pieces of ore are thrown with great velocity against bars or arms, or against each other, and so reduced to powder; in other machines iron balls or iron rollers are whirled by centrifugal force against an iron casing and grind any mineral contained inside it. These pulverizers are much less used than stone-breakers, stamps, and rolls for the disintegration of metallic ores.

(3) Classification of a crushed ore into sizes is absolutely necessary in some cases and advisable in others, because the subsequent concentration is dependent upon the fall of the particles in water, as will be presently explained. Classification by size is effected by sieves. Hand sieves and flat sieves placed one above the other have been superseded at most dressing establishments by cylindrical or conical revolving screens known as trommels. These screens are made of wire web or of perforated sheets of metal, and they are often arranged so as to discharge one into the other, so that the ore from a crusher can quickly be separated into classes of various sizes.

With sizes of less than 1 millimetre ($\frac{1}{25}$ inch) trommels are no longer employed, and recourse is had to the so-called separators or classifiers. These are boxes in the shape of inverted cones or pyramids into which the finely crushed ore is brought by means of a current of water; a jet of clean water is often made to rise up in the bottom; the larger and the specifically heavier particles fall and are discharged with a stream of water at or near the bottom, whilst the smaller and specifically lighter particles flow away at the top. The separators do not effect a true classification by size; they merely cause a division by *equivalence*, a term which will be explained immediately.

Concentration. (4) We now have to deal with the enriching of the ore, or the concentration of the valuable particles into as small a bulk as is economically advantageous. The concentration is generally brought about by the fall of the particles in water. Occasionally the fall in air is utilized; mercury is employed as a collecting agent in the case of gold and silver, and in a few instances magnetism can be applied.

The concentration in water depends upon the difference in specific gravity of the valuable ore and the waste veinstone or rock. A piece of galena with a specific gravity of 7·5 sinks to the bottom more quickly than a similar piece of quartz, the density of which is only 2·6. Nevertheless a large piece of quartz may fall to the bottom as quickly as a small piece of galena. Particles which have equal velocities of fall, though differing in size and specific gravity, are said to be *equal-falling*, or *equivalent*. P. von Rittinger shows that a sphere of quartz of $\frac{1}{4}$ inch in diameter would sink in water exactly as quickly as a sphere of galena of $\frac{1}{16}$ inch in diameter, and these two particles are therefore equal-falling. Consequently, before we can separate properly by water it is necessary to classify the particles by size, so that equivalence shall not prevent a separation or lessen its sharpness. It is nevertheless true that in the early part of the fall of equivalent grains the influence of the specific gravity preponderates, and the denser particles take the lead; therefore, by a frequent repetition of very small falls, particles which have not been closely sized may still be separated.

The principal machine for concentrating particles of sizes ranging between 1 inch and $\frac{1}{50}$ inch is the jig or jigger. The hand jigger is merely a round sieve which is charged with the crushed ore and then moved up and down in a tub full of water. The particles gradually arrange themselves in layers, the heaviest on the bottom and the lightest at the top. On lifting out the sieve the light waste can be skimmed off with a scraper, leaving the concentrated product below ready for the smelter or for further treatment. Similar sieves worked by machinery were for a long time employed in dressing establishments, but the introduction of the improved continuous jiggers has led to thei abandonment in all works of any importance. The continuous jigger is one of the most useful dressing machines of the present day. It consists of a box or hutch divided by a partial partition into two compartments; in one is fixed a flat sieve *s* (fig. 99), which carries the ore, and in the other a piston *p* is made to work up and down by means of an excentric. The hutch being full of water, the movement of the piston causes the water to rise up and fall down through the ore, lifting it and letting it fall repeatedly. The effect of these frequent lifts and falls is to cause a separation of the previously sized ore into layers of rich mineral at the bottom, light waste at the top, and particles of ore mixed with waste in the middle.

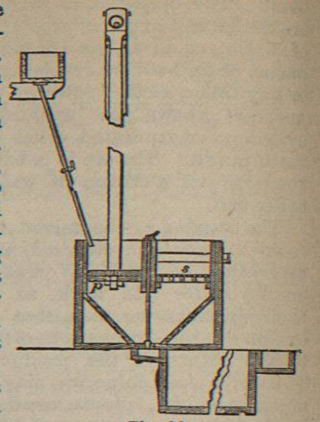

Fig. 99.

The great value of these jiggers is the continuous discharge of the products without stoppages for their removal. Several methods are in vogue, viz., the end discharge, the central discharge, and the discharge through the meshes of the sieve. With the first, the enriched product lying at the bottom of the sieve passes out through openings at the end of the jigger, and the amount escaping is governed by an adjustable cap or shutter, by which the size of the openings can be increased or diminished at pleasure; the middle product can be discharged by openings placed a little higher up, whilst the waste is washed over the top of the end of the jigger at each pulsation. Very often a first sieve simply separates a concentrated product and discharges the poorer product into a second sieve, where a similar separation is effected. With the central discharge, a pipe is brought up through the bottom of the sieve, and the size of the opening for the escape of the concentrated ore is regulated by a cylindrical cap which can be raised or lowered by a screw. The discharge through the sieve is especially adapted for the finer products from the crusher, though it is also used in some cases for grains up to $\frac{1}{4}$ inch in diameter. The mesh of the sieve is chosen so that the particles under treatment will just pass through, but above the sieve a layer of clean ore is placed which prevents anything but the heavier particles from being discharged. The pulsations of the water, as before, cause a separation into layers, and the heavy rich particles find their way through the bed and drop into the hutch, whence they can be drawn off through a hole at pleasure. The poorer part passes over a simple sill at the end of the sieve, or to a second sieve if necessary. Three or four sieves are occasionally arranged in a row in one machine.

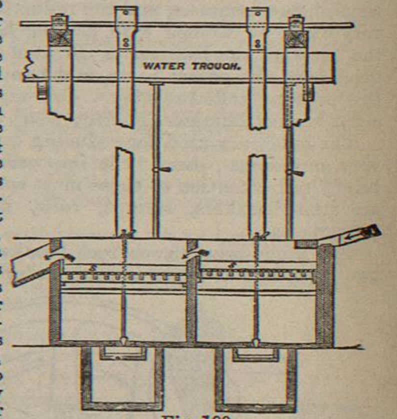

Fig. 100.

Fig. 100 is a section through the two sieves of a Harz sand jig. The pistons act in the manner explained by fig. 99.

The smaller sizes are concentrated by a variety of machines. The action of many of them is based upon the behaviour of particles carried down an inclined plane by a thin stream of water. If the gradient of the plane and the strength of the thin current are properly arranged, the denser particles will be deposited and the specifically lighter ones washed away, although they may be *equal-falling* if allowed to settle in deep water.

