a *gad* is a pointed wedge (fig. 20). The so-called "pick and gad" work consists in breaking away the easy ground with the point of the pick, wedging off pieces with the gad driven in by a sledge or the poll of the pick, or prizing them off with the pick after they have been loosened by the gad. The Saxon gad is held on a little handle, and is struck with a hammer. It is used for wedging off pieces of jointy ground, and in former days even hard rocks were excavated by its aid. The process consisted in chipping out a series of parallel grooves and then chipping away the ridges left between the grooves. As a method of working this process is obsolete; but it is useful on a small scale for cutting recesses (*hitches*) for timber, for dressing the sides of levels or shafts before putting in dams, and for doing work in places where blasting might injure pumps or other machinery.

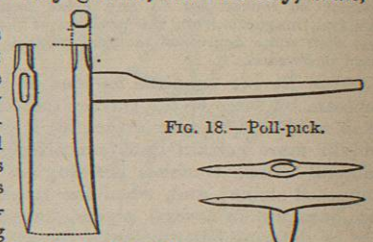

FIG. 18.—Poll-pick.

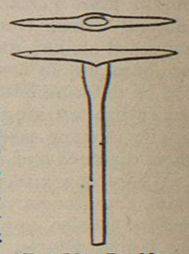

FIG. 19.—Double-pointed Pick.

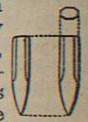

FIG. 20.—Gad.

We now come to hard ground; and in this class we have a large proportion of the rocks met with by the miner, such as slate of various kinds, hard grits and sandstone, limestone, the metamorphic schists, granite, and the contents of many mineral veins. Rocks of this kind are attacked by boring and blasting. The tools employed are the jumper, the borer or drill, the hammer, the sledge (*mallet*, Cornwall), the scraper and charger, the tamping bar or stemmer, in some places the pricker or needle, the claying bar, the crowbar, and finally the shovel for clearing away the broken rock.

The jumper (fig. 21) is merely a long bar of iron terminating in two chisel-like edges made of steel; generally there is a swelling in the middle, and sometimes the jumper tapers all the way from the middle to the edge or bit. The jumper is most commonly used when it is necessary to bore holes downwards, and is

Fig. 21.

largely employed in quarries; occasionally it is used in boring holes horizontally, as for instance in the salt mines of Cheshire. The jumper is held in the desired direction, lifted up, and thrust down; it is turned a little after each stroke.

However, the miner's tool is generally the borer proper, or drill (fig. 22), which is a bar of round or octagonal steel, usually from ⅞ inch to 1½ inches in diameter, with one end forged into a chisel-shaped edge, the exact shape and degree of sharpness varying according to the hardness of the rock. The hole is bored by striking the drill with a hammer or sledge and turning it after each blow. Boring is said to be single-handed if the miner holds the drill in one hand and strikes with the hammer in the other, whilst it is called double-handed when one man turns and another strikes. The hammers for single-handed boring usually vary in weight from 2 to 6 or 7 lb. The double-handed boring hammer, or sledge (fig. 23), weighs from 6 to 10 lb or more. If a hole is directed downwards, the miner pours in a little water and bores the hole wet. From time to time he draws out the sludge with the scraper, a little disk at the end of a metal rod, and he takes a fresh borer when the tool he is using has become blunt. The depth bored varies with the rock and the nature of the excavation; but in driving levels in the ordinary way the depth is commonly from 18 inches to 3 feet.

Fig. 22.

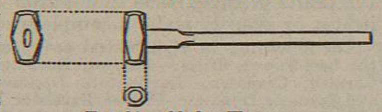

FIG. 23.—Sledge-Hammer.

Holes for blasting are sometimes bored by tools like carpenters' augers. One of the simplest, which is used in some French slate-mines, is very like a brace and bit, and the tool is kept pressed against the rock by means of a screw fixed in a frame resting on the ground.

The pricker, or needle, is a slender tapering rod of copper or bronze, with a ring at the large end. It is used for maintaining a hole in the *tamping* through which the charge can be fired. The use of needles made of iron is prohibited in many countries, on account of the danger of their striking sparks which might fire the charge. The tamping bar, or *stemmer*, is a rod of iron, copper, or bronze, or iron shod with copper, and it is used for ramming in dried clay, slate pounded up, or other fine material, upon the powder, and so creating a resistance sufficient to make the gases generated by the explosion of the charge rend the rock in the manner required. The claying bar is used for lining wet holes with clay, and so rendering them temporarily watertight.

Shovels vary much in different districts. In the south-west of England the long-handled shovel is preferred to the common one with a short handle; in Germany the ore or rubbish is frequently scraped into a tray with a sort of hoe.

