by a windlass. One great disadvantage of this method is that the ore and water have to be drawn up some distance by hand labour; much timber is required for the stulls if there is a large quantity of worthless stuff in the vein, or if the sides are weak. The advantages are that ore can be worked away as soon as the level is driven, that the men are always boring downwards, and, lastly, that the ore can be carefully picked after it is broken, without fear of any valuable particles being lost.

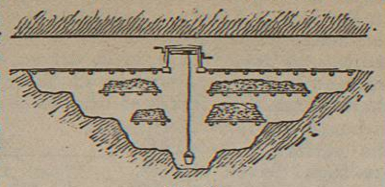

Fig. 60.

A more economical method of working by underhand stopes, and one largely employed in Cornwall at the present day, consists in reserving any attack upon the ore-ground until a lower level has been driven. An intermediate shaft (*winze*) between the two levels is then made, either by sinking from the upper level or rising from the lower one. The work of stoping is commenced at the two upper ends of the winze, and the lode is removed in a succession of steps, the workings assuming the appearance exhibited in fig. 61. The steps are generally made steep, so that the ore may readily roll into the winze, and so that the bore-holes may do better execution; but these steep stopes are dangerous if a man happens to slip and fall. The huge open chasms left by the removal of a large lode in this way are also a source of danger; for there is always a risk of falls of rock, and from places which cannot easily be examined.

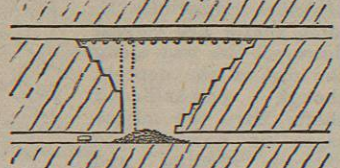

Fig. 61.

Figs. 62 and 63, kindly supplied by Captain Josiah Thomas,[1] explain the general arrangement of the workings of the largest tin mine in Cornwall. The lode after producing copper ores to a considerable depth changed its character and became rich in tin. The workings for tin ore are confined almost entirely to the granite. The section fig. 62 shows that the main shaft of the mine is at first vertical and then carried down on the dip of the lode.

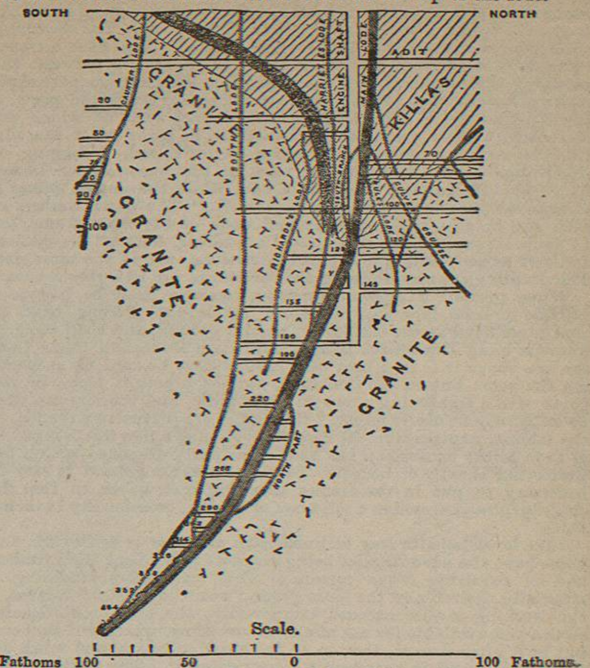

Fig. 62.—Transverse Section, Dolcoath Mine, Cornwall.

The process of overhand stoping is precisely the reverse of that

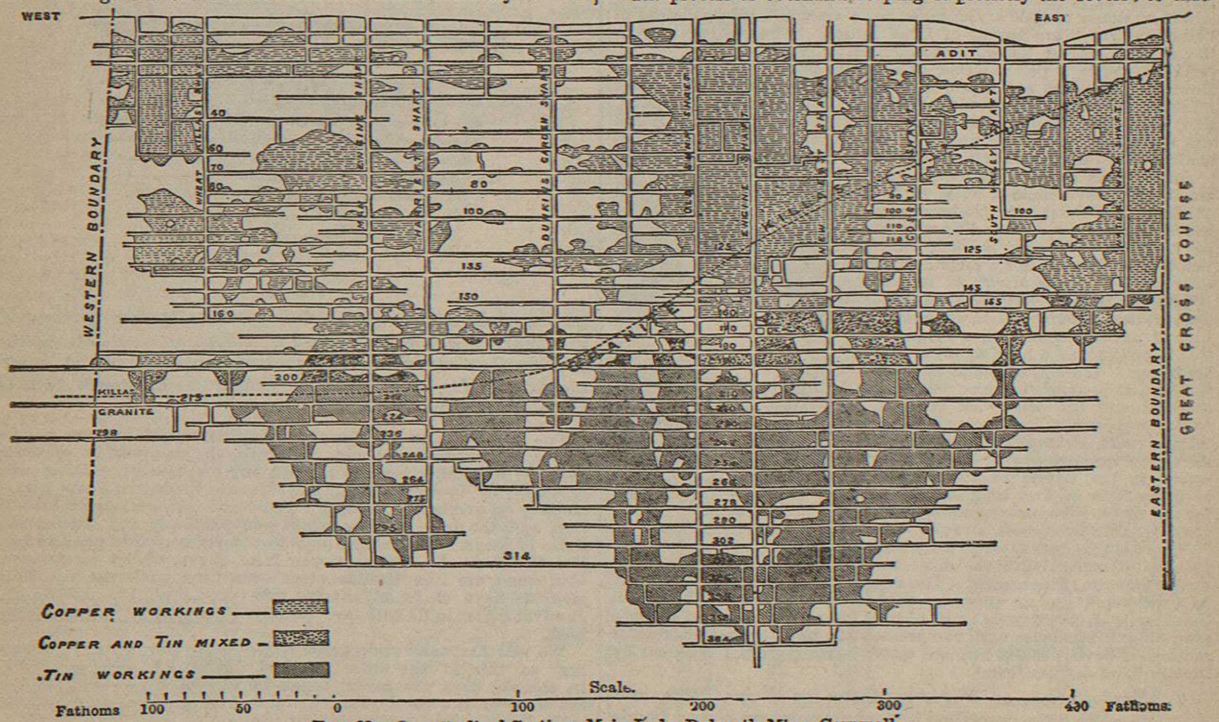

Fig. 63.—Longitudinal Section, Main Lode, Dolcoath Mine, Cornwall.