The principal machines for concentrating fine sands and slimes are the frame, rotating frame, percussion frame, side-blow percussion frame, revolving belt and Frue vanner, the hand buddle, the round buddle, and the keeve.

The frame is simply an inclined wooden table upon which a thin deposit is formed by the sheet of ore-and-waste-bearing water which is made to flow over it gently The stream is then stopped and the deposit washed off by hand or automatically, and collected in pits for subsequent retreatment by similar appliances if necessary.

The rotating frame is a round table with a very flat convex conical surface; the ore for suspension flows on at one part of the centre and forms a thin deposit which is richest at the top and poorest at the bottom, and this deposit is washed off so as to form two classes by means of jets of water, under which the table passes as it turns round. Concave rotating tables, fed at the circumference, are also employed.

The percussion frame, the *Stossheerd* of the Germans, is a table suspended by four chains which receives a succession of blows from a cam in the direction of the stream flowing over it; after each blow it bumps against a piece of timber before receiving the next blow. These bumps cause the ore to settle, and after a thick deposit is formed it is dug off with the shovel, the upper end being richer than the middle or the tail.

Rittinger's side-blow percussion frame is a suspended rectangular table ABCD (fig. 101), receiving blows and bumps on the side and not on the end. A stream of orey water S is fed on at the corner A; clean water W is supplied by the other head-boards H, H, H; and the table is pushed out by cams in the direction of the arrow, and is driven back by a spring so that the cross-piece E strikes against a bumping-block K. The light particles travel down the table much faster than the heavy ones, and take a comparatively straight course; whereas the heavy and richer particles remain on the table, subject to the influence of the side-blows, for a much longer time, and travelling along a curved path reach the bottom at F. The middle class is discharged at G and the poor waste at K. The exact degree of richness of the products can be regulated by altering the pointers, strips of wood which can be turned so as to divide the stream of ore and waste where thought most desirable. The great advantage of this machine over the old percussion frame is its continuous action.

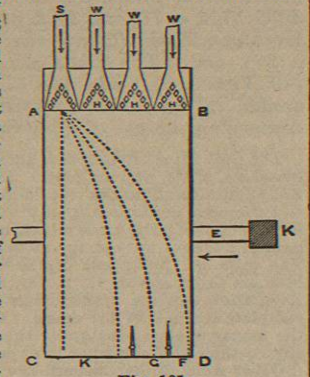

Fig. 101.

The Frue vanner (fig. 102) may be looked upon as an improved form of Brunton's simple revolving belt. It is an endless band of india-rubber cloth, flanged on each side, which revolves slowly in the direction of the arrows, whilst at the same time it is shaken sideways by a crank motion. The orey water is fed on at A, clean water at B. The natural path of the particles is down the inclined belt, but the specifically heavier ones settle upon it and are carried upwards. Those that can resist the action of the stream of clean water at B go over the end and are washed off as the belt passes through the tank. The poor stuff falls into the waste launder. The degree of concentration can be regulated by the slope and speed of the belt and the strength of the streams of ore and water. The Frue vanner has the disadvantage that it makes only two classes, rich and poor, without any intermediate product.

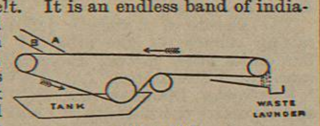

Fig. 102.

The hand buddle is a rectangular wooden box with a sloping bottom. A stream of fine ore and waste suspended in water is fed in at the upper end and gradually forms a deposit on the bed of the buddle. A boy with a broom keeps the top of the sediment smooth, so as to ensure regularity of action After a thick deposit has accumulated, it is dug out in sections which decrease in richness from the upper end (*head*) to the lower end (*tail*).

Round buddles, like rotating frames, are of two kinds, convex and concave. The convex round buddle (figs. 103[1] and 104) is a circular pit with a truncated cone, or head, of varying size in the centre, and a bottom sloping towards the circumference. The orey stream A falling over this head runs down gently, depositing the heaviest particles near the top, the lighter ones further down, whilst the lightest of all flow away at C. The surface of the sediment is kept even by revolving brushes D. This machine may be compared to a number of hand buddles arranged radially round a centre. The deposit that is formed is dug out in rings of varying richness.

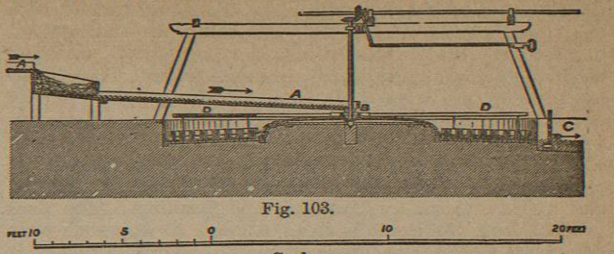

Fig. 103.

Scale.

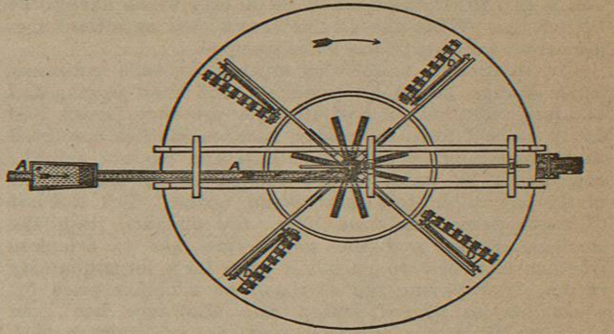

Fig. 104.

The concave buddle is a circular pit with the bottom sloping towards the centre. The stream of ore is fed all round the circumference, and runs inwards to the middle, where the lightest particles escape. The rich head is of course near the circumference.

The keeve is a large tub in which the fine stuff is stirred with Keeve. water and then is allowed to settle from a state of suspension while blows are being struck on the side of the tub. The deposit is afterwards scraped out in layers which increase in richness as they approach the bottom.

The series of processes employed in dressing an ore varies, Dressing different ores. not only according to the nature of the particular mineral to be concentrated, but also according to the size of its particles and the nature of the other minerals with which it is associated.

With gold the reduction in size is usually effected by Gold stone-breakers and stamps, and much of the metal is then caught by mercury; what escapes is concentrated with its accompanying pyrites by inclined tables covered with blankets, or by buddles, and the concentrate is treated by amalgamation or chlorination. See GOLD, vol. x. p. 746.