In addition to these tools the miner requires an explosive, and a means of firing the charge at the bottom of the hole which will give him time to escape. Twenty years ago gunpowder was the only explosive in common use in mines, but at the present day its place has been taken to a very large extent by mixtures containing nitro-glycerin or gun-cotton. The powder used for blasting in mines usually contains less saltpetre than that which is employed for sporting or military purposes. The following is an analysis of mining powder by Captain Noble and Sir F. Abel:[1]—

Saltpetre	61·66	Oxygen	2·23
Potassium sulphate	0·12	Ash	0·59
,, chloride	0·14	Water	1·61
Sulphur	15·06		
Carbon	17·93		100·00
Hydrogen	0·66		

[1] "On Fired Gunpowder," *Phil. Trans.*, 1880, p. 225.

Gunpowder compressed into cylinders of diameters suitable for bore-holes, and provided with a central hole for the insertion of the fuse, has lately been brought forward with some success.

Nitro-glycerin or glyceryl nitrate is a light-yellow oily liquid which is very sensitive to shocks; under the action of a fulminating cap it explodes with great violence. Its chemical composition is expressed by the formula $C_3H_5(NO_2)_3O_3$ or $(C_3H_5)3NO_3$; its specific gravity is 1·6. It has been found so dangerous that its use by itself has been given up; but on the other hand the mixture of nitro-glycerin and infusorial earth (*Kieselguhr*) called dynamite or giant powder is now one of the commonest explosives met with. It has the advantage over powder that it is far more powerful, that it may be used in wet holes or under water, that it is very effective even in ground full of "vughs" or cavities, and that it requires no hard tamping, which is always a source of danger. Its plasticity too enables it to fill the space at the bottom of a bore-hole, which is rarely a true cylinder, more completely than any solid cartridge can do. One disadvantage is that it has to be thawed in cold weather, and there is also the fact that occasionally the whole of a charge of dynamite fails to go off, and unnoticed remnants have exploded and caused serious and even fatal accidents when struck with the pick or borer. The danger is enhanced when the remnants have been left in contact with water, which causes a separation of the sensitive nitro-glycerin, so that even a blow upon the adjacent rock may lead to an accident if any of the explosive oil has leaked into cracks. The strongest dynamite contains about 75 per cent. of nitro-glycerin, the rest being kieselguhr. A newer explosive is blasting gelatin; it is made by mixing nitro-cotton with nitro-glycerin, until enough nitro-cotton has been dissolved to convert the nitro-glycerin into a jelly-like mass. The blasting gelatin in ordinary use contains no less than 93 per cent. of nitro-glycerin, with 7 per cent. of nitro-cotton, and its strength is very great.

Gun-cotton *per se* is not much in favour in ordinary mining; but mixed with some nitrate or mixture of nitrates, such as the nitrates of barium and potassium, and known as cotton powder, tonite, and potentite, it is employed extensively. Though not quite so powerful as dynamite, nitrated gun-cotton possesses the important advantage of not requiring to be thawed in cold weather. As in the case of dynamite, accidents have been caused by remnants of charges; and with both explosives it is necessary to examine carefully the bottoms of all holes after blasting, and to destroy any possible remnants by firing off a detonator in any bottom or "socket" which cannot with certainty be pronounced free from danger.

The commonest method of firing a charge is by means of the *safety-fuse*, a cord containing a core of gunpowder introduced during the process of manufacture; it may be rendered waterproof by tar or gutta-percha. Safety fuse.

In blasting in the ordinary way the charge of gunpowder is put in either loose or enclosed in a paper bag, and it is pressed down to the bottom of the hole with a wooden stick, whilst a piece of fuse also is inserted extending from the charge well beyond the hole. If the powder is loose the miner carefully wipes down the sides of the hole with a wet *swab stick* (a wooden rod with the fibres frayed at one end), or with a wisp of hay twisted round the scraper, in order to remove any loose grains adhering to the fuse or the sides of the hole, and then presses in a wad of hay or paper. A little fine tamping, often the dust from boring a dry hole, is now thrown in and rammed down with the wooden charging stick, and the same process is repeated, and when harder tamping is required the metal bar is brought into operation, until the hole is completely filled.

As the safety-fuse burns slowly, at the rate of about 2 or 3 feet a minute, the miner can secure ample time for retreat by taking a sufficient length. It is usual to ignite the fuse by a candle-end fixed under it by a piece of clay, and it takes a little time for the candle to burn through the fuse.

The old plan of firing a charge, which is still in use in many