which has been just described; the work is commenced from a rise (fig. 64 A), or better from the two bottom ends of a winze (fig. 64 B). As soon as the men have excavated a sufficient height of the roof of the level, they put in strong pieces of timber from wall to wall, and

[1] See *Report of Miners' Association of Devon and Cornwall for* 1882, and R. J. Frecheville, *Trans. Roy. Geol. Soc. Cornwall*, vol. x. part v.

cover these cross-pieces (*stempels, stull-pieces*) with boards or poles, and throw down the rubbish upon the platform (*stull, bunning*) thus formed. In the midst of the rubbish chimney-like openings (*mills, passes*) are reserved, lined with boards or dry-walling, and

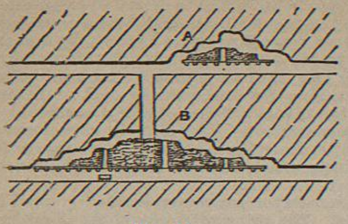

Fig. 64.

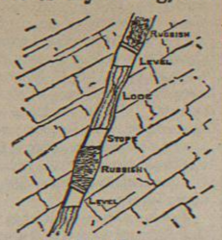

Fig. 65.

closed at the bottom with shoots provided with doors. The ore is thrown into these passes, which are tapped when necessary; the ore falls into the tram-waggon placed ready to receive it.

Fig. 65 gives a transverse section showing the rubbish resting on the stull. This is what may be called the typical method of stoping, when the lode affords rubbish enough for the men to stand on and to keep them close to the rock they are attacking. Very often such is not the case, and the whole of the lode has to be sent to the surface for treatment. If the walls are firm, the lode is sometimes stoped away, a stull put in, and a sufficient heap of broken ore is left upon the stull to give the men good standing ground; the excess is thrown over the ends of the stull, or the great heap is tapped by cutting a hole in the stull-covering, and allowing a quantity to run down into the level.

Another method consists in putting in temporary stages upon which the men stand to do their work, whilst the excavation is left as an open space (fig. 66).

Fig. 66.

This mode of working is incompatible with weak walls. If a lode does not afford rubbish enough for completely filling up the excavated space, or if it is too narrow for men to do their work comfortably, one of the walls may be cut into and blasted down (fig. 67), so that the men always stand upon a firm bed of rubbish while at work, and there is no fear of a collapse of the mine. In certain special cases rubbish is sent down from the surface to fill up the excavations.

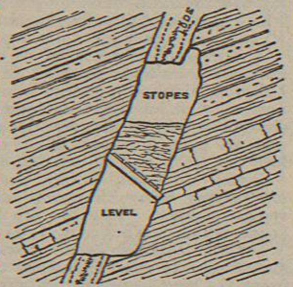

Fig. 67.

The advantages of overhand stoping are—that the miner is assisted by gravity in his work, that no ore or rock has to be drawn up by hand labour, and that less timber is required. On the other hand, the miner is always menaced by falls, but as he is close by he can constantly test the solidity of the roof and sides by sounding them with his sledge; there is the further disadvantage that particles of ore may be lost in the rubbish, but this loss is often prevented by laying down boards or sheets of iron while the lode is being broken down.

When very wide lodes come to be worked, recourse is often had to special methods. The great lode at the famous Van mine, in Montgomeryshire, is sometimes 40 feet in width, and the hanging wall is weak. The lode is stoped away overhand, and the cavities packed with rubbish, part of which is derived from the lode itself, whilst the greater portion is supplied from a special quarry at the surface. Fig. 68[1] explains the details of the case. A is the original cross-cut (not in the line of section) by which the lode was reached, B is the *flucan*, C the bastard lode, generally worthless, E the main lode, H permanent levels, and K *ore-pass* reserved amidst the rubbish (*deads*) D, I *pass* down which rubbish is shot, N crosscut connecting the level H with P the permanent level in the *country*.

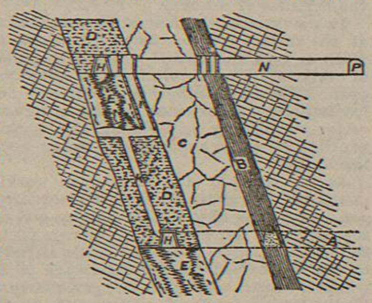

Fig. 68.

If the lode is not firm enough to allow of the stopes being carried for its full width, the crosscut method is adopted; the workings in this case, instead of proceeding along the strike, are carried across the deposit from one wall to another.

The lode is removed in successive horizontal slices A, B, C, D, E, and for each slice a level (L, fig. 69) is driven, either in the lode, or partly or entirely in the country; from this level crosscuts are put out 6 or 8 feet wide, as shown in the plan (fig. 70). These are regularly timbered according to the necessities of the case, and, when No. 1 is completed, No. 2 is begun, and the rubbish from No. 2 thrown into the empty space of No. 1 crosscut. If the quantity is insufficient, deads are brought in from the surface or from exploratory workings in worthless rock in the neighbourhood. Sometimes the crosscuts are not driven side by side, but 1 and 5 would be driven first, leaving 2, 3, and 4 as a solid pillar; then 3 would be worked away, and finally 2 and 4 between the timber and rubbish on each side. The greater part of the timber can be recovered when the next slice above is taken off, as the props are put in with the small ends downwards, and can be drawn up with levers. M (fig. 69) is a level reserved in the deads for traffic and ventilation. This method of working is applicable not only to lodes but also to irregular masses.