In the case of silver the ore is frequently pulverized by Silver. stamps, and the resulting *pulp* amalgamated in pans or barrels. The ore may also be concentrated by any of the various machines described, and delivered to the smelter. Many of the ores of silver are sent to the smelting works without any concentration by water, as this would cause a serious loss.

Lead ore is generally crushed by rolls, often after a preliminary reduction in size by the stone-breaker. The crushed ore is classified by revolving screens down to the size of 1 mm., and the resulting grains concentrated by jigging; *dredge*, or grains of ore and matrix, must be recrushed, sized, and jigged. The finer sizes are classified by pyramidal boxes and concentrated by frames, rotating tables, and buddles.

Zinc ore is dressed in the same way as lead ore; and, as galena and zinc-blende are frequently intimately associated together, it is necessary to separate them by the use of the jig, buddle, and frame.

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[1] Henry T. Ferguson, "On the Mechanical Appliances Used for Dressing Tin and Copper Ores in Cornwall," *Proc. Inst. Mech. Eng.*, 1873 pl. 41.

Tin-bearing rock is crushed by the stone-breaker and then stamped fine. The resulting sand and slime may be concentrated by the repeated use of the round buddle, with the keeve for a final cleaning; but often the sand only is enriched by the buddle, whilst the very finest particles, constituting an almost impalpable mud (*slime*) when mixed with water, are treated by frames. When much pyrites is present it is necessary to make a preliminary concentration and roast the enriched product (*witts*) in a furnace. The calcination converts the heavy iron and arsenical pyrites into a light oxide which can be got rid of with the rest of the waste by buddling and framing. The final product from the keeve is clean enough to approach pure cassiterite in the percentage of metal. Alluvial tin ore is concentrated in *sluice-boxes*, and sometimes by jiggers, after a preliminary treatment in a *puddling-machine* (GOLD, vol. x. p. 745) if there are balls of clay which have to be broken up. When the alluvial ore occurs as a hard conglomerate (*cement*), it has to be stamped.

Copper.

Copper ores are treated by crushing by rolls and sometimes stamps, sizing by trommels, and then jigging and buddling; but, as some of the ores are very friable and easily carried away by water, hand-picking is employed to a greater extent than with lead and tin ore, and the enrichment by water is not carried so far on account of the inevitable loss that would ensue. The amount of concentration depends upon the distance from the smelting works, and the mine-owner has to calculate whether it is best to get a low price for a large quantity of ore, after paying the carriage, or a higher price for a smaller lot (*parcel*) when due allowance has been made for the cost of dressing and loss sustained in that process. Thus, for instance, in Cornwall, the ore containing copper pyrites is dressed so as to contain only from 5 to 8 or 9 per cent. of metal, because it can easily be conveyed to Swansea by sea, and because further reduction in bulk would cause greater loss in value than the saving of freight.

Loss in dressing.

The loss in dressing is very considerable. P. von Rittinger estimates it at from 30 to 50 per cent., and stubborn facts bear out his conclusions. Heaps of refuse from dressing floors are frequently worked over again with profit; and in the year 1881 no less than 909 tons of "black tin" (*i.e.*, concentrated tin ore fit for the smelter), worth £35,283, were extracted from the muddy water allowed to flow away from the dressing floors of some of the principal Cornish tin mines.

The fall in air has been employed instead of the fall in water for concentrating purposes, and several ingenious air-jigs have been constructed and worked upon this principle.

Separation by magnetism.

In exceptional cases magnetic attraction may be utilized. Magnetic iron can be separated in this way, and the magnetic process is applied for treating mixed blende and chalybite, the specific gravities of which are too close to render concentration by water practicable. The mixed ore is calcined, and the chalybite is thus converted into magnetic iron, which can be extracted by a magnetic separator, leaving saleable blende.

Before concluding this part of the subject we will briefly enumerate the principal improvements that have been made in metal-mining during the last quarter of a century. They are as follows:—diamond-drill for prospecting; machine drills for driving, sinking, and stoping; use of compressed air for winding underground; stronger explosives, especially the nitro-glycerin compounds dynamite and blasting gelatin; increased use of steel for various purposes; Blake's stone-breaker and continuous jiggers; extended application of hydraulic mining; larger employment of electricity both for blasting purposes and for signalling by telegraph and telephone. It may be reasonably hoped that ere long electricity will render increased services to the miner for lighting the workings and for the transmission of power.

14. *Recent Legislation affecting Mines in the United Kingdom.*[1]—In England the person owning the surface of a freehold is *prima facie* entitled to all the minerals underneath, excepting in the case of mines of gold and silver, which belong to the crown. The crown, however, does not claim gold and silver extracted from the ores of the baser metals. The ownership of the minerals can be, and often is, severed from that of the surface, the latter being sold whilst the mineral rights are reserved by the original owner. Local customs, now regulated by Acts of Parliament, are still in force in Derbyshire (High Peak Mining Customs and Mineral Courts Act, 1851, 14 & 15 Vict. c. 94, and the Derbyshire Mining Customs and Mineral Courts Act, 1852, 15 & 16 Vict. c. 43) and in the Forest of Dean (1 & 2 Vict. c. 43, and 24 & 25 Vict. c. 40). The Stannaries Act (32 & 33 Vict. c. 19) regulates the commercial dealings of mining companies in Cornwall and Devon, and provides for their liquidation.

The working of mines in the United Kingdom is controlled by five Acts of Parliament, viz., "The Coal Mines Regulation Act, 1872" (35 & 36 Vict. c. 76), "The Metalliferous Mines Regulation Acts, 1872 and 1877" (35 & 36 Vict. c. 77, and 38 & 39 Vict c. 39), "The Stratified Ironstone Mines (Gunpowder) Act, 1881" (44 & 45 Vict. c. 26), and "The Slate Mines (Gunpowder) Act, 1882" (45 Vict. c. 3). The last three Acts simply refer to the annual returns, and exemptions from certain restrictions concerning the use of gunpowder.

The Coal Mines Regulation Act applies to mines of coal, stratified ironstone, shale, and fire-clay. The Metalliferous Mines Regulation Act applies to all mines not included under the Coal Mines Act, and therefore controls not only workings for lead, tin, copper, and iron, commonly known as mines, but also the salt-mines, and underground quarries worked for stone, slate, or other earthy minerals. The principal provisions of the Coal Mines Regulation Act have been set forth at vol. vi. p. 78; those of the Metalliferous Mines Regulation Act are similar, but less strict owing to the almost complete absence of fire-damp. One important difference is that the manager of a mine under the Metalliferous Act need not hold any certificate of competency or service.

Other Acts of Parliament are the "Explosives Act, 1875" (38 Vict. c. 17), regulating the manner in which explosives are stored; the "Elementary Education Acts, 1876 and 1880" (38 & 39 Vict. c. 79, and 43 & 44 Vict. c. 23), regulating the employment of children; the "Factory and Workshop Act, 1878" (41 Vict. c. 16), which applies to the dressing floors of mines under the Metalliferous Mines Regulation Act.

The statute of Elizabeth (43 Eliz. c. 2) which was passed for raising money for the relief of the poor mentions coal mines, but omits other mines; these have been made subject to poor-rates by "The Rating Act, 1874" (37 & 38 Vict. c. 54). The "Employers' Liability Act, 1880" (43 & 44 Vict. c. 42), extends and regulates the liability of employers to make compensation for personal injuries suffered by workmen in their service. Finally, if, as sometimes happens, works are put up at a mine for roasting copper ores with common salt in order to extract the metal by the wet way, the provisions of the "Alkali, &c., Works Regulation Act, 1881" (44 & 45 Vict. c. 37), must be attended to.

It is thus very evident that the laws affecting mines have received most important additions during the last few years.

Accidents.

15. *Accidents in Mines.*—Mining is one of the occupations that may decidedly be called hazardous. This fact has been thoroughly impressed upon the public mind by explosions of fire-damp in collieries; but, though accidents of this kind are appalling, owing to the number of victims who perish at one time, fire-damp is by no means the worst enemy with which the miner has to contend. Falls of roof and sides both in collieries and metal mines are far more fatal in their results. With the risks attending the collier's calling we need not deal, as statistics upon this subject have been already given (see COAL, vol. vi. p. 79); but the figures below relating to metalliferous mines prove that the occupation of the metal miner is very little less dangerous.

*Mines classed under the Metalliferous Mines Regulation Act in Great Britain and Ireland.*

| | Persons Employed. | | | Number of Deaths from Accidents. | | | | | | Death-rate from Accidents per 1000 persons employed. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Under Ground. | | | | Above Ground. | General Total. | | | |
| | Under Ground. | Above Ground. | Total. | Falls of Ground. | In Shafts. | Miscellaneous. | Total. | | | Under Ground. | Above Ground. | Under Ground and Above Ground. |
| 1874 | 34,036 | 22,325 | 56,361 | 40 | 34 | 15 | 89 | 14 | 103 | 2·61 | 0·62 | 1·82 |
| 1875 | 34,905 | 23,168 | 58,073 | 32 | 35 | 33 | 100 | 19 | 119 | 2·86 | 0·82 | 2·05 |
| 1876 | 34,109 | 23,388 | 57,497 | 25 | 16 | 23 | 64 | 6 | 70 | 1·87 | 0·25 | 1·21 |
| 1877 | 34,095 | 23,300 | 57,395 | 41 | 21 | 24 | 86 | 11 | 97 | 2·52 | 0·47 | 1·69 |
| 1878 | 30,624 | 20,834 | 51,458 | 27 | 19 | 23 | 69 | 8 | 77 | 2·25 | 0·38 | 1·49 |
| 1879 | 28,265 | 18,795 | 47,060 | 24 | 16 | 16 | 56 | 8 | 64 | 1·98 | 0·42 | 1·36 |
| 1880 | 32,045 | 20,863 | 52,908 | 31 | 21 | 19 | 71 | 13 | 84 | 2·21 | 0·62 | 1·59 |
| 1881 | 33,291 | 21,651 | 54,942 | 36 | 22 | 32 | 90 | 9 | 99 | 2·70 | 0·41 | 1·80 |
| 1882 | 33,814 | 21,692 | 55,506 | 30 | 27 | 17 | 74 | 18 | 92 | 2·18 | 0·83 | 1·65 |
| Total and averages for the nine years | 295,184 | 196,016 | 491,200 | 286 | 211 | 202 | 699 | 106 | 805 | 2·37 | 0·54 | 1·63 |

This table[1] shows that the average accidental mortality of the persons employed *underground* in metalliferous mines is 2·37 per 1000. During the ten years 1873–1882 the corresponding mortality at mines under the Coal Mines Act was 2·57, showing a difference of only 0·20 per 1000 in favour of the metal miner; and when we take the well-known metalliferous district of Cornwall and Devon we find a death-rate for the ten years mentioned of 2·63 per 1000, which therefore exceeds that of coal mines.

Reference to the table shows that more than one-third of the deaths were caused by falls of ground. The actual percentages of the deaths are as follows:—falls of ground 35·5, in shafts 26·2, miscellaneous 25·1, on surface 13·1. The accidents in shafts are due to falls from ladders, cages, and man-engines, ropes and chains breaking, overwinding, and other causes, whilst the miscellaneous accidents include numerous fatalities in connexion with blasting operations. The surface accidents are mostly caused by persons becoming entangled in machinery, and there have been several fatal boiler explosions.

In spite, however, of all the dangers to which miners are exposed, they are less likely to be the victims of accident than railway servants, among whom the rate of fatal accidents varies from 2·5 per 1000 on passenger traffic lines to 3·5 per 1000 on lines possessing a heavy goods traffic.[2]

Statistics concerning accidents in mines are published by many foreign countries; the most minute are those prepared by the Government mining engineers in Prussia. The average annual death-rates per 1000 persons employed below ground and above ground from accidents in mines in Prussia during the fifteen years 1867 to 1881 have been:—coal mines 2·952, lignite mines 2·474, metal mines 1·446, other mines 1·693, all the mines together 2·476. In making any comparison between these figures and those we have given for Great Britain, it is necessary to recollect that the mines under the Coal Mines Act include some workings which in Prussia would be classed as metalliferous, and that British mines under the Metalliferous Act include underground stone-quarries.

Before concluding the subject of accidents, it is necessary to point out that successful efforts have been made of late years to mitigate their results. In the first place, persons equipped with the Fleuss breathing apparatus can now enter mines after explosions, in spite of the noxious and irrespirable gases, and save lives which would otherwise be sacrificed.[3] Secondly, by means of the instruction afforded by classes established by the St John Ambulance Association, miners are learning how best to render first aid to the injured before the arrival of a medical man, and there is no doubt that many valuable lives have been lost in times past for want of this knowledge. Thirdly, a vast amount of good has been done by the establishment of Miners' Permanent Relief Societies in different districts, which afford aid to persons disabled by accidents and to the dependent relatives of those who have unfortunately lost their lives by any mining fatality.