Fig 69.

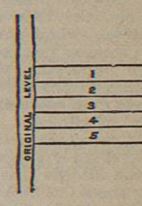

Fig. 70.

In working away the soft "bonanzas" or ore-bodies of the great Comstock lode, which are from 10 to 30 or even 40 or 50 feet wide, and which are enclosed in very unstable ground, a special method of timbering is employed (figs. 71 and 72).[2] "It consists in framing timbers together in rectangular sets, each set being composed of a square base placed horizontally, formed of four timbers, sills, and cross-pieces, 4 to 6 feet long, framed together, surmounted by four posts 6 to 7 feet high, at each corner, and capped by a frame-work, similar to that of the base. These cap-pieces, forming the top of any set, are at the same time the sills or base of the next set above, the posts, as the sets rise one above the other in the stope, being generally placed in position directly over those below." "The timbers are usually of 12-inch stuff square-hewn or sawn." Each post has a tenon 9 inches long at the upper end, and a tenon of 2 inches at the lower end, which fit into mortices in the cap and sill respectively; and "the sills and caps have short tenons on each end and shoulders cut to receive the ends of the post and the horizontal cross-pieces." The walls of the excavation are sustained by a lagging of 3-inch or 4-inch plank. The whole width of the ore-body is stoped away at once, and its place supplied by timbering, and finally the vacant space is filled with waste rock derived from dead work in the mine or from special excavations,—underground quarries in fact,—in barren ground. The stoping is carried on overhand, starting from an intermediate shaft or winze, and fig. 73 will explain how the different frames are built up one above the other.

Comstock lode.

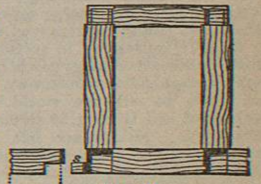

Fig. 71.

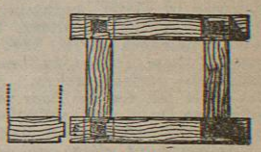

Fig. 72.

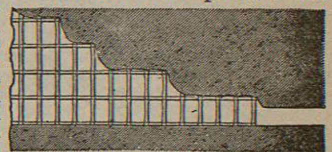

Fig. 73.

Another method of working a wide lode is to attack it in slices

[1] C. Le Neve Foster, "Notes on the Van Mine," *Trans. Roy. Geol. Soc. Cornwall*, vol. x. p. 41.

[2] James D. Hague, *United States Geological Exploration of the Fortieth Parallel*, vol. iii. "Mining Industry," p. 112.

parallel to the dip, working away each slice separately as if it were a lode of ordinary dimensions, and filling up with rubbish (fig. 74).

Fig 74.

We now come to beds or seams. The mode of working the most important beds that occur in the earth's crust, viz., coal seams, has already been described in the article COAL (vol. vi. p. 64 *sq.*), and details have been given concerning the removal of the mineral by pillar working and long-wall working. Both these methods are applicable in the case of seams of other minerals. Such for instance are the beds of fire-clay and clay-ironstone which are wrought by both the processes just mentioned, and often in connexion with coal.

Next in importance to coal is ironstone, and a brief account of the workings in the Cleveland district will explain the manner in which more than one-third of the iron ore raised in the British Isles is obtained by mining. It resembles the "bord and pillar" system used for working coal in Durham.

The Cleveland ore occurs in the form of a bed from 6 to 16 feet thick in the Middle Lias, lying pretty level. A mainway (fig. 75) is driven about 12 feet wide for a considerable distance, and at right angles to it *bords* are driven 5 yards wide for a length of 30 yards, and then at right angles a *wall* 7 or 8 feet wide and 20 yards long. By drivages of this kind the bed is cut up into pillars or blocks 30 yards long by 20 yards wide. The pillars are subsequently removed in the following way. A *place*, or drift, *ab*, 6 feet wide, is driven across the pillar 10 yards from the corner, and portions (*lifts*) about 6 yards wide are worked away in the order 1, 2, 3. After No. 1 lift has been removed, the timber put in to support the roof temporarily is withdrawn, and the roof is allowed to fall; No. 2 is then taken, and No. 3 in the same way. While these lifts are being taken out, another place *cd* is being driven across the pillar 10 yards from the first, and the pillar removed entirely by a series of fresh lifts.

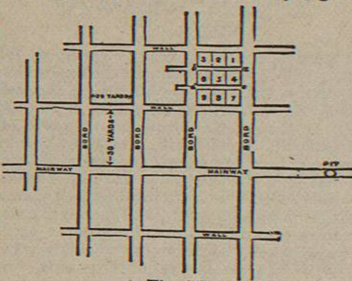

Fig. 75.

Gypsum quarries. Fig. 76 represents in section and plan the chambers and pillars of the underground gypsum quarries which supply the well-known plaster of Paris to all the world.[1] The principal bed is from 50 to 60 feet in thickness; pillars are left 10 feet square at the base, and the *stalls* between them are 16 feet wide. The workings are slightly arched, and are not carried up to the roof, for the purpose of better maintaining the security of the chambers, because heavy damages would have to be paid if they "caved in" and rendered the surface useless. A similar layer left for the floor prevents *creep* (see COAL, vol. vi. p. 64), and enables the underground roads to be kept in good repair.

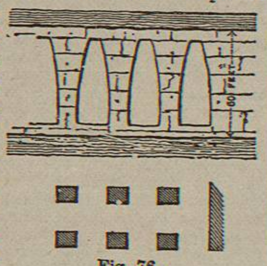

Fig. 76.

Underground slate quarries afford examples of very various methods of removing thick beds of mineral of comparatively little intrinsic value. At Angers in France, where the beds dip at a high angle, the underground workings are carried on like an open quarry

Fig. 77.

Fig. 78.

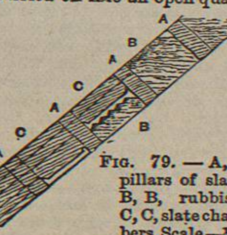

FIG. 79. — A, A, pillars of slate; B, B, rubbish; C, C, slate chambers. Scale $\frac{1}{3000}$.

under a strong roof of slate; the floor is continually being worked away in steps, and an immense open chamber is left. In the Festiniog district in North Wales the principal bed, or *vein* as it is called, is more than 100 feet thick in places, and the method of working consists in making alternate pillars and chambers each 30 feet to 50 feet wide along the strike (cross-section and plan, figs. 77 and 78). The pillars follow lines of natural cross-rending PP′, which commonly make an angle of 25° to 35° with the direction of the dip. The excavations are arranged in regular lines, and form continuous chambers extending very often from the surface to the very lowest workings. A, B, C, D are the original working levels. The slate of the supporting pillars is entirely lost, as these cannot be removed with safety. This method of working requires a strong roof. In the Ardennes, on the contrary, the pillars are carried along indefinitely along the strike (fig. 79, cross-section). The slate in each longitudinal chamber is removed in slices parallel to the bedding, and the men stand upon the rubbish, which finally fills up the chambers completely.

Rock-salt constitutes another important mineral which occurs in the form of stratified deposits. The principal source of the Cheshire salt is a bed 84 feet thick lying horizontally; but only the bottom part, 15 feet to 18 feet thick, is mined. Pillars 10 yards square are left promiscuously about 25 yards apart, as shown in fig. 80, which represents part of Marston Hall rock-salt mine.[2] The workings

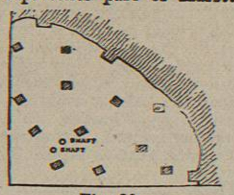

Fig. 80.

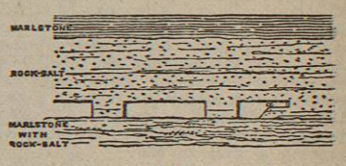

Fig. 81.

are advanced by making in the upper part an excavation 5 feet 9 inches high, called the *roofing* (*a*, fig. 81); and then the lower two-thirds of the part worked are removed by blasting slanting holes. Many of the old salt mines have collapsed from weakness of the roof or insufficiency of the pillars, and have become inundated; the brine is then extracted by pumping and evaporated for salt.

In some countries, especially when the beds of salt are impure or much mixed with clay or shale, the formation of brine is conducted regularly by making a network of drivages within a rectangular, elliptical, or circular area in thick beds of saliferous marl, and then introducing fresh water by pipes, so as to form underground ponds which gradually dissolve the roof and sides. The brine is drawn off and either pumped up or conveyed by adits to the surface.

A few words remain to be said about open workings. Some minerals are always obtained in this way; others are worked open before regular underground mining begins; and, thirdly, it often happens that underground and surface work are both carried on simultaneously on the same deposit. Among deposits worked open-cast are peat, numerous kinds of stone, iron ore, cupreous pyrites, lead ore, gold- and tin-bearing alluvia, and diamantiferous rock.

Owing to its soft, spongy, and fibrous texture, and the fact of its often lying below the water-level, peat has to be worked in a special manner. Trenches are dug about a foot deep with a sharp spade, which cuts out sods of convenient size for drying and burning. When one layer has been removed in this way, another is taken off, and so on. If water is reached the working can still be pursued by using the long spade (*grand louchet*, France) with a handle of 16 or 20 feet. It cuts out a sod 3 or 4 feet long at each thrust.

When a deposit is more or less solid the workings are frequently arranged in steps, the height and breadth of each depending upon the firmness of the rock

In many cases the first work consists in removing worthless rock at the surface (*overburden*), and where the underlying deposit is thick or very valuable it will pay to remove a very great thickness of overburden, on account of the advantages of working a deposit open. These advantages are—entire removal of the deposit without loss in pillars, no expense for timbering or for packing with rubbish or for ventilating or lighting the workings, better ventilation, easier supervision, longer working hours, less danger.

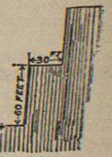

Fig. 82.

As an example of a large open working may be mentioned the great Penrhyn slate quarry near Bangor, employing about 3000 hands, and worked by a succession of terraces on an average 60 feet high by 30 feet wide (fig. 82). Reference has already been made to the thick lead-bearing sandstone of Mechernich, which is in part worked as an open quarry. Mokta-el-Hadid, near Bona in Algeria, and the Rio Tinto mines in Spain, afford instances of extensive combined open and underground workings for iron ore and cupriferous pyrites respectively.

Local laws regulating the size of the working areas, or claims,

[1] Callon, *Lectures on Mining*, vol. ii. plate xii.