16. *Useful Minerals produced in Various Parts of the Globe.*

*Great Britain and Ireland.*—The mineral produce of the United Kingdom for the year 1881 is summed by Mr Robert Hunt[4] as follows:—

| Minerals. | Quantities. | | Values. | | |
|---|---|---|---|---|---|
| | Tons | cwts. | £ | s. | d. |
| Coal | 154,184,300 | 0 | 65,528,327 | 10 | 0 |
| Iron ore | 17,446,065 | 6 | 6,201,068 | 6 | 6 |
| Tin ore | 12,898 | 3 | 697,444 | 5 | 3 |
| Copper ore | 52,556 | 1 | 190,057 | 8 | 7 |
| Lead ore | 64,702 | 5 | 656,725 | 0 | 0 |
| Zinc ore | 35,527 | 7 | 110,043 | 10 | 8 |
| Iron pyrites | 43,616 | 14 | 30,033 | 6 | 5 |
| Gold ore | | 1½ | 18 | 0 | 0 |
| Silver ore | 5 | 19 | 358 | 7 | 0 |
| Cobalt and nickel ore | 63 | 14 | 309 | 12 | 8 |
| Manganese | 2,884 | 0 | 6.441 | 5 | 0 |
| Wolfram | 54 | 7 | 544 | 1 | 9 |
| Ochre and umber | 7,996 | 9 | 12,286 | 7 | 0 |
| Arsenic | 6,156 | 8 | 45,070 | 7 | 6 |
| Fluor spar, &c. | 372 | 14 | 253 | 10 | 0 |
| Clays | 2,401,421 | 0 | 1,200,210 | 0 | 0 |
| Salt | 2,298,220 | 0 | 1,149,110 | 0 | 0 |
| Barytes | 21,313 | 11 | 23,894 | 3 | 10 |
| Sundry minerals, including coprolites, gypsum, calcspar, shales, &c. | ... | | 349.500 | 0 | 0 |

The total value of minerals produced in 1881 was £76,201,695, 2s., exclusive of slate, building-stone, limestone, and other stones worked by mines and quarries.

The quantity of coal raised in 1882 was 156,499,977 tons.

The metals obtained from the ores produced in the United Kingdom in 1881 were—

| Metals. | | Quantities. | Values. |
|---|---|---|---|
| | | | £ |
| Gold | ounces | 4½ | 18 |
| Silver, from ore | „ | 1,650 | 360 |
| Silver, from lead | „ | 308,398 | 67,140 |
| Pig iron | tons | 8,144,449 | 20,361,122 |
| Tin | „ | 8,615 | 839,680 |
| Copper | „ | 3,875 | 263,500 |
| Lead | „ | 48,567 | 728,805 |
| Zinc | „ | 14,947 | 252,608 |
| Other metals, estimated | | ... | 1,275 |
| Total value of metals produced in 1881 | | ... | £22,514,508 |

The total value of minerals and metals obtained from the mines and other mineral workings of the United Kingdom in 1881 was—

| | £ |
|---|---|
| Coal | 65,528,327 |
| Metals, as above | 22,514,508 |
| Minerals, not reduced—salt, clays, &c. | 2,817,652 |
| | £90,860,487 |

From these tables it is evident that coal and iron are by far the most important mineral productions of the United Kingdom, as 94 per cent. of the total value is due to these two substances.

*France.*—The mineral productions of France[5] for the year 1880 are set forth in the following table:—

| | Quantities. | Values. |
|---|---|---|
| | Metric Tons. | Francs. |
| Mineral fuel | 19,362,000 | 246,687,000 |
| Peat | 248,000 | 2,755,000 |
| Asphalt rock and bituminous shale | 144,000 | 1,023,000 |
| Iron ore | 2,874,000 | 14,909,000 |
| Iron pyrites and sulphur | 133,000 | 2,114,000 |
| Metallic ores | 53,000 | 4,690,000 |
| Rock-salt | 333,000 | 11,814,000 |
| Bay-salt | 367,000 | 6,719,000 |
| General tofals | 23,514,000 | 290,711,000 |

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[1] For information concerning the laws relating to mines in the United Kingdom, see W. Bainbridge, *A Treatise on the Law of Mines and Minerals*, 1878, and Arundel Rogers, *The Law relating to Mines, Minerals, and Quarries in Great Britain and Ireland, with a Summary of the Laws of Foreign States*, 1876.

[1] From *Reports of H.M. Inspectors of Mines for the year* 1882, p. xxxvi.

[2] *The Rate of Fatal and Non-Fatal Accidents in and about Mines and on Railways, with the Cost of Insurance against such Accidents*, by Francis G. P. Neison, London, 1880.

[3] *Reports of H.M. Inspectors of Mines for the year* 1881. Mr Bell's Report, p. 463.

[4] *Mineral Statistics of the United Kingdom* for 1881, p. ix.

[5] *Statistique de l'Industrie Minérale et des Appareils à Vapeur en France et en Algérie*, Année 1880, Paris, 1882, p. 45.

The quantities of metal produced in France from native and foreign ores in 1880[1] were—

| | | | |
|---|---|---|---|
| Pig iron | 1,725,000 metric tons. | Nickel | 30 metric tons. |
| Lead | 6,500 " " | Gold | 31 kilogrammes |
| Copper | 3,400 " " | Silver | 40,400 " |
| Zinc | 16,200 " " | Aluminium | 1,150 " |

*Germany.*—The mining industry of the German empire is of high importance. The output of the mines in 1881 is shown by the following table,—taken from the *Stat. Jahrb. für das Deutsche Reich*, Berlin, 1883, p. 27. The production of common salt, potassium chloride, and other salts from brine is also considerable. The total quantity for the German empire in 1881 was 693,000 metric tons, worth 33,567,000 marks, including 113,200 tons of potassium chloride valued at 14,090,000 marks.

| | Coal. | Lignite. | Rock-Salt. | Potash Salts. | Iron Ore. | Zinc Ore. | Lead Ore. | Copper Ore. | Silver and Gold Ore. | Iron Pyrites and other Vitriol and Alum Ores. | Other Mining Products. | Total Value of all the Mining Products. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Unit 1000 Metric Tons. | Unit 1000 Metric Tons. | Unit 1000 Metric Tons. | Unit 1000 Metric Tons. | Unit 1000 Metric Tons. | Unit 1000 Metric Tons. | Unit 1000 Metric Tons. | Unit 1000 Metric Tons. | Unit 1000 Metric Tons. | Unit 1000 Metric Tons. | Unit 1000 Metric Tons. | Unit 1000 Marks. |
| Prussia[2] | 43780·5 | 10412·2 | 207·8 | 545·4 | 3906·3 | 659·2 | 159·7 | 523·6 | 0·1 | 142·0 | 33·2 | 326,423 |
| Bavaria | 519·8 | 18·1 | 0·9 | ... | 75·6 | ... | 0·8 | 0·0[3] | ... | 1·1 | 1·5 | 5,124 |
| Saxony[4] | 3707·8 | 600·7 | ... | ... | 23·8 | ... | 1·7 | 0·1 | 26·7 | 0·1 | 1·2 | 33,057 |
| Würtemberg | ... | ... | 84·2 | ... | 19·3 | ... | ... | ... | ... | 0·1 | ... | 752 |
| Baden | 9·4 | ... | ... | ... | ... | 0·3 | ... | ... | ... | ... | 0·0[3] | 110 |
| Hesse | ... | 30·7 | ... | ... | 133·8 | ... | ... | ... | ... | ... | 0·6 | 1,115 |
| Mecklenburg | ... | 12·3 | ... | ... | ... | ... | ... | ... | ... | ... | ... | 46 |
| Thuringia | 0·9 | 735·3 | ... | ... | 28·4 | ... | ... | 0·0[3] | ... | 0·4 | 1·4 | 1,626 |
| Brunswick | ... | 273·7 | ... | ... | 96·4 | ... | 0·9 | ... | ... | ... | 18·0 | 1,578 |
| Anhalt | ... | 766·1 | 19·0 | 360·5 | ... | ... | 1·4 | ... | ... | ... | 2·1 | 6,344 |
| Schaumburg-Lippe | 108·9 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 965 |
| Waldeck | ... | ... | ... | ... | 32·3 | ... | ... | ... | ... | ... | 0·0[3] | 170 |
| Alsace-Lorraine | 560·9 | 3·2 | ... | ... | 1096·0 | ... | 0·3 | ... | ... | 2·4 | 9·7 | 6,690 |
| German empire | 48688·2 | 12852·3 | 311·9 | 905·9 | 5411·9 | 659·5 | 164·8 | 523·7 | 26·8 | 146·1 | 67·7 | 384,000 |
| Luxemburg | ... | ... | ... | ... | 2161·9 | ... | ... | ... | ... | ... | ... | 4,994 |
| Together | 48688·2 | 12852·3 | 311·9 | 905·9 | 7573·8 | 659·5 | 164·8 | 523·7 | 26·8 | 146·1 | 67·7 | 388,994 |

*Austria-Hungary.*—Among the famous mines of the Austria-Hungarian empire may be mentioned those of Hungary and Transylvania for gold and silver; Styria produces much of the iron; quicksilver is yielded by the mines of Idria in Carniola, lead and silver by those of Przibram in Bohemia; salt is obtained in the Austrian Alps and in Galicia, which also produces petroleum and ozokerite.

The production of minerals and metals in Austria[5] during the year 1881 was as follows:—

| | | | | | |
|---|---|---|---|---|---|
| Gold ore | 784 | metric tons | —Metallic gold | 18·6 | kilogrammes. |
| Silver ore | 12,383 | " " | — " silver | 31,359 | " |
| Quicksilver ore | 48,204 | " " | — " mercury | 398 | metric tons. |
| Copper ore | 4,445 | " | — " copper | 481 | " " |
| Iron ore | 618,963 | " " | — " iron | 379,639 | " " |
| Lead ore | 3,542 | " " | — " lead | 6,385 | " " |
| | | | Litharge | 2,996 | " " |
| Zinc ore | 27,339 | " " | —Metallic zinc | 4,119 | " " |
| Manganese ore | 9,109 | " " | | | |
| Graphite | 13.379 | " ". | | | |
| Petroleum | 1,249 | " | | | |
| Lignite | 8,961,498 | " | | | |
| Coal | 6,343,315 | " | | | |

Exclusive of salt, the value of the produce of the Austrian mines in 1881 was 44,693,692 florins. The total output of salt in 1881 was 267,279 metric tons, valued according to the monopoly prices at 23,000,498 florins.

Hungary in 1879[6] produced

| | | | |
|---|---|---|---|
| Gold | 1,593 kilogrammes. | Iron | 118.321 metric tons. |
| Silver | 18,660 " | Coal | 674,008 " " |
| Copper | 1,035 metric tons. | Lignite | 932,475 " " |
| Lead | 1,967 " " | Iron pyrites | 56,282 " " |
| Mercury | 22 " " | | |

*Belgium.*—Belgium is rich in coal, the output in 1881 being no less than 16,873,951 metric tons, valued at 163,704,242 francs. Though it produces iron ores, it is largely dependent upon other countries, and especially the grand-duchy of Luxemburg, for supplies for its blast furnaces. The principal lead mine is that of Bleiberg, and the calamine deposits in the neutral territory of Moresnet have long been worked with success by the celebrated Vieille Montagne Company, which also owns zinc mines in Belgium, Germany, Sweden, Sardinia, and Algeria.

*Russia.*—In a vast empire like Russia it is not surprising that there should be valuable deposits of a great variety of minerals. Among the most important are the auriferous alluvia of the Ural mountains and Siberia, which in 1880 yielded 115,940 troy ℔ of gold, worth more than 5 millions sterling. Platinum is found associated with the gold-bearing sands of the Urals; the output in 1880 was 7895 troy ℔. Zinc ore is largely worked in Poland. Important supplies of chromic iron ore are derived from the Urals, amounting in 1880 to more than 8000 tons. The metallic copper produced in 1880 was about 3100 tons, and the oil wells of Baku yielded in that year 346,000 tons of petroleum. Russia also possesses mines of iron ore, manganese, lead, silver, coal, and lignite. A little tin ore is furnished by Finland.

*Italy.*—The most important mineral in Italy[7] is sulphur, 359,540 tons (metric), worth 36,448,453 lire, having been obtained in 1880, and mainly from seams containing the native element in the Miocene rocks of Sicily and Romagna.

The celebrated iron mines of the island of Elba have been worked from very early times, and furnish a valuable ore; and the deposits of calamine, lead ore, and silver ore in Sardinia form no small proportion of the mineral wealth of the Italian kingdom. The gold mines in and near the Val Anzasca (Piedmont) are producing more than 7000 ounces of metal yearly.

*Spain.*—Spain is justly celebrated for its mineral wealth. It produces more cupreous pyrites than any other country in the world, and very large amounts of lead ore and quicksilver; and its iron ores are abundant and of excellent quality. The principal lead mines are in the provinces of Jaen (Andalusia) and Murcia, and the total amount of metallic lead produced in Spain or from Spanish ores is estimated to be 120,000 tons yearly.