[2] Joseph Dickinson, "Report on the Salt Districts," *Reports of the Inspectors of Mines for the year* 1881, p. 66.

owned by separate individuals or companies, considerably affect the methods of working. This is especially the case with the diamond deposits of South Africa. The diamantiferous rock at the celebrated Kimberley mine (formerly called Colesberg Kopje) occurs in the shape of an elliptical upright mass, the greatest length being about 330 yards and the greatest breadth about 200 yards. The superficial area is about 9 acres; the mass extends downwards within almost perpendicular walls of shale, and is worked in places to a depth of about 400 feet. The claims are only 31 feet square, and are more than four hundred in number, and these have in some instances been subdivided into portions as small as the sixteenth of a claim; but, as at the present time one company may own very many claims, the number of individual holdings is less numerous than formerly when the limit was two claims. The working is carried on vertically downwards, and, as the claims are not all worked at the same rate, those that progress most rapidly are surrounded by perpendicular walls of neighbouring claims. The shale, or *reef*, enclosing the deposit is constantly falling into the huge open pit, and has to be cut away to a slope, the expense of this work being charged to the claim-holders generally by the mining board. The diamantiferous rock is extracted by innumerable wire-rope inclines.

Evils attending hydraulic mining. We have already referred to the method of working gold-bearing alluvia by the hydraulic process, which has rendered such services in the United States (GOLD, vol. x. p. 746). At the same time one must not be blind to the evils of this method of working, which have at last necessitated legislative interference. Some idea of the extent of the mischievous results of hydraulic mining will be gathered from the statement that one working alone, the Gold Run Ditch and Mining Company, for the last eight years has been discharging 4000 to 5000 cubic yards of sand, gravel, and boulders daily, for a period of five months each year, into a tributary of the Sacramento. As a natural consequence deposits are formed lower down the river, obstructing the navigable channels, rendering overflows more frequent and destructive, and causing valuable land to be destroyed by deposits of sand. The superior court of Sacramento county, California, has recently decided that the hydraulic mining companies must build dams to impound the coarse and heavy débris, or take other efficacious means to prevent their being washed down the rivers.

Underground transport. 8. *Carriage or Transport of Minerals along the Underground Roads.*—After the mineral has been broken down in a deposit it is necessary to pick out any barren rock and then convey to the surface all that is of value.

Carriage by workers. The simplest and oldest method of transport along underground roads is carriage on the back, and this method may still be seen at the present day even in countries where the art of mining is generally highly advanced. Thus, for instance, in the little slate mines near Cochem on the Moselle men and lads carry up all the blocks of slate upon their backs, walking upon steps cut in the rock; they come up with their hands upon the ground bent almost double under the weight of the block, which rests upon a thick pad. Again, the blocks of slate are still carried on the back from the actual working place to the nearest tram-road, in the slate mines of the Ardennes. In the Sicilian sulphur mines the same method is common, and it is found also in parts of Spain and China, where baskets are used, whilst bags are employed in Mexico and also in Japan. Even in England the system still survives in the Forest of Dean, where boys carry iron ore in wooden trays from the very irregular ore-producing cavities either to the surface or to the nearest shaft.

Sledges, or *sleds*, enable greater loads to be transported; but they are not available unless the conveyance is along roads sloping downwards. They have been largely employed in coal mines, and are still resorted to in some collieries for conveying the coal from the working place to the nearest tram-road.

We next come to wheeled carriages. The simplest is the wheelbarrow. The barrow used in Cornwall at the present day is not unlike that figured more than three centuries ago by Agricola. The navvy's barrow is more advantageous, but it requires a wider and higher level. The barrow runs upon the natural floor of the level, upon boards, or upon thin strips of iron. Carts drawn by horses may be used in large underground quarries. Excepting in special cases it is advisable to replace barrows by waggons running upon rails. The oldest form is the German *Hund*. It consists of a rectangular wooden body, with four wheels, resting upon two boards as rails, and it is kept on the track by a pin which runs between the boards.

Cast-iron tram-plates were introduced in the last century, and were finally succeeded by iron rails, which are now in general use, though steel threatens to displace iron in this as in other departments of mining. Various forms of rail are employed. The simplest is a bar of iron set on its edge in transverse sleepers, or flat iron nailed to longitudinal sleepers. Small T-headed and bridge rails are not uncommon. In the Harz the rails sometimes lie on stone sleepers; a hole is bored in the stone, plugged with wood, and the rail is nailed on. The gauge varies from 14 inches to 3 feet or more; 20 inches to 22 inches is a common gauge in metal mines. Arrangements of course have to be made for passing from one line to another by *points*; but the transference is frequently best effected by putting down flat plates of cast iron, upon the smooth surface of which the waggons can be handled with ease and turned in any direction; raised ledges guide the wheels into any particular track.

The form and size of the waggons running upon the rails necessarily vary according to the size of the underground roads and the manner in which the mineral is raised in the shaft. In some mines the practice exists of loading the mineral in the level into an iron bucket (*kibble*) standing upon a *trolley*, which is merely a small platform upon wheels. This trolley is pushed (*trammed*) to the shaft; the full kibble is hooked on to the winding-rope and drawn up, whilst an empty kibble is placed upon the trolley and trammed back along the level, where it is again loaded from a shoot (*mill*, *pass*) or by the shovel. The usual plan, however, is to have a waggon, which is tipped on coming to an enlargement of the shaft (*plat*, *lodge*) where the level joins it. These waggons may be made of wood or sheet-iron, and of late years sheet-steel for the body and cast-steel for the wheels have been coming into favour.

The most modern system in metal mines is to imitate collieries, and use waggons which are drawn up in cages. Fig. 83 represents the plain but strong waggon of the Van mines, consisting of a rectangular body of sheet-iron resting on an oak frame, and provided with cast-steel wheels. The wheels are loose upon the axles, which themselves run loose in the pedestals. The waggon is emptied by being run on to a "tippler," which enables it to be completely overturned with great ease. A commoner plan is to construct the waggon with a hinged door at one end, and the contents are discharged by opening this door and raising the body.

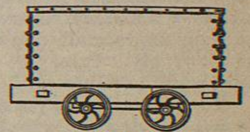

Fig. 83.

The motive power for tramming waggons along the levels of metal mines is generally supplied by men or boys, though, where large quantities have to be extracted, and where the roads are favourable, recourse may be had to ponies and horses and the various kinds of mechanical haulage described in COAL, vol. vi. p. 69.

Trains of cars are sometimes drawn along underground railways by locomotives; they have the great disadvantage of polluting the air with the products of combustion, and consequently they are not available unless the ventilation is very good. A small locomotive of 2 horse-power nominal is used on an 18½-inch track in the adit-level of the Great Laxey mine (Isle of Man), now approaching a mile in length, and full-sized locomotives ply along the adit of the Rio Tinto mines. Locomotives worked by compressed air improve the ventilation instead of injuring it, and are not a source of danger in cases where fire-damp may be present; but, except in special cases, they cannot be worked so cheaply as engines fired with coal. Conveyance by electric railroads underground has hardly gone beyond the experimental stage, but the results obtained at the Zaukeroda colliery in Saxony[1] show that electricity can be applied with profit in this department of mining.

A few instances of transport by boats may still be met with. The boats used in the underground canal at Klausthal are 31 feet

[1] *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen auf das Jahr* 1883, p. 50

long by 4 feet 6 inches wide, and 2 feet 11 inches deep. Each boat carries 5 or 6 tons.

Where roads have a strong gradient, inclined planes are employed, either self-acting if the mineral has to be lowered, or worked by stationary engines if the mineral has to be raised (see COAL, vol. vi. p. 69).

9. *Winding, or Raising in the Shafts, with the Machinery and Apparatus required.*—In speaking of the transport by underground roads, we mentioned that the mineral is occasionally brought to the surface on the backs of men or boys. In other cases daylight is reached by adit-levels provided with railroads; but in by far the greater number of mines it is necessary to hoist the mineral, and often much rubbish, up vertical or inclined pits generally known as shafts.

In beginning to sink a shaft from the surface, or in sinking a winze, hand-power applied by a windlass is sufficient. The broken rock at the bottom of the shaft is shovelled into a wooden or iron bucket (*kibble*), which is drawn up by a rope passing round the barrel of the windlass. When a depth of 20 or 30 yards has been reached it is more advantageous to introduce horse-power, and the usual machine by which this power is applied, called a *gin* or *horse-whim*, is a common sight in many metalliferous districts. It consists of a vertical axis carrying a barrel or drum 8 to 12 feet in diameter, round which is coiled the rope, which after passing over a pulley hangs down the shaft. The axis carries an iron pin at each end, the lower one working in a stone and the upper one in a socket in the span-beam or cross-bar of the supporting frame. Under the barrel is a long driving beam to which a horse is harnessed, and, as will be readily understood, the kibble is drawn up or lowered down as the horse walks round. It is most economical to have two kibbles, for then they balance each other.

Where steam and water-power are not available, a large number of horses or mules are sometimes harnessed to whims, and ore raised from depths of 200 fathoms. These, however, are exceptional cases; and, especially since the introduction of portable engines, the use of steam-power even for comparatively small depths, such as 100 yards, is daily increasing. In hilly districts water-power is generally at hand, and huge reservoirs are frequently constructed for storing the rainfall, and so affording an adequate and constant supply. It may be utilized by water-wheels, turbines, and water-pressure engines.

There are three systems of winding by steam or water-power which are in regular use:—(1) by buckets (*kibbles*), baskets, or bags swinging loose in the shafts; (2) by boxes working between guides (*skips*, Cornwall); (3) by cages carrying one or more waggons.

The buckets are made of wood, sheet-iron, or sheet-steel. Their shape varies; it may be round or elliptical, straight in the side or bulging in the middle. Fig. 84 represents a kibble made of sheet-iron. When the shaft is inclined, the side upon which the kibble slides is carefully filled with boards (*bed-planks*) resting upon cross sleepers. Planks of hard wood like beech last longer and require fewer repairs than deal boards. In the Harz, poles fixed lengthwise take the place of boards, which are customary in Great Britain. Even where shafts are perpendicular a lining of planks is often put in round the winding compartment, unless the space is considerable, and the kibble then glides up smoothly, and there is less risk of accidents. A more modern system is to use wire-rope guides for the kibble, which is thus kept from swinging about. Another advantage of this plan is that a light cage can easily be substituted for the kibble and used for the ascent and descent of the men. Mr Galloway has patented a method of sinking shafts with wire-rope guides the upper ends of which are coiled upon drums at the surface. By adopting this expedient the guides can be lengthened as the shaft is deepened.

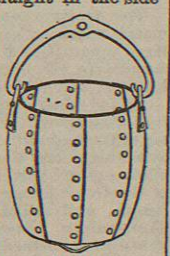

Fig. 84.

A word must be said about the actual loading and emptying of the kibble. Sometimes, as already mentioned, the kibble is filled at the working place or from a shoot (*pass*, Cornwall) carried down into the level, and then conveyed on a trolley to the shaft; where it is hooked on to the rope and drawn up. More frequently the filler standing in the *plat* loads the kibble with a shovel; and in order to save time two kibbles are often provided, one being filled while the other is making the journey to and from the surface. In this case it is necessary to have some kind of *clevis*, which will enable the kibble to be readily detached from the winding-rope, and quickly and securely fastened on again. On its arriving at the surface the *lander* seizes an eye or ring at the bottom of the kibble by a pair of tongs suspended by a chain, and the rope is now lowered. The kibble is thus turned over and the contents fall into a tram-waggon.