Cinnabar, the heavy red ore of mercury, naturally attracted attention at a very early date, and the world-renowned Almaden mine has been worked from time immemorial. The output in 1880 was 1387½ tons (metric) of quicksilver.[8]

The cupreous pyrites, often known as sulphur ore, is obtained from the province of Huelva, where vast deposits occur over a belt of country nearly 100 miles long by 20 miles wide. The Rio Tinto mines are the largest in the district, and are worked on a gigantic scale. The company employs upwards of 10,000 hands, or more persons than are engaged in all the Cleveland iron mines, and the output is upwards of a million tons per annum. About one-quarter of this, containing 3½ per cent. of copper, is exported, mainly for the manufacture of sulphuric acid and subsequent treatment for copper and silver, whilst the remaining three-quarters, with 2⅓ to 2½ per cent. of copper, are treated on the spot. The ore contains rather less than 1 oz. of silver to the ton, and a few grains of gold. These are profitably extracted from the burnt ore by Claudet's process, and some idea of the importance of the copper and silver will be gained by reference to the following figures.[9] During the year 1881 there were obtained from cupreous pyrites imported into the United Kingdom in 1881, mainly from Spain and Portugal, 14,000 tons of copper, 258,463 oz. of silver, and 1490 oz. of gold. The total value of the silver and gold was £64,195.

The total output of iron ore in 1880 was 3,565,338 metric tons,[10] more than two-thirds, viz., 2,683,627 tons, being obtained from the celebrated mines near Bilbao in the province of Biscay. England, France, Belgium, and Germany are all glad to draw supplies of excellent red and brown hæmatite from the Bilbao mines. Murcia comes next in importance to Biscay, with a production of 539,328 tons.

*Portugal.*—The great mineral belt of Huelva extends into Portugal, and deposits of cupreous pyrites almost identical with that of Rio Tinto have been wrought from very early ages. The principal mine, San Domingos, is close to the Spanish frontier. It is estimated that the workings had yielded up to the year 1877 no less than 3,578,745 English tons of cupreous pyrites, by far the greater part of this having been extracted in recent times. The quantity of ore raised from the mine in 1882 was 405,029 tons.

Portugal possesses notable manganese mines, but produces comparatively small quantities of iron, lead, and copper.

*Norway.*—The mines at Kongsberg are famous for the large quantities of native silver they produce, and enormous masses are sometimes met with. The annual output is from 10,000 to 12,000 troy ounces. Copper ore and cupreous pyrites are also mined in Norway, and there are important workings for nickel and cobalt and for apatite. Alluvial gravels have been washed for gold in Norwegian Finland.

*Sweden.*—The most important mineral obtained in Sweden is iron ore, much being in the form of magnetite; red hæmatite also is mined, and brown hæmatite is dredged up from some of the lakes. The principal iron-producing districts are those of Norberg, Dannemora, Nora, and Perseberg. The output of the Swedish mines in 1880 was—

| | | | |
|---|---|---|---|
| Iron ore | 775,205 tons. | Zinc ore | 43,452 tons. |
| Lead ore | 12,988 " | Copper ore | 29,380 " |

*Greece.*—One of the most interesting undertakings of modern times has been the re-working of the Laurium mines, which are situated in the southern extremity of Attica; and an account of them written by Cordella furnishes many curious details concerning the methods of mining, washing, and smelting employed by the ancients. The workings for lead and silver appear to have been carried on with the greatest vigour between 600 B.C. and the Peloponnesian War, and were finally abandoned in the 1st century of the Christian era. Huge piles of slag which had accumulated from the old smelting works were found to be well worth being re-worked for silver and lead, and operations were commenced in 1864. Five years later the old heaps of mine refuse began to be treated, and at last in 1875 a French company resumed working the mine. A Greek company employing some 3000 persons is now producing annually from the old mine heaps no less than 8000 to 9000 tons of pig lead, yielding 45 oz. of silver to the ton, whilst the mines of the *Compagnie française des mines du Laurium* made an output in 1881 of 36,664 tons (metric) of roasted calamine, with 40 to 60 per cent. of zinc, in addition to lead ore and mixed ores. Cordella calculates that during the three hundred years the Laurium mines were worked by the ancients the total amount of lead produced was 2,100,000 tons, with 22½ million troy ℔ of silver. Besides this the ancients left behind two million tons of lead slags containing on an average 10·67 per cent. of lead, 109 million tons of mine refuse with 1½ to 18 per cent. of lead, and excavations to the extent of 51 million cubic yards with lead ore still in sight. They did not touch the calamine deposits.[1] Next in importance to lead, silver, and zinc comes bay-salt, and after that emery. The island of Naxos furnished 3300 metric tons of emery in 1877, valued at £28,000.

*Africa.*—Algeria is rich in iron, and three-fourths of the value of its total mineral output are due to ores of this metal. In 1880 the iron mines produced 614,000 metric tons of ore, Mokta-el-hadid mine, near Bona, alone yielding about 300,000 tons. Algeria also possesses mines of copper, lead, zinc, and antimony.

The name "Gold Coast" applied to part of the shores of Africa, denotes its productiveness of the precious metal, and it is probable that very important supplies of gold will one day be derived from various districts of the Dark Continent.

Cape Colony possesses rich copper mines in the Namaqualand division, which in 1882 produced ore and metal worth £331,546; however, the most valuable and remarkable mineral deposits of Africa at the present time are the diamond mines. The first diamonds were obtained from recent gravel in the bed of the Vaal river, and it was afterwards discovered that the precious stones could be obtained from the so-called dry diggings. The most important of these, the Colesberg Kopje, now known as the Kimberley mine, produced in 1881 diamonds weighing 900,000 carats, worth £1,575,000. Three other neighbouring mines are Old De Beer's, which yielded 300,000 carats in 1881, worth £600,000, Du Toit's Pan, and Bulfontein. The value of the diamonds raised in South Africa since 1870 amounts to forty millions sterling;[2] indeed the Kimberley mine alone was estimated in 1877 to have already produced ten million pounds worth of diamonds, extracted from 4 million tons of diamantiferous rock.