The inconveniences of this method of winding are considerable, especially in inclined shafts where the direction and amount of the inclination are not constant. There is great wear and tear of the bed-plank and casing-boards; and, unless constant attention is paid to repairs, places are worn out where the kibble catches, causing the rope to break. The fall of a kibble and its contents not only does much damage to the shaft, but also is a source of danger to the men. The introduction of boxes (*skips*) working **Skip**
between guides or conductors was therefore a decided step in advance, for the system allows the winding to be carried on with less friction and with greater rapidity and safety. The guides are often made of pieces of timber (like *r*, fig. 53) bolted to the end-pieces and dividings. It is only in perpendicular shafts that guides made of wire-rope or iron rods can be applied. The skip is a box of rectangular section made of sheet-iron or sheet-steel, with a sloping bottom, and provided with a hinged door closed by a bolt for discharging its contents. Fig. 85[1] shows how the skip runs upon

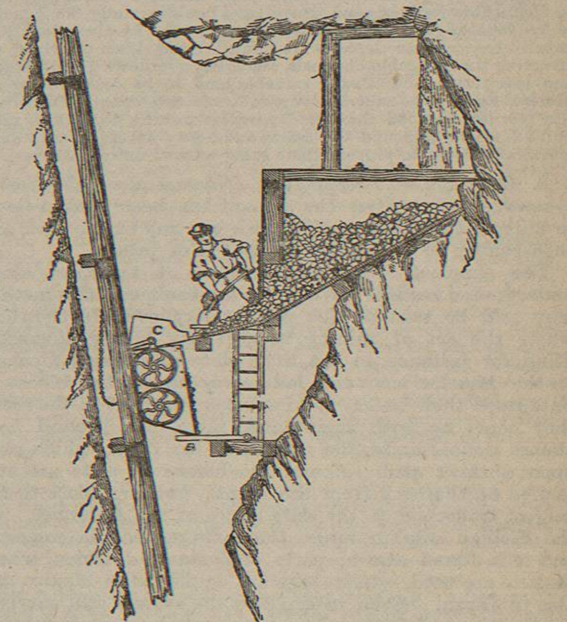

Fig. 85.

the guides by means of four cast-iron or (better) cast-steel wheels. In an inclined shaft the guides sometimes have iron rails laid on them so as to diminish the wear. Some of the skips in Cornwall are made to hold as much as a ton and a half of tin-bearing rock. The skip is filled with a shovel by a man standing in the plat, but a better plan is to arrange shoots leading from large hoppers, so that the ore can be made to run in without any shovelling. The skip is sometimes tilted completely over instead of being emptied by a hinged door; this arrangement is in use in some of the German mines, where the skip is made of wood, and is guided on each side by two pins or rollers running between two conductors. When the skip has reached the surface two catches are made to support the lower rollers, whilst the upper ones pass through openings in the front guides, and the skip, turning upon the lower ones, is tipped over and so emptied.

The most satisfactory system of winding is by cages; there is less handling of the mineral, and the hoisting proceeds at far greater speed. This system, which is almost universal in collieries, is employed also for working deposits of other minerals, and, though

[1] Moissenet, *Annales des Mines*, ser. 6, vol. ii., 1862, plate vii.

in vein-mining the skip and kibble still prevail in England, the managers are beginning to recognize the advantages of the cage and equip their mines with more modern appliances than have hitherto been customary. The cages used in the mines on the Comstock lode are very light and simple in construction, as will be seen from fig. 86. The cage in fact is a mere timber platform, 5 feet by 4,

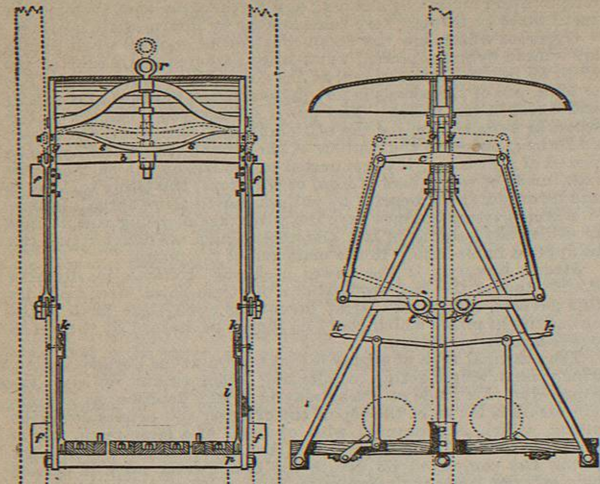

FIG. 86.—Cage used in Comstock Lode.

resting on iron bars *p*, and supported by iron rods on each side. It is provided with a sheet-iron bonnet to protect the men if they are inside, and also with safety catches *t*, *t*, which come into play if the rope breaks. The hand levers *k*, *k* at the ends of the cage raise up blocks which keep the car in its place during the ascent or descent; *g*, *g* are guides for the end of the crossbar *b*; *c*, bar working teeth *t*, *t* by levers; *f*, "ear" or "shoe" embracing the guide-rod in shaft; *r*, lifting bar; *s*, strong spring.

The most important details concerning the use of cages, ropes, and other hoisting appliances such as pulleys, pulley-frames, detaching hooks, and winding engines, have already been set forth in the article COAL, vol. vi. p. 74; and it is therefore needless to repeat these particulars, especially as the art of winding mineral cheaply, speedily, and safely has been carried to a far greater pitch of perfection in collieries than in the majority of metal mines. It is often convenient to fix winding engines underground for the purpose of sinking shafts and winzes, and drive them by compressed air brought down in pipes from the surface.

Koepe system. The Koepe system of winding, which appears to be viewed with favour on the Continent, consists in having what is practically an endless rope with one large sheave over the shaft, in the place of the two drums. There are two cages, and the rope below them acts as a counterbalance, so that the load is uniform throughout.

Blanchet's method. The most novel hoisting apparatus is that of M. Blanchet (COAL, vol. vi. p. 76), which has now been regularly at work in the Hottinguer shaft at Épinac in France for the last six years. M. Blanchet's method consists in fixing in the shaft a large pipe in which is arranged a piston; from this is suspended a cage carrying waggons. By exhausting the air above the piston the load is gradually forced up by the atmospheric pressure below it. The Hottinguer shaft is 660 yards deep, and the pipe is 5 feet 3 inches in diameter, made up of a succession of cylinders of sheet-iron about $\frac{5}{16}$ inch thick and 4 feet 4 inches high, joined by flanges and bolts. The 485 rings composing the long pipe weigh altogether 418 statute tons. The cage has nine decks, and arrangements are made for unloading three at a time; each waggon holds half a ton, so that the total useful load is 4½ tons. The speed of hoisting is 20 feet per second. If two hoisting pipes are connected the dead weights may be made to balance each other, and the power required is simply that which is necessary to overcome the weight of the useful load. All the men prefer the pneumatic hoist to the ordinary cage for descending and ascending the mine, and are regularly lowered and raised by it. The advantages claimed by M. Blanchet for this system are—(1) the possibility of hoisting from depths at which rope-winding would no longer be practicable; (2) getting rid of the costly ropes and dangers connected with rope-winding; (3) better utilization of the engine power; (4) improvement of the ventilation and diminution of the amount of fire-damp.

10. *Drainage.*—The mineral having been raised to the surface, the task of the miner might appear to be at an end; but this is not the case, for it is further necessary that he should keep his mine free from water and foul air. These two indispensable operations of draining and ventilating frequently require special appliances which add considerably to the general cost of mining.

In all cases where it is possible, endeavours should be made to keep the water out of a mine, so as to save the expense of pumping it; and the method of putting in a watertight lining (*tubbing*) in a shaft has been already described (COAL, vol. vi. p. 62). When large streams of water happen to be intersected by underground workings, and threaten to overpower the available pumping machinery, or when it is advisable to save the expense of draining abandoned workings, the entry of this water into the mine may often be prevented by stoppings, called *dams*, constructed of timber or brickwork.

In spite of all precautions, the miner generally has to contend with water which percolates into the workings. Four methods of getting rid of this water are available, viz., adits, siphons, winding machinery, and pumps.

An adit, day-level, or sough is a nearly horizontal tunnel **Adits.**
with one end opening at the surface, allowing the water to drain away naturally. In hilly countries mines are often worked entirely by adits, and even when a mine is deepened below the drainage level the utility of the adit is still threefold:—it lessens the quantity of water which tends to percolate into the lower workings; it lessens the depths to which the water has to be pumped; and, by furnishing a certain amount of fall, it enables water to be applied as power. On account of these important advantages some very long and costly adits have been driven for the purpose of aiding the miners in certain metalliferous districts.

Thus in the Harz the Ernest Augustus adit ("Ernst August Stolln") has been driven a distance of nearly 6½ miles into the Klausthal district. The total length of the adit, including the branches, is no less than 14 miles. It intersects many of the lodes at a depth of upwards of 400 yards from the surface. The total cost of this adit is estimated at £85,500.

Another long adit is the celebrated "Rothschönberger Stolln," which unwaters some of the most important mines at Freiberg in Saxony. The length of the main or trunk adit is more than 8½ miles; the gradient of the greater part of it is only 1·18 inch in 100 yards. The branches of this adit among the mines are more than 16 miles in length, so that the total length of the main adit with its branches amounts to nearly 25 miles. Many of the mines are now drained naturally to a depth of 250 to 300 yards. The cost of the main tunnel was £359,334, or nearly £24 per yard, but this includes the cost of eight shafts, heavy expenses for pumping from these shafts, the walling of the adit for ¾ mile, and all general expenses. The length of time occupied in driving this adit was thirty-three years. The "Kaiser Josef II. Erbstolln" in Hungary is another remarkable mining tunnel, which was commenced in 1782, and completed in 1878 at a total cost of 4,599,000 florins. It is 10¼ miles in length, extending from the valley of the river Gran to the town of Schemnitz, where it intersects the lodes at depths varying from 300 to 600 yards according to the contour of the surface.

In Cornwall the Great County adit was driven for the purpose of relieving the Gwennap mines of their water, and it was pushed on nearly to Redruth. This adit differs from the great works undertaken in Germany by the fact that it commences in the mining district, and, though the length of all the drivages amounts to more than 30 miles, the water from the most distant mine does not run more than about 6 miles before reaching daylight. The average depth is only 70 or 80 yards from the surface. In fact this great adit, though a work of great utility when the Gwennap district was in a flourishing condition, is merely a network of comparatively shallow drivages, often along the lodes themselves, among the mines, and therefore for boldness of execution cannot for one moment be compared to the great Schemnitz, Freiberg, and Klausthal drainage tunnels which have just been mentioned. The Blackett Level in Northumberland is an adit which has been driven a distance of about 4¾ miles, and it will have to be extended about 2 miles further before reaching Allenheads. Its depth from the surface at this place will be about 200 yards.

The main part of the Halkyn tunnel in Flintshire is 2 miles 1256 yards in length, and the branch driven out to Rhosesmor mine intersected the vein at a distance of 809 yards, making a total of about 3½ miles. The greatest depth from the surface is 230 yards, and the average depth in Halkyn Mountain about