*Asia.*—For many centuries India was regarded as possessing fabulous mineral wealth, and a strong basis for this idea may be found in the existence of traces of mining on a very extensive scale. No doubt in early days India did supply what then appeared to be very large quantities of metals, and a country that produces gold and precious stones is apt to be endowed by the popular mind with boundless riches. The actual amounts of mineral raised in India at the present day are comparatively small. Gold exists over considerable areas, but it remains to be proved that the gold mines of the Wynaad and Mysore can be profitably worked by British companies. Diamonds occur and are worked in alluvial diggings and in a conglomerate belonging to the Vindhyan formation. Sapphires and rubies are obtained from Upper Burmah. Ceylon[3] produced in 1880 no less than 10,286 tons of graphite or plumbago, valued at £192,879. Petroleum is abundant in Upper Burmah, and oil from wells has been utilized for upwards of twenty centuries. The total output in 1873 was estimated to be about 10,000 tons yearly. Tin ore occurs and is worked in Tenasserim. Passing into Siam and the Malay Peninsula we find deposits of alluvial tin ore, producing what is known in commerce as Straits tin. A little to the east are the islands of Banca and Billiton, which for many years have been a source of wealth to the Dutch Government. The sales of Banca tin in 1881 amounted to 4339 tons, and those of Billiton tin to 4735 tons, whilst 11,475 tons of Straits tin were exported from Penang and Singapore.[4] Stanniferous alluvia are also worked in Karimon, Singkep, and Sumatra, whilst the latter island possesses also valuable seams of coal.

Borneo furnishes coal, antimony ore, and some cinnabar; and river-gravels are washed for diamonds, gold, and platinum.

There is no doubt that the mineral wealth of China is enormous. In addition to important coal-fields it possesses numerous metallic mines. The province of Yunnan in the south of the empire seems to be specially favoured with regard to metalliferous wealth, for mines of gold, silver, copper, lead, tin, and iron are worked there, whilst jade and precious stones are found in the beds of rivers.

Japan produces more than 3000 tons of copper yearly, or about as much as the British Isles. The output of lead and tin is insignificant, but the quantity of silver, exceeding 300,000 oz. yearly, is worthy of notice. Gold, iron, and petroleum are other products of Japan.

The gold of Siberia has been mentioned in speaking of Russia.

*Canada.*—The Dominion of Canada is rich in minerals. Gold-bearing quartz veins are worked in Nova Scotia, whilst in British Columbia alluvial deposits are the main source of the supply. Silver occurs on Lake Superior, the most important mine being that of Silver Islet, which from 1869 to the spring of 1877 yielded 2½ million ounces of silver, and gave a profit of £200,000.

Rocks resembling the copper-bearing strata of the United States territory are mined in Michipoten island in Lake Superior. Iron ores, in the form of magnetite, red hæmatite, limonite, and ilmenite, are worked in various parts of Canada.

Petroleum is derived from oil wells in Western Ontario, and the quantity refined in 1875 was about 210,000 barrels, each of 40 gallons. It is in Ontario also that the veins of apatite exist from which a large amount of that useful mineral has been raised.

*United States.*—The mineral wealth of the United States is admirably summed up by Mr Richard P. Rothwell in his address to the American Institute of Mining Engineers.[5]

"*Production of Coal, Metal, and Petroleum in* 1881.[6]

| | |
|---|---|
| Anthracite | 30.261,940 tons (of 2240 ℔). |
| Bituminous coal | 42,417.764 " (of 2000 ℔). |
| Pig iron | 4,144.000 " (of 2240 ℔) |
| Lead | 105,000 " |
| Copper | 31 000 " |
| Quicksilver | 59,000 flasks (of 76½ lb. avoir |
| Gold | $31,870,000 (=1,541,711 oz.). |
| Silver | $45.078.000 (=34.865.960 oz.). |
| Petroleum | 27,264,000 barrels (of 42 gallons). |

"The statistics of other useful minerals and metals show an equally marvellous advance during the past thirty years. The production of pig iron, which in 1852 was 541,000 net tons, in 1861 was 653,000 tons, and in 1871 was 1,708,000 tons. Ten years later, in 1881, we produced no less than 4,144.000 tons, an increase in thirty years of nearly 800 per cent.

"Lead, which appears at 14,400 tons in 1852, varied but little from that figure until the construction of railroads into the argentiferous lead-mining districts of the west about 1870. Eureka, Nevada, Utah, and more recently Colorado, with its Leadville bonanzas, rapidly raised the production from 18,000 tons in 1871 to 47,000 tons in 1873, 75,000 tons in 1877, and 105.000 tons in 1881.

"Our production of copper steadily increased from 1000 tons in 1852 to 31.000 tons in 1881,—the enormous output of that unrivalled mine Calumet and Hecla steadying the production and neutralizing the fluctuations of the lesser mines.

"Quicksilver has shown wide fluctuations, due more to trade combinations than to the condition of the mines. In 1852 the output amounted to 20.000 flasks;

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[1] *Statistique de l'Industrie Minérale et des Appareils à Vapeur en France et en Algérie*, Année 1880, Paris, 1882, pp. 59 and 72.

[2] Detailed statistics concerning the mineral produce of Prussia are given every year in the *Zeitschrift für das Berg-, Hütten-, und Salinen-Wesen im Preussischen Staate* (Berlin).

[3] Quantity less than 50 tons.

[4] Detailed statistics of the mineral produce of Saxony are given yearly in the *Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen* (Freiberg).

[5] *Stat. Jahrb. des k. k. Ackerbau-Ministeriums für* 1881, Heft iii., Lief. 1, Vienna, 1882.

[6] "Der Bergwerksbetrieb Ungarns im Jahre 1879," *Oesterreichische Zeitschrift für Berg und Hüttenwesen*, 1881, p. 271.

[7] *Notizie statistiche sulla Industria Mineraria in Italia dal* 1860 *al* 1880, Rome, 1881, p. 406.

[8] *Estadística Minera de España, correspondiente al año de* 1880, Madrid, 1882, p. 37.

[9] Hunt, *Mineral Statistics*, &c., p. 45.

[10] *Estadística Minera*, &c., *ut supra*, p. 15.

[1] A. Cordella, "Mineralogisch-geologische Reiseskizzen aus Griechenland," *Berg- und hüttenmännische Zeitung*, vol. xlii., 1883, p. 21.

[2] A. J. Macdonald, "The Value of the Cape as a Dependency of Great Britain," *The Times*, 3d May 1883.

[3] *Statistical Abstract for the Several Colonial and other Possessions of the United Kingdom in each year from* 1860 *to* 1880, London, 1882, p. 39.

[4] Hunt, *Min. Stat.* for 1881, p. 9.

[5] *Engineering and Mining Journal*, vol. xxxiv. p. 174.

[6] The total production of coal in the United States in 1882 amounted to 86,862,614 tons of 2240 ℔ (*Colliery Guardian* for 1883, p. 731). The quantities of metals produced in 1882 are estimated to be—pig iron 4,623,323 gross tons of 2240 ℔ each, lead 123,000 gross tons, copper 40,000 gross tons (*The Iron, Steel, and Allied Trades in* 1882, p. 188; *Eng. and Min. Jour.*, vol. xxxv. p. 